COMMUNICATIONS, CIRCUITS and EDUCATIONAL TECHNOLOGIES

Proceedings of the 2014 International Conference on Electronics and Communication Systems II (ECS '14)

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Keynote Lecture

Interpolation and Projective Representation in Computer Graphics, Visualization and Games

Vaclav Skala
University of West Bohemia
Plzen, Czech Republic
E-mail: skala@kiv.zcu.cz

Rongjiang Pan
Shandong University
Jinan, China
E-mail: panrj@sdu.edu.cn

Abstract: Today's engineering problem solutions are based mostly on computational packages. However the computational power doubles in 18 months. In 15 years perspective the computational power will be of 2^10 = 1024 of today's computational power. Engineering problems solved will be more complicated, complex and will lead to a numerically ill conditioned problems especially in the perspective of today available floating point representation and formulation in the Euclidean space.
Homogeneous coordinates and projective geometry are mostly connected with geometric transformations only. However the projective extension of the Euclidean system allows reformulation of geometrical problems which can be easily solved. In many cases quite complicated formulae are becoming simple from the geometrical and computational point of view. In addition they lead to simple parallelization and to matrix-vector operations which are convenient for matrix-vector hardware architecture like GPU.
In this short tutorial we will introduce "practical theory" of the projective space and homogeneous coordinates. We will show that a solution of linear system of equations is equivalent to generalized cross product and how this influences basic geometrical algorithms. The projective formulation is also convenient for computation of barycentric coordinates, as it is actually one cross-product implemented as one clock instruction on GPU. Selected examples of engineering disasters caused by non-robust computations will be presented as well.

Brief Biography of the Speaker: Prof.Vaclav Skala is a Full professor of Computer Science at the University of West Bohemia, Plzen, Czech Republic. He received his Ing. (equivalent of MSc.) degree in 1975 from the Institute of Technology in Plzen and CSc. (equivalent of Ph.D.) degree from the Czech Technical University in Prague in 1981. In 1996 he became a full professor in Computer Science. He is the Head of the Center of Computer Graphics and Visualization at the University of West Bohemia in Plzen (http://Graphics.zcu.cz) since 1996.
Prof.Vaclav Skala is a member of editorial board of The Visual Computer (Springer), Computers and Graphics (Elsevier), Machine Graphics and Vision (Polish Academy of Sciences), The International Journal of Virtual Reality (IPI Press, USA) and the Editor in Chief of the Journal of WSCG. He has been a member of several international program committees of prestigious conferences and workshops. He is a member of ACM SIGGRAPH, IEEE and Eurographics Association. He became a Fellow of the Eurographics Association in 2010.

Prof.Vaclav Skala has published over 200 research papers in scientific journal and at international research conferences. His current research interests are computer graphics, visualization and mathematics, especially geometrical algebra, algorithms and data structures. Details can be found at http://www.VaclavSkala.eu

Prof. Rongjiang Pan is a professor in the School of Computer Science and Technology, Shandong University, China. He received a BSc in computer science, a Msc in computer science, a PhD in computer science from Shandong University, China in 1996, 2001 and 2005, respectively. During 2006 and 2007, he was a visiting scholar at the University of West Bohemia in Plzen under a program supported by the international exchange scholarship between China and Czech governments. He is now a visiting professor at the School of Engineering, Brown University from 2014 to 2105 under the support of China Scholarship Council.

He is a Member of the ACM. His research interests include 3D shape modeling and analysis, computer graphics and vision, image processing. He has published over 20 research papers in journal and at conferences

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ERNA - Embedded, Self-Calibrating Robotic-Arm for Gamificated Learning

Carsten Seeger, Christoph Käding, Christopher Manthey and David Neuhäuser
Institute of Computer Science
Friedrich-Schiller-University
07737 Jena, Germany
{carsten.seeger,christoph.kaeding,christopher.manthey,david.neuhaeuser}@uni-jena.de

Abstract—ERNA - Educational Robotic iNteractive Arm - is an embedded, self-calibrating robotic-system. ERNA in its recent configuration is capable to perform the game "Tower of Hanoi." School children and university students, not familiar with the principle of recursion, can play the game against the robotic-system step by step. Trying to beat the robot, the players will acquire a solution approach based on recursion to optimally play and win "Tower of Hanoi." ERNA is based on simple, low-budget components and can be rebuilt with different difficulties by high school children and univerity students. Several design challenges like mechanical tolerances, mass inertia, and switch bouncing, had to be handled to develop the robotic-system. This paper describes the design of the robotic-system and its application in detail.

Keywords: human-computer interaction, gamification, interactive learning, embedded system, self-calibration, recursion, robot, MBED, micro-controller, low budget

I. Introduction

ERNA - Educational Robotic iNteractive Arm - is an embedded, self-calibrating robotic-system to support gamificated learning [3]. It is embedded, meaning it performs without any additional, external computer control. It can autonomously solve its given task. It is self-calibrating, meaning any mechanical inaccuracy will be compensated by sensor supported absolute positioning. The robotic-system in its recent configuration is capable of playing "Tower of Hanoi" against a human player step by step.

"Tower of Hanoi" was invented 1883 by the french mathematician Edouard Lucas [5] as a challenging intelligence game for one player. At start, perforated disks of different size are sticked on three poles of equal height, see Fig. 1. At every step of the game, a single disk may be moved from one pole to another. At no time may a larger disk rest on a smaller one. The aim of the game is to use as little steps as possible to move all disk from the first to the third pole.

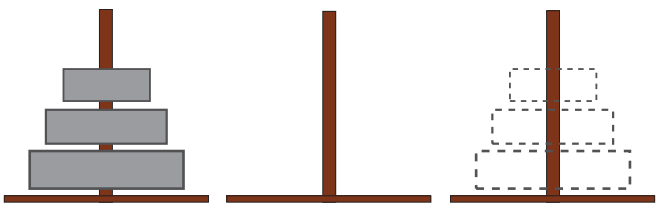

Fig. 1. Schematic of the game "Tower of Hanoi"

When playing with ERNA, the human player and the robot have their own game set up with equal amounts of disks. In every turn, the human player is first to move a disk. After completing its move, the human signals the robot to move a disk by pushing a button. When playing optimally in terms of using few disk moves, the human player will eventually beat the robot by finishing the game first. On the other hand, when the human makes any mistake, the robot will win since it plays optimally every time. To win the game continuously the human needs to find a playing strategy based on recursion. Using the robot, school children and students can be playfully introduced to the concept of recursion. This has been successfully demonstrated at the public science event "Long Night of Science" [9]. The robotic-system combines human-computer interaction and gamification.

The robot itself was also designed to be rebuilt by school children and students. The mechanical components can be assembled by both groups. The programming can be realized by older school children and students. The electrical wiring should be carried out by students. In this way, the robotic-system covers different aspects of gamification: learning with, learning from, and learning about robots [11].

II. Robotic-system

A. Specification

The scope was to design a robotic-system for solving the problem of "Tower of Hanoi".

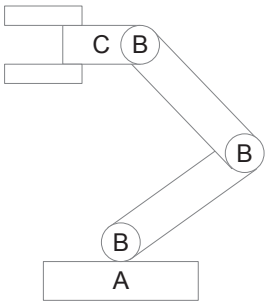

Fig. 2. Schematic of the robot: (A) electric powered wheel, (B) hinge, (C) gripper/magnet

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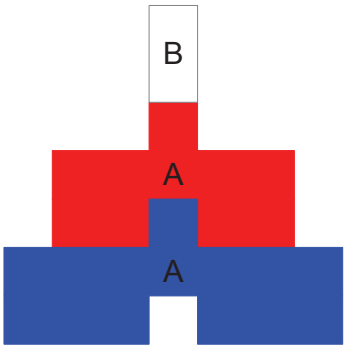

Fig. 3. Design of "Tower of Hanoi" suitable for the robot: (A) disks (B) magnet

To simplify this task some restrictions were applied. A stack of only three disks has to be moved. The solution algorithm inside the robot only needs a predefined static initial state of the towers. Additionally the system should be flexible by reaching arbitrary positions. For this purpose the robotic-system should be designed using hinges (see Fig. 2) which are realized using servo-motors. To energize the motors a self-designed circuit with a micro-controller is used. The mechanical environment is built with kits from fischertechnik [1].

To be able to grab a disk, two robot design alternatives arise. We can either using a magnet or a gripper, see Fig. 3. By using a magnet the original design of tower of Hanoi has to be modified. The poles have to be removed to easily grab the disks. With a gripper usage, two design options are given. The first is to grab the disk from above and the second one is to grab from the side. To reduce the amount of heavy mechanical parts, we decided to use an electrical magnet to grab the disks.

The system is supposed to be able to solve the Tower of Hanoi fully autonomously. No additional host is required. A micro-controller is used to control the robotic-system. It should be able to be programmed in a suitable language and have

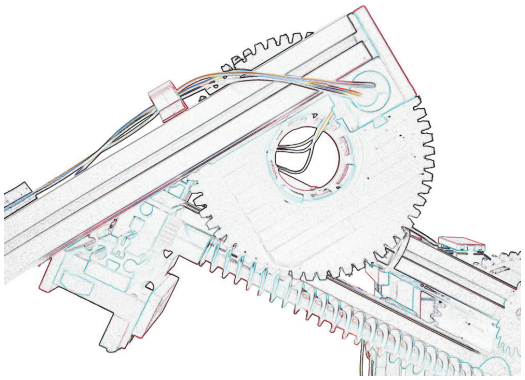

Fig. 4. Hinge with cogwheel and screw

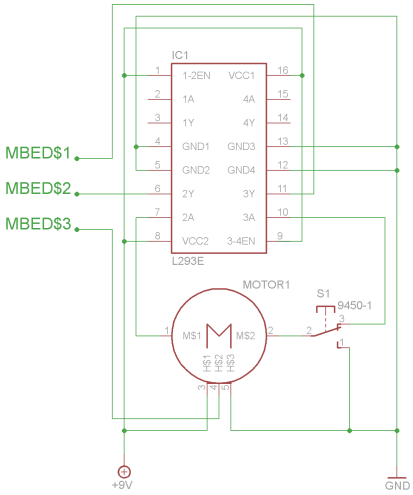

Fig. 5. Motor control wiring

ports which make it possible to connect the controller to the magnet, any needed sensors, and the motors. Furthermore it should be possible to rebuild the project by school children and students.

B. Hardware development

The first approach was to develop a control to test the motor behavior. Therefore the motor was directly connected to the micro-controller. Some tests like inertia behavior and pulse count were performed.

The motor itself is a geared 9V motor using a regulated power supply. To spin the motor the power supply is activated for a specific amount of time. This is regulated with the help of an additional driver controlled by the micro-controller to regulate the power supply. To determine the exact position of the motor, it issues a PWM signal [10] to the micro-controller.

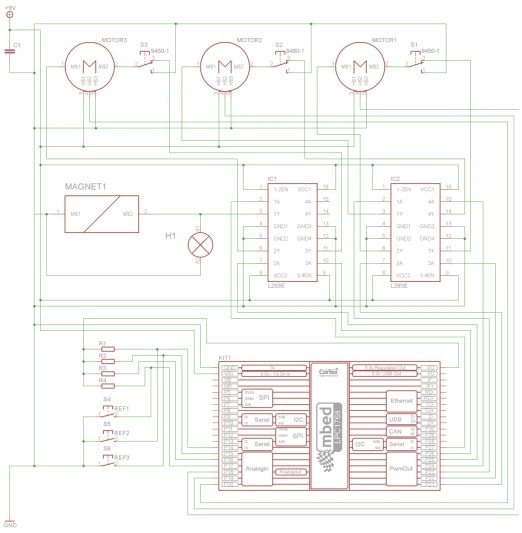

Fig. 6. Robot wiring plan

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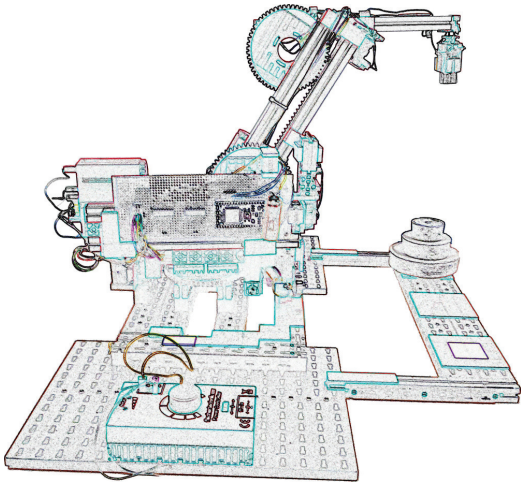

Fig. 7. Fully assembled robotic-system

For exact results it is necessary to define threshold values for low and high outputs of the PWM pulse.

During tests some unwanted behavior was noticed, for example inertia with and without load and mechanical blocking. Inertia handling and blocking detection were realized on the software side and will be discussed later.

The next step was to develop a hinge design. Important decision indicators were inertia prevention and the value of load. Therefore a design was used, were the gears which are responsible to move the segments of the arm, are not directly connected to the driving motor gear. An axis with screw and a cogwheel is located between these two gears. This has several advantages. For example, the load which is caused by the weight of the construction does not act in the direction of the rotation of the gears. So there is no need to spend some energy to hold the robotic-system in place. It locks itself and protects the motor mechanics. With the hinge design in Fig. 4, a first system with three degrees of freedom was built.

The micro-controller uses 5 V supply voltage. A driver element is needed (see Fig. 5) to use higher voltages driving the motors with more power. Using such an electronic driver, the motors can rotate forward and backward with high force.

The three motors and the magnet are connected via the drivers to the micro-controller. Several pull-up resistors and a capacitor are used to guarantee the stability of the motor driving voltage. At last the calibration switches are linked to the micro-controller to read the sensor activation on reaching calibration positions. Fig. 6 shows all parts connected together. The fully assembled robotic-system is shown in Fig. 7.

C. Software development

At first we implemented a blocking system to prevent damaging the motors while testing. The blocking system uses the fact that if a motor blocks at some point no PWM signal restores back to the micro-controller. If the motor gets input by the power supply but no PWM signal is received for a defined amount of time, a blocking is detected and the motor

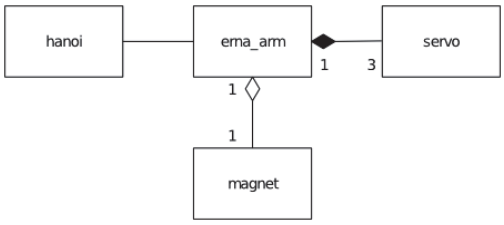

Fig. 8. Software classes and their relation

was triggered to stop performing.

After creating the first versatile version of ERNA, software was needed to perform movement. A micro-controller MBED LPC 1768 [6] [7] programmable in C++ was used in addition with L293DNE drivers by Texas Instruments [2]. The Software itself is class-based with four classes called motor, magnet, erna_arm and hanoi. These classes represent the objects used by the system and behave like shown in the UML pattern in Fig. 8.

The most important class is the hanoi class which uses the erna_arm class to perform movement to positions calculated by a standard recursive algorithm to solve the “Tower of Hanoi” [4]. The erna_arm class uses three motor objects and the magnet object to move itself to a given position. It uses a radial coordinate system which gains position feedback from the motors and behaves like shown in Fig. 9.

Each of the three motors gets a specific position on its own circle. To move from an absolute position to another the motor class calculates the relative movement the motors need to perform. The magnet and motor classes are the low level classes interacting with the hardware.

To use absolute positions a null position has to be defined. For each motor a mechanical interrupt switch was installed on a defined null position. To reach this position all motors move in direction of their mechanical interrupt switch until they hit them. The mechanical interrupt switch itself breaks only the connection used for the direction towards the switch, the

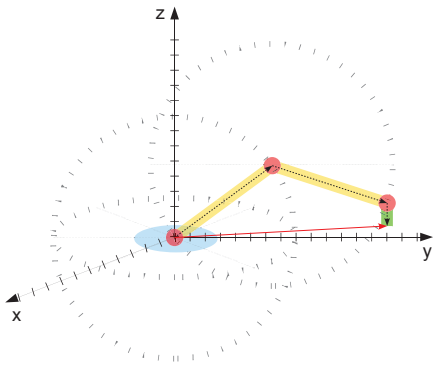

Fig. 9. Radial coordinate system: arm segments marked yellow, hinges red, magnet green.

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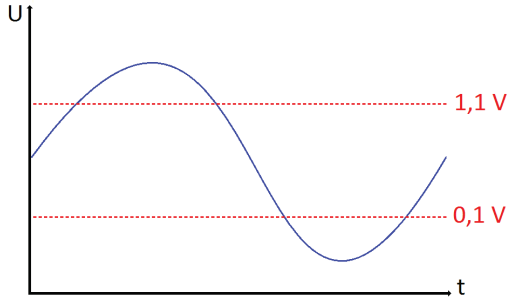

Fig. 10. PWM-signal thresholds

direction away from the switch stays connected. If a motor hits the switch it directly stops movement without the need of a blocking protection or software control. This was needed to differentiate the null position from a blocking position. On the first start of the micro-controller an initialization procedure moves the arm segments of ERNA to these null positions.

1) Evaluation and control of PWM-signals: The PWM-signals are sampled analog and evaluated by the software using pre-defined threshold values, see Fig. 10.

This design choice was made to reduce the complexity of the circuit. A software routine reads the input of the PWM-signal in cyclic time periods. Discretized voltage values are used to reconstruct the PWM-signal. The sampling frequency is 200 times higher than the maximum frequency of the motor and reconstructs the PWM-signal without loss. This sampling frequency fulfills the Nyquist-Shannon [8] theorem.

Another fact to consider is the inertia of a moving motor. The position has to be adjusted if an inertia movement is registered. To quantify the value of the inertia movement the PWM values between deactivating the supply voltage of a motor and the stopping of the PWM-signals are used.

To minimize inertia movement behavior a PWM control is needed. While using a DC motor a PWM controlled voltage equals to a lower direct current. The duty cycle is the relation between the low and high current time of the PWM-signal. For example a 0.5 duty cycle reduces the motor speed by half compared to a 1.0 duty cycle. This was used to reduce motor speed when coming closer to the target position. Four duty cycle levels where defined, the initial duty cycle and three levels downgrading the motor speed with empirical defined values.

2) Testing: Firstly we tested the motor behavior with and without weight load. The result was as expected, the motor moves without load with higher error rate as with heavy load.

Secondly we tested movement with compensation against inertia. This results in an unusable movement. The movement error is higher than the possible compensation.

The most important test is the precision test. We performed 50 movement iterations with and without PWM control. ERNA has to move between two points to show the deferment of the positions caused by repeated movements. This test shows a significant position deferment due to high tolerances of the mechanical parts. As a result, the robotic-system will not be capable of solving the problem of ”Tower of Hanoi” without any form of self-calibration.

3) Self-Calibration: To calibrate the robotic-system three sensors called reference switches were added on specific positions. These positions are physically fixed. If a motor activates the sensor the calculated position will be compared with the physical position of the sensor. If they don’t match the calculated position will be overwritten with the sensor position. In Fig. 11 a schematic of the calibration positions is shown. When moving between positions I and II, II and III, I and III, I and IV, II and V, III and VI a sensor is triggered and corrects the calculated position. Due to mechanical dimensions of the sensor, the actual physical position when activating the sensor differs when moving from I to II or from II to I, as well as for the other positions respectively. To compensate the physical dimension of the sensor two positions per switch are used in combination with the actual direction of the motor. The switches are debounced on software side. The hard-coded positions of the switches are empirical detected.

4) Hanoi algorithm: A standard recursive C++ implementation is used for the Hanoi algorithm [4]. This version was

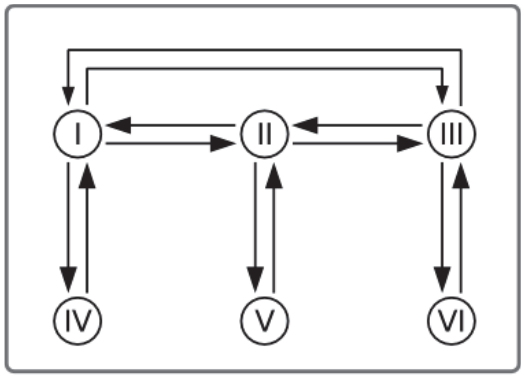

Fig. 11. Gripper positions used for calibration

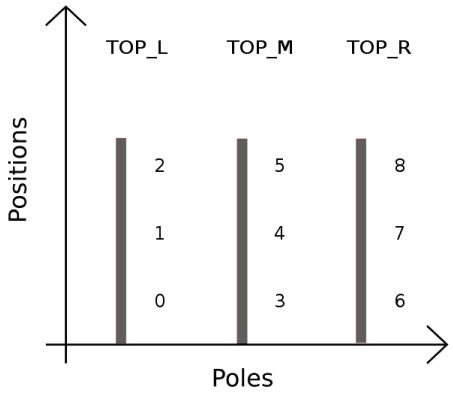

Fig. 12. Gripper position encoding

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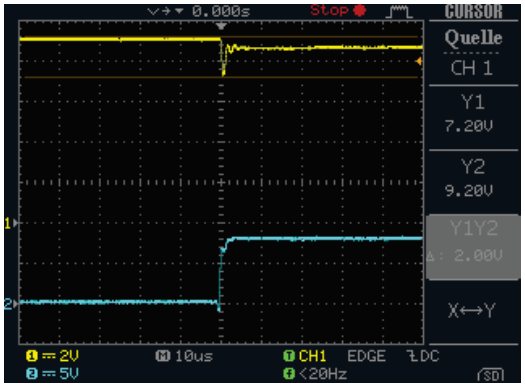

Fig. 13. Example of a voltage drops. Channel 1 (yellow): supply voltage dropping 2V down. Channel 2 (blue): motor voltage on starting induced by the robot arms mass inertia.

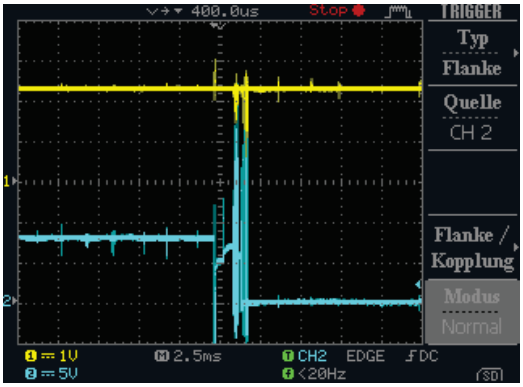

Fig. 14. Induced voltage when stopping a motor: channel 1 (yellow) signal of the switch, channel 2 (blue) drops on motor voltage

modified by adding a stack-based data structure representing the poles of the game. By using three different integer stacks, the information about position and height could be saved in this data structure. An advantage using this data structure is that pushing and pulling from a stack has the same behavior as pushing or pulling a disk from a pole in the real game. The positions are coded like shown in Fig. 12.

This encoding allows to calculate the top position by position modulo 3. For the left top position this value is lower then 1.0 for middle one between 1.0 and 2.0 and for the right one higher than 2.0 . A solve sequence is generated through a function using the origin and destination position of the calculated movement and saved in a FIFO data structure.

D. Solving the problem of "Tower of Hanoi"

As described before the major class is the hanoi class using the robotic-arm class to perform movement. Furthermore it triggers the hanoi algorithm with the standard parameters which start at the left pole with all disks and end at the right pole with all disks and uses three disks in total. This generates the solve sequence dynamically and could also generate solve sequences for all valid intermediate positions. After generating the solve sequence a loop grabs two elements of the FIFO data structure and creates a movement where the first element is the position of the disk which should be moved to the position represented by the second element. This additionally needs to use the top positions of every position in between. These positions can easily be calculated as described in II-C4. One loop iteration uses four positions: first the top position of the original position of the disk, then the original position itself, third the top position of the destination of the disk and at last the destination position itself.

III. Design Challenges

The most time consuming challenge is to ensure the precision of the whole system, jeopardized by the high tolerances of the cogwheels. Furthermore the motors state their movement by PWM-signals but can not be controlled with PWM input. The motors are powered by a constant current. Constant current can result in inertia which has to be calculated additionally.

Voltage drops are another problem as shown in Figure 13. The motors need a high voltage. The time delay of the power source to provide high voltage causes voltage drops when the motors start to move [10]. This can result in dysfunctions of the system. Additional capacitors charged during normal movement and discharged during movement starts are a suitable solution. Induced voltage can also occur when a motor stops movement, see Fig. 14.

A sensor problem is the bouncing behavior of switches shown in Fig. 15. This reduces the precision while generating random tolerances. Using a high sampling frequency reduces the effect but can not totally circumvent it. Another solution is using hardware debounced switches.

To program the MBED micro-controller in C++ an online compiler given by the company MBED has to be used (www.mbed.org/compiler). The IDE is not very user friendly and does not support C++ in its full usability. For example exception handling was not supported. This results in an unnecessary complicated software development process.

IV. Summary

A. Conclusion

ERNA - Educational Robotic iNteractive Arm - is an embedded, self-calibrating robotic-system. It is suitable to playfully teach school children and students the concept of recursion by competitively playing the game "Tower of

Fig. 15. Schematic of switch bouncing

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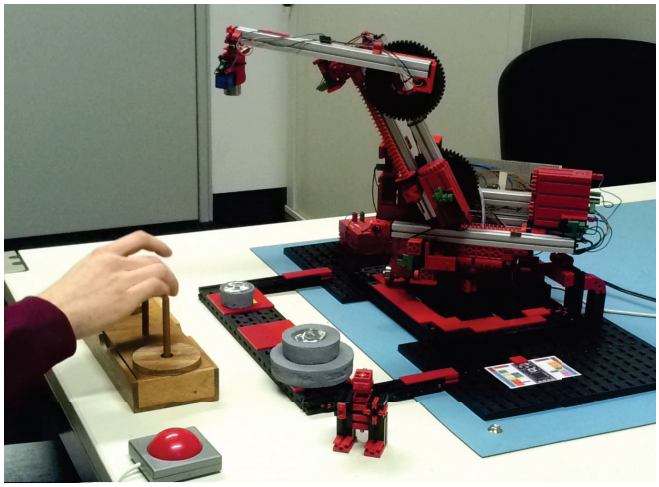

Fig. 16. Playing with ERNA

Hanoi", see Fig. 16. The robotic-arm has been successfully demonstrated at the public science event "Long Night of Science" [9].

ERNA is made of low-budget, simple components and can be rebuilt in class. Design challenges arising from using simple components have been solved successfully.

B. Future work

1) Multi-Threading architecture: The Robotic system does not support parallelized movement of the hinges. This can be achieved by using a more sophisticated micro-controller capable of multi-threading. Moving all hinges in parallel will reduce the time consumed by the robot to perform one step of the game.

2) Camera system: The system can be extended with a video camera to acquire and validate the initial state of the Hanoi disks to improve human-computer interaction.

3) Redesign: To avoid high hardware tolerances the system should be redesigned using better and in most times cheaper hardware. This will result in a much better precise and fault tolerant system. Maybe no calibration system is needed anymore, if the precise increases enough to minimize the differences between positions over a high amount of iterations.

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Synergitics synthesis of aircraft hierarchical control systems

G. Veselov, T. Motienko

Abstract: We have considered principles of hierarchical structures organization in aircraft systems and made a review of existed approaches to the problem of control action determination for such systems. Basing of this researches in the paper we propose new approach for solving the problem of hierarchical synthesis of multi-linked, multi-dimensional and nonlinear control systems.

***Keywords*:** Hierarchical structure, System's synthesis, Nonlinear systems, Aircrafts, Synergetics.

I. INTRODUCTION

According to the modern scientific views the world represents the union of a numerous number of developing systems and subsystems of various types. Technical progress serves to create artificial systems with more complex structure, which consist of variety of subsystems connected by processes of dynamic interaction and interchange of energy, substance and information. Almost any modern technical system represents the complex of various subsystems, machines, apparatuses and aggregates which carry out certain functions and which constantly interact with each other.

Phenomenology of complex technical systems viewed in the paper lies in the fact that, firstly, they can be represented as the range of hierarchical subsystems and secondly, these systems are controlled. Under the hierarchical system we will understand the range of vertically placed interacted subsystems which organize independent hierarchical levels. And at the same time located above subsystem's influence the process of functioning of any system by way of coordinating of their operation. The investigation of such systems is complicated by the fact that they are characterized by the numerous amounts of variables and parameters, by the number of cross-connections, processes of interaction among them are usually described by non-linear mathematical models. The more difficult task is the synthesis of control of these systems. The majority of approaches of control theory face difficulties - *multi-linked*, *multi-dimensional* and *nonlinear* characteristics in these systems. That's why the development of a new approach to the synthesis of hierarchical systems of multi-linked, multi-dimensional and nonlinear control systems is considered to be of current importance.

In the systems viewed in this paper a typical description for a certain area of variables and parameters is assumed on each hierarchical level [1]. In such systems a subsystem placed above influences a certain subsystem on each level. But though the impact for subsystems of levels placed below is obligatory and there is a priority of action and purposes of levels above in this impact the interaction between the higher element and each of lower elements is that the success of the action of one of them depends on actions of another. So, the effectiveness of system action in general depends not only on *interference* directed top-down, but on the response from down-top, that is on the coordinated actions of all systems elements. Hierarchical organization is peculiar to systems of various structures. In natural, social and economical systems structuring can be often relative and is carried out for reaching certain purposes, solving certain tasks [3].

Nomenclature of technical systems which are characterized by hierarchical order of included components is various enough.

The designing of big systems control strategies is faces troubles because of their complexity and the number of components involved in these systems, type of their interaction and the necessity of operating of a big amount of position coordinates. As a result of it, there appeared a tendency connected with the decomposition of complex systems into simple independent subsystems [4-9]. The majority of approaches, guided by the principle of decomposition use numerical procedures in synthesis of control algorithms [4], and this determines their low effectiveness in real systems, as in using then it is necessary to have full information about structure and parameters of a mathematical model of dynamic system. A differentially geometrical approach to a reduction of control systems is presented in the monograph. According to it, using the theory categories or Burbaku structures theory, initial non-linear object is compared to isomorphous object, factor object and sub-object. The main problem in using of this approach is the fact that construction of a certain mathematical differentially geometrical machine is required for each category of objects.

Methods of hierarchical control systems synthesis are developed in Pjatnickiy works [6]. They are based on decomposition. According to it, back couplings, which compensate interference of subsystems, are introduced at first, and then in the regime of decomposition coordinating control is formed up. It provides the executing control purposes on system motion path. A.A.Krasovskiy proposed the idea of forming up the hierarchical structure of control algorithms with dividing the dynamic system on slow and fast processes [7]. Methods of control systems synthesis by non-linear dynamic systems which are described by Lagrange equations are given in F.L.Chernousko works [8]. This approach is based on principle of decomposition. According to it the dynamic

system of a given class is separated into independent subsystems which represent linear systems with one level of autonomy. At the same time it is assumed that highest possible values of non-linear components of initial system model and external disturbance are restricted and are lesser than available values of control values. Control laws of separated models are searched for by means of playing approach.

The proposed in [8] approach to synthesis of coordinated and autonomous control algorithms by Lagrange systems which is based on decomposition [6] and method of reverse problems of dynamics was developed in P.D. Krutko works [9]. In methods developed by P.D. Krutko the essential principle in forming up of control effects is the condition when in the process of IP of control system instantaneous values of local functional worked out at a reference models paths will be situated in a small neighborhood of extreme-minimum. Reference models are intruded by each of the subsystems corresponding to each level of autonomy, from technical requirements to dynamic characteristics of designing system.

So we can point out the following main tendencies in forming up of control systems by non-linear, multi-dimensional and multi-linked dynamic objects. Firstly, it is restrictedly used for separate classes of mathematical models which describe the nature of control objects, first of all these are systems with scalar control. Secondly, it is the lack of regular procedures of taking into account interference between channels of outlet values regulation of designing systems and which is tend to get rid of by means of compensation of cross back couplings or taking into account these interferences in the form of limited unmeasured disturbing effects. The mentioned peculiarities of synthesis methods of control effects don't allow designing of control systems reflecting in full measure physical (chemical, mechanical and etc.) nature of processes which take place in the investigated objects. A principally different approach to the designing control systems of multi-dimensional, multi-linked and non-linear dynamic objects is given in the synergetic conception of system-defined synthesis [10, 11].

II. SYNERGITICS SYNTHESIS OF AIRCRAFT HIERARCHICAL CONTROL SYSTEMS

The method of constructing an aircraft hierarchical control system based on the principle of relationship hierarchy levels. While at the upper levels of a hierarchical system formed solutions aimed at the achievement of the control tasks. These tasks are generated in the form of requirements to subsystems of the lower level , where regulators form control software tasks for electrical , hydraulic and pneumatic servo drives that implement the specified control surface deflection . As noted previously , consideration of the residual dynamics actuators, belonging to the lower - level subsystem , substantially increases the efficiency of the overall system being synthesized.

In general, the technique of constructing a hierarchical traffic control system aircraft can be described as follows [12-15].

Let the behavior of the top-level subsystems described by the following equations:

$$S_N:\ \begin{aligned} \dot{x}(t) &= A(x)x + B(x)D + H(x, f)f; \\ y &= C(x)x, \end{aligned} \tag{1}$$

$x \in R^n$ – state vector top level subsystems, $y \in R^n$ – output vector, $D \in R^{N-1}$ – vector control surface deflection angle for drives, $f \in R^{\vartheta}$ – perturbing forces vector, $A(x)$, $B(x)$, $C(x)$, $H(x, f)$ – functional matrices state input, output and disturbance.

Behavior of each subsystem drives can be described by the following expressions:

$$S_j:\ \begin{aligned} \dot{z}^{(j)}(t) &= R^{(j)}(z^{(j)})z^{(j)} + P^{(j)}(z^{(j)})u^{(j)} + S^{(j)}M_l{}^{(j)}; \\ D_j &= d^{(j)}(z^{(j)})z^{(j)}; \quad j = \overline{1, N-1}, \end{aligned} \tag{2}$$

$z^{(j)} \in R^{\chi-1}$ – state vector of the j-th subsystem drive, D_j – output variable (angle) j-th subsystem drive, $u^{(j)} \in R^{\kappa_j}$ – vector control actions j-th subsystem, $M_l{}^{(j)}$ – static moment load, $R^{(j)}$ и $P^{(j)}$ - input and output matrix.

At first must to define a set of goals for the lower level subsystems. This should include technological invariants ensure compliance management objectives, as well as invariants, which define performance management systems in synthesized subobjects S_i, $i = \overline{1, N-1}$ required relations.

Dimension of the subset Σ_j can't exceed the dimension of the corresponding control subsystem S_i, $i = \overline{1, N-1}$.

On the basis of the generated subset of the input set of invariant manifolds $\psi^{(j)} = 0$, which must satisfy the homogeneous solution of differential equations of the form:

$$\frac{d\psi^{(j)}}{dt} + \mathrm{I}^{(j)}\psi^{(j)} = 0. \tag{3}$$

Matrix such that the solution is asymptotically stable.

When hit in the neighborhood of the image point S_i, $i = \overline{1, N-1}$ of intersection varieties subobjects $\psi^{(j)} = 0$ behavior will be described decomposed systems of equations of lower order - equations "residual dynamics":

$$S_j:\ \begin{aligned} \frac{\hat{z}^{(j)}}{dt} &= \hat{R}^{(j)}(\hat{z}^{(j)}, \varphi^{(j)})\hat{z}^{(j)} + \hat{S}^{(j)}\hat{M}_l{}^{(j)}; \\ D_j &= d^{(j)}(\hat{z}^{(j)}, \varphi^{(j)})\hat{z}^{(j)}; \quad j = \overline{1, N-1}, \end{aligned} \tag{4}$$

$\varphi^{(j)}$ – the setpoint for the j-th subsystem. Decomposed drive model has a reduced dimension vector, and the states can be written as:

$$\hat{z} = [\delta, \omega]^T, \tag{5}$$

δ – angle of rotation, ω – angular frequency.

Then decompose the object model is conveniently written in the form:

$$S_j:\ \frac{d\delta_j}{dt}=\omega_j;$$
$$\frac{d\omega_j}{dt}=\hat{r}^{(j)}(\omega_j,\delta_j)\omega_j+\hat{s}^{(j)}M_l{}^{(j)};\quad j=\overline{1,N-1}. \tag{6}$$

Moments impact subsystem drives depend on the angular velocity:

$$\frac{d\omega_j}{dt}=a^{(j)}(x)x+b^{(j)}(x)M_j+h(x,f)f. \tag{7}$$

Expressing (6) point static load $M_l{}^{(j)}$, $j=\overline{1,N-1}$,and substituting the appropriate vector $M=\begin{bmatrix}M_1 & M_2 & ,..., & M_{N-1}\end{bmatrix}^T$, we obtain:

$$\frac{d\omega_j}{dt}=\hat{a}^{(j)}(x,\varphi^{(j)})+h(x,f)f. \tag{8}$$

Then the extended model of the top-level subsystems level can be represented as:

$$S_N:\ \frac{dx}{dt}=\hat{A}(x,\varphi)+H(x,f)f;$$
$$y=C(x)x. \tag{9}$$

Expression (9) describes the behavior of not only the top-level subsystem controllers, actuators and subsystems but in the domain of attraction of the corresponding local attractors.

Next, at step controller synthesis top level, you must define a set of goals Σ_N, based on the totality of which will be introduced varieties $\psi^{(N)}=0$ which satisfy the solution of differential equations of the form:

$$\frac{d\psi^{(N)}}{dt}+\mathrm{I}^{(N)}\psi^{(N)}=0. \tag{10}$$

Matrix $\mathrm{I}^{(N)}$ such that the solution $\psi^{(N)}=0$ is asymptotically stable.

As a result, the synthesis of hierarchical control system aircraft are regulators implementing equation form:

$$u^{(j)}=u^{(j)}(z^{(j)},\varphi^{(j)}),\ \ j=\overline{1,N-1}, \tag{11}$$

which produce a variety of purposes Σ_j, $j=\overline{1,N-1}$ for the lower level subsystems and provide subset solutions Δ_j, $j=\overline{1,N-1}$.

In addition, the regulator is formed by coordinating

$$\varphi=\varphi(x), \tag{12}$$

which produces a subset of solutions Δ_N, aimed at achieving the objectives of subsets Σ_N.

III. Conclusion

This article deals with the synthesis problem of complex aircraft systems. We were presented a new approach to the synthesis of hierarchical control structures multiply, multi-dimensional, nonlinear dynamic systems based on the principles and methods of the synergetic control theory. A distinctive feature of the proposed approach is that the use of synergetic ideology allows a natural decomposition of complex nonlinear dynamic systems multiply into many interacting subsystems, and as a result of the synergistic synthesis of each subsystem (or sub-groups) "immersed" at the intersection of the local attractors - invariant manifolds, reflecting a specific subset of goals, and the entire system as a whole "immersed" in the global attractor, corresponding to the initial set of goals. At a higher level of decision-making complexity it is taken into account the behavior of the subsystems on the lower levels, in the form of the equations describing them as "residual momentum" - the behavior of the local attractors (invariant manifolds).

To consider a hierarchy of control problems of spatial motion of aircraft. Are the most common approaches of decomposition methods are highlighted functional and temporal decomposition, allow you to create the most flexible control laws [15-17].

On the lower level of the hierarchy are the actuators that provide the necessary deviation of steering bodies and allow you to create the necessary control points. The generalized method of constructing a hierarchical traffic control system aircraft , according to which the upper levels of a hierarchical system is the formation of sets of solutions aimed at the achievement of the task management. These jobs are generated in the form of requirements to subsystems of the lower level, where regulators form management software for electrical , hydraulic and pneumatic servo drives that implement the specified control surface deflection. Residual dynamics actuators subsystem included in the lower layer increases the efficiency of the overall system being synthesized.

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Statistical Wound-Rotor IM Diagnosis Method Based on Standard Deviation using NVSA

K. Dahi, S.Elhani and S.Guedira

***Abstract*—** In this paper we address the problem of rotor faults in Wound Rotor Induction Machine by using two different signal processing methods to voltage between neutrals such as Standard deviation calculation and Hilbert Transform (HT). This last is employed as an effective technique for fault detection in induction machines. The mathematical simplicity of the proposed technique, compared with some commonly used algorithms from the literature, renders it competitive candidate for the on-line diagnosis of machines.

Experimental results are provided to verify the proposed method and to evaluate its performance as pre-processing for monitoring of Wound Rotor Induction Machine. An algorithm has been tested on neutral between voltages under different load conditions and rotor fault degrees that shows that the studied diagnosis method can be used as a valid methodology for this type of phenomena.

***Keywords*—** Diagnosis; Rotor fault; WRIM; Neutral voltage; Standard deviation.

I. Introduction

WOUND Rotor Induction Machine WRIM has recently known a new life due to the worldwide development, The wound rotor induction machine offers a number of advantages over other types of asynchronous machines, including the ability to produce a high starting torque with low starting current, and also they are easy assembly compared to asynchronous squirrel cage machine, thanks to these benefits that the WRIM is frequently used in the industry for any application requiring large rotating machines. However, these wind generators suffer from some electric stresses that can affected the profitability of these machines.

In this type of application, monitoring of WRIM is crucial due to their working environment, and fault diagnostics requires measures sensitive to the change greatness of the WRIM and an appropriate method to obtain a diagnostic index and a threshold indicating the limit between the healthy state and the defective one. There are a number of research papers on technical monitoring of electrical machines which are most relevant are [1] - [6].

K.Dahi and S.Elhani are with the Department of electrical engineering, at the Ecole Normale Supérieure de l'Enseignement Technique, Mohammed V Souissi University, Rabat-Morocco
(e-mail: Khalid.dahi@ um5s.net.ma; s.elhani@um5s.net.ma).

S. Guedira is with the "Ecole Nationale de l'Industrie Minérale" Rabat, Morocco, laboratoire de recherché commande protection et surveillance des installations industriels (e-mail: said.guedira@gmail.com).

Studies carried out by articles have shown that defects of the stator windings and rotor windings are assumed equal because they are inadequately protected. However, the vast majority of articles dealing mainly with rotor fault first and then with stator faults and finally bearing faults.

In this paper we focus on the rotor fault, this fault which physically resembles to the stator fault resulting either by short/open circuits or by increasing of the rotor resistance. In this case, the machine can also operate after the application of a fault, while in case of short/open circuits the machine operation is limited by a brief duration. In our case an additional resistance is added to one of the phases of the rotor to create the rotor fault.

Generally, MCSA "Motor Current Signal Analysis" [7] [8] [9][10]. (Widely known in the literature) is the most commonly used technique and well established. In fact, MCSA is simple and effective in appropriate operating conditions. However, this technique has significant limitations due to the increasing complexity of electrical machines and drives [1]:

1) It is influenced by the operating conditions (e.g. low load conditions, load oscillations);
2) The fault diagnosis is difficult or impossible if the system operates under time-varying conditions or the machine is supplied by a power converter;
3) The diagnosis is difficult or impossible in machines with special magnetic structure (e.g. machines with double cage in which there are a strong influence of interbar currents or only the outer cage has a fault).
4) The induction machines are now frequently installed with inverters which provide a number of advantages and therefore make the stator current inaccessible to diagnosis.

To reduce these limitations, the proposed work focuses on the use of voltage between neutrals NV "Neutral Voltage" [12] - [17] that we will name in this paper V_{NN}. The method has performance comparable to MCSA or better is based on the analysis of the potential difference between the neutral of star-connected stator and the neutral network in the case of a direct feed or artificial neutral in the case of a supply voltage by inverter in order to detect a rotor fault in induction machine.

In addition, by using this signal we follow the same steps as G.DIDIER [9] who has developed a method by MCSA for the detection of rotor faults without need to reference, this reference obtained in a healthy functioning. This approach is based on standard deviation calculations taken on two

frequency ranges, the first standard deviation will be calculated on the first frequency range, this range identifies where the phase jump whose frequency (*3-4s*)*fs*. The second standard deviation is a picture of measurement noise present between jumps being located at frequencies (*3-4s*)*fs* and (*3-6s*)f_s.

Thereafter, an analysis of phase spectra by the Hilbert transform is made, this transform is usually used in image processing, where the phase contains more relevant information than its module, its advantage is that the Hilbert transform calculated from the amplitude spectrum of the signal to analyze, which allows to conclude on the nature of fault.

This paper is organized as follows. Section II presents the theory background that we use in this study. The neutral voltage signal analysis NVSA is described in Section III. Proposed method is presented and explained in Section IV. In Section V, experimental results are validated and discussed.

II. Theory Background

The purpose of this section is to present some mathematical signal processing notions used to develop the studied method. To permit the reader to navigate the various strands, this section is subdivided into three main topics: Fourier and Hilbert transform, discrete Hilbert transform and standard deviation.

A. Phase Fourier transform

Recall the mathematical equation of the Fourier transform of a finite sequence ***{ps (0). . . , P (N - 1)}***

$$\mathcal{F}(k)=\frac{1}{N}\sum_{n=0}^{N-1}p_s(n)e^{-j\frac{2\pi nk}{N}} \tag{1}$$

By applying this relationship, the result is a complex signal with a real part and an imaginary part such as:

$$\mathcal{F}(k)=\Re(\mathcal{F}(k))+j\Im(\mathcal{F}(k)) \tag{2}$$

In our work we are interested in the form of the phase of NV, the phase of the Fourier transform is given by:

$$\varphi_{FT}(k)=\arctan\left(\frac{\mathcal{F}_{\mathrm{Im}(k)}}{\mathcal{F}_{\mathrm{Re}(k)}}\right) \tag{3}$$

B. Hilbert Transform

To start we present first the theory of the Hilbert transform

Let's consider a real measurement signal: $x(t)\in\mathcal{L}^{(2)}$

Where $L^{(2)}$ is the signal class with integral square

The Hilbert transform of the signal *x*(*t*) is : [18][19]

$$\tilde{x}(t)=\mathcal{H}\{x(t)\}=\int_{-\infty}^{\infty}\frac{x(\tau)}{\pi(t-\tau)}d\tau \tag{4}$$

$\tilde{x}(t)$ is improper named the conjugate of *x*(*t*), and we also have : $\tilde{x}(t)\in\mathcal{L}^{(2)}$

x(*t*) is the inverse Hilbert transform of $\tilde{x}(t)$

$$x(t)=\mathcal{H}^{-1}\{\tilde{x}(t)\}=-\frac{1}{\pi}\int_{-\infty}^{\infty}\frac{\tilde{x}(t)}{t-\tau}d\tau \tag{5}$$

Let's observe that $\tilde{x}(t)$ is determined by the convolution of *x*(*t*) with the signal 1/πt:

$$\tilde{x}(t)=x(t)*\frac{1}{\pi t} \tag{6}$$

Like Fourier transforms, Hilbert transforms are linear operators.

The above relation allows the calculus of the spectral density of $\tilde{x}(t)$:

$$\tilde{X}(j\omega)=X(j\omega).\mathcal{F}\{\frac{1}{\pi t}\} \tag{7}$$

Since: $$\mathcal{F}\left\{\frac{1}{\pi t}\right\}=-j\,\mathrm{sgn}(\omega)$$

It results: $$\tilde{X}(j\omega)=X(j\omega)\left[-j\,\mathrm{sgn}(\omega)\right] \tag{8}$$

Or:

$$\tilde{X}(j\omega)=\begin{cases}-jX(j\omega),\omega>0\\ jX(j\omega),\omega<0\end{cases} \tag{9}$$

As a result, the spectral density function of the *x*(*t*) signal's conjugate is obtained by changing the phase of the spectral density for *X*(*jω*) by ±π/2. And it results:

$$\tilde{x}(t)=\mathcal{H}\{x(t)\}=\mathcal{F}^{-1}\{\tilde{X}(j\omega)\} \tag{10}$$

Taking into account relation (8) it results:

$$x(t)=-\mathcal{H}\{\tilde{x}(t)\}=\begin{cases}-\mathcal{F}^{-1}\{j\tilde{X}(j\omega)\},\omega>0\\ \mathcal{F}^{-1}\{-j\tilde{X}(j\omega)\},\omega<0\end{cases} \tag{11}$$

The analytic signal

A useful point of view to understand and to compute the Hilbert Transform of *x*(*t*) is using the analytic signal *z*(*t*) associated with *x*(*t*), defined, as explained before, as:

$$z(t)=x(t)+j\tilde{x}(t) \tag{12}$$

That can be rewritten also as:

$$z(t)=A(t)*e^{j\theta(t)} \tag{13}$$

Where *A*(*t*) is called the envelope signal of *x*(*t*) and *θ*(*t*) is called the instantaneous phase signal of *x*(*t*). In terms of *x*(*t*) and $\tilde{x}(t)$, it is clear that:

The use of Hilbert phase analysis is applied to the module of Fourier transformation frequency of the signal *x*(*t*). Indeed, the analytic signal and the corresponding phase are given by:

$$A(t)=[x^2(t)+\tilde{x}(t)]^{1/2} \tag{14}$$

$$\varphi(t)=\tan^{-1}\left[\frac{\tilde{x}(t)}{x(t)}\right]=2\pi f_0 t \tag{15}$$

Or:

$$\varphi(f)=\arctan\frac{\mathcal{H}\left[|X(f)|\right]}{|X(f)|} \tag{16}$$

And the "instantaneous frequency" is given by:

$$f_0=\left(\frac{1}{2\pi}\right)\tan^{-1}\left[\frac{\tilde{x}(t)}{x(t)}\right] \tag{17}$$

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C. Discrete Hilbert Transform

Having the signal $x(t)$ defined on the time interval $[0,t_N]$ using a sampling period T_e, we obtain the discrete signal $x[n]$:

$$x(n) = x(nT_e), n \in \overline{0, N-1} \quad (18)$$

Where: $T_e=t_N/N$

The sampling frequency f_e is chosen so that the frequency $f_e/2$ is greater or equal to the least significant frequency from the spectrum of $x(t)$. We consider the discrete frequency step:

$$f_0 = \frac{f_e}{N} \quad , \qquad \omega_0 = \frac{2\pi}{N} f_e \quad (19)$$

The discrete Fourier transform (DFT) is:

$$TFD\{x[n]\} = X[k] = \sum_{n=0}^{N-1} x[n] e^{-jnk\frac{2\pi}{N}}, k \in \overline{0, N-1} \quad (20)$$

The sample of the spectral density corresponding to frequency $k\omega_0$ is determined with the relation:

$$X(jk\omega_0) = T_e X[k] \quad (21)$$

Where $X(j\omega)$ is the Fourier transform in continuous time.

O the other hand:

$$X[k]^* = X[N-k] = X[-k] \quad (22)$$

Which show that the sample $X[N-k]=X[-k]$ has a correspondent sample of the spectral density, with the negative frequency $X(-k\omega_0)$.

Similarly to (10) the discrete Hilbert transform is defined as:

$$\mathcal{H}\{x[n]\} = \tilde{x}[n] = TFD^{-1}\{\tilde{X}[k]\} \quad (23)$$

Where for N-even:

$$\tilde{X}[k] = \begin{cases} -jX[k], k = \overline{1, \frac{N}{2}-1}, Neven \\ jX[k], k = \overline{\frac{N}{2}+1, N-1}, Neven \end{cases} \quad (24)$$

D. Standard deviation formula:

The RMS can be computed in the frequency domain, using Parseval's theorem. For a sampled signal

$$\sum_n x^2(t) = \frac{\sum_n |X(f)|^2}{n} \quad (25)$$

Where $X(f)=\text{FFT}\{x(t)\}$ and n is number of $x(t)$ samples.

In this case, the RMS computed in the time domain is the same as in the frequency domain:

$$RMS = \sqrt{\frac{1}{n}\sum_n x^2(t)} = \sqrt{\frac{1}{n^2}\sum_n |X(f)|^2} \quad (26)$$

If is the arithmetic mean and is the standard deviation of a waveform then:

$$x_{rms}^2 = \tilde{x}^2 + \sigma_x^2 \quad (27)$$

The standard deviation (represented by the Greek letter sigma, σ) shows how much variation or dispersion from the average exists, and it's defined by:

$$\sigma_x = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}\left(x_i - \frac{1}{N}\sum_{i=1}^{N} x_i\right)^2} \quad (28)$$

III. Neutral Voltage Signal Analysis (NVSA)

A. NVSA frequency

1998, M.A.Cash [12] used the voltage between the neutral of the supply voltage and the neutral of induction machines (Fig. 1) to detect short circuits between spiral in stator coils. A similar analysis was carried out by [14] [15] in order to detect rotor fault in induction machines.

The voltage between the neutral and the neutral WRIM of the power source is given by the following mathematical relationship:

$$V_{NN} = R_a I_{sa} + L_a \cdot \frac{dI_{sa}}{dt} + \frac{dL_a}{d\theta}\Omega I_{sa} - V_{Supply} \quad (29)$$

Where:

R_a represents the stator-phase resistance,
L_a his inductance,
I_{sa} the current passing through it,
Ω Rotation speed, θ the angular position of the rotor and V_{supply} simple voltage generated by network supply.

The presence of a fault rotor reveals additional components in the spectrum of NV. Indeed, M.E.K. OUMAMMAR [17] demonstrated by a complex analysis, that the appearance of a rotor fault induces additional components in the frequency spectrum of the NV at frequencies given by the relation:

$$f_h = \lfloor 3h - (3h \pm 1)s \rfloor f_s \quad (30)$$

s: slip, f_s: supply frequency, h = 1,3,5, ...

The speed ripple induced additional harmonic components around the previous frequency, and the frequencies of all components can be expressed as follows:

$$f_h = \lfloor 3h(1-s) \pm s(1+2k) \rfloor f_s \quad (31)$$

B. FFT Analysis

The information given by the spectrum of the voltage at the third harmonic [11], i.e., nears the spectral line having the frequency 150 Hz can be used for WRIM fault diagnosis. We present in Fig.3 the power spectral density of NV for a rotor fault near this harmonic. We note the presence of the main frequency component (2) and additional components around these main components.

It is important to note that the rotor fault is created by adding an extra resistance on one of the rotor phase in order to have a dissymmetry in the rotor. For that the value of the rotor resistance has been progressively varied during the experiment from $R_{add} = 0$ to $R_{add} = 1.25R_r$, from this variation we can see its effect on the spectrum of the NV according to (27), the value of $f_{fault} = 145$ Hz.

In fig.2 is shown that the magnitude of the characteristic harmonic frequency due to a rotor fault changes as function of the additional resistance.

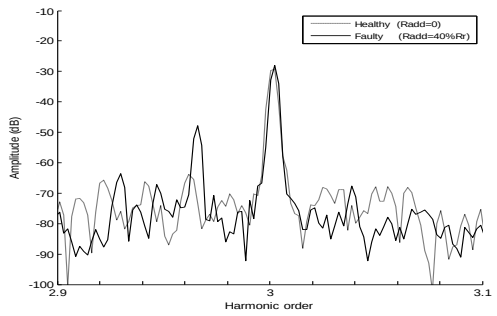

Fig. 1. Experimental results for the WRIM. Spectrum of neutral voltage in healthy (light black solid line) and faulty (solid line)

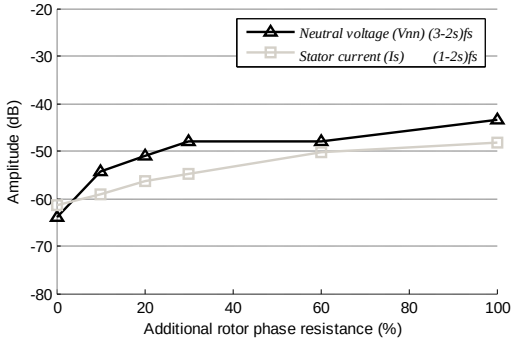

Fig. 2. Effect of a faulty operating conditions given by an increment of the rotor-phase resistance (neutral voltage and stator current)

IV. Proposed Method

In this work we perform a rotor fault diagnosis based on standard deviation calculation, for that we propose an algorithm to decision making by analyzing the exclusive NV signal.

Studies [15] [16] have shown that all asynchronous machines have a slight asymmetry of construction induced, in the spectrum of NV, a frequency component:

$$f_h = \lfloor 3h(1-s) \pm s(1+2k) \rfloor f_s \tag{32}$$

This method has been developed by G.DEDIER who used it on stator current analysis. We follow the same steps and we study first the phase $\varphi\mathcal{F}(f)$, particularly the jump present at the frequency $(3\text{-}4s)f_s$. Normally, this phase jump is very small or even zero for a healthy induction machine whatever the level of load. For the studied machine, figure 4 shows this slight fluctuation.

We propose the detection of a rotor fault by studying exclusively the phase jump located at the frequency $(3\text{-}4s)f_s$. We compare the standard deviation of the phase $\varphi\mathcal{H}(f)$ and the phase $\varphi\mathcal{F}(f)$ based on two different frequency ranges. Indeed, the first standard deviation, noted σ_j will be calculated on the frequency range (R_1), this range identifies where is the phase jump whose frequency $(3\text{-}4s)f_s$. The second standard deviation, which we note σ_n will be calculated on the frequency range (R_2) This standard deviation is a picture of measurement noise present between jumps being located at frequencies $(3\text{-}4s)f_s$ and $(3\text{-}6s)f_s$.

$$R_1 = \left\lfloor (3-4s) f_s - \frac{\delta}{2}, (3-4s) f_s + \frac{\delta}{2} \right\rfloor \tag{33}$$

$$R_2 = \left\lfloor (3-4s) f_s - \frac{\delta}{2}, (3-6s) f_s + \frac{\delta}{2} \right\rfloor \tag{34}$$

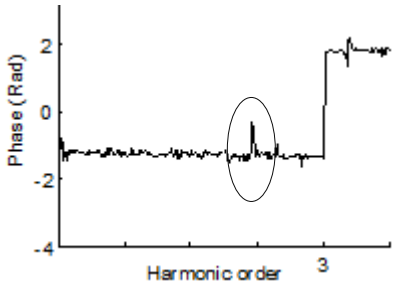

Fig. 3. Fluctuations at Spectrum phase in healthy case

The mathematical relationship to calculate the standard deviation σv, unbiased, of the Neutral Voltage is:

$$\sigma_v = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}\left(v_n - \frac{1}{N}\sum_{i=1}^{N} v_n\right)^2} \tag{35}$$

Fig. 5 shows a representation for an adequate understanding of the calculation of these deviations. The standard deviation σ_j is calculated on the gray frequency range while the standard deviation σ_n is calculated on the black frequency range.

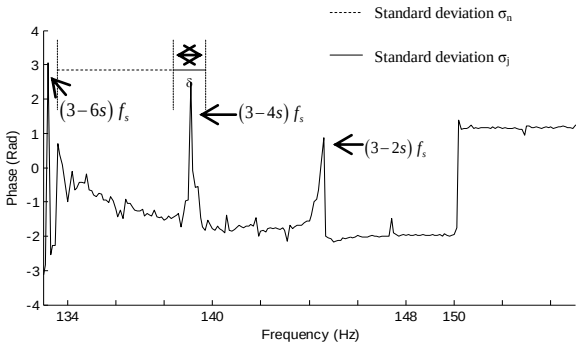

Fig. 4. Calculation of standard deviations σ_j and σ_n

For the further diagnosis it is necessary to calculate the slip s of the machine in both frequency ranges R_1 and R_2.

In most machines, the jump located at the frequency $(3\text{-}4s)f_s$ is always present in the Fourier and Hilbert phase, it adds that is this jump is more pronounced among other jumps (same thing for stator current phase, where $(1\text{-}2s)f_s$ is the most pronounced in the spectrum) .The calculation of this shift will inform us about the frequency $(3\text{-}4s)f_s$ desired. The detection of the jump located at the frequency $(3\text{-}2s)f_s$ is given since we know the fundamental frequency f_s.

The maximum slip of the machine allows obtaining the minimum frequency:

$$f_{def_{\min}} = (3 - 2s_{\max})\, f_s \quad (36)$$

The proposed methodology to diagnose rotor fault in WRIM is shown in Fig. 5 Based on these algorithm we present in the next section some experimental results to validate the proposed method.

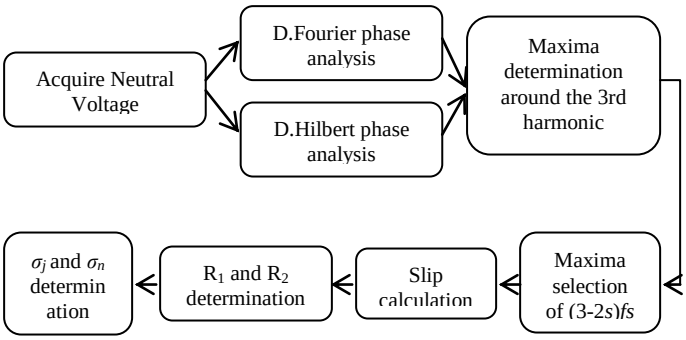

Fig. 5. Proposed methodology

V. Results and Discussion:

The diagnostic procedure presented in this paper has been tested through an off-line approach in which different degrees of additional resistance to create the rotor asymmetry have been forced in the WRIM.

A. Experimental Setup

Experimental Tests were developed on a 3kW, 50Hz, 220V/380V, 4-poles Wound Rotor Induction Machine (Table.IV and V). The motor was directly coupled direct current machine acting as a load. Two voltage sensors are used to monitor the induction machine operation. The IM voltages are measured by means of the two sensors which are used as inputs of the signal conditioning and the data acquisition board integrated into a personal computer.

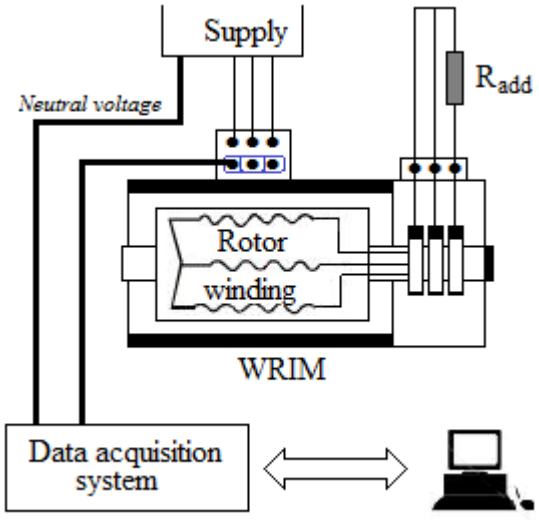

Fig. 6. Experimental set-up

For those two variables, the sampling frequency was 2 kHz and each data length was equal to 2^{14} values. Eight data sets of induction machines neutral voltage subject to different numbers of rotor fault and load conditions were analyzed (Table I).

TABLE I Analyzed Data sets

Set	Machine condition
s1	Healthy, unloaded
s2	Healthy, 75% Load
s3	Healthy, Full load
s4	Fault, unloaded
s5	Fault, 75 % load, R_{add}=10%R_r
s6	Fault, 75 % load, R_{add}=20%R_r
s7	Fault, 75 % load, R_{add}=100%R_r
s8	Fault, 100 % load, R_{add}=10%R_r

B. Method diagnosis based on Fourier transform phase analysis

In this section, we apply the detection method described above on NV when the machine is directly connected to the three-phase network.

The results are presented in Table II, the first column of this table corresponds to the rotor state, the second gives the value of the frequency $(3\text{-}2s)f_s$, third and fourth in succession values σ_j and σ_n calculated on the frequency ranges R_1 and R_2, the fifth gives σ_j/σ_n report that allows the decision making by the last column. Thus, we represent in Fig.6 curve $\varphi\mathcal{F}(f)$ phases for s2, s4,s5,s6,s7 and s8 tests.

According to the column giving σ_j/σ_n report we note that it is low for a machine operating with a healthy rotor, then we perceive that for some healthy functioning we do not detect jump phase $(3\text{-}2s)f_s$ in this case we consider the rotor in good condition.

The appearance of a partial rotor fault does not induce a significant increase of σ_j relative to σ_n, which does not allow to conclude on such a failure, it may be the low point method using $\varphi\mathcal{F}(f)$. For an important rotor fault (s8) we note that this report is greater 10 times that in tests where the machine is healthy

From the results of the Table II, we can validate the proposed approach, even if σ_j/σ_n report in tests s6 and s5 is less pronounced as seen in Table II, but the results are satisfactory.

According to Fig. 7 and Table II, the first problem for this approach is the high level of noise in the frequency range studied. The second problem is the wrong detection of the phase jump at frequencies located at frequency characterizing the rotor fault for the NVSA. In fact, the presence of random phase jumps in the frequency range does not allow proper detection of the phase jump required to calculate the slip.

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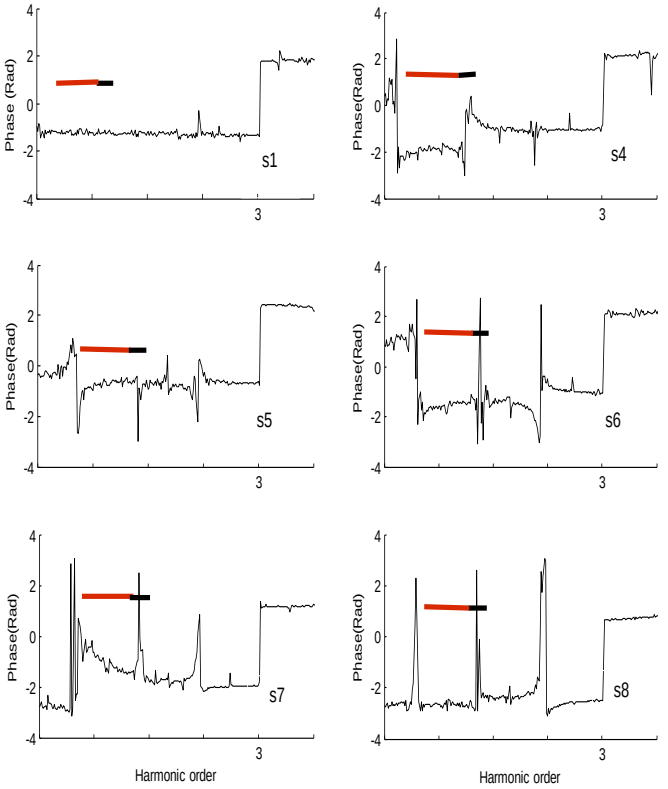

Fig. 7. Standard deviations σ_j and σ_n calculation by $\varphi F(f)$

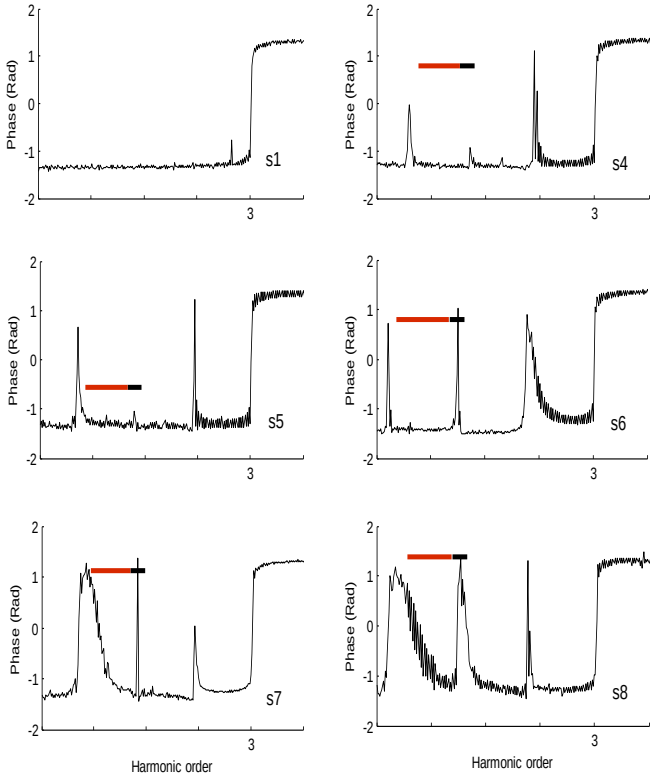

Fig. 8. Standard deviations σ_j and σ_n calculation by $\varphi \mathcal{H}(f)$

TABLE II RESULTS OF DIAGNOSTIC METHOD APPLIED TO THE PHASE OF THE FOURIER TRANSFORM

Rotor state	*(3-2s) fs.* (Hz)	*(3-4s) fs.* (Hz)	σ_n	σ_j	$\frac{\sigma_J}{\sigma_N}$
s1	No max detection				
s2	No max detection				
s3	145.23	139.19	0.240	0.091	2.64
s5	144.40	138.81	0.065	0.063	1.03
s8	146.33	140	0.969	0.026	37.30
s4	144.40	138.81	0.240	0.091	2.64
s6	143.8	138	0.51	0.079	6.52
s7	142.95	137.31	0.42	0.051	8.34

C. Hilbert transform phase analysis

We have already seen that even the good results that phase spectrum analysis compared to the module spectrum analysis, this method has two drawbacks.

1) The noise level is high, which makes detection difficult.
2) The second is that the form of the phase is not fixed. Indeed, the real and imaginary parts can take random values.

To stabilize the form of phase, we must find a solution to control the values of the real and imaginary parts of the spectrum, the idea is to obtain a phase always equal to$[-\pi/2]$ to the left of *f*s and equal to $[\pi/2]$ right f_s, the real part must be zero at frequencies $\pm f_{def}$ and f_s.

These problems can be circumvented with the use of the Hilbert transform, as we will see below.

In order to support the results obtained, we give in Fig. 8 the curves of phase $\varphi \mathcal{H}(f)$ with different fault level. In these figures, we stand once again by a continuous gray line the frequency range where the standard deviation σ_j is calculated, for a continuous black line the frequency range where the standard deviation σ_n is calculated, and a red line the maximum of the phase jump at the frequency located at $(3\text{-}2s)f_s$.

By use of the Hilbert transform (Table III), the two sets s4 and s5 were detected which is not the case when using the Fourier transform. Except this particular case, the results are better than those given in Table II. This better detection is possible because the noise in the phase of the signal analysis is much less important when the machine is running at low load torque. In addition, it is important to note that the signals obtained by the Hilbert transform are much less noisy than those calculated from the Fourier transform.

We show in Fig. 9 a comparison between the Hilbert approach and Fourier one in both healthy and faulty cases. We note that the σ_j/σ_n report does not vary too much despite the variation in the load level. In the defective case we see a notable variation between fault conditions.

From Fig.9, we note that the σ_j/σ_n report does not exceed 3 for a healthy machine and it is greater than 3 for a defective machine. This conclusion led the authors in [9] to operate to make an induction machine diagnosis method without reference (this reference usually obtained from a healthy functioning). In other words if the report σ_j/σ_n is less than 3

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then the machine is healthy, and defective if greater than 3.

From this result we can draw a law diagnostic decision support such as that given by G.DEDIER[9].

TABLE III RESULTS OF DIAGNOSTIC METHOD APPLIED TO THE PHASE OF THE HILBERT TRANSFORM

Rotor state	*(3-2s)fs* (Hz)	*(3-4s)fs* (Hz)	σ_n	σ_J	$\frac{\sigma_J}{\sigma_N}$
s1	No max detection				
s2	145.23	139.19	0.384	0.108	3.56
s3	145.23	139.19	0.105	0.073	1.45
s5	144.40	138.81	0.056	0.005	10.64
s8	146.33	140	0.29	0.003	79.30
s4	144.40	138.81	0.015	0.007	2.15
s6	143.8	138	0.302	0.006	48.01
s7	142.95	137.31	0.36	0.006 3	56.3

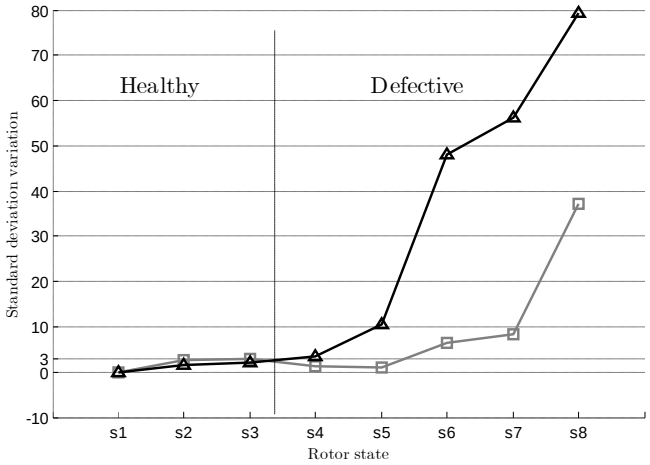

Fig. 9. Hilbert (Black line) and Fourier Transform (Gray line) method comparison

VI. CONCLUSION

Two approaches have been proposed to diagnose rotor fault. The first approach is based on the calculation of Fourier transform phase of Neutral Voltage. This phase contained relevant information on the status of the asynchronous machine. The results are relatively interesting.

To improve fault diagnosis, a second approach has been proposed. This method uses the same approach as described above, the only difference lies in the fact that this is not the phase of the Fourier transform of the Neutral Voltage which is analyzed by the program decision, but the phases of the analytic signal obtained by Hilbert transform of the amplitude spectrum of Neutral Voltage. This analysis helped to detect other defects that were not detected by the first approach.

In conclusion, the latest proposed method provides more meaningful results that the analysis of the phase spectrum of Neutral Voltage. Similarly, it would be interesting to validate this approach on asynchronous machines with different characteristics (higher power machines for example) to help determine a law of behavior for α parameter used in the detection criterion.

APPENDIX

TABLE IV WRIM PARAMETERS

Parameter	***Value***	
Rated power	kW	3
Rated stator voltage	V	220
Rated frequency	Hz	50
Rated speed	rpm	1400
Stator phase resistance	Ω	0.621
Rotor phase resistance	Ω	0.4
Rotor inductance	H	0.013
Pole pairs		2

TABLE V WRIM SENSORS

Parameter	***Value***	
Current sensor type		LA100
Current sensor accuracy	%	0.45
Current sensor Bandwidth	kHz	200
Voltage sensor type		DV1200
Voltage sensor accuracy	%	0.3
Voltage sensor Bandwidth	kHz	6.5

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Khalid Dahi was born in Errachidia, Morocco, in 1988. He received the M.S. degree in electrical engineering in 2012 from the Mohammed V Souissi University, Rabat-Morocco- where he is currently working toward the Ph.D. degree in the department of electrical engineering. Since 2012, His research interests are related to electrical machines and drives, diagnostics of induction motors. His current activities include monitoring and diagnosis of induction machines in wind motor.

Dr. Soumia El Hani, Professor at the ENSET (Ecole Normale Supérieure de l'Enseignement Technqique-Rabat, Morroco) since October 1992. Research Engineer at the Mohammed V Souissi University Morocco. In charge of the research team electromechanical, control and diagnosis. Member of the eesearch eaboratory in electrical engineering at ENSET -Rabat. In charge of electrotechnic and power electronic competences group. Author of several publications in the field of electrical engineering, including robust control systems, diagnosis and control systems of wind electric conversion.

Dr. Said GUEDIRA, Professeor at ENIM (Ecole Nationale de l'Industrie Minérale - Rabat – Morroco) since 1983. Research Engineer and Director of the research laboratory CPS2I (Control, protection et surveillance des installations industrielles). Author of several publications in the field of Electrical Engineering, including diagnosis and control of mechatronic systems.

Stability Analysis of Mechanical Systems with Time Delay via Decomposition

Alexander Yu. Aleksandrov, Elena B. Aleksandrova, and Alexey P. Zhabko

***Abstract*—Certain classes of mechanical systems whose motions are described by the second order differential equations with delay are studied. The delay is assumed to be a continuous nonnegative and bounded function of time. By the usage of the Lyapunov direct method and the Razumikhin approach, the conditions are found under which the stability problem for the original time-delay second order system can be reduced to that for two independent delay free first order subsystems. The proposed approaches are applied to the stability analysis of hybrid mechanical systems with switched force fields.**

***Index Terms*—Decomposition, delay, mechanical systems, stability.**

I. Introduction

The stability analysis of mechanical systems is a fundamental research problem [1–3]. In numerous applications, motions of mechanical systems are described by multivariate differential equations of the second order, and this essentially complicates the investigation of their dynamics [3–5]. A general and efficient approach to stability analysis for multidimensional systems (for large-scale or complex systems) is the decomposition method [3, 4]. It consists of, firstly, a decomposition of a complex system into the interconnected subsystems, secondly, stability investigation of isolated subsystems and constructing of Lyapunov functions for them, and, thirdly, subsequent aggregation of the obtained functions in one scalar or vector Lyapunov function for the original system.

This method has been effectively applied to wide classes of mechanical systems, see, for example, [3–9] and the references cited therein. Nevertheless, the problem of further development of decomposition method remains an actual one. Its importance is caused by the fact that stability conditions of complex systems obtained by the application of the method depend on the precision of estimation of a Lyapunov function derivative with respect to the considered system. Therefore, by means of appropriate choice of aggregation form, one can define more exactly the domain of system parameter values guaranteeing the stability of a programmed motion.

Furthermore, it is worth mentioning that realistic models of numerous mechanical systems must incorporate aftereffect phenomena in their dynamics [10–12]. For this aim delay differential equations can be used. In particular, feedback control mechanical systems unavoidably involve delay because a certain time is needed for the system reaction on the input signal.

It is well known that the presence of time delay could cause instability, see [12, 13]. In some applications, it is not possible to assure that delay is sufficiently small, and even known. Therefore, it is important to obtain restrictions for delay values under which stability for the considered systems can be guaranteed [11–17]. This problem is especially difficult for systems with time-varying delay [13].

In the present paper, linear mechanical system with a large parameter at the velocity forces and with delay in the positional forces is studied. The delay is assumed to be a continuous nonnegative and bounded function of time. By the usage of the Lyapunov direct method and the Razumikhin approach, the conditions are found under which the stability problem for the original time-delay second order system can be reduced to that for two independent delay free first order subsystems. Furthermore, the conditions of decomposition are obtained as well for the case of linear velocity forces and essentially nonlinear homogeneous positional forces with time-delay. It is shown that the proposed approaches can be applied to the stability analysis of hybrid mechanical systems with switched force fields.

II. Statement of the Problem

Let motions of a mechanical system are described by the equations

$$A\ddot{q}(t) + hB\dot{q}(t) + C_1 q(t) + C_2 q(t - \tau(t)) = 0. \qquad (1)$$

Here $q(t)$ and $\dot{q}(t)$ are n-dimensional vectors of generalized coordinates and generalized velocities respectively; A, B, C_1, C_2 are constant matrices; h is a large positive parameter; the delay $\tau(t)$ is a continuous nonnegative and bounded for $t \in [0, +\infty)$ function. We assume that the matrices A and B are nonsingular. Systems of the form (1) are widely used as linearization of equations of gyroscopic systems motions [3, 6]. The term $-C_2 q(t-\tau(t))$ can be treated as a control vector, whereas the presence of delay $\tau(t)$ might be caused by a time lag between the moments of measuring of the state and the application of the corresponding control force.

In the sequel, R denotes the field of real numbers, and R^n the n-dimensional Euclidean space. Let $\tau_0 = \sup_{t \geq 0} \tau(t)$. We assume that initial functions for solutions of (1) belong to the space $C([-\tau_0, 0], R^n)$ of continuous functions $\varphi(\theta) : [-\tau_0, 0] \to R^n$ with the uniform (supremum) norm $\|\varphi\|_{\tau_0} = \max_{\theta \in [-\tau_0, 0]} \|\varphi(\theta)\|$, and $\|\cdot\|$ denotes the Euclidean norm of a vector.

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A. Yu. Aleksandrov, E. B. Aleksandrova, and A. P. Zhabko are with the Faculty of Applied Mathematics and Control Processes, Saint Petersburg State University, Saint Petersburg, Russia 198504 e-mail: alex43102006@yandex.ru; star1460@yandex.ru; zhabko@apmath.spbu.ru

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Consider the auxiliary delay free subsystems

$$B\dot{y}(t) + (C_1 + C_2)y(t) = 0, \tag{2}$$

$$A\dot{z}(t) + Bz(t) = 0. \tag{3}$$

We look for conditions under which the asymptotic stability of subsystems (2) and (3) implies that for system (1).

In the case when $\tau(t) \equiv 0$, such conditions have been obtained in [6]. In [18], results of [6] were extended to system (1) with a constant delay. However, it is worth mentioning that approaches proposed in [6] and [18] are based on the Lyapunov first method, and they are inapplicable to systems with time-varying delay.

Another approach to stability analysis of system (1) without delay has been proposed in [7]. It is based on the Lyapunov direct method. Let us note that, unlike the results of [6], this approach permits to obtain stability conditions for some types of time-varying systems. In particular, in [19], it was used for the stability investigation of hybrid linear mechanical systems with switched positional forces.

In this paper, we will show that the Kosov approach is applicable to system (1) with time-varying delay.

Furthermore, we will study decomposition conditions for the essentially nonlinear system of the form

$$A\ddot{q}(t) + B\dot{q}(t) + Q_1(q(t)) + Q_2(q(t-\tau(t))) = 0, \tag{4}$$

where components of the vectors $Q_1(q)$ and $Q_2(q)$ are continuously differentiable for $q \in R^n$ homogeneous functions of the order $\mu > 1$, and the rest notation is the same as in (1).

Finally, we shall consider systems of the forms (1) and (4) with switched positional forces. Based on the developed approaches, the conditions guaranteeing the asymptotic stability for an arbitrary admissible switching signal will be obtained.

III. Decomposition of systems with linear positional forces

Let the linear time-delay system (1) be given.

Theorem 1: Assume that the isolated subsystems (2) and (3) are asymptotically stable. Then, for any continuous nonnegative and bounded for $t \in [0, +\infty)$ delay $\tau(t)$, there exists a number $h_0 > 0$ such that system (1) is asymptotically stable for all $h \geq h_0$.

Proof: According to the approach suggested in [7], let us define new variables by the formulae

$$\dot{q}(t) = z(t), \qquad A\dot{q}(t) + hBq(t) = hBy(t). \tag{5}$$

Substitution (5) does not disturb stability properties and transforms system (1) to the form

$$\begin{aligned}
&B\dot{y}(t) = -\tfrac{1}{h}\left(C_1 + C_2\right)y(t) \\
&-\tfrac{1}{h}C_2(y(t-\tau(t)) - y(t)) \\
&+\tfrac{1}{h^2}C_1B^{-1}Az(t) + \tfrac{1}{h^2}C_2B^{-1}Az(t-\tau(t)), \\
&A\dot{z}(t) = -hBz(t) - C_1y(t) - C_2y(t-\tau(t)) \\
&+\tfrac{1}{h}C_1B^{-1}Az(t) + \tfrac{1}{h}C_2B^{-1}Az(t-\tau(t)).
\end{aligned} \tag{6}$$

It is known, see [1, 20], that from the asymptotic stability of isolated subsystems (2) and (3), it follows the existence of quadratic forms $V_1(y)$ and $V_2(z)$ such that the inequalities

$$a_{11}\|y\|^2 \leq V_1(y) \leq a_{12}\|y\|^2, \quad a_{21}\|z\|^2 \leq V_2(z) \leq a_{22}\|z\|^2,$$

$$\left\|\frac{\partial V_1}{\partial y}\right\| \leq a_{13}\|y\|, \qquad \left\|\frac{\partial V_2}{\partial z}\right\| \leq a_{23}\|z\|,$$

$$\dot{V}_1\big|_{(2)} \leq -a_{14}\|y\|^2, \qquad \dot{V}_2\big|_{(3)} \leq -a_{24}\|z\|^2$$

are valid for all $y, z \in R^n$. Here a_{ij} are positive constants, $i = 1, 2$, $j = 1, 2, 3, 4$.

Choose a Lyapunov function for system (6) in the form

$$V(y, z) = \varepsilon h^2 V_1(y) + V_2(z), \tag{7}$$

where ε is a positive parameter. Differentiating $V(y, z)$ with respect to system (6), we obtain

$$\begin{aligned}
\dot{V}\big|_{(6)} \leq &-a_{14}\varepsilon h\|y(t)\|^2 - ha_{24}\|z(t)\|^2 + \\
&+\varepsilon b_1\|y(t)\|\left(h\|y(t-\tau(t)) - y(t)\| + \|z(t)\| + \|z(t-\tau(t))\|\right) \\
&+b_2\|z(t)\|\Big(\|y(t-\tau(t))\| + \|y(t)\| \\
&+\frac{1}{h}\|z(t)\| + \frac{1}{h}\|z(t-\tau(t))\|\Big).
\end{aligned}$$

Here $b_1 = \text{const} > 0$, $b_2 = \text{const} > 0$.

Let us prove that, for sufficiently large values of h, the Lyapunov function (7) satisfies all the conditions of Theorem 4.2 from [10]. Assume that, for a solution $\left(y^T(t), z^T(t)\right)^T$ of (6), the Razumikhin condition $V(y(\xi), z(\xi)) \leq 2V(y(t), z(t))$ is fulfilled for $\xi \in [t-2\tau_0, t]$. Then there exist positive numbers c_1 and c_2 such that the esimates

$$\|y(\xi)\| \leq c_1\left(\|y(t)\| + \frac{1}{h\sqrt{\varepsilon}}\|z(t)\|\right),$$

$$\|z(\xi)\| \leq c_2\left(h\sqrt{\varepsilon}\,\|y(t)\| + \|z(t)\|\right)$$

hold for $\xi \in [t - 2\tau_0, t]$.

Applying the Mean Value Theorem, we obtain

$$\begin{aligned}
\|y(t-\tau(t)) - y(t)\| \leq \tau_0 c_3\Big(&\frac{1}{h}\|y(t-\eta\tau(t))\| \\
&+\frac{1}{h}\|y(t-\eta\tau(t)-\tau(t-\eta\tau(t)))\| + \frac{1}{h^2}\|z(t-\eta\tau(t))\| \\
&+\frac{1}{h^2}\|z(t-\eta\tau(t)-\tau(t-\eta\tau(t)))\|\Big),
\end{aligned}$$

where $c_3 = \text{const} > 0$, and $0 < \eta < 1$.

With the aid of these estimates, we arrive at the inequality

$$\begin{aligned}
\dot{V}(y(t), z(t)) \leq &-a_{14}\varepsilon h\|y(t)\|^2 - ha_{24}\|z(t)\|^2 \\
&+\varepsilon\tilde{b}_1\|y(t)\|\Big((\tau_0 + \tau_0\sqrt{\varepsilon} + h\sqrt{\varepsilon})\|y(t)\| \\
&+\left(1 + \frac{\tau_0}{h} + \frac{\tau_0}{h\sqrt{\varepsilon}}\right)\|z(t)\|\Big) \\
&+\tilde{b}_2\|z(t)\|\left((1+\sqrt{\varepsilon})\|y(t)\| + \left(\frac{1}{h} + \frac{1}{h\sqrt{\varepsilon}}\right)\|z(t)\|\right).
\end{aligned}$$

Here $\tilde{b}_1$ and $\tilde{b}_2$ are positive constants.

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Let the parameter ε satisfy the condition $4\tilde{b}_1\sqrt{\varepsilon} < a_{14}$. Then, for chosen value of ε, there exists a number $h_0 > 0$ such that

$$\dot{V}(y(t), z(t)) \le -\frac{1}{2}\left(a_{14}\varepsilon h\|y(t)\|^2 + h a_{24}\|z(t)\|^2\right)$$

for all $h \in (0, h_0]$. Hence [10], system (6) is asymptotically stable, and this implies the asymptotic stability of the original system (1). This completes the proof.

Remark 1: The proof of Theorem 1 contains a constructive procedure for the finding of the estimate of the set of large parameter values for which the asymptotic stability can be guaranteed.

Remark 2: Theorem 1 remains valid for the case when τ_0 is a function of h; and it can be even unbounded for $h \in (0, +\infty)$. The only restriction on it is the condition $\tau_0(h)/h \to 0$ as $h \to +\infty$.

Example 1: Let the control system

$$\ddot{q}(t) + h\begin{pmatrix} b & -g \\ g & b \end{pmatrix}\dot{q}(t) - \begin{pmatrix} c & 0 \\ 0 & c \end{pmatrix} q(t) = u \quad (8)$$

be given. Here $q(t), \dot{q}(t) \in R^2$; b, g, c are positive constants; $u = (u_1, u_2)^T$ is a control vector; h is a positive parameter.

It is known [1], that, in the case when $u = 0$, system (8) is unstable. Consider the problem of stabilization of this system under the following restrictions on the control law:

(i) control forces should be nonconservative;

(ii) there exists a delay in the control scheme.

We assume that delay might be unknown and time-varying, and only an upper bound $\tau_0 > 0$ for delay values is given.

Define the control vector by the formula

$$u = \begin{pmatrix} 0 & p \\ -p & 0 \end{pmatrix} q(t - \tau(t)),$$

where $p = \text{const} > 0$. For this control law, the closed-loop system takes the form

$$\ddot{q}(t) + h\begin{pmatrix} b & -g \\ g & b \end{pmatrix}\dot{q}(t) - \begin{pmatrix} c & 0 \\ 0 & c \end{pmatrix} q(t) + \begin{pmatrix} 0 & -p \\ p & 0 \end{pmatrix} q(t - \tau(t)) = 0. \quad (9)$$

Consider subsystems (2) and (3) corresponding to system (9). We obtain

$$\dot{y}(t) = \frac{1}{b^2 + g^2}\begin{pmatrix} bc - gp & bp + gc \\ -bp - gc & bc - gp \end{pmatrix} y(t), \quad (10)$$

$$\dot{z}(t) = \begin{pmatrix} -b & g \\ -g & -b \end{pmatrix} z(t). \quad (11)$$

Subsystem (11) is asymptotically stable, and for the asymptotic stability of subsystem (10) it is necessary and sufficient the fulfilment of the inequality

$$p > \frac{bc}{g}. \quad (12)$$

Applying Theorem 1, we obtain that, under the condition (12), for an arbitrary given number $\tau_0 > 0$, there exists $h_0 > 0$ such that the closed-loop system (9) is asymptotically stable for all $h \ge h_0$ and for any continuous delay $\tau(t)$ satisfying the inequalities $0 \le \tau(t) \le \tau_0$.

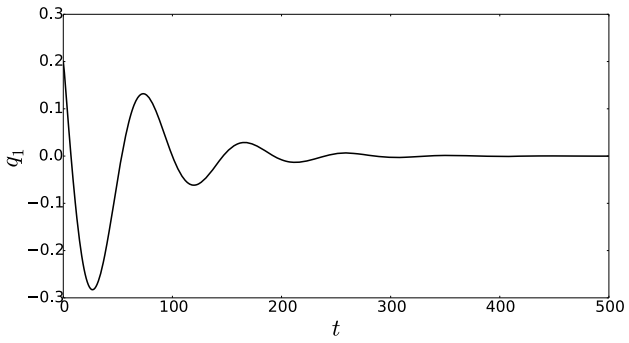

Fig. 1. Simulation results (the case of stable system).

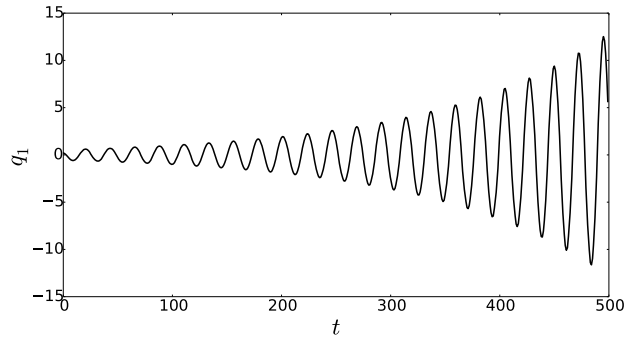

Fig. 2. Simulation results (the case of unstable system).

The results of numerical simulation are represented in Figs. 1 and 2, where the dependence of the coordinate q_1 on time is shown. It was assumed that $\tau = \text{const} > 0$, and the following values of parameters of the system and initial conditions were chosen: $b = 2$, $c = 1$, $g = 1$, $p = 5$, $t_0 = 0$, and $q_1(\theta) = 0.2$, $q_2(\theta) = -0.3$, $\dot{q}_1(\theta) = 0$, $\dot{q}_2(\theta) = 0$ for $\theta \in [-\tau, 0]$.

Fig. 1 corresponds to the case of stable system. Here $h = 7$, $\tau = 1$.

On the other hand, Fig. 2 shows that the increasing of the value of delay and decreasing of the value of h might cause the instability. In this case, $h = 2.9$ and $\tau = 2$.

IV. Decomposition of systems with nonlinear positional forces

Next, we turn to the case of nonlinear system (4). The system admits the equilibrium position $q = \dot{q} = 0$. We look for conditions of asymptotic stability for this equilibrium position.

Since $\mu > 1$, equations (4) are essentially nonlinear. Hence, stability analysis can not be carried out on the basis of linear approximation system. To solve the stated problem, let us apply again the decomposition approach.

Construct the isolated subsystems

$$B\dot{y}(t) = -Q_1(y(t)) - Q_2(y(t)), \quad (13)$$

$$A\dot{z}(t) = -Bz(t). \quad (14)$$

Thus, instead of time-delay system (4) consisting of n nonlinear second order differential equations, we will consider two auxiliary first order delay free subsystems (13) and

(14). Notice that subsystem (14) is linear, whereas (13) is a nonlinear system with homogeneous right-hand sides.

Theorem 2: Let the zero solutions of isolated subsystems (13) and (14) be asymptotically stable. Then the equilibrium position $q = \dot{q} = 0$ of (4) is asymptotically stable for any continuous nonnegative and bounded for $t \in [0, +\infty)$ delay $\tau(t)$.

Proof: By the usage of the substitution

$$\dot{q}(t) = z(t), \qquad A\dot{q}(t) + Bq(t) = By(t),$$

we transform (4) to the system

$$\begin{aligned} &B\dot{y}(t) = -Q_1(y(t)) - Q_2(y(t)) \\ &+ \big(Q_1(y(t)) - Q_2(y(t) - B^{-1}Az(t))\big) \\ &-\Big(Q_2\left(y(t-\tau(t)) - B^{-1}Az(t-\tau(t))\right) \\ &-Q_2(y(t))\Big), \\ &A\dot{z}(t) = -Bz(t) - Q_1(y(t) - B^{-1}Az(t)) \\ &-Q_2\Big(y(t-\tau(t)) - B^{-1}Az(t-\tau(t))\Big). \end{aligned} \tag{15}$$

The equilibrium position $q = \dot{q} = 0$ of the original system (4) is asymptotically stable if and only if the zero solution of (15) is asymptotically stable.

It is known, see [20], that from the asymptotic stability of the zero solutions of subsystems (13) and (14) it follows the existence of continuously differentiable for $y \in R^n$ and $z \in R^n$ homogeneous of orders γ_1 and γ_2 respectively Lyapunov functions $V_1(y)$ and $V_2(z)$ satisfying the assumptions of the Lyapunov asymptotic stability theorem. It is worth mentioning that, in the computation of these functions, one can take for γ_1 and γ_2 arbitrary numbers greater than 1.

Consider the function

$$V(y, z) = V_1(y) + V_2(z). \tag{16}$$

For this function and its derivative with respect to system (15) the following estimates are valid

$$\begin{aligned} a_1\left(\|y\|^{\gamma_1} + \|z\|^{\gamma_2}\right) \le V(y,z) \le a_2\left(\|y\|^{\gamma_1} + \|z\|^{\gamma_2}\right), \\ \dot{V}\big|_{(15)} \le -a_3\left(\|y(t)\|^{\gamma_1+\mu-1} + \|z(t)\|^{\gamma_2}\right) \\ +a_4\|y(t)\|^{\gamma_1-1}\|z(t)\|\left(\|y(t)\|^{\mu-1} + \|z(t)\|^{\mu-1}\right) \\ +a_5\|y(t)\|^{\gamma_1-1}\left(\|y(t) - y(t-\tau(t))\| + \|z(t-\tau(t))\|\right) \\ \times\left(\|y(t)\|^{\mu-1} + \|y(t-\tau(t))\|^{\mu-1} + \|z(t-\tau(t))\|^{\mu-1}\right) \\ +a_6\|z(t)\|^{\gamma_2-1}\Big(\|y(t)\|^{\mu} + \|z(t)\|^{\mu} \\ +\|y(t-\tau(t))\|^{\mu} + \|z(t-\tau(t))\|^{\mu}\Big), \end{aligned}$$

where $a_1, \ldots, a_6$ are positive constants.

We will show that if for the orders of homogeneity γ_1 and γ_2 the inequalities

$$\gamma_2 < \gamma_1 < \mu\gamma_2 - \mu + 1 \tag{17}$$

hold, then the Lyapunov function (16) satisfies all the conditions of Theorem 4.2 from [10].

Choose a number $\delta > 0$. Assume that, for a solution $(y^T(t), z^T(t))^T$ of (15), the inequality $\|y(\xi)\| + \|z(\xi)\| < \delta$, and the Razumikhin condition $V(y(\xi), z(\xi)) \le 2V(y(t), z(t))$ are fulfilled for $\xi \in [t - 2\tau_0, t]$. Then there exist positive numbers c_1 and c_2 such that the esimates

$$\begin{aligned} \|y(\xi)\| \le c_1\left(\|y(t)\| + \|z(t)\|^{\gamma_2/\gamma_1}\right), \\ \|z(\xi)\| \le c_2\left(\|y(t)\|^{\gamma_1/\gamma_2} + \|z(t)\|\right) \end{aligned} \tag{18}$$

hold for $\xi \in [t - 2\tau_0, t]$.

Using estimates (18) and applying the Mean Value Theorem, we obtain

$$\begin{aligned} \|y(t-\tau(t)) - y(t)\| \le \tau_0\|\dot{y}(t - \eta\tau(t))\| \\ \le c_3\tau_0\left(\|y(t)\|^{\mu} + \|z(t)\|^{\mu} + \|y(t)\|^{\mu\gamma_1/\gamma_2} + \|z(t)\|^{\mu\gamma_2/\gamma_1}\right), \end{aligned}$$

where $c_3 = \text{const} > 0$, and $0 < \eta < 1$.

By the use of homogeneous functions properties, see [20], it can be shown that if the parameters γ_1 and γ_2 satisfy the condition (17), then, for sufficiently small values of δ, the inequality

$$\dot{V}(y(t), z(t)) \le -\frac{a_3}{2}\Big(\|y(t)\|^{\gamma_1+\mu-1} + \|z(t)\|^{\gamma_2}\Big)$$

is valid. Thus, for the Lyapunov function (16), all the assumptions of Theorem 4.2 from [10] are fulfilled. So the zero solution of (15) is asymptotically stable. This implies that the equilibrium position $q = \dot{q} = 0$ of (4) is also asymptotically stable. This completes the proof.

Remark 3: It is worth mentioning that mechanical systems with essentially nonlinear positional forces have been considered, for instance, in [2, 21–24]. In particular, in [21, 22], they were applied for the developing of seismic mitigation devices.

Remark 4: Unlike Theorem 1, in Theorem 2 it is not required the presence in the considered equations of a large parameter.

Remark 5: The fulfilment of assumptions of Theorem 2 guarantees that the equilibrium position $q = \dot{q} = 0$ of (4) is asymptotically stable for any continuous nonnegative and bounded for $t \in [0, +\infty)$ delay $\tau(t)$. Thus, we obtained cocalled delay-independent stability conditions, see [13].

Example 2: Consider the control system

$$\ddot{q}(t) + b\,\dot{q}(t) + \|q(t)\|^2 \begin{pmatrix} 0 & c \\ -c & 0 \end{pmatrix} q(t) = u, \tag{19}$$

where $q(t), \dot{q}(t) \in R^2$; b and c are positive constants; $u = (u_1, u_2)^T$ is a control vector. Equations of such type are used, for instance, for the modelling of rotor dynamics in a magnetic bearing system [25].

We are going to design a feedback control law to stabilize the equilibrium position $q = \dot{q} = 0$ of system (19). Assume that the control law depends on q, and is independent of $\dot{q}$. Furthermore, we consider the case when there exists a delay in the control scheme. The delay may be unknown and time-varying.

It is known, see [12, 13], that for the linear control law

$$\begin{aligned} u_1 = \alpha_{11}q_1(t - \tau(t)) + \alpha_{12}q_2(t - \tau(t)), \\ u_2 = \alpha_{21}q_1(t - \tau(t)) + \alpha_{22}q_2(t - \tau(t)), \end{aligned}$$

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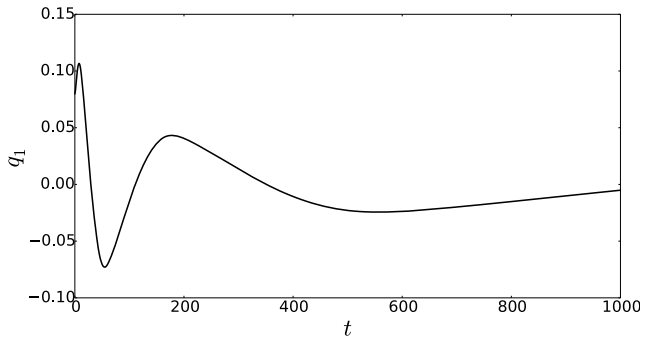

Fig. 3. Simulation results ($q_1(\theta) = 0.08$, $q_2(\theta) = -0.08$).

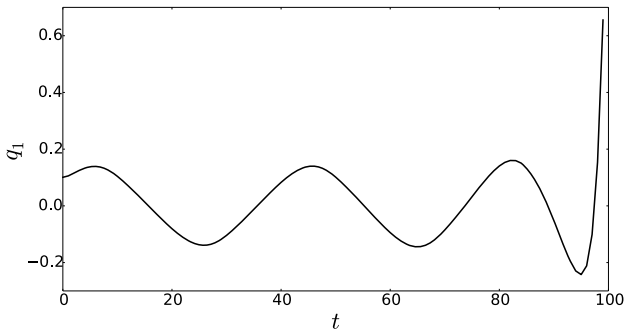

Fig. 4. Simulation results ($q_1(\theta) = 0.1007$, $q_2(\theta) = -0.1007$).

where $\alpha_{11}, \alpha_{12}, \alpha_{21}, \alpha_{22}$ are constants, the presence of delay might result in instability of the equilibrium position.

Choose now functions u_1 and u_2 in the form

$$u_1 = -\alpha_1 q_1^3(t - \tau(t)), \qquad u_2 = -\alpha_2 q_2^3(t - \tau(t)). \quad (20)$$

Here α_1 and α_2 are positive constants.

Applying Theorem 2, we obtain that for the control law (20) the equilibrium position $q = \dot{q} = 0$ of the corresponding closed-loop system is asymptotically stable for any continuous nonnegative and bounded for $t \geq 0$ delay $\tau(t)$.

The results of numerical simulation are represented in Figs. 3 and 4, where the dependence of the coordinate q_1 on time is shown. The following values of parameters of the system were chosen: $b = 1$, $c = 8$, $a_1 = 2.5$, $a_2 = 1.5$, $\tau = 3$.

Fig. 3 corresponds to the case when $t_0 = 0$, $q_1(\theta) = 0.08$, $q_2(\theta) = -0.08$, $\dot{q}_1(\theta) = 0$, $\dot{q}_2(\theta) = 0$ for $\theta \in [-3, 0]$, whereas for Fig.4 we have $t_0 = 0$, $q_1(\theta) = 0.1007$, $q_2(\theta) = -0.1007$, $\dot{q}_1(\theta) = 0$, $\dot{q}_2(\theta) = 0$ for $\theta \in [-3, 0]$.

These results show that, for nonlinear systems, we can guarantee only local asymptotic stability of the equilibrium position.

V. Decomposition of systems with switched positional forces

We will show now that the approaches proposed in the present paper can be used for the stability analysis of some classes of switched mechanical systems. A switched system is a particular kind of hybrid dynamical system that consists of a family of subsystems and a switching law determining at each time instant which subsystem is active [26–28].

In various cases, it is necessary to design a control system in such a way that it remains stable for any admissible switching law [26, 29]. A general approach to the problem is based on the construction of a common Lyapunov function for family of subsystems corresponding to switched system. This approach has been effectively used in many papers, see, for instance, [19, 26, 27, 29–33], and the references cited therein. However, the problem of the existence of a common Lyapunov function has not got a constructive solution even for the case of family of linear time-invariant systems [26, 29]. This problem is especially difficult for mechanical systems with switched force fields. Such systems possess a special structure. Therefore, well known approaches developed for switched systems of general form may be inefficient or even inapplicable for mechanical systems, see [19].

In this section, we consider time-delay mechanical systems of the forms (1) and (4) with switched positional forces. We will look for conditions under which these systems are asymptotically stable for an arbitrary admissible switching law.

Let the family of linear time-delay mechanical systems

$$A\ddot{q}(t) + hB\dot{q}(t) + C_1^{(s)} q(t) + C_2^{(s)} q(t - \tau(t)) = 0, \quad s = 1, \ldots, N, \quad (21)$$

be given. Here $C_1^{(s)}$ and $C_2^{(s)}$ are constant matrices, and the rest notation is the same as in (1).

Switched system generated by the family (21) and a switching law σ is

$$A\ddot{q}(t) + hB\dot{q}(t) + C_1^{(\sigma)} q(t) + C_2^{(\sigma)} q(t - \tau(t)) = 0. \quad (22)$$

Hereinafter, a switching law is defined as a piecewise constant function $\sigma = \sigma(t) : [0, +\infty) \to S = \{1, \ldots, N\}$. We assume that the function $\sigma(t)$ is right-continuous, and on every bounded time interval the function has a finite number of discontinuities. This kind of switching law is called admissible one.

Consider subsystem (3) and the family of subsystems

$$B\dot{y}(t) + \left(C_1^{(s)} + C_2^{(s)}\right) y(t) = 0, \quad s = 1, \ldots, N. \quad (23)$$

Theorem 3: Let subsystem (3) and all subsystems from the family (23) be asymptotically stable, and family (23) admit a continuously differentiable for $y \in R^n$ homogeneous of the second order common Lyapunov function $V_1(y)$ satisfying the assumptions of the Lyapunov asymptotic stability theorem. Then, for any continuous nonnegative and bounded for $t \in [0, +\infty)$ delay $\tau(t)$, there exists a number $h_0 > 0$ such that system (22) is asymptotically stable for all $h \geq h_0$ and for an arbitrary switching law.

Proof: Substitution (5) transforms (21) to the family

$$\begin{aligned} &B\dot{y}(t) = -\tfrac{1}{h}\left(C_1^{(s)} + C_2^{(s)}\right) y(t) \\ &-\tfrac{1}{h} C_2^{(s)} (y(t - \tau(t)) - y(t)) \\ &+\tfrac{1}{h^2} C_1^{(s)} B^{-1} A z(t) + \tfrac{1}{h^2} C_2^{(s)} B^{-1} A z(t - \tau(t)), \\ &A\dot{z}(t) = -hBz(t) - C_1^{(s)} y(t) - C_2^{(s)} y(t - \tau(t)) \\ &+\tfrac{1}{h} C_1^{(s)} B^{-1} A z(t) + \tfrac{1}{h} C_2^{(s)} B^{-1} A z(t - \tau(t)), \\ &s = 1, \ldots, N. \end{aligned} \quad (24)$$

Let $V_1(y)$ be a common Lyapunov function for subsystems (23) possessing the properties specified in the theorem. From the asymptotic stability of subsystem (3), it follows the existence of a quadratic form $V_2(z)$ satisfying the assumptions of the Lyapunov asymptotic stability theorem.

Consider the Lyapunov function $V(y,z)$ defined by the formula (7). Similar to the proof of Theorem 1, it can be shown that, for sufficiently small values of ε and sufficiently large values of h, $V(y,z)$ is a common Lyapunov function for family (24) satisfying all the assumptions of Theorem 4.2 from [10].

Remark 6: Theorem 3 permits to reduce, for sufficiently large values of h, the problem of finding of a common Lyapunov function for family (21) consisting of second order systems to that for family (23) of first order systems. Unlike systems from (21), systems from the family (23) are delay free, and, generally, do not possess a special structure. Therefore, some known conditions of the existence of a common Lyapunov function can be applied to family (23).

For instance, applying the commutativity condition of systems matrices, guaranteeing the existence of a common quadratic Lyapunov function for a family of linear time-invariant systems, see [26, 29], we arrive at the following corollary.

Corollary: Let subsystem (3) and all subsystems from the family (23) be asymptotically stable, and the conditions

$$\left(C_1^{(s)}+C_2^{(s)}\right)B^{-1}\left(C_1^{(r)}+C_2^{(r)}\right)$$
$$=\left(C_1^{(r)}+C_2^{(r)}\right)B^{-1}\left(C_1^{(s)}+C_2^{(s)}\right),\quad s,r=1,\dots,N,$$

hold. Then, for any continuous nonnegative and bounded for $t\in[0,+\infty)$ delay $\tau(t)$, there exists a number $h_0>0$ such that system (22) is asymptotically stable for all $h\geq h_0$ and for an arbitrary switching law.

Remark 7: It is worth mentioning that the commutativity condition is inapplicable to the original family (21), even in the case when $\tau(t)\equiv 0$, see [19].

Next, cosider the family of nonlinear time-delay systems

$$A\ddot{q}(t)+B\dot{q}(t)+Q_1^{(s)}(q(t))+Q_2^{(s)}(q(t-\tau(t)))=0,$$
$$s=1,\dots,N,$$

and the corresponding switched system

$$A\ddot{q}(t)+B\dot{q}(t)+Q_1^{(\sigma)}(q(t))+Q_2^{(\sigma)}(q(t-\tau(t)))=0. \quad (25)$$

Here components of the vectors $Q_1^{(s)}(q)$ and $Q_2^{(s)}(q)$ are continuously differentiable for $q\in R^n$ homogeneous functions of the order $\mu>1$, and the rest notation is the same as in (4).

Construct the auxiliary family of delay free homogeneous subsystems

$$B\dot{y}(t)=-Q_1^{(s)}(y(t))-Q_2^{(s)}(y(t)),\quad s=1,\dots,N. \quad (26)$$

Theorem 4: Let the zero solutions of subsystem (3) and all subsystems from the family (26) be asymptotically stable, and family (26) admit a continuously differentiable for $y\in R^n$ common homogeneous Lyapunov function $V_1(y)$ satisfying the assumptions of the Lyapunov asymptotic stability theorem. Then the equilibrium position $q=\dot{q}=0$ of (25) is asymptotically stable for any continuous nonnegative and bounded for $t\in[0,+\infty)$ delay $\tau(t)$ and for an arbitrary switching law.

The proof of the theorem is similar to that of Theorem 2.

Remark 8: Sufficient conditions for the existence of a common homogeneous Lyapunov function for a family of homogeneous systems have been obtained in [31].

Example 3: Let the family consisting of two control systems

$$\begin{cases}\ddot{q}_1(t)+\dot{q}_1(t)-q_2^3(t)=u_1^{(1)},\\ \ddot{q}_2(t)+\dot{q}_2(t)+q_1^3(t)=u_2^{(1)},\end{cases} \quad (27)$$

$$\begin{cases}\ddot{q}_1(t)+\dot{q}_1(t)+q_2^3(t)=u_1^{(2)},\\ \ddot{q}_2(t)+\dot{q}_2(t)-q_1^3(t)=u_2^{(2)}\end{cases} \quad (28)$$

be given. Here $q_1(t),q_2(t)\in R$; $u_1^{(1)}$, $u_2^{(1)}$, $u_1^{(2)}$, $u_2^{(2)}$ are control variables.

It is known [34], that, in the case when $u_1^{(1)}=u_2^{(1)}=u_1^{(2)}=u_2^{(2)}=0$, the equilibrium position $q_1=q_2=\dot{q}_1=\dot{q}_2=0$ for both systems (27) and (28) is unstable. Consider the problem of stabilization of the equilibrium position.

Assume that the control variables are chosen in the form

$$u_1^{(1)}=0,\quad u_2^{(1)}=-2q_2^3(t-\tau(t)),$$
$$u_1^{(2)}=-2q_1^3(t-\tau(t)),\quad u_2^{(2)}=0.$$

Then we obtain the family of closed-loop systems

$$\begin{cases}\ddot{q}_1(t)+\dot{q}_1(t)-q_2^3(t)=0,\\ \ddot{q}_2(t)+\dot{q}_2(t)+q_1^3(t)+2q_2^3(t-\tau(t))=0,\end{cases} \quad (29)$$

$$\begin{cases}\ddot{q}_1(t)+\dot{q}_1(t)+q_2^3(t)+2q_1^3(t-\tau(t))=0,\\ \ddot{q}_2(t)+\dot{q}_2(t)-q_1^3(t)=0.\end{cases} \quad (30)$$

In this case, the corresponding subsystem (3) is

$$\begin{cases}\dot{z}_1(t)+z_1(t)=0,\\ \dot{z}_2(t)+z_2(t)=0,\end{cases} \quad (31)$$

and the family (26) can be written as follows

$$\begin{cases}\dot{y}_1(t)-y_2^3(t)=0,\\ \dot{y}_2(t)+y_1^3(t)+2y_2^3(t)=0,\end{cases} \quad (32)$$

$$\begin{cases}\dot{y}_1(t)+2y_1^3(t)+y_2^3(t)=0,\\ \dot{y}_2(t)-y_1^3(t)=0.\end{cases} \quad (33)$$

It is easily verified that the zero solutions of subsystems (31), (32), (33) are asymptotically stable. Moreover, in [31], it was proved that the family consisting of subsystems (32) and (33) admits the common homogeneous Lyapunov function

$$V(y_1,y_2)=5y_1^2+4y_1y_2+5y_2^2.$$

Applying Theorem 4, we obtain that the equilibrium position $q_1=q_2=\dot{q}_1=\dot{q}_2=0$ of the switched system generated by the family (29), (30) and a switching signal $\sigma(t)$ is asymptotically stable for any continuous nonnegative and bounded for $t\in[0,+\infty)$ delay $\tau(t)$ and for an arbitrary switching law.

VI. Conclusion

In the present paper, by the usage of the decomposition method, sufficient conditions of the asymptotic stability for some classes of time-delay mechanical systems are obtained. It should be noted that, to provide the decomposition, in the linear case the presence of a large parameter in the considered equations is required, whereas, in the nonlinear case, the decomposition is ensured by orders of homogeneity of positional forces.

The results of the paper can be extended to mechanical systems with essentially nonlinear velocity forces. Moreover, the proposed approaches permit to obtain stability conditions for systems with delay both in positional forces and in velocity ones.

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Throughput of Three-Hops ARQ Protocol Using Hybrid Relaying

Maymouna Ben Said, Hatem Boujemaa
University of Carthage, Higher School of Communications of Tunis
COSIM Research Lab. Tunisia
maymouna.bensaid@supcom.rnu.tn, boujemaa.hatem@supcom.rnu.tn

***Abstract*—In this paper, we analyze the throughput of three-hops *ARQ* protocol using different hybrid Amplify/ Decode and Forward relaying modes. Hybrid relaying offers close performance to *DF* with a lower computational complexity and transmissions. Besides hybrid relaying outperforms *AF* relaying. Theoretical expressions of the packet error probability and throughput are derived. Simulation results are provided to validate our analysis.**

***Index Terms*—*ARQ* Protocol, Decode and Forward relaying, Amplify and Forward Relaying, Rayleigh fading channels.**

I. Introduction

Multihop relaying has emerged as a practical and efficient solution to board coverage and enhance throughput in wireless communication systems. In such technology, relay nodes are placed between source and destination to help in the transmission. Due to shorter hops, the average end to end signal to noise ratio *SNR* is improved.

Two relaying modes are extensively used, namely amplify and forward *AF* and decode and forward *DF*. In *AF* mode, relay amplifies the received signal before forwarding it to destination while in *DF* mode, relay decodes and regenerates signal before forwarding it to destination.

There has been significant works on multihop networks [1, 2, 3, 4]. A general analytical framework for the evaluation of the outage probability with *AF* relaying was presented in [1]. In [2], authors proposed an *MGF* based approach to derive the average symbol error probabilities. In [4], a new static hybrid multihop relaying protocol where some relays use *AF* and the rest use *DF* was proposed. Static hybrid *AF / DF* relaying was first proposed with dual-hop system in [5] where relay nodes close to the source amplify and forward the signal and the remaining ones use *DF* relaying.

Automatic repeat request *ARQ* mechanisms have been widely used in multihop network to increase reliability. In ARQ protocol, packets that are received in error at destination are retransmitted. The throughput of hybrid *AF / DF* cooperative *ARQ* protocol with opportunistic relaying was studied in [6].

In this paper, we study the throughput performance of three-hops *ARQ* system. Three cases of study are considered: conventional *AF-AF*, conventional *DF-DF* and hybrid relaying *AF-DF / DF-AF*. For each mode, we derive theoretical expression of the end to end bloc error probability to evaluate the system throughput.

The remainder of this paper is organized as follows. Section II describes the system model. Section III presents the performance analysis of the different relaying schemes. Section IV, provides some simulation results. Concluding remarks are given in section V.

II. System and Protocol Description

We consider a three-hop wireless communication system with a source S, a destination D and two relays R_1, R_2. We assume there is no direct link between source and destination. As for the channel, we consider a block fading Rayleigh model where channel coefficients remain constant during each transmission and independent during different transmissions.

The received instantaneous signal to noise ratio *SNR* between two nodes X and Y, $\{X, Y\} \in (\{S, R_1\}, \{R_1, R_2\}, \{R_2, D\})$ is exponentially distributed random variable with cumulative density function *CDF* and probability density function *PDF* given by

$$F_{\gamma_{X,Y}}(z) = 1 - e^{\frac{-z}{\overline{\gamma}_{X,Y}}}, \tag{1a}$$

$$f_{\gamma_{X,Y}}(z) = \frac{1}{\overline{\gamma}_{X,Y}} e^{\frac{-z}{\overline{\gamma}_{X,Y}}}, \tag{1b}$$

where $\overline{\gamma}_{X,Y}$ is the expectation of $\gamma_{X,Y}$.

We consider an *ARQ* protocol so erroneous decoded packet is reported by a negative acknowledgment *NACK* to the source which proceeds by a retransmission until positive acknowledgment *ACK* is sent. Packets are composed of k information bits and n_p parity bits for error detection.

The evaluation of the system performance is provided in terms of the throughput efficiency, which is given by [7]

$$\eta = \frac{k}{k + n_p}(1 - P_{bloc}^{S,R_{1,2},D}), \tag{2}$$

where $P_{bloc}^{S,R_{1,2},D}$ is the average end-to-end block error probability and depends on the used relaying modes.

III. Conventional AF-AF Relaying

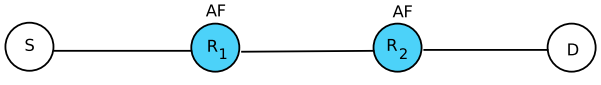

Fig. 1. Conventional *AF-AF* relaying

For the *AF-AF*, the source starts by broadcasting the packet to the first relay R_1. R_1 amplifies and forwards the received

signal to the second relay R_2. Finally, and same as R_1, R_2 amplifies and forwards the packet to the destination.
The received signal at the relay R_1 (resp. the relay R_2, resp. the destination D) is given by

$$\begin{aligned} y_{S,R_1} &= \sqrt{E_S} h_{S,R_1} s + n_{S,R_1}, \\ y_{R_1,R_2} &= G_{R_1} h_{R_1,R_2} y_{S,R_1} + n_{R_1,R_2}, \\ y_{R_2,D} &= G_{R_2} h_{R_2,D} y_{R_1,R_2} + n_{R_2,D}, \end{aligned} \tag{3}$$

where E_S is the transmitted energy per symbol by the source S, s is the transmitted symbol, $h_{X,Y}$ is the Rayleigh fading coefficient of the $X-Y$ link and $n_{X,Y}$ is an additive Gaussian noise with variance N_0. The average block error probability $P_{bloc}^{S,R_{1,2},D}$ is given by

$$P_{bloc}^{S,R_{1,2},D} = 1 - \int (1 - Q(\sqrt{2x}))^{(k+n_p)} f_{\Gamma_{S,R_{1,2},D}}(x) dx, \tag{4}$$

where $Q(x) = \int_x^\infty \frac{1}{\sqrt{2\pi}} e^{-\frac{\gamma^2}{2}} d\gamma$ is the Gaussian Q function and $f_{\Gamma_{S,R_{1,2},D}}(x)$ is the *PDF* of the received *SNR* at destination.
For *AF-AF* relaying the *SNRs* of the three hops are statistically dependent. The end-to-end *SNR* can be written as [1]

$$\gamma_{S,R_{1,2},D} = \frac{\gamma_{S,R_{1,2}} \gamma_{R_2,D}}{1 + \gamma_{S,R_{1,2}} + \gamma_{R_2,D}}, \tag{5}$$

where $\gamma_{S,R_{1,2}}$ is the *SNR* of the first dual-hop and $\gamma_{R_2,D}$ is the *SNR* of the third hop.
The CDF of $\gamma_{S,R_{1,2},D}$ can be expressed as follows

$$\begin{aligned} F_{\gamma_{S,R_{1,2},D}}(\gamma) &= Pr(\gamma_{S,R_{1,2},D} \leqslant \gamma) \\ &= 1 - Pr(\gamma_{S,R_{1,2}} > \frac{\gamma(1+\gamma_{R_2,D})}{\gamma_{R_2,D} - \gamma}, \gamma_{R_2,D} > \gamma) \\ &= 1 - \int_\gamma^\infty (1 - F_{\gamma_{S,R_{1,2}}}(\frac{\gamma(1+x)}{x-\gamma})) f_{\gamma_{R_2,D}}(x) dx, \end{aligned} \tag{6}$$

where $f_{\gamma_{R_2,D}}(y)$ is given by (1b) and $F_{\gamma_{S,R_{1,2}}}$ is given by [8]

$$\begin{aligned} F_{\gamma_{S,R_{1,2}}}(y) &= 1 - 2e^{-y(\frac{1}{\overline{\gamma}_{S,R_1}} + \frac{1}{\overline{\gamma}_{R_1,R_2}})} \\ &\sqrt{\frac{1}{\overline{\gamma}_{S,R_1} \overline{\gamma}_{R_1,R_2}} y(y+1)} \\ &\times K_1(2\sqrt{\frac{1}{\overline{\gamma}_{S,R_1} \overline{\gamma}_{R_1,R_2}} y(y+1)}), \end{aligned} \tag{7}$$

where $K_\nu(\gamma)$ is the ν^{th} order modified Bessel function of the second kind [9, eq.(8.432.6)].
By replacing $F_{\gamma_{S,R_{1,2}}}(\frac{\gamma(1+x)}{x-\gamma}))$ and $f_{\gamma_{R_2,D}}(x)$ by their expressions and by setting $z = x - \gamma$, we obtain

$$\begin{aligned} F_{\gamma_{S,R_{1,2},D}}(\gamma) &= 1 - \frac{1}{\overline{\gamma}_{R_2,D}} e^{-\frac{\gamma(\overline{\gamma}_{S,R_1} + \overline{\gamma}_{R_1,R_2})(1+\overline{\gamma}_{R_2,D})}{\overline{\gamma}_{S,R_1} \overline{\gamma}_{R_1,R_2} \overline{\gamma}_{R_2,D}}} \\ &\times \int_0^\infty e^{(\frac{1}{\overline{\gamma}_{S,R_1}} + \frac{1}{\overline{\gamma}_{R_1,R_2}})(\frac{1}{z}\gamma(1+\gamma) - \frac{z}{\overline{\gamma}_{R_2,D}})} \\ &\times 2\sqrt{\frac{\gamma(1+\gamma)}{\overline{\gamma}_{S,R_1} \overline{\gamma}_{R_1,R_2}} (1 + \frac{1}{z}(1+2\gamma) + \frac{1}{z^2}\gamma(1+\gamma))} \\ &\times K_1(2\sqrt{\frac{\gamma(1+\gamma)}{\overline{\gamma}_{S,R_1} \overline{\gamma}_{R_1,R_2}} (1 + \frac{1}{z}(1+2\gamma) + \frac{1}{z^2}\gamma(1+\gamma))}) dz. \end{aligned} \tag{8}$$

The *PDF* of $\gamma_{S,R_{1,2},D}$ can be found by taking the derivative of $F_{\gamma_{S,R_{1,2},D}}(\gamma)$ with respect to γ.
Since the above integral equation is difficult to solve, an upper bound of the end to end *SNR* is generally used

$$\gamma_{S,R_{1,2},D} \leq \gamma_{S,R_{1,2},D}^{up} = min(\gamma_{S,R_1}, \gamma_{R_1,R_2}, \gamma_{R_2,D}) \tag{9}$$

IV. Conventional DF-DF Relaying

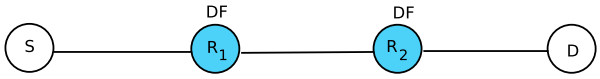

Fig. 2. Conventional *DF-DF* relaying

For the *DF-DF*, the received signal at the relay R_1 (resp. the relay R_2, resp. the destination D) is given by

$$\begin{aligned} y_{S,R_1} &= \sqrt{E_S} h_{S,R_1} s + n_{S,R_1}, \\ y_{R_1,R_2} &= \sqrt{\hat{E}_{R_1}} h_{R_1,R_2} s + n_{R_1,R_2}, \\ y_{R_2,D} &= \sqrt{\hat{E}_{R_2}} h_{R_2,D} s + n_{R_2,D}, \end{aligned} \tag{10}$$

where

$$\hat{E}_{R_i} = \begin{cases} E_{R_i} & \text{if } s \text{ received correctly} \\ 0 & \text{otherwise} \end{cases}. \tag{11}$$

The *SNRs* of the three hops are statistically independent. The average block error probability $P_{bloc}^{S,R_{1,2},D}$ is given by

$$P_{bloc}^{S,R_{1,2},D} = 1 - (1 - P_{bloc}^{S,R_1})(1 - P_{bloc}^{R_1,R_2})(1 - P_{bloc}^{R_2,D}), \tag{12}$$

where

$$\begin{cases} P_{bloc}^{S,R_1} = 1 - \int (1 - Q(\sqrt{2x}))^{(k+n_p)} f_{\gamma_{S,R_1}}(x) dx, \\ P_{bloc}^{R_1,R_2} = 1 - \int (1 - Q(\sqrt{2x}))^{(k+n_p)} f_{\gamma_{R_1,R_2}}(x) dx, \\ P_{bloc}^{R_2,D} = 1 - \int (1 - Q(\sqrt{2x}))^{(k+n_p)} f_{\gamma_{R_2,D}}(x) dx, \end{cases} \tag{13}$$

$f_{\gamma_{S,R_1}}(x)$,$f_{\gamma_{R_1,R_2}}(x)$ and $f_{\gamma_{R_2,D}}(x)$ are given by (1b).

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V. Proposed hybrid AF-DF Relaying

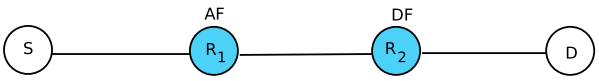

Fig. 3. Hybrid *AF-DF* relaying

For the *AF-DF*, the received signal at the relay R_1 (resp. the relay R_2, resp. the destination D) is given by

$$\begin{aligned} y_{S,R_1} &= \sqrt{E_S} h_{S,R_1} s + n_{S,R_1}, \\ y_{R_1,R_2} &= G_{R_1} h_{R_1,R_2} y_{S,R_1} + n_{R_1,R_2}, \\ y_{R_2,D} &= \sqrt{\hat{E}_{R_2}} h_{R_2,D} s + n_{R_2,D}, \end{aligned} \tag{14}$$

The SNRs $\gamma_{S,R_{1,2}}$ and $\gamma_{R_2,D}$ are statistically independent. The average block error probability $P_{bloc}^{S,R_{1,2},D}$ is given by

$$P_{bloc}^{S,R_{1,2},D} = 1 - (1 - P_{bloc}^{S,R_{1,2}})(1 - P_{bloc}^{R_2,D}), \tag{15}$$

with

$$\begin{cases} P_{bloc}^{S,R_{1,2}} = 1 - \int (1 - Q(\sqrt{2x}))^{(k+n_p)} f_{\gamma_{S,R_{1,2}}}(x) dx, \\ P_{bloc}^{R_2,D} = 1 - \int (1 - Q(\sqrt{2x}))^{(k+n_p)} f_{\gamma_{R_2,D}}(x) dx, \end{cases} \tag{16}$$

$f_{\gamma_{R_2,D}}(x)$ is given by (1b) and $f_{\gamma_{S,R_{1,2}}}(x)$ is given by [8]:

$$\begin{aligned} f_{\gamma_{S,R_{1,2}}}(y) &= 2e^{-y(\frac{1}{\overline{\gamma}_{S,R_1}} + \frac{1}{\overline{\gamma}_{R_1,R_2}})} [\frac{1}{\overline{\gamma}_{S,R_1}\overline{\gamma}_{R_1,R_2}}(2y+1) \times \\ & K_0(2\sqrt{\frac{1}{\overline{\gamma}_{S,R_1}\overline{\gamma}_{R_1,R_2}} y(y+1)}) \\ & + (\frac{1}{\overline{\gamma}_{S,R_1}} + \frac{1}{\overline{\gamma}_{R_1,R_2}}) \sqrt{\frac{1}{\overline{\gamma}_1 \overline{\gamma}_{R_1,R_2}} y(y+1)} \\ & K_1(2\sqrt{\frac{1}{\overline{\gamma}_{S,R_1}\overline{\gamma}_{R_1,R_2}} y(y+1)})]. \end{aligned} \tag{17}$$

VI. Proposed hybrid DF-AF Relaying

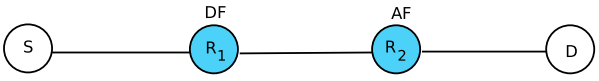

Fig. 4. Hybrid *DF-AF* relaying

For the *DF-AF*, the received signal at the relay R_1 (resp. the relay R_2, resp. the destination D) is given by

$$\begin{aligned} y_{S,R_1} &= \sqrt{E_S} h_{S,R_1} s + n_{S,R_1}, \\ y_{R_1,R_2} &= \sqrt{\hat{E}_{R_1}} h_{R_1,R_2} s + n_{R_1,R_2}, \\ y_{R_2,D} &= G_{R_2} h_{R_2,D} y_{R_1,R_2} + n_{R_2,D}. \end{aligned} \tag{18}$$

The SNRs γ_{S,R_1} and $\gamma_{R_{1,2},D}$ are statistically independent. The average block error probability $P_{bloc}^{S,R_{1,2},D}$ is given by

$$P_{bloc}^{S,R_{1,2},D} = 1 - (1 - P_{bloc}^{S,R_1})(1 - P_{bloc}^{R_{1,2},D}), \tag{19}$$

with

$$\begin{cases} P_{bloc}^{S,R_1} = 1 - \int (1 - Q(\sqrt{2x}))^{(k+n_p)} f_{\gamma_{S,R_1}}(x) dx, \\ P_{bloc}^{R_{1,2},D} = 1 - \int (1 - Q(\sqrt{2x}))^{(k+n_p)} f_{\gamma_{R_{1,2},D}}(x) dx, \end{cases} \tag{20}$$

$f_{\gamma_{S,R_1}}(x)$ is given by (1b) and $f_{\gamma_{R_{1,2},D}}(x)$ is given by (17) by replacing $\gamma_{S,R_{1,2}}$ (resp.γ_{S,R_1}, resp. γ_{R_1,R_2}) by $\gamma_{R_{1,2},D}$ (resp.γ_{R_1,R_2}, resp. $\gamma_{R_2,D}$).

VII. Simulations Results

In this section, we provide simulation results of the system throughput. Simulations are carried out with BPSK modulation with equal power allocation for source and relays $E_S = E_{R_1} = E_{R_2} = \frac{E_b}{3}$, where E_b is the average transmitted energy per coded bit. The average *SNR* between node X and Y is modeled as follows

$$\overline{\gamma_{X,Y}} = \frac{E_X}{N_0} \frac{\alpha}{(\frac{d_{X,Y}^{eff}}{d_{S,D}})^{\beta}}, \tag{21}$$

where α is the path loss at the reference distance $d_{S,D}$, β is the path loss exponent and $d_{X,Y}^{eff}$ is the effective distance between X and Y. α and β were set to : 1 and 3.
For the ARQ protocol, we considered packets of length $k + n_p = 500$.
Fig. 5 shows simulation results for the throughput performance for $d_{S,R_1} = 0.3$, $d_{R_1,R_2} = 1$ and $d_{R_2,D} = 1$. *DF-DF* offers the best performance while *AF-AF* offers the worst one. As for hybrid relaying, we verify that *AF-DF* outperforms *DF-AF*. In fact, the first relay is close to the source which means the *SNR* of the first hop is always high. The system behaves as dual hop with *DF* relaying where *DF-AF* behaves as dual hop with *AF* relaying. The advantage in such scenario is that *AF-DF* offers similar performance as *DF-DF* with low cost since decoding is not performed at the first relay.
Fig. 6 shows simulation results for the throughput performance for $d_{S,R_1} = 1$,$d_{R_1,R_2} = 1$ and $d_{R_2,D} = 0.3$. We verify that in such relay positions, *DF-AF* outperforms *AF-DF* and offers similar performance to *DF-DF* relaying.

VIII. Conclusion

In this paper, we analyzed the throughput performance of three-hop hybrid *AF / DF* relaying *ARQ* system. we have evaluated the average block error probability of four configurations, namely *AF-AF*, *AF-DF*, *DF-AF* and *DF-DF*. Results showed hybrid relaying, *AF-DF* and *DF-AF*, may offer same performance as *DF-DF* with low complexity.

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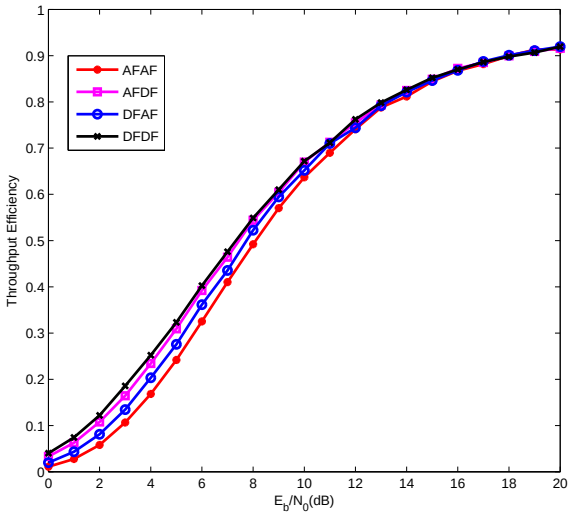

Fig. 5. Throughput of three-hop relaying for $d_{S,R_1} = 0.3$,$d_{R_1,R_2} = 1$,$d_{R_2,D} = 1$

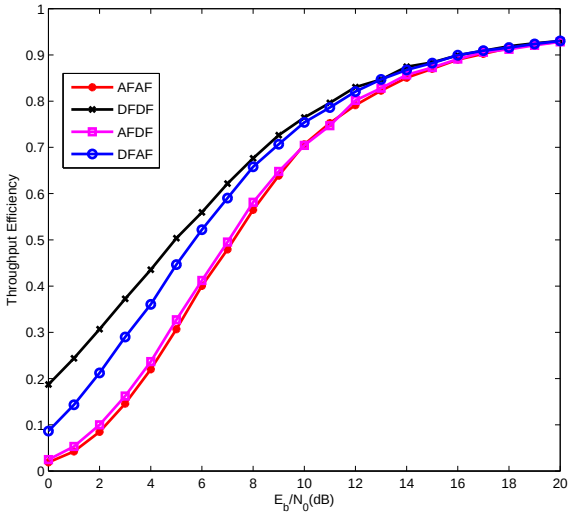

Fig. 6. Throughput of three-hop relaying for $d_{S,R_1} = 1$,$d_{R_1,R_2} = 1$,$d_{R_2,D} = 0.3$

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GraphTea: Interactive Graph Self-Teaching Tool

M. Ali Rostami, Azin Azadi, and Masoumeh Seydi

***Abstract*—**It is becoming increasingly difficult to ignore the importance of graph theory and it's application in various scientific areas. There is an urgent need for new tools to investigate this field. Since the aspects of graph algorithms are tricky to be understood by students, there are literatures pointing specially to the educational concepts of this topic. We propose an educational framework, targeting all aspects of graph theory and algorithms. This paper presents the design paradigm of such a framework as well as the teaching strategy using this tool.

***Keywords*-**Graph theory and algorithms, rich graph-editing framework, interactive educational software, GraphTea, self-teaching tool.

I. Introduction

GRAPH representation is applicable in several scientific fields in which the solutions are heavily based on the structure of the problem. Graph interpretation provides another view of the problem. Neural networks, sparse matrices, routers in internet, social networks, and train networks are just a few examples of the areas which benefit from this theory. Graphs can play an essential role in modeling, better understanding, and simplifying of problems. The importance of this field has motivated the educational system to investigate various ideas and make so many efforts to teach it. Therefore, numerous softwares and libraries have been developed to edit and visualize different classes of graphs. However, a general-purpose software targeting all aspects of graph theory is not easy to implement. Also, a area-specific graph theory software is not meant to cover also all aspects of other areas. In social networks, for example, the dense subgraphs are in the center of interest and in sparse matrices, the connection between matrix and graph. Large graphs and suitable small graph visualization can be intended too. As soon as the visualization of graph is done, the graph algorithm visualization becomes a priority.

The comprehensive understanding of the graph and algorithms in classroom is the aim of this paper. We have designed a software that provides a flexible and easy-to-work environment for teachers so that they can design new courses on graph theory and algorithms using this software. Moreover, since the instructions regarding the algorithm steps are provided to be followed by the student, the software is considered as a self-teaching tool. The new contribution of this software is to provide a rich editing framework while focusing on educational aspects besides.

In this paper, we will present a software and also a process explaining how to utilize this software for teaching and learning graph theory. In Sec II, the related works are discussed and the unique properties of our software. Then we introduce our tool, called GraphTea, and its abilities in Sec III. Sec IV takes a more detailed look at the algorithm visualization module of GraphTea. Finally, Sec V concludes this paper and discusses future works.

M. A. Rostami is with the department of Mathematics and Computer Science, Friedrich Schiller University Jena, Jena, Germany. Masoumeh Seydi is with the department of Computer Science, University of Konstanz, Konstanz, Germany. Azin Azadi is working in Jovoto, Berlin, Germany.

II. Related Work

Wide application of graph theory has been a motivation to design multiple tools to study these topics in academia. Some of these tools are designed for educational purposes, but they are not good enough in visualization. Some others have satisfying visualization features, however they do not provide adequate editing power. In our knowledge, there is no other general-purpose software other than GraphTea with the focus on education, that has rich editorial and visualization options. In addition, most of these softwares are not facilitated for self-teaching and they need to be taught and explained step-by-step by an instructor in a classroom. Here, we look at a few important tools with educational focus.

CABRI-Graph [1] and Gato/CATBox [2] are well-designed for graph algorithm visualization and animation. However, the interactively editing power of the graph structure is very limited. Tulip [3], [4] is another tool for information visualization. This tool could be used efficiently when the user knows how to program Python language. Again, this tool does not have a suitable interactive editing power as well as flexible way of creating graphs. Furthermore, there is software that is specifically designed for teaching a particular area, such as EXPLAIN [5], [6], and Heath [7].

III. GraphTea

GraphTea is a rich graph-editing framework, which has been started to develop under the name of "GraphLab" in the Department of Mathematics in Sharif University of Technology. The authors later continued to develop the software more focusing on educational purposes. The strength of GraphTea is the consideration of different aspects of graphs which would be essential in designing an educational plan. GraphTea attempts to ease the teaching process for both teachers and students by emphasising the visual features and educational ones. Figure 1 shows an overview of GraphTea together with graph coloring results and the independent sets, in which one result is selected. The major parts of graph theory and algorithms are implemented in GraphTea, from which we go through three important ones. The graph generation and modification in GraphTea is explained in Sec. III-A and the graph reports in Sec. III-B. Also, the algorithm visualization and its application are explained in Sec. IV

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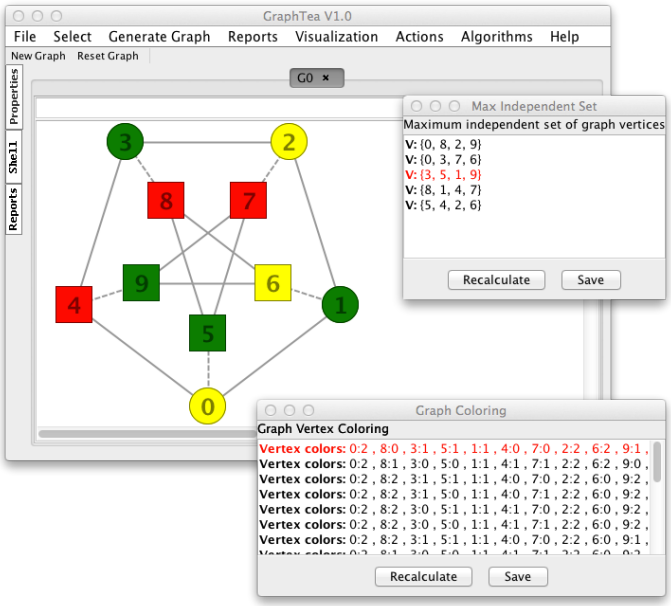

Fig. 1. An overview of GraphTea and two visualized reports on a given graph.

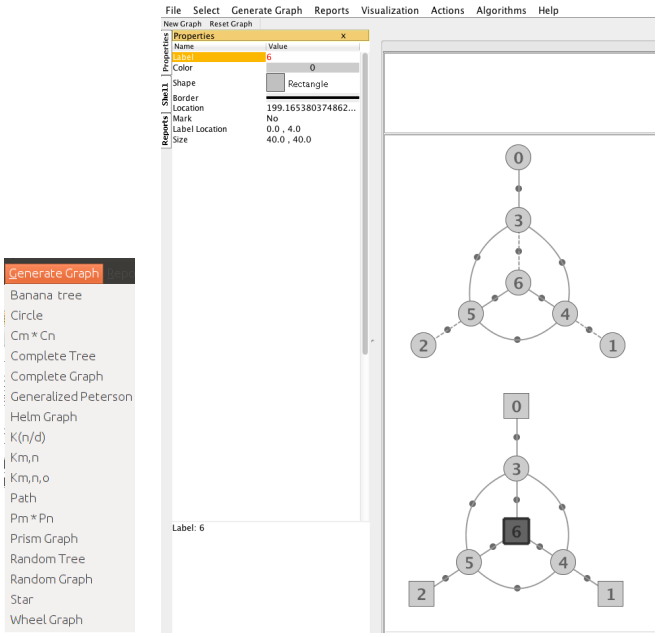

Fig. 2. (Left) List of predefined graphs, accessible under the menu "Generate Graph". (Right) Properties of the selected vertex is shown. Each vertex can be handled alone. The properties of edges are already changed to be curved edges.

A. Graph Generation and Modification

Graph generation could be named as the main feature in a graph educational software. In GraphTea, a graph can be generated in three ways. The simplest way is to use the mouse. Each mouse click on the main windows adds a new vertex. Two vertices can be connected by click on the source vertex and dragging the mouse to the center of destination vertex. The generated vertices and edges or a group of them can be selected by mouse left-click. The selected vertices and edges can be moved or deleted. The mouse right-click opens a menu, which provides different functionality over the selection.

The second way of generating a graph is to use the predefined ones under the menu "Generate Graph". As it could be seen in Figure 2 (Left), there is a list of highly usable graphs in this menu, which are generated by the software and prepared to be used. When a graph from this list is selected, a window will be opened asking the parameters of the target graph. For example, if a complete graph is selected, the number of vertices would be asked as a parameter.

The graph can also be loaded from a file as a third way. Three types of files are supported so far in GraphTea. GraphML [8] and Matlab file formats are two classic ones. In addition, GraphTea has its own file type for saving and loading, called "SimpleGraph".

As mentioned before, GraphTea is powerful in graph modification. The properties of graph in general as well as vertices and edges are editable. The properties are available in left toolbar "Properties". By selecting an edge or a vertex the corresponding properties will appear. No selection means the generic properties of the graph is demanded. Shapes, colors, sizes, and many other properties are shown by this toolbar. Figure 2 (Right) shows how to alter the properties of a graph. The shape of vertices 0, 6, 2, and 1 has changed from circular to rectangular. Some edges, like the edge between 3 and 4 are curved edges, though some others are straight lines. This confirms the strength of GraphTea and how almost all properties of vertices and edges are editable easily.

B. Graph Reports

GraphTea provides desired information as reports about the graph, which the user would request. Reports in GraphTea are divided into two groups, the one with numbers or string as the results, and the other resulting in a set of vertices or edges. In case that vertices and edges are outputs, there is an option to visualize the result on the corresponding graph. For example, Figure 1 shows the visualized report of independent set and coloring. It is seen that graph has five independent sets and the student can select each of them to see them instantly on the graph. Hence, a report is provided either as a list containing a set of information or in a visualized form (see Figure 3). The reports are available via the menu "Reports" and left toolbar as well, as shown in Figure 3. This toolbar has the option to generate all reports and to prepare them altogether.

IV. Algorithm Visualization: Teaching Depth-First Search (DFS) with GraphTea

In GraphTea, an algorithm is a step-by-step procedure, when each step applies an action. An action is either getting some input from the student or modifying the graph. The input could be a mouse click, key input, or any numerical and string input. For example, starting and destination vertices should be selected in shortest path algorithm and are considered as inputs. The changes in the graph can be coloring, removing, adding, or even moving a vertex or an edge.

Since the information of algorithm and its progress are described as instructions, for each step the instruction is

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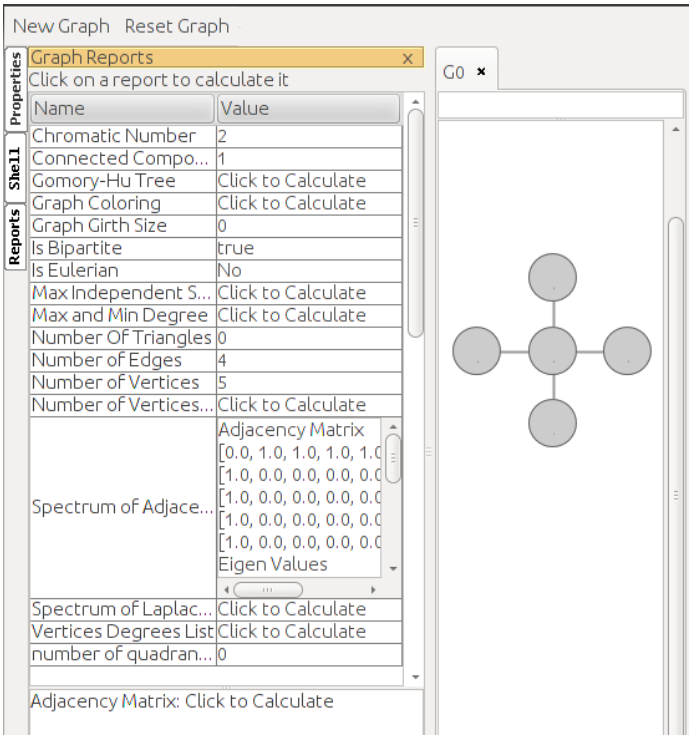

Fig. 3. Left toolbar of GraphTea provides another way to compute reports on the graph.

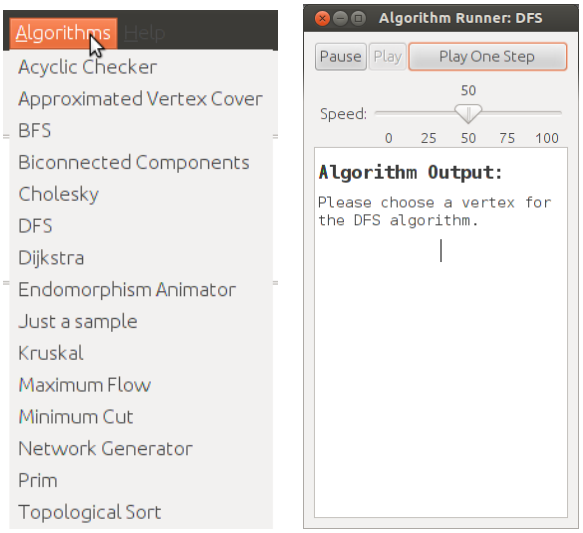

Fig. 4. (Left) List of algorithms accessible under the menu "Algorithms". (Right) The Algorithm Runner dialog.

explaining either the algorithm status in that step or the input required (see Figure 4(Right)). As a consequence, the algorithm education can be done by students without any tutorial sessions. Besides, the instructions are printed along with the algorithm execution and this helps to simultaneously see the algorithm output of each step on the graph and consequently to understand it better. Additionally, GraphTea has the possibility of controlling the speed of algorithm execution and results representation on the graph. This feature prevents the student from getting bored or losing some steps. The speed control can be done by a slide bar as shown in Figure 4(Right). The student could stop the algorithm to analyse specific steps more precisely, such as getting different reports at that stage. When the algorithm is stopped, the student can go forward one step in the algorithm or resume the normal execution.

Here we are going to illustrate this educational process with an example in a classroom, which of course could be done by student themselves. Suppose teaching DFS algorithm [9] is the goal and the given graph is visualized. DFS algorithm should be selected from the list of algorithms listed in "Algorithm" menu (see Figure 4(Left)). Then, the dialog "Algorithm Runner" appears as in Figure 4(Right). This dialog provides the functionality of pausing and playing the steps, and playing just one step of the algorithm. In addition, the speed could be controlled by the existing slide bar. The part "Algorithm Output" contains the instructions. After choosing a vertex, the algorithm starts to run and the visited vertices are colored.

It should be mentioned that the student can edit the graph at any stage and reinstate or continue the algorithm. When the algorithm is completed, the results are still present on the main window until the "Reset Graph" is selected. The resulting graph with colors on it can be saved in alternative formats as an image or a graph.

As an example, Figure 5 illustrates the DFS algorithm running on a banana tree. In Figure 5(a), the algorithm asks for a vertex to start the algorithm. After choosing any vertex, the algorithm continues. The vertex is either visited or left in the DFS algorithm. GraphTea uses purple for leaving a vertex and green for visiting a vertex in this algorithm. Color utilization here makes a better representation of the algorithm details and helps to have easier visual perception. Figure 5(c) shows the state in which the algorithm is finished, i.e. all vertices are left.

V. Conclusion and Future Works

GraphTea is currently being developed as a rich graph-editing framework focused on educational aspects of graph theory and algorithms. The first version "GraphTea 1.0" is already released and is accessible under the address: *graphtheorysoftware.com*. The software provides the user the ability to design a teaching plan and to add instructions and to engage students more in the teaching process. Famous and widely used graphs, reports on them, and graph algorithms are already implemented in GraphTea. Furthermore, the suitable visualization of graph algorithms in addition to the flexible way of editing, are the power of GraphTea along with educational functionality.

There are other directions to extend GraphTea. Converting the current version to an online version, which can be accessed completely on a website would improve the usage flexibility. Moreover, returning back in algorithm steps could help the students to the better perception of the algorithm idea. Searching for the educational requirements in application areas, like wireless network visualization, social network, and scientific computing, in which there is an urgent need for such a tool in classroom.

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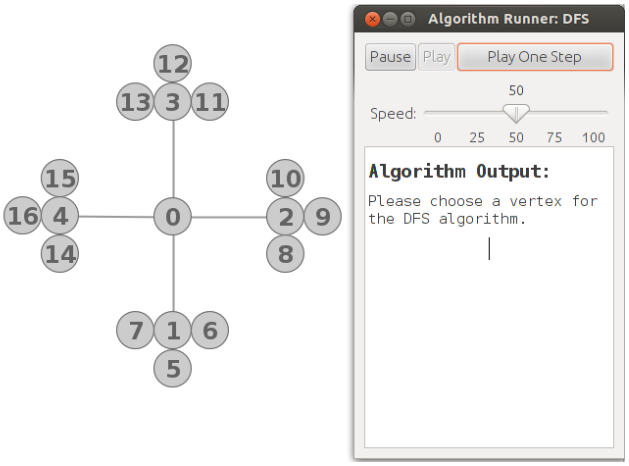
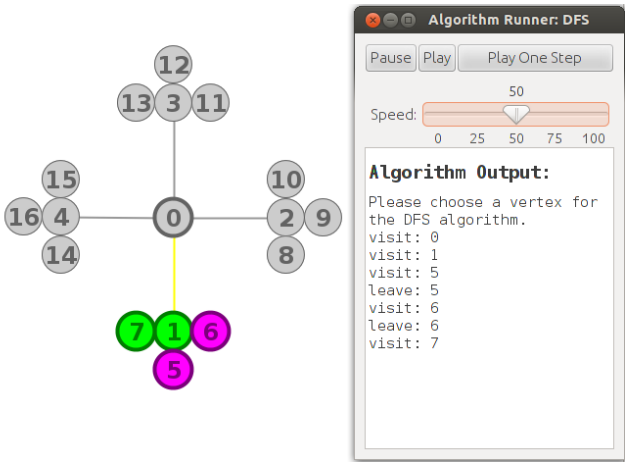
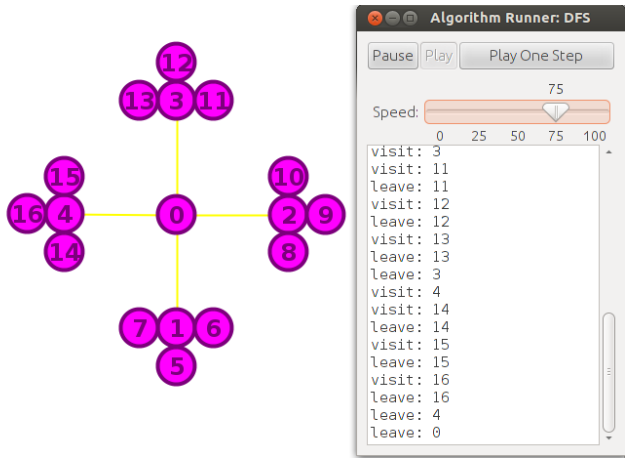


(a) The first instruction is to select a vertex as a input to the DFS algorithm.



(b) Having the vertex 0 as an input, the algorithm starts with the first neighbour which is the vertex 1 here and then the neighbours of the vertex 1.



(c) The algorithm finishes after traversing all vertices in the graph which is the goal of the DFS algorithm.

Fig. 5.

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Hardware-In-the-Loop simulator for turboprop and turboshaft engine control units

J. Vejlupek, M. Jasanský, V. Lamberský, R. Grepl

***Abstract*—** This paper presents the development and implementation of the Hardware-In-the-Loop (HIL) Simulator for turbo-prop and turbo-shaft engine control units (ECUs) on a low-cost embedded microcontroller. Developed HIL Simulator is a subsystem of a complex test device TPR_CPSP_SIM designed for use in the development and also in the manufacturing process of the ECUs.

In this document, we describe the development process of the part of the HIL simulator, which runs the engine simulation model and provides selected signals for the tested control unit. Main goal for this project was to implement turbo-prop and turbo-shaft engine (gas turbines) TP100 and TS100 models into the microcontroller and set-up the peripherals for the interaction with the rest of the system to obtain reliable HIL simulation platform.

***Keywords*—**Hardware-In-the-Loop Simulation, Engine Control Unit, ECU, CAN Aerospace, Rapid Code Generation.

I. Introduction

ONE of the key steps in a modern product development is a product testing stage. HIL simulation is often used for complex tests of electronical control units (ECUs), sometimes also coupled with power electronics (Power-HIL), placing additional requirements on the HIL simulation. HIL Simulation techniques are widely used specially in automotive and aerospace industry [1], [2], [3]. Various hardware and software platforms specially designed for HIL simulations are commercially available, from low cost [4] to very expensive devices [5], [6]. For this project we have selected custom build hardware, as there were many specific requirements for the signal conditioning. Software was created using Rapid Control Prototyping [7] and Rapid Code Generation [8] techniques in Matlab/Simulink.

Test stand TPR_CPSP_SIM is designed for HIL testing of the ECUs for turbo-prop and turbo-shaft engines (gas turbines) TP100 and TS100. Part of this test stand is the EVA_PIC32 module, which task is to run the engine simulation and provide respective signal processing. Either the signals are generated based on the operator request via the software running on external PC, or based on the engine model running on the microcontroller which is the core part of the EVA_PIC32 module. A 32-bit PIC microcontroller implements the model (both engines TP100 and TS100), and handles the IO signals for the ECU and also the rest of the test stand. Chapter System description and requirements provides more detailed description of the whole HIL simulator system, and summarizes the requirements for the EVA_PIC32 subsystem. In chapter SW implementation we describe the implementation of the engine model, and how the peripherals are handled.

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J. Vejlupek is a PhD candidate at the Brno University of Technology – Faculty of Mechanical Engineering. His current research focuses on Hardware in the Loop simulation, Rapid Control Prototyping and Rapid Code Generation for embedded applications. (e-mail: vejlupek@fme.vutbr.cz)

M. Jasanský is with the UNIS, a.s. company, Division of Aerospace and Advanced Control. (e-mail: mjasansky@unis.cz)

V. Lamberský is a PhD candidate at the Brno University of Technology – Faculty of Mechanical Engineering. His current research focuses on Rapid Code Generation for embedded applications.

R. Grepl is a Associate Professor at the Brno University of Technology – Faculty of Mechanical Engineering.

II. System description and requirements

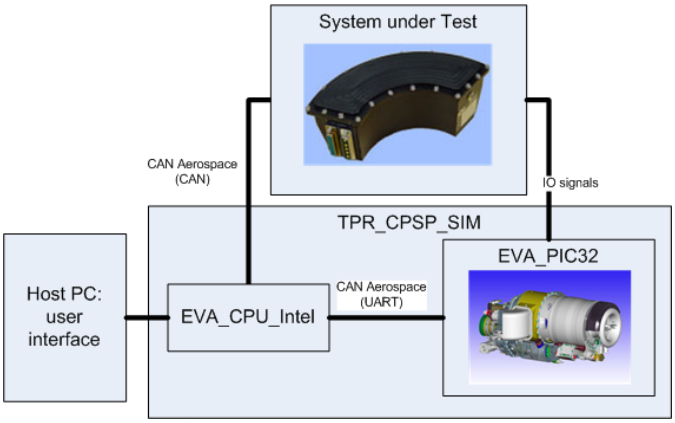

Fig. 1: HIL system scheme

Fig. 1 shows the scheme of the HIL system setup, individual components and related items are described below:

A. System under test: Engine Control unit (UNIS)

The ECU is an electronic device intended for control of TP100 / TS100 gas turbine engines (manufactured by PBS Velká Bíteš a.s., Czech Republic). The ECU also provides +28 V DC power supply for other onboard devices. There are two types of ECU: one for turbo-prop engine, and one for turbo-shaft engine. They are both very similar in design.

Main functions of the ECU are the following:

- regulation of turbine rational speed to desirable value (0 to 60000 rpm)
- regulation of the free turbine speed
- turbine start and stop regulation

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- onboard electric supply
- turbine operational parameters monitoring and checking

B. TP100 / TS100 engines (PBS)

TP100 is turboprop engine designed for use in ultralight airplanes (piloted as well as UAVs) and TS100 is a turboshaft engine intended for use in ultralight helicopters. Both engines are based on the TJ100 turbojet engine. In a simplified way, the TJ100 works as the gas generator driving the free turbine. The main mechanical difference between TP and TS variant is the gearbox, where the TP100 nominal speed is 2158 rpm, and TS100 has nominal speed of 6000 rpm.

C. TPR_CPSP_SIM

Test stand TPR_CPSP_SIM is a HIL simulator designed for manual and automatic HIL tests of the ECUs. Tests are managed by the user from an application (created by UNIS) running on external PC.

TPR_CPSP_SIM enables two modes of operation: *Tester* and *Simulator*. The *Tester* mode is designed to inspect individual functions of the system, such as analogue and digital read-outs, communication, software functionality, etc. The *Simulator* mode is using the TP100 / TS100 engine model for the HIL test, in this mode, the ECU is running as it would be with a real engine in the aircraft. Mode selection is done using the switch on the TPR_CPSP_SIM front panel.

Key components of the TPR_CPSP_SIM are:

- Central control unit EVA_CPU_Intel, which provides communication interface between EVA_PIC32 (UART), ECU (CAN), and PC (RS232).
- EVA_PIC32, module described by this document, implements the TP100 / TS100 engine model and part of the signal processing for the interaction with the System-Under-Test (SUT) (ECU)
- BLDC Electronic Speed Controller (ESC) and BLDC motor M5 representing the jet engine. M5 is mechanically connected with M3 – BLDC motor used as starter-generator, driven by ECU.
- Fuel pumps M1 and M2, connected together with BLDC motor M4 creating the load for both fuel pumps by being permanently loaded with resistors. M4 is also connected to EVA_PIC32 for speed sensing.
- Relay and I/O boards used for fault condition simulation by disrupting selected signals.

D. EVA_PIC32 engine simulator module

EVA_PIC32 module is one of the key components of the TPR_CPSP_SIM HIL simulator. Its purpose in the system is to provide signals generated by the TP100 / TS100 engine for the ECU. These signals are, depending on the mode of operation (*Tester* / *Simulator*), generated either by the user through an external application, or by the engine model running on the EVA_PIC32 microcontroller.

Key functions of the EVA_PIC32 are:

- Communication with the EVA_CPU_Intel via UART using CAN Aerospace protocol.
- Generate signal representing the speed of the free turbine (doubled signal: nVTa, nVTb)
- Drive the ESC for the BLDC motor M5 representing the jet engine.
- Check the speed of the fuel pump through the M4 motor.
- In the *Simulator* mode, run the TP100 / TS100 engine model and handle respective signals accordingly.

Tester / Simulator switch is directly connected to the EVA_PIC32 as a digital input. Next, there is a STOP button, which when pushed resets the module to default values, most importantly stops all motors.

Both speed measuring inputs are in form of frequency: pulses with 50% duty cycle are connected to the Input Capture peripheral. Frequency is directly proportional to the speed. Signal generated for the ESC is standard RC signal: 100-400Hz and pulse width between 1ms and 2ms.

Communication with the rest of the system is realized through the UART peripheral, and the protocol used is the CAN Aerospace, data are transmitted using the HEX representation.

III. SW Implementation

Software for the 32-bit PIC microcontroller is created using the Rapid-Control-Prototyping and Rapid-Code-Generation techniques enabled by MATLAB-Simulink Embedded Coder together with Kerhuel Toolbox. This set of tools allows us to generate the C code (including microcontroller setup and peripheral handling) for the microcontroller directly from MATLAB Simulink. This is very convenient way especially for the development phase, when the model of the engine is being often modified during the development phase. Nevertheless, some functionality had to be coded manually in C code, as the Kerhuel Toolbox does not enable all the functionality needed.

This section describes the requirements in more technical details and explains how they have been implemented and fulfilled.

A. System settings

The core of the EVA_PIC32 board is a 32-bit PIC microcontroller pic32mx320f128h clocked with external 10MHz crystal and scaled up to 80MIPS. Main execution loop time step is set to 0.01s (100Hz), all the functions (if enabled) are executed at this rate. Actual functionality is determined by the state-machine implemented using Stateflow (MATLAB Simulink Blockset). State machine is in detail described bellow in section D. Overall system performance is summarized in section E.

B. CAN Aerospace protocol

CAN Aerospace protocol [9] is data format definition designed for airborne applications using microcontrollers with CAN peripheral. However in this case, ACAN protocol is used over the UART simply by taking the data part of the CAN message.

To have the complete message, the information about the

length of the data (0-8), and the CAN ID is added before the actual message. As the CAN ID could range from 0 to 2031 (11-bit identifier), it has to be represented by two bytes: CAN_ID High, and CAN_ID Low. Furthermore the CAN_ID is aligned by bit-shift by 5 bits to the left, before it is split. This is due to convention used by the third-party UART-to-CAN converter which is used inside the TPR_CPSP_SIM simulator.

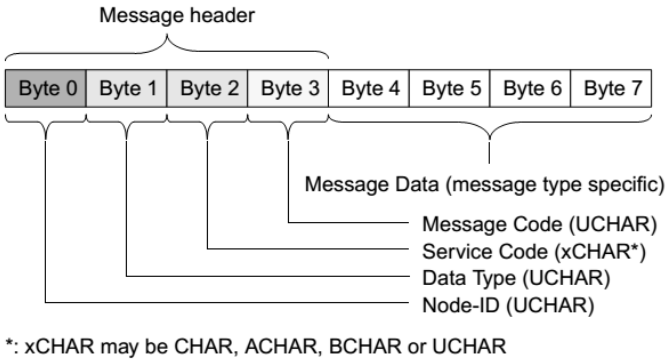

Fig. 2 ACAN General message format [1]

As an example we show how the "*Low priority Node Service data*" (NSL) message is transmitted over UART: NSL message type is defined over the CAN-ID range of 2000-2031. UNIS uses this messages for read and write operations on control registers. Where the D1 – Node ID specifies the target control unit, D2 – Data Type specifies the data type of the data in the message (for read register is D2 = 0: "No data"), D3 – Service Code determines the type of operation, where 102 means RCRS – *Read Configuration Register Service*, and 103 means SCRS – *Set Configuration Register Service*. These messages are defined internally by UNIS. D4 – Message Code then identifies the register. In Table I we show how the ACAN message asking node with ID 211 to send value of register 150 (RCRS) is transmitted over UART.

Data are transmitted using the HEX representation: Byte (0-255) is taken in the hexadecimal notation (0x00-0xFF), split into two characters, and their representation is sent in Byte representation via the UART. This method enables simple way to delimit the message frames. Data frame is terminated with *carriage return* character.

TABLE I. SENDING RCRS FOR REGISTER 150 TO NODE 211

	Data length	CAN_ID = 2000		D1	D2	D3	D4	termination character
		CAN_ID High	CAN_ID Low	Node ID	Data Type	Service Code	Message Code	
DEC	4	250	0	211	0	102	150	
HEX	04	FA	00	D3	00	66	96	
UART	48 52	70 65	48 48	68 51	48 48	54 54	57 54	13

Implementation of the receiver is done in two while loops: inner loop reads the UART buffer until it founds the termination character, or until the buffer is empty. If the termination character is found, then the complete formatted message is sent for processing. Outer loop checks only if the buffer is empty. If the buffer is empty, the receiver loop ends until the next time step iteration.

Messages transmitted from the EVA_PIC32 are basically of two kinds: response to received message, which are handled directly by the received message processing function, and data requests based upon the actual mode of operation by individual function blocks – inside enabled subsystems.

C. IO Signals

This section discusses individual digital inputs and outputs aside from UART communication, which has been described in the previous section.

1) STOP button and Tester/Simulator switch

To ensure the safety of the operator, tested control unit, and test-stand itself, STOP button has to be present on the TPR_CPSP_SIM tester. It is placed on the front panel of the device. This button is connected to the EVA_PIC32 board, and when pushed, all the driving signals need to be reset to their default values. This applies above all to the signal driving the ESC controller for the BLDC motor M4, and the free turbine speed signal.

Switching between *Tester* and *Simulator* modes is done by the Tester / Simulator switch, which is also on the TPR_CPSP_SIM tester front panel. If the state of the switch changes the state machine controlling the mode of operation goes through the stop procedure and switches the mode. Further description is below in the section D.

2) Driving M5 with ESC

Motor M5 represents the jet engine, and is connected to M3, which represents the starter-generator. M3 motor works in the motor mode (driven by the ECU) while the Tx100 engine is starting, after the jet engine goes to stable run mode, M3 is used in the generator mode, producing the power for the onboard electronics (through the ECU).

Motor M5 is a BLDC motor, and it is driven by the customized ESC with fast RC signal – control frequency is up to 400 Hz, with the standard pulse width between 1ms and 2ms. Signal for the ESC is generated by the PIC microcontroller using the Output Compare peripheral. As the pulse width ranges from 1ms (zero speed) to 2ms (full speed), we have decided that the 8-bit resolution would be sufficient. So the pulse width between 1 and 2 ms was divided into 256 values, with 0 representing 1ms, and 255 representing 2ms. Timer 3 is used as a time base for the OC3 providing the PWM signal. Timer 3 is scaled from the main 80 MHz clock by the factor of 64 down to 1.25 MHz, and the period register is set to 12499. This sets the Timer 3 for 100Hz period. OC3 is configured for the PWM mode with fault pin disabled (OCM = 0b110), and the secondary compare register is by default (and by the reset) set to OC3RS = 1250, generating the 1ms width pulses. Function which sets the secondary compare register has lower saturation set to 1250 (1ms) and upper saturation set to 2500 (2ms), ensuring the valid signal for the ESC. OC3 is enabled at the TPR_CPSP_SIM tester power-up and unless the value is changed by the operator (in tester mode), or by the running engine model (in simulator mode), it generates the 1ms pulses, so the M5 remains still.

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3) Free turbine signal generation

Signals nVTA and nVTB are doubled signal representing the output of the free turbine speed sensor. This signal was defined as square wave signal, with frequency ranging from 60 to 6000Hz, with step of 1Hz, and maximal error of 0.08%.

Both signals are identical, to generate nVTA OC1 is used, and for nVTB OC2 is used. We will describe how these signals are generated on the nVTA, as these methods apply also for the nVTB.

Since the signal is defined as square wave signal, output compare peripheral is used in the PWM mode with fault pin disabled (OCM = 0b110). In this case, the duty cycle is 50% and the period (frequency) is variable. To guarantee the maximal error of 0.08% and required frequency range, we had to implement timer prescaller switching. As a clock source for the Output Compare, Timer 2 is used, and the prescaller is set to 1, 8, or 64, depending on the frequency generated. Fig. 3 shows achieved accuracy for the generated frequency.

Maximum theoretical error is calculated from period T corresponding to each frequency f, and prescaller resolution t_{ps} ($0.0125\mu s$ for 1x prescaler, $0.1\mu s$ (for x8 prescaler), $0.8\mu s$ for x64 prescaler).

$$e_f = t_{ps} / T_f / 100 \quad (1)$$

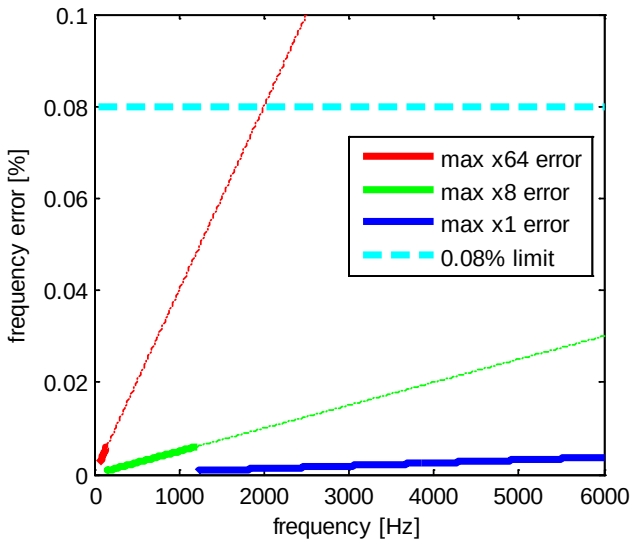

Fig. 3 Generated frequency - achieved accuracy

Reason for the prescaller switching is the wide frequency range and low error tolerance: to be able to generate as low frequency as 60Hz, prescaller with factor of 64 has to be used:

With 16-bit timer[1] the prescaller factor of 1 allows generating frequencies down to 1220Hz, prescaller factor of 8 allows frequencies down to 152Hz and prescaller factor of 64 allows frequencies down to 19 Hz. However we cannot use the prescaller factor of 64 as the low error requirement is not achievable with it. To illustrate this problem, we will calculate the period register for the frequency of 6000Hz using the prescaller factor of 64:

$$\left((80,000,000/64)/6,000\right) = 208.\overline{3} \quad (1)$$

Since the Output Compare peripheral works only with integer numbers, we have to round the value to the closest integer (208) to calculate the frequency actually generated. In this case, we will get:

$$\left((80,000,000/64)/208\right) = 6009.615Hz \quad (2)$$

Since the maximum allowed error is 0.08%, which at 6000Hz is 4.8Hz and at 60Hz is 0.048 Hz, we can see that we need better resolution – lower prescaller factor.

To solve this problem, timer prescaller switching was implemented in a following way:

- Prescaller factor 1: freq. from 1221Hz up to 6000Hz
- Prescaller factor 8: freq. from 153Hz up to 1220Hz
- Prescaller factor 64: freq. from 60Hz up to 152Hz

This implementation allows us to keep the error of nVTA and nVTB signals bellow 0.015%.

Default value for nVTA and nVTB is 0Hz – logic level on OC1 and OC2 pins is held low, and Output Compare is off. First valid setting of the free turbine speed register turns the Output Compare peripherals on and starts the pulses. If the STOP button is pressed, both pins are driven low and respective Output Compare channels are disabled.

4) Starter-generator speed measurement

Measurement is done using the Input Capture peripheral which reads the square signal from the motor (after voltage level conversion). IC4 is used for the measurement. Measured frequency range is from 500Hz up to 4000Hz, which corresponds to the speed range of 7500rpm…60000rpm ($n = f \cdot 15$).

Speed of the starter-generator motor is also used in the control loop for driving the M5. As the ESC does not provide any speed feedback, or characteristics about the result speed, speed of the M5 is assumed to be the same as the speed of the starter-generator M3, since they are connected together mechanically.

5) Fuel pump speed measurement

Fuel pump speed is determined in a very similar way as the speed of the starter-generator described in section *4)*. For the signal measurement IC1 is used (also configured with Timer3 as clock source). Frequency measured is assumed in range of 150Hz…750Hz, corresponding to speed range of 3000rpm…15000rpm ($n = f \cdot 20$). Speed of the fuel pump determines the output of the jet engine, and it is the only input to the TP100 / TS100 simulator model.

D. System modes of operation

As mentioned before, there are two modes of operation: *tester* mode, and *simulator* mode. Beside this, some other events need to be considered, such as STOP button and

[1]32-bit timer is not available, due to the fact that for OC and IC peripherals are available only two 16-bit timers: T2 and T3. These would be both consumed to form one 32-bit timer, but T3 is used for OC3, which provides the control signal for ESC.

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switching between the tester / simulator mode. To implement these features state machine programmed in Stateflow (MATLAB Simulink Blockset) is used. Inputs for the Stateflow besides control registers are functions reading the digital inputs: tester/simulator switch, and the STOP button. State machine determines the actual mode of operation and handles the enabling of the correct subsystems.

Both modes of operation are described in the sections below. However there are two significant events that need to be checked in parallel:

- STOP button pressed:
  - sets the ESC signal to default value (1ms pulse)
  - sets the free turbine signals to default value (zero)
  - stops the operation of all tester / simulator subsystems
- Tester/Simulator switch is toggled:
  - Performs the STOP sequence described above.

1) Tester mode

Tester mode is intended for calibration and production testing of the ECUs. It is fully manual mode – all actions have to be issued by an operator via external interface. Main functions of the tester mode are:

- measure the speed of fuel pump *nFPump*
- measure the speed of the starter-generator *nOut*
- drive motor M5 via the ESC *pwmM5*
- simulate the free turbine speed signals *nVTA*, *nVTB*

From the software view of the state machine: Transition from the default case is made in case that the STOP button is released and the switch is in the Tester position. First, the tester initialization is executed: this ensures the reset of all control registers, and that the simulator subsystems are disabled. In the tester mode, only incoming ACAN messages are handled, there are no messages generated by the microcontroller (aside from responses to the incoming commands).

2) Simulator mode

Simulator mode is intended for the semi-automated and for the automated HIL tests. In this mode, the engine model (TP100 / TS100) is run based on the input commands and provides feedback to the tested ECU. Engine model is selected at the end of the simulator initialization sequence. Selection is based upon the state of the register R120 (set by the user) designated for this purpose. Initialization sequence enables the ACAN communication, then the model waits until all conditions are met:

- Starter-generator speed is over 6000rpm
- Fuel pump speed is over 3000rpm
- Ignition is on
- Fuel valve is open
- Output temperature is higher than Tcomb

If all conditions are met, state machine decides which model (TP100 / TS100) to use, based upon the value in R120 and switches to the "rev-up" mode. The "rev-up" mode simulates the start-up and ignition of the engine, after that the transition to the state "simulator_run_Tx100" is executed. This state enables the respective model and in case of TS100 also ACAN request for the R17, which stores the settings of the collective.

Model runs continuously as long as the fuel valve is open, or until the STOP button is pressed, or the mode of operation is changed (*tester* / *simulator* modes). When the model execution is stopped, the model is disabled and all the outputs are set to default values. After that the state machine switches to the default state and waits for the next run.

E. System performance

To measure the system performance in the terms of the microcontroller load, "busy flag" method is used: At the beginning of each computational step selected digital output pin is set high, and after all the functions have been handled, it is set low. This will give us 100Hz square wave signal (with 0.01s time step), where the duty cycle represents the actual work load of the microcontroller. However, this method does not consider all the interrupt routines, but they are considered to have a minor effect on the result. More significant than the interrupt routines is the serial communication.

Measured workloads:

- Tester mode: 8 %
- TS100 simulator mode: 30 %
- TP100 simulator mode: 28 %

Code was compiled using Microchip C30 compiler; following are the memory usage statistics:

- RAM used: 6254 bytes (38%)
- Flash used: 70500 bytes (49%)

IV. CONCLUSION

Software for the EVA_PIC32 board described in this paper was created as a cooperative project between University of technology Brno and UNIS company. Results are used by UNIS and their customer (PBS) during the unit manufacturing and assembly process of the ECUs and the Tx100 engines.

Presented work describes how the methods of Rapid-Code-Generation were used in the development process of the HIL simulator subsystem. It shows, that not all of the required functionality could be created using RCG methods (i.e.: interrupt routines). However RCG is still a substantial asset as it enables very clear arrangement of the "source code" in the MATLAB Simulink, ease of implementation of the changes, and also ease of implementation of the algorithms created in MATLAB Simulink. Some of the unimplemented features could be taken as an inspiration for developers as an idea on what to improve.

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Information systems interoperability in the case of partnership between companies within a port area.

ABID Mehdi, SERHANE Yassine, NSIRI Benayad and BENABDELHAFID Abdellatif

***Abstract*—**This document analyzes a critical issue in the study of interoperability and communication partnerships between companies in a port area as an extended business.
This article's purpose is to give an overview of the definition and adoption of a system that allows to interact with heterogeneous systems and make all data available in the time and location where they are required, based on the homogeneity of the structural and semantic conflicts.
In this paper, we propose architecture based on mediation, offering a modular organization of an information system in order to exploit the data sources connected by networks architecture, where the objective is to establish a solution which provides a flexible and scalable architecture of ports information systems.
Our architecture is based on three levels: 1) User level 2) Mediation level, 3) Source level. The first level is dedicated to applications and users, the second includes various tools to process queries and solve conflicts (technical, structural, semantic) through mediators and ontologies. Each mediator has a local ontology, where it interacts directly with a global ontology interconnected with all local ontologies. The third level concerns local information systems and adapters that provide unified interface information systems. The use of XACML allows a good independent modules and rigorous structuring of communications and decisions to standardize access control for documents.

Keywords: Interoperability, Extended business, Mediation, Local ontology, Global Ontology, XACML.

I. INTRODUCTION

Nowadays technological change has increased significantly so that all firms are connected together by a set of hardware resources and software related to the transmission and exchange of information between different entities. This change requires all companies to develop their cooperation in all sectors to provide their products and services while minimizing the cost and increasing earnings. In addition, studies on relational data exchange scheme and mappings were initiated several years ago [1]-[2]-[13] to facilitate geographical forced exchanges.

Indeed a company's information system in a port area shall not operate as a separate system, however it must be incorporated in a set of business networks to facilitate communication and exchange of data, ensuring confidentiality and security of data exchanged (means of access) and to maintain traceability in the deduction of data (especially the nomenclature).

Variety of information systems for port companies creates a conflict of interoperability between these heterogeneous information systems, which is a difficulty in modeling and designing an information system, that develops a methodology for collaboration between systems ensuring secure communication in a network and ensuring their semantic interoperability, can ensure that the precise meaning of exchanged information is understood and preserved throughout exchanges between different parts, allowing organizations to exploit this information [3]. In this paper we propose a practical architecture that integrates several heterogeneous port companies' information systems to ensure good communication between them and in syntactic and semantic level between them and share their data without changing the internal architecture of each system.

II. BACKGROUND

Information system management that enables interoperability between port companies remains a challenge with unique requirements, so far many studies contributed to the development of a heterogeneous port's information system. Several ports' information systems of the community are used in various port companies, but they are often heterogeneous. Such as, the computerization of administrative and commercial procedures for the development of EDI tools. EDI (Electronic Data Interchange) systems are means of telecommunications

Mehdi ABID is with laboratoire d'informatique et d'aide à la décision. Faculté des Sciences Ain Chock, Université Hassan II. Casablanca Maroc (e-mail: 90.abidmehdi@gmail.com).

Yassine SERHANE is with laboratoire d'informatique et d'aide à la décision. Faculté des Sciences Ain Chock, Université Hassan II. Casablanca Maroc (e-mail: serhane.y@gmail.com).

Benayad NSIRI is with laboratoire d'informatique et d'aide à la décision. Faculté des Sciences Ain Chock, Université Hassan II. Casablanca Maroc.

Abdellatif BENABDELHAFID is with laboratoire de Mathématique Appliquées du Havre. Université du Havre. Le Havre France

which makes it possible to electronically exchange information on the communications networks using standardized forms. [4] This system became clear to ports' professionals as part of their competitiveness. Indeed, whatever the information's level for each separate business, the issue of documents exchange between them are established, where the exchanged data are inconsistent and lead to conflict areas of definitions, meaning or interpretation of the same given. It encompasses more precisely following conflicts: A) name conflicts: synonyms (different words expressing the same information) homonym (different information with the same name) polysemy (same term changes meaning depending on the context). B) Value conflicts: different ways to encode the same information in different systems (data representation conflicts: integer, boolean, string).

Therefore professionals' main objective is to establish dedicated information system to the port communication to integrate all the heterogeneous information systems and share all available data As in Fig. 1.

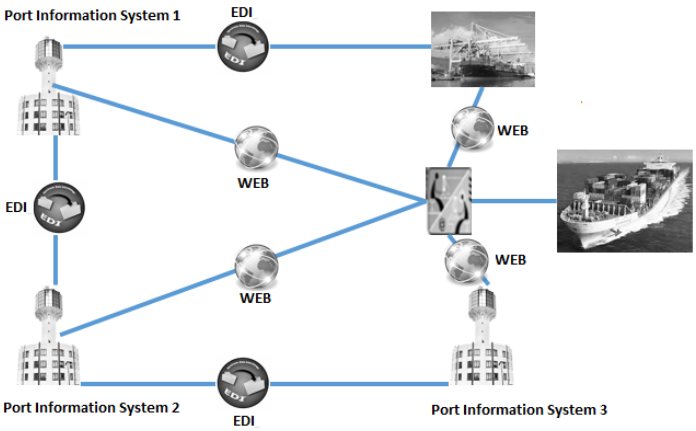

Fig. 1 Exchange Network

Due to the large number of heterogeneous information systems, several aspects of integration are required, namely: data integration in a technical, structural and semantic level as well as the workflow's integration in everything related to the validation of spots between different actors of the systems, which generates the difficulty of establishing a management system that has as role a common standard among all different information systems.

To develop this problem, this paper proposes a mediation architecture of context regarding port information systems, contexts mediation is based on an explicit representation of the data semantics through the notion of context. This context can be described using tools such as metadata [5] or ontology. A context specifies a library of knowledge on structure, features or values of a specific object in order to understand the semantics.

III. Method

The architecture we built is based on a modular information system that focuses on the concept of mediation context to manage the semantic heterogeneity between concepts and vocabulary manipulated by different systems ensuring proper understanding and correct interpretation exchanged. The concept of mediation context is based on four specific elements: The mediator, the global ontology, the local ontology, the adapter.

The mediator simplifies, abstracts, combines and describes the data [6] it aims to obtain and process the incoming data depending on the specific needs of each different port information system. Several mediators can be structured in an organized and structured hierarchy of any information system.

The local ontology: deposit local knowledge ontology of each mediator, all concepts and properties that it wishes to incorporate in its data dictionary; this ontology has its own structure of generalization / specialization that is not imposed by the domain ontology, although it meets the specialization relations [7] at this level this ontology is a class that belongs to the global ontology.

The global ontology is used in a specific domain and describes the vocabulary with a link to a generic domain (loading, handling ...) while specifying the high-level concepts [8], this ontology contains the relative area of an intelligent system description for port's platform.

We can define this ontology as a vocabulary that is based on a knowledge library; the use of the latter implies an agreement between all the different systems on a common knowledge representation to ensure their interoperation. The use of these ontologies have a key role in our system architecture, given the variety of many different port information systems which creates various problems (data analysis, decision making ...) when exchanging data. So the purpose of the use of ontology will allow the unification of exchanged data on a syntactic, semantic and structural level between all ports' systems.

The adapter: acts as a translator and is positioned between mediators and databases to establish consistency between the various port systems sharing the same data sources.

Each integration of a new information system development requires a special adapter to define the conceptual model of these components and the various access rights of its data assigned to each port existing information systems. This adapter has the aim of bringing together different applications by different users through a common interface between all systems to hide the heterogeneity among all port information systems.

The structure of our mediation architecture is designed to assemble & integrate data and keeping their semantics between different heterogeneous port information systems. As in Fig. 2 describes our architecture which is based on 3 levels.

The first level: User level is dedicated to different applications of port systems. the 2nd level: Mediation level which consists of mediators and ontologies (local and global) that encapsulate the various functions, methods and tools to address the queries to resolve the various technical, semantic and structural conflicts. The 3rd level: Source level which

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consists of adapters and the various ports' information systems' databases.

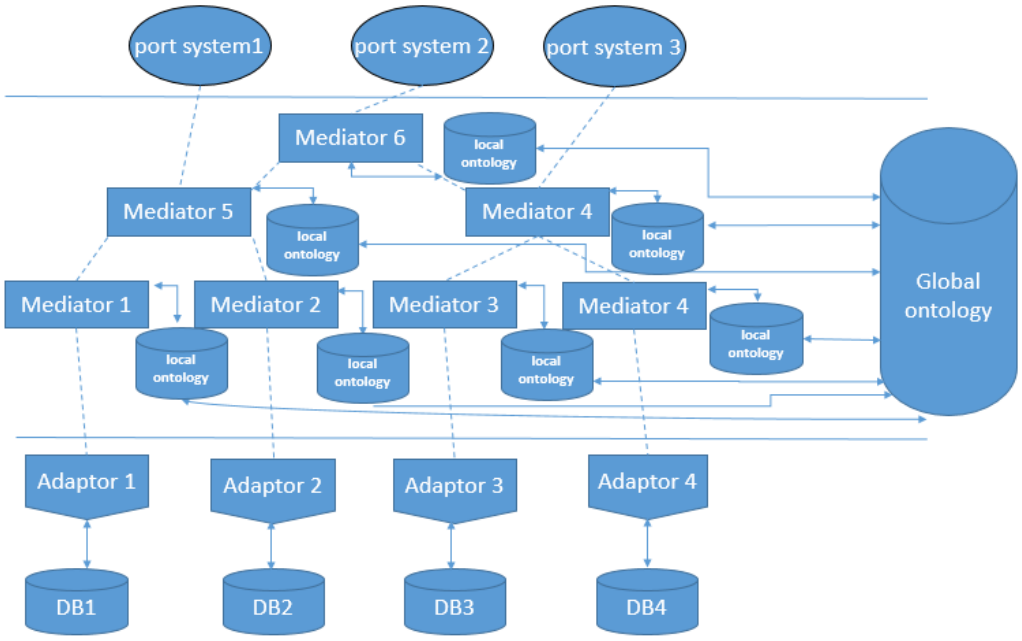

Fig.2 Mediation architecture based on local and global ontology

In our architecture, each mediator presents intermediary services between data resources and port information systems. Their goal is to establish an integrated targeted information without requiring the integration of data sources. In this architecture, the level of mediation is split on several mediators, where each one owns a local ontology in order to use the vocabulary concepts of this local ontology to solve any internal changes' conflict on a syntactic, semantic and structural level.

All local ontologies are related to a single global ontology to solve technical, semantic and structural heterogeneity of each information system as well as to optimize the changed data flow in each internal system without the need of the global ontology.

To incorporate different data, each adapter must be characterized according to the mediator where it was saved in order to translate the requests of the mediator in terms understandable by the data sources. Once a port system user sends a request, it will be sent through the mediator who will handle the sources distribution (sources location, decomposition and query optimization) this request will be interpreted and transformed by an adapter in order to access the data sources, the answer will then be transferred to the mediator via the adapter where the mediator combines, reconstructs and solves all the technical, structural and semantic conflicts of the adapters' results before handing these results to the system user.

Given the confidentiality of the data exchanged between the port information systems and to protect everything that is in the context of a collaboration in the port area, the security approach of XML data remains essential. XML has become a standard technology for a wide variety of data exchange on the web and the internet for its structure, labels, probability and scalability [9]. In this context, several studies have been developed to provide control over the content of XML exchanged data in Fig. 3, the main reason for choosing XACML, is that it is a mature OASIS [10]. XACML provides a method for facilitating data access control for the exchanged documents, and facilitate the use of different encryption standards during the exchange of sensitive data shared in the case of interoperability of ports information systems.

```
<SIP>
        <ID_AgentMartinie>
                <id type="Id_BI" value="1A230FE5">
        </ ID_AgentMartinie >
        <source>Casablanca</source >
        <destination>Le Havre</ destination>
        <TypeMarchandise>Voiture neuves</ TypeMarchandise >
        <DateChargement>24/01/2014</ DateChargement >
        <HeureChargement>15 :01</HeureChargement >
</SIP>
```

Fig.3 Sample of the Exchanged data in XML format

W3C and ITETF offer standard data and XML tags encryption in a document [11]. This will create access to data

encryption to protect sensitive information using different keys, this encryption will send the same information to different port systems in Fig. 4, and only systems with the decryption key specific to various files can decrypt the parts concerning the encrypted data.

```
<SIP>
        <ID_AgentMartinie>
                <id type="Id_B1" value="1A230FE5">
        </ ID_AgentMartinie >
        <source>Casablanca</source >
        <destination>Le Havre</ destination>
          <EncryptedData Id='ED1' xmlns='http://www.w3.org/2001/04/xmlenc#'
           Type='http://www.w3.org/2001/04/xmlenc#Element'>
                        <CipherData>
                                <CipherValue>A23B4C56</cipherValue>
                        <CipherData>
        </EncryptedData>
        <DateChargement>24/01/2014</ DateChargement >
        <HeureChargement>15 :01</HeureChargement >
</SIP>
```

Fig.4 Sample of the Exchanged data in XACML format

IV. Results

We adapted a standard model of two extended port systems which aim to develop their collaborative information exchange of raw materials supply to transform them into finished products and distribute them to clients. The problem that arises is that these companies are in two different locations using two different systems which creates a heterogeneity problem in a semantic and structural level. When exchanging information, each company can send different information based on its own architecture.

According to the study of mediation architecture based on local and global ontologies that fit in our article, in Fig. 5 describes the exchange prototype that happens between these two port companies which are totally different on a modeling, design and database management system level.

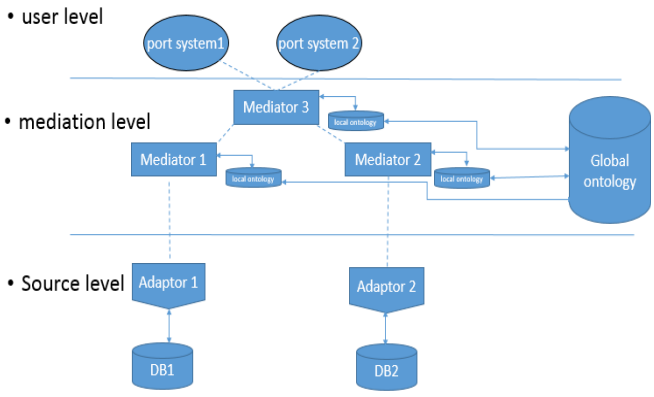

Fig.5 exchange prototype between the two port companies

User Level:

Level that contains different ports information systems where each system handles, collects and broadcasts this information according to its own needs, each system can be modeled or implemented differently.

Mediation level:

This level deals with heterogeneity issues between the two ports information systems; it consists of three mediators where each one of them has a specific task to achieve. The third mediator is based on the sources location, and queries decomposition in queries adapted in order to facilitate the various processes of other mediators (mediator 1 and 3) which are designed to ensure sending the data by solving semantic and structural conflicts as in Fig. 6 before the transmission to the associated adapters.

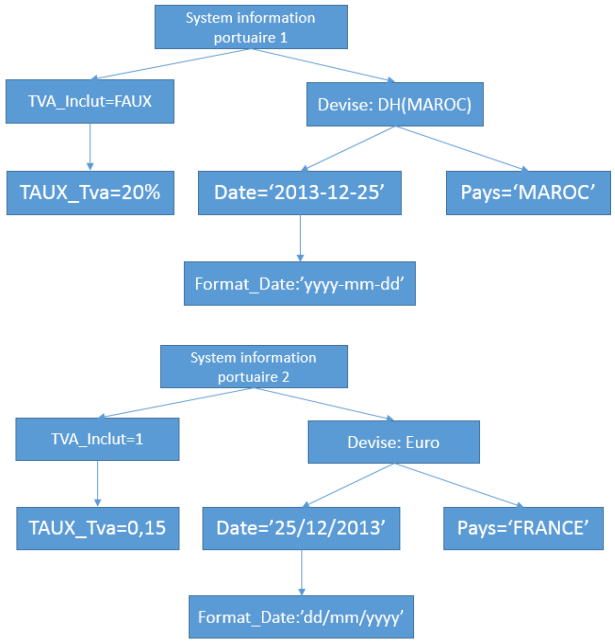

Fig.6 conflict of values between the two port information systems

To improve the interpretation of the data exchanged between the two systems on a data semantic level and thus hide semantic heterogeneity conflicts when sharing information, and to achieve semantic resolution (synonym, homonym, polysemy) we opted to create a port ontology which is based on EDIFACT standards (United Nations Rules for the exchange of computerized for administration, commerce and transport), a set of international standards, directories and manuals for the exchange of computerized data. [12].

We have implemented a knowledge base that depends on different port systems as in Fig. 7.

This global ontology is directly related to the other two

local ontologies to unify the language between the different ports information systems.

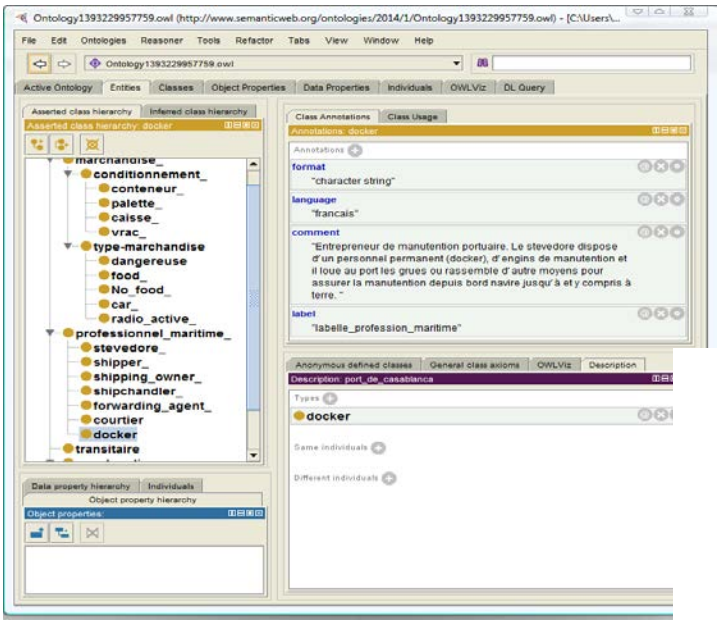

Fig.7 Interface ontology designed as protected

Source level:

We previously advised that these two ports information systems were developed and modeled differently and according to the following figure (With P1 and P2 two ports information systems).

INFORMATION SYSTEM	MODELING	DESIGN
IF PORT P1	MERISE	MySQL
IF PORT P2	UML	POSTGRESQL

Fig.8 Comparative table between the two port information systems

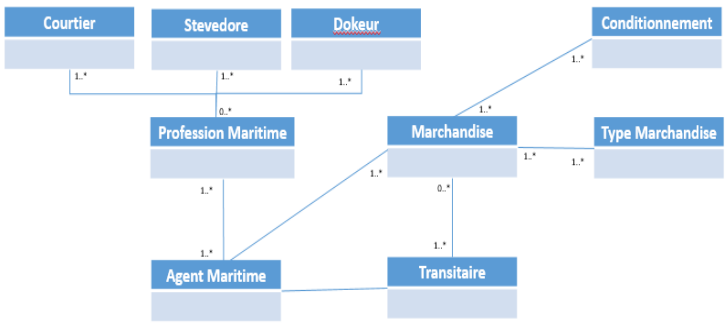

Fig.9 UML class diagram of the first port information system (P1)

According to Fig. 8 and Fig. 9 we can obviously deduce that there is a heterogeneity conflict:

• Schematic conflict, Date In and Date Out in the table "Merchandises" are represented by attributes in the information system (P1) however they are represented by a table in the information system (P2).

• Generalization / specialization conflict is linked to the differences in the ranking of the same information, in the first information system (P1) data of type Employee are implemented on different entities whereas in the information system (P2) data of an Employee is defined in a single table.

• Type conflict refers to differences in data type in our case the merchandise type is represented in Boolean form {1.0} in

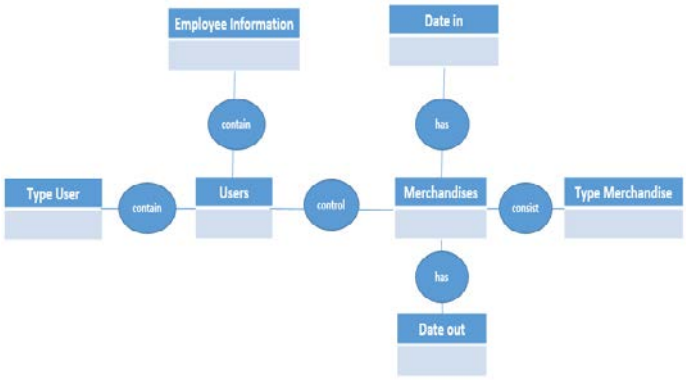

Fig.10 MLD second port information system (P2)

(P1) however in the system (P2) the Merchandise type is represented as a string.

Thanks to the prototype defined on the mediation level, heterogeneity problems have been solved thanks to the data distributions as well as ontologies based on the unification of data to avoid all semantic conflicts during the process of data exchange.

CONCLUSION

The work presented in this paper covers the issue of information exchange between heterogeneous ports information systems. We proposed in this paper an architecture based on mediation to resolve any semantic, technical and structural conflict in the data exchange between different ports systems.

This architecture of type 3-tiers (user, mediation and source) ensures the integration and the opening on a new perspective and will improve the inter-exchange and performance in the various port companies on a collaborative level.

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QoS-aware MPDU Aggregation of IEEE 802.11n WLANs for VoIP Services

Shinnazar Seytnazarov and Young-Tak Kim
Department of Information and Communication Engineering,
Graduate School, Yeungnam University
Gyeongsan-si, Kyungbuk, 712-749, KOREA
seytnazarovsho@ynu.ac.kr, ytkim@yu.ac.kr

***Abstract*— Currently, IEEE 802.11n higher throughput wireless LAN (WLAN) is widely deployed, and most mobile portable devices are expected to use WLANs for broadband mobile Internet services. IEEE 802.11n has been developed with MPDU aggregations to enhance overall throughput utilizing the increased physical layer transmission rate up to 600 Mbps. In currently available IEEE 802.11n WLAN implementations, however, the MPDU aggregation is not applied to realtime voice traffic (e.g., VoIP) considering the strict upper bounds of end-to-end delay and jitter. As a result, when realtime voice traffics are intermixed without MPDU aggregation the overall throughput becomes poor because of the protocol overhead of relatively short voice packets and increased contention level in CSMA/CA-based WLAN. In this paper, we propose an efficient QoS-aware MPDU aggregation of IEEE 802.11n WLANs for efficient VoIP service provisioning. The QoS-aware MPDU aggregation is applied to realtime voice traffic with controlled total buffering delay time for MPDU aggregation; different buffering delay thresholds are configured individually according to different access category and destination IP address. The proposed QoS-aware MPDU aggregation scheme has been evaluated with a series of tests on a real IEEE 802.11n WLAN test bed with 10 stations and 1 AP. Experimental results show that the proposed QoS-aware MPDU aggregation scheme enhances the overall throughput of IEEE 802.11n WLAN by 60% when 10 stations generate 64Kbps PCM voice traffic at 270 Mbps physical layer transmission rate, compared to the existing scheme, while the QoS performance of realtime voice traffic is guaranteed[1].**

Keywords*— MPDU aggregation, QoS, realtime voice traffic, throughput, IEEE 802.11n.

I. INTRODUCTION

Nowadays almost every mobile user devices (such as smartphones, laptops, and tablet PCs) are using Wi-Fi WLAN for broadband mobile Internet access [1, 2]. They run different types of user applications which generate huge traffic volume with diverse characteristics. Real-time multimedia applications such as Voice over IP (VoIP), Video over IP, online games demand strict Quality of service (QoS) constraints, while web browsing and file transfer require relatively less strict end-to-end delay time limits from the transport network. QoS-guaranteed realtime service provisioning is an important issue in broadband IEEE 802.11n WLAN [3, 4], and enhanced total throughput with efficient network resource utilization is a key factor in mobile Internet access networking.

An important feature of IEEE 802.11n WLANs is frame aggregation mechanism. High physical layer transmission rates do not necessarily mean high throughputs at upper protocol layers. IEEE 802.11n employs MPDU (MAC protocol data unit) aggregations to increase overall throughput utilizing the enhanced physical layer transmission rate up to 600 Mbps. In currently available IEEE 802.11n WLAN implementations, however, the MPDU aggregation is not applied to realtime voice traffic (e.g., VoIP) considering the strict upper bounds of end-to-end delay and jitter; this limited MPDU aggregation causes poor throughput when realtime voice traffic and non-realtime data traffic are intermixed.

Existing off-the-shelf schedulers for IEEE 802.11n (such as ath9k driver [5]) perform separated MPDU aggregation for individual access category (AC) of video, back ground and best effort (AC_VI, AC_BK, AC_BE), while they do not perform aggregation for Voice Access Category (AC_VO) (e.g., VoIP). Since realtime voice traffic packets are usually small and isochronous, they increase contention level in CSMA/CA-based WLAN. As a result, this limited MPDU aggregation scheme causes poor network resource utilizations that lead to degraded throughput.

Other existing scheduler proposals in [7-9], propose aggregation mechanisms that dynamically adapt the aggregated frame size with different parameters. But they do not consider block acknowledgement window (BAW) and end-to-end QoS constraints which are important features in MPDU aggregations for realtime multimedia traffic.

In this paper, we propose an efficient QoS-aware MPDU aggregation of IEEE 802.11n WLANs for broadband IoT service provisioning. The QoS-aware MPDU aggregation is applied to realtime voice traffic with controlled total buffering delay time for MPDU aggregation (up to 50ms for VoIP); different buffering delay thresholds are configured individually to different access category and destination address. It adapts the A-MPDU size based on the predefined buffering delay thresholds and access delay statistics which are periodically updated for each AC and destination IP address. The proposed MPDU aggregation scheme has been evaluated with a series of tests on a small scale real IEEE 802.11n WLAN test bed with 10 stations and 1 AP.

Experimental results show the proposed QoS-aware MPDU aggregation scheme enhances the overall throughput of IEEE

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802.11n WLAN by 60% when 10 stations generate 64Kbps PCM voice traffic at 270 Mbps physical layer transmission rate, compared to the existing scheme, while the QoS requirements (i.e., less than 150ms of end-to-end delay and less than 50ms of jitter) of realtime voice traffic is guaranteed. The major contribution of this paper is QoS-aware MPDU aggregation for voice traffic that adaptively adjust A-MPDU size to maximize the throughput based on the statistics of end-to-end delay and jitter.

The rest of this paper is organized as follows. Section II briefly reviews the MPDU aggregations in IEEE 802.11n standard and related work. Section III explains the proposed QoS-aware MPDU aggregation in detail. Section IV is dedicated to the performance evaluation. Finally section V concludes this paper.

II. Related Work

A. MPDU Aggregations in IEEE 802.11n

IEEE 802.11n introduced enhancements not only in Physical (PHY) layer but in Medium access control (MAC) layer as well [3]. PHY enhancements such as Multiple Input/Multiple Output (MIMO) [4], channel bonding and Short guard interval (SGI) altogether increased the transmission rate from 54 Mbps to 600 Mbps. But, increments in PHY transmission rate decreased the efficiency of legacy MAC [12], because the protocol overhead dominates the total required time for frame transmissions. For example, even under ideal channel conditions the MAC efficiency decreases from 42% to 10% when the PHY rate is increased from 54 Mbps to 432 Mbps [7]. MAC inefficiency issue led to new MAC improvements in IEEE 802.11n, namely MPDU aggregation (A-MPDU), MSDU aggregation (A-MSDU), and block ACK mechanisms. The aim of these mechanisms is to facilitate achieving high efficiency at higher layers through MAC and PHY overhead reduction.

A-MPDU aggregation is the most widely used and more efficient aggregation mechanism in IEEE 802.11n networks. Thus, most of the IEEE 802.11n wireless LAN cards support only A-MPDU mechanism. Several higher layer packets are given individual MAC headers and frame checksum (FCS) field, and transmitted back-to-back once the station gains an access to the medium. Each packet equipped with MAC header and FCS field is referred as MAC protocol data unit (MPDU) and thus the aggregation of MPDUs is called A-MPDU as shown in Fig. 1. During the aggregation process, MPDU delimiter and padding bytes are added before and after each MPDU respectively; MPDU delimiter has 4 bytes length and is responsible to tell the receiver about the MPDU position and length information while padding can vary between 0 – 3 bytes and added in order to make the MPDU length the multiple of 4 bytes.

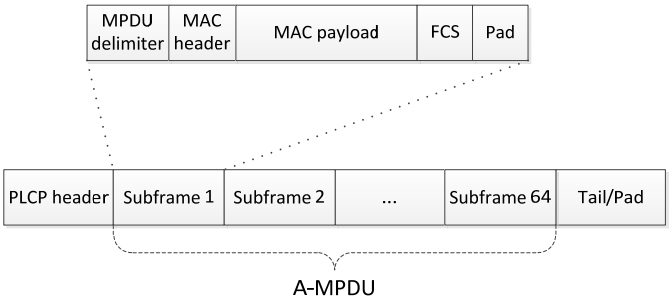

Fig. 1. Aggregation of MPDUs

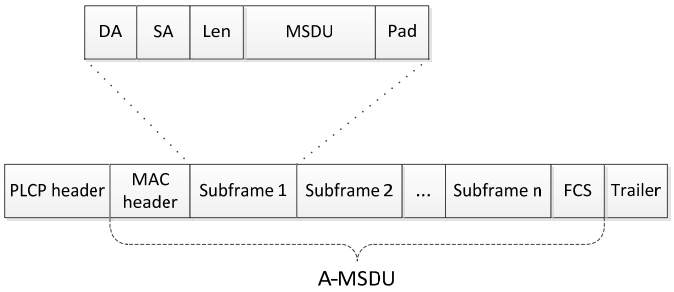

Fig. 2. Aggregation of MSDUs

Another frame aggregation mechanism is A-MSDU. Several higher layer packets together form a single MAC frame (Fig. 2). Destination address, Source address, Length fields and padding will be attached to each IP packet and this IP packet with its header fields is referred as a MSDU or A-MSDU subframe. Unlike A-MPDU, A-MSDU has only one MAC frame, only one MAC header and FCS field. Thus, if one of the subframes was received with error, this error is applied to the whole A-MSDU. A-MSDU can have a maximum size of 7,955 bytes.

B. Block Acknowledgement Window (BAW)

Ath9k driver implementation has Block ACK Window (BAW) mechanism that is one of the important features for aggregation enabled WLANs. BAW size is equal to 64 that is the maximum allowed A-MPDU length in 802.11n. Sender can transmit the MPDUs that are within the BAW. BAW continues sliding forward unless any of the MPDUs inside the BAW fail. If the sequence number of the first failed MPDU is seq, then BAW includes the MPDUs with sequence numbers from seq up to seq + 64. Failed MPDUs will be retransmitted in the next A-MPDU along with new MPDUs in the BAW if there is any. Let's look at example given in Fig. 3. In previous state, the BAW included MPDUs with sequence numbers between 101

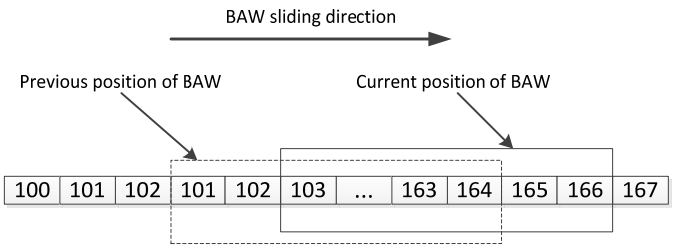

Fig. 3. BAW sliding example

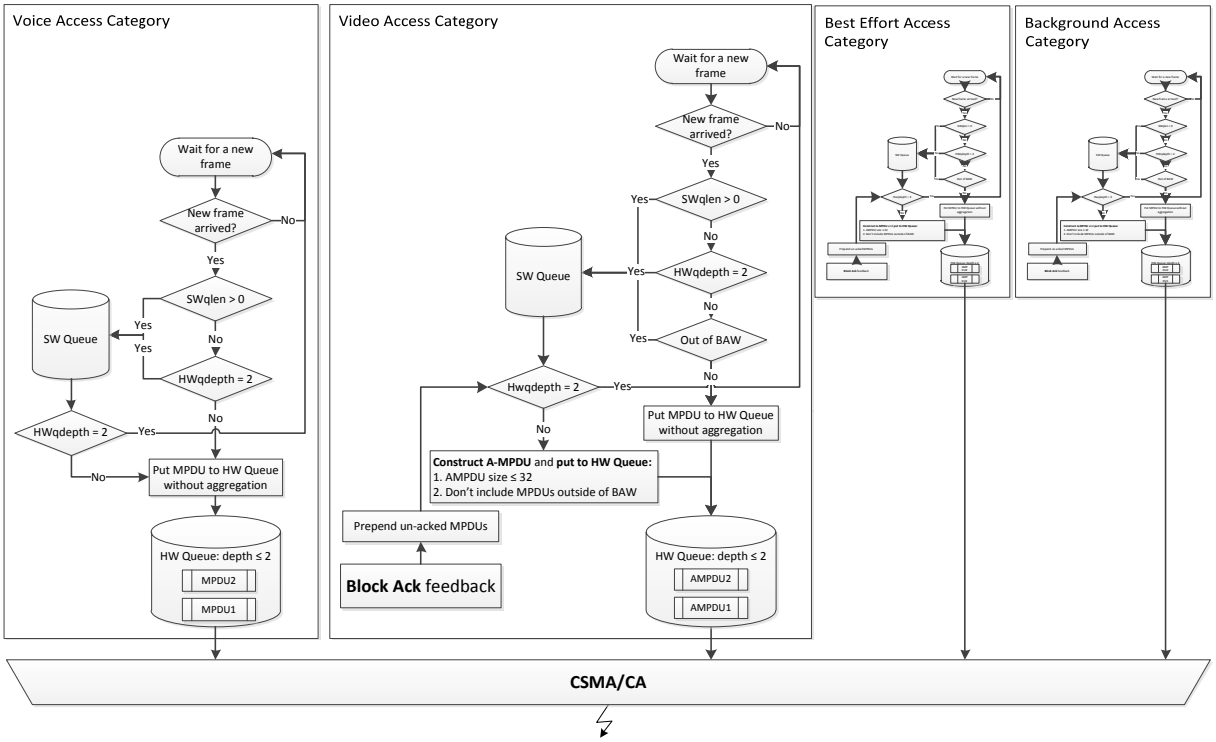

Fig. 4. Existing scheduler scheme in ath9k driver

and 164; station constructed an A-MPDU and transmitted and all MPDUs except MPDU with sequence number 103 were acknowledged by receiver. Thus, BAW advanced only for two MPDUs and now sequence number 103 will be retransmitted in next A-MPDU together with newly included MPDUs in BAW i.e. MPDUs with sequence number 165 and 166 and BAW will not move further until sequence number 103 will be successfully transmitted.

C. *Existing Off-the-Shelf MPDU Aggregaton Scheduler of IEEE 802.11n*

In the IEEE 802.11n standard, the aggregation sessions are handled individually for each receiver address (RA) and access category (AC). However, the standard does not define any specific scheduling mechanism for aggregations, and it was remained to be implemented based on the preference of vendors. For example, ath9k driver for 802.11n specifies two types of scheduling algorithms: one for Voice AC and another one for other ACs (i.e., Video, Best Effort and Background) [6] as depicted in Fig. 4.

Both schedulers use software queue and hardware queue. MPDUs are buffered at SW queue if there is no space in HW queue. Depth of HW queue is limited to 2 frames; they can be either two A-MPDUs or two non-aggregated MPDUs. HW queue can include only the MPDUs that are within Block ACK Window (BAW), and thus its length is limited to 64 MPDUs.

Scheduler of Voice AC does not use aggregation mechanisms. In other words, AC_VO MPDUs are transmitted individually as in legacy 802.11a/b/g. When new AC_VO MPDU arrives it will be queued in SW queue if there is no space in HW queue, otherwise it will be directly put to HW queue. HW queue can contain up to 2 frames at a time, and these frames are transmitted separately in sequential channel accesses.

Voice AC scheduler without MPDU aggregation has several drawbacks:

- It may work well for light load traffics like VoIP, but some applications might use Voice AC for their high load traffic in which case this scheduler severely decreases the performance since it does not use the aggregation mechanism;
- Even VoIP traffic itself can cause significant performance degradation when the network is under saturated condition because of the presence of other high load traffics such as Best Effort or Video.

Unlike AC_VO scheduler, the other scheduler for non-voice ACs employs MPDU aggregation mechanism. A-MPDUs can include up to 32 MPDUs. MPDUs will be queued into SW queue if any one of the following condition is true, otherwise the incoming MPDU will be queued into HW queue directly without aggregation:

- If SW queue has MPDUs, i.e., SW queue length is greater than 0;
- If there are already two frames in HW queue, i.e., HW queue length is equal to 2;
- If incoming MPDU is out of Block ACK Window .

When Block ACK is received for A-MPDU transmission, the failed MPDUs are put to the head of SW queue for earliest retransmissions. Then, A-MPDU will be constructed from

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pending MPDUs in SW queue if there is any. The MPDU must be inside the BAW in order to be aggregated into A-MPDU; if it's not, then MPDU will not be included, aggregation process is stopped here even A-MPDU length did not reach 32 yet, and A-MPDU will be given to HW queue for further transmissions.

This scheduling mechanism also has a number of shortcomings:

- The scheduler always tries to fill the HW queue with frames, thus under light load traffics it usually cannot accumulate enough number of MPDUs to construct A-MPDU, consequently transmits MPDUs individually like in legacy 802.11;
- Even under relatively heavy traffic loads it cannot fully utilize the A-MPDU size, because whenever there will be space in HW queue it immediately constructs A-MPDU with existing small number MPDUs in SW queue;
- It does not enforce any waiting time in SW queue to make an efficient aggregation even for delay insensitive ACs such as Best-Effort and Background. Thus, it can increase a network congestion causing intolerable delays for other real-time ACs like Voice and Video.

D. Other Existing Aggregation Scheduler Schemes in Literature

There are number of other scheduler proposals with 802.11n frame aggregations. For example, [7, 9] proposed a scheduler mechanism that dynamically adapts the aggregated frame size and aggregation mechanism based on different parameters. [8] made similar proposal as in [9] but for multimedia applications; the work proposes some parameters for making the aggregations effectively but the values of the parameters are not defined thus the proposed mechanism is not clear.

Moreover, all above mentioned work have the following common drawbacks:

- None of them considers the BAW mechanism which impacts the aggregated frame size under erroneous channel conditions;
- The proposed scheduler schemes were not evaluated in multi-station environment thus they do not provide performance evaluations for congested network conditions.

III. QoS-Aware MPDU Aggregation Scheduler For IEEE 802.11n Networks

In this section, we propose an efficient QoS-aware MPDU aggregation of IEEE 802.11n WLANs for broadband Internet of Things service provisioning.

A. Adaptive Adjustment of Access Network Delay according to the QoS requirements of realtime voice and video

Realtime voice and video service generally require QoS parameters of less than 150 ms end-to-end delay and less than 50 ms jitter. Since realtime voice and video applications are using RTP (realtime transport protocol) that conveys time stamp, the timing information (including end-to-end delay and jitter) can be measured at the destination station, and feed back to the source station. The measured end-to-end delay includes delays as access network, transit network and destination terminal.

According to the statistics of end-to-end delay and jitter, the source terminal can adjust the access network delay threshold to maximize the MPDU aggregations for realtime voice and video traffic. When the source station and destination are physically close (e.g., same campus network or same city with few hops), the transit network delay will be short, and the allowed access network delay can be longer; as a result, the A-MPDU size for realtime voice traffic can be increased by minimized MAC protocol layer overhead, and throughput can be enhanced. When the A-MPDU size of realtime voice traffic is increased, the number of CSMA/CA accesses to the AP/WLAN is also decreased, and the throughput is enhanced even further.

B. QoS-aware MPDU Aggregation

In this paper, we propose an efficient QoS-aware MPDU aggregation of IEEE 802.11n WLANs for broadband Internet of Things service provisioning. The QoS-aware MPDU aggregation scheduler pushes the earlier arrived MPDUs in the queue to wait for other MPDUs in order to include more MPDUs in A-MPDU consequently increasing the network resource utilization.

TABLE I. ACCESS NETWORK DELAY THRESHOLD VALUES FOR ACS

Access Category	Access network delay threshold (ms)
Voice	50
Video	50
Best effort	500
Background	500

Algorithm 1. Algorithm for access delay calculation and statistics update

```
// ampdu_hw_queued_time: Time when A-MPDU was given to HW queue
// Short inter-frame space period
SIFS = 10us
// Time spent for A-MPDU transmission
ampdu_tx_duration = PLCP_duraton + ampdu_length / phy_rate
// access_delay calculation
access_delay = current_time - block_ack_duration - SIFS -
               ampdu_tx_duration - ampdu_hw_queued_time
access_delay_sum += access_delay
ampdu_count += 1

if (current_time - last_updated_time ≥ 1 sec) then
   // update the average access delay statistics
   if (average_access_delay > 0)
      average_access_delay = (average_access_delay×(100 - EWMA) +
                  access_delay_sum×EWMA / ampdu_count) / 100
   else
      average_access_delay = access_delay_sum / ampdu_count
      access_delay_sum = ampdu_count = 0
      last_updated_time = current_time
   end if
end if
```

Fig. 5 depicts the newly proposed QoS-aware MPDU aggregation scheduler for IEEE 802.11n networks. Unlike reference scheduler included in ath9k driver, in proposed scheduler, any newly arrived MPDU from upper layer will bu queued into SW queue regardless of current status of HW queue. Since earlier arrived MPDUs may suffer a lot due to the time spent for waiting other MPDUs especially in the case of light load traffics, the proposed scheduler introduces number of variables and mechanism to maintain the delay within acceptable thresholds. For this purpose, it defines different *access network delay thresholds* for each Access Category (Table 1). The *access network delay threshold* is a maximum acceptable delay that MPDU may face within WLAN access network.

Since realtime multimedia services (e.g., realtime voice and video) require strict QoS policies from network, we defined *access network delay threshold* of 50ms. Other non-realtime traffics such as best effort (AC_BE) and background (AC_BK) are assigned 500ms *access network delay threshold* value. In the proposed scheduler with AC_VO MPDU aggregation, MPDU are buffered in the SW queue as long as the access network delay for that session (according to access category and the destination address) is allowed.

In order to maintain the access network delay of the earliest arrived MPDU within predefined delay threshold values in Table 1, the QoS-aware MPDU aggregation always needs to find the most appropriate *waiting time* that MPDU can spend in queue SW queue waiting for other MPDUs before A-MPDU construction. Because the number of stations and offered traffic load of the network usually changes over the time scheduler keeps the statistics on *average_access_delay* for each AC; it calculates the *access_delay* of each A-MPDU right after Block ACK reception and accumulates access delay values and *ampdu_count, and* after every second it updates the *average_access_delay* statistics using Exponential weighted moving average (EWMA) level with 25% as shown in Algorithm 1. *Access_delay* can be referred as a time amount that A-MPDU spends in HW queue until the station gets collision-free access to the medium to transmit this A-MPDU.

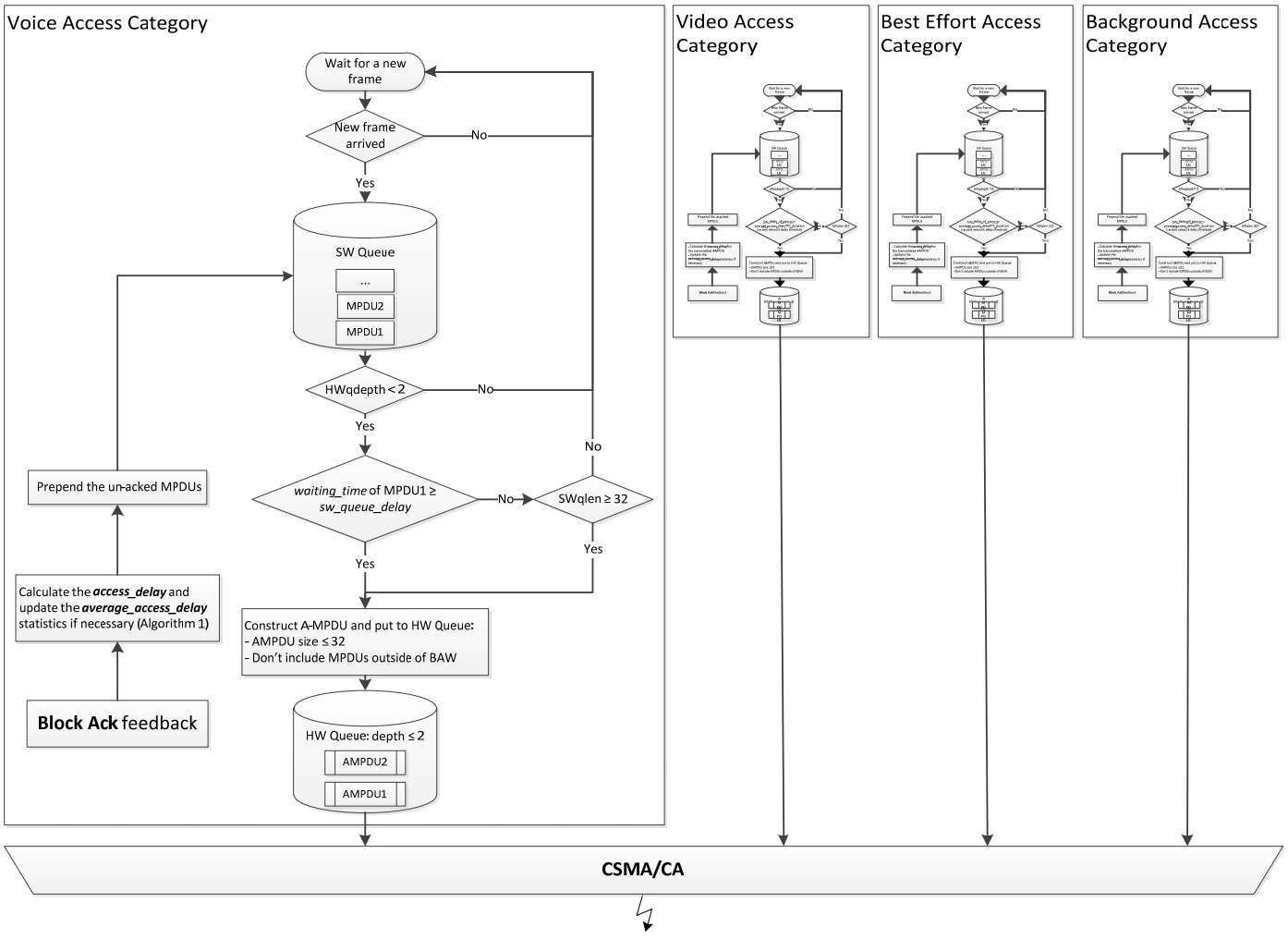

Fig. 5. QoS-aware MPDU aggregation scheduler

Upon arrival of each new frame in SW queue, the scheduler updates *ampdu_tx_duration* variable, that is a transmission duration of A-MPDU that can be formed using the current pending MPDUs in the SW queue. Then it obtains *sw_queue_delay* that head MPDU is allowed to wait in SW queue based on Eq. (1).

$$sw\_queue\_delay = access\_network\_delay\_threshold - average\_access\_delay - ampdu\_tx\_duration \quad (1)$$

The QoS-aware MPDU aggregation scheduler constructs a new A-MPDU and puts it into HW queue for further transmission once the following conditions become true:

i) If the HW queue depth is lower than 2 i.e. it has an enough space to put an A-MPDU;
ii) Either the *waiting_time* of the first MPDU in SW queue reaches *sw_queue_delay* or the number of MPDUs in SW queue reaches 32.

C. Implementation of QoS-aware MPDU Aggregation in Ath9k Driver

During the implementation process of QoS-aware MPDU aggregation, we adopted the fundamental features of the reference aggregation mechanism of ath9k driver in order to make fair performance comparisons during the performance evaluation process. First of all, we made the SW and HW queue features same as in [6]. Also, we fixed the maximum allowed A-MPDU size to be 32 MPDUs.

Moreover, Block ACK window (BAW) was also adopted, since it is an important part of aggregation enabled WLANs. When there is any failed MPDU in the previous transmission, those failed MPDU is re-transmitted immediately.

IV. Performance Evaluations

A. Experimental Test-bed Configuration

Experiments were conducted on TL-WDN4800 wireless cards that use Atheros AR9380 chipsets. This card can operate in both 2.4 and 5 GHz bands and supports up to 3×3 MIMO configuration, 20/40 MHz channel width and SGI/LGI. In the experiments, we used 10 stations and 1 access point (AP). The experiments include two scenarios, one for the analysis of Video traffic impact on overall network throughput and the other is dedicated for the analysis of VoIP traffic impact.

Fig. depicts the test-bed topology. In each scenario, the number of stations was increased from 1 to 10, and throughput, jitter and delay statistics were collected before adding new station. Experiments of the first scenario were done for 150 and 270 Mbps physical layer transmission rates, and each station generated both upstream video (AC_VI) and best effort (AC_BE) traffics.

In the experiments of the second scenario, however, only 270 Mbps physical layer transmission rate was used to clearly compare the impact of voice traffic on the overall throughput at higher physical transmission rate. Each station generated upstream VoIP and best effort traffics. All traffics were generated and measured using Iperf [13].

Traffic generation parameters are shown in TABLE 2. As voice traffic, Iperf was configured to generate 64 Kbps PCM audio stream. Each packet contains 80 bytes realtime audio data that is equivalent to 10ms voice sample. If we consider ADPCM voice, the packet size will be become smaller than the case of 64Kbps PCM, and the throughput performance with existing scheduler will be even worse.

In these experiments, we focused on the overall throughput of IEEE 802.11n WLAN with reasonable congestion status by multiple wireless stations. So, the WLAN physical channel condition was configured to be ideal in all experiments.

TABLE 1. Traffic Generation Tool Parameters

Traffic type	UDP payload size (Bytes)	Offered load (Kbps)
Voice	80	64
Video (H.264)	1470	4000
Best Effort	1470	Buffer is always saturated

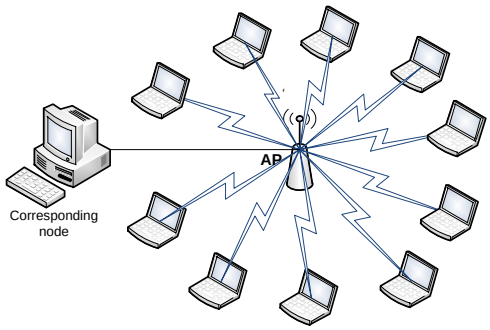

Fig. 6. Test-bed topology

B. Analysis of Video Traffic Impact on Network Throughput

Fig. 7 illustrates the average network throughput that includes both video and best effort traffic of the network. Moreover, the graph gives some understanding about the impact of Video traffic on total network bandwidth at different transmission rates and different congestion levels.

The proposed scheduler outperforms the existing scheduler scheme at both 150 and 270 Mbps transmission rates. It provides significant throughput improvement at both of the transmission rates (Fig. 7). The improvement tends to increase as the number of stations in the BSS (basic service set) increases. Also, when the transmission rate increases from 150 Mbps to 270, the throughput improvement becomes even bigger. This is because, the existing scheduler scheme always tries to transmit any number of MPDUs in its SW queue even sometimes resulting in single MPDU transmission without aggregations, thus it shows very low delay when there are few stations in network. As the number of stations increases, the congestion also increases resulting in high contention with longer access delays consequently increasing the average access network delay and jitter; consequently, the existing scheduler ends up with around 110ms access network video delay (Fig. 8) and 55ms jitter when the number of stations reaches to 10 at 150 Mbps transmission rate (Fig. 9). The

average access network delay and jitter of existing scheme are relatively low in case of 270 Mbps, but it also increases as long as the number of stations increases and becomes higher than the delay of the proposed scheme when there are 10 stations in the network.

Unlike existing scheduler scheme, our proposed scheduler buffers the MPDUs to wait in SW queue for the next MPDUs in order to make efficient aggregations. Moreover, it adjusts the SW queue delay of MPDUs according to the statistics of end-to-end delay and jitter. As a result, it shows almost constant access network delay and jitter. Even though the access network delays of the proposed scheduler are longer than the existing scheduler when the number of stations is less than 6, the delays are limited to be less than 30 ms that guarantees the end-to-end delay constraint of realtime multimedia services.

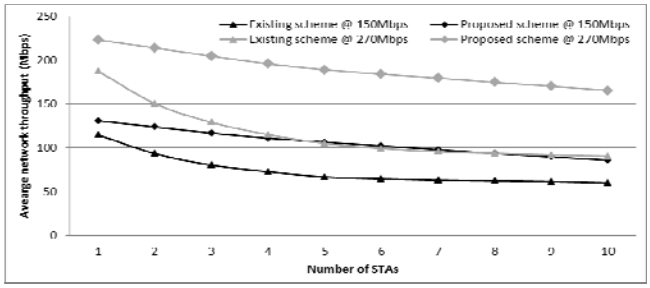

Fig. 7. Average network throughput comparison at 150 and 270 Mbps PHY rates

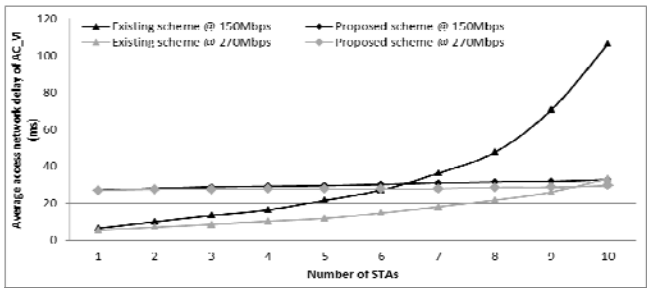

Fig. 8. Average access network delay comparison of AC_VI at 150 and 270 Mbps PHY rates

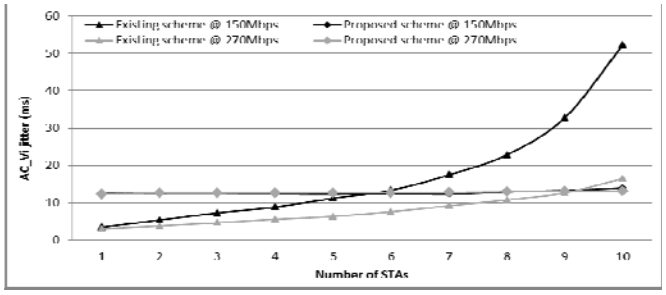

Fig. 9. Jitter comparison of AC_VI at 150 and 270 Mbps PHY rates

C. *Analysis of the Impact of Voice Traffic on Throughput*

Although VoIP traffic is very small, it can have a significant impact on the overall network throughput. Especially when the network is saturated with some lower priority traffics such as Best Effort. We can find out from Fig. 10, throughput gap between the existing and the proposed schedulers tends to increase as the number of stations increases in the network. This is mainly because the existing scheduler does not aggregate the AC_VO MPDUs instead transmits them individually as in a legacy 802.11. When there is single station in the network there will be one VoIP frame transmission in each 10 ms, because inter-arrival time of VoIP frames is 10 ms in our example. But when the number of stations increases up to 10, there will be one VoIP frame transmission in every 1ms. Total required time for one VoIP frame transmission excluding medium access delay is around 118 us and 114 us at 150 Mbps and 270 Mbps transmission rates, respectively. This means 80 bytes length VoIP traffic with frame inter-arrival time of 10ms utilizes around 12 % of medium when there are 10 stations in the network even we exclude the collisions and errors.

Because Voice AC has 50ms access network delay threshold in our proposed scheduler, it can aggregate up to 5 VoIP MPDUs, consequently decreasing the network medium accupation period of VoIP traffics by the factor of 5. Since earlier arrived MPDUs needs to wait in SW queue for the next MPDUs, the average access network delay (Fig. 11) and jitter (Fig. 12) are greater than in existing scheduler case, but they are within acceptable delay thresholds.

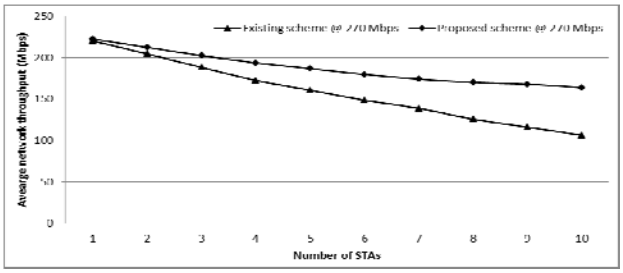

Fig. 10. Average throughput comparison at 270 Mbps PHY rate

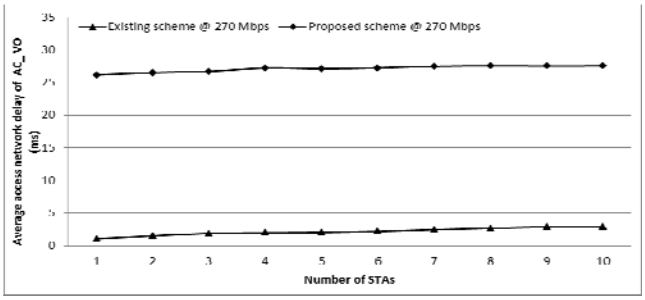

Fig. 11. Average access network delay comparison of AC_VO at 270 Mbps PHY rate

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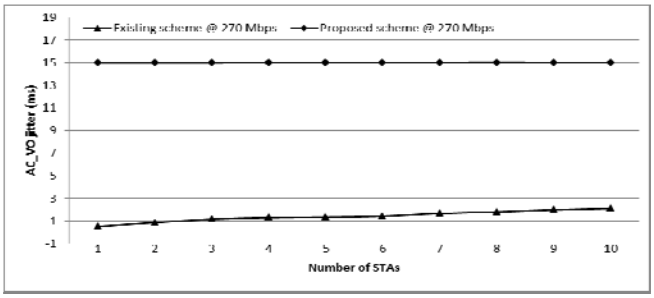

Fig. 12. Jitter comparison of AC_VO at 270 Mbps PHY rate

V. CONCLUSION

In this paper, we proposed an efficient QoS-aware MPDU aggregation of IEEE 802.11n WLANs for realtime VoIP service provisioning. The QoS-aware MPDU aggregation is applied to realtime voice traffic with controlled total buffering delay time for MPDU aggregation; different buffering delay thresholds are configured individually to different access category (up to 50ms for realtime voice traffic and video traffic) and destination address. It adapts the A-MPDU size based on the measured end-to-end delay and jitter. It predefines the buffering delay thresholds and access delay statistics which are periodically updated for each AC and each destination IP address. As QoS requirements of realtime VoIP services, the end-to-end delay is limited to be less than 150 ms while jitter is limited to be less than 50 ms.

The proposed QoS-aware MPDU aggregation architecture has been tested with a series of experiments on a test bed with 10 IEEE 802.11n mobile stations and an AP. Each mobile station is configured to generate 64Kbps PCM voice traffic, and each voice MPDU contains voice data of 10 ms duration. The actual throughputs have been measured for 1 ~ 10 WLAN stations with 150 Mbps and 270 Mbps physical layer transmission rate. The throughputs with and without the MPDU aggregation of voice traffic were compared at different number of WLAN stations.

Experimental results show the proposed QoS-aware MPDU aggregation scheme enhances the overall throughput of IEEE 802.11n WLAN by 60% at 10 stations with 270Mbps physical layer transmission rate, compared to the existing scheme, while the QoS requirements (i.e., less than 150ms of end-to-end delay and less than 50ms of jitter) of realtime voice traffic is guaranteed. The major contribution of this paper is QoS-aware MPDU aggregation for voice traffic that adaptively adjust A-MPDU size to minimize contention level in CSMA/CA-based WLAN and to maximize the throughput based on the statistics of end-to-end delay and jitter.

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A Novel Method for Partial Rub Detection Based on Cumulation of Liftered Full Spectrum

Jan Jakl, Jindrich Liska

***Abstract*—**Contemporary trend in design of turbomachinery leads to increase of efficiency through reducing the seal clearances. Tight rotor-to-seal clearance may lead to undesirable contact between rotating and stationary part of the machine, called simply rubbing or rub. The methods, standardly used for rub detection, are mainly based on observation of bending rotor, which is very common symptom of rotor rubbing with a part of stator. One way to detect bending rotor is monitoring of phasor of first harmonics (1X) signal component. Other symptoms of partial rub are subsynchronous spectral components, which arises from rotor periodic motion during rub. In this paper, the method of cumulative full spectrum, based on cepstral liftering and subsequent cumulation of full spectrum is introduced. This method is suitable for offline and also online detection of partial rub.

***Keywords*—**Rotor-stator rub, full spectrum, cepstral liftering, characteristic values.

I. Introduction

TENDENCY of steam turbine designers and developers leads to increasing of machine efficiency. Standardly used way is tightening clearances between rotor and stator seals. This trend is in opposite direction to another important property of turbine, which is reliability. Reduced seal clearance increases risk of contact between rotating and stationary parts of machine. Rubbing arises, when overall rotor vibrations exceed allowable clearance, and involves several physical phenomena, e.g. impacts, friction, system natural frequency modification due to physical coupling etc. This problematic is very well described in [1].

At present, the rub diagnostics is based on offline analysis of measured vibrational data. During machine operation, mainly overall rotor vibrations and phasor of the 1X component are traced. Linear system theory gives simplified but sometimes sufficient description of rotor dynamic properties. The output of linear system excited by harmonic input signal with frequency ω, which is in case of rotating shaft the unbalance force, is also harmonic with the same frequency. For constant values of frequency ω are amplitude and initial phase of vibrational signal also constant. Changes of 1X amplitude and phase during constant shaft rotational frequency indicate bend shaft due to nonhomogeneous thermal field around rotor when rub occurs [2]. This is indirect method for detection of rub, because not only rub causes rotor bending.

Several authors proposed methods for rub detection, [3]-[5]. These methods are mainly based on time-frequency signal analysis. Methods of time-frequency signal processing allow description of changes in signal frequency content. The signals used for methods testing are commonly acquired by numerical simulations of rotor/stator contact model, as in [3], or by experiments on laboratory rotor stand [7]. Methods of rub detection are normally based on relative rotor or absolute stator vibration analysis. Methods using signals of acoustic emission were also proposed, e.g. in [8].

A special type of rub is the periodical partial rub, when rotor comes into contact with stator n times per m turns. Common symptoms of the partial rub are subsynchronous frequencies in signal spectrum, and their multiples. Frequency of these components matches the impact frequency of rotor/stator contacts. In [9] and [10], a new method for periodic partial rub detection based on scaling and cumulation of full spectrum was already described. In this paper, we introduce a new addition of this method based on computation of spectral envelope and suppression of nonsynchronous signal components by cepstral liftering technique.

II. Rotor/Stator Rub

A. Types of rotor/stator rub

Types of the rub can be categorized according to several criterions [1]. One option is to divide types of rubbing according to contact time duration and relevant rotor precession (see Fig. 1). During the partial rub, the contact occurs only for a short part of rotor turn. This motion can be generally periodic, nonperiodic or chaotic [11]. For periodic motion case, the new spectral components correspond to the frequency of contacts considering the machine speed. If the contact occurred n times per m revolutions, a component with frequency n/mX arises. The rotor motion during rub is generally not harmonic function, so there will be also multiplies of these frequencies. Typically rotor orbits on these frequencies are elliptical and their both precession components

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J. Jakl is with the University of West Bohemia, NTIS - European Centre of Excellence, Pilsen, 30614 Czech Republic (e-mail: jjakl@kky.zcu.cz).

J. Liska is with the University of West Bohemia, NTIS - European Centre of Excellence, Pilsen, Univerzitni 22, 30614 Czech Republic (phone: +042-377632521; fax: +420-377632502; e-mail: jinliska@ kky.zcu.cz).

are positive, unlikely to oil whirl instability, which manifests itself only with forward precession. If contact occurs periodically one or more times per revolution, no subsynchronous frequencies appear in the frequency spectrum.

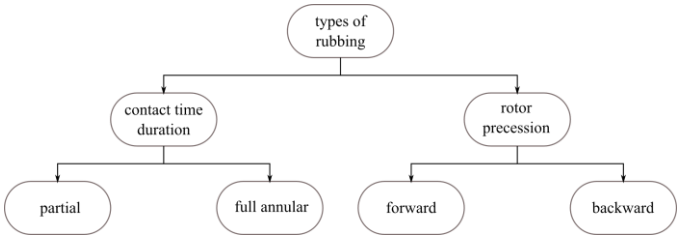

Fig. 1 Type of rubbing

On the other hand, if the rotor is in permanent contact with stator part, this type is called full annular rub. Conditions for originating of this type of rub depend on friction between rotor and stator part, rotor unbalance and damping. Full annular rub with forward precession, also called dry whirl causes increase of 1X vibration level. Very dangerous for machine health and reliability is full annular rub with backward precession, called dry whip. During dry whip, the rotor whirling frequency is different from rotational frequency and rotor whirls with new natural frequency given by increased stiffness of coupled rotor and stator. Origination of full annular rub with backward precession may lead to turbine catastrophic failure [12].

B. Equations of motion

In very simplified case, the rotor can be described by two linear differential equations (as in [13])

$$\begin{aligned} m\ddot{x}(t)+b_x\dot{x}(t)+k_x x(t) &= m_u r\omega^2\cos(\omega t+\beta),\\ m\ddot{y}(t)+b_y\dot{y}(t)+k_y y(t) &= m_u r\omega^2\sin(\omega t+\beta)-F_g, \end{aligned} \tag{1}$$

where $x(t)$ and $y(t)$ denotes rotor vibrations in horizontal and vertical direction, m is rotor mass, b_x and b_y are horizontal and vertical damping coefficients, k_x and k_y are horizontal and vertical stiffnesses, m_u is mass unbalance, r is unbalance radius, ω is angular rotational frequency of shaft, β is angle of unbalance vector with respect to initial time t_0 and F_g is the gravity force.

In the case of rub, normal force F_n and tangential force F_t start to act on the rotor, see Fig. 2. Rub arises when overall vibrations exceed allowable clearance given by difference of stator and rotor radii R_s-R_r. If we assume normal force according to Hertzian contact theory and Coulomb frictional force, we can write these forces in form:

$$\begin{aligned} F_n &= \begin{cases} 0, & A<\delta,\\ (A-\delta)^n k_s, & A\geq\delta, \end{cases}\\ F_t &= \mu F_n, \end{aligned} \tag{2}$$

where A denotes rotor overall vibrations, δ is clearance, k_s is stator stiffness and μ is coefficient of friction. Exponent n is often set to 1, but according to Hertzian contact theory for contact between two bodies with curved surfaces should be set to 3/2. Contact theory is described e.g. in [14].

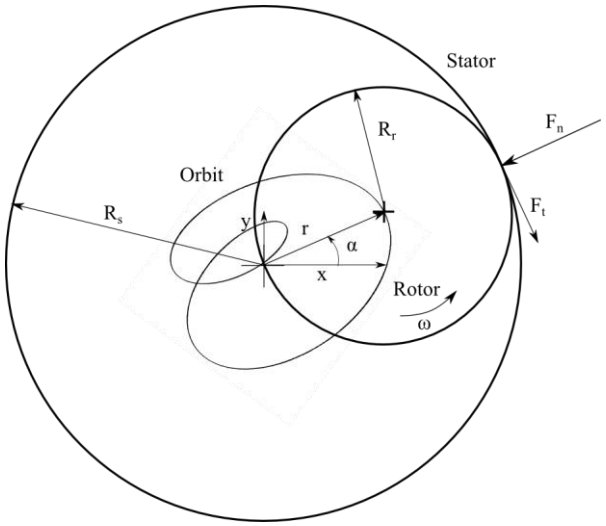

Fig. 2 Rotor/stator rub

Equations of motion can thus be written in following form:

$$\begin{aligned} m\ddot{x}(t)+b_x\dot{x}(t)+k_x x(t) &= m_u r\omega^2\cos(\omega t+\beta)+F_x,\\ m\ddot{y}(t)+b_y\dot{y}(t)+k_y y(t) &= m_u r\omega^2\sin(\omega t+\beta)+F_y-F_g. \end{aligned} \tag{3}$$

F_x and F_y are resultant forces in horizontal and vertical directions. These forces can be expressed as

$$\begin{aligned} F_x &= -\left(1-\frac{\delta}{A}\right)^{3/2}\frac{k_s}{A}\left(x-\mu\cdot sign(v_{rel})y\right),\\ F_y &= -\left(1-\frac{\delta}{A}\right)^{3/2}\frac{k_s}{A}\left(\mu\cdot sign(v_{rel})x+y\right). \end{aligned} \tag{4}$$

Relative speed v_{rel} is given by

$$v_{rel}=\omega R_r+\omega_w A, \tag{5}$$

where ω_w is whirling frequency of the shaft. System described by (3) is clearly nonlinear.

III. Signal Processing Methods

Changes in rotor vibrations due to rub in measured signal are badly detectable in time waveforms and relate with changes of signal frequency content. In this chapter, several methods used in further will be briefly described.

A. Short-time Fourier transform

Response of system (3) cannot be analyzed by standard Fourier transform, because such signal is not periodic and stationary. Such signals should be transformed into joint time-frequency domain. Very popular and usually used method is

short-time Fourier transform (STFT) [15] described by following expression

$$X(t,f)=\int_{-\infty}^{\infty} x(\tau)h(\tau-t)e^{-j2\pi f\tau}d\tau, \quad (6)$$

where *x(t)* is analyzed signal and *h(t)* is window function. Function *X(t,f)* is complex function and one can define amplitude and phase spectrograms

$$|X(t,f)|=\sqrt{\mathrm{Re}^2[X(t,f)]+\mathrm{Im}^2[X(t,f)]}, \quad (7)$$

$$\Phi(t,f)=\mathrm{arctg}\left\{\frac{\mathrm{Im}[X(t,f)]}{\mathrm{Re}[X(t,f)]}\right\}, \quad (8)$$

where *Re[Z]* and *Im[Z]* denotes real and imaginary part of complex number *Z*.

Decrease of signal energy due to window weighting must be compensated to obtain correct signal amplitudes by energy of window function. Let's define compensated amplitude spectrum

$$A(t,f)=\frac{|X(t,f)|}{\int_{-\infty}^{\infty} h(\tau)d\tau}. \quad (9)$$

Resolution of STFT in time-frequency domain depends on spectral properties of window function. Equation (6) represents Fourier transform of product of two functions in time domain. Using basic properties of Fourier transform, we can rewrite (6) into form

$$X(t,f)=X(f)*H(f)e^{-j2\pi ft}. \quad (10)$$

X(f) and *H(f)* denote Fourier transforms of functions *x(t)* and *h(t)*. From (10) it's clear that for given time instant *t*, the STFT is convolution of *X(f)* and product of *H(f)* and complex exponential function with frequency *f*.

Restrictions of STFT time-frequency resolution are given by Heisenberg-Gabor uncertainty principle [15].

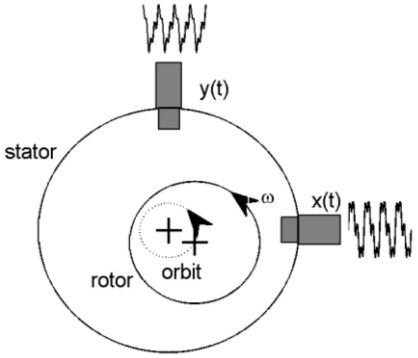

Fig. 3: Sensors in XY configuration

B. Full spectrum

Relative rotor vibrations are generally measured by two sensors, installed in XY configuration, i.e. under angle of 90°, see Fig. 3. In such case, rotor vibrations can be analyzed in terms of orbit.

For proper monitoring of steam turbine, the informations about rotor precession on dominant frequency components are important. Assume complex signal *z(t)* with real and imaginary parts represented by measured signals

$$z(t)=x(t)+jy(t). \quad (11)$$

Further assume, that signals *x(t)* and *y(t)* are monocomponent, i.e. contain only one harmonic component with frequency *f*. Trajectory of signal *z(t)* in complex plane has generally elliptical shape and such orbit can be decomposed into sum of two vectors, with constant amplitude and the opposite frequencies, see Fig. 4. It means that first vector is rotating clockwise (CW) and the second vector is rotating counterclockwise (CCW). Further assume CCW rotor rotation. Orbit is described by:

$$z(t)=A_x\sin(2\pi ft+\varphi_x)+jA_y\sin(2\pi ft+\varphi_y), \quad (12)$$

or

$$z(t)=A_f e^{j(2\pi ft+\varphi_f)}+A_b e^{-j(2\pi ft+\varphi_b)}, \quad (13)$$

where A_f, or φ_f belong to vector with forward precession, i.e. rotating in the same direction as rotor (in our case its CCW rotation) and A_b, or φ_b belongs to vector with backward precession. Unknown parameters may be described by following relations (similar relations can be found in [16])

$$A_f=\frac{1}{2}\sqrt{A_x^2+A_y^2+2A_xA_y\sin(\varphi_x-\varphi_y)}, \quad (14)$$

$$A_b=\frac{1}{2}\sqrt{A_x^2+A_y^2-2A_xA_y\sin(\varphi_x-\varphi_y)}, \quad (15)$$

$$\varphi_f=\tan^{-1}\left(\frac{A_y\sin\varphi_y-A_x\cos\varphi_x}{A_y\cos\varphi_y+A_x\sin\varphi_x}\right), \quad (16)$$

$$\varphi_b=\tan^{-1}\left(-\frac{A_y\sin\varphi_y+A_x\cos\varphi_x}{A_x\sin\varphi_x-A_y\cos\varphi_y}\right). \quad (17)$$

Previous relationships can be generalized for signals contained by more spectral components, this leads to so called full spectrum, or in short-time version to full spectrogram. Unlikely to standard spectrum calculated from single real signal, full spectrum are always two sided, it means they are displayed for both positive and negative frequencies. Amplitudes on positive frequencies correspond to magnitudes of vectors with forward precession and amplitudes with

negative frequencies correspond to magnitudes of vectors with backward precession.

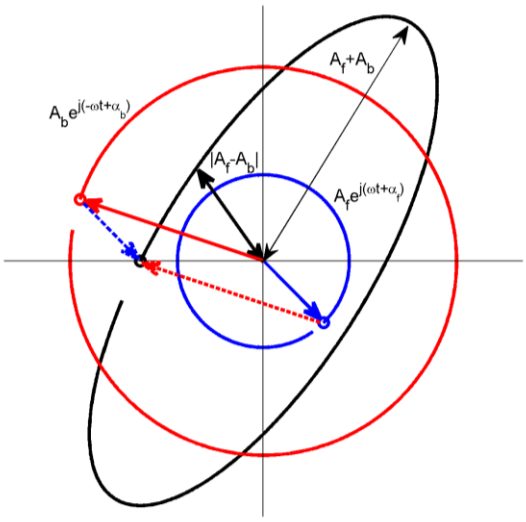

Fig. 4 Principle of full spectrum

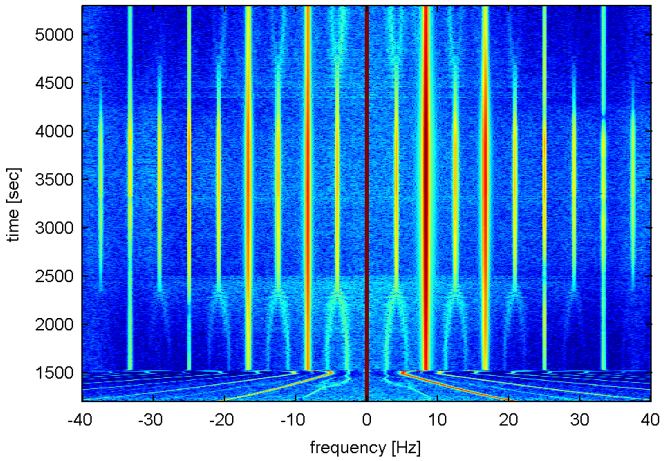

Fig. 5 Full spectrogram with rub symptoms

Example of full spectrogram calculated from measured signals on 80 MW steam turbine in 2009 during rundown and subsequent regime with constant rotational frequency is shown on Fig. 5. Nonzero frequency component with highest amplitude (red color) corresponds with rotational frequency 1X and we can also see higher multiplies of 1X with both forward and backward precession. Moreover, the spectrum contains also subsynchronous frequencies and their higher multiples. These components are typical symptoms of partial rub.

C. *Cepstrum*

Cepstrum, or cepstral analysis, is special type of signal frequency analysis. Cepstrum is defined as inverse Fourier transform of a nonlinear function, generally natural logarithm, of amplitude spectrum. Real cepstrum is defined by following relation

$$c(t) = F^{-1}\left\{\log\left[\left|X(f)\right|\right]\right\}. \tag{18}$$

In literature, the definitions of other types of cepstrum, e.g. complex ceptrum or differential cepstrum [17], can be found. If analyzed signal is real function, its amplitude spectrum is odd function and inverse Fourier transform in (18) can be replaced by direct Fourier transform. Thus the cepstrum can reveal periodic repetitions in log amplitude spectrum.

Domain of cepstrum is quefrency. Operations in frequency and quefrency domain are analogous. If we want to modify frequency content of signal, we transform into frequency domain, modify signal spectrum by suitable weighting function and transform back to time domain. Analogously we can process also signal log spectrum by modifying cepstrum by some window function. This process is generally called liftering, or liftering in cepstral domain. Window functions are called lifters [18]. Liftered log amplitude spectrum is given by Fourier transform of weighted cepstrum, thus:

$$\ln\left(\left|X_l(f)\right|\right) = F\left(c_w(t)\right), \tag{19}$$

where $c_w(t)$ denotes weighted cepstrum. Previous relation can be rewritten into form

$$\ln\left(\left|X_l(f)\right|\right) = \ln\left(\left|X(f)\right|\right) * F\left(w(t)\right), \tag{20}$$

where process of filtration is very clear.

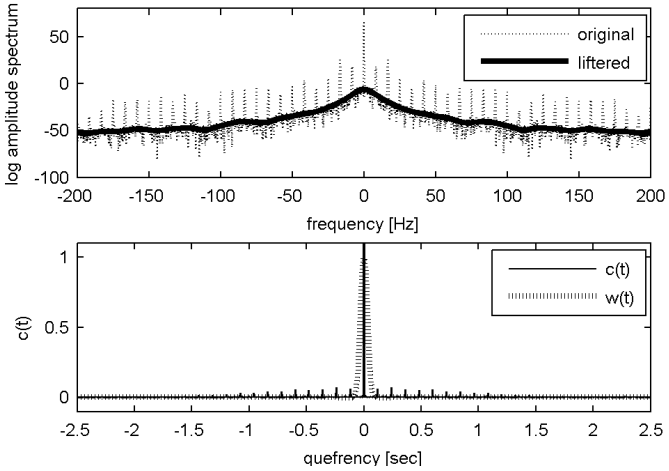

Fig. 6 Spectral liftering

Analogously as in time domain filtration, one can distinguish several types of lifters: low quefrency (short-time) lifter – suppressing slow changes of log spectrum, high quefrency (long-time) lifter – suppressing fast changes of log spectrum, bandpass or bandstop quefrency lifter or their combination. In this paper, two types of lifters will be used. The first lifter is low quefrency lifter used for estimation of spectral envelope and the second consists of set of bandpass lifters. The example of spectral envelope calculation is in Fig. 6. The original log amplitude spectrum (dotted) of analyzed signal and its liftered form (solid) are shown in upper part of figure. We can see, that

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slow changes are described well by the liftered spectrum. In bottom part, the real cepstrum (solid) and Gaussian window function (dotted) are shown.

IV. Cumulative full spectrum

As we can see, typical symptoms of periodical partial rub are subsynchronous frequencies. Such frequencies are also accompanied by their higher multiplies as is depicted on Fig. 5. The new method for partial rub detection is based on averaging of full spectrum in frequency domain, so that information about subsynchronous components is transformed from wide range of frequencies into one frequency interval.

A. Cumulation of full spectrum

Cumulative full spectrogram is defined by

$$A_{cf}(t, f_n) = \frac{1}{N_c} \sum_{k=0}^{N_c-1} A_f\left(t, \left(f_n + sign(f_n)k\right) f_{rot}\right), \quad f_n \in (-1,1). \tag{21}$$

In (21) $A_f(t,f)$ denotes full spectrogram, f_{rot} is rotational frequency and N_c denotes number of full spectrum intervals used for averaging. Principle of full spectrum cumulation is shown in Fig. 7. There is a plotted full spectrum for time instant 2700 sec from spectrogram shown in Fig. 5. Multiples of rotational frequency are plotted by dashed vertical lines.

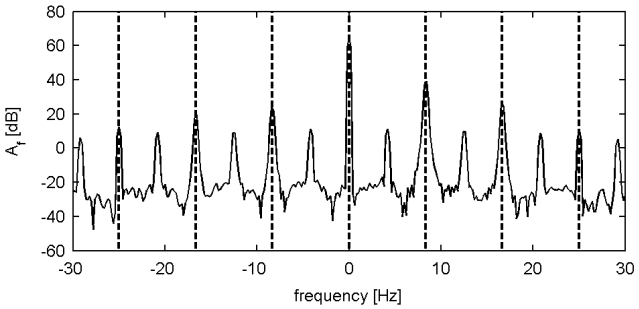

Fig. 7 Cutting of full spectrum according to rotational frequency

The result of cumulation for the whole spectrogram from Fig. 5 is shown in Fig. 8. Information about subsynchrounous frequencies is clearly transferred from wide frequency range into simple interval. Upon this result, one can design a suitable method for automated rub detection. Unfortunately the situation is not always such ideal as in this case. There are two main drawbacks when full spectrum is only cumulated. The first problem is depicted in Fig. 9. The full spectrum was calculated from signals measured during the same event as signals from spectrogram in Fig. 5, but on different bearing pedestal. Subsynchronous frequencies in frequency range from -20 to 20 Hz are masked by low frequency noise. Amplitudes of subsynchrounous component in frequencies above 20 Hz are comparable with amplitudes of noise and averaging of full spectrum in frequency domain will not lead to desired result.

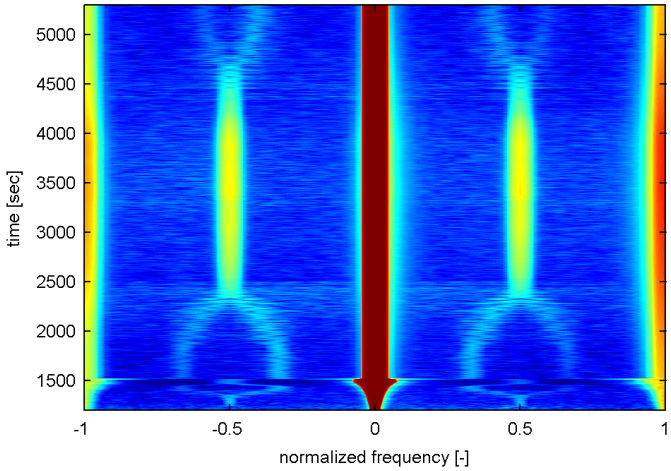

Fig. 8 Cumulative full spectrogram

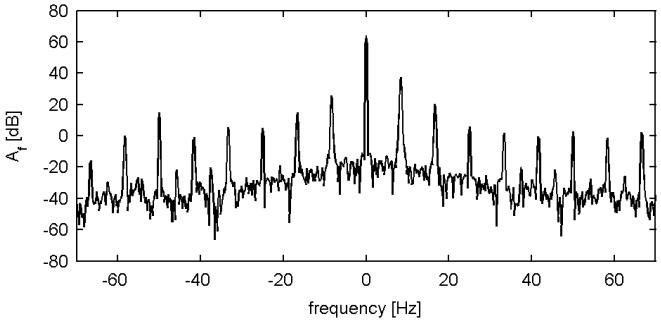

Fig. 8 Full spectrum with low frequency noise

Another drawback is in presence of parasitic spectral components which look like subsynchronous components after the cumulation of full spectrum. Example of spectrum with such components is plotted in Fig. 10. Full spectrum was calculated from signals measured on 220 MW steam turbine during turning gear operation. Rotational frequency was 0.775 Hz. In addition to rotational frequency and higher harmonics, we can also observe frequency 0.575 Hz and its multiples. Such parasitic frequencies perfectly match subsynchrounous 1/4X, 1/2X, and 3/4X after cumulation of full spectrum and can cause false alarm in automated rub detection.

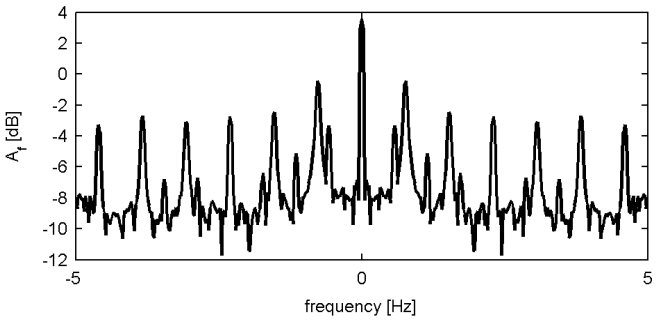

Fig. 9 Full spectrum with parasitic components

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In next sections a solution of both problems of separate cumulation of full spectrum using cepstral liftering will be described.

B. Scaling of full spectrum

Low frequency noise of full spectrum, masking subsychronous frequencies, is equivalent to slow changes in spectrum and can be estimated by spectral envelope. Liftered log amplitude spectrum is given by inverse Fourier transform of cepstrum weighted by cepstral lifter. In this work the Gaussian function was used as prototype of lifter. Lifter is thus

$$w(t) = e^{-\frac{4t^2 f_{rot}^2}{25}}. \tag{22}$$

Lifter given by (22) can be used universally for various values of rotational frequencies. Full spectrum with suppressed background noise is described by

$$\ln\left(A_{nfc}(f)\right) = \ln\left(A_f(f)\right) - \ln\left(A_{fl}(f)\right), \tag{23}$$

where $A_{fl}(f)$ is liftered full spectrum (spectral envelope). Scaled full spectrum from Fig. 9 is depicted on next figure. Original full spectrum is plotted by dotted line. Amplitudes on subsynchronous frequencies exceed amplitudes of noise and cumulation can be performed.

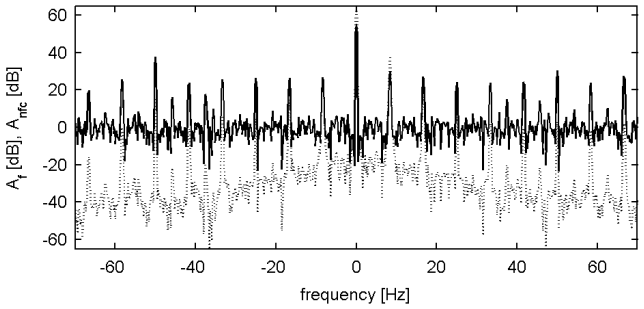

Fig. 10 Full spectrum with suppressed background noise

Equation (23) can be further rearranged into the form

$$\ln\left(A_{nfc}(f)\right) = F\left\{c(t)\left(1 - w(t)\right)\right\}. \tag{24}$$

In previous equation $c(t)$ denotes cepstrum of full spectrum. We can see that full spectrum with suppressed background noise can be computed directly with slightly modified lifter.

C. Filtering of nonsynchrounous spectral components

The ideal full spectrum used for cumulation should contain only frequencies related to rotational frequency. Nonsynchrounous frequencies can lead to false detection of subsychronous frequencies as illustrated in Fig. 9. For the purpose of filtration nonsynchronous frequencies, another cepstral lifter was designed. Assume following lifter

$$w(t) = \sum_{k=-K}^{K} e^{-\frac{(t - k/f_{rot})^2}{25}}, \tag{25}$$

where K control the number of partial lifters formally same as in (22). Lifter (25) keep cepstral coefficients only on quefrencies related to rotational speed. Using (20) the liftered full spectrum can be expressed by

$$\ln\left(A_{lf}(f)\right) = \ln\left(A_f(f)\right) * F\left\{w(\tau)\right\}. \tag{26}$$

Now we derive Fourier transform of lifter given by (25) using basic properties of Fourier transform. Using linearity of Fourier transform we can write

$$F\left\{w_l(t)\right\} = \sum_{k=-K}^{K} \int_{-\infty}^{\infty} e^{-\frac{(t - k/f_{rot})^2}{25}} e^{-j2\pi ft} dt. \tag{27}$$

Thus

$$F\left\{w_l(t)\right\} = 5\sqrt{\pi} e^{-25\pi^2 f^2} \sum_{k=-K}^{K} e^{-j2\pi fk/f_{rot}}. \tag{28}$$

Limiting $K \to \infty$ we obtain

$$F\left\{w_l(\tau)\right\} = 5\sqrt{\pi} e^{-25\pi^2 f^2} \sum_{k=-\infty}^{\infty} \delta\left(f + kf_{rot}\right). \tag{29}$$

The filtered full spectrum according to (26) can be further expressed in the form

$$\ln\left(A_{lf}(f)\right) = 5\sqrt{\pi} e^{-25\pi^2 f^2} \left[\ln\left(A_f(f)\right) * \sum_{k=-\infty}^{\infty} \delta\left(f + kf_{rot}\right) \right], \tag{30}$$

and thus

$$\ln\left(A_{lf}(f)\right) = 5\sqrt{\pi} e^{-25\pi^2 f^2} \sum_{k=-\infty}^{\infty} \ln\left(A_f\left(f + kf_{rot}\right)\right). \tag{31}$$

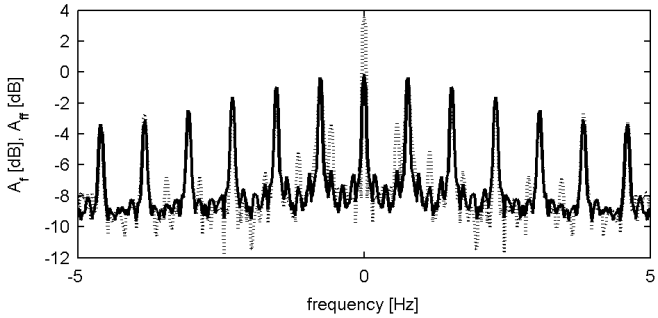

Fig. 11 Liftered full spectrum with filtered nonsynchronous frequencies

Weighting of cepstrum by combination of shifted Gaussian function is equivalent to averaging of log full spectrum in frequency domain weighted by another Gaussian function. The case of finite K is just approximation of this averaging, but derivation of relationship (31) helps to understand this procedure.
Steps of full spectrum scaling and liftration can be combined into one procedure applying cepstral lifter described by

$$w(t)=\left(1-e^{-\frac{4t^2 f_{rot}^2}{25}}\right)\cdot\sum_{k=-K}^{K}e^{-\frac{(tf_{rot}-k)^2}{25}}, \tag{32}$$

leading to calculation of liftered (scaled and filtered) full spectrum suitable for cumulation.

D. Characteristic values

Cumulative full spectrum are suitable for offline detection of partial rub. For online, or automated, detection a method based on evaluation of so called characteristic values was developed. Calculation of characteristic values is based on comparison of amplitude of cumulative full spectrum at given subsynchronous frequency and amplitudes on frequencies surrounding this subsynchrounous frequency. Similar principle is used by skilled user for rub detection. Characteristic value for frequency f is defined by

$$\tilde{\xi}_{fX}^{\pm}(t)=\sum_{l=1}^{1/f-1}\frac{A_{nfc}(t,l\cdot f)}{\frac{1}{N_f}\sum_{k=l\cdot f-N_f/2}^{l\cdot f+N_f/2}A_{nfc}(t,k)}, \tag{33}$$

where A_{nfc} is short time scaled filtered cumulative full spectrum, N_f defines number of frequencies in surrounding of frequency f. There are always two characteristic values for given frequency f, the first for positive frequencies and second for negative frequencies of cumulative full spectrum. Resulting characteristic value is defined as average value of both characteristic values

$$\tilde{\xi}_{fX}(t)=\frac{\tilde{\xi}_{fX}^{-}(t)+\tilde{\xi}_{fX}^{+}(t)}{2}. \tag{34}$$

It turned out that for automated rub detection it is suitable to approximate characteristic value by its mean value. Because of nonstationary of characteristic value, the recursive algorithms should be used. In this work the recursive least mean square method with exponential forgetting was used. We can write estimation of mean value as

$$\xi_{fX}(t)=(1-\lambda)\tilde{\xi}_{fX}(t)+\lambda\xi_{fX}(t-1), \tag{35}$$

where λ denotes forgetting factor.
Behavior of characteristic values $\xi_{1/2X}(t)$ and $\xi_{1/3X}(t)$ calculated from full spectrogram in Fig. 5 are shown in Fig. 13 and Fig. 14.

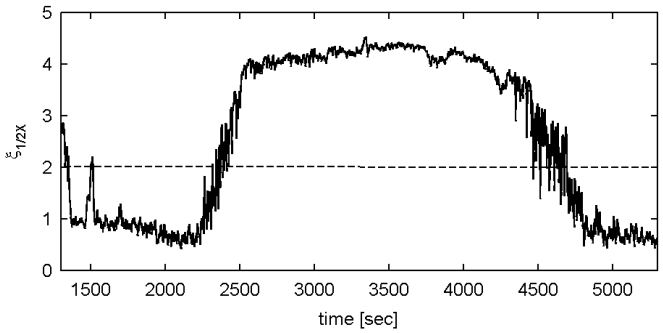

Fig. 12 Characteristic value 1/2X

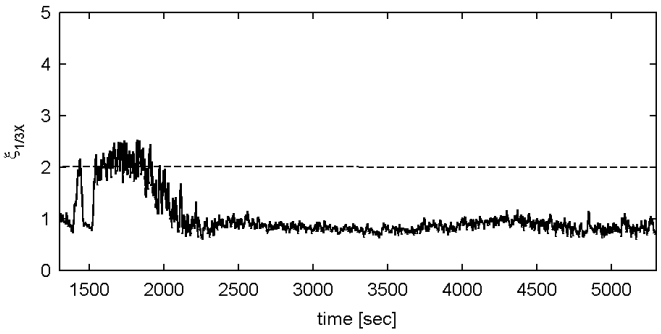

Fig. 13 Characteristic value 1/3X

It is obvious that characteristic values are suitable for detection of subsynchronous frequencies in full spectrum, which are symptoms of periodic partial rub. Thresholds are also marked in figures, which may be used for automatic rub detection.

V. Conclusion

Contact between rotating and stationary part of steam turbine is unwelcome but not rare event. Early detection of this phenomenon is critical for machine health and integrity and prevent serious malfunction. One of the types of partial rub occurs periodically and one of its symptoms is occurence of subsynchronous frequencies in vibrational signal amplitude spectrum. For offline and online partial rub detection a new method based on cumulation, equivalently averaging in frequency domain, of full spectrum and cepstral liftering was developed. Cepstral liftering is used for suppression of low spectral noise and filtration of nonsynchronous frequencies. Based on this method a calculation of characteristic values was also proposed. Those values could be used for automatic rub detection in monitoring systems. This method is based mainly on data measured on steam turbines during rub and this makes this method powerful tool for rub detection. Method of cumulative full spectrum and calculation of characteristic values were also tested on experimental rotor stand RK4. Proposed methods were implemented into diagnostic system RAMS (Rub Advanced Monitoring System) developed on Department of Cybernetics at University of West Bohemia in Pilsen. This diagnostic system is used for rub monitoring on two steam turbines of 220 MW and 270 MW in Czech Republic.

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The impact of the PiP EPG method for the processing time of IPTV channel change requests and QoE

R. Bruzgiene, L. Narbutaite and T. Adomkus

***Abstract*—**The broadcast of the digital Internet Protocol Television channels is an exclusive due to the each user behaviour in the search of the desired television program. The different methods for the channel searching and selection affect the channel change process and its duration, called the channel zapping time. This impact depends on the quantity of requests for the channel change and its processing time in the network. So, the authors proposed a method that modifies the process of the channel change in order to reduce the processing time of the requests and increase the user's perceived quality assessment for Internet Protocol Television service.

***Keywords*—**Channel change, EPG, IPTV, Picture in Picture.

I. Introduction

THE IPTV (Internet Protocol Television) service providers are looking for the newer ways to attract the users and retain them due to the increasing offers of TV (Television) services and the expansion of the number of new competitors. According to the users, there is a need for an easily used electronic program guide (EPG), the fast change process of IPTV channel, the functionality during TV program selection and so on. All these needs influence the attractiveness of IPTV service in respect of QoS (Quality of Service) and QoE (Quality of Experience) parameters. TV channel zapping time is the most important criteria influencing the subjective IPTV QoE evaluation [1], because the user's visual perception of IPTV quality based on the evaluation of TV channel change process. It was determined that the biggest impact on the user's visual perception has a black screen on TV tuner during the channel change process [2]. It means that, the longer the user does not see the selected channel, the more negative attitude formed on IPTV quality. A longer channel zapping time not only negatively affects the user of the service, but also increases the problems in the delivery process. A longer channel change process affects the parameters of the service quality: higher network delay, the loss of IP (Internet Protocol) packets, wrong IP packets, etc.

The scientific research showed that IPTV service becomes unacceptable if the channel zapping time is longer that defined by ITU – T G.1030 [3]. According to this recommendation the channel zapping time should not exceed 2 seconds. Shorter than 500 ms channel zapping interval is perceived as instantaneous and the user doesn't perceive adversely effect of the change process. If the channel zapping time takes longer than 2 seconds, the user may become frustrated.

IPTV channel zapping time affects the relationship between IPTV service quality and service quality perception level (Fig. 1).

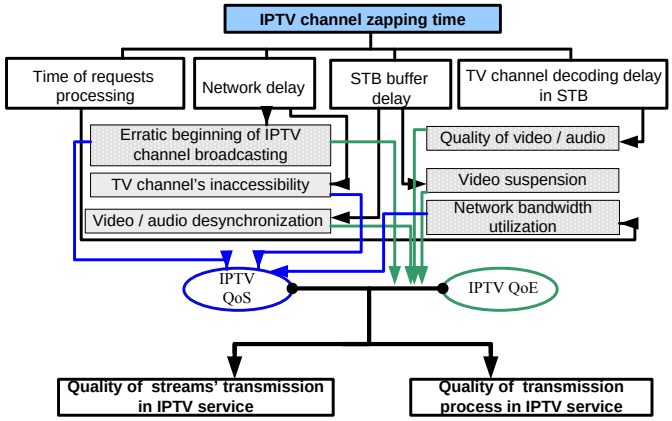

Fig. 1. Influence of channel zapping time on IPTV QoS and QoE

The impact of the channel zapping time on IPTV service QoS and QoE relationship (Fig. 1) is directly dependent on main components of IPTV channel change process: time of requests for TV channel change processing, network delay, Set Top Box (STB) buffer delay and TV channel data stream decoding delay in STB.

Many research methods have been proposed to reduce channel zapping time and to increase IPTV QoE. Some methods that improve the video encoding, flow scheduling methods, prejoining channels, predictive tuning or modify Protocol Independent Multicast-Sparse Mode (PIM-SM) protocol have been proposed [4]-[9].

Every single or a set of components of TV channel change process affect IPTV service delivery by problems tracked both of service users and service providers [10]. However, in addition to main components, IPTV channel change process and its zapping time is also affected by factors of user's

Rasa Bruzgiene is with Department of Telecommunications at Kaunas University of Technology, Studentu str. 50-452, Kaunas LT-51368, Lithuania (corresponding author to provide by e-mail: rasa.bruzgiene@ktu.lt).

Lina Narbutaite is with Department of Telecommunications at Kaunas University of Technology, Kaunas, Lithuania (e-mail: lina.narbutaite@ktu.lt).

Tomas Adomkus is with Department of Telecommunications at Kaunas University of Technology, Kaunas, Lithuania (e-mail: tomas.adomkus@ktu.lt).

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behaviour. Due to this, the model of TV channels' search and the selection of TV programs must be evaluated individually for each user in order to improve the current prediction's accuracy. Therefore, we proposed the modified IPTV channel change process method, which includes the main new aspect - loading the streams of the IPTV channels of small resolution Picture in Picture (PiP) in the aggregated devices. The impact of the proposed method on the processing time of the TV channel change requests and IPTV QoE according to the user's behaviour presented in this paper. The created modified process enable to ensure require parameters of QoS to the service provider by reducing the load of the network due to smaller number of the requests for the TV channel change and a shorter route for transmission of the requests.

II. IPTV CHANNEL CHANGE PROCESS WITH THE PROPOSED PIP EPG METHOD

The proposed method called PiP EPG (Picture in Picture Electronic Program Guide) and the flowchart of the proposed method for the transmission of IPTV channel change flow are presented in Fig. 2 and Fig. 3.

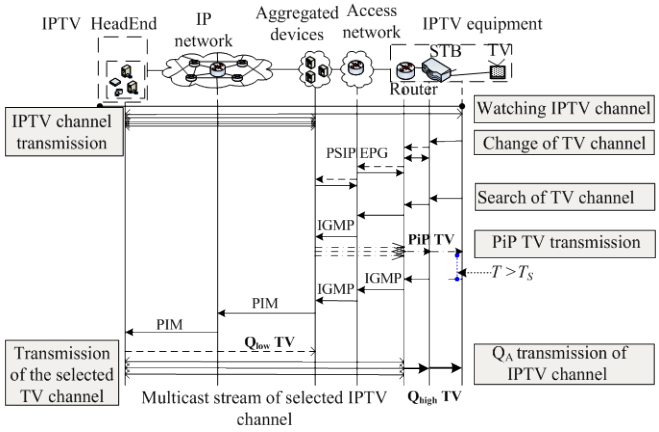

Fig. 2. The proposed method of IPTV channel change flow transmission during the channel change process

The IPTV service provider forms the statistics of the most commonly viewed - the most popular TV channels' selection according to the prediction of the user's behaviour in TV channel search and selection. The statistics are regularly updated. The statistics are used for the TV channels' grouping by their audiences. The groups of the users for these TV channels' broadcast and the TV schedule of IPTV channels in the EPG are based on these statistics also. The low quality (Q_{low}) streams of these TV channels' groups are hosted in the aggregated devices (AG) according to the formed groups of the users and the most popular TV channels assigned to them. These TV channels are transmitted to the user as a picture in picture (PiP) data streams of a lower resolution at the process of TV channel change. When the user initiates the process of TV channel change, the STB (Set Top Box) sends the PSIP (Program and System Information Protocol) query to the aggregated device for information presentation of the user's most frequently watched IPTV channel. This user sees the information in the graphical interface of the electronic

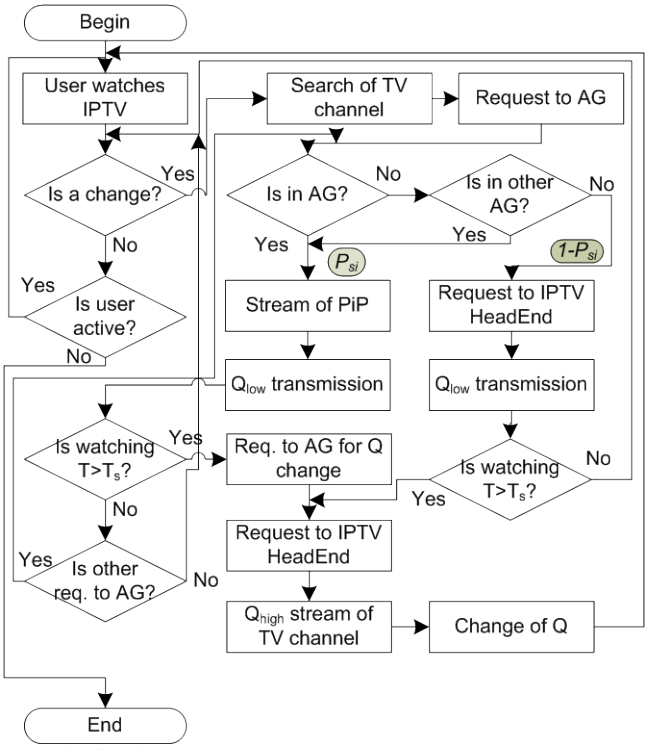

Fig. 3. The flowchart of the proposed PiP EPG method

program guide. When the user selects the TV channel on the EPG and presses the remote control button, the Set Top Box sends the IGMPv3 (Internet Group Management Protocol version 3) Join request for the selected TV channel to the aggregated device. The aggregated device starts transmission of the selected TV channel of low quality and lower resolution as the PiP data stream. The user sees both channels in the TV screen: the previously watching TV channel and the transmission of the selected TV channel in the graphical interface of the EPG. In this case, the main TV channel stream is not terminated and the user watches the selected TV channel broadcasting on TV screen at the same time. If the IPTV user watches the transmission of the selected TV channel for a longer than the minimum viewing period (T_s), the selected TV channel low quality transmission is changed to high quality (Q_{high}). The marking P_{si} is the probability, that the selected IPTV channel will be transmitted from the aggregated device in Fig. 3.

The use of different search methods for TV channels leads to the different amount of the requests for TV channel's change performance. It results the processing time of the requests for TV channel's change. The aggregated device serves for the multiple users' groups, so the number of the requests to change TV channels can greatly increase at the same time. In this case, the channel zapping time will be much longer. The proposed PiP EPG method will reduce the amount of the channel change requests, as well as its processing time. The next positive aspect of this method - the user will be able to search for the other IPTV channel without interrupting the broadcasting of watched digital IP television channel.

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III. The Analytical Model for the Evaluation of the Processing Time of IPTV Channel Change Requests

It is necessary to analyze the processes of TV channel change using the different methods of channel search, in order to assess the impact of the processing time of the channel change requests. The processes of TV channel change using the sequential, random and proposed methods of IPTV channel search are presented in Fig. 4 – Fig. 6.

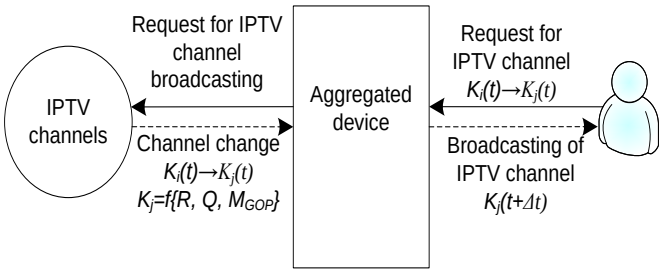

Fig. 4. IPTV channel change process using the sequential TV channel's selection

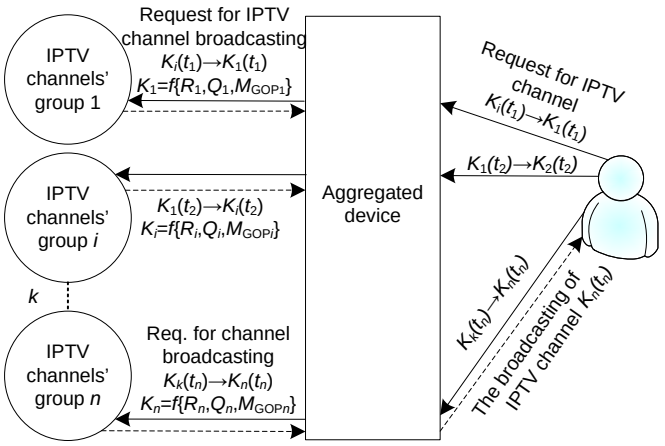

Fig. 5. IPTV channel change process using the random TV channel's selection

The user initiates the request for IPTV channel change $K_i(t) \rightarrow K_j(t)$ at the time t. IPTV channel K is described as a function $K=f\{R,Q,M_{GOP}\}$, which variables are: R – the transmission rate of the video data stream; Q – the quality of broadcasting IPTV channel; M_{GOP} – the length of Group of Pictures (GoP) in the video stream of IPTV channel. The aggregated device initiates the channel change process after the request for IPTV channel from the user. The broadcasting of the changed IPTV channel starts at the time $t+\Delta t$ (Fig. 4) or $t_n+\Delta t$ (Fig. 5).

The situation is different if the user uses the proposed PiP EPG method for IPTV channel's selection (Fig. 6). The user may choose the television channels from the list of IPTV channels in the electronic program guide, but it does not generate any additional requests. The user performs his choice on seeing the different programs of IPTV channels and the broadcasting of selected K_n channel starts in time t_n.

The *Markov* processes were used for the simulation of TV channels searching methods and evaluation the duration of the process of requests in the aggregated device. The user generates the requests for IPTV channel change with the intensity λ and these requests are processed with intensity μ in

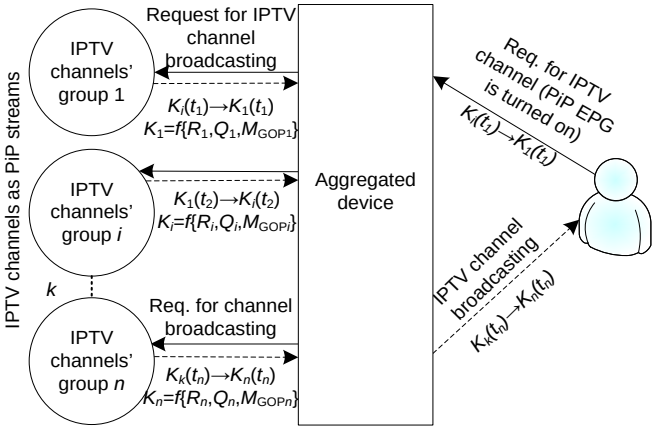

Fig. 6. IPTV channel change process using the proposed PiP EPG method

the aggregated device. The probabilities of the stationary states in system p_s are:

- in the case of the sequential TV channels searching method

$$p_s = \frac{\lambda^n \cdot \mu}{(\lambda+\mu)^{n+1}}; \quad (1)$$

- in the case of the proposed PiP EPG TV channels searching method

$$p_1 = \frac{\mu}{\mu+\lambda \cdot p_{12}}; \quad p_2 = \frac{\lambda \cdot p_{12}}{\mu+\lambda \cdot p_{12}}. \quad (2)$$

- in the case of the random TV channels searching method

$$p_s = \begin{cases} \dfrac{\mu \cdot (1-p_{12})}{\lambda \cdot p_{12} + \mu \cdot (1-p_{12})}, & if \quad s=0 \\ \dfrac{\lambda \cdot \mu \cdot (1-p_{12})}{(\lambda \cdot p_{12} + \mu \cdot (1-p_{12}))^2}, & if \quad s=1 \\ \dfrac{\lambda^i \cdot p_{i-1,i}^{i-1} \cdot \mu \cdot (1-p_{i,i+1})}{(\lambda \cdot p_{i,i+1} + \mu \cdot (1-p_{i,i+1}))}, & if \quad s=2\ldots n \end{cases}; \quad (3)$$

The duration T_{proc} of the process of requests in the aggregated device is calculated using the probabilities of the stationary states in the system:

$$T_{proc} = \frac{\overline{N}}{\mu}; \quad (4)$$

where $\overline{N} = \sum_{s=0}^{n} s \cdot p_s$ is the mean number of requests; μ is the average intensity of the processing of requests in AG; s is the system number of the state.

IV. The Results of the Evaluation of the Processing Time of IPTV Channel Change Requests

One of most important parameters, affecting total TV zapping time is processing duration of the requests for TV channel change in the aggregated device. For assessment of the IPTV channel change process, it is necessary to evaluate the influence of the user's behaviour on the processing of the channel change requests in the aggregated device. Therefore the analysis of influence of this parameter in the case of

different TV channel search methods was carried out. The processing time of requests for TV channel change in the aggregated device was calculated using (4). The dependencies of the processing time of requests for IPTV channel change in the aggregated device T_{proc} versus the intensity of the channel change requests λ and the intensity of the requests processing μ were determined in order to evaluate the effect of the proposed PiP EPG method on the IPTV channel change process. The probability, that there would be initiated more than one channel change request until the channel will be selected is variable $P_{i,j}$=0.01;0.4;0.6;0.8;0.9. The intensity of the requests processing in the aggregated device is $\mu = 90$ reqps. The results are presented in Fig. 7 and Fig. 8.

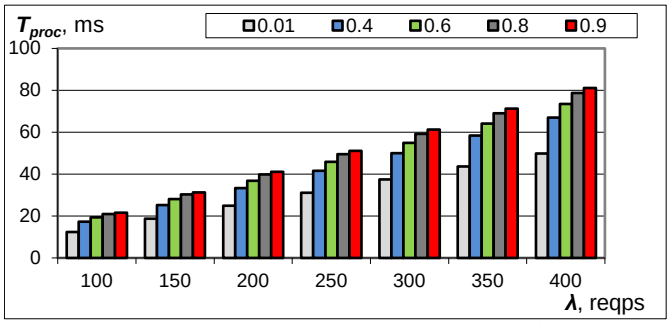

Fig. 7. The dependence of the processing time of IPTV channel change requests on the intensity of the requests, when TV channel is selected randomly

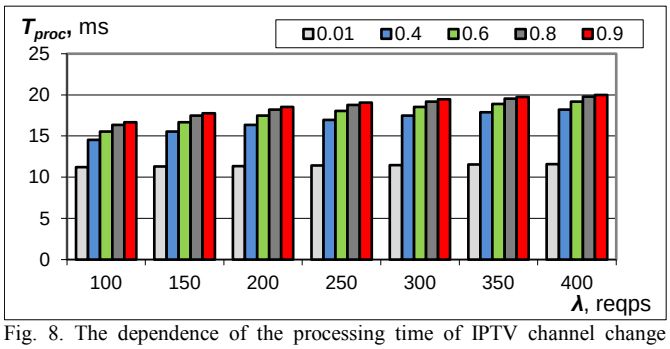

Fig. 8. The dependence of the processing time of IPTV channel change requests on the intensity of the requests, when TV channel is selected using the proposed PiP EPG

According to the results in Fig. 7 and Fig. 8, it can be seen, that the proposed PiP EPG method allows to reduce the processing time of the requests for IPTV channel change ~60 ms compared to a random TV channel search, if the intensity of requests is $\lambda = 400$ reqps and $P_{i,j}$=0.9.

The results (in Figure 9) obtained in the case when $P_{i,j}$=0.7 and the intensity of the requests processing is 90 reqps. According to these results (Fig. 9), it can be seen, when the intensity of the requests of TV channel change increases, the use of the proposed PiP EPG method for the channel search helps to reduce the processing time compared to a random and the sequential search of the TV channel. The proposed PiP EPG method allows to reduce the processing time of the requests for IPTV channel change ~20 ms compared to a random TV channel search or ~8 ms compared to a sequential TV channel search, if the intensity of requests is $\lambda = 400$ reqps and $P_{i,j}$=0.7.

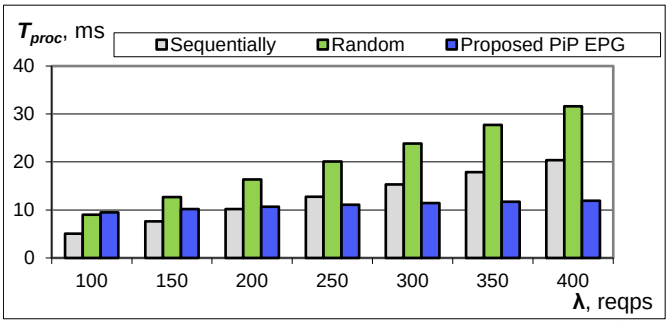

Fig. 9. The dependence of the processing time of IPTV channel change requests on the intensity of requests

The dependence of the processing time of requests for TV channel change on the intensity of the processing of requests, when λ is 270 reqps, is presented in Fig. 10.

The results in Fig. 10 showed, that the proposed PiP EPG method allows to reduce the processing time of the requests for IPTV channel change ~10 ms compared to a random TV channel search, if the intensity of requests' processing

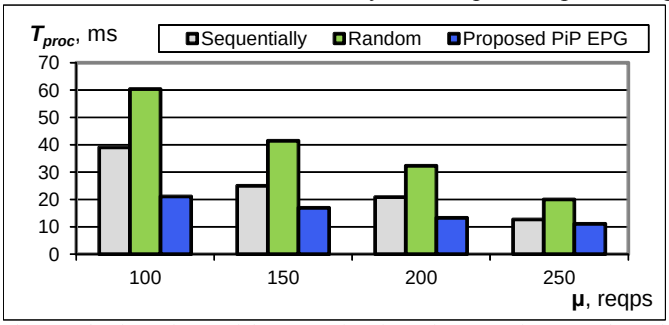

Fig. 10. The dependency of the processing time of requests for IPTV channel change on the request processing intensity

is $\mu = 250$ reqps. The processing time of requests for TV channel change is only a few milliseconds longer in the aggregated device compared to the channel search using the proposed PiP EPG method, if the user selects IPTV channel sequentially.

V. The Influence of the Channel Zapping Time to IPTV QoE

For the evaluation of the influence of proposed PiP EPG method to IPTV channel zapping time and QoE the experiments were carried out, according to the behaviour of the user for TV channel search. The three methods for TV channel search were used: sequential, random and proposed PiP EPG. During the sequential TV channel selection users switch TV channels one after another in fixed order, recording the selected TV channel after the initial channel change. During the random TV channel selection, IPTV service users switch TV channels randomly, repeating channel change process until desired TV channel selection and record. Measurements of IPTV channel zapping times were made during the highest load hours, determined according to the statistical data from TV audience – on Saturdays and Sundays from 6 p.m. to 10 p.m. Measurements were performed by changing 57 IPTV channels. Experiments were lasted for 5 weeks. The independent respondents, from 29 to 72 years old, all different gender and with different levels of education

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ranked IPTV QoE, according to the TV channel zapping time. One respondent submitted 57 assessments of IPTV QoE during single experiment. The respondents evaluated IPTV QoE using the subjective method MOS (Mean Opinion Score) and expressing the perceived quality of service on MOS scale of 1 (*TV channel zapping time is very long and particularly unacceptable to the user*) to 5 (*TV channel zapping time is quick and user is satisfied of provision of IPTV services*).

In order to evaluate the relationship between the user perceived quality of service in MOS scale and TV channels zapping times the statistical regression analysis for collected data during the experiments were performed [11]. However, the regression analysis does not reveal critical thresholds of the changes in the user's reactions. Therefore, it is relevant to determine which of IPTV channel zapping times value is critical the user‘s reaction to the perceived quality of service. The determination of this critical value was made by the approximation of the experimental data by using the arctangent function and optimization (Fig. 11).

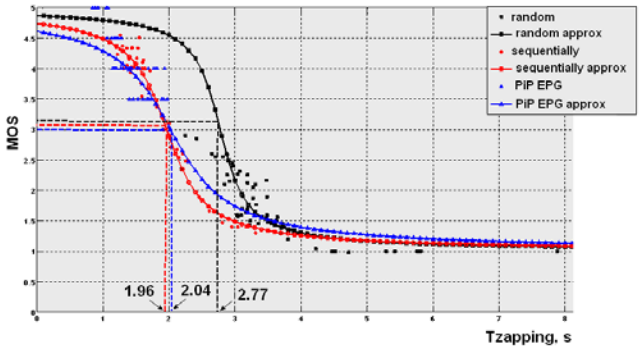

Fig. 11. The relationship between the user perceived quality of service (MOS) and TV channels zapping times using the different methods for IPTV channel search

The analysis of user’s reaction for channel zapping time increase shows, that the biggest negative reaction of user to the delivery of IPTV service is using a method of random channel search. Using the proposed PiP EPG method, user’s reaction for channel zapping time increase is equal and if the channel zapping time exceeds 2.04 s the user assess it as an acceptable delivery of IPTV service. After the analysis of the experimental data, it was found that the standard deviation of the TV channel zapping time was $\sigma_1 = 0.52$, when TV channel was selected sequentially. The standard deviation of the TV channel zapping time was $\sigma_2 = 0.9$, when TV channel was selected random.

The basic mathematical expression of the evaluation of MOS values for the objective assessment of IPTV QoE were carried out by the evaluation of the TV channel zapping time according to the behaviour of the users for the TV channels selection [11]. This expression is presented in (1).

$$MOSo = \begin{cases} 5, & if \quad T_{zapping} \le 1.96 - \sigma_1 \\ MOS1, & if \quad 1.96 - \sigma_1 < T_{zapping} \le 1.96 + \sigma_1 \\ MOS2, & if \quad 1.96 + \sigma_1 < T_{zapping} \le 2.7 + \sigma_2 \\ 1, & if \quad T_{zapping} > 2.7 + \sigma_2 \end{cases}, \quad (5)$$

where: $T_{zapping}$ is IPTV channel zapping time; σ is the standard deviation of the experimental data of IPTV channel zapping time.

The mathematical expression for MOS evaluation using the experimental results was carried out depending on the range of the interval of the IPTV channel zapping time and this expression is presented below [11].

$$MOSo = \begin{cases} 5, & if \quad T_{zapping} \le 1.4 \\ MOS1, & if \quad 1.4 < T_{zapping} \le 2.5 \\ MOS2, & if \quad 2.5 < T_{zapping} \le 3.6 \\ 1, & if \quad T_{zapping} > 3.6 \end{cases}, \quad (6)$$

where $MOS1$ is the expression presented in (7) and $MOS2$ is the expression presented in (8). These expressions were carried out during the determination of the regression analysis by third and fifth degree polynomials [11].

$$MOS1 = -0.032 \cdot (T_{zapping})^3 + 0.627 \cdot (T_{zapping})^2 - 4.020 \cdot T_{zapping} + 9.372 \quad ; \quad (7)$$

$$MOS2 = -0.072 \cdot (T_{zapping})^5 + 0.273 \cdot (T_{zapping})^4 + 2.014 \cdot (T_{zapping})^3 - 12.752 \cdot (T_{zapping})^2 + 21.276 \cdot T_{zapping} - 6.756 \quad . \quad (8)$$

The proposed mathematical expression for the evaluation of MOS values can be used for the objective assessment of IPTV QoE according the channel zapping time.

Taking into account influence of user behaviour to channel zapping time, it is important to assess influence of integrated QoE of IPTV service. The comparison of integrated QoE according channel zapping time using different methods for channel search was carried out. The results are presented in the Fig. 12.

The results shows, that proposed PiP EPG method allows to

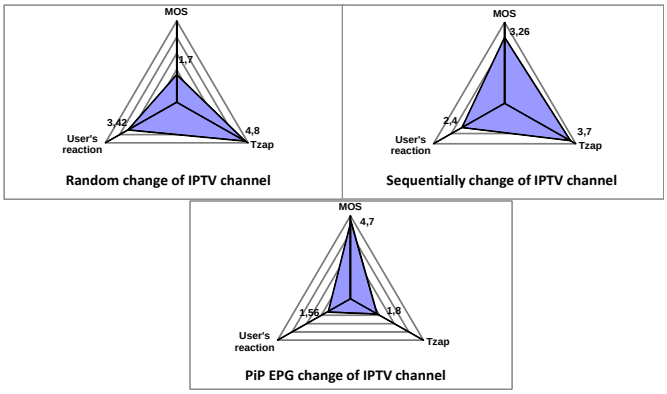

Fig. 12. The integrated IPTV QoE according the channel zapping time, using the different methods for channel search

increase common QoE of IPTV service at least 2 times, compared with other methods for TV channel search. The integrated QoE evaluation of IPTV service is most sensitive of users when the method of random channel search is used.

It can be stated, that the proposed PiP EPG method for IPTV channel change allows for service providers to increase the attractiveness of digital IP television. So, increasing service attractiveness will grow the demand for IPTV service,

which will provide the economic benefit for IPTV service's providers.

VI. CONCLUSIONS

The results of the evaluation of the processing time of IPTV channel change requests showed that the proposed PiP EPG method enables to reduce the processing time of requests on average 15 ms in the aggregated device compared to other methods for IPTV channel search. It can be concluded also that the processing time of requests for TV channel change very little depends on the intensity of the channel change requests in the aggregated device if users of IPTV service are using the proposed PiP EPG method. This is very important fact because the processing time of requests for TV channel change has big influence on total TV channel zapping time.

The authors' solution for MOS evaluation enables the objective assessment of IPTV quality of experience (QoE). Due to this, the proposed PiP EPG method for IPTV channel change allows for service provider to analyze users' demands for TV channel transmission, enabling IPTV service more attractive and increasing service QoE more than 2 times.

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Rasa Bruzgiene received her Ph.D. degree in Electrical and electronics engineering from the Department of Telecommunications at Kaunas University of Technology (KTU), Lithuania, in 2012. Her current title is the lecturer in the Department of Telecommunications at Kaunas University of Technology. Dr. R. Bruzgiene's current research interests include wireless networks, wireless sensors, the integration of the next generation mobile networks, reliability and efficiency of the telecommunications systems, QoS and QoE in telecommunications services.

Lina Narbutaite received her Ph.D. degree in Electrical and electronics engineering from the Department of Telecommunications at Kaunas University of Technology (KTU), Lithuania, in 2001. Her current title is the associate professor in the Department of Telecommunications at Kaunas University of Technology. Dr. L. Narbutaite's current research interests include hybrid and heterogeneous broadband networks, wireless sensors, interactive real time services, reliability, QoS/QoE, efficiency of the telecommunications systems.

Tomas Adomkus received his Ph.D. degree in Electrical and electronics engineering from the Department of Telecommunications at Kaunas University of Technology (KTU), Lithuania, in 2006. His current title is the associate professor in the Department of Telecommunications at Kaunas University of Technology. Dr. T. Adomkus's current research interests include QoS of data transfer and multimedia services, data security, wireless sensors, the integration of the next generation mobile networks, reliability and efficiency of the telecommunications systems.

Students' Perceptions on the Use of Simulation Technologies for Leadership Competency

Jowati Juhary and Masdini Harina Ab Manan

***Abstract*—**This paper begins with the hypothesis that simulations could enhance students' leadership capabilities. To test this hypothesis, it is critical to also understand the learning environment where the study takes place. The National Defence University of Malaysia (NDUM) is the youngest public higher learning institution in Malaysia, and it aims at producing 'intellectual leaders of characters.' Realising this, this paper is timely since leadership is crucial in military institutions. At present, there is only one academic programme that utilises new technologies for learning and teaching. Notwithstanding this, it needs to be emphasised that leadership training at the NDUM is integrated in the curriculum of the university. This paper adopted a quantitative descriptive approach to research. 191 students of the Maritime Technology Programme (MTP) participated in a survey. The items in the survey were adopted from previous projects conducted on leadership and technology. Further, the survey was conducted in three main stages because some of the respondents attended practical training on-board naval ships. The data were then analysed using a Statistical Package for Social Sciences (SPSS) Version 15. The key findings of this paper are threefold. The findings have led to three important suggestions for the academic programme specifically and the university generally.

***Keywords*—**leadership training, maritime technology, military leadership, National Defence University of Malaysia, simulation technologies.

I. Introduction

SIMULATIONS are amongst new technologies that receive both praises and criticisms. Because of their potential, many educational institutions are attracted to implement and use them. On the other hand, because of their costs, many academics are sceptical about these new tools. Apart from the costs, many scholars argue about the effectiveness of using digital technologies to improve students' grades. Actually, there is no guarantee that any *one* learning and teaching approach or tool could help students perform better academically. That is why it is always a wise decision to blend the learning and teaching strategies.

The National Defence University of Malaysia (NDUM) is the latest addition of higher learning institutions in Malaysia. Since its inception, the university has been examining many learning and teaching strategies to be adopted. Ultimately, these strategies will become its educational philosophy. At present the university mainly employs face-to-face teaching for all academic learning and teaching, with the exception of one academic programme, the Maritime Technology Programme (MTP).

As an upgrade from the previously known the Military Academy of Malaysia (MAM), the NDUM is a unique and boutique university [1]. The unique part about being in this university is that it is supported by two different ministries, the Ministry of Education, Malaysia (MOE) and the Ministry of Defence, Malaysia (MINDEF). At the same time, the university runs academic and military training concurrently. In fact because of the unique learning and teaching environment, the university is labelled as a 'boutique' university by the MOE. This suggests that the graduates are 'tailored to specific measurements and requirements' of the clients cum stakeholders and/or future employers. Further, a boutique university implies that the student population is capped at a maximum of 5,000 per academic session.

A. The Maritime Technology Programme

The MTP provides training for military cadets who will navigate Malaysia's navy vessels. To qualify as a navigator for the Royal Malaysian Navy (RMN) ships, the NDUM cadets are trained and assessed on the Computer-Based Training (CBT) laboratories and a ship simulator. By insisting on this training programme, the international requirements of the Standard of Training and Watch Keeping Certification 1995 (STCW 95) are met. As for civilian students, the MTP will open opportunities for the graduates to work in the dynamic maritime industry.

In the NDUM, this MTP is the only academic programme that uses e-learning (through CBT) and simulation technologies. It is very essential for the students to have these two tools. The reasons for this are threefold. Firstly, if the NDUM wants to be effective and efficient in learning and teaching, the programme must have the CBT and simulators. This is especially true for naval cadets who cannot visualise the problems and tactical aspects of navigation without training in the simulator. Secondly, the accreditation for seamen or ship navigators requires that students are taught using the CBT and simulators. The facilities must be validated and certified by the STCW 95, a world standard certification. This world standard certification is central since the terminologies used are standardised. Thirdly, students will face

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Jowati Juhary is with the NDUM, Sungai Besi Camp, Kuala Lumpur, 57000 Malaysia (phone: 603-9051-4447; fax: 603-9051-4458; e-mail: jowati@upnm.edu.my).

Masdini Harina Ab Manan is with the NDUM, Sungai Besi Camp, Kuala Lumpur, 57000 Malaysia (e-mail: masdini@upnm.edu.my).

problems on-board real ships if they are not trained and taught first using the CBT and simulators. Initially, students must be exposed to the CBT and simulators and gain some level of competency before being allowed on-board a ship. Given that Malaysia's navy is roaming international waters, the NDUM training programme has no option but to comply with international standards or risk being banned from proceeding beyond territorial waters.

B. The Problem Statement

New technologies are able to assist in many aspects of education and training [2]. However, the advantages of new technologies are not widespread throughout the student population at the NDUM. Only students enrolled in the MTP may garner the benefits offered by technology. The main question that will be addressed in this paper is the relation between new technologies and leadership awareness and understanding at the defence university. Hence, the objectives of this paper are twofold, first to investigate students' perceptions of leadership training with new technologies, and second to identify students' level of awareness and understanding of their leadership competency.

C. The Significance of the Study

This paper attempts to investigate how digital technologies could be used to enhance students' leadership awareness and understanding. Although the only one programme that uses new technologies at the NDUM is running academic programme, this paper will not look into how the students view these tools to improve their academic grades. Rather this paper is more interested to look at how soft skills, particularly leadership are being nurtured in this academic programme.

The hypothesis of this study is that *new technologies could improve students' awareness and understanding of leadership*. In order to test the hypothesis, three research questions will be answered at the end of this paper including,

1) How perceptive are students on leadership issues?
2) Are students aware of what leadership types or skills acquired when they use new technologies?
3) How do students view new technologies in relation to their leadership understanding and proficiency?

In concluding this section, the authors would like to emphasise that although a lot of research has been conducted on leadership and technology, focus has been lacking in the area of leadership and military learning environments. This paper could only cover aspects that are present in the NDUM, as this is the only tertiary military learning environment in Malaysia. To understand the key concepts in this paper, the next section will examine the relevant literature.

II. Leadership and Technology

A. Leadership

Leadership training has become very important in the landscape of Malaysian tertiary education. It is part of the soft skills needed for all graduates in order to secure employment. Subsequently, soft skills, in Malaysian tertiary setting, are critical components for the graduates to attain. In fact, leadership proficiency is one of the seven core thrusts in the Compulsory Soft Skills Scheme for graduates of the Malaysian public and private universities. As part of building intellectual leaders of characters, the NDUM is serious about producing quality graduates. Because of the nature of about 80 percent of the graduates, who will receive their commissions in the Malaysian Armed Forces (MAF), they must be exposed to the right blend of characteristics for becoming respectable leaders.

Leadership on its own is a very complex subject matter; some scholars argue that leaders are not trained; they are borne to become one. Although heavily researched, little is understood about leadership [3]. In broad terms, it is an inter-personal or social process of persuasion involving a series of complex interactions between leaders and followers, which depends on multiple situations. Organisationally, leadership is associated with influencing the belief and motivation of the followers towards some common goals. The military is relying heavily on the ability of the officers to lead and command. It is no surprise, then, that styles of leadership were examined thoroughly by the military, for instance, by the U.S. Army. According to *Military Leadership* [4], there are three prominent styles of military leadership, including authoritarian, participative and delegative. Although nowadays, the military institutions are adopting transformative style of leadership [5], the most important aspect in the military is the ability to lead; failure to lead reflects failure of the personnel to show strong characters. Therefore, leadership training is critical in the making of great leaders, especially military leaders, and it is one of the soft skills that is not easy to measure and quantify.

The main concern that must be addressed is whether military leadership differs from that of educational leadership or any other forms of leadership, and whether these differences or similarities would affect leadership training at the NDUM. In many instances, references to military leaders will always be accompanied by the term 'to provide military leadership.' Military leadership could be defined as the process of getting the soldiers to accomplish a task [6]. Looking at this definition, it resembles the universal definition provided by other scholars. What makes this definition stands out and particularly relevant to a military learning environment is the term 'soldiers to accomplish tasks.' This is because military is often respected on its ability to command and get any jobs done efficiently and effectively, hence the term military leadership.

According to Stevenson [7], military leadership could be associated with transformational leadership. In a broader sense, this association appears relevant because transformational leadership allows for personal growth as well as organisational development. Transformational leadership requires the organisation to expect the best from its personnel. Each individual does not only rely on him/herself in completing his/her tasks, he/she also relies on other individuals

in the organisation. In general, there are four components of transformational leadership including charisma or idealised influence; inspirational motivation; intellectual stimulation; and individualised consideration or attention [8]. These components suggest that a transformational leader will challenge the subordinates to achieve their potential and encourage them to go above and beyond their limits.

In short, what the NDUM wants to achieve at the end of the students' academic and military programmes is to transform these young leaders to become adaptive of their environments; they can lead as well as become followers. Notwithstanding this, this paper is not able to determine whether the graduates are able to adopt transformational leadership because the students were not particularly asked to name their leadership styles. Hence, the differences and similarities between various types of leadership and military leadership will provide leverage when analysing the issues on leadership training at the NDUM. The best possible approaches to inculcate leadership are what the young university seeks.

B. New Technologies

Before venturing further, new or digital technologies will be defined for this particular paper. Nonetheless, only the simulation technologies will be highlighted in the finding and discussion sections since the survey questions only focus on the simulator. The term *e-learning* refers to learning and teaching activities that use information communication technology (ICT). *Simulation* is specifically designed courseware or programmes to simulate situations/events for the purposes of learning. These simulated situations/events depict scenarios from real life in the expectation that students can learn from reconstructions of events and situations that they are likely to confront in their professional life. Simulations are often built to engage students in situations or events that would be too costly, difficult or hazardous in the real world [9], and so enable them to 'practise' responses to such situations. One great advantage of simulation is that it allows military trainees to make mistakes without serious consequences [10]. Since mistakes can be a powerful learning mechanism when they happen in a safe and blame-free environment [11], simulation is considered to be one of the best learning tools. Complex operations in particular, can often be explained more effectively through simulations.

In much of the literature it has been suggested that technologies can extend the opportunities for the kind of resourceful learning process. Although these benefits are not unique to military learning environments, they are particularly pertinent to the training of military leadership. The assumed benefits are summarised in the next two paragraphs below.

Digital technologies, as believed by many scholars, can facilitate students' construction of knowledge; test and generate a diverse array of ideas; appreciate multiple perspectives; engage in social and intellectual interaction and dialogue; engage in critical thinking and problem-solving exercises; and increase participation and reflection (self-directed learning). All these benefits are crucial in making students develop multiple modes of representation and becoming more self-aware of their surroundings. Further, e-learning and simulation technologies facilitate students' engagement in a meaningful learning context and thus increase the 'ownership' over their own learning.

The emergence of simulation technologies converges with trends in new pedagogy that allows for greater student control, personal responsibility and collaboration. Creating collaborative learning environments embraces the concept of active learning, which in itself requires students to understand the concept of leadership – students actively "constructed" their knowledge with peers and teachers, creating an arena where different discourses and learning styles could comfortably co-exist [12]. e-Learning and simulations provide a suitable platform in which student-centred principles are particularly relevant as students become the centre of the learning environment. This view has been strongly supported by researchers who claim that courses conducted through computer technologies require active learning strategies and participation [13], [14], [15]. More critically, leadership training can be nurtured when students learn with new technologies. Furthermore, in successful online courses, students may assume significant instructional roles such as offering instructional tips and constructing new knowledge that are once the domain of educators [16]. This could prove especially relevant to the aims of most military institutions where students are expected to assume larger roles and take command and control of most situations.

Based on the discussion above, whatever transpires in classroom learning and teaching must focus on the *transfer of learning*. Transfer of learning involves the students' ability to work both independently and collaboratively. At the same time, this new science of learning would encourage classrooms to be student-centred.

It is critical to understand how new technologies could help students polish their awareness and understanding of leadership. As the world relies heavily on computing facilities and sophisticated forms of communication, future leaders must be trained to be comfortable working with technology. The best training time for this would be during their tertiary education. The NDUM's graduates must not only understand the application of technology to the battlefield, but they must also be comfortable using it in all sorts of more fundamental applications. The military institutions in the world change dramatically in the 19th century, driven in a large part by technology [17]. This applies even more so to the 21st century. According to Price [18], amongst the trends that will shape military leadership is that new technology will go on driving rapid change. He further stresses that effective leaders drive change to take advantage of emerging technology. The fact that e-learning and simulations are able to hone leadership skills is at least agreed by a group of scholars [19], [20], who comment that computerised simulations are helping leaders to think strategically and ethically, and technology can be a tool for leadership development.

As mentioned in the earlier part of this paper, leadership training at the NDUM is incorporated in academic classes. This makes the use of new technologies for academic classes increasingly critical since subtly and gradually, leadership competency may be enhanced in these classes. That is why only the MTP students will become the respondents of this paper as further discussed in the next section.

III. Methodology

This paper adopted a quantitative descriptive method of research. The data for this paper were gathered from 191 first, second and final year civilian students and cadets, who are enrolled in the MTP at the university. They were informed that their responses will be used for a project on digital technologies for the university and each student answered a set of questionnaire on digital technologies and leadership. The data were categorised into three themes, namely awareness on leadership issues; leadership preferences; and leadership and new technologies.

A. Sample Population

In actual fact, the total number of students in the MTP was 213 during the academic year 2009/2010. There were 41 first year students (20 civilian students); 112 second year students (22 civilian students); and 60 third year students (all naval cadets). The paper aimed at getting all 213 students to participate in the survey, nonetheless, during the stages of questionnaire distributions, 22 students had medical leaves and attended tests/other projects. The MTP students make up about 10 to 15 percent of the total student population at the NDUM. In this way, it can be concluded that this group of students is an elite group of students because the MTP is specific to the RMN only, and for the civilian students, they have a huge employment potential in the maritime industry.

B. Data Collection

Both authors were involved in the data collection process by distributing and collecting the questionnaires. Both of them received assistance from the lecturers who conducted the classes for the MTP students. The distribution of questionnaires was done in three stages as summarised below. The first two stages were conducted for the first, second and third year students while the last stage was conducted for half of the second year students who just returned from practical training on-board naval ships. It needs to be emphasised that at the time the survey was performed, only the first year students have never gone through practical training on-board naval ships. The second and third year students, then, have a very solid basis for comparing the simulator and the real ships for leadership training.

Table 1: Stages of Questionnaire Distribution

Stage(s)	Date(s)/Month(s)/Year(s)	Number of Questionnaires
1	5 April 2010	80
2	12 April 2010	65
3	14 July 2010	46
	Total	191

C. Research Instruments

The questionnaires have three main sections. The first section elicits responses about awareness issues on leadership and technology. The second section examines the roles of technology in leadership training. The third section seeks to understand students' styles of leadership. The items in the questionnaires were mainly adopted from Clark [21] especially on the issues of leadership training and styles of leadership, and Michigan Technological University (through its Excel Programme) [22] for other issues on technology and leadership. As the items have been used and modified several times by other scholars, the authors are confident that they are reliable and valid for achieving the objectives of this paper.

A pilot test was conducted with 10 respondents, and the main aim of this test was not for validation or reliability purposes since the instrument was adopted. Rather, the purpose of the test was to seek any technical problems that may be faced by the respondents. There was only one prominent problem, that was, the language issue; students' inability to comprehend the original questions in English. This matter was rectified by having bilingual sets of questionnaires.

D. Data Analysis

Table 2: Labelling of Questionnaires

Year of Studies	Labelling of Questionnaires	No. of Respondents	No. of Enrolled Students
1	Q.1-Q.38	38	41
2	Q.39-Q.93; Q.145-Q.191	103	112
3	Q.94-Q.144	50	60
	Total	191	213

Analysis of the data collected was done using the Statistical Package for Social Sciences (SPSS) Version 15. Each returned questionnaire totalling the same distributed number of questionnaires was labelled from 1 until 191 following their years of studies with the exception of number 145 until 191, which belonged to the second year students. Table 2 further explains the labelling procedures. Based on the hypothesis and research questions of this paper, the analysis of the data only involves simple statistical analysis that is descriptive statistics.

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IV. Findings

A. Demographic Data

Tables 3, 4, 5 and 6 describe the respondents' year of studies, genders, categories, and whether they have the experiences of using the simulator.

Table 3: Years of Study

Year of Study	Frequency	Percentage
1	38	19.9
2	103	53.4
3	50	26.7
Total	191	100.0

Table 4: Genders of Respondents

Gender	Frequency	Percentage
Male	175	91.6
Female	16	8.4
Total	191	100.0

Table 5: Categories of Respondents

Category	Frequency	Percentage
Naval Cadets	149	78.0
Civilians/ROTU	42	22.0
Total	191	100.0

Table 6: Experiences in Using Simulators

Experienced in using simulator	Frequency	Percentage
Yes	191	100
No	0	0
Total	191	100.0

B. Awareness Issues

The respondents had to answer 10 questions for Section A and the results are in Table 7.

Table 7: Awareness Issues

No	Statements	Level of agreement 1	2	3	4	5	Mean	S.D.
1	I am able to identify my style of leadership	19.9 (38)	48.2 (92)	25.7 (49)	5.8 (11)	0.5 (1)	2.19	0.84
2	I have a solid role model for leadership	17.8 (34)	41.9 (80)	31.4 (60)	7.9 (15)	1.0 (2)	2.32	0.89
3	My role model for leadership is always my lecturers	26.7 (51)	34.6 (66)	33.0 (63)	5.2 (10)	0.5 (1)	2.22	1.14
4	My role model for leadership is always my senior and friends	5.8 (11)	35.6 (68)	38.2 (73)	17.8 (34)	2.6 (5)	2.76	0.90
5	Leadership needs training	58.6 (112)	27.7 (53)	8.4 (16)	3.7 (7)	1.6 (3)	1.62	0.90
6	Leadership comes naturally	14.1 (27)	26.2 (50)	35.1 (67)	19.9 (38)	4.7 (9)	2.75	1.08
7	Leadership is nurtured	37.7 (72)	41.9 (80)	14.7 (28)	4.2 (8)	1.6 (3)	1.9	0.91
8	New technologies are able to assist in leadership training	38.2 (73)	44.5 (85)	12.6 (24)	3.1 (6)	1.6 (3)	1.85	0.87
9	Not everybody could lead	23.0 (44)	20.4 (39)	32.5 (62)	15.7 (30)	8.4 (16)	2.66	1.23
10	Leadership qualiti es depend on training, experience and opportunities	52.4 (100)	37.2 (71)	6.8 (13)	2.1 (4)	1.6 (3)	1.63	0.83

1= Almost Always True 2 =Frequently True 3 =Occasionally True 4 = Seldom True 5 = Almost Never True

C. The Relationships between Leadership and New Technologies

Seventeen items were asked in this section (Section B) as illustrated in Table 8.

Table 8: Leadership and New Technologies

No	Statements	Level of agreement 1	2	3	4	5	Mean	S.D.
1	I am confident that each lesson in the simulator helps my leadership proficiency	41.4 (79)	41.9 (80)	10.5 (20)	4.7 (9)	1.6 (3)	1.83	0.91
2	I do not take lessons seriously in the simulator	4.7 (9)	6.8 (13)	13.6 (26)	36.6 (70)	38.2 (73)	3.97	1.10
3	I realise how simulation technologies help me polish my leadership quality	34.6 (66)	47.6 (91)	13.1 (25)	4.2 (8)	0.5 (1)	1.88	0.83
4	I learn to be more aware of my surroundings in the console	24.6 (47)	48.7 (93)	21.5 (41)	4.7 (9)	0.5 (1)	2.10	0.83
5	I learn to be more appreciative of my roles and others in the console	27.7 (53)	52.4 (100)	16.8 (32)	2.1 (4)	1.0 (2)	1.96	0.79
6	I am more confident of myself after the exposure in the simulation console	39.3 (75)	47.1 (90)	8.9 (17)	3.7 (7)	1.0 (2)	1.80	0.83
7	I am better at managing my time after the exposure in the simulation console	17.3 (33)	51.3 (98)	24.1 (46)	6.8 (13)	0.5 (1)	2.31	1.71
8	I better appreciate the sense of urgency after the exposure in the simulation console	26.2 (50)	49.7 (95)	19.9 (38)	3.7 (7)	0.5 (1)	2.03	0.81
9	I know what my leadership style is after the exposure in the sim ulation console	22.0 (42)	48.2 (92)	24.6 (47)	4.2 (8)	1.0 (2)	2.14	0.84
10	I would most likely act as the spokesperson of my group after the exposure in the simulation console	22.5 (43)	44.0 (84)	27.7 (53)	4.7 (9)	1.0 (2)	2.18	0.87
11	I would encourage e xtra work (no more than average) with the use of simulation technologies	17.8 (34)	50.3 (96)	26.2 (50)	4.2 (8)	1.6 (3)	2.21	0.84
12	I would permit the members to use their own judgement	14.1 (27)	48.7 (93)	30.4 (58)	6.3 (12)	0.5 (1)	2.25	0.8
13	I would s tress being ahead of competing groups because technologies could facilitate better	18.3 (35)	47.6 (91)	27.7 (53)	5.8 (11)	0.5 (1)	2.23	0.83
14	I would let the members do their work the way they think best with simulation technologies	26.2 (50)	49.7 (95)	18.3 (35)	4.7 (9)	1.0 (2)	2.05	0.85
15	I would be working hard for a better position	49.7 (95)	35.1 (67)	11.0 (21)	3.7 (7)	0.5 (1)	1.70	0.85
16	I would tolerate postponement and uncertainty because simulation technologies would help recover the loss time	16.2 (31)	44.0 (84)	24.1 (46)	11.5 (22)	4.2 (8)	2.43	1.03
17	I would be willing to make changes because simulation shows the various ways to make them	20.9 (40)	48.2 (92)	23.6 (45)	6.3 (12)	1.0 (2)	2.18	0.87

1= Almost Always True 2 =Frequently True 3 = Occasionally True 4 =Seldom True 5 = Almost Never True

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D. Leadership Preferences

In Section C, 12 questions were asked and the results are as per table below.

Table 9: Leadership Preferences

No	Statements	Level of agreement 1	2	3	4	5	Mean	S.D.
1	I always retain the final decision making authority within my group	8.9 (17)	39.3 (75)	38.7 (74)	10.5 (20)	2.6 (5)	2.59	0.89
2	I always try to include one or more group members in determining what to do and how to do it. However, I maintain the final decision making authority	13.1 (25)	43.5 (83)	31.4 (60)	10.5 (20)	1.6 (3)	2.43	0.90
3	My group members and I always vote whenever a major decision has to be made	15.2 (29)	41.4 (79)	29.3 (56)	12.0 (23)	2.1 (4)	2.45	0.96
4	When someone makes a m istake, I tell them not to ever do that again and make a note of it	24,1 (46)	53.9 (103)	15.7 (30)	4.7 (9)	0.5 (1)	2.15	1.73
5	I want to create an environment where the group members take ownership of the project. I allow them to participate in the decisi on making process	29.3 (56)	50.3 (96)	16.8 (32)	3.1 (6)	0.5 (1)	1.95	0.80
6	I allow my group members to determine what needs to be done and how to do it	19.9 (38)	48.7 (93)	19.9 (38)	11.0 (21)	0.5 (1)	2.24	0.91
7	When something goes wrong, I tell my group members that a procedure is not working correctly and I establish a new one	20.4 (39)	46.1 (88)	25.7 (49)	7.9 (15)	- -	2.21	0.86
8	I allow my group members to set priorities with my guidance	15.7 (30)	48.2 (92)	31.4 (60)	4.7 (9)	- -	2.25	0.77
9	I deleg ate tasks in order to implement a new procedure or process	32.5 (62)	46.1 (88)	14.7 (28)	5.2 (10)	1.6 (3)	1.97	0.91
10	Group members seek mainly security	8.4 (16)	33.0 (63)	41.4 (79)	14.1 (27)	3.1 (6)	2.71	0.92
11	Group members know how to use creativity and ingenuity to solve organisational problems	23.0 (44)	47.6 (91)	24.1 (46)	4.7 (9)	0.5 (1)	2.12	0.83
12	My group members can lead themselves just as well as I can	23.0 (44)	47.1 (90)	23.6 (45)	4.7 (9)	1.6 (3)	2.15	0.88

1= Almost Always True 2 =Frequently True 3 = Occasionally True 4 =Seldom True 5 = Almost Never True

V. Discussions

A. Research Question 1

Based on Table 7, it could be deduced that the respondents had a high level of awareness towards the issues of leadership and good role models for leadership. Out of 10 items asked in the table, seven items have a standard deviation below 1.0: items No. 1, 2, 4, 5, 7, 8 and 10. The rest of the items have a standard deviation of 1.14 (item No. 3), 1.08 (item No. 6) and 1.23 (item No. 9).

Table 10: Seniors and Friends as Role Models

		Year of Study 1	2	3	Total
My role model for leadership is always my senior and friends	Almost Always True	1	8	2	11
	Frequently True	11	31	**26 (52%)**	68
	Occasionally True	**14 (36.8%)**	**42 (40.7%)**	17	73
	Seldom True	11	18	5	34
	Almost Never True	1	4	0	5
Total		**38**	**103**	**50**	**191**

Given that the learning environment is military bias, the respondents have the advantage of comparing and contrasting the role models for leadership training. 140 respondents were very sure that they have solid role models to emulate. Further, out of 191 respondents, 117 saw their lecturers as their model of leadership while 79 agreed on their senior and friends as their leadership models. This acceptance on the seniors and friends as their leadership models is further analysed based on the respondents' years of studies as shown in Table 10.

It is expected that the first year students would have a higher percentage on the "Almost Always True" and "Frequently True" because they rely on the surrounding environments to help mould their attitudes. The fact remains that even the second and third year students have the same pattern as the first year. What this exemplifies is that the students, in a closed learning environment such as the NDUM, rely on each other for role modelling.

On the question of whether everybody could lead, only 16 respondents agreed that the statement is true. The majority believed that 'not everybody could lead.' This strong feeling could be related to the environment in which the respondents are placed. A military learning environment heavily emphasises on leadership and based on the respondents' observations, leadership appears not to suit everyone. On the issues of whether leadership is natural or nurtured, the respondents were consistent in their answers: they felt that leadership is nurtured and needs training (a standard deviation of 0.91 and 0.90 respectively).

B. Research Question 2

This question could be broken down into two: leadership types and leadership skills. Based on previous discussions, the leadership styles have three categories, namely authoritarian, participative and delegative. Table 9 has mixed items that correspond to these three leadership types.

Table 11: Selected Issues on Leadership Skills

No	Statements	Mean	S.D.
4	I learn to be more aware of my surroundings in the console	2.10	0.83
9	I know what my leadership style is after the exposure in the simulation console	2.14	0.84
10	I would most likely act as the spokesperson of my group after the exposure in the simulation console	2.18	0.87
11	I would encourage extra work (no more than average) with the use of simulation technologies	2.21	0.84
12	I would permit the members to use their own judgement	2.25	0.8
13	I would stress being ahead of competing groups because technologies could facilitate better	2.23	0.83
14	I would let the members do their work the way they think best with simulation technologies	2.05	0.85
16	I would tolerate postponement and uncertainty because simulation technologies would help recover the loss time	2.43	1.03
17	I would be willing to make changes because simulation shows the various ways to make them	2.18	0.87

Items No. 1, 4, 7 and 10 are questions for authoritarian style of leadership; items No. 2, 5, 8 and 11 for participative style of leadership; and items No. 3, 6, 9 and 12 for delegative style of leadership. Table 9 presents the respondents' thoughts that they must have the combinations of all leadership styles in

order to function in military organisations. This is because the mean for all items in the table is about 2.00 with the exception of item No. 9 which has a mean of 1.97. This is surprising despite the belief that the respondents value all three styles of leadership in order to function well in their environment, they appear less confident in their comrades to implement a new procedure.

For leadership skills, the respondents showed that they have acquired or rather polished some skills including independence, awareness/alertness and self-discovery. This concurs with the literature examined earlier that student-centred learning can be promoted *more* when using new technologies. Table 11 (from Table 9) summarises the respondents' opinions on their leadership skills. The exception is item No. 9, which actually shows that the respondents confirmed that they are aware of their leadership style after the exposure in the simulator (a mean of 2.14 and standard deviation of 0.84). This confirmation can be back up by the respondents' responses in item No. 1, Table 7 with a mean of 2.19 and standard deviation of 0.84. While it is difficult to discern whether the respondents can actually name the style of leadership that they prefer, the authors strongly argue that the military learning environment in which the respondents are located has contributed a lot to their perceptions of their own leadership styles.

Table 12: Items on Being Authoritarian

		Year of Study			Total
		1	2	3	
1. I always retain the final decision making authority within my group	Almost Always True	5	10	2	17
	Frequently True	8	**42 (40.7%)**	**25 (50%)**	75
	Occasionally True	**17 (44.7%)**	38	19	74
	Seldom True	5	12	3	20
	Almost Never True	3	1	1	5
	Total	**38**	**103**	**50**	**191**
		Year of Study			Total
		1	2	3	
4. When someone makes a mistake, I tell them not to ever do that again and make a note of it	Almost Always True	**20 (52.6%)**	16	10	46
	Frequently True	15	**56 (54.3%)**	**32 (64%)**	103
	Occasionally True	3	22	5	30
	Seldom True	0	7	2	9
	Almost Never True	0	2	1	3
	Total	**38**	**103**	**50**	**191**
		Year of Study			Total
		1	2	3	
7. When something goes wrong, I tell my group members that a procedure is not working correctly and I establish a new one	Almost Always True	13	19	7	39
	Frequently True	**14 (36.8%)**	**44 (42.7%)**	**30 (60%)**	88
	Occasionally True	10	30	9	49
	Seldom True	1	10	4	15
	Almost Never True	0	0	0	0
	Total	**38**	**103**	**50**	**191**
		Year of Study			Total
		1	2	3	
10. Group members seek mainly security	Almost Always True	4	10	2	16
	Frequently True	13	29	**21 (42%)**	63
	Occasionally True	**15 (39.4%)**	**43 (41.7%)**	**21 (42%)**	79
	Seldom True	4	17	6	27
	Almost Never True	2	4	0	6
	Total	**38**	**103**	**50**	**191**

For this paper, the transformative style of leadership will be viewed as a combination of three styles mentioned previously. As explained earlier, the respondents did not get the chance to give their views on this style of leadership. However, it is a critical concept to highlight in this paper for its relevance to military institutions. The authors further argue that in military institutions, the three styles – authoritarian, participative and delegative – will co-exist depending on the situations that warrant each style. This argument is based on a study on leadership by St Xavier's College, Kolkata in 2005.

The authors believe that it is fundamental to look at how the year of studies of the respondents influences their understanding of leadership styles. Table 12 summarises the data based on one type of leadership, authoritarian. What the table demonstrates (and from the data for other leadership preferences) is that there is no significant relations between the year of studies and the respondents' perceptions of these three leadership styles. In general, the senior the students are, the more they agree to items No. 1, 4, 7 and 10. This is a perplexing scenario given that students at the NDUM are exposed to various levels of leadership throughout their studies on campus.

C. Research Question 3

Table 13: Selected Issues on Leadership and New Technologies

No	Statements	Mean	S.D.
1	I am confident that each lesson in the simulator helps my leadership proficiency	1.83	0.91
3	I realise how simulation technologies help me polish my leadership quality	1.88	0.83
5	I learn to be more appreciative of my roles and others in the console	1.96	0.79
6	I am more confident of myself after the exposure in the simulation console	1.80	0.83
7	I am better at managing my time after the exposure in the simulation console	2.31	1.71
8	I better appreciate the sense of urgency after the exposure in the simulation console	2.03	0.81

Based on Table 13 (which originated from Table 8), it could be concluded that the respondents were very positive about the use of simulation technologies to enhance their leadership proficiency. For example, item No. 1 has a mean of 1.83 and standard deviation of 0.91. This suggests that more than 75 percent of the respondents have chosen to agree with the item (choosing scale 1 means "Almost Always True" and 5 "Almost Never True"). This trend is also identical to items No. 3, 5 and 6 with the means of 1.88, 1.96 and 1.80 respectively. All these lead to an initial summary that the respondents were almost adamant in their opinions that simulations could help them in leadership training.

Another aspect of leadership in military institutions is discipline and time management. The respondents felt that with new technologies they are better at managing their time and understand the concept of urgency; this is exemplified by the students' responses to items No. 7 and 8. It is interesting to note that while the learning environment at the NDUM is tight

with different types of activities including academic, physical and military training, the respondents have found a way to appreciate the value of technologies in facilitating their leadership competency. Comparing the year of studies for all respondents may prove interesting since it is assumed that the seniors should have a better ability to manage their time. Table 14 illustrates the third year or the seniors agreed that they are better at handling their time (60 percent of the third year students). However, the first year students were more agreeable to the statement than the second year students (52.6 percent and 46.6 percent respectively). While it is difficult to explain this situation, the authors argue that the second year students may have *lesser* time spent in the simulator since the number of students is comparatively higher than the first and third year students.

Table 14: Time Management and New Technologies

		Year of Study			Total
		1	2	3	
I am better at managing my time after the exposure in the simulation console	Almost Always True	8	11	14	33
	Frequently True	**20 (52.6%)**	**48 (46.6%)**	**30 (60%)**	98
	Occasionally True	7	35	4	46
	Seldom True	2	9	2	13
	Almost Never True	1	0	0	1
Total		38	103	50	191

D. An Evaluation of the Hypothesis

This part attempts to test the hypothesis of the paper which is *new technologies could improve students' awareness and understanding of leadership*. Based on the findings and discussions, the hypothesis needs to be modified. Even though the respondents were very positive about the use of technology for leadership, and that they agreed to some extent that the simulator is able to improve their understanding of leadership and leadership skills, the authors opine that the respondents are more concerned with the lack of facilities for them to practise their leadership competency in the simulator. The respondents asked were all the MTP students and they have the advantages of training with and without technology during their three-year degree programme at the NDUM. They appear appreciative of the technology and what it does to their leadership training, and yet they are also quite sceptical about the facilities in the simulator. Given this, the authors could conclude that this paper has successfully identified the respondents' perceptions of new technologies and leadership training; nonetheless further research is needed to determine the students' adoption of leadership competency outside the classrooms, or the simulator.

VI. Conclusion and Recommendations

Based on the data analysed in previous sections, the simulator could be seen as a tool not only to supplement academic learning, but it is also a tool to support leadership competency. Special attention needs to be paid to how students can be encouraged to actively participate in honing their leadership skills not only in the simulator but also on campus in general. The students need to monitor their own leadership training by participating in leadership activities and articulating their views in appropriate contexts.

Three recommendations could be highlighted to the highest authority at the NDUM based on the findings of this paper,

1) the MTP becomes the internal role model for the adoption of new technologies at the NDUM. The documentations by the department must be shared with the whole university so that the action plans for all departments are clear.
2) the number of simulators must be increased immediately. For a student population of about 250 for the MTP, there should be at least four simulators for the learning and teaching process to be more effective and efficient. At the same time, the existing simulator should be upgraded in order to suit the latest requirements of the maritime and naval industries.
3) new technologies can be used as one part of the assessment procedures for leadership competencies. This suggests that the facilities for all students must be present in order to allow students to feel comfortable and to learn *with* technology and not *from* technology [23].

As this paper is investigating the potential of digital technologies for military cadets as well as civilian students, leadership training has certainly reaped the benefits by using new technologies. This can be seen in the only academic programme that has new technologies, the MTP. Apart from the academic advantages, simulations allow students to improve their awareness and understanding of leadership. The authors argue that at this stage, it is not necessary to identify whether the students embrace a singular authoritarian, participative or delegative style of leadership; or a combination of any of these styles. The most important agenda is to make sure that students are aware of what are expected of them from their parent services; amongst the expectations is their ability to demonstrate leadership prowess when necessary.

Acknowledgment

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Flipped classroom, web-based teaching method analysis focused on academic performance

Radim Špilka, Martina Maněnová

***Abstract*—** The paper aims to introduce the experimental teaching in elementary school, when within half a school year (five months), was to teach mathematics using the flipped classroom method. Teaching took place in the classical pedagogical experiment, where a control group consisted of one class of pupils and the experimental group then the second class of students. Have met the conditions of entry experiment (pupils achieved similar knowledge test score). For the application of the method has been used a short tutorial videos created by the teacher. The subject matter discussed was divided into a total of twenty five animated videos. Students completed the intermediate and final testing. In post-test, a statistically significant difference between the control and experimental group.

***Keywords*—** flipped classroom, web-based teaching, educational video, pedagogical experiment.

I. Introduction

From the beginning of 21st century web-based learning environments have become increasingly pervasive in education. On-line study materials are not only used for distance education, but also school classes offered on-line components that complement classroom activities. Online classes use websites that provide a user-friendly interface and easy access to text, graphics, audio, and video materials that may be used and managed in a consistent and convenient manner. Usually, these websites include basic course information such as syllabus, announcements lists, instructor notes and links to other digital resources, and very often integrate tools for synchronous or asynchronous communication, streaming video, and applications sharing. Online learning is different than traditional classroom-based learning. This is mostly due to the fact that teachers and students do not have face-to-face contact. Thus, the teachers can have little control over their students' learning situations. Online components are accessible when the student needs them and learning is self-paced, providing students the chance to identify their learning goals and objectives and create their own path through course material. Although more flexible than the conventional school classroom learning, the online environment increases complexity. Students are forced to determine their own learning strategies and manage their time and resources [1].

Currently, for the creation of online learning materials use mobile devices (the so-called m-learning). This trend corresponds to a typical behavior of today's Internet users to access content from several sources at once. We talk about the multicreening [2]. Multiscreening is a very strong direction, which are adapted to simple websites and also advanced web applications. One response to this trend is that with websites and applications began to promote the so-called responsive web design. If a page uses responsive web design, it means that it is designed so that its contents and appearance of the device for adapting a window size of website browser. This makes it possible for example that if the page appears on a small mobile phone display, automatically organize elements on the page and place themselves under the navigation links are displayed pop-up menu, which is better suited for touch control. [3].

Current uses of information and communication technologies in education aim to reflect modern practices. One of them is also the flipped classroom method where the learning environment can use any mobile technology.

II. Flipped classroom method

In 2007, high school teachers Sams and Bergmann, from the state of Colorado began recording their hours for students who missed out on their lessons. After some time, they found that the majority of their students use video for repetition, during homework. This formed the basis Flipped classroom teaching methods [4].

At the end of 2004, Salman Khan began explain math through video conferencing. Increasing number of requests for tutoring forced him to record his interpretation, further placed on YouTube. With the growing number of videos as well as their popularity grew. In 2008, Khan founded the nonprofit Khan Academy and launched the first version of its website. His web khanacademy.org contains more than 4,000 educational videos [5].

Flipped classroom model came from blended learning rotation-model implementation in which a given course or subject (e.g., math), students rotate on a fixed schedule between face-to-face teacher-guided practice or projects in classroom during the standard school day and online delivery of content and instruction of the same subject from a remote location after school. The primary delivery of content and instruction is online, which differentiates a flipped classroom from students who are merely doing homework practice online at night. The flipped classroom method accords with the idea that blended learning includes some element of student control over time, place, path, and/or pace because the model allows students to choose the location where they receive content and

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instruction online and to control the pace at which they move through the online elements [6].

In the flipped classroom method is direct interpretation of the teacher replaced online video. Teaching is so that pupils learn through video with the subject matter at home online and come to school already with specific questions. Pupils can embed their questions under video as comment or debate in social network environment, which they share with the teacher. Teacher analyze questions and prepare learning activities focusing on problematical parts of subject matter. Easily understood part of the course will not pay too much attention. In class the teacher uses time efficiently because it focuses mainly those passages of the subject matter, which the students did not understand in educational video. During class, students learn to discuss and ask questions to the studied topics. In a way, they refines knowledge and gain a deeper insight into the issue. From passive listeners to become active learners. At home watching videos every student gets an opportunity to follow in the matter at their own pace. At the same time they learn to be responsible for their own learning. Method flipped classroom gives the opportunity to better understand subject matter and allows each student to reach the maximum of their abilities [7].

III. Math Animated Educational Video

Flipped the context of innovation at all levels of the education system, the use of information technology and communications tools is becoming increasingly common practice. These technologies in education, enabling integration into an active method of teaching.

Thus, the use of new teaching-learning tools, as postcasting and networked educational videos [8], are tools in expansion within the academic setting. But the speed with which these technologies have appeared and progressively consolidated, lead to get first evidences in this moment and draw real possibilities scenario, in order to identify more efficient and effective learning methods and improve teaching quality.

Caspi, Gorsky and Privman [9] divide educational videos into three categories depending on use and purposes: demonstration videos, narrative videos and lecture sessions videos. First of these categories, demonstration videos, are a really good tool for explaining the technical and natural sciences in order to allow and improve autonomous learning, becoming more effective than other methods based on more traditional teaching, such as books and written or oral manuals.

Mathematics is a systematic way of thinking that creates solutions to real events. In teaching math teacher try to model reality through simplification. In mathematical educational videos just animation allows to simplify and allows students to focus on understanding the nature of mathematics. Widely used option is screencasting [1], the creator of the video is recorded using the software of your notes and display the records in your comment. Another option is to create a method of direct video animation without disturbing the cursor. The method of direct animation, there are sophisticated commercial programs or you can use a combination of freeware software resources.

Therefore, this method allows educators, to develop new teaching and learning strategies, adding a new dimension in the teaching material.

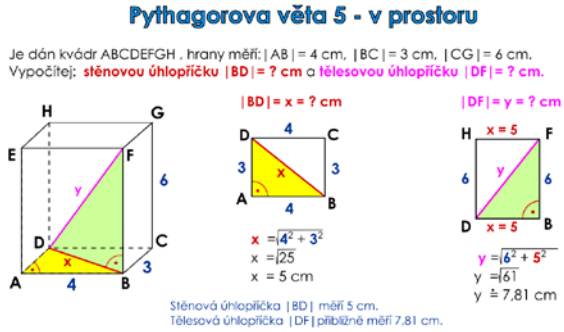

Fig. 1 Screenshot from direct animated educational video

IV. The Project

Traditional teaching methods (such as explanation, dialogue, description, laboratory exercises, etc. [10] and motivational teaching methods (such as dramatization, project training, field training, etc. [10] are used in conditions of secondary level of primary schools in the Czech Republic. The use of information and communication technology brings new possibilities, new procedures and methods. The project was focused on the application of flipped teaching method, when pupils learned some chapters of mathematics through educational online screencasts.

A. The project Aims

The aim of the research project was to implement training using the flipped classroom method and find out whether this method can help to increase students' academic performance. Based on your goals we have set the following hypotheses:

H_{01}: *In the resulting average score of pre-test we do not expect statistically significant difference between the control and experimental students groups.*

H_{02}: *In the resulting average score of intermediate test we do not expect statistically significant difference between the control and experimental students groups.*

H_{03}: *In the resulting average score of post-test we do not expect statistically significant difference between the control and experimental students groups.*

B. Methodology

Long term classical pedagogical experiment was used to verify the functionality of created screencasts [11]. We worked with the control and experimental group (always one class of the same school year). The control group of pupils progressed by traditional teaching methods, especially new exposition of the new curriculum took place during lessons. The experimental group had available educational videos that was specially created for the purpose of the experiment. For

distribution educational videos were created websites (prevracenatrida.cz).

Fig. 2 Infograpic from website (prevracenatrida.cz)

There we also explain, what flipped classroom teaching method is. Students watched video during home preparation. They had the opportunity to comment each video and discuss the problematic part of the matter on the social network. Brief summary of the topic and explanation of the problematic parts was performed in classes. Emphasis was placed on independent work and deepening knowledge. At the beginning of the experiment the control and experimental group went through a didactic test (pre-test). In the middle of experiment students pass intermediate test. At the end of the experiment both groups then passed another didactical test (post-test). Twenty-five educational videos were created that cover the mathematics curriculum first half of the eighth grade. The researcher was also a math teacher for the experimental group.

At the end of pedagogical experiment pupils of the experimental group filled out a simple questionnaire, which consisted of three closed questions. The questionnaire was chosen as a fast feedback of pupils to the new method. Pedagogical experiment was conducted from September 2013 to January 2014.

Statistical software NCSS and Excel was used for data processing. Basic values of descriptive statistics were calculated for testing hypotheses, then Student t-test and the Mann-Whitney nonparametric test whereas the normality tests did not confirm unequivocally normal distribution of the collected data. Hypotheses were tested at a significance level $\alpha = 0{,}05$.

C. *Research sample*

Pedagogical experiment was attended by 54 students, 27 in the control and experimental class (Fig. 3, Fig 4).

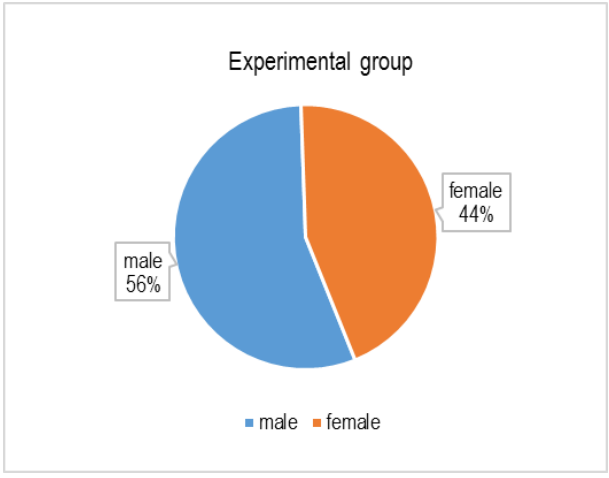

Fig. 3 Distribution experimental groups by gender

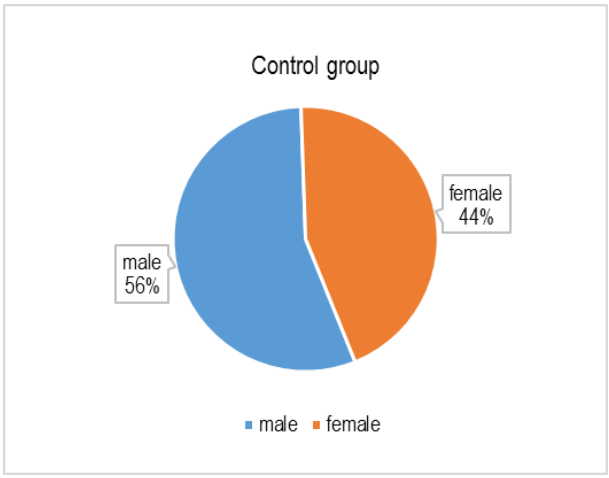

Fig. 4 Distribution control groups by gender

The average age of students in the control group was 13.4 years (standard deviation 0.96) in the experimental group was 13.2 (standard deviation 1.15).

D. *The research results*

The basic task to enter the pedagogical experiment was to compare the input knowledge of students. The pupils finished entering pre-test, the descriptive results are shown in Table 1.

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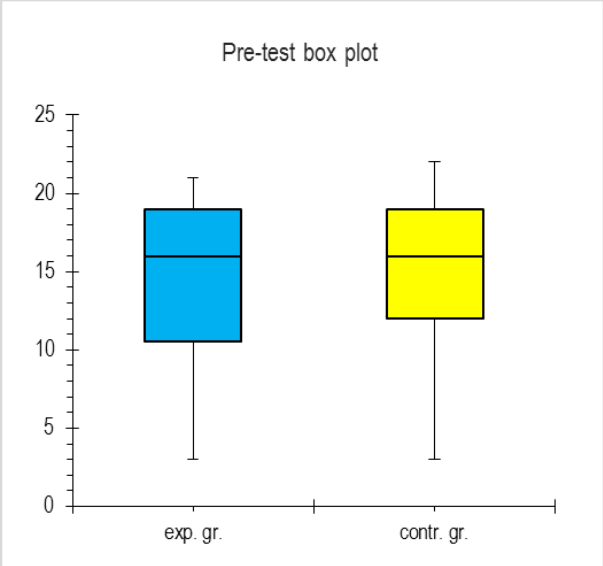

Fig. 5 Box plots for data of pre-test

Table 1 Descriptive Statistics for pre-test

	Experimental group	Control group
Mean	14,3	14,4
Standard deviation	5,45	6,1
Mode	19	-
Median	16	16
Minimum	3	3
Maximum	21	22
Range	18	19

To compare the level of knowledge of mathematics in the control and experimental groups of students, we drew on we drew on the formulation of the null hypothesis: null hypothesis:

H_{01}: *In the resulting average score of pre-test we do not expect statistically significant difference between the control and experimental students groups.*

The test results are shown in Table 2, and then Figure 5 shows the distribution of the input results in both groups

Table 2 Results for T-test and Mann-Whitney test for pre-test

	t-test	Z-value	Hypothesis H01
Control group	-0,0959	-0,3213	Accept
Experimental group			

Based on the results of the Student's T-test and Mann-Whitney test (see tab. 2) has been accepted and the null hypothesis was thus fulfilled the basic requirement of pedagogical experiment that the input is no difference between the control and experimental groups in the observed variables.

For this testing and subsequent testing of intermediate and output simultaneously with the parametric Student's t-test, nonparametric Mann I-Whitney test, because the data obtained clearly not a normal distribution (normality of data was tested by Kolmogorov Smirnov test, D'Agostino Skewness tests, D'Agostino Kurtosis and D'Agostino Omnibus).

Given that pedagogical experiment continued five months, we performed an experiment in intermediate continuous testing. Descriptive statistical results of both groups are shown in box plot (Fig. 6) and Table 3.

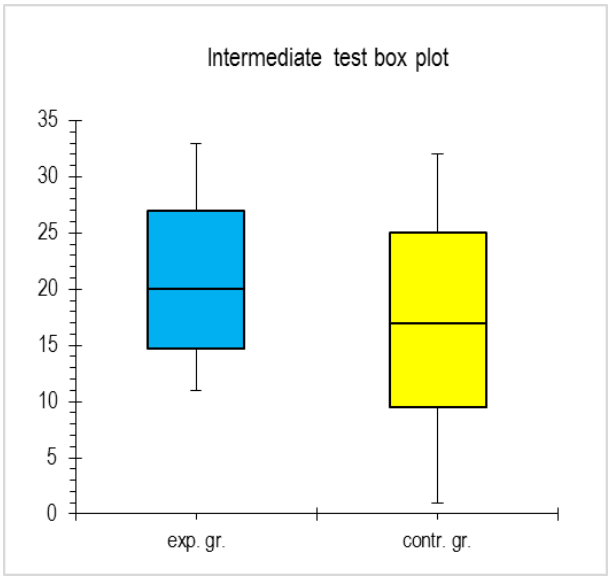

Fig. 6 Box plots for data of intermidiate test

Table 3 Descriptive Statistics for intermediate test

	Experimental group	Control group
Mean	21,0	16,7
Standard deviation	7,41	9,66
Mode	12	-
Median	20	17
Minimum	11	1
Maximum	33	32
Range	22	31

When comparing the results of the experimental and control groups, we drew on the formulation of the null hypothesis:

H_{02}: *In the resulting average score of intermediate test we do not expect statistically significant difference between the control and experimental students groups.*

In intermediate test (after approximately 2.5 months of experimental teaching) were not statistically significant differences in student performance. Null hypothesis was accepted .Testing was carried out using the same statistical tests as input and test results are reported in Table 4.

Table 4 Results for T-test and Mann-Whitney test for intermediate test

	t-test	Z-value	Hypothesis H02
Control group	1,8035	1,6124	Accept
Experimental group			

At the end of January (at the end of the fifth month of experimental teaching) was lower the output test. The descriptive results are shown in and Table 5. From fig. 7 can be seen that the experimental group students achieved higher test scores than the control group.

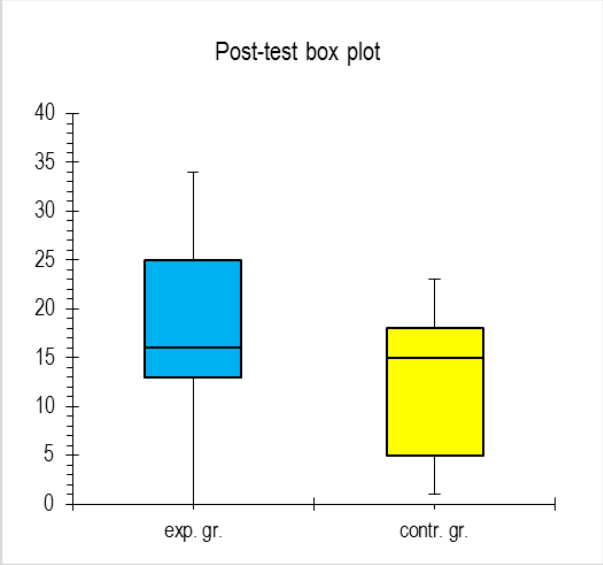

Fig. 7 Box plots for data of post-test

Table 5 Descriptive Statistics for post-test

	Experimental group	Control group
Mean	18,2	12,6
Standard deviation	7,87	7,02
Mode	-	-
Median	16	15
Minimum	0	1
Maximum	34	23
Range	34	22

Again we used the same procedure and taking the formulation the null hypothesis, we tested using Student's t-test and the nonparametric Mann-Whitney test.

H_{03}: *In the resulting average score of post-test we do not expect statistically significant difference between the control and experimental students groups.*

Results of testing the output of the test are shown in Table 6 and box plot (Fig. 7).

Table 6 Results for T-test and Mann-Whitney test for post-test

	t-test	Z-value	Hypothesis H03
Control group	2,6763	2,2093	Reject
Experimental group			

From the results shown in Table 6 shows that we reject the null hypothesis and we can conclude that he was found statistically significant difference in test results output in the control and experimental groups of pupils.

The results of the questionnaire showed that 96 % of pupils well understood screencasts content, to 89 % of pupils videos helped to understand the new mathematic matter and 96 % of pupils would like to continue teaching mathematics by flipped classroom method.

V. Conclusion

After evaluating the long term pedagogical experiment we can conclude, that there was significant difference in achievement (evaluated based on post-test) between pupils of experimental and control groups in the selected thematic unit of mathematics. Flipped classroom method, when students are studying a new educational material using educational animated videos, did significantly affect academic performance of students. Creative videos were evaluated positively. We assumed that the new method of teaching pupils interested, especially because the use of modern technology. Which was confirmed.

Research studies met our goals. Method of flipped classroom was tested in educational practice and based on long term pedagogical experiment using simple reflection questionnaire, we received useful result of testing this method in teaching.

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Properties of Thinking and Adoption of Mathematical Knowledge

Valentina Gogovska, Katerina Anevska, Risto Malcheski

Abstract. *In mathematics instruction, basic and derived mathematical concepts, procedures, laws, and regularities are adopted, and different types of thinking are developed, i.e. the properties of thinking are adopted which enable students' development of creativity, acquisition of formal knowledge and skills. This paper reviews the properties of thinking and provides possibilities for development of the properties of thinking through appropriate examples.*

Keywords **-** Appropriateness, breadth, critical, depth, flexibility, formalization and rationality thinking.

I. INTRODUCTION

What is mathematical thinking? Does it really exist? If the answer to the second question is affirmative, then we have to admit that there is also physical, biological, chemical, geographical thinking, and many more, or in other words, there are as many ways of thinking as there are scientific disciplines. Clearly, this is not entirely acceptable. However, the accepted methods of reasoning and structuring of knowledge in mathematics and in other disciplines, as well, are substantially different because in different scientific disciplines different methods are used for reasoning and structuring of knowledge. In any science, according to the character of the researched object, certain approaches and methods of reasoning are imposed as dominant or merely permissible. We can see form the history of mathematics that the following approaches and methods are imposed in mathematics:

i) Technical procedures based on determined operations and relations,

ii) Defining concepts with the exception of the basic concepts, bearing in mind that definitions include only minimal properties sufficient for the identification of the appropriate objects,

iii) Logical thinking used to prove the object's properties, except for the basic properties otherwise known as axioms.

The elements from these approaches and methods are found in all other scientific disciplines as well, but for a number of reasons, in mathematics they are imposed as merely permissible. We can say that the previously mentioned methods and procedures determine the properties of thinking that form the so-called mathematical thinking and they are: *flexibility, formalization, depth, appropriateness, rationality, breadth, and critical thinking*.

Valentina Gogovska Ph.D. is with the Faculty of natural science and mathematics, Skopje, Macedonia (corresponding author to provide phone: +389 70 240999; e-mail: valentinagogovska@gmail.com).

Katerina Anevska M.Sc. is with FON University, Skopje, Macedonia.(e-mail: anevskak@gmail.com).

Risto Malcheski Ph.D. is with the FON University, Skopje, Macedonia (e-mail: risto.malceski@gmail.com).

II. CHARACTERISTICS OF THE PROPERTIES OF "MATHEMATICAL" THINKING

Flexibility of thinking is characterized by the ability to easily pass from one way of solving the problem to another, discover new ways of solving the problem when the conditions change, and restructure the system of knowledge that enables adoption of new knowledge. An effective way to develop flexibility of mathematical thinking and creating conditions for its appearance is conscientious discovery of all activities that can be fulfilled when adopting and applying each theorem. Clearly, all this contributes to the systematization of knowledge. Regarding students in primary education, the flexibility of thinking can be best developed by finding more ways to solve one and the same task, as shown in the following example.

Example 1. *In how many ways can we distribute eight pencils to three students so that each student receives at least one pencil?*

We will provide two different methods to solve this task, and the transition from one way of solving the task to the other is due to the elasticity of thinking.

Method I. The following represents the distribution of 8 pencils to three students, so that the first student gets two, the second student four and the third student two pencils:

$$\bullet\bullet|\bullet\bullet\bullet\bullet|\bullet\bullet$$

All possible distributions of the pencils are represented in the following table (x represents the number of distributions):

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The first student gets	the second and third student get	x
1 pencil	1+6, 2+5, 3+4, 4+3, 5+2, 6+1	6
2 pencils	1+5, 2+4, 3+3, 4+2, 5+1	5
3 pencils	1+4, 2+3, 3+2, 4+1	4
4 pencils	1+3, 2+2, 3+1	3
5 pencils	1+2, 2+1	2
6 pencils	1+1	1
	Total	21

Accordingly, 8 pencils can be distributed among three *students, thus each students receiving at least one pencil, in 21* ways.

Method II. If we use the previous drawing and the empty places between the pencils, which are 7, and we mark them with the numbers 1, 2, 3, 4, 5, 6 and 7, then we get a new situation which is shown in the following drawing:

$$\bullet^1\ \bullet^2\ |\ \bullet^3\ \bullet^4\ \bullet^5\ \bullet^6\ |\ \bullet^7\ \bullet$$

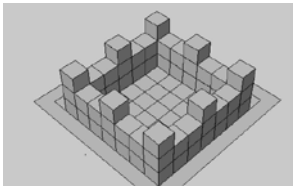
Further, we note that the distribution in the drawing is determined by the empty places 2 and 6, i.e. the number 26. Clearly, to each distribution corresponds a two-digit number, to different distributions different numbers. Reversely, to each of the numbers presented in the following table corresponds one and only one distribution.

12 13 14 15 16 17
23 24 25 26 27
34 35 36 37
45 46 47
56 57
67 .

There are total of 21 two-digit numbers, hence follows that the number of distributions of 8 pencils to three students, thus each students receiving at least one pencil, equals 21. ■

Teachers in primary education face a serious problem in the attempts to develop flexibility of thinking in students, because the obstacle lies in the small quantum of adopted mathematical knowledge. However, the following example shows that this should not be considered an obstacle for the development of this important property of thinking.

Example 2. *The drawing represents a castle built of blocks. How many blocks are used to build the castle?*



We will provide two different methods to solve this task, where the transition from one way of solving the task to the other is due to the elasticity of thinking.

Method I. There are 8 blocks in the top row of the castle, and $8+16=24$ blocks in the remaining two rows of the castle. Therefore, the castle is built of total $8+2\cdot 24=56$ blocks.

Method II. The castle is built of 8 towers, each tower made of 3 blocks. Between the towers there are 8 walls each built of $2\cdot 2=4$ blocks. Therefore, the castle is built of total $8\cdot+8\cdot 4=56$ blocks. ■

Formalization of thinking is a serious obstacle for creative thinking. It normally occurs because of inappropriate organization of the teaching process and the influence of false analogies, the application of which is not conscientiously directed by teachers. Observation shows that when solving tasks students usually follow adopted patterns. For example, when solving the inequality $2+5x-7x<1$, following the pattern for solving linear equations, students subsequently get $5x-7x<1-2$, $-2x<-1$ where instead of $x>\frac{1}{2}$ they find $x<\frac{1}{2}$.

Formalization of thinking explains typical mistakes in algebra made by students, like for example "simplifying":

$$\frac{a+b}{a+c}=\frac{b}{c}.$$

Formalization of thinking is also connected with the effect of the so-called "functional stability", according to which the object is used only in the given form, without needing a new quality, which cannot be clearly seen from the given conditions, but nonetheless follows from a theorem or definition. Functional stability is characteristic for tasks provided in the following example.

Example 3. When solving the following task:
The parallel lines AB and CD are intersected by the line OD. One of the interior angles in point O is 130° and the ray OM is the bisector of this angle. Find $\angle OMD$.
difficulties occur with the bisector OM as a transversal, that is, the students' inability to realize this property of OM. This situation can also be a consequence of the incomplete adoption of definitions, axioms and theorems because the realization of the new characteristic of a given object relies on them. ■

In order to overcome formalization of thinking, it is necessary to guide students with comments like:

- Try solving this task in a different way, and remember there are many ways to solve it, not just one.
- Do not use standard methods only.
- Can we formulate this task in a different way?

However, formalization of thinking does not only have negative consequences. Namely, it helps to avoid adoption of previously adopted knowledge for the operations, which through multiple repetitions transform into technical procedures, and the previously adopted formulas and theorems. In addition, formalization can be useful while discovering certain algorithms; therefore, it should be creatively nurtured with tasks as shown in the following example.

Example 4. Mirjana drew three figures made of hexagons,

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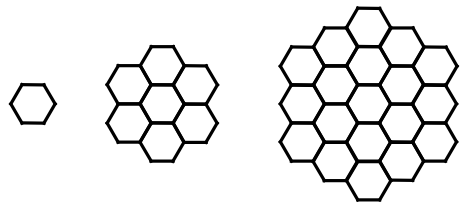
as shown in the picture. She continued drawing the pattern in the same manner. How many hexagons does the fifth in the row figure contain?



Solution. The first figure contains one hexagon. The second figure contains $3+2\cdot 2=7$ hexagons. The third figure contains $5+2\cdot 4+2\cdot 3=19$ hexagons. The fourth figure contains $7+2\cdot 6+2\cdot 5+2\cdot 4=7+12+10+8=37$ hexagons. The fifth figure contains

$$9+2\cdot 8+2\cdot 7+2\cdot 6+2\cdot 5=9+16+14+12+10=61$$

hexagons. ■

Depth of thinking is characterized by the ability to gain insight into the essence of the studied facts, to see their connection with other facts, to model different situations, to discover how these models can be used in practice, etc. Clearly, structuring and adoption of mathematical knowledge prefer the depth of thinking, but at the same time they develop it, that is, they contribute to overcome superficial thinking.

The depth of thinking can be tested and formed with the help of questions and tasks formulated especially for that purpose, as the following:

For real numbers, the following operations are defined: addition, multiplication, and raising to the power (which is partial). Why do we have two inverse operations at raising to the power: extracting roots and logarithming, and only one inverse operation at adding and multiplication, subtraction and division accordingly.

Obviously, the answer to this non-standard question can be expected only from students that have greater depth of thinking. Namely, only these students will connect the answer of this question to the fact that the operation raising to the power is not commutative, that is, $a^b \neq b^a$, for $a \neq b$ and therefore it has two inverse operations.

In addition to the guidance of students by the presented or similar questions, it is desirable that the teacher uses some "non-mathematical" tasks, like the following:

Slavko and his son, and Jordan and his son are fishing. Slavko caught as many fish as his son and Jordan caught three times more fish than his son. All the caught fish totals 35 fish. Slavko's son is Nikola. What is the name of Jordan's son?

Obviously, when solving this task, students will easily get the equation of type $2x+4y=35$ and majority of them will realize that this task has no solution. However, students with greater depth of thinking and non-dominant formalization of thinking will look for the solution in the family relation between Slavko, Jordan and their sons, i.e. they will realize that the task only makes sense if Jordan is Slavko's son.

Appropriateness of thinking is the ambition to fulfill a rational selection of methods and means for solving a problem, continually concentrating on the goal set in the problem, and discovering the shortest paths to fulfill it. Proving of theorems and solving tasks in general in mathematics teaching is an irreplaceable tool for the development of skills for the selection of means (definitions, axioms, theorems) to achieve the set goal. However, appropriateness of thinking is closely linked to curiosity and is most frequently described by the questions: "Is it like this?", :Why?", "What will happen if I do things in a different way?" etc. therefore the teacher should continually nurture students' curiosity.

Improvement in the students' appropriateness of thinking can be achieved through systems of tasks similar to the system in the next example.

Example 5. When studying prime and complex numbers, students often encounter tasks of the following type:

a) Prove that for any natural number $n>1$ the number n^4+4 is composite.

b) Prove that the natural number $2^{2006}+5^{2004}$ is composite.

c) Prove that the number of type $4n^4+1$, $n\in\mathbf{N}$ is prime only if $n=1$.

d) Prove that for every $n>1$ the natural number n^4+4^n is composite.

e) Prove that the natural number 2005^4+4^{2005} is composite.

These tasks are appropriate for the improvement of students' appropriateness of thinking, and teachers can accomplish this if they follow the subsequent procedure:

- Students understand that each of the given numbers is of type a^4+4b^4,
- Teachers ask students, using the formulas for abridged multiplication,

  $(a-b)(a+b)=a^2-b^2$ and $(a+b)^2=a^2+2ab+b^2$

  to prove Sophie Germain's identity:

  $$a^4+4b^4=(a^2+2b^2+2ab)(a^2+2b^2-2ab),$$

- Write each of the given numbers in the form a^4+4b^4 and apply the previously proved identity. ■

Appropriateness of thinking enables the appearance of one more property, an that is *rationality*. This property is characterized by the economy in relation to the necessary time and means for solving a given problem. In mathematics teaching, it occurs through the so-called rationality at performing calculations. This is based on some general statements, which in a final form, as an "essence", contain other operations and instead of all of them, only one activity is performed, for example, formulas of abridged multiplication.

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This fact contributes to making these rational activities attractive to students, therefore, it should be used to motivate students to learn mathematics. Improvement of students' rational thinking can be achieved by type of tasks as in the following example.

Example 6. Calculate: $64^2 - 36^2$ and $267^2 - 117^2$.

Solution. If we use the formulas for abridged multiplication, we get:

$$64^2 - 36^2 = (64+36)(64-36) = 100 \cdot 28 = 2800$$

and

$$267^2 - 117^2 = (267-117)(267+117) = 150 \cdot 384$$
$$= (100+50) \cdot 384 = 38400 + 19200 = 57600,$$

where in the second part, the distributive law for addition and multiplication of real numbers is skillfully used as well. ■

Breadth of thinking is characterized by the ability to encompass problems as a whole, to broaden the application of the obtained results, etc. The application of mathematical symbols and technical procedures should be conscientiously used to convince students in the rationality and strength of mathematical symbolism, thus developing the breadth of thinking. We can achieve this through a well-selected system of tasks, after solving several tasks of this type, providing and solving a general task which includes the previous tasks as partial cases. Accordingly, the nurture of students' breadth of thinking can be achieved through tasks as shown in the following example.

Example 7. *Are the numbers* 276276, 458458, 764764 *divisible by* 13?

We can solve this task by a separate immediate trial for each of the listed numbers. However, if we write these numbers in the form:

$$\overline{abcabc} = \overline{abc} \cdot 1000 + \overline{abc} = 1001 \cdot \overline{abc},$$

then, out of $13 \mid 1001$ follows that the numbers are divisible by 13. Clearly, we can immediately conclude that these numbers are divisible by both 7 and 11. ■

The breadth of thinking comes to the fore when we try to simplify the task from example 3. Namely, if we give this task to high school students, then to the question:

How many hexagons does the $n-^{th}$ *figure contain?*,

it is logical to expect from students with highly developed breadth of thinking to realize that the $n-^{\text{th}}$ figure is symmetrical, in the middle there is a sequence of $2n-1$ hexagons, and on the left and right there is a $n-1$ sequence each consisting subsequently of $2n-2, 2n-3, ..., n$ hexagons. Obviously, after these realizations, students answer that the $n-$ figure consists of

$$(2n-1) + 2[(2n-2) + (2n-3) + ... + n] = 2n-1+(n-1)(3n-2)$$

hexagons.

Critical thinking is the property not to accept different opinions without enough arguments, but to subject them to assessment. Clearly, critical thinking is one of the qualities that led humanity to the necessity of conviction in the accuracy of the statement and finding objective criteria for the assessment of their truthfulness. Convincing the individual in the accuracy of the statements is an effective tool to develop students' creativity. At the same time, we should take into consideration that this is the best way, in mathematics teaching, to introduce students to the deductive way of thinking and its application. Hence, the best way to nurture critical thinking is to solve:

- textual tasks with constructing mathematical models,
- tasks with proving identities,
- tasks from elementary theory of numbers, etc.

III. CONCLUSION

Nurturing the qualities of thinking, i.e. the improvement of the same, should be a continuous activity for every teacher. Therefore, during the adoption of new knowledge and skills, as well as during reviewing of adopted knowledge and skills, well-planned and organized activities are necessary in the direction of improving the qualities of thinking of every student individually. The last is of special importance because the heuristic activity in teaching is not possible unless students have significantly developed *flexibility, appropriateness, depth, breadth of thinking and critical thinking*.

Naturally, successful nurture of the qualities of thinking of every student individually can be achieved if:

- The teacher is capable to accomplish this important and delicate task,
- The teacher has enough teaching time available, and
- Textual and other didactic resources support the nurture of the students' quality of thinking.

It is very difficult to answer to what extent and manner the mentioned conditions are fulfilled. However, we can say that greater part of the textual didactic resources insufficiently supports the nurture of quality of thinking, and another problem arises with the tendency to reduce the number of mathematic classes. Regarding teachers' training to nurture students' quality of thinking successfully, it appears that this problem can be solved very quickly. Namely, almost without exception, teachers have the necessary mathematical knowledge and foreknowledge of psychology, therefore their further training can be fulfilled within a continuous additional education implemented in every country.

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Architecture framework for control strategies under risk and hazard conditions – CONTROL STRATEG

Gheorghe Florea[1], *Radu Dobrescu*[2],*

[1]Societatea de Inginerie Sisteme SIS SA, Bucharest, Romania
[2]Politechnica University, Bucharest, Romania
*Corresponding Author: gelu.florea@sis.ro

Abstract - The main motivation and the driving force behind the Control Strateg strategy is the need to respond to the main drawbacks related to the efficient control and risk management of safety-critical applications through the use of advanced data processing and intelligent control techniques that will enable the development of integrated generic and reliable control solutions. The aim of the Control Strateg project is to develop an integrated platform that will offer the much needed support for the decision making process at an organizational level regarding the safe operation of industrial plants and achievement of strategic objectives. The proposed system will tackle some of the most important problems related to the safe management of such applications, namely the early identification of potentially harmful situations and the optimization of the controlled process behavior, both under nominal operating conditions and in the presence of failures and malfunctions that have a negative influence on the system stability and dynamic performances.

Keywords - fault detection, safety shut-down strategies, risk and hazard conditions, data warehouse, integrated platform

I. INTRODUCTION

We live in a modern industry based society where automation undoubtedly is the key for success. The technology has been changing over the last decades toward full control systems and the requirement specifications for Safety Instrumented Systems (SIS) goes to more than a safety system, working together to have the ability to maintain the process running even with less functionalities instead of shut down. The integration of the Fault Detection and Diagnosis, Risk Analysis, Risk and Hazard Control, Reconfigurable Control strategies and System Optimization components within the same safety, security and control application is the main distinctive feature of the Control Strateg strategy.

The field of automatic control for the safe operation of industrial plants, while rather conservative for a long period of time, has been undergoing significant developments during the last two decades as a result of the increasing control demands of safety-critical complex applications. Therefore, it becomes obvious that the classical control solutions are no longer sufficient in the context of a modern industrial society, and that process control and automation technology are definitely the key factors for success.

For this reason, more complex control applications have been developed in order to tackle the various problems related to the efficient risk management of safety-critical plants, namely system optimization, early fault detection and diagnosis, system reconfiguration or restructuring, on-line risk assessment and analysis, prevention of potentially hazardous situations, energy efficiency.

Global requirements of control application in time and with critical environments should lead to the integration of computing, communication and storage capabilities within entities in the physical word [1]. As a result, significant effort has been made for the development of new integrated systems that will respond to all these problems, thus offering powerful support tools for the total risk management of complex industrial installations. There are, however, certain aspects that should be further addressed in order to ensure that such a solution provides the accurate answers to the above mentioned problems in an efficient manner, within the rather restrictive constraints given in real-time control applications.

More complex control applications have been developed in order to tackle the various problems related to the efficient risk management of safety-critical plants but these subjects have been treated rather disparately and the lack of an integrated control solution is becoming a major drawback for any organization that operates in this field.

The most important problem is the fact that there is a very large volume of data involved in the decision making process stored in disparate collections that are used for very specific purposes and serve the needs of different types of users and little effort is being made towards the integration of the separate data streams into a single coherent database; this could then be manipulated more easily and become the building block for a strong knowledge base that will ensure the continuous optimization of the proposed solutions.

During the last decades, the industry has been investing heavily both in Automation Control Systems (ACS) and in Management Information Systems (MIS), like Manufacturing Execution Systems (MES), Enterprise Resource Planning (ERP) or Supply Chain Management

(SCM). The information systems that are used for monitoring and management of industrial plants are usually hierarchically structured in order to deal with the large collection of functional components. However, when it comes to risk analysis and hazard prevention, the monitored process information is far from being used efficiently. Moreover, complex software systems tend to be unpredictable and this is not acceptable in safety-critical application such as chemical and petro-chemical plants or power production plants.

When it comes to risk analysis and hazard prevention, the monitored process information is far from being used efficiently. Majority of the available solutions rely heavily on hardware redundancy, while analytical redundancy [2], plays a least important role. There is a stringent need for more precise and versatile modeling and simulation tools for continuous processes [3].

Since industrial plants often operate near criticality points, in conditions that are far from ideal from the point of view of their controllability and stability, safety is an important aspect of nowadays process control applications; this is, unfortunately, a results of the numerous accidents that occur in industrial plants and that compel the industry to take a better look at current practices like process design, process control, risk analysis and management. Consequently, worldwide organizations have developed standards for the engineering of process safety.

Stand-alone safety systems are the traditional method but this means separate design and operation requirements for Basic Process Control Systems (BPCS) and Safety Instrumented Systems (SIS) [4].

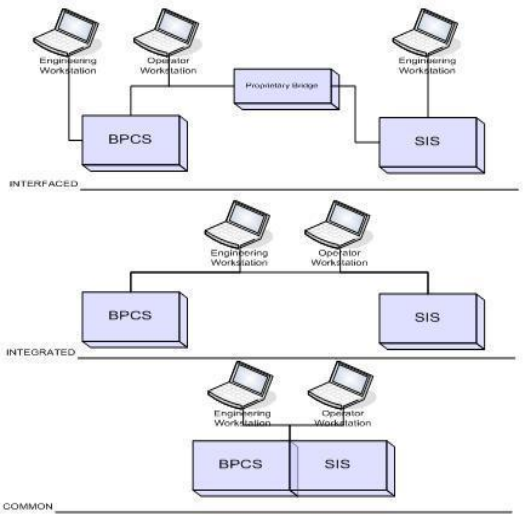


Figure 1. SIS and BPCS Integration Levels

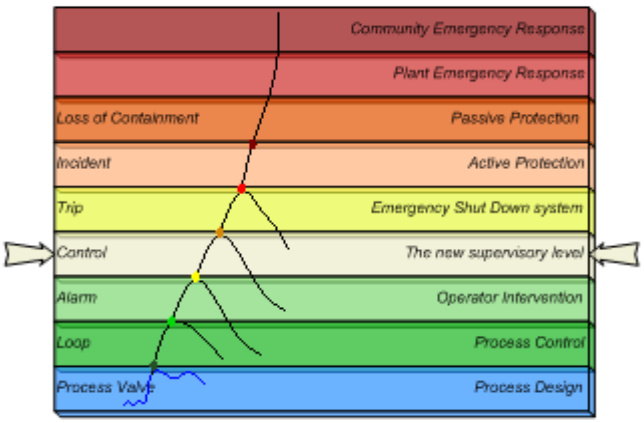
Separate systems were developed for process control and for safe operation, but this is an approach that affects the cost of infrastructure acquisition, system integration, control and instrumentation hardware, wiring, project execution, installation and commissioning, as well as ongoing expenses such as training, spare parts procurement and logistics contracts. Integrating safety and control has become a cost effective way for manufactures that could not justify a separate SIS.

According to process safety standards, the process risk has to be reduced to a tolerable level as set by the process owner. The solution is to use multiple layers of protection, including Basic Process Control System (BPCS), alarms, operator intervention, mechanical relief system and a SIS. The BPCS is the lowest layer of protection; Operator Intervention (OI) attempts to solve the problem SIS Layer brings the plant in a safe condition. The author's approach [5] is based on the introduction of a new decision level – Risk and Hazard Control and a new state of the process-safety state. The layers of protection and also the impact over the process are illustrated in the picture below.

When it comes to the automatic control of industrial processes, a common practice consists of using a hierarchical structure with three levels, namely the executive one, the supervisory one and the decision making one. The executive

Figure 2. Layers of protection and impact of the process

Level is in charge of computing the corresponding



commands based on the data acquired from the process and on the given set-points. The supervisory level offers the system operators the possibility to monitor the system status and to manage unexpected events. Finally, the decision level is in charge of determining the optimal functioning regime so that a number of quality criteria, like production quantity or energy efficiency, are maximized; this is performed through the computation of the corresponding set-points that are further sent to the executive level.

Unfortunately, the majority of the control systems that are in use nowadays only take into consideration the optimization of the process behavior under nominal operating conditions. When the system functioning point is driven outside the boundaries of the admissible domain as a result of perturbations r of the occurrence of a fault, however, the generally accepted practice is to proceed to the system shut-down; this is a costly and inefficient procedure that could be avoided in a significant number of cases. It is needless to say that the provided solutions, limited as they are, only address a certain type of users, namely the system

operators. Other applications are needed in order to support the decisions taken at higher levels in the management structure of the organization.

II. MATERIALS AND METHODS

The proposed approach is a hybrid one, combining elements of the classical Fault Tolerant Control Systems (FTCS) with certain techniques that are characteristic to Artificial Intelligence (AI) in order to obtain a reliable and generic risk management application to be used in a wide range of industrial plants.

The proposed system responds to the needs of plant monitoring, control and management and will represent a powerful support tool for taking the best decisions in critical situations, under severe time constraints. Moreover, the architecture that will be adopted for the integrated system, control strategies and algorithms that will be implemented, will guarantee the successful coherent integration of a large volume of data from various disparate sources and the efficient manipulation of this data, which are the most important requirements from the point of view of the successful implementation.

The technical approach will be based on reusability in the broadest sense using functional blocks. Object technology can be one of the cornerstones of this approach. Reusability can be achieved for any stage in the system life cycle: from requirements and design to commissioning and maintenance. The approach is based on the availability of design template and reusable component implementation with few design compromises. These implementations are flexible enough to be adopted or modified to fit new requirements with little effort. Function block based development and integration middleware concepts provide the basis for reusability. Risk and Hazard Control will incorporate components for process control, safety and security, risk analysis, optimization.

The system will make use of advanced processing techniques for a large amount of data that will be acquired from various sources and that is relevant for the accurate description of the process status at all time and also of intelligent control techniques in order to perform on-line risk assessment based on fault diagnosis and statistical analysis, on the one hand, and also to establish the optimal control strategies in view of maximizing the production potential hazards and unnecessary plant shut-downs during impaired operation, on the other hand.

The Control Strateg strategy will offer solutions to most of the problems related to the efficient supervisory control of safety-critical applications, like chemical and petro-chemical plants, energy production plants, utilities storage and distribution, while also establishing a strong knowledge base for further developments in the field for the constant improvement of the proposed solutions.

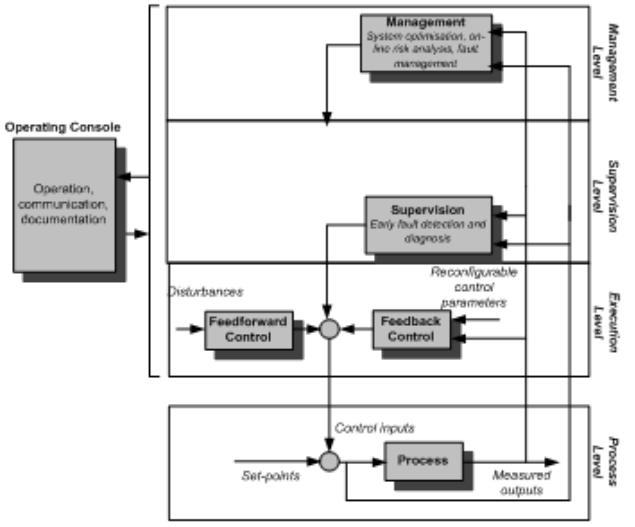


Figure 3A. Classical Control System Architecture

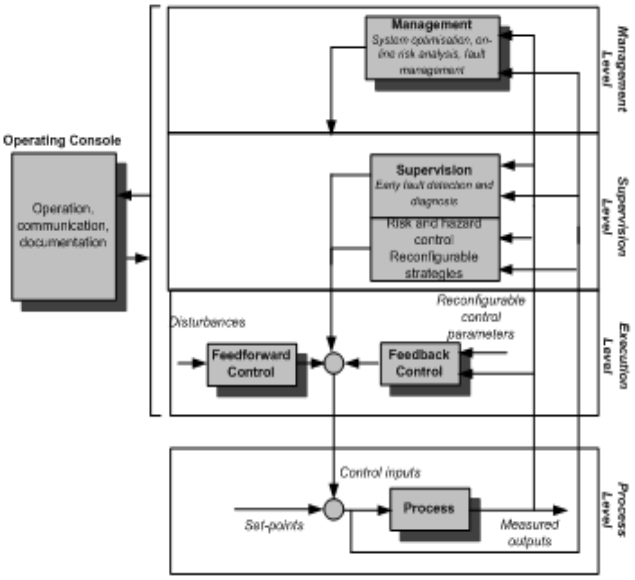


Figure 3B. Control Strateg System Architecture

In comparison to the classical approach, the Control Strateg strategy proposes a solution that will determine the optimal control strategies for a wide variety of industrial applications, both under nominal operating conditions and in the presence of system faults, perturbations or modeling uncertainties that can affect the behavior of a plant in such manner that not only the dynamic performances are degraded, but also the system stability is loss. The basic idea is to make use of all the available data from the plant in order to establish the need for system reconfiguration or restructuring in order to accommodate the detected faults and to determine the best strategies that will guarantee the closed-loop stability and the graceful performance degradation, while avoiding the plant shut-down whenever this is possible.

Figures above illustrate the main differences between the majority of the control systems that are in use nowadays for the management of industrial plants and the solution

proposed by the Control Strateg strategy.

The first important aspect that differentiates the two approaches is the utilization of the available data describing the process behavior, both instantaneously and in time. More precisely, the Control Strateg system will provide an efficient way of integrating a large volume of data from rather disparate sources in order to obtain an accurate and complete description of the process status at all times. For this purpose, three main types of data will be considered, namely real-time, statistical and modeling data.

Real-time data is acquired on-line from the various components of a classical system, like sensors or controllers, and it usually consists of the measured process outputs and the computed control inputs. This data can be used for early fault detection and diagnosis and for system optimization under nominal operating conditions.

Statistical data refers to data collected over longer periods of time and stored in view of its processing. In the case of the Control Strateg strategy, statistical data will be used for the accurate assessment of the risk level associated to the occurrence of an unexpected event.

Modeling data is computed on-line in order to overcome the drawbacks generated by the lack of information relevant to the description of the process behavior and to support the decision making process regarding the control strategy that should be implemented in a critical situation. Therefore, process modeling will play an active role in the control of industrial plants, as opposed to just supporting the design procedure, which is the case in most applications available nowadays.

Given the diversity and the large volume of the data that will be integrated within the Control Strateg system, it is essential to ensure that there is a reliable solution to the acquisition and correlation of information from various streams. The approach proposed through this project is based on the principles of the OPC UA (Unified Architecture), which is the most recent OLE for Process Control (OPC) specification from the OPC Foundation and differs significantly from the previous specifications by providing a patch to a cross-platform Service Oriented Architecture (SOA) [6] based on different logical levels for process control, while enhancing security and providing an information model [7].

The advantages of the OPC UA approach consist of its multi-platform implementation capabilities, its scalability, its multi-threaded and also single-threaded operation, security based on new standards, configurable time-outs for each service and the ability to incorporate big datagram's.

The most important aspect, however, is the architecture of the OPC information model, which is referred to as a Full Mesh Network based on nodes that can include any kind of meta information, from attributes for read access (DA – Data Access, HDA – Historical Data Access) to methods that can be called commands and triggered events that can be transmitted (AE – Alarms and Events).

The OPC UA can be used for a wide range of applications dedicated to the different levels of control, from the field and process control levels, to the plant and even the enterprise level. This makes it the ideal solution for developing and implementing the integrated system proposed by the Control Strateg strategy, which focuses on the efficient processing of all available data about the process behavior in order to address some of the most important issues related to overall risk and hazard control of industrial applications. Moreover, OPC UA not only offers solutions for data communication and integration, but also for the development of reliable control strategies and for their application with the use of the corresponding generic algorithms in order to ensure the safe operation of the controlled plant.

As illustrated in Figure 2B, there are several system components that will be developed in order to achieve the proposed goals of the project and to ensure that the Control Strateg system respond to all the control requirements of safety-critical applications.

The first one of these functions is early Fault Detection and Diagnosis (FDD). Model-based Fault Detection is a two-step procedure. First, a residual is generated based on the information available from the process (known command inputs and measured outputs). The residual is a linear or non-linear function of the system inputs and outputs. The computed value is further compared with a threshold in order to establish whether a fault has occurred or not. It is essential for the correct performance of the system that the threshold is chosen appropriately because if its value is too low there is a high false alarm probability whereas if its value is too high certain faults can remain undetected.

If a fault is detected, then Fault Diagnosis has to be performed in order to establish its location (Fault Isolation) and magnitude (Fault Identification/Estimation). The Fault Isolation consists of generating a residual set describing the possible fault scenarios and of comparing the given residuals with the elements of the set. The minimal distance between the computed residual from the fault detection module and the elements of the set in terms of vector norm indicates the faulty component or components (sensors, actuators, components of the physical plant). The Fault Estimation/Identification consists of identifying the post-fault process model.

A modern approach to Fault Diagnosis, however, makes use of artificial intelligence techniques, like fuzzy logics, artificial neural networks, genetic algorithms or various combinations of these techniques in order to perform pattern recognition for particular faults or system states [8] that are difficult to map using the more classical modeling procedures, including also nonlinear systems or processes that are highly affected by disturbances.

The Control Strateg strategy will take into consideration both the model-based and the knowledge-based approaches to FDD in order to obtain a high-performing and efficient technical diagnosis module that will be able to work within

the rather restrictive real-time constraints imposed by the nature of safety-critical applications and to cover the detection, isolation and estimation of a wide range of faulty or otherwise undesired system states that could occur during the plant operation. Through the diagnosis of system faults that were not initially anticipated in the process design phase, the degree of reliability of the controlled application will increase; this approach relies heavily on analytical redundancy and less on hardware redundancy, which makes it more cost effective.

Nowadays, a reliable FDD module is becoming a must in every risk management application as it represents the building block for the control strategies that are meant to guarantee the safe operation of the plant in risk and hazard situations. For this reason, it is important to understand the relation between FDD and Risk Analysis (RA), which is the next phase in achieving the objectives of the strategy.

While a hazard is not a fault, it can be caused by the occurrence of one or more faults concurred with certain environment conditions, influencing the stability and safe operation of the plant and, ultimately, endangering the environment and the population safety if left unattended for. Depending on the influence of the fault on the system safety and reliability, there are several hazard classes and the corresponding supervisory actions taken for the fault management can vary from shut-down if there is an imminent danger for the process or the environment to reconfiguration, maintenance and instantaneous repair [9,10].

The hazard risk assessment is performed based on the information received from the FDD module and also using statistical analysis of the available data; the procedure is less generic than the FDD one, since a-priori information related to the specific behavior of the plant in certain risk scenarios has to be incorporated within the analysis. The nature of the RA problem and the large volume of data involved are the main factors that impose the integration of knowledge-based techniques with the classical approaches in order to develop generic and reliable tools for the accurate assessment of hazard risk for a wide enough range of industrial applications.

After the FDD and the RA, the final stage of the reliable risk and hazard control approach proposed by the Control Strateg strategy is the System Optimization (SO). This generally refers to the development and implementation of the appropriate control strategies and of the corresponding algorithms that guarantee the system stability and the best dynamic performances of the process by report to several criteria.

While SO is already a component of most control systems already in use in the industry, it is only used for improving the plant performances under nominal operating conditions. The problems, in this case, are the definition of the quality criterion or criteria that need to be maximized, the identification of the optimization model based on historic data acquired from the physical plant and the computation of the corresponding parameters that ensure the maximization of the chosen criterion or criteria for that particular model. These parameters represent the set-points that are further sent to the control elements at the executive level in order to drive the system behavior as close as possible to the optimal functioning point.

However, when the system is under the influence of a fault or disturbing signal that affects its stability and dynamic behavior, the generally accepted practice is to proceed to the plant shut-down. Safe shut-down strategies have already been established for safety-critical industrial plants. Therefore, the Control Strateg strategy does not propose new methods for performing this action, but takes into consideration the integration of the already existing solutions to this problem within the risk and hazard management platform that will be developed.

Another major difference between the Control Strateg system and the classical applications is the fact that, when the risk level is acceptable, new solutions are sought for the accommodation of the fault or otherwise the management of the undesired event that has led to the degraded plant performance or that has affected the system stability. The objective is to find new control parameters or even new control structures that will stabilize the plant and will ensure graceful performance degradation when possible, thus avoiding unnecessary and costly plant shut-downs.

In other words, new control strategies need to be established on-line in order to allow the plant to keep running, even if certain performance degradation is accepted and sometimes unavoidable, while still maintaining the desired safety level. This phase can involve both analytical and physical redundancy and consists of solving an optimization problem where the quality criterion is usually defined so that it describes the closeness between the accommodated and the desired plant behavior. The RHC (Risk and Hazard Control) module is a new component of process control, involved when a hazard state can activate the emergency shut-down (ESD) system to stop the plant, having the goal to ensure the continuous operation. One of the most efficient ways to avoid the shut-down of the plant when key parameters are for from the nominal state is the reconfiguration. Reconfigurable set of sensors, of actuator, of interconnections can be used but Reconfigurable Control (RC) strategies and reconfigurable process can be more effective. All this tools will be analyzed and used in order to implement the most affordable and flexible solution.

The integration of the FDD, RA and SO components as described above within the same hazard and risk control application is the main distinctive feature of the Control Strateg strategy.

The project quantifiable or qualitative expected impacts are:

- ✓ Optimisation of large-scale plants operation under normal conditions from the point of view of productivity increase and operation costs decrease;

- ✓ Improvement of plants functioning under the influence of system faults, based on modelling uncertainties and external disturbances;
- ✓ Decrease of hazard occurrence risk as a result of permanent system monitoring, early failure detection and diagnosis, fault accommodation algorithms and hazard prevention procedures;
- ✓ Financial savings for the users due to the elimination of unnecessary plant shut- downs;
- ✓ Energy saving through the optimisation algorithms and the early detection of malfunctions;
- ✓ Support for the research and further developments in this field based on a strong knowledge base for professionals in the domain.

III. CONCLUSIONS

The main expected result of our project is a commonly accepted system architecture that will guarantee that all the control requirements of safety-critical industrial applications are met through an integrated solution that will support the decision making process regarding hazard risk management for all types of users.

Further work will focus on:

- Coherent data collection for the complete and accurate description of the process dynamic behaviour.
- Generic fault detection and diagnosis strategies and algorithms.
- Generic risk assessment strategies for industrial plants.
- Experience-based learning strategies and techniques for the continuous optimisation of the control solution.
- Integrate with remote control system for the total risk management in industrial applications.

Any comments and suggestions are welcomed so that we can constantly improve this template to satisfy all authors' research needs.

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Development of Simulink blockset for embedded system with complex peripherals

V. Lamberský, J. Vejlupek, V. Sova, R. Grepl

***Abstract*—** Automatic code generation from Simulink model for embedded processors is very useful feature, available for various targets. This Simulink functionality is provided by build in or third party blocksets. However the supported peripheral functionality is usually limited, as these blocksets support only on chip peripherals. This paper presents method for creating blockset for unsupported platform CEREBOT MX7 cK which uses complex peripherals (OLED2 display unit). The main challenge during developing blockset for Cerebot target is implementing automatic code generation for display unit. This complex peripheral module cannot be modeled in Simulink using native tools without adding special functionality to them. A new concept presented in this paper which introduces automatic block generation was developed to overcome this limitation. Main advantages and limitations of created blockset are listed in summary section.

***Keywords*—**Automated code generation, blockset, Simulink, Cerebot

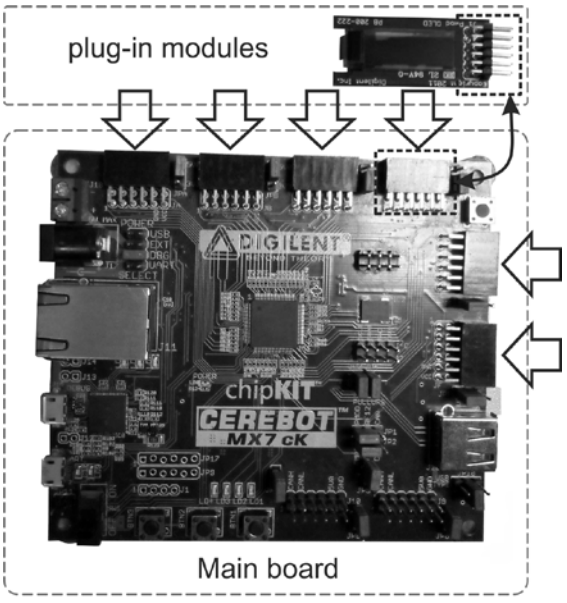
I. Introduction

Today's trends in embedded microcontrollers can be characterized by constantly decreasing price and increasing computing power [1]. These trends open new areas of applications where implementation of embedded microcontrollers was too expensive before. From design perspective these microcontrollers are becoming very popular since their implementation can significantly improve product behavior while not making it more expensive. And it can significantly improve user experience as well. This is done for instance by introducing components such as touch screens. These components allow better user interaction with the device and provide simple overview of the device operation. Not all advantages of the microcontroller used in various applications can be named here. Together with a huge demand to develop new embedded applications daily, the need to make the software development process for these devices faster and easier is obvious.

Programing languages used to create program from embedded microcontrollers can be divided into two categories: low level and high level. Each category has some advantages over the other one. For most complex applications, high graphical programing languages like Simulink provide superior coding efficiency and development speed which makes this group of programming languages preferred choice over low level programing ones [2], [3].

Rapid prototyping and development platforms became very popular [4], [5] when developing new embedded application. They contain micro controller with basic circuits so any devices can be connected to that board easily. However since the connection interface between development board and peripheral devices is not standardized, some wiring usually needs to be done manually.

To further accelerate development of embedded applications a standardized interface were introduced for selected boards and peripheral modules. One of such hardware platforms is a Cerebot hardware. It consists of a main board and different types of peripheral modules which can be easily plugged to the main board (see illustration of Cerebot main board and plug-in module on Fig. 1).



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V. Lamberský is a PhD candidate at the Brno University of Technology – Faculty of Mechanical Engineering. His current research focuses on Rapid Code Generation for embedded applications.

J. Vejlupek is a PhD candidate at the Brno University of Technology – Faculty of Mechanical Engineering. His current research focuses on Hardware in the Loop simulation, Rapid Control Prototyping and Rapid Code Generation for embedded applications.

V. Sova is a PhD candidate at the Brno University of Technology – Faculty of Mechanical Engineering. . His current research focuses on advanced BLDC motor control algorithms and Rapid Code Generation for embedded applications.

R. Grepl is associate professor at the Brno University of Technology – Faculty of Mechanical Engineering..

Fig. 1 Cerebot main board with plug in module

Based on which type of application is being developed, particular modules are selected and connected to the main board.

This type of platform can be very useful not only for rapid prototyping, but also can take a part in small series market products as well, because of its fairly low price.

The blockset for the Cerebot platform that was created for automated code generation from graphical programing language seems to be very beneficial. It enables other people to work with this hardware even if they have no knowledge of C programming language. Beside this, the board with support for direct code generation is more suitable for research. As more time can be spent for working with data and system modeling, since there is no need to write code in C language for operating peripherals, which would be necessary otherwise without this blockset.

The blockset we have created presents significant benefit over commercial products as this one is prepared as open-source. It means anyone can modify and reuse our blocks in different projects. This can be a huge advantage as sometimes small change in existing blockset eliminates the necessity to create a huge amount of new code needed during authoring new block. Therefore created open platform for Cerebot can save a lot of time when designing code for similar peripherals, which are not yet supported in presented blockset.

II. State of the Art in Automatic Code Generation

This section summarizes targets that are currently supported for automated code generation, mechanisms that are involved in this process and how it can be used for the Cerebot hardware.

A. Platforms supported for automatic code generation

Today, various targets are supported for automatic code generation from Simulink. Some targets have inherent support from products that are a part of Mathworks Embedded Coder, support for other products can be added by purchasing a third party tools or developing them [6].

From category of blocksets for a 32-bits Microchip processors several commercial blocksets are available. Particularly, one blockset was created by Kerhuel [7] and second from a Microchip Company is being developed, currently support only 16 bit microprocessors [8]. However, these blocksets support only some build-in MCU peripherals. Beside this, in some cases a non-typical application can require peripheral functionality which is not supported by the available blocksets.

In cases where missing support from blocked does not allow fully automatic code generation from Simulink some options are available. Automatically generated code from Simulink can be imported into a hand written C project.

This process is usually referred as cogeneration. Matlab provides tools for simple creation of generic C code which is ready to be imported into C project where target specific functions (for handing peripherals) are written manually. This concept is further explained and demonstrated in [9]. This approach is suitable for applications with hardware which is not expected to be used in further projects.

For other applications creating a blockset is recommended approach. Although creating a new block set is quite complex task, when reusing created blocks in various designs the time saved when generating code directly from Simulink can compensate costs for developing new block set.

B. Cerebot platform

Cerebot MX7 cK target is equipped with one of the most powerful 32bit PIC microcontrollers available (PIC32MX795). This makes the board suitable for implementing fairly complex algorithms.

There is a wide range of various peripheral modules which can be purchased and used with Cerebot board. It contains various types plug-in modules suitable for mechatronics applications (temperature sensor, acceleration, etc.)

Cerebot has a superior position in its category of embedded rapid prototyping boards for its number of ports trough which extending peripheral modules can be connected. And for high number of various types of extension peripheral modules that are available for this platform.

For these special properties, we have decided to create support for Cerebot platform to enable option for automatic code generation directly from the Simulink model. This blockset will further increase the number of applications for this board as now this board can be used without any knowledge of low level programming languages and the software can be developed much faster.

One of the most complex peripherals which can be connected to a Cerebot board is display unit (referred as OLED2 module). Although it can display only 16 shades of one color and has resolution of 64x256 pixels, it can display quite advanced graphic elements.

There is no similar blockset for any platform which would enable automatic code generation for this peripheral unit. As standard approaches using masked blocks or calling Matlab GUI for configuring block parameters does not provide feasible flexibility for modifying block which generates various types and quantity of functions with different parameters. Therefore, a special java application was developed to provide such functionality in Simulink model.

Some alternative solutions to this approach represent programmable display modules which can be purchased together with graphical programming environment. From its specialized environment the code can be automatically generated, however these tools can be used only with hardware, which they are designed for. Beside this, the price for autonomous Serial graphic displays which are produced by Electronic assembly is not very low (compared to displays equipped with simple driver).

C. Generating code from Simulink

Generating code directly from Simulink for embedded targets is getting very popular even if this was not original

purpose of Matlab/Simulink software.

Since Simulink was not designed for generating code for embedded processors, several additional toolboxes were designed to support this process. Particularly, Embedded Coder was designed to generate efficient C code from Simulink model suitable for execution on embedded processors.

During code generation stage, the Simulink model represented in *RTW* record is translated into C code. In next step the generated C files are processed with target specific compiler and linked to executable file, which can be then directly loaded into the flash memory and executed on the target hardware.

This section will explain which files and scripts need to be created to have the Simulink model suitable to generate a new program which can be loaded into the microcontroller using only one click action.

To achieve this type of functionality, two type files and scripts need to be created. The first group of scripts consists of files used in Matlab/Simulink environment to control code generation. The second group consists of programs and scripts running outside Simulink which are used to translate generated files and load executable code to a microcontroller.

Steps involved during code generation process are illustrated in Fig. 2.

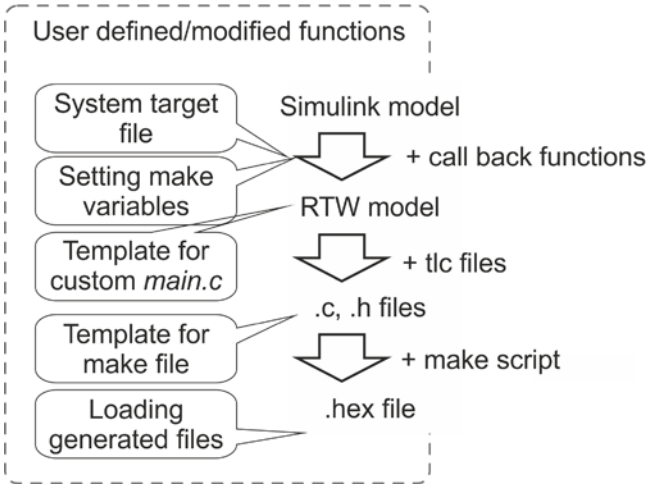

Fig. 2 User defined files used during various stages of code generation process

The entry point to code generation process from Simulink is invoking make_rtw function. This is done when the build button is pressed in Simulink model. In first stage Simulink model is prepared for code generation, no modifications of this function are necessary as this procedure only rewrites Simulink model representation to a *RTW* one.

In the second step the *RTW* file is translated using *TLC* templates to .c and .h files. At this point we need to add functionality for non-generic C functions.

The first processed file when generating code is target tlc file. Beside its function as entry point for "transforming" Simulink model it can modify Simulink dialog for entering user parameters affecting the generated code by setting *TLC* and *MAKE* variables. These variables are usually used to specify compiler settings, enable automatic load of generated code, etc.

The Cerebot main file is created using file customization template. The main file contains macros for hardware initialization and function which is called periodically and is used to schedule execution of generated code in target hardware.

Since the Cerebot platform is designed only for one type of microcontroller without interchangeable crystals, unlike other blocksets, this one does not support setting parameters for crystal speed and configuration options for clock dividers or multipliers. Although this can be seen as unwanted limitation of the blockset flexibility, it makes using this blockset with Cerebot platform easier as no initial configuration is required from the user.

In order to compile files, the makefile template (.tmf) which controls creation of makefile to match used C compiler was modified. The makefile is automatically executed after its creation so no specific actions are required when using default settings.

Hook functions are ideal for calling external user program or scripts during various stages of code generation process (e.g. before or after make command). This option is used to call external program to load generated binary file into microcontroller after compiling and linking is done.

Besides creating previously described files which provide functionality for generating and loading files to a microcontroller, functions for peripheral handing need to be added. These functions will be provided as a block in Simulink model. This concept is illustrated in Fig. 3.

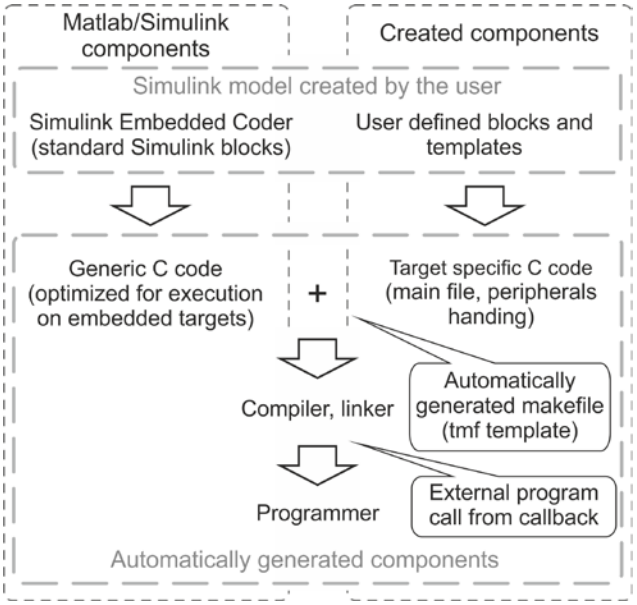

Fig. 3 Simulink model and components for code generation

Matlab/Simulink provides tools for creating blocks for

implementing user defined functions to model.

Basically, two types of functionality for each Simulink block need to be implemented, one for simulation and second one which is used during code generation process.

The function used during simulation, referred as *MEX* function, can be implemented in several supported languages and translated with supported compiler into .mex or .mex64 (based on type of operating system being used) file which will be used with Simulink. When developing the Cerebot blockset, these functions were programmed in C language.

The second type of created functions, which are used during code generation process, are scripts and functions in *TLC* language. During code generation phase, virtually any code can be placed in position of particular Simulink block. It can be any c language expression or function call. Description of code placed in block position during code generation is provided in *TLC* function.

III. Blockset for Cerebot

This section will describe developed blocks and atypical aspects of Cerebot blockset considered during code generation.

A. Simulink blocks for simple peripherals

These blocks are used for implementing functionality of basic peripherals which does not require complex configuration. For creating these blocks standard options available from Simulink were used. That means creating a masked block using mask editor and created block c.mex and .tlc functions were not dynamically modified once the block was created.

For the intended purpose of the developed blockset, individual block functionality for simulation does not have to be implemented as modeling peripheral behavior was not necessary. This simplification saved a significant amount of time during Cerebot blockset development.

Particularly, blocks in our blockset which represent output peripherals have inputs for signals which are not used during simulation time. That means, no calculations are performed with signal which was connected to that block.

Input peripherals need to output some signal during simulation. But it can be constant value. The default zero value was outputted from blocks representing input peripherals.

This might seem as a limitation for development purposes. However, when testing the designed algorithm arbitrary signal can be used instead of input peripherals (ADC input, UART) blocks. Blocks of these peripherals need to be used only for code generation and does not to be present during algorithm development or testing.

Typical examples of blocks which are not available in commercially available blocksets are blocks for peripherals specific for particular board design

For instance the block for controlling LEDs: such block is not available on any other targets, as signaling LEDs are usually connected to various digital pins on microcontroller unit. When using a blockset for microchip MCU a digital output port block needs to be used. This concept is less clear as the user has to find to which port is the particular led connected. On the other hand, our block has inputs for each led making it easy to identify LEDs and corresponding block inputs (see Fig. 4).

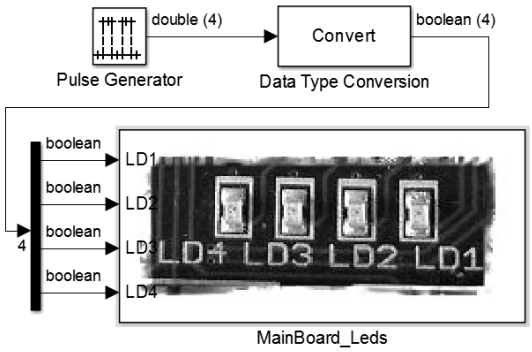

Fig. 4 Identifying block inputs and corresponding led location on board is simple

Another example of blocks crated for particular hardware version is blocks for controlling serial port (Fig. 5).

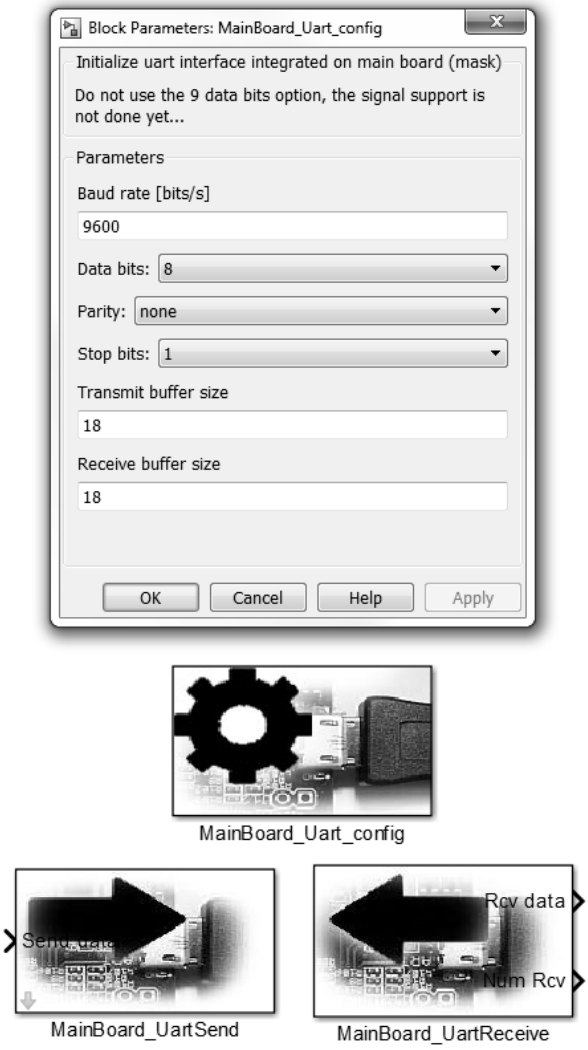

Fig. 5 Blocks and user interface for UART peripheral

One block is used for configuring UART port properties – speed, data parity etc. Other blocks are used for writing and reading data. All blocks use icons to illustrate their function. Since these blocks are configured to use only one build-in UART port, using this blockset is much easier compared to other products for automated code generation as the icon on blocks will help to identify proper port which is used with this particular block. These blocks and configuration interface are illustrated in Fig. 5.

B. Simulink blocks for complex peripherals

Implementing block for controlling display peripheral unit using Simulink mask editor or Matlab GUI wouldn't provide simple way for implementing tool for setting graphic components for display unit driven by embedded microcontroller. Therefore a special application was developed for this task.

The Microchip Company provides free graphic library with source code for creating various graphic object which can be implemented with arbitrary graphic display unit (user only need to implement low lever layer of hardware drivers and configure the library based on used hardware type).

Implementing functions from Microchip graphic library saved significant amount of time since we can call these functions from generated code without the need to create them by ourselves.

The main task of blocks used to generate code for display unit is to:

- Place selected functions calls from graphic library into generated code. Most functions are executed during model step. Object initialization is moved to initialization section.
- Configure and maintain variables used as input for functions from graphic library. If the function requires an object as an input parameter, the generated code has to pack variables to appropriate structure.
- Link the selected variables with the Simulink signal (this mechanism allows controlling displayed objects from the Simulink model). Each signal used in the generated code has to have proper parameters (data type and size).
- Generate the functions which will be needed by the graphic library functions during linking code. Some functions use extern functions or variables, modules containing this objects need to be added to the compiled units.
- Generate request for adding library modules to compiled code. As some functions are using functions from other modules when starting the code generation process, all the required modules for the compilation are needed to be saved to MAKE variables. Once the *TLC* compiler starts, *RTW* parameters are locked and no changes done to them will be reflected in generated code.
- Provide the suitable user interface for selecting object which will be displayed and configure them. Easy to use graphical user interface was created for comfortable and easy display layout configuration.
- Create a link for calling the Microchip Graphic Resource Converter program. Before for instance bitmaps can be loaded and displayed, they need to be converted to proper format. Microchip provides the utility, which can perform the conversion. This utility can be started from program for modifying scene options. The generated files are detected automatically and objects (fonts and images) are then available for selection in object options in scene editor program.

Previously specified functionality was implemented using two Simulink blocks for the configuration of the generated code. Fig. 6 illustrates created blocks and hardware which is running code generated from this Simulink model.

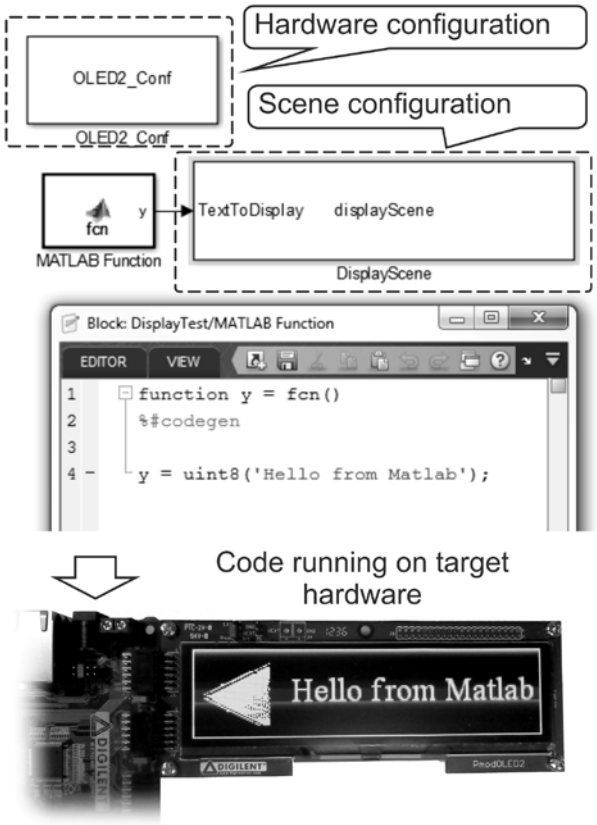

Fig. 6 Code generated from Simulink running on target hardware

One block (Hardware configuration) creates interface for configuring the selected display unit (creating driver layer based on the resolution of the display and the pin connection configuration. Second block (Scene configuration) configures the display layout. Since the layout represents a very complex structure a separate java application was created to provide user interface for configuring scene and mechanism for generating required files.

Creating a new instance of display scene block will create empty scene layout. When double clicking on scene layout block the external application will be called. After modifications of the scene parameters are complete, the *MEX* file is compiled if necessary and block mask updated. Scheme

of the external application used for configuring display scene is illustrated in Fig. 7.

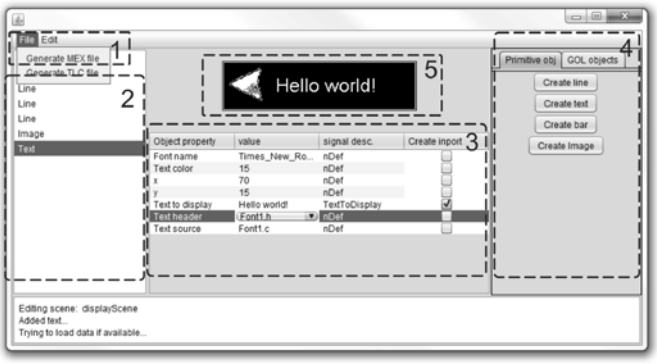

Fig. 7 Overview of display scene layout editor

Functions of different areas labeled in Fig. 7 are explained below.

1. The File option popup panel which presents options to generate new .mex and .h file for particular scene.
2. List of object placed to scene and allows its selection is displayed in this section.
3. The selected scene object properties are presented in this table. Based on element type, its properties can be fixed or entered from a Matlab Simulation. When Create inport option is checked a input port to a block with label corresponding to text in signal desc option is created. Value from this signal then modifies displayed item.
4. Clicking on buttons in this panel will place a corresponding object on screen.
5. Is used as a preview for generated scene layout preview.

As described in this chapter generating code for project which uses the display peripheral is very easy when using Cerebot blockset. Adding one configuring and at least one scene block is sufficient to display objects on OLED2 module. The display scene is configured in graphical user interface and selected object properties can be controlled from model using Simulink signals (connected to input port of scene option block).

C. Blockset "supporting" files

Another group of files which were created or configured, to integrate external tools to support code generation process, were make script and callback hooks.

When make script is generated it is automatically calls XC32 compiler with proper parameters. Once the executable code is generated, callback method is used to invoke loader, which loads generated program to a MCU flash memory. This loader was written in Java language using free libraries for communication with the programmer provided by a Microchip Company. The programmer/debugger chip is a part of the Cerebot platform and has an USB interface for communication with a PC.

IV. Conclusion and Future Work

Main assets of the created blockset presented in this paper are the more convenient and faster embedded application development process. Process of the Rapid Code Generation have been taken as far so literally it can be generated from the MATLAB Simulink environment, compiled by MPLAB compiler, and loaded onto the chip just by clicking one button in Simulink. We have proposed a way of generating more complex code outside the MATLAB Simulink environment, which gives us more flexibility.

Basic mechanisms which are used to schedule code generated from Simulink are not suitable for scheduling complex systems which use very complex peripherals. When generating code from Simulink using default templates, the monolithic scheduler is generated. Meaning that task running with lower period can't be interrupted with faster task executed with smaller period.

This can be a problem for some applications which need part of the code to be executed very fast as displaying an object on OLED module takes long time when big part of the screen is redrawn. Implementing operating system which will allow preemption of the slower task should be feasible solution to this problem.

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Simulation-based Optimization of Signaling Procedures in IP Multimedia Subsystem

Jasmina Barakovic Husic, Alisa Hidic, Mesud Hadzialic, and Sabina Barakovic

***Abstract*—**This paper presents a simulation-based optimization of signaling procedures in Internet protocol Multimedia Subsystem (IMS). The aim is to improve the performance of signaling procedures by applying an algorithm for Session Initiation Protocol (SIP) message classification and prioritization that is proposed in our previous work. This three-priority level classification of SIP messages is implemented in Network Simulator version 2 (ns-2). Its effectiveness is verified through the simulation-based study of SIP signaling procedures under different conditions. The simulation results are analyzed in terms of Registration Request Delay (RRD), Session Request Delay (SRD), and Session Disconnect Delay (SDD). These SIP performance metrics are improved if IMS is configured to process SIP messages using the proposed algorithm. Differentiated handling of SIP messages reduces the overload in IMS and thereby improves the overall Quality of Service (QoS). This encourages our next step in research activity, i.e., implementation and incorporation of SIP message classification and prioritization algorithm into experimental environment.

***Keywords*—**classification, optimization, prioritization, SIP signaling, simulation

I. Introduction

THE Internet protocol Multimedia Subsystem (IMS) supports the development of next generation services. This causes the rapid growth in new services, subscribers and devices that increase the signaling volume. The growing amount of signaling may result in congestion and impact the Quality of Service (QoS) [1]. The IMS procedures used for QoS negotiation and signaling are based on Session Initiation Protocol (SIP). These signaling procedures play an important role in affecting the overall Quality of Experience (QoE) [2]. In this regard, there is a need for an optimization of SIP signaling procedures.

In a large IMS network with millions of potential user agents, several thousand or more SIP messages may be processed by individual SIP proxy servers [3]. Conventional SIP proxy servers are configured to process SIP messages using First In First Out (FIFO) scheduling. However, FIFO scheduling may have several disadvantages: (1) it may be inefficient, (2) it does not enable service differentiation, (3) it does not permit differentiation based on the classes of service, and (4) it exposes the network to possible instability because of SIP messages that are allowed to loopback through SIP proxy servers.

In the view of these disadvantages, the SIP message classification and prioritization algorithm is proposed in our previous work [4]. Although this algorithm is primarily intended to improve the performance of IMS in high-load and overload conditions, it may be also considered as an extension of our previously published approach [5], which is based on prioritizing of signaling information transmission. According to this approach, signaling service class is given the highest priority over all other user service classes. Although this approach is signaling protocol independent, it is discussed in the context of SIP. Therefore, our previously proposed algorithm further extends this approach by classifying SIP messages into three priority classes.

This paper presents an implementation of this SIP message classification and prioritization algorithm in Network Simulator version 2 (ns-2). The aim is to analyze the impact of implemented algorithm on the SIP performance metrics and compare the results with those obtained using the conventional FIFO scheduling. The intention is to perform the simulation-based optimization of SIP signaling procedures, especially under high-load or overload conditions, in order to improve their performance as an important factor that contributes to the QoE.

The rest of the paper is organized as follows. Section II summarizes the related work. Section III gives an informal and a formal description of algorithm for SIP message classification and prioritization, which is implemented in ns-2. Section IV considers the algorithm's impact on SIP performance metrics. It discusses the obtained results, together with their analysis to show that the conclusions are warranted. Section V concludes the paper and outlines open issues for future work.

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J. Barakovic Husic is with the Faculty of Electrical Engineering, University of Sarajevo, Zmaja od Bosne bb, 71000 Sarajevo, Bosnia and Herzegovina (phone: +387 33 250 700; fax: +387 33 250 725; e-mail: jbarakovic@ etf.unsa.ba).

A. Hidic is with the Faculty of Electrical Engineering, University of Sarajevo, Zmaja od Bosne bb, 71000 Sarajevo, Bosnia and Herzegovina (e-mail: ah15310@ etf.unsa.ba).

M. Hadzialic is with the Faculty of Electrical Engineering, University of Sarajevo, Zmaja od Bosne bb, 71000 Sarajevo, Bosnia and Herzegovina (e-mail: mhadzialic@etf.unsa.ba).

S. Barakovic is with the Ministry of Security of Bosnia and Herzegovina, Trg BiH 1, 71000 Sarajevo, Bosnia and Herzegovina (e-mail: barakovic.sabina@gmail.com).

II. Related Work

While the performance evaluation of IMS is a subject of emerging research activities, there are many related works regarding the SIP server overload control. Two broad categories of SIP overload control mechanisms are identified in [6]: load balancing approach and load reducing approach. Load balancing approach tries to avoid the overload by distributing the traffic load equally among the local SIP servers. Load reducing approach tries to prevent the overload collapse by reducing the traffic load in the whole SIP network. This approach differentiates three categories of mechanisms for SIP overload control: priority-based, push-back, and retransmission-based. Load balancing mechanisms have been deployed in operator networks, while other three types of load reducing mechanisms are in the stage of research proposals.

The problem of SIP server overload control is the subject of many research activities. As a result, a wide range of mechanisms and algorithms have been developed in order to solve this problem. In this respect, three novel load-balancing mechanisms have been introduced in [7]. Each mechanism combines knowledge of the SIP, dynamic estimates of server load, and Session-Aware Request Assignment (SARA). The proposed mechanisms provide finer-grained load balancing resulting in throughput and response-time improvements.

An optimized algorithm for SIP server overload control that randomly makes the decision of acceptance or rejection of every SIP massage is proposed in [8]. This algorithm is based on the calculation of the queue length and the reject probability of SIP messages. The simulation results show that the algorithm better meet the demand on SIP signaling network under overload conditions.

A distributed and adaptive window-based overload control algorithm is proposed in [9]. This algorithm controls the amount of calls that are forwarded to a downstream SIP server in an attempt to prevent it from being overloaded, and does not rely on explicit feedback. This algorithm performs better both in terms of call setup delay and throughput than a commonly used overload control algorithm that is based on maintaining Central Processing Unit (CPU) utilization.

A backpressure-based SIP overload control mechanism called Bassoon is proposed in [10]. It consists of two parts: (1) optimal load balancing algorithm that ensures full utilization of available of available network resources, and (2) end-to-end load control algorithm that regulate traffic at the edge of the network. The Bassoon effectively controls overload in SIP networks and outperforms existing schemes in terms of goodput, fairness and responsiveness.

The implementation and comparison of Adaptive Rate Control (ARC) and Support Vector Machine (SVM)-based algorithms are described in [11]. The ARC is a queue delay-based algorithm. The SVM-based algorithm is based on integration of four input data: call establishment delay, queuing delay, SIP 100 Trying status code delay, and database response time. The comparison shows that the SVM-based algorithm outperforms ARC algorithm in terms of goodput.

Most of the SIP overload control mechanisms are focused on User Datagram Protocol (UDP), although Transmission Control Protocol (TCP) is more suitable for the transport of SIP messages [12]. Therefore, a novel mechanism that effectively uses TCP flow control to aid application level SIP overload control has been developed. Other experiments indicate that throughput with SIP-over-TCP exhibits similar overload collapse behavior as that with SIP-over-UDP [13].

Priority-based overload control mechanisms aim to mitigate the overload by rejecting the SIP messages with low priority [6]. Prioritization may be performed by using different SIP message header fields [14]. In addition, four approaches to SIP message prioritization are proposed in [15]. A SIP messages scheduling mechanism that is applied on service broker is presented in [16]. This approach balances the load on application servers and enhances the overall QoS. Furthermore, it is proposed an automatic originator regulation of IMS multiple traffic by stateless signal prioritization based on the types, message order and retransmission of SIP messages within each call session [17]. It is shown that best prioritization is to give a higher priority to a message type appearing at a later stage in each session and a lower priority to a retransmitted message. Moreover, light-weight messages like instant messaging are assigned higher priority than those generated by voice calls.

Considering this, the SIP message classification and prioritization algorithm is proposed in our previous work [4]. This algorithm is discussed in detail in Section III.

III. SIP Message Classification and Prioritization Algorithm

This paper presents the ns-2 implementation of our algorithm for SIP message classification and prioritization. The decision to use the ns-2 is based on comparative analysis of several simulators [18]. The simulators are compared in terms of modelling capabilities, credibility of simulation models and results, extendibility, usability, and cost of licenses. The analysis shows that commercial OPNET Modeler provides the largest support for IMS simulation [19]. However, ns-2 is chosen because it is free and open-source simulator [20] that provides IMS functionality by adding an independently developed SIP module [21]. This SIP module is based on ns-2.27 version.

A. Informal Algorithm Description

The SIP message classification and prioritization algorithm involves two modes of operation: (1) normal mode, wherein the SIP messages are processed using FIFO scheduling, and (2) priority mode, wherein the Priority Queuing (PQ) scheduling is used for three-priority level classification of SIP messages. The normal mode of operation is switched to the priority mode when congestion is detected. The congestion is determined by exceeding the predefined queue length. In priority mode of operation, the packet's content is checked, and packets are put into three-priority classes according to SIP message type.

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The class 1 includes SIP messages that terminate the communication session, such as BYE or CANCEL, and those that appear at the later stage in each communication session, such as ACK or 2xx status codes. This class of SIP messages is given the highest priority in the overload conditions. The class 2 includes lightweight SIP messages such as REGISTER, MESSAGE, PUBLISH, NOTIFY, and SUBSCRIBE. These types of SIP messages are less delay sensitive and have lower processing time than INVITE messages [3]. The retransmitted messages are also involved into class 2. A recent studies show that the presence service can account for 50% or more of the total signaling traffic that IMS network handles. Thus, the number of NOTIFY messages is several times larger than the number of other SIP messages. Therefore, this class of SIP messages is assigned medium priority. The class 3 includes the SIP messages that establish the communication session such as INVITE, and those that provide provisional responses, such as 1xx status codes. The class 3 messages are given the lowest priority in the overload conditions [4].

B. Formal Algorithm Description

To implement the previously described algorithm, a modification of existing ns-2.27 source code is done. This modification refers to the adjustment of class *Queue* in order to enable two modes of operations, which are required to discuss advantages and disadvantages of the algorithm. The modification of class *Queue* entails the modification of class *DropTail*, which implements FIFO scheduling. This class is derived from class *Queue*. The class *Queue* is child class of class *Connector*. This class is derived from class *NsObject*, which is the base class for all network objects in ns-2. This is shown on Fig. 1, which represents a class diagram of the SIP message classification and prioritization algorithm.

Fig. 2 and Fig. 3 present sequential diagrams of the proposed algorithm that illustrate the sequence of messages between objects in an interaction in case of normal mode and priority mode of operation.

In the process of SIP message receiving, an internal message *CongestionCheck* is sent to a *bufferManager*. The *bufferManager* checks the queue length. If the queue length is less than congestion threshold, *bufferManager* allocates the memory for one queue and sends an internal message *NoCongestion*. If the queue length is greater than congestion threshold, *bufferManager* creates three queues for each priority class and returns an internal message *Congested*. When *NoCongestion* message is received, the SIP message is forwarded into the created queue. However, when *Congested* message is received, an appropriate priority is assigned to SIP message, which is further placed into corresponding queue.

In the process of SIP message forwarding, the *bufferManager* checks the mode of operation. In normal mode of operation, the packets are served by FIFO scheduling. In priority mode of operation, the PQ is used to forward packets that carry SIP message. The packets in the highest priority queue are forwarded first to the output interface. If there are no packets in the highest priority queue, the packets from the medium priority queue are sent next. Failing that, the lowest priority queue is inspected and packets from that queue are forwarded to output interface.

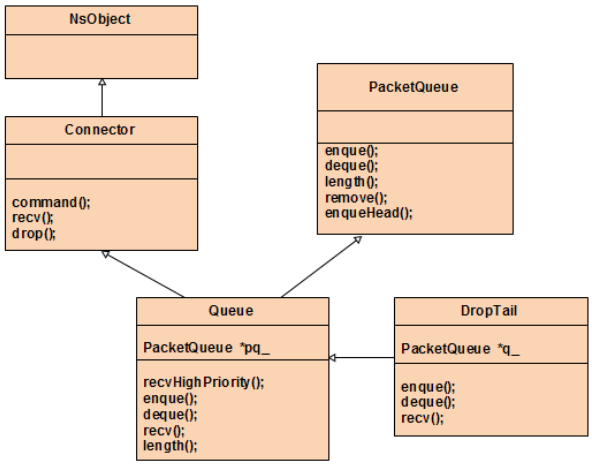

Fig. 1. Class diagram of the algorithm for SIP message classification and prioritization.

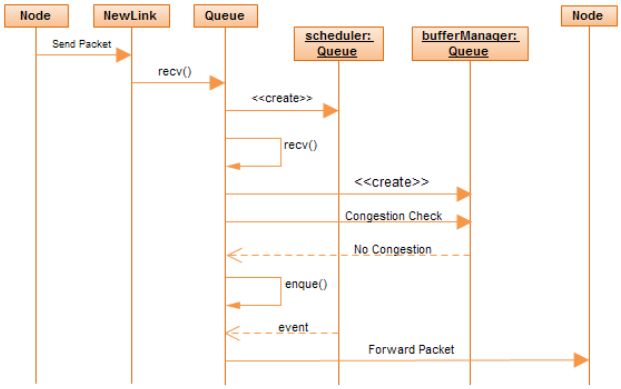

Fig. 2. Sequential diagram of the algorithm for SIP message classification and prioritization in normal mode of operation.

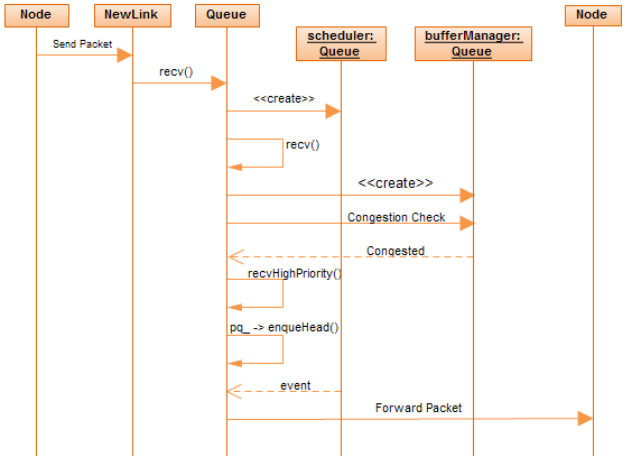

Fig. 3. Sequential diagram of the algorithm for SIP message classification and prioritization in priority mode of operation.

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IV. Simulation of SIP Message Classification and Prioritization Algorithm

To verify the effectiveness of SIP message classification and prioritization algorithm, the simulation study is performed.

A. Simulation Setup and Environment

The simulations are based on two different scenarios. The simulation scenarios differ in SIP message scheduling algorithm. In Scenario 1, SIP messages are processed using conventional FIFO scheduling. In Scenario 2, SIP messages are processed using proposed algorithm, which is based on FIFO/PQ scheduling.

The simulations are performed on the simple network topology consisting of two boundary routers and one interior router. Boundary routers are connected to SIP domain consisting of SIP proxy servers and SIP user agents. Every SIP domain includes 150 SIP user agents that are used for generating background traffic. The links between routers are dimensioned to implement simple network configuration. The links capacities are configured to 1 Mbps. The delay of all links is set to 10 milliseconds and the queue lengths equal to 100 packets.

The network is loaded by different number of SIP messages generated and exchanged during the signaling procedures. Three types of SIP signaling procedures are considered: registration, session establishment and session termination. Different number of simultaneous SIP signaling procedures is initiated in order to generate the background traffic. This number is in the range from 0 to 900 for the purpose of measuring the SIP performance metrics.

B. Simulation Results and Discussion

The simulation results are analyzed in terms of Registration Request Delay (RRD), Session Request Delay (SRD), and Session Disconnect Delay (SDD). These SIP performance metrics are defined in Request for Comments (RFC) 6076. The simulation results for these SIP performance metrics are shown on Fig. 4. They are not discussed in comparison with results published in related works [2], [22] because the measurements are performed under different conditions and environment. However, the simulation results are analyzed with the aim to show the impact of the implemented algorithm on the SIP performance metrics.

Fig 4(a) shows the comparative analysis of RRD when FIFO and FIFO/PQPQ scheduling is used. It is noticed that the RRD increases in both scenarios with increasing the number of simultaneous SIP signaling procedures. The RRD values are identical in both scenarios until the network is loaded by 60 simultaneous SIP signaling procedures. For a larger number of simultaneous SIP signaling procedures, the RRD grows slower when FIFO/PQ scheduling is used. In this case, the RRD is approximately 150 milliseconds lower in overload conditions. This can be explained by that fact that the FIFO is used in normal load conditions, while the PQ is activated when the overload is detected. Moreover, the REGISTER requests are put in class 2 that has a medium priority in high-load and overload conditions.

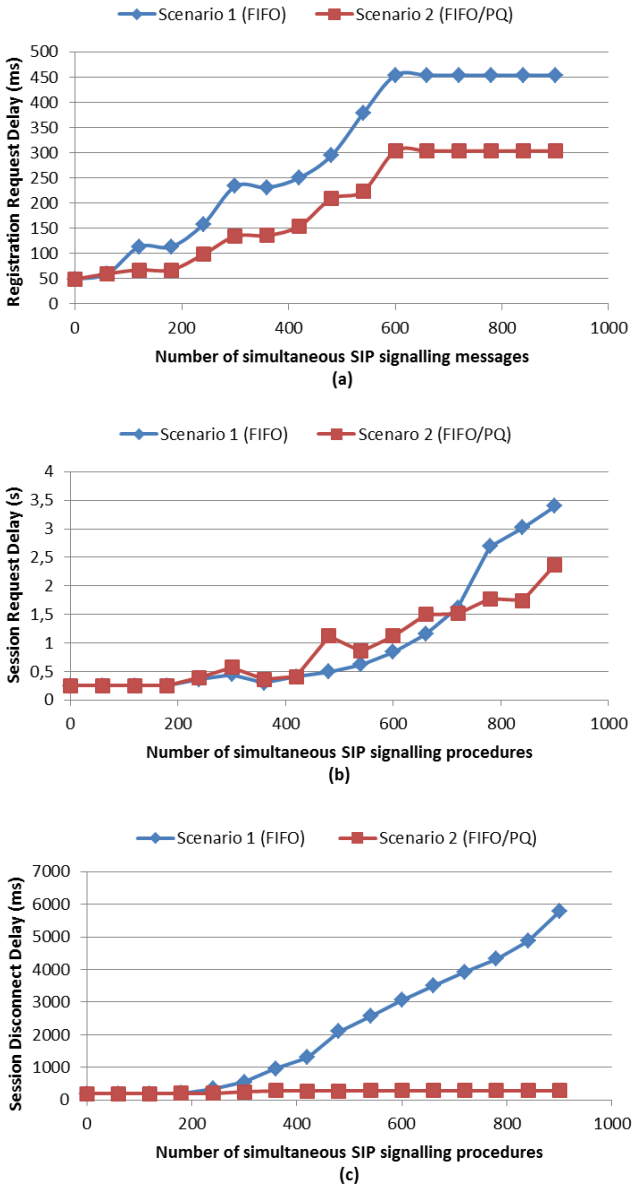

Fig. 4. Simulation results: (a) Registration Request Delay (RRD); (b) Session Request Delay (SRD); (c) Session Disconnect Delay (SDD).

Fig. 4(b) shows the comparison of SRD values when FIFO and FIFO/PQ scheduling is used. The SRD values are identical in both scenarios until the network is loaded by 180 simultaneous SIP signaling procedures. The increasing number of SIP signaling procedures leads to the faster deterioration of SRD if FIFO/PQ scheduling is used. This can be explained by the fact that the PQ scheduling is activated in high-load or overload conditions giving the lowest priority to INVITE messages. However, when network is loaded by more than 720 simultaneous SIP signaling procedures, the FIFO/PQ scheduling achieves the better SRD values. This is the consequence of giving a higher priority to SIP messages that terminate the existing sessions and thereby reduce the overload. Moreover, this leads to faster processing of INVITE requests and reducing of SRD values, consequently.

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Fig. 4(c) compares the SDD values obtained when FIFO and FIFO/PQ scheduling are used. The SDD values are identical in both scenarios until the network is loaded by more than 120 simultaneous SIP signaling procedures. This can be explained by the fact that PQ is not activated in normal load conditions. Therefore, better results are achieved in high-load or overload conditions if FIFO/PQ scheduling is used. The insignificant increase of SDD value is noticed until the network is loaded by 480 simultaneous SIP signaling procedures. Then the SDD value becomes constant and equals to 282 milliseconds. This is the consequence of putting the BYE requests into the class 1, which is given the highest priority in high-load and overload conditions.

V. Conclusion

This paper presents the simulation-based optimization of SIP signaling procedures in IMS. The optimization is achieved by implementing SIP message classification and prioritization algorithm that is proposed in our previous work. This algorithm is based on three-priority classification of SIP messages. The main idea is to assign the highest priority to SIP messages that may serve to reduce the demand on the SIP proxy server. Giving a higher priority to SIP messages that terminate the existing sessions rather than those used to open the new sessions reduces the overload in IMS and thereby improves the overall QoS.

This SIP message classification and prioritization algorithm is implemented in ns-2 simulator. Its effectiveness is verified through the simulation-based optimization of SIP signaling procedures under different conditions. The simulation results are analyzed in terms of RRD, SRD, and SDD. These SIP performance metrics deteriorate with the increasing network load. However, better results are achieved if our algorithm is used instead of conventional approach. In this case, SIP signaling procedures have a shorter duration time, which improves the QoS. Therefore, the simulation results encourage the development and deployment of SIP message classification and prioritization algorithm in the experimental environment. This is going to be a starting point for our next research activities.

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Area Coverage and Surround of Found Targets by Self-organizing Multi-Robotic System

Jolana Sebestyénová, and Peter Kurdel

***Abstract*—**Self-organizing robotic systems are able to accomplish complex tasks in a changing environment through local interactions among individual agents and local environment. A swarm of small autonomous mobile robots is a set of inexpensive robots that explore a dangerous environment with aim to locate enemies or other targets. Area coverage is one of the emerging problems in multi-robot coordination. The foundations of automata theory in swarm systems come predominantly from the cellular robotics systems. The problem addressed here is to entrap stationary (in future also mobile) targets using a few mobile robots, i.e. coordination mechanisms for the distributed contamination boundary coverage problem with a swarm of miniature robots. In the proposed model, field vector-based area coverage is used in combination with search and surround of some targets distributed in the area.

***Keywords*—**Area coverage, Autonomous mobile robots, Self-organizing multi-robot system, Surround of searched targets

I. Introduction

NOWADAYS many of autonomous mobile robots under development no longer work alone, they work collaboratively. Collaborative robotics can be taken to mean robots collaborating with other robots or with a human; in this context we have taken it to mean collaboration with other robots working towards the same goal.

Collections of locally interacting embodied agents can generate collective performances that are beyond the possibilities of individual agents [1]. Through their interactions they can coordinate and organize their behaviors so that they can achieve goals that are impossible to achieve by individual agents acting alone, e.g. agents can be informed by other agents about portions of the environment that are currently beyond direct sensory access on the part of the individual agent, or collecting information provided by many agents to generate a global knowledge of the environment.

Collaborative robotics is a way to increase the solving performance of a robot team without significantly modifying the robots capacities. When collaboration is obtained with stigmergic mechanisms (i.e. implicit communication via the environment) or with simple explicit communication schemes such as binary signaling, the task accomplished by the team can be more complex and its performance enhanced without loosing autonomy or increasing in a relevant way the complexity at the individual level. Collaborating robots must successfully share the task they are assigned. The key to this is the introduction of roles, a type of behavior that the robot must exhibit. Behavior based control of a robot is nothing new, but in the framework of a team of collaborating robots, this must be applied as a series of different roles which the robots can use as a means to function more effectively.

Self-organization is one of the most important features observed in social, economic, ecological systems and biological systems. Self-organizing robotic systems are supposed to be able to accomplish complex tasks in a changing environment through local interactions among individual agents and local environment without an external global control. Self-organizing robotic systems should exhibit life-like features such as self-reconfiguration, self-repair, self-reproduction, self-development, and context awareness. Developing such self-organizing systems, where desired global behaviors can emerge through contextual local interactions among individuals and with the environment is a very challenging task [2].

Team of robots can perceive its environment from multiple disparate viewpoints. Team members may exchange sensor information, help each other to scale obstacles, or collaborate to manipulate heavy objects.

Team of robots which coordinates the actions of individual but centrally controlled robots in the group is called swarm robots. Usage of such robots teams could help to minimize hazardous work for humans, e.g. in fire fighting or similar dangerous tasks. Efficient search and cooperative completion of the task is possible via sophisticated communication methods. A multi-robot system has several advantages, including maximum coverage of the scanned area.

There is a growing variety of autonomous robots that are inspired by living systems. These robots are intended for inspection of sewage pipes, monitoring of pollution through underwater measurements, space exploration, bio-medical interventions, or nano-engineering. A swarm of small mobile robots is a set of inexpensive robots that explore a dangerous environment with aim to locate enemies or other targets. In non-communicative swarming, the swarm comprises homogeneous and anonymous robots, i.e. robots able to

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Jolana Sebestyénová, is with the Department of Discrete Processes Modeling and Control, Institute of Informatics, Slovak Academy of Sciences, 845 07 Bratislava, Slovakia (phone: +421 2 5941 1182; fax: +421 2 5477 1004; e-mail: sebestyenova@savba.sk).

Peter Kurdel is with the Department of Parallel and Distributed Computing, Institute of Informatics, Slovak Academy of Sciences, 845 07 Bratislava, Slovakia (phone: +421 2 5941 1167; fax: +421 2 5477 1004; e-mail: peter.kurdel@savba.sk).

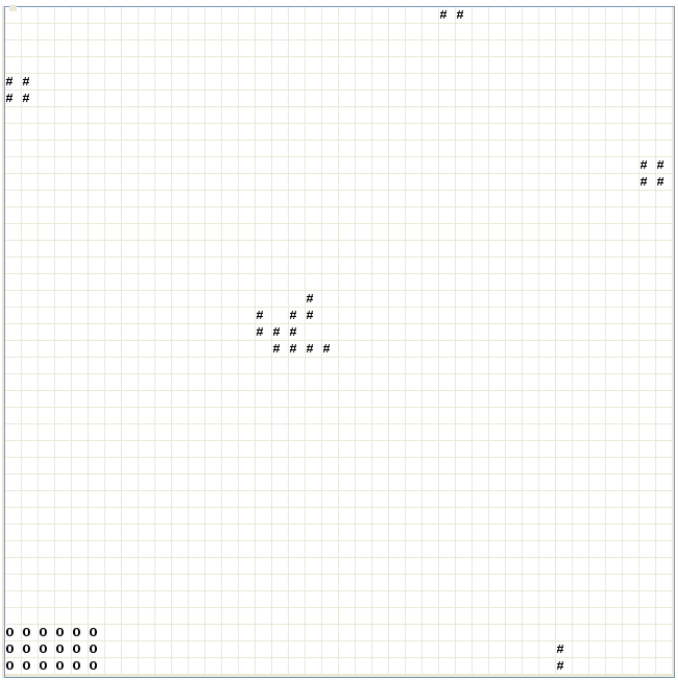

Fig. 1 Start position of robots (circles) and targets (#)

recognize other robots but un-capable to identify them individually.

Communicative swarming is distinctively more efficient than non-communicative one as it increases the swarm control ability. In communicative swarming, the swarm robots interchange information concerning their environment, which enables to arrive to information-aware conclusions. Moreover, the robots make use of the information received from each other, which enables to control cooperative behaviors as e.g. cooperative area coverage or cooperative search/exploration. Multi-robot systems communication can be direct or indirect. Indirect interaction uses passive or active mechanism of indirect coordination between agents or actions (stigmergy).

A swarm is defined as a massive collection that moves with no group organization, much like a swarm of bees or a flock of birds. Similar is a formation, the distinction is made in that it maintains a global structure, much like a flock of geese or a marching band [3]. Robot formations have been applied to applications such as automated traffic cones, while swarm behavior control has been applied to urban search-and-rescue robotics.

The majority of existing multi-robot systems for pattern formation rely on a predefined pattern, which is impractical for dynamic environments where the pattern to be formed should be able to change as the environment changes. In addition, adaptation to environmental changes should be realized based only on local perception of the robots. In [4], a hierarchical gene regulatory network (H-GRN) for adaptive multi-robot pattern generation and formation in changing environments is proposed.

The traditional artificial intelligence (AI) approach to robot control is known as deliberative control. In the sense-plan-act paradigm, the robot senses its environment and, taking into account a model of that environment, decides to start the appropriate action. The week point of the deliberative control is possible failure in case of unexpected change of the environment. On the other hand, a reactive system observes the sense-act plan, coupling perception to action without any representation or history stepping in. Reactive control does not need a model of the environment or traditional planning, as it relies on a number of simple behaviors.

In the scope of bio-inspired soft robotics behavior is orchestrated rather than controlled [5]. Different bio-inspired multi-robot coordination systems have been developed [6]: distributed robots for search and rescue, environmental monitoring by highly agile autonomous robots, etc. Agent-based models consist of dynamically interacting, rule-based agents [7].

Area coverage is one of the emerging problems in multi-robot coordination [8]. In this task a team of robots is cooperatively trying to observe or sweep an entire area, possibly containing obstacles, with their sensors or actuators. The goal is to build an efficient path for each robot which jointly ensures that every single point in the environment can be seen or swept by at least one of the robots while performing the task. In barrier coverage robot guards are deployed to prevent intrusion [9].

The foundations of automata theory in swarm systems come predominantly from the cellular robotics systems.

Cellular automata (CA) are abstract models of complex natural systems having large quantities of identical, locally interacting simple components. Modeling based on CA leads to extremely simple models of complex systems. It carries discrete lattice of cells, generally in more dimensions where each cell in the lattice contains a number of cells. Each cell can interact with the cells located in its neighborhood. CA modeling represents an accomplished modeling method in biology, but likewise in computer science. Though the CA's construction is simple, its behavior can be very complex.

This paper introduces the multi-robot area coverage problem, wherein a group of robots must inspect every point of a 2-dimensional test environment and surround all contaminations (or enemies) found. We present some of our initial simulation results. Fig. 1 illustrates start positions of robots and positions of searched targets (contaminations or enemies) in the test area.

A cellular automaton consists of a chain (1-dimensional) or lattice (2-or-3-dimensional) of computational cells, each cell being in one of a given set of states that evolve through discrete time steps. The dynamic behavior of the automaton is determined by a set of rules that govern the change of state of an individual cell with respect to its neighbors. Many practical implications must be considered when a given environment is represented topologically as a cellular automaton referred to as a world-space cellular automaton [3]. One of them is increasing risk of collisions when two robots attempt to move to the same unoccupied grid cell. Other approach is to treat the robots in the formation as cells in a 1-dimensional robot-space cellular automaton. It distinguishes in that the actual robots that make up the global structure (i.e., not the structure itself)

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are represented by the cells. This approach overcomes many of the limitations inherent in a world-space automaton.

Similar methods making use of cellular automata do only area coverage or only move on patrol around a given building [17]. Other methods enabling search for target and its encircling, as e.g. morphogenetic swarm robotic systems [2] (dealing with the self-organization of swarm robots using genetic and cellular mechanisms underlying the biological early morphogenesis) use ingenious estimation of shapes and resulting formation of appropriate encircling robots patterns.

II. Collective Emergent Behaviors

Robotic system architectures can be centralized - characterized by a single control agent, or decentralized architectures - no central control agent. The behavior of decentralized systems is often described using such terms as "emergence" and "self-organization." It is not clear whether the scaling properties of decentralization offset the coordinative advantage of centralized systems. Many systems do not conform to a strict centralized/decentralized dichotomy, e.g. many largely decentralized architectures that utilize "leader" agents. The centralized knowledge store or source of control can be a bottleneck that severely constrains the abilities of the robot team.

Emergence and its accompanying phenomena are a widespread process in nature [10]. Despite of its prominence, there is no agreement in the sciences about the concept and how to define or measure emergence. One of the most contentious issues discussed is that of top-down causation as a defining characteristic of systems with emergence.

The behavior-based approach [11] has become very popular to cope with several robotic applications, also including service robotics (also termed reactive control). It refers to the direct coupling of perception to action as a specific technique which provides time-bound responses to robots moving in dynamic, unstructured and partially unknown environments.

A behavior is defined to be a control law for achieving and/or maintaining a particular goal. Usually, robot agents have multiple goals, including at least one achievement goal and one or more maintenance goals. This requires robot agents to be equipped with a number of behaviors, whose activation or inhibition must be triggered by a specialized module - the arbiter. Depending on its sensor data and/or information coming from an external supervisor, it provides either spatial or temporal ordering of behaviors. The former causes the concurrent activation of a set of primitive reflexive behaviors, also referred to as static arbitration; the latter brings about a sequential activation of different sets of primitive reflexive behaviors, also referred to as dynamic arbitration.

Roles can be defined statically in advance, but they may not necessarily be given to a robot and maintained statically. Instead, robots will often switch roles dynamically, for example when a robot soccer player finds itself in a role that is not suited to its current position as well as another role might be.

A behavior-based approach assumes a robot to be situated in, and surrounded by, its environment. This means that a robot interacts with the world on its own, without any human intervention, i.e. its perspective is different from that of the observer.

The distinction between collective and cooperative behavior is made on the basis of communication. If cooperative behaviors require negotiation between agents, then direct communication is also required. Cooperation is a form of interaction based on some form of communication.

The first, essential step enabling the emergence of a collective behavior is a careful design of the behaviors that any individual robot agent will contain. Further, one has to specify which tasks a group of individual robots can accomplish. Last but not least, a mechanism to initialize the cooperative behavior, eventually considering the level of cooperative strategies the robots must follow to collectively solve given tasks, is necessary. The result of the actions provided by the individual agents will be emergence of a collective behavior.

Rescue robots are useful for rescuing jobs in situations that are hazardous for human rescuers [12]. They can enter into gaps and move through small holes, which is impossible for humans and even trained dogs. Robots should explore in collapsed structure, extract the map, search for victims and report the location of victims in map. The main task of rescue robots is to acquire information about damaged area and victims [13]. The most important work in rescue activity for disaster mitigation is to get the reliable information. One of the goals of the rescue robots is to develop maps of disaster scenes for the human rescue members who go into the scenes for actual rescue works.

An additional potential application of the proposed model is for cordoning off hazardous materials. When the distribution of the hazardous materials is detected, model can encircle detected hazardous materials and prevent people from moving into the dangerous area.

In order to traverse through a complex environment, swarm robotic systems need to self-organize themselves to form different yet suitable shapes dynamically to adapt to unknown environments [14]. Insects are particularly good at cooperatively solving multiple complex tasks. For example, foraging for food far away from the nest can be solved through relatively simple behaviors in combination with communication through pheromones. As task complexity increases, however, it may become difficult to determine the proper simple rules which yield the desired emergent cooperative behavior, or to know if any such rules exist at all. For such tasks, machine learning techniques like evolutionary computation (EC) may prove a valuable approach to searching the space of possible rule combinations.

III. Problem Formulation

Multi-robot shape construction and pattern formation, a typical task for MRSs, has been widely studied. Algorithms in this research field can be roughly divided into three groups: leader/neighbor-following algorithms, potential field algorithms, and nature-inspired algorithms.

Leader/neighbor-following algorithms require that

individual robots follow neighbors or leader that knows the aim or target to which the team needs to go. These following robots should get behind a leader's root in a specific geometric relationship with the ones they follow. The second group of multi-robot shape construction algorithms is based on potential field method. The basic idea of this group of algorithms is that each robot moves under the governance of the gradients of potential fields, which are the sum of virtual attractive and repulsive forces. The third group is nature-inspired algorithms.

In field vector-based collision avoidance both target (the attractor) and obstacles (the repulsors) generate their own specific vectors. The target generates a purely attractive field, proportional to the distance, while the obstacles generate a rotational field.

The problem we are addressing is to entrap stationary (in future also mobile) targets (e.g. contamination or enemy), using a group of mobile robots. In the proposed model, field vector-based area coverage is used in combination with search and surround of some targets distributed in the area (similar to boundary coverage). Communication via environment (similar to pheromones) is used to share local knowledge on area gained by individual robots. Basic simple behaviors of the robots are:

- area coverage
- collision avoidance
- search for a target
- walk around the target found
- standing on guard at the found targets.

Cognitive and behavioral capabilities in animals are closely coupled and dependent on one another. However, in artificial systems the distinction can be made much more explicit, since models which are focusing on cognitive capabilities are often neglecting or strongly simplifying agent-environment dynamics e.g. assuming complete or global information of the world and other agents.

A better way to design the system is to view the global information as providing general guidance for the longer-term actions of a robot, whereas the local information indicates the more short-term, reactive actions the robot should take within the scope of the longer-term goals. This can often be achieved by combining the use of local and global information into a composite control law that more intelligently interprets the local information in the context of the global knowledge.

This, however, requires a mutual knowledge system [1] for symbolic knowledge (facts) as well as perceptual knowledge. The symbolic knowledge must contain data descriptions of fixed and dynamic objects, their attributes and the relations between the objects. As the system (a robots team) covers a dynamically changing environment, it must be able to learn and forget symbolic knowledge as well as perceptions. The system must be able to ground perceptions to symbols, i.e. label it and relate it to facts. As an example, a vague black blob, perceived by some robots, can be labeled as “door” by a human, after that the robots can use this fact in their world model.

Robotic actions are of two main classes: Ordinary actions effect changes in the world: positioning, displacement, rotation of objects in the workspace, random walk, move forward or backward, turn left or right, effector’s movements, obstacle avoidance, docking, following, … Sensing actions effect changes in robot’s knowledge.

A. Assumptions

In proposed model, the following assumptions have been made:

1) All the robots move with equal speed.
2) There is a base station containing a sufficient number of robots.
3) All robots have a limited sensing range, and therefore, they can detect targets and other robots that are within their sensing range only.
4) The communication range between robots is limited. Robots can communicate information such as targets’ location with their immediate neighbors (distance between the two robots is within the communication range). We assume that the communication between the robots and the base station is not limited.
5) The robot can distinguish between obstacle and boundary.

B. Model

One way to simulate a 2D cellular automaton (k = 2) is with an infinite sheet of graph paper along with a set of rules for the cells to follow. Each square is called a cell and each cell has some possible states. There are several possible lattices and neighborhood structures for 2D cellular automata. This paper considers square lattices. At start, the robots are arranged in one of the corners of the area (left down on Fig.1). Number of robots and number of rows in which the robots are ordered are optional. All robots are oriented to Nord at start, and speed of robots equal. From two most common 2-D CA neighborhood templates (Moore neighborhood and von Neumann neighborhood - may be extended) Moore neighborhood (eight surrounding cells, n = 8) is used in the model. State of a cell is from a set: empty, robot is in it, target is in it.

Neighborhood size in the model as well as sensors range (for example for contamination detection) is one cell distance (r = 1). The model can be further generalized by enabling that the neighborhood size can be optionally one or more cells distances, and sensors range can be different for different kinds of sensors.

For all cells, attraction at start is equal and changes are computed according to robots moves and targets found.

Extra states are used to code the robot's current direction, as well as for remembering cells where some robot already appeared, which is then used for slow forgetting of the robots position history. All cells remember whether and when any of the robots visited the cell. State transition is fired by a set of rules.

C. Basic Rules

Each robot looks at the attractions of the nearby cells, and its own actual direction, and then applies the transition rule, specified in advance, to decide its move in the next clock-tick.

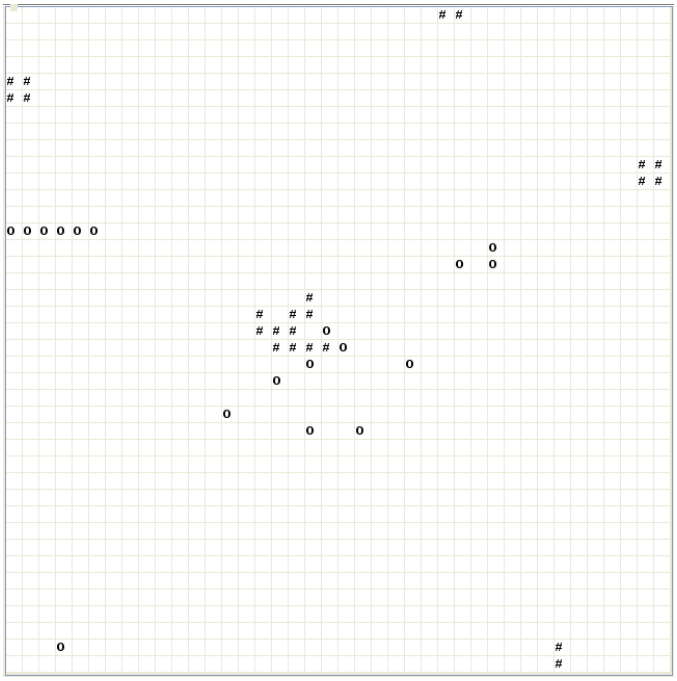

Fig. 2 Position of robots after some steps

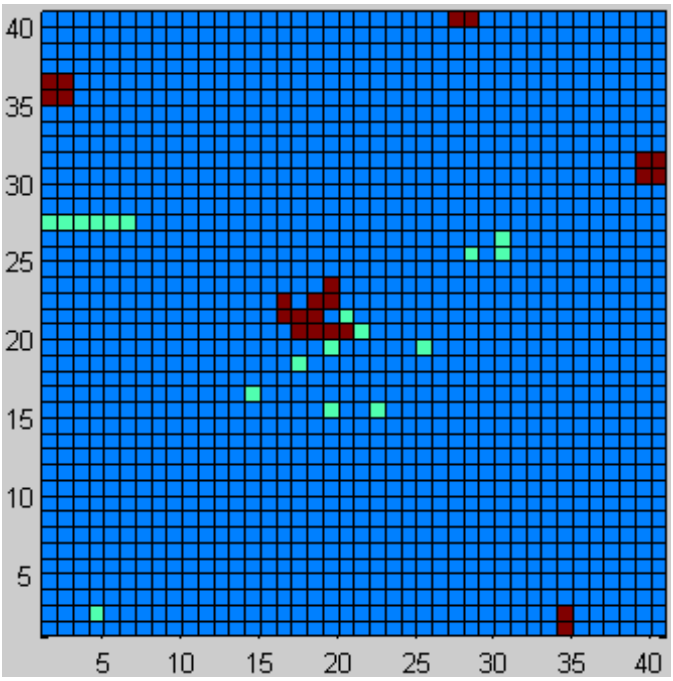

Fig. 3 Position of robots after some steps (same as in Fig. 2) using pseudo-color plot

All the cells change at the same time.

Each robot moves to empty neighbor cell with maximal attraction. It tries to move in direction in which it is facing. In case, it is not possible, the robot direction is rotated clockwise.

Some delicate configuration may happen, e.g. the robot must decide if it is more convenient, or even possible (e.g. by sliding along a wall), to turn around the obstacle, instead of passing through, and which direction to select for this turnaround. We have also considered boundaries as particular kinds of obstacles. A serious problem may arise if both of two opposite directions are blocked due to some difficult configuration. We decided the robot does not move for a while, waiting the other robots' moves.

Basic rule for robots moves is specified as

$$a_r^t \times l_r^t \rightarrow c_r^t$$

where a is attraction, l is location of robot, c is cell to which the robot will move, t is time, and r is range.

All used data are specified and/or evaluated in subsequent simulation steps in multidimensional cells representing the area (area width × area length × number of used data types, in our case 40 × 40 × 8):

- Attraction field - at start, attractions of cells are equal (specified maximal attraction value).
- Contamination positions (targets) are input data of a simulation tool.
- Robot identifiers at positions (start and actual positions) and their directions; number of robots and their starting positions are input data. Robot speed is 1 cell per 1 simulation step. Robot range may be different according to carried sensors ranges, e.g. robot may view the target in 2 - 3 cells distance.

  Cell occupied by any of robots is an obstacle, no other robot can take the place.

  Just released cell will set zero attraction.
- Forgetting a visit of a robot - in subsequent simulation steps cell forgets the visit (in each step a small value, and after many steps cell forgets the visit completely). Using these values, the attraction of the cell again raises.
- Obstacles in area (now only area boundaries are considered)
- Positions of found obstacles (e.g. deep ditch - robots can't path through - will be considered in future version)
- Found targets as well as positions and IDs of robots guarding on them.

  In case, the robot views the target (or it senses the target according to used sensor), it needs information whether this target is already guarded on by any other robot: If not, the robot remains to stay (start to guard on and it raises the attraction of the target cell and also of its outskirts). If yes, robot continues in walking around the target (one target may cover more cells). One robot can guard on more than one target cells according to its sensors ranges. The robots guarding on found target cells not only need to see the target, they also need to see each other to form a secure surround.
- Repulsion - the robot starting to guard on the target increases the repulsion of its position's cell with surroundings within sensors distances. In future version, the obstacles will also increase repulsion.

IV. Simulation

The proposed model is simulated in Matlab [15]. Fig 2 depicts positions of robots after several simulation steps (start positions of robots is depicted in Fig. 1 in section I.). Fig 3 illustrates the same situation, using pseudo-color plot.

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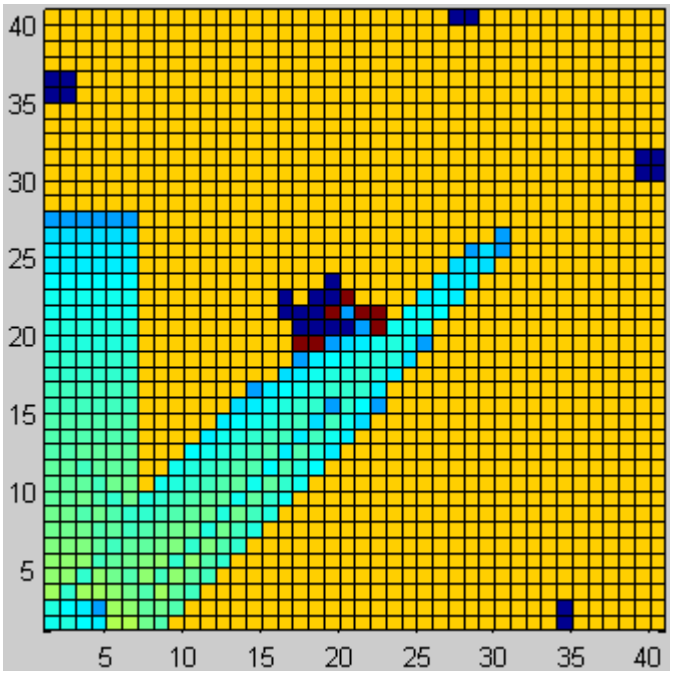

Fig. 4 Same situation as in figures 2 and 3 illustrating changes in attraction field

Changes of attraction field in the same situation can be seen on Fig 4.

In Fig 5, attraction field changes illustrate that attractions around contamination found have highly increased after some more simulation steps (with respect to situation on Fig. 4). If a target is some kind of contamination, the kind of detected contamination is given by the type of sensors carried by the robots. As the target obviously covers more than one cell, probability to find more cells with not guarded target increases in case a robot starts to walk around target. Each robot can guard more targets in its neighborhood range (in this version, the range r = 1).

Positions of robots standing on guard around found contaminations are illustrated in Fig 6. From the group of 18 robots in the simulated example, 13 robots were enough to guard on all targets in the area, and 5 robots continue in area coverage.

Targets are the static objects in the environment that need to be encircled by the robots. Robot standing on guard refers to the robot that detects at least one target in the environment. Searching robot refers to the robot not yet detecting any target in the environment, i.e. doing an area coverage. Searching robots can become robots standing on guard if they detect a target not yet guarded by any other robot.

At first simulation steps, robot group moves together, and the robots always try to move in direction they are looking in. As some of the cells are engaged by other robots, or some of the cells have decreased attraction, the group diverged. The isolated robot starts to increase the attraction in its surroundings with the aim to form a robot formation in order to do area coverage more effectively [16].

The movement behavior of robots not having detected any target is governed by the area coverage, avoid collision, and search for a target behaviors.

Compared to other published multi-robot pattern formation algorithms, one major advantage of approach presented here is that it provides an adaptive mechanism that can dynamically generate an appropriate surround pattern adapted to environmental changes. Most existing MRSs for pattern

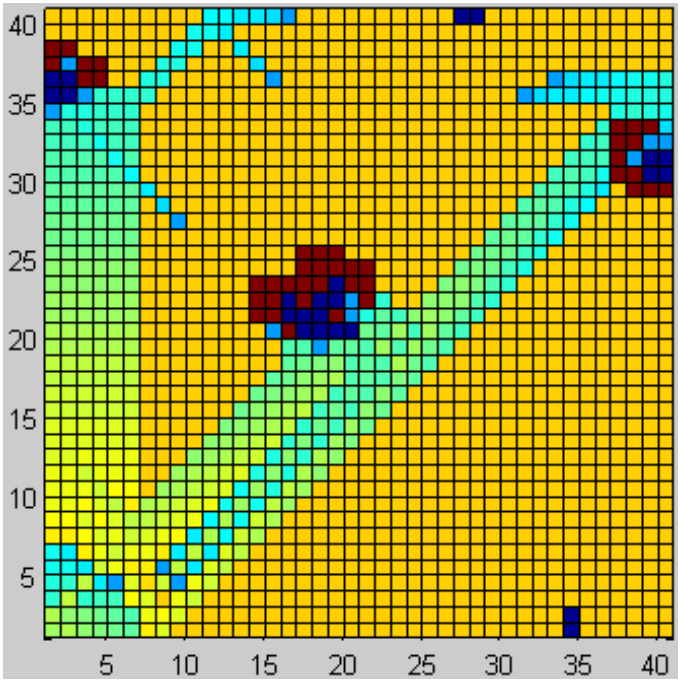

Fig. 5 Attraction field after some more steps (attractions around contamination found are highly increased)

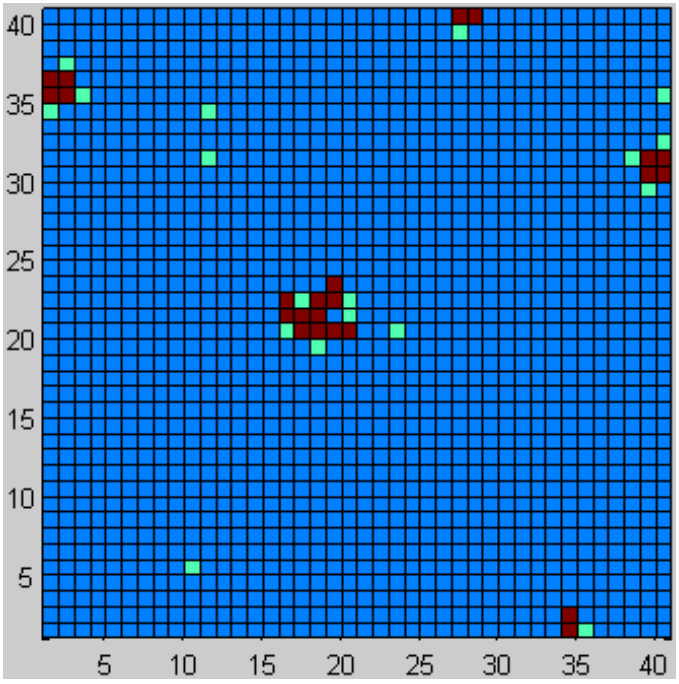

Fig. 6 Positions of robots standing on guard around found contaminations (5 robots continue in area coverage)

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formation rely on a predefined pattern, which is not applicable to changing environments.

V. Conclusion

Multi-robot boundary coverage requires the robots to cover a given boundary at a given location defined in the global coordinate system. Applications of multi-robot boundary coverage include perimeter defense and area protection, whereas algorithms for multi-robot pattern formation can also be employed to simulate the self-organizing properties found in nature.

This paper introduces the multi-robot area coverage problem, wherein a task of a group of robots is to inspect every point of a 2-dimensional test environment and surround all contaminations (or enemies) found. Some of first simulation results are presented. Similar methods making use of cellular automata provide only area coverage or only move on patrol around a given building, etc. Other methods enabling search for target and its encircling as e.g. morphogenetic swarm robotic systems use ingenious estimation of shapes and resulting formation of appropriate encircling robots patterns.

The main new feature of the proposed model compared to existing published solutions is that the target search and round pattern generated by the robots need not be predefined and is adaptable to environmental changes, e.g., the number and location of the targets to be entrapped.

In future work, the presented model will be modified so as to be able to work with mobile targets. It should be pointed out that successful entrapping of the mobile targets is conditioned on the assumption that the movement speed of the robots is faster than that of the targets.

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Jolana Sebestyénová graduated in Automation at the Faculty of electrical engineering of Slovak Technical University in Bratislava, and received the Dipl. Eng. degree in 1976. She has received the PhD. degree in Automation and control from the Faculty of electrical engineering and information technology of Slovak Technical University in Bratislava in 2006.

She worked with Institute of Technical Cybernetics, Slovak Academy of Sciences in Bratislava in years 1976 - 1991. During 1991 - 2001, she worked with Institute of Control Theory and Robotics SAS. Since 2001, she is with Institute of Informatics, Slovak Academy of Sciences in Bratislava. She works in department of Discrete processes modelling and control. She was researcher of the EU founded projects: Copernicus project Geometric Modelling for CIM-oriented Virtual Reality (1993-1995), and Enabling Grids for E-sciencE EGEE I, II, III (2004-2010). Since 2010, she is researcher of EGI-InSPIRE project (Integrated Sustainable Pan-European Infrastructure for Researchers in Europe). Her current research interests include discrete event systems, decision support systems, logistics.

Ms. Sebestyénová was member of organizing and program committees, and editor of the Proceedings of a series of Int. Workshops on Grid Computing for Complex Problems, in years 2006 - 2011. In WSEAS transactions on computers, she published "About knowledge management and distributed computing for collaborative E-science in Grid infrastructure" (2007), and "Grid workflow specification and verification" (2008).

Peter Kurdel graduated in Computers at the Faculty of electrical engineering of Slovak Technical University in Bratislava, and received the Dipl. Eng. degree in 1973.

He worked with Institute of Technical Cybernetics, Slovak Academy of Sciences in Bratislava in years 1974 - 1991. During 1991 - 2001, he worked with Institute of Control Theory and Robotics SAS. Since 2001, he is with Institute of Informatics, Slovak Academy of Sciences in Bratislava. He works in department of Parallel and distributed computing. In 2009, he was co-author and co-editor of textbook on Grid computing (in Slovak). He was researcher of the EU founded projects: Copernicus project Geometric Modelling for CIM-oriented Virtual Reality (1993-1995), and Enabling Grids for E-sciencE EGEE I, II, III (2004-2010). Since 2010, he is researcher of EGI-InSPIRE project (Integrated Sustainable Pan-European Infrastructure for Researchers in Europe). His current research interests include robotics, visualization, grid computing.

Mr. Kurdel was member of organizing and program committees, and editor of the Proceedings of a series of Int. Workshops on Grid Computing for Complex Problems, in years 2006 - 2011. In WSEAS transactions on computers, he published "About knowledge management and distributed computing for collaborative E-science in Grid infrastructure" (2007), and "Grid workflow specification and verification" (2008).

Performance Analysis of Cognitive Radio networks using Adaptive Power Control Mechanisms

S.Praveen Chakkravarthy, C.B.Steffi Baby

***Abstract*— An optimization of threshold level with energy detection to improve the spectrum sensing performance is the ultimate task. Determining threshold level to minimize spectrum sensing error both reduces collision probability with primary user and enhances usage level of vacant spectrum, resulting in improving total spectrum efficiency. However, when determining threshold level, spectrum sensing constraint should also be satisfied since it guarantees minimum required protection level of primary user and usage level of vacant spectrum. To minimize spectrum sensing error for given spectrum sensing constraint, we derive an optimal adaptive threshold level by utilizing the spectrum sensing error function and constraint which is given by inequality condition. The dynamic multiuser scheduling algorithm offers greater adaptability to the system in terms of reducing sensing error. Simulation results show that the proposed scheme provides better spectrum sensing performance compared to conventional schemes.**

***Keywords*—Cognitive Radio Networks, Collision Probability, Spectrum Sensing error**

I. INTRODUCTION

Demand for ubiquitous wireless services requires the use of more spectrum resources. However, today's wireless networks are characterized by a fixed spectrum assignment policy. As a result, few spectrum resources such as 2.4 GHz unlicensed industrial, scientific, and medical (ISM) band are currently available for future wireless applications [1]. Operating in unlicensed band is risky since interference between heterogeneous systems degrades system performance [2]. To alleviate this problem, cognitive radio is being recognized as an intelligent technology due to its ability to rapidly and autonomously adapt operating parameters to changing environment [4-6]. One important task for realizing cognitive radio is spectrum sensing since the devices need to reliably detect weak ongoing(or primary) signals. In general, spectrum sensing techniques can be classified into three

categories; energy detection, matched filter coherent detection, and cyclostationary feature detection. Since non-coherent energy detection can be applied to anywhere and is able to locate spectrum occupancy information quickly, it is widely used in cognitive systems. In spectrum sensing, it is desired to minimize spectrum sensing error (i.e., sum of false alarm and miss detection probabilities) since minimizing spectrum sensing error both reduces collision probability with primary user and enhances usage level of vacant spectrum[6-9]. To provide reliable spectrum sensing performance (i.e., minimize spectrum sensing error), one of the great challenges is determining threshold level since spectrum sensing performance depends on the threshold level. When determining threshold level, besides spectrum sensing error, spectrum sensing constraint which requires false alarm and mis detection probabilities to be below target level should also be considered since it guarantees minimum required protection level of primary user and usage level of vacant spectrum.

Due to lack of power at both levels of transmission, the proposed research work aims at improving the stability of Cognitive radio network by Adaptive power control mechanism. This system is capable of acquiring dynamic threshold so that spectrum sensing error is very much reduced. The data applied to the system with variety of bandwidth specifications will clearly provide the effectiveness of the technique and reliability of the system. This novel idea to make the threshold to acquire dynamic nature will clearly depict the usefulness of the proposed system in variety of applications.

The research work is organized as follows: In section I, optimization of threshold level with energy detection to improve the spectrum sensing performance is performed and in section II, the temporal shadow fading correlation effects are observed in the primary signal strengths measured at cooperative sensors induced by the Primary user's mobility

II. SYSTEM MODEL

In spectrum sensing, it is desired to minimize spectrum sensing error (i.e., sum of false alarm and mis detection probabilities) since minimizing spectrum sensing error both reduces collision probability with primary user and enhances usage level of vacant spectrum. To provide reliable spectrum sensing performance (i.e., minimize spectrum sensing error), One of the great challenges is determining threshold level since spectrum sensing performance depends on the threshold level. When determining threshold level, besides spectrum sensing error, spectrum sensing constraint which requires false alarm and mis detection probabilities to be below target level should also be considered since it guarantees minimum

required protection level of primary user and usage level of vacant spectrum.

Consider the following system model that tends to optimize threshold level with energy detection to minimize the spectrum sensing error for a given sensing constraint. The false alarm and miss detection probabilities are monotonically increased and decreased, respectively, as the threshold level increases. Therefore, the spectrum sensing error function has concave or convex properties for certain threshold level duration. To optimize threshold level, besides spectrum sensing error, spectrum sensing constraint which is given by inequality condition should also be considered. Based on properties of spectrum sensing error function and inequality spectrum sensing constraint, we derive an adaptive optimal spectrum sensing threshold level minimizing spectrum sensing error while satisfying spectrum sensing constraint.

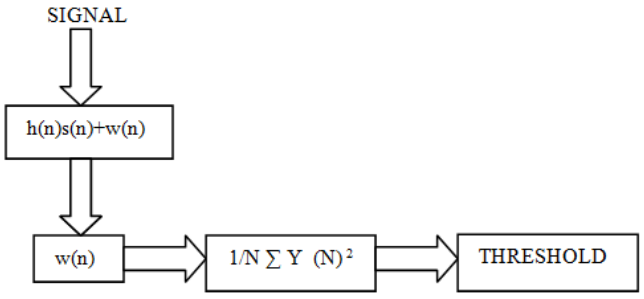

Fig. 1 depicts the system model for spectrum sensing, where cognitive (or secondary) user detects the presence of ongoing (or primary) user's signal using a hypothesis test.

The received signal sample of a secondary user can be represented as,

$$y(n) = \begin{cases} h(n)s(n)+w(n): H_0 \\ w(n): H_1 \end{cases} \quad (1)$$

We consider the use of energy detection for the spectrum sensing. Then, the test statistic for the energy detector can be represented as,

$$E(n) = \frac{1}{N}\sum_{n=0}^{N} |W(n)^2| \quad (2)$$

The detection process is normalized by equating the energy detection to the following hypothesis

H_0 : PU not present
H_1 : PU present

A. SPECTRUM SENSING SCHEME

We determine the threshold level for the energy detection to minimize the spectrum sensing error for a given spectrum sensing constraint. It can be shown that the test statistic is a random variable having a chi-square distribution with 2N degrees of freedom. From the central limit theorem, test statistic can be approximated as a Gaussian random variable with mean and variance.

Probability of Misdetection is obtained as,

$$P_{md} = 1 - \int_{e_k}^{\infty} \frac{1}{2\sigma^2} \cdot \left(\frac{y}{\mu}\right)^{\frac{\frac{e_k}{d_{t-1}}}{T-\tau}} \times \exp[-P] \quad (3)$$

$$P = \frac{1}{2\sigma^2}(y+\mu) \quad (4)$$

False alarm Probability is obtained as,

$$P_{fa} = Q(X_N^2) \times \left(\frac{\overline{e_k}}{\sigma^2}\right) \quad (5)$$

It is seen that lower the false alarm probability, larger the capacity of the secondary user due to more chances to access to vacant spectrum. On the other hand, the lower the miss detection probability, the larger the capacity of the primary user due to high protection level about ongoing transmission. It can be seen that the spectrum sensing performance depends on threshold level. Therefore, it is desired to determine the threshold level for the test statistic to minimize the spectrum sensing error (i.e., sum of false alarm and miss detection probability) while satisfying spectrum sensing constraints.

To alleviate above spectrum sensing error, we consider an optimization of threshold level to minimize the spectrum sensing error while satisfying spectrum sensing constraint sufficiently. Therefore, the level optimization problem can be represented as,

$$SE(e_k) = E(n) \le e_k |H_0 + E(n) \ge e_k |H_1 \quad (6)$$

Note that since we set the number of samples to achieve target pair of probabilities (False alarm Probability and Misdetection Probability) the threshold level satisfying sensing error as a function of threshold should also satisfy false alarm constraint.

In optimizing threshold level, we also consider the spectrum sensing constraint that is required to make the mis detection probability below maximum allowable misdetection probability. Since the spectrum sensing constraint can be represented as the functions of,

$$P_{fa} = Q(1-P_{md}) \quad (7)$$

Where,

$$P_{md} = 1-Pd \quad (8)$$

$$P_d = p(y > e_k/H_0)$$

The threshold level providing minimum required detection performance can be represented as a function of (Pfa + Pmd) which will interlink with threshold e_k.

In this section of work, the optimization of threshold level with energy detection to minimize the spectrum sensing error for a given inequality spectrum sensing constraint are considered. By considering both property of spectrum sensing error function and inequality spectrum sensing constraint, an optimal adaptive threshold level is derived. Through the use of

the proposed sensing threshold, spectrum sensing error can be minimized while satisfying spectrum sensing requirement.

III. Optimal Distributed Channel Access Strategy

In Cognitive Radio Network's (CRN's), in order to enhance utilization of spatial spectrum opportunities, SUs must be able to accurately and reliably track the location of small-scale mobile PUs. To accomplish this, we propose a framework, for accurate, attack/fault-tolerant tracking of small-scale mobile PUs. The key idea is that it exploits the temporal shadow fading correlation in the primary signal strengths measured at cooperative sensors induced by the primary's mobility. To realize this idea, we augment the conventional Sequential Monte Carlo (SMC)-based target tracking with shadow-fading estimation. By estimating shadow-fading gain between the primary transmitter and sensors, the proposed framework will not only significantly improve the accuracy of primary tracking in the absence of attack, but will also successfully tolerate sophisticated attacks, such as "slow-poisoning," preserving localization accuracy and improving spatial spectrum efficiency.

We envision that future mobile devices will incorporate CR-functionality and be capable of dynamic and flexible spectrum access. To enable DSA for mobile CRs, we identify and address fundamental challenges posed by mobile SUs that do not exist in the case of stationary CRNs where the locations of PUs and SUs are known a priori to the secondary BS. Specifically, we model spectrum availability from the mobile CR devices' perspective. Based on the spectrum availability model, we design an efficient spectrum-sensing strategy to protect PUs' communications from SUs' mobility-induced interference. In addition, to better utilize spatio-temporal spectrum opportunities, we design an optimal distributed channel-access strategy for mobile SUs. We demonstrate the accuracy of our SU mobility-aware spectrum availability model via in-depth simulation study. Moreover, our evaluation results show that our proposed spectrum sensing and access mechanisms significantly improve SUs' throughput performance and reduce energy consumption due to spectrum sensing, while protecting PUs' communications.

A. Analysis of Shadow Fading Gain

Consider a multiuser MIMO system, with M antennas at the base station and N antennas at each of the K users. Each link is modeled as (user index is omitted for simplicity)

$$Y = (P)^{1/2} H_x + n \quad (9)$$

Where Y is received vector and X is transmitted vector with total power equally divided among transmit antennas, H is the channel matrix representing small scale fading, while P captures the common large scale fading effect and n is the noise vector.The entries of H and n are independent and identically distributed (i.i.d.) complex Gaussian with zero mean and unit variance.

The cumulative distribution function (CDF) of P is given by,

$$F_P(x) = 1\text{-}Q\left[\frac{\ln(x) - L\mu l}{L\sigma l}\right] \quad (10)$$

Where,

Q(·) is the standard Gaussian tail function.

The energy of signal can be interpreted as,

$$E(P) = e^{L\mu_l} + (L^2\sigma_l^2/2) \quad (11)$$

and

$$E(P^2) = e^{2L\mu_l} + 2L^2\sigma_l^2 \quad (12)$$

Outage capacity is a common metric in MIMO communications with block fading assumptions, where the instantaneous channel capacity is given by,

$$C = \log \det [I + \rho/MP\ HHH] \quad (13)$$

Where,

$$p = P[C < C^{(p)}] \quad (14)$$

With the outage capacity the system is able to adapt power and detect the Mobile PU user information using following scheduling algorithm.

B. Dynamic Multiuser scheduling algorithm

The rate at which the PU user transmitting the data is estimated in the channel by obtaining optimal power level with respect to outage capacity (C) of the channel and is represented as,

$$P = \max \sum_{k=1}^{K} \log \bar{R} \quad (15)$$

With the above Power, the switching time between base stations and a single mobile PU user is subjected to,

$$\sum_{k=1}^{K} \sum_{n=1}^{N} P(R) = P_T \quad (16)$$

$$P_T \geq 0\ \forall n \text{ and } \forall k \quad (17)$$

To optimize the PU power level the system tends to determine the loss exponent which is given by,

$$L = 40(1 - 4\times10\text{-}3\ \Delta hb)\log10R - 18\log10\Delta hb + 21\log10f + 80 \quad (18)$$

1.Calculate the link capacity of the k^{th} user on the n^{th} sub channel at given scheduling epoch with respect to the loss exponent whose time interval is same as that of the transmission time interval of primary user.

2. Initialize the new link capacity from the above step and determine the new power level that exists between the base station and PU user. Select the new power level of PU subjected to the condition.

$$\{PU_{NEW}\} = \arg [P]\max \quad (19)$$

3. If PU_{NEW} determined is capable of establishing link connectivity between the CR's and base station as well as between base station and PU Transmitter the above equation holds good, otherwise go to step 1 with new value of R and obtain new PU_{NEW}.

The lower the spectrum sensing error, large numbers of samples are serviced with more efficient and enhanced

manner and the results of the proposed algorithms are shown in following section.

IV. Simulation Results

A. *SIMULATION PARAMETERS*

Parameter	Value
Cell Radius	1 Km
Total Power	20 W
Total Bandwidth	20 MHz
Path Loss Exponent	4
Number of Sub Channels	4,16,32,63
Scheduling Period	5 ms,15 ms

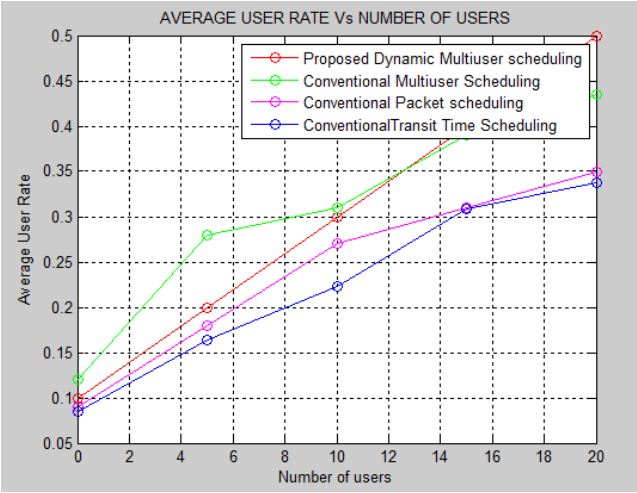

Fig.1.Average User Rate Vs Number of Users

The result shows that average user rate in the proposed system rapidly increases even when the number of users increase to its significant level and obtaining desired performance.

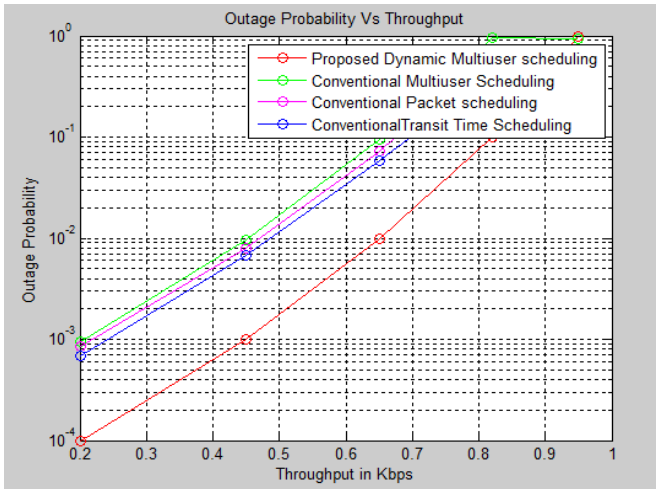

Fig.2.Outage Probability Vs Throughput

The result show that outage probability in the proposed system reduces even while the throughput increases. The curve depicts the fact that throughput beyond 0.7 plays a vital role in defining stability of the network. The Proposed Dynamic Multiuser scheduler performs well even the SNR level falls below the desired and expected parameters.

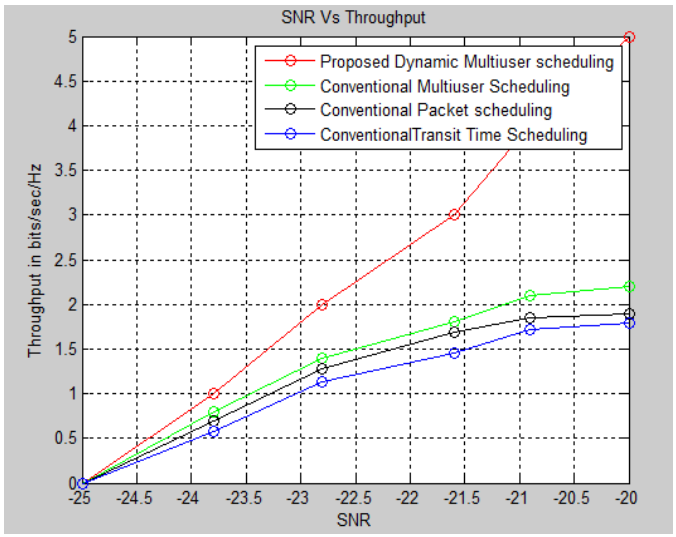

Fig 3. SNR Vs Throughput

The result shows the adaptation of signal power with respect to throughput. The worst the SNR level yields minimum but maximum achievable throughput level.

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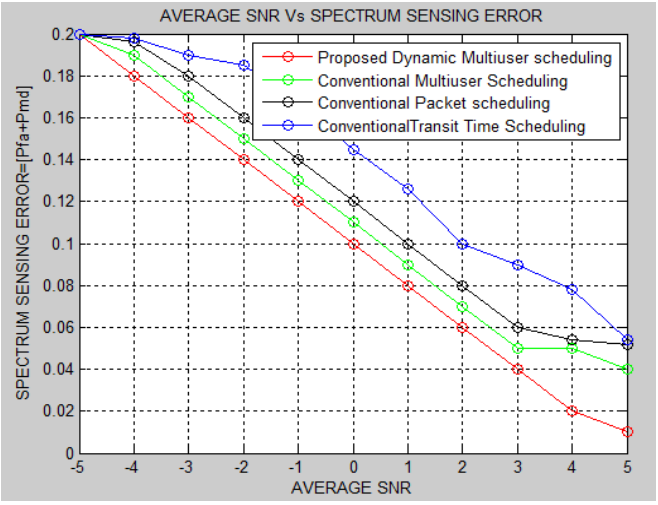

Fig 3.4.Average SNR Vs Spectrum Sensing Error

The result show the decrease in spectrum sensing error throughout average increase in SNR levels

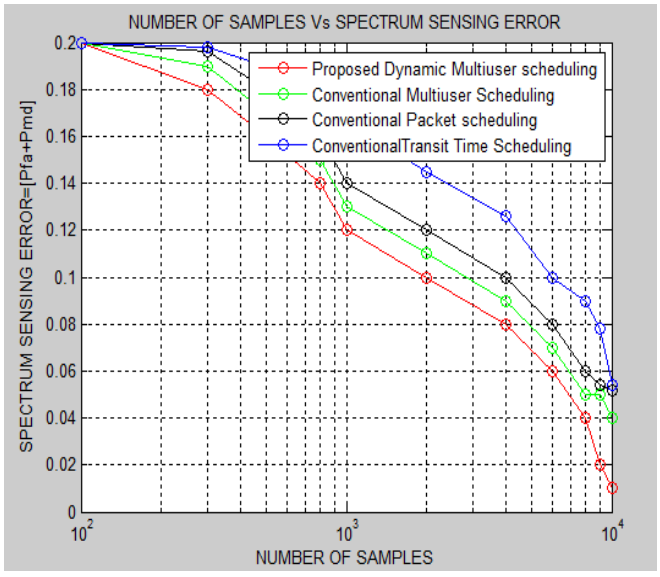

Fig 3.5.Number of Samples Vs Spectrum Sensing Error

The result shows the decrease in spectrum sensing error when the numbers of samples are increased.

V. CONCLUSION

In this method, the Adaptive power control was carried out including Dynamic Threshold allocation .The system proposed is capable of achieving high efficiency and greater stability at minimum received power and maximize SNR by which spectrum sensing error is reduced to the desired level. By using the Dynamic Multiuser Scheduling algorithm, the adaptive power allocation for CR users is done which capable of mitigating all forms of interference by selecting the proper received power updated by the dynamic threshold .This yields the desired output with minimum spectrum sensing error and at the same time maximizing SNR. The interference power is reduced by estimating the probability of detection with which the received vector with minimum sensing error is selected. The target if achieving higher signal strength and greater synchronization with minimum sensing error is achieved by calculating average user rate. Adaptive Power control with dynamic multiuser scheduling is shown to be a promising method for supporting variable data rate for large number of users. In addition, various Data rates can easily be supported by changing the number of samples. The Dynamic Multiuser scheduling algorithm regains the desired signal strength and decode properly for a system with very high speed data rate. For number of bits to be transmitted, the system is capable of generating sensing error at minimum error rate. Analytical Expressions in presence of Gaussian noise was derived .It was shown that the signal constellation rotation affects the system performance and the Spectrum sensing error expressions with respect to adaptive power and dynamic threshold were extended to incorporate the effect of signal constellation rotation. It was shown that for a Cognitive Radio system, an appropriate adaptive power control mechanism will yield significant performance improvement.

VI. FUTURE WORK

The idea can be implemented in a Universal Software Radio Peripheral (USRP) which is the equivalent hardware module of a Software Defined Radio.

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S.Praveen Chakkravarthy received his Bachelors Degree in Electronics and Communication from Bharthiar University, Coimbatore,India in the year 2003.He received his Masters Degree in Communication Systems from Anna University in the year 2006.At present he is pursuing PhD in Anna University, India in the field of signal processing and working as Senior Lecturer in Coimbatore Institute of Engineering and Technology ,Coimbatore, India. His specialization includes Signal Processing, Analog and Digital Communication, Antenna systems, RF& Microwaves.

C.B.Steffi Baby received her Bachelors Degree in Electronics and Communication from Anna University, Coimbatore,India in the year 2012. At present she is pursuing PG in Anna University, India ,specialized in Communication systems. Her expertise include Image processing ,Analog and Digital communication and Microwaves.

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Predictability of Asia Pacific Stock Market Indices Futures using Signals from A Dynamic Volatility Indicator, Adjustable Moving Average, AMA'

Jacinta Chan Phooi M'ng and Rozaimah Zainudin

Abstract— This research studies the daily stock market indices futures contracts' returns from the Asia Pacific countries, namely Australia's SPI Futures (SPIF), Hong Kong's Hang Seng Futures (HSF), Japan's Nikkei 225 Futures (NikkeiF), Korea's KOSPI Futures (KOSPIF), Malaysia's FBMKLCI30 Futures (FKLI) and Singapore's SiMSCI Futures (SiMSCIF), from 2008 to 2012 to examine the predictability of these time series returns using some simple technical analysis trading systems like moving average trading rules, and a new innovated dynamic volatility trading system, called Adjustable Moving Average (AMA'). AMA' adjusts to the volatility in the prevailing market condition to avoid some whipsaws in range trading and to enter into the new trends early in trend trading. By using the past trading signals from these moving averages rules, evidences of abnormal returns after transaction costs, above the passive buy-and-hold are found in these time series' returns; especially more so for AMA'. In particular, for this study period, AMA' generates more abnormal returns for Hang Seng Futures, Nikkei Futures and SPI Futures than the other trading rules. The results from this research suggest that it is worthwhile to investigate more adjustable trading rules, the profitability of these rules, and the predictability of time series using these adjustable rules.

Keywords— Automated adjustable moving average, Automated algorithmic trading, Futures timeseries returns, Technical analysis indicators.

I. Introduction

TECHNICAL ANALYSIS has been a part of financial practice for many decades, even though this discipline has not received the same level of academic scrutiny and acceptance as other more traditional approaches like fundamental analysis; thus one of the greatest gaps between the academicians and market practitioners is the vast difference in levels of acceptance of technical analysis [1]. As some academic studies suggest, technical analysis can be an effective method for extracting useful information from market prices and volumes [2, 3, 4, 5, 6, 7, 8, 9, 10 and 11]. Using simple moving average concept, technical analysis offers market practitioners established trading rules to decipher market's behavioural patterns while maintaining profit maximization with a minimal loss situation [7]. However, Brock, Lakonishok and LeBaron [4] highlights the drawback of this common moving average trading rule method where it practically ignores the element of ever changing volatility characteristic that is present in financial markets. Market volatility plays a vital role in influencing the return predictability [12]. Balsara, Carlson and Rao [14] discusses the importance of new trading systems that can align with the prevailing market condition, whether it is a ranging or a trending market. Empirical evidence highlights the importance of new trading rules system that able to account the dynamic market condition [14 and 15]. Hence, this study introduces an adjustable volatility based algorithm into an adjustable moving average trading system called Adjustable Moving Average (AMA'). AMA' generates automatically adaptive parameters to fit historical and current data and thus market condition.

The objectives of this research paper are to investigate if these Asia Pacific stock index futures contracts follow some trends and to test if in the long run, algorithm technical trading rules perform better than the passive buy-and-hold strategy advocated by random walk hypothesis. Specifically, we test if AMA' generates more net profits for the stock index futures contracts for the period 2008 to 2012 than some of the other common technical analysis indicators. Thus, we begin with testing the trading rules specified by Brock, Lakonishok and LeBaron [4] and others like Appel [16], Kaufman [17] ranging from simple moving average trading systems to a newly innovated algorithm trading model, AMA', to verify if these trading systems generate net profits in the long run; then we compare these models profit performance against the passive buy-and-hold strategy in the long run. Based on the results of the back tests for these stock index futures contracts, most of these trading systems generate positive net returns after transaction costs.

In the next section, a brief investigation on the properties of the behaviour of the stock index futures contracts is described, followed by the trading system methods used. Then the results are presented and discussed. Finally, a conclusion wraps up this research paper.

II. Data description

This study uses the closing prices of FTSE Bursa Malaysia Kuala Lumpur Composite Index Futures (FKLI) from Malaysia, KOSPI Futures from Korea, Nikkei Futures from Japan, SiMSCI Futures from Singapore and SPI Futures from Australia for the period of 01/02/2008 to 12/31/2012. The

daily closing prices are transformed into daily returns using $\log(Close_t/Close_{t-1})$ where $Close_t$ and $Close_{t-1}$ represent current close price and previous close price. The statistical characteristics of the daily returns from these stock index futures contracts derived from a preliminary data analysis performed are presented in Table I. Based on the data analysis, the existence of non-normality distribution in these six tested series cannot be rejected.

Table I: Descriptive statistics of daily returns from 1/2/2008 to 12/31/2012

	FKLI	HSF	KOSPIF	NIKKEIF	SiMSCIF	SPIF
Mean	0.000122	-0.000333	5.73E-05	-0.000294	-0.00026	-0.000295
Median	0.00063	0.000143	0.000767	0.000383	0.00029	-0.000207
Maximum	0.03823	0.110139	0.09531	0.131596	0.083145	0.059871
Minimum	-0.075654	-0.114469	-0.10536	-0.113802	-0.09847	-0.085168
Std. Dev.	0.010427	0.019081	0.017092	0.019282	0.015657	0.013707
Skewness	-0.742301	0.038489	-0.44148	-0.158861	-0.21777	-0.329362
Kurtosis	7.94605	8.082662	8.759255	10.61901	7.765287	6.589336
Jarque-Bera	1368.929	1274.743	1703.09	2958.395	1210.714	703.5947
Probability	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Testing the observation that the standard deviations of these daily returns are non-constant and tend to vary with time, we find evidence of this non-constant characteristic in the standardized residuals, presented in the Table II. Mandelbrot [18] reports that volatilities tend to cluster in periods of high volatilities, followed by periods of low volatilities and vice versa. From the evidence of these dynamic volatilities, it can be deduced that using a constant moving average throughout the whole study period is not suitable for producing the best profitable results. Therefore, this research proposes to adjust the moving average for each different period according to the volatilities characteristic of that particular period using the prevailing Efficacy Ratio (EffR) which is derived from the standard deviations of two periods (refer to III. Estimation Techniques).

Table II: Descriptive Statistics of Standardized Residuals from 1/2/2008 to 12/31/2012

	Mean	Median	Maximum	Minimum	Mean	Median	Maximum	Minimum
	FKLI				*NIKKEIF*			
2008	-0.0660	-0.0088	2.6206	-4.3798	-0.0454	0.0488	2.5411	-2.7604
2009	-0.0078	-0.0238	3.1305	-2.5074	-0.0250	-0.0155	3.5403	-3.2411
2010	-0.0431	-0.0104	2.8232	-3.4957	-0.0432	0.0115	2.7633	-3.2442
2011	-0.0929	0.0325	1.9385	-4.2415	-0.0650	-0.0234	2.6502	-3.9180
2012	-0.0173	2.0330	2.3550	-3.3905	-0.0055	-0.0397	2.9831	-3.3657
	HSF				*SiMSCIF*			
2008	-0.0296	0.0297	3.1811	-2.7923	-0.0583	-0.0682	3.4017	-3.5656
2009	0.0035	-0.0706	2.6106	-2.7047	-0.0026	0.0124	2.7043	-2.6892
2010	0.0093	0.0536	2.3743	-3.6165	-0.0589	-0.0379	2.3876	-3.5192
2011	-0.0038	0.0260	2.6142	-3.2861	-0.0344	-0.0237	2.3720	-2.9575
2012	0.0050	-0.0082	3.7490	-3.1614	-0.0248	0.0959	2.5070	-3.3538
	KOSPIF				*SPIF*			
2008	-0.0436	0.0573	3.2956	-3.3219	-0.0303	-0.0969	2.5427	-3.9912
2009	-0.0232	-0.0236	2.6332	-4.1658	-0.0250	-0.0168	2.9728	-3.5530
2010	-0.0564	-0.0177	2.0442	-3.3341	-0.0539	-0.0252	2.5786	-2.7610
2011	-0.0195	-0.0053	3.2519	-4.0552	-0.0307	0.0026	2.8073	-3.4052
2012	-0.0625	-0.0238	3.0103	-2.8914	-0.6071	-0.0549	2.2732	-4.2019

III. Estimation Techniques

To confirm the observations of trends evident in these stock index futures contracts, the tests begin on a similar approach to that used by Lukac, Brorsen and Irwin [3], testing:

1) Five (4) common renowned methods used by Brock, Lakonishok and LeBaron [4] a Simple Moving Average (SMA), Moving Average Crossover (MAC), Trading Range Breakout (BO), 1% Bands from Moving Average (MA1%));
2) Three (3) innovated methods used by Appel [16] (Moving Averages Convergence Divergences (MACD)), Kaufman [17] (Kaufman Adaptive Moving Average (KAMA)), Chan [19] (Standard Deviation Bands Z-Statistics (BBZ)); and
3) One (1) newly innovated method proposed by this research (Adjustable Moving Average (AMA')).

The aims are to compare the returns' performances of these eight (8) trading systems against: a) the threshold buy-and-hold (BH) for abnormal profit results, and b) each other to identify the best algorithm trading system. The best trading system will fulfil the following criterions: i) it should not encounter large losses, or show net large loss in any of the years; ii) it should work well in practice as in testing; iii) it can adjust automatically to the parameter shifts; and iv) slippage and transaction costs should be taken into account.

Simple 21 Days Moving Average (SMA)

The most common trading system is the Variable Moving Average (1,21,0%) used Brock, Lakonishok and LeBaron [4]. (1 represents the current closing price, 21 represents 21-days simple moving average and 0% represents 0% from the 21-days simple moving average). 20 or 21 days is used because it represents one (1) month of trading days. The average of 21 daily closing is computed, and it is then compared that to the current closing price. If the current closing price exceeds the 21-days SMA, a buy signal is generated. If the current closing price is below the 21-days SMA, then the signal is to sell.

3 and 21 Days Moving Average Crossover (MAC)

The other common trading system is the Variable Moving Average (3,21,0%) tested by Brock, Lakonishok and LeBaron [4], with a slightly different condition from SMA. 3 and 21 days of simple moving averages are estimated and compared. If the 3-days SMA exceeds the longer 21-days SMA, then a buy signal is generated, otherwise a sell. The lengths, 3 and 21 are arbitrary chosen.

Moving Average Convergence Divergence (MACD)

Appel [16] introduces MACD in the late 1970s. MACD can be estimated by first computing MACD by subtracting a shorter-term (12-days) exponential MA from a longer-term (26-days) exponential MA, and then computing the Signal Line by calculating 9-days exponential averages of these differences (MACD). A buy signal is generated when MACD crosses up above Signal Line and a sell signal is generated when MACD crosses below the Signal Line.

Kaufman Adaptive Moving Average (KAMA)

Kaufman [17], one of the first to posit a non-constant moving average, apportions different weightages to the current data and past smoothened data series according to Efficiency

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Ratio. Efficiency Ratio (ER) takes into account the amount of the closing prices' movement within n periods in relation to the sum of all daily movements.

$KAMA_t = \alpha\ ER\ C_t + (1-\alpha)\ ER\ KAMA_{t-1}$

$$where\ \ \alpha = \left[\left(ERx\left(\frac{2}{3}-\frac{2}{31}\right)\right)+\frac{2}{31}\right]^2$$

$$ER = \frac{(C_t - C_{t-n})}{\Sigma|C_t - C_{t-1}|}$$

C_t is the current closing price and C_{t-1} is the closing price at period t-1. If the current closing price is above $KAMA_t$, a buy signal is generated. If the current close is below the $KAMA_t$, then the signal is to sell.

Trading Range Breakout (BO)

Trading Range Breakout trading system (BO) uses the breakout from recent highs or lows, to identify new trading opportunities (similar application in Donchian [20] and Brock, Lakonishok and LeBaron [4]. Using a 20-days trading range breakout rule, a buy signal is generated when the price breaks up above 20 days' high; likewise a sell signal is produced when the prices breaks down below the 20 days' low.

1% Bands from MA (MA1%)

The moving averages trading systems are turn-and-reverse models, which means that using these trading systems, the trader gets out of his existing position and immediately enters a new position in the opposite direction. Thus, he is trading all the time. To overcome losses brought about by whipsaws in range market, a certain percentage bands above and below the moving average are added. In Brock, Lakonishok and LeBaron [4], MA(1,21,1%) refers to 1% band above and below the 21-day SMA. To construct the upper band, 1% is added to the 21-day SMA whereas to establish the lower band, 1% is deducted from the 21-day SMA. 1% above the SMA gives additional confirmation of an uptrend while 1% below the SMA confirms the downtrend. A buy-on-uptrend signal is called upon when the closing price transcends above the upper 1% band. An exit-long signal is triggered when the closing price returns below the upper 1% band. Vice versa, a sell-on-downtrend signal will be prompted when the closing price dips below the lower 1% band and an-exit-short signal will emerge when that price bounces back above the lower 1% band. The upper and lower 1% bands are calculated as follows:
1.01 x $SMAn_t$ and 0.99 x $SMAn_t$ respectively;where

$$nSMA_t = \left(\frac{1}{n}\right)\sum_{i=0}^{n} C_{t-i}\ .$$

BB Z-Test-Statistics (BBZ)

To avoid trading unprofitably during range periods, BBZ [19] generates trading signals only when volatility increases, that is, when the closing price moves above +1 or below -1 standard deviation band. BBZ first computes the 21-days MA and 1 standard deviation and then adds 1 standard deviation to the 21-days MA to derive the upper band and to deduct 1 standard deviation from the 21-days MA to obtain the lower band. If the closing price is above the upper band, then the signal is to buy and when the closing price is below the upper band, the signal is to exit long. If the closing price is below the lower band, then the signal is to sell and when the closing price is above the lower band, the signal is to exit short.

Adjustable Moving Average' (AMA')

While KAMA uses Efficiency Ratio to apportion the weights of the current data and past smoothened data series, AMA' adjusts the length of the moving average for each different period according to the prevailing Efficacy Ratio (EffR).

$EffR = LT\sigma / ST\sigma$

where $LT\sigma$ and $ST\sigma$ represent the long term standard deviation and short term standard deviations respectively. This study proposes to use a ratio of 34-days $LT\sigma$ and 6-days for $ST\sigma$. EffRatio dynamically and automatically varies to suit the current market condition. This adaptability potentially addresses the most important common problem encountered by traders in gauging whether the market is ranging or beginning to trend. If the current closing price is above AMA'_t, then a buy signal is generated. If the current closing is below AMA'_t, then the signal is to sell.

IV. Empirical Results

The results show that the objectives of this research which are to find abnormal returns of the eight trading systems above that of passive buy-and-hold (BH) (considering transaction costs); and to show how the new AMA' model outperforms the other tested trading systems, have been achieved. Table III shows all the trading systems' results surpass the BH and that KAMA outperforms the rest of the trading systems and marginally against AMA' by 24 index points over the five years period. Tables IV, VI and VIII show AMA' outperforming BH and also the other trading systems for Hang Seng Futures, Nikkei Futures and SPI Futures by relatively large margins. This indicates that AMA' may be an ideal trading system in fast changing markets like Hang Seng Futures and Nikkei Futures. However, for markets like KOSPI Futures and SiMSCI Futures, slower trading systems like MACD and MAC are more useful as shown in Tables V and VII.

Table III: FKLI Results

FKLI	BH	SMA	MAC	MACD	KAMA	BO	MA1%	BBZ	AMA'
2008	-562	416	388	288	499	278.5	256	214	430
2009	388	21	47	-125	68	288	166.5	149	51
2010	250	-8	20	24	47	107.5	62.5	65	90
2011	-91	70	79	-33	10	-87.5	132.5	13	-14
2012	161	124	89	23	67	-291	30.5	23	109
Total	146	623	622	177	690	296	648	463	666

Table IV: Hang Seng Futures Results

HSF	BH	SMA	MAC	MACD	KAMA	BO	MA1%	BBZ	AMA'
2008	-13263	9160	9306	1613	1397	450	5972	5762	12525
2009	6886	-2480	-3622	-2465	1056	4302	1198	-898	3232
2010	1219	-207	-853	-330	3484	227	2025	928	2887
2011	-4576	-5327	-6344	-3421	-1096	-229	-2267	-1139	-4614
2012	3864	502	-1747	1042	-1435	2682	-208	-1607	594
Total	-5870	1648	-3260	-3561	3406	7432	6720	3046	14624

Table V: KOSPI Futures Results

KospiF	BH	SMA	MAC	MACD	KAMA	BO	MA1%	BBZ	AMA'
2008	-95.10	34.85	41.35	24.70	-22.60	51.30	1.00	55.10	42.20
2009	75.60	-46.80	-13.55	-8.25	-56.10	0.75	-16.80	5.35	1.90
2010	51.50	-15.95	-3.00	35.15	-7.35	32.15	8.70	-7.60	-13.40
2011	-35.40	-44.80	-31.55	29.40	-57.45	-97.60	-45.40	-25.10	24.40
2012	26.90	9.95	-18.95	8.55	31.05	-23.90	-0.50	-5.35	-7.80
Total	23.50	-62.75	-25.70	89.55	-112.45	-37.30	-53.00	22.40	47.30

Table VI: Nikkei Futures Results

NikkeiF	BH	SMA	MAC	MACD	KAMA	BO	MA1%	BBZ	AMA'
2008	1505	-85	2475	-4800	-340	1795	-155	-1405	795
2009	1525	1870	0	1125	1530	-400	1595	1180	5165
2010	-435	1570	840	1390	785	600	435	-1550	-585
2011	-1950	25	685	905	150	-3375	-1535	-465	150
2012	2155	2620	1930	860	1880	50	2405	2315	1840
Total	2800	6000	5930	-520	4005	-1330	2745	75	7365

Table VII: SiMSCI Futures Results

SIMSCIF	BH	SMA	MAC	MACD	KAMA	BO	MA1%	BBZ	AMA'
2008	-206.5	60.4	89.6	62.6	-19.2	134.5	12.8	0.2	30.0
2009	130.7	68.2	82.6	-40.5	42.8	111.5	45.5	53.3	73.0
2010	28.9	37.3	39.7	16.7	20.0	13.9	-3.9	-7.8	39.1
2011	-78.1	-29.0	-36.5	-45.5	-57.2	-72.8	-13.9	-16.4	-7.9
2012	59.8	65.4	36.3	52.7	44.3	-12.9	20.4	24.0	46.8
Total	-65.2	202.3	211.7	46.0	30.7	174	61	53.3	181.0

Table VIII: SPI Futures Results

SIMSCIF	BH	SMA	MAC	MACD	KAMA	BO	MA1%	BBZ	AMA'
2008	-206.5	60.4	89.6	62.6	-19.2	134.5	12.8	0.2	30.0
2009	130.7	68.2	82.6	-40.5	42.8	111.5	45.5	53.3	73.0
2010	28.9	37.3	39.7	16.7	20.0	13.9	-3.9	-7.8	39.1
2011	-78.1	-29.0	-36.5	-45.5	-57.2	-72.8	-13.9	-16.4	-7.9
2012	59.8	65.4	36.3	52.7	44.3	-12.9	20.4	24.0	46.8
Total	-65.2	202.3	211.7	46.0	30.7	174	61	53.3	181.0

It is noted in studies [9] and in real life trading that transaction costs account for a chunk of the trading losses and thus, it would unrealistic if transaction costs are not included in this study. The transaction costs are converted into the nearest index point(s) to account for brokerage commission including exchange and clearing fees as well as slippage. For example, in the case of FKLI, the maximum transaction cost for a 2 way transaction (in and out of the position) amounting to RM50 is equivalent to 1 index point. Similarly, 1 index point cost SPI Futures, while 10 index points are applied to Hang Seng and Nikkei Futures and 0.1 index point constitutes the transaction costs for the smaller contracts like KOSPI Futures and SiMSCI Futures.

Taking transaction costs into consideration, the mean returns (in average percentage per year) are reproduced in Table IX after deducting for the number of transactions generated by the trading systems. Even after taking into account the hefty transaction costs, the trading results do not differ much from the original results. The trading systems that are profitable before, continue to outperform the BH. Table IX shows that overall AMA' is the most profitable trading model, generating profits above BH for all the given time series. For Hang Seng Futures, Nikkei Futures and SPI Futures, AMA' remains the most profitable trading model.

Table IX: Mean Returns After Transaction Costs

	BH	SMA	MAC	MACD	KAMA	BO	MA1%	BBZ	AMA'
FKLI	2.02%	7.26%	7.43%	3.88%	8.24%	1.40%	7.96%	3.55%	7.39%
HSIF	-4.85%	0.41%	-3.42%	-3.68%	1.69%	5.98%	4.44%	1.28%	11.25%
KospiF	1.99%	-6.83%	-2.68%	8.31%	-10.25%	-7.65%	-7.25%	-1.12%	2.88%
NikkeiF	3.81%	7.11%	6.04%	-0.83%	3.49%	-0.88%	0.91%	-1.16%	8.24%
SIMSCIF	-3.09%	9.09%	9.70%	1.72%	0.78%	8.15%	2.20%	1.77%	8.00%
SPIF	-5.42%	-5.29%	-4.39%	-1.82%	-1.62%	1.58%	-5.26%	-2.98%	1.85%
Total	-8.84%	15.01%	9.99%	9.37%	2.78%	13.61%	9.52%	7.32%	47.28%

Table X shows the mean returns' differences from the buy-and-hold. The mean returns differences from BH are computed by taking the difference between the trading system's mean return and the mean return of the respective BH. Except for KOSPI Futures and Nikkei Futures, all the trading systems outperform the BH for selected Asia Pacific indices futures. In terms of total performance across the selected stock index futures contracts, Table X shows that AMA' is the only trading model that generates abnormal profits. This indicates that AMA' is a robust trading model and can be used for all these markets. AMA' outperforms SMA, the second best trading system in terms of profits, by a relatively large margin and thus, can be taken into consideration as a viable trading model for the professional model trading desk of financial institutions.

Table X: Differences of Mean Returns from Buy-and-Hold after Transaction Costs

	SMA	MAC	MACD	KAMA	BO	MA1%	BBZ	AMA'
FKLI	5.24%	5.41%	1.85%	6.22%	-0.62%	5.94%	1.53%	5.37%
HSIF	5.26%	1.43%	1.16%	6.54%	10.83%	9.28%	6.13%	16.10%
KospiF	-8.82%	-4.67%	6.33%	-12.24%	-9.64%	-9.23%	-3.10%	0.90%
NikkeiF	3.30%	2.23%	-4.64%	-0.32%	-4.70%	-2.90%	-4.97%	4.43%
SIMSCIF	12.18%	12.79%	4.81%	3.87%	11.24%	5.29%	4.86%	11.09%
SPIF	0.13%	1.03%	3.60%	3.79%	7.00%	0.16%	2.44%	7.27%
Total	23.84%	18.83%	18.21%	11.62%	22.45%	18.36%	16.16%	56.12%

V. Conclusion

The profitable results computed in this research are entirely consistent with the findings reported by Lukac, Brorsen, Irwin [2], Brock Lakonishok and LeBaron) [4], and Bessembinder and Chan [6] where the presence of abnormal returns using various technical trading rules are found. Considering the time varying condition in the markets and the need to program trading models to be adaptive to the market, like the genetic programmes done by Gencay and Stengos [7], machine learning by Andrada-Felix and Fernandex-Rodriquez [8] and the dynamic MACD standard deviation embedded in MACD indicator for accurate adjustment by Gandolfi, Rossolini, Sabatini and Caselli [21], this study introduces AMA' which outperforms the simple moving averages, the trading range breakout trading system and the traditional MACD for the stock indices futures in Asia Pacific region for the period between 2008 and 2012.

AMA' is designed to address some of the common problems encountered by most trend trading systems such as floods of orders generated by common trading systems (like SMA), being whipsawed in range market and failed to correctly time the trend (entering the trend too late and exiting the trend too early). AMA' has the ability to adjust accordingly in different

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market conditions and across different time frames. Based on the results, this research ascertains that the price movements of these six stock index futures contracts tested are not random. The trading systems from ranging simple moving averages to the newly innovated AMA' can be used to compute the abnormal returns arising from trending behaviour. Finally, AMA' is a robust adaptive algorithm trading model that can be implemented based on past and current empirical evidence and it is possible that it can contribute to the profits of the model trading desk.

The ability of AMA' to adjust according to the prevailing market condition, points a new direction for research in incremental machine learning trading systems. New adaptive new trading models like AMA' can be applied immediately on any professional model trading desk. Despite good preliminary results, future research can explore and find specific algorithms that cater for automatic determination of the length for the long and short term standard deviations, and thus the length of the variable moving average. With artificial intelligent algorithms, neural networks can learn the behaviour of the market, whether it is trending or ranging, and adjust the algorithms automatically according to the prevailing market condition.

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Risk and Hazard Control the new process control paradigm

*Gheorghe Florea[1], Radu Dobrescu[2],**

[1]Societatea de Inginerie Sisteme SIS SA, Bucharest, Romania
[2]Politechnica University, Bucharest, Romania
*Corresponding Author: gelu.florea@sis.ro

***Abstract*—**Process control and optimization represent the current base for safer and more efficient industrial plants, while risk management represents the base for new control algorithms and strategies. The technology has been changing over the last decades towards full control systems and the requirement specifications for Safety Instrumented Systems (SIS) forms the central network for the process risk and hazard assessment to be carried out. Despite the debate pro and against the integrated approach of Basic Process Control System (BPCS) and SIS there is a necessity for more than a safety system to maintain the process running even with less functionalities instead of shut down. The professionals recognize the need for better and more extensive solutions for tackling problems belonging to the tactical and strategic layers of control. They also recognize the need for vertical integration of the layers (in terms of flow of information). In the mean time the safety and security are major problems in the real time world. Based on our experience the only approach to performance is toward a totally integrated system. The three important levels cover the process, the management and the business control but we added the new level: Risk and Hazard (RH) control. This new hierarchical decision level can complete the mission regarding safety when the control room is not functional or cannot act properly in a hazard situation. Layers of protection should be used in order to reduce the risk to an acceptable level. The key is RH control implemented as a superior hierarchical level of decision and intervention. Emerging technologies used for engineering and implementing can help designers to apply the proposed system architecture. The simulation and concurrent engineering are basic approaches to accomplish the functionalities of the new system architecture and the results of an R&D project (PH Center) show the feasibility.

***Keywords*—**Concurrent engineering, Diagnostics, Hierarchical decision, Remote intervention, Risk and hazard assessment, Simulation, SIS.

I. INTRODUCTION

PROCESS control and optimization represent the current base for safer and more efficient industrial plants, while risk management represents the base for new control algorithms and strategies. There is a stringent need for the enhancement of process operations at plant production management level, because plants should often operate near criticality, meaning in conditions far from ideal ones from the point of view of control and stability. Continuous process industries are usually very complex and difficult to model and kept under control. There is a tremendous need for better and more versatile simulation and modeling tools but no product in the market offers the necessary capabilities to deal with the uncertain nature of complex plants including safety and security threats.

Safety is an important issue nowadays that received an increasing amount of focus lately. The reasons are, unfortunately, the numerous accidents occurred in industry plants which require the process industry to take a hard look at current practices like process design, process control, risk analysis and control, risk assessment. Worldwide engineering organizations have developed standards for the engineering of process safety. IEC released two standards IEC 61508 aimed at the suppliers of process safety equipment and IEC 61511 aimed at the end users of process safety equipment. In order to achieve the required level of safety and security, we should take into consideration four important phases: analyze the needed level of SS for the plant, design, implementation and maintenance.

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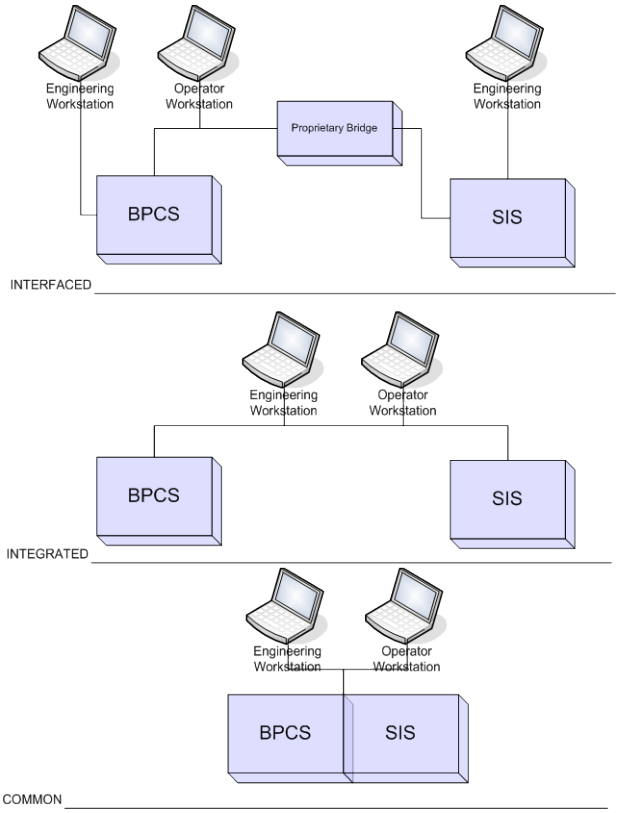

Fig. 1 – SIS and BPCS Integration Levels

Today, integrating safety and control has become a cost effective way for manufacturers that could not justify a separate SIS in the past [1].

Entire issue of safety has direct influence on the activity of the plant and therefore it must be integrated into the plant control system.

II. RH CONTROL – THE NEW LEVEL OF DECISION

According to the IEC 61511/ISA 84 process safety standards, the process risk has to be reduced to a tolerable level as set by the process owner [2]. The solution is to use multiple layers of protection, including the basic process control system, alarms, operator intervention, mechanical relief system and a SIS.

The Basic Process Control System is the lowest layer of protection and is responsible for the operation of the plant in normal conditions. If BPCS fails or is incapable of maintaining control, then, the second layer, Operator Intervention (OI) attempts to solve the problem. If the operator also cannot maintain control within the requested limits, then the SIS Layer must attempt to bring the plant in a safe condition [3]. Our approach is based by the introduction of a new decision level- Risk and Hazard Control and a new state of the process-safety state. The layers of protection and also the impact over the process are illustrated in Fig. 2.

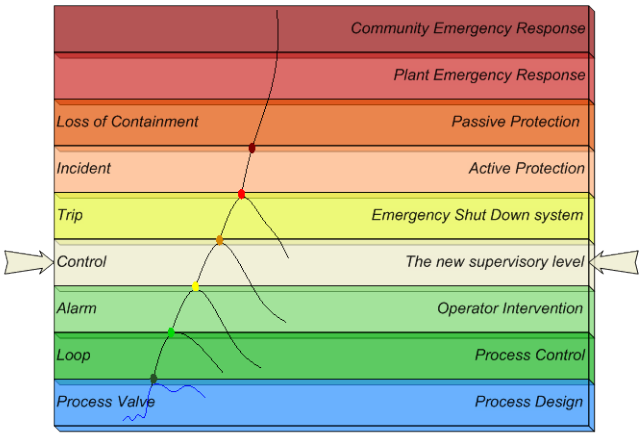

Fig. 2 - Layers of protection and impact on process

Risk is defined as the combination of the probability and the severity of a hazardous event, meaning how often it can appear and how bad are the consequences when it does. The best way to reduce risk in a manufacturing plant is to design safer processes. Unfortunately, it is impossible to eliminate all risks, so a manufacturer must agree on a level of risk that is considered tolerable. After identifying the hazards, a hazard and risk analysis must be performed to evaluate each risk situation [4].

Risk assessment means that a quantitative value is assigned to a task, action, or event.

Types of Risk:

Total Risk - The sum of identified and unidentified risks.

Identified Risk - Risk that has been determined through various analysis techniques. The first task of system safety is to identify, within practical limitations, all possible risks.

Unidentified Risk - Risk not yet identified. Some unidentified risks are subsequently identified when a mishap occurs. Some risk is never known.

Unacceptable Risk - Risk that cannot be tolerated by the managing activity. It is a subset of identified risk that must be eliminated or controlled.

Acceptable Risk - Acceptable risk is the part of identified risk that is allowed to persist without further engineering or management action. Making this decision is a difficult yet necessary responsibility of the managing activity. This decision is made with full knowledge that it is the user who is exposed to this risk.

Residual Risk - Residual risk is the risk remaining after system safety efforts have been fully employed. It is not necessarily the same as acceptable risk. Residual risk is the sum of acceptable risk and unidentified risk. This is the total risk passed on to the user [5].

Using a risk assessment matrix helps differentiate between low-risk and high-risk:

Table 1 - Risk assessment matrix

Likelihood	Severity			
	Catastrophic	Critical	Marginal	Negligible
Probable	High	High	Serious	Medium
Occasional	High	Serious	Medium	Low

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Remote	Serious	Medium	Medium	Low
Improbable	Medium	Medium	Medium	Low

BPCS, along with process alarms and facilities for manual intervention, provide the first level of protection and reduce the risk in a manufacturing facility. Additional protection measures are needed when a BPCS does not reduce the risk to a tolerable level. They include SIS along with hardware interlocks, relief valves, and containment dikes but the process must be stopped. The start-up of the process means a lot of time and money.

In Fig. 3 we detailed the risk assessment procedure, consisting in 10 steps:

- Step 1 – 5 – deal with current situation, threat, vulnerability and likelihood identification, current and planned controls;
- Step 6 – deals with the impact resulting from a successful threat exercise of a vulnerability;
- Step 7 – assess the level of risk to the system;
- Step 8 – implement controls that could mitigate or eliminate the identified risks;
- Step 9 – once the risk assessment has been completed, the results should be documented in an official report.
- Step 10 – monitoring the process behavior.

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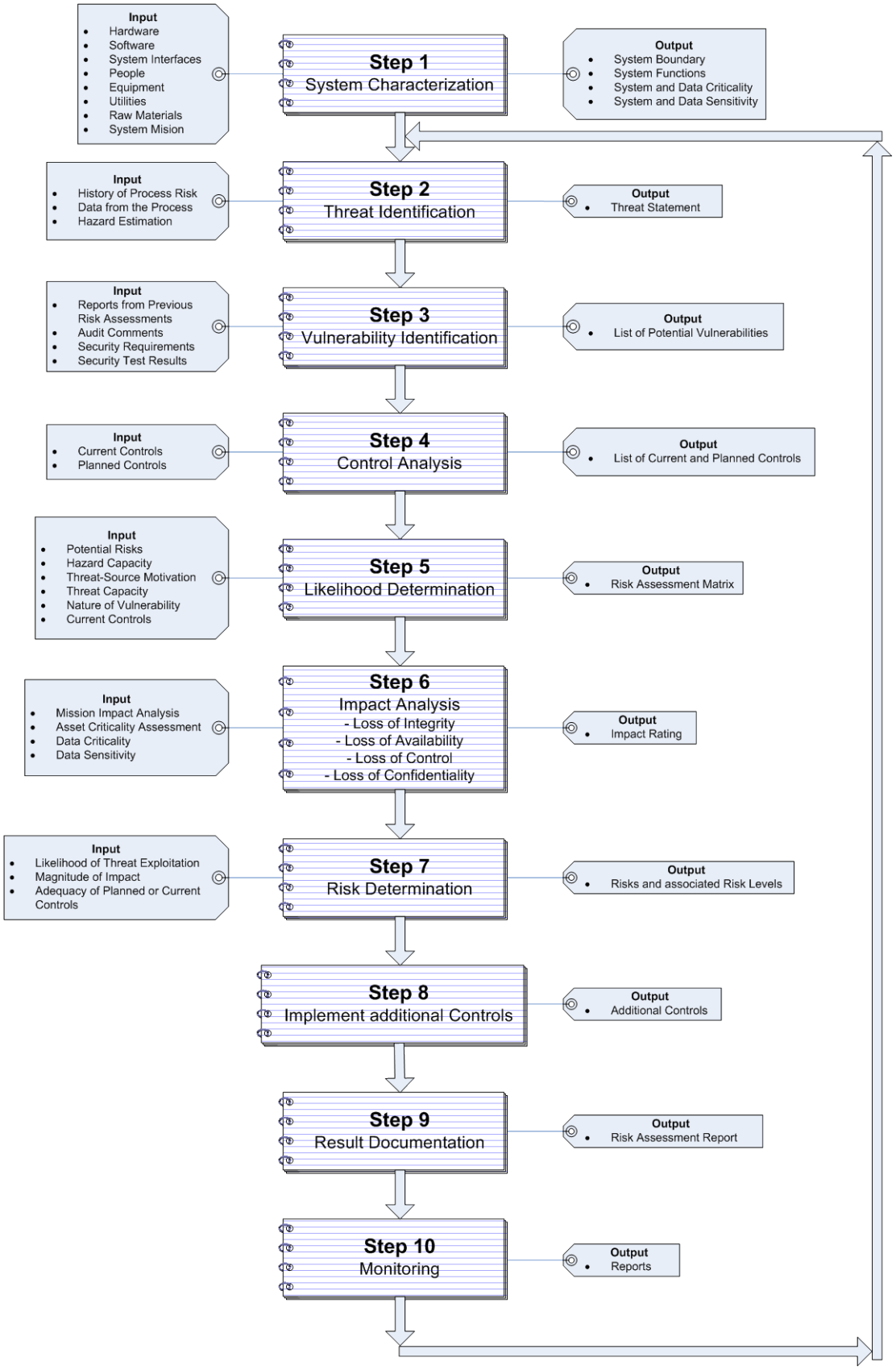

Fig. 3 - Risk assessment procedure

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To implement additional risk and hazard control is the next goal of Process Control. The technical approach tries to provide reusability in the broadest sense using functional blocks. Object technology can be one of the cornerstones of this approach [6]. Reusability can be achieved for any stage in the life cycle: from requirements and design to commissioning and maintenance. The approach is based on the availability of design template and reusable component implementation with few design compromises. These implementations are flexible enough to be adapted or modified to fit new requirements with little effort. Function block based development and integration middleware concepts provide the basis for reusability. RH Control will incorporate components for process control, risk analysis, optimization, etc.

The customized components will be integrated in a global architecture using a real-time integration. This software, based on function block specification, will incorporate extensions to make possible its use in real-time applications. This facilitates the easy reuse of components and even the reuse of the global application architecture because run-time components can be easily changed without affecting other components behavior.

The industry has heavily invested (and still investing) in both ACS and also Management Information Systems (MIS) like MES, R/PE, ERP, SCM or SSM (OMG Manufacturing Domain Task Force, 1998). Information systems in plants are hierarchically structured in order to deal with the large collection of functional components. Complex software systems tend to be unpredictable and this is not acceptable in some types of plants. Heterogeneous environments are the common infrastructure for advanced control systems. Almost everybody recognizes the need for better and more extensive solutions for tackling problems belonging to the tactical and strategic layers of control. They also recognize the need for vertical integration of the layers (in terms of flow of information. In the mean time the safety and security are major problems in the real time world.

Based on our experience the only performing approach is toward a totally integrated system. The three important levels cover the process, the management and the business control but we aid the new one; RH Control. In Fig. 4 we present our proposed architecture underlying the main function on each level.

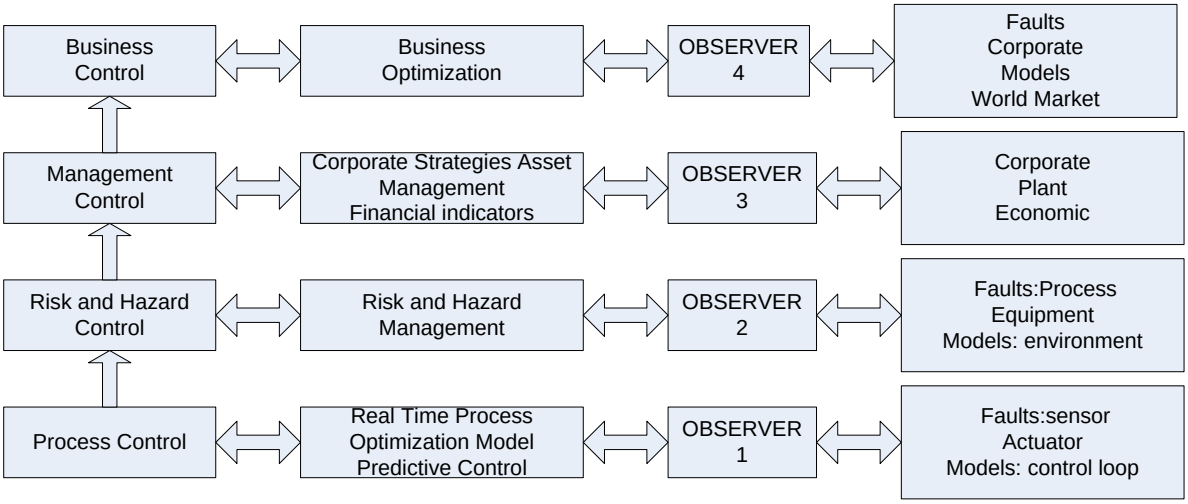

Fig. 4 - Business Integrated Control

A. The advantages

The benefits of this approach can be classified into two categories:

- From the user's point of view: the implementation addresses the problems related to the global management of the plant while taking into account the interrelation of the strategic objectives, such as production, quality, maintenance, safety, efficiency and continuity, as well as problems closer to the process control layer.
- From the systems integrator's point of view: the development of an open software architecture based on OPC and function block specification, will allow the construction of distributed intelligent control systems on top of the existing control systems being used in the industrial plants with back-up functions.

B. System architecture

Better automation is a key aspect for improving industrial competitiveness. Intelligent automation at management levels - in particular - can play a major role regarding this aspect. RH Control aim is to help in this improvement by building a new architecture and a distributed and generic software system that addresses decision support for near critical situation management in continuous process industries. In particular, assistance, in terms of diagnosis and solutions, is provided to the plant and/or to the staff when situations suitable to be corrected, prevented or enhanced are detected.

The focus is on new algorithms and strategies for the integration of different software components as well as on

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the system architecture itself. These software components include core modules, user interface modules and problem solving modules.

RH Control follows the conceptual structure of most distributed control systems that is a hierarchical and multilayered structure, similar to a pyramid. The complexity of the control mechanism increases in higher layers. All the basic functionalities of the system are grouped into problem solving components that work in a cooperative way to find a solution to the plant problems or to optimize the plant objectives.

These applications include the following functionalities at the different control layers:

- Strategies: Management of global objectives of the plant and their interrelation (management of maintenance operations, incident prevention, risk and hazard control, assessment of production costs in real time, loop tuning optimization, quality deviation detection and alarm management)
- Tactics: Assistance through the problem lifespan, including process failure prevention, risk detection and diagnosis, plant-wide analysis, corrective actions, actions or recommendations for reestablishing effective control.
- Operations: Tasks such as filtering and validation of plant data, variable estimation, alarms analysis and optimization, intelligent alerting based on intuitive technologies and trend forecasting.

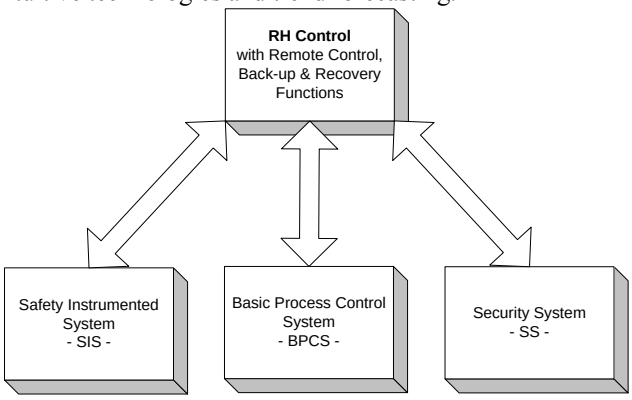

Fig. 5 - System architecture

The software architecture will be Service Oriented Architecture - SOA based approach [7]. It is common that the infrastructure and the environment of applications are very important security-related issues in the system and it gets even more important, if a SOA-based on Web Services has been chosen as application-architecture. For this reason asymmetric cryptography will be used, meaning a pair of two keys: public key and private key.

III. EMERGING TECHNOLOGIES

Future applications of simulation technology applied to process control will be driven by advancing capabilities of simulators. Much of this advancing capability is the direct benefactor of advancing computing technology applied to activities with high return on investment in areas such as concurrent engineering, process fault detection, self testing capabilities for hardware and internet retrievable simulation models and tools.

A. Simulation technology

Simulation technologies are not something new but till our days the research, contributions and experiments was more theoretical. The evolution of computing, of hardware performances, of software capabilities are the fundamentals to implement simulation in real time. Some of these advancements are:

- Advanced networking

Advances in network technology are making possible to link computers together to share data at increasing speeds, enables multiple computers to work in parallel to simulate more complex systems and to connect the simulator and controller. Three types of network interfacing applicable to simulation can be use:

- Bus adapter and shared memory
- Data broadcast network
- Internet

- Intelligent I/O

Applied Dynamics International developed and uses an intelligent input/output processor card to predict outputs and update the value more frequently than the update rate from the simulator increasing speed for the next prediction

- Very High Speed Simulation

This approach is based on development of digital hardware-in-the-loop simulations that allow simulation frame-times below 10 microseconds.

There are many approaches to be used to achieve good results and in time, the most important we will describe briefly.

- Integration algorithms

Integration algorithms are used to solve a function in time, given the differential equation for the variable of interest. Runge-Kuta is probably the best known integration algorithm. A newer algorithm, named after its developers R. Bulirsch and J. Stoer is gaining popularity and may replace Runge-Kuta.

- Discrete-Event Simulation

Two types of discrete-event simulation tools are available; the state transition diagram editor and user/resource queuing tools.

State-transition diagram editors allow the user to model a process by what state the process is in and by events that cause a transition from one state to another [8]. The use of state-transition diagrams allows the behavior of a process to be dependent on the state. A process simulator with a state-transition-diagram editor allows different dynamics to be assigned to different operational states of the same process. Fig. 6 shows the classical states; start-up, nominal and shut-down. We will add risk and hazard state (RH state) to keep process under control.

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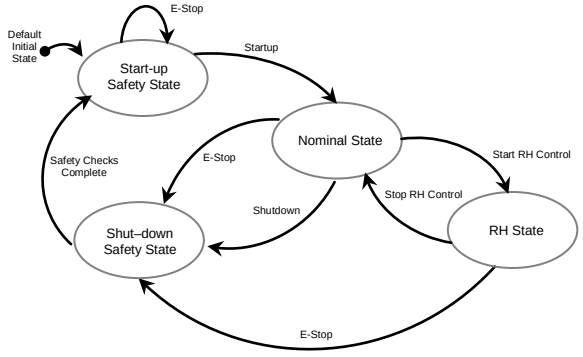

Fig. 6 - Operational states

User/resource analyzes tools queuing systems that can be characterized by a collection of resources and tasks using these resources [9]. The modeling tools allow resources to service tasks in many priorities such as firs-come-first-served, infinite servers, last-come-first-served, processor-sharing. System parameters such as response times, utilization rates, queue populations and throughput rates can be assessed. Probability distributions and tasks attributes such as creating, terminating and delaying can be changed. This will be used further to implement the appropriate DCS or PLC and SCADA strategies to run on the site system or remote.

- System Identification

The data handling and computing capability available today enables not only standard on-line identification techniques but also sophisticating empirical model development methods that in the past were to difficult to be done by hand. Tools are available with today's simulators to help gather perturbation data from the process and develop empirical that sometimes are with much fidelity than classical models. Even the theory of system identification has been around for a long time, only recently these theoretical tools become practicable because of the large amount of data processing required.

B. Concurrent Engineering

An activity that requires a high degree of effort by a design company, but not without rewarding return on investment is concurrent engineering. This design paradigm is based upon the principle that the process and the associated control strategy are design in parallel before the process is built. Trade-off analysis is performed before conflicting criteria of the two designs. Even the HAZOP study was performed to establish the functions, algorithms and strategies for SIS from the beginning, the concurrent engineering must perform the total approach of the whole process. The evolution of Software Engineering methodology, from waterfall to spiral, from spiral to agile, indicates that high concurrency, iterative development and short cycles are key factors for effective Software Engineering [10]. Using concurrent engineering not only to establish the general architecture of the integrated system but to software engineering also it is recommended. In the mean time dynamic process simulators must be combined with traditional static simulators to assess transient behavior and controllability of the process.

C. Other emerging technologies

- Controller Testing

Using simulators to test control systems is an increasing trend in almost every industry. Simulator-based control system testing removes control software development from the project critical path. A test using simulators can be more comprehensive than a test using actual process because the normal safety or process operational limits are not a concern, so the virtual test can transcend those limits, if necessary, to perform a more robust test. The networking options enable interfacing a simulator to a control system at a higher level in the system architecture than in the past when individual wiring terminations were required.

- On-line Diagnostics

Modern simulators offer the ability to detect faults in operating plants. A well tuned model of the plant runs in parallel with the plant, on-site or remote, comparing the model's outputs with the real outputs. As shown in Fig. 7 a difference between the two indicate a fault. Advanced fault-detection algorithms will lead the RH control or supervisory engineers to provide the appropriate action.

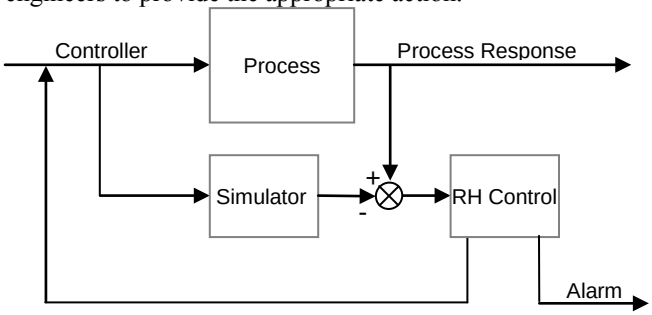

Fig. 7 - Online diagnostics

- Asset management

The new approach of asset management taken in to consideration not only process assets but instrumentation and process control system is the first step to more safety of the plant. Probably the evolution from compressors and drums to sensors and valves will continue incorporating the operator, may be the most important "asset" from the safety and security of the process point of view.

- Internet Applications

This amazing technology (NEOXITE [11]) offers today the capability to interconnect the on-site system with a remote control center (PH Center) and to perform simulation, on-line identification, RH strategies, on-line tests and training, back-up and restoration. Based remote from the site the Process Help center will host not only the copy of the process control system but the strategies and algorithms to accomplish the safety task and to maintain the process running even in hazard and risk conditions.

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IV. RESULTS

The totally new approach in process control systems engineering, based on new process control algorithms, scalable and modular architectures and platforms, risk and hazard control, is independent of the industry sector. The capability of the systems to perform the 4 state; start-up, nominal, risk and hazard, shut-down having 4 different strategies and the capability to change the state accordingly with the functional parameters can be taken in consideration by concurrent-engineering. The diagnosis system hosted remotely will be improved continuously by gathering knowledge from various applications, based on identified problems, the solutions offered and their impact on the plant performance. The correlation factor between these different applications will influence the future decisions. This way, the time needed for solving a problem will be minimized, as well as the time that a plant needs to be shut down because of instrumentation process control strategy.

Some of the expected results are the integrated exploitation of a collection of heterogeneous technologies for the prevention of anomalous situations related to the safety of an industrial complex and the suitability of function blocks and OPC based development for integrated control systems construction.

From the user's point of view, the accomplishment is that RH Control will allow the integration of the preventive and corrective aspects of safety, which were dealt, until this moment, in a separate way. Another advantage of great importance arises able to take into account automatically the constraints posed by the current plant situation and the ongoing maintenance operations.

The results achieved so far within the R&D project "Help Center and platform for remote diagnosis and remote intervention for the management of plants in hazardous situations – PH Center" will be used in order to develop and implement the hierarchical superior level for safety and security problems. The work carried out in the project establish the base for a new architecture of process control taken into consideration the risk and hazard situation correlated with capability to be remote from site (Fig. 8).

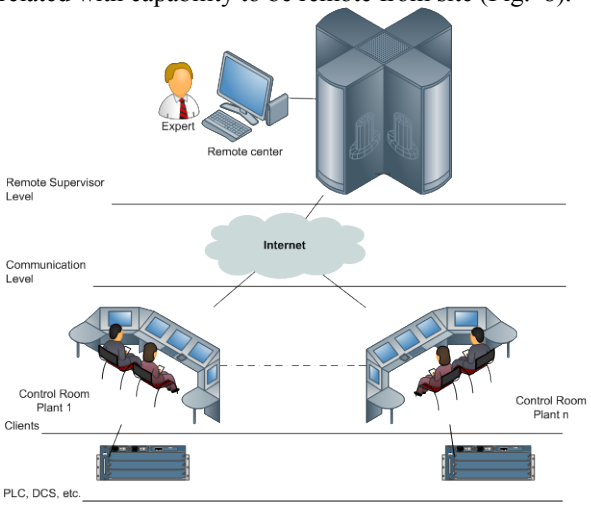

Fig. 8 - PH Center architecture

In the main time the results achieved underlay the feasibility. This statement is based on two reasons:

- The two demonstrators have been designed according to real plant requirements with a large involvement of the site staff. At present, both applications installed are under operation after a period of user validation and evaluation.
- The three generic products constructed within the project are truly reusable and exploitable components.

As stated by many relevant projects, safety and security can be better managed through IT technologies and can increase systems autonomy and performances. This project demonstrates that advanced control technology can be modularized, deployed and integrated with legacy control systems, progressing effectively toward complete automatic operation.

V. CONCLUSIONS

In the past SIS were strictly separate from the BPCS, mainly to segregate the safety and control functions and to have higher availability and reliability. Lately, there have been many launches of new "integrated" control systems that have both BPCS and SIS systems in the same package. But still, in the view of the standards bodies (like IEC and ISA), these two systems have to be separate, as the safety systems have to be dedicated to only the safety critical parts of the plant and the garden-variety DCS cannot be said to be robust, fail-safe and sure to operate the safety critical instruments at all times.

Hazard identification, risk assessment and control are on-going processes which involve a critical sequence of information gathering and the application of a decision-making process. These assist in discovering what could possibly cause a major accident (hazard identification), how likely it is that a major accident would occur and the potential consequences (risk assessment) and what options there are for preventing and mitigating a major accident (control measures).

The work carried out by the team has direct deliverables:

- the new paradigm - Risk and Hazard control
- a novel architecture
- tools and methods to be used to develop such systems

In the following picture we present the architecture of one on-going project: adding to the PH Center the control system from LPG terminal, Midia, Navodari [12].

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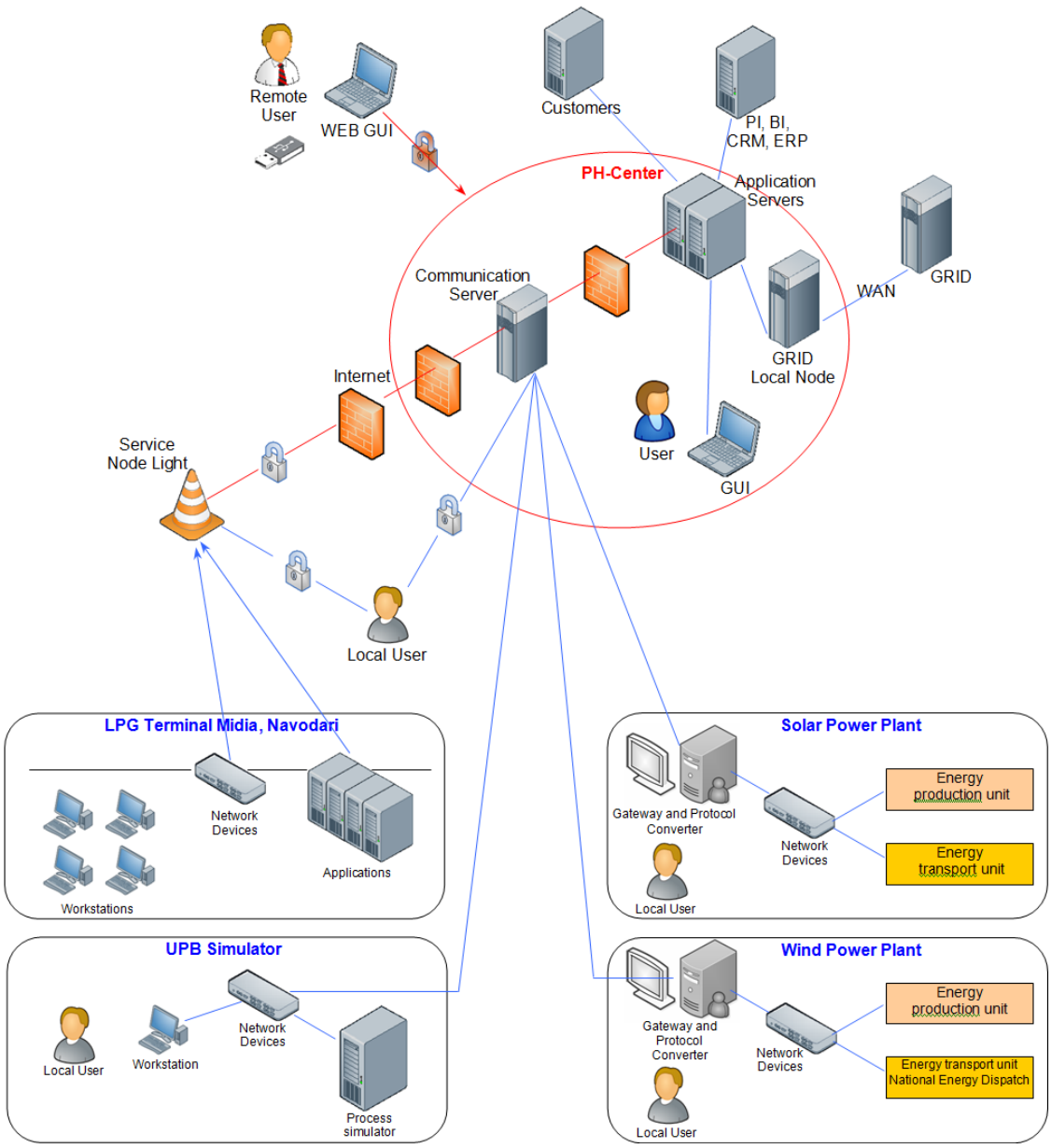

Fig. 9 – PH Center application

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Telematics system for increasing the usage of parking facilities for trucks on the highways

Z. Lokaj, M. Srotyr, T. Zelinka, M. Jerabek, P. Kumpost

***Abstract*—**Due to an increase in the intensity of freight transport on the road network in the Czech Republic, are increasingly occurs problems of lack of parking spaces for heavy goods vehicles. This leads to very dangerous situations with improper parking of trucks. The paper presents the proposed telematics system, which provides information for drivers of trucks over 3.5t about the predicted occupancy for the nearest parking. Providing this information to drivers will optimize the usage of existing parking areas on the highway network and to drivers to facilitate decisions about the appropriate place for parking, which will contribute to the fluency and safety of traffic as a whole.

***Keywords*—** electronic toll, parking, telematics, prediction.

I. Introduction

With the lack of parking spaces for heavy goods vehicles face the entire road network in the Czech Republic. The worst situation is on highways, where we often encounter dangerous situations parked truck right onto the ramp to gas stations or their exits. This situation is similar throughout Europe; the importance of this issue is demonstrated by the Action Plan for the Deployment of Intelligent Transport Systems in Europe, which contains measures "Development of appropriate measures including best practice guidelines on secure parking places for trucks and commercial vehicles and instructions for parking and reservation telematics systems". The high traffic intensity raises a number of transportation problems related to the lack of parking spaces, and therefore is accurate and accessible information about available parking spots very valuable in everyday use and also very important for the planning of efficient and safe transport.

The project, which partial result describes this article, is focused on creating a telematics system that will be based on the input data of the toll system to predict the occupancy of individual parking spaces to provide information to optimize the usage of existing parking areas on the highway network. The outputs of the model will be forwarded to appropriate channels for drivers who thereby greatly facilitate decisions about the appropriate place for parking and thus contribute to the overall fluency and traffic safety as a whole.

Reasons for system of increasing the usage of parking facilities for trucks on the highway network in the Czech Republic using prediction models are especially:

- increasing the intensity of freight transport on the highway network in the Czech Republic, for the reason that road freight transport is still cheaper than the railway, resulting in the observed lack of capacity
- 30-40% of road accidents are caused by driver fatigue, due to the extending of driving and ignoring the mandatory rest breaks
- priorities of the EU, increasing parking capacity on highways handles projects as CONNECT, Easyway, Intelligent truck parking, etc.
- inefficient use of parking lots
- uneven distribution of load of parking lots
- driving round highways and finding a parking space, which means the formation of undesirable emissions, congestion on local roads, noise and hazards caused by parking in places that are not intended to (emergency stopping lanes, ramps, etc.)
- lack of information on capacity and current vacancies in the parking areas
- determining the need for construction of new parking lots
- increased demand for parking due to the Just-in-Time
- reduction of investment in transport infrastructure construction, which increases the demand for optimizing the use of existing infrastructure

The expected benefits of implementing an information system to increase parking utilization capacity are divided by system participants, because for each group are different.

The Benefits of implementing the system from the perspective of truck drivers

- knowledge of the current traffic situation before

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T. Zelinka is with the Department of Applied Informatics in Transportation, Faculty of Transportation Sciences, Czech Technical University in Prague, Czech Republic (e-mail: zelintom@fd.cvut.cz).

Z. Lokaj is with the Department of Applied Informatics in Transportation, Faculty of Transportation Sciences, Czech Technical University in Prague, Czech Republic (e-mail: lokajzde@fd.cvut.cz).

M. Srotyr is with the Department of Applied Informatics in Transportation, Faculty of Transportation Sciences, Czech Technical University in Prague, Czech Republic (e-mail: srotymar@fd.cvut.cz).

P. Kumpost is with the Department of Transportation Systems, Faculty of Transportation Sciences, Czech Technical University in Prague, Czech Republic (e-mail: kumpopet@fd.cvut.cz).

M. Jerabek is with the Department of Applied Informatics in Transportation, Faculty of Transportation Sciences, Czech Technical University in Prague, Czech Republic (e-mail: jerabem1@fd.cvut.cz).

entering to the parking lot
- reduce the risk of stressful situations for drivers due to pressure on compliance with statutory breaks and thus enhance the security (reducing the risk of accidents due to fatigue during driving overtime)
- increased comfort while driving
- higher probability of finding a free parking place - eliminates the need for finding alternative places
- more effective route planning associated with savings of distance traveled and time

The Benefits of implementing the system from the perspective of car park operators
- increase the satisfaction and comfort of drivers
- optimized parking and better use of existing parking capacity
- elimination of the problem of exceeding the capacity of parking areas
- an increase in revenues from products and services offered on the parking lots due to optimized parking
- optimization planning - supplying, staffing shifts, etc.

The Benefits of implementing the system from the perspective of the State
- reduce the externalities arising from traffic accidents, ie. disposal costs, damages, costs for emergency operations, the cost of treating injuries, reducing state revenues due to the loss of the taxpayer (in the case of death)
- reduce the externalities arising due to leaving the highway network (emissions, noise, damage to roads)
- Financial savings for the construction and maintenance of highway infrastructure, which arise due to fewer required newly built parking lots and also because there is no need to look for alternative parking outside the toll network
- achieving the objectives of the European "TEN-T" program by using telematics systems
- use of the toll system as a source of current traffic data (composition and characteristics of traffic flow) for the prediction model
- increase traffic safety
- reduce accidents
- increase driver satisfaction
- increase the usage of parking areas, and thus the potential increase in tax revenues (the driver will use more parking at us and there will be motivated to refuel, buy goods and services)

The Benefits of implementing the system from the perspective of roads administrator
- effective planning of maintenance of highways infrastructure
- effective planning the construction of parking areas on the highway network
- reduction of required maintenance and the associated costs on roads close to the highway network
- reducing the number of traffic restrictions associated with the construction and maintenance of new parking areas

II. Architecture of the Telematics System

Architecture of the telematics system for predicting the occupancy of parking spaces on highways and expressways in the Czech Republic connects the database, prediction model and distribution channels for the providing information to end users.

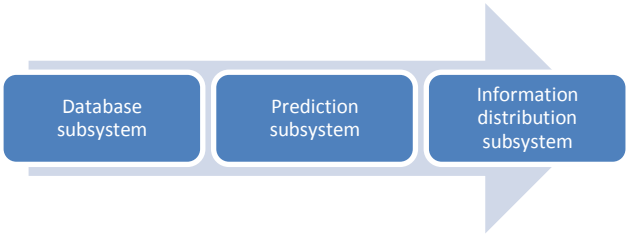

Fig. 1 Architecture of the telematics system

Architecture of the telematics system consists of three basic subsystems:
- database subsystem - data primarily consists of transactional data from electronic toll collection system, which are provided on-line (or at intervals close to on-line transmission) to prediction subsystem;
- prediction subsystem – the core of this subsystem consists of a predictive model that calculates by defined algorithms the probable occupancy of parking spaces on the highway network based on the data
- Information distribution subsystem – this subsystem uses the results of prediction model that processes and distributes an intelligible information to end users.

A. Database subsystem

Subsystem of database combines data from data sources, both historical data and current data. This data are stored in the operational database in which the data are preprocessed so those with them are able to run a prediction model to predict the occupancy of parking lots on the highway network in the Czech Republic. Especially it is the calculation of driving time each detected vehicle and calculates intensity in each toll section.

Data base draws data from the following sources.
- the primary source are transactional data from electronic toll collection system, namely: a) historical data, which are recorded to operational database one-off; b) actual data, which are sent to

the production database on-line c) telematics data (speed and composition of traffic flow), which are sent to the production database in batches;

- secondary sources are a) data from detection sensors located at the entrance and exit of the selected parking lot, used to calibrate the prediction model, these data are sent to the production database on-line as an individual transactions and batch for a defined time intervals, b) data from manual vehicle census at selected parking lots serving the calibration and validation of the prediction model; c) data from automatic vehicle census at selected parking lots from mobile surveillance vehicle of toll collection system; d) other traffic data, e.g. data from traffic sensors on highways etc.

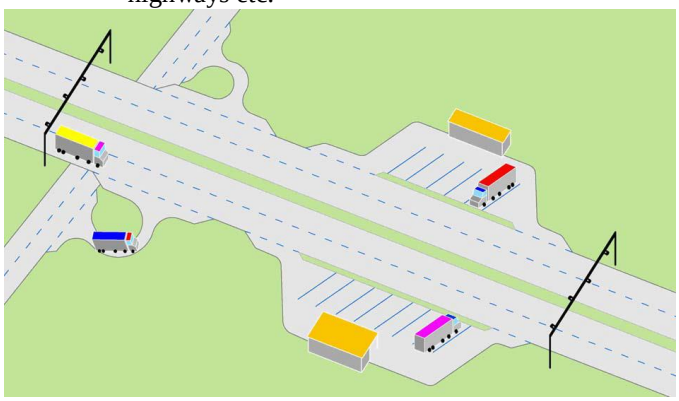

Fig. 2 Simplified diagram of the highway network with the location of parking areas, toll gates, entrance and exit ramps

B. *Prediction subsystem*

The prediction subsystem is the core of the entire system. It is connected to the subsystem of database over which implements the defined prediction algorithms.

The predictions are calculated in systems derived on the basis of fully formalized statistical methodology. At the core of the whole approach is the fact that value which is needed to predict, i.e. the number of free parking spaces, is directly unobservable. The prediction of this value should be constructed on the basis of correct algorithms derived from models for time series of observable variables. Basically, it is an estimate of the status-type model, which we deal with in a few steps. First, we construct the proxy variable for the latent number of vehicles parked on the parking lot at a time from the observed data on the passage of vehicles through toll gates. For the proxy variable we build a statistical model completely describing its dynamic and probabilistic behavior. Unknown parameters of the model of a particular class we estimate from the historical data from a passage through the toll gates. After more statistically demanding estimate the unknown parameters of the data (identification), the model has been fixed and used for routine, already simply available, predictions with parameters fixed at estimated values. With extended operation will be appropriate in the context of the entire system service (e.g. annually) to "re-learn" model, i.e. to re-estimate the parameters, or modify (or choose an entirely new) class model. According to our previous tests the stability of the estimated parameters using several months of data is significant and re-learning is not a critical requirement. From the estimated model we derive using the theory of Markov chains (Resnick, 1992 Klebaner, 2005) method for calculating the prediction of the number of vehicles parked on the parking lot for a set of necessary horizons. For fast and efficient implementation of predictive calculations in real traffic, we use a method based on Monte Carlo simulations. Prediction of the number of free parking spaces is obtained as the difference between extended parking capacity and prediction of parked vehicles, and for each of the required horizons. Prediction of the number of free parking spaces is using the subsystem distribution information transmitted to end users. Solution of the prediction system has been described in [1], [2] and [3].

The prediction subsystem is implemented in the first version of the telematics system as a script in the statistical software "R". This script implements algorithms for the minimum and maximum prediction horizons from 5 minutes to 150 minutes with a time step of 5 minutes.

Prediction process is performed at regular intervals and the results of the process are recorded in the table in the operational database where they are available to end users through distribution channels.

For each parking lot is available the information about the GPS position, the maximum capacity, detail of gas station or other information. This information is static and changes only when the layout changes such as reconstruction. For each parking lot are regularly at 10 minute intervals calculated prediction of the state of occupancy in several prediction horizon. In the functional sample we predict for the four parking lots on the highway D5. The prediction subsystem additionally maintains the entire history of the calculations of predicted occupancy for the all monitored parking lots. Historical data are another source of verification and validation of the prediction model.

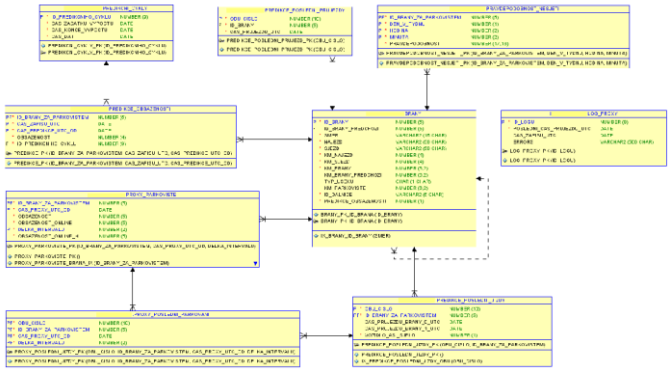

Fig. 3 Relational schema of the production database

Table of occupancy prediction for the parking lot contains the following parameters:

- ID of parking lot
- date and time of update
- prediction horizons – from a computational

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reasons the prediction is calculated for several horizons (windows), not continuously for each time point. The maximum prediction horizon is 150 minutes. Horizons are divided in 5 minutes and counting since the last update time,

- predicted occupancy status – for each forecast horizon is on the basis of the developed model calculated the predicted occupancy. Aggregate channel then assign a specified color according to the following table (Tab.1) to predicted occupancy.

Occupancy [%]	color
<0,60)	green
<60,80)	yellow
<80,+∞)	red

Tab. 1 occupancy intervals and their color for drivers

C. Information distribution subsystem

Subsystem of distribution of information is from the end user perspective crucial component of the entire system. Distribution channels are the only interface between the telematics system and end-user, i.e. truck drivers. Selecting the appropriate information channel therefore fundamentally affects the efficiency of the entire system and the acceptability of the system by the drivers. Nowadays there are more and more options to display and distribute information.

For intelligent parking system is necessary to resolve the distribution of information channels that are suitable for this type of system. Distribution channel must be selected properly to be effective for distributing information and also for end users, truck drivers, acceptable.

1) A prototype of a mobile application

The developed prototype of mobile application communicates with the communication layer of prediction system and shows the acquired prediction of the parking lots in the driving direction, as shown in the following figure.

The application is adjusted so that it can be tested without the presence on the D5 highway, thanks to manually input the current position on the highway D5 and average vehicle speeds, which are input parameters for prediction of occupancy parking lots along the route.

Fig. 4 An example of the mobile application in the vehicle

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Towards Developing Requirement Analysis Model of iLMS

Souvik Sengupta[A] and Ranjan Dasgupta[B]

Abstract — Intelligent Learning Management System (iLMS) has been a focus area for the researchers over years since the proliferation of world-wide-web and Intelligent Tutoring System (ITS). Several novel approaches have been proposed and implemented to enrich the features of iLMS, but very few work contributed towards methodologies related to software engineering approach of it. In this paper we first describe a generic architecture for iLMS and its core functionalities. Then we propose a comprehensive approach for Requirement Analysis of iLMS that integrates use of semi-formal (Unified Modeling Language) and formal (Vienna Development Method) methods. We observe that a combined approach is better suited for building the Requirement Analysis Model than following any single development methodology. We also discuss about the completeness and consistency rules for the proposed model. Our implemented software "CompTutor" is taken as a case study for giving the illustrations.

Keywords — iLMS, Requirement Analysis Model, Formal Specification, UML, VDM, Consistency Rules.

I. INTRODUCTION

Intelligent Learning Management System is the integration of the ITS over the web based Learning Management System. It has five core modules; three of them namely the student model, the tutor model and the domain model are inherited from ITS. The other two, communication model and interface model are adaptation of web technology with LMS. From the perspective of software engineering, it is obvious that the design of iLMS entails a systematic illustration of requirements preferably using a Requirement Analysis (RA) model. The advantage of building a RA model over the specification written in Natural Language (NL) is that ambiguity due to NL sentences are reduced and the requirements can be tested early in the development phase. A system design should be generated through a series of specifications at different levels of abstraction, where each specification is more concrete and closer to the implementation than the previous one [1]. The main difference between specification of Analysis Model and Design Model is that the analysis model follows reverse engineering approach as the existing system is understood by means of the model. On the other-hand, the design model is forward engineering, as the system is constructed starting from the model [2].In this paper we form the RA model for iLMS with help of UML and VDM and then we deduce a state based model. The state based model is used to check completeness and consistency in the RA model.

A. Prof. Souvik Sengupta is with Department of CSE in Bengal Institute of Technology, Kolkata-150, India (e-mail: mesouvik@ gmail.com).
B. Prof Ranjan Dasgupta is Head, Department of CSE in National Institute of Technical Teachers' Training and Research, Kolkata, India (e-mail: ranjandasgupta@ieee.org)

Work presented in this paper is broadly divided in three sections. The first section covers article 3 to article 3.5 and it represents the general software architecture of iLMS. The next section spans from article 4 to 4.4 and it focuses on the importance of analysis model and the methodologies that can be useful in building such models. The last section covers article 5 to 5.5 and it shows with a case study, how to develop an analysis model and also explores issues with completeness and consistency checking.

II. RELATED WORKS

Researches with ITS have a very long history, started back in 1970s, ample amount of contribution are made in the mechanism of student modeling, pedagogy and domain modeling [8]. As iLMS is the web adoption of ITS, all the existing basic features of ITS automatically fit in iLMS. Unfortunately the software engineering approach of building iLMS is often unexplored by the researchers.

In [9] we see a conceptual framework for the integration of Intelligent System (IS) and Learning Management System (LMS) in to Intelligent Learning Management System (iLMS) is portrayed. Instead of the presenting unidirectional transfer of knowledge in the form of Learning Content (LC) from the system (LMS) to learner, it (iLMS) appreciates the bidirectional learning between learner and system.

In another work [10] integration of the Semantic Web technologies in intelligent learning systems is proposed for an intelligent learning management system (ILMS) architecture This system is a Web-based environment for the development the e-learning courses and for the use of them by the students. This system enables the teachers to develop tutoring systems for e-learning courses and for the students to use them.

The idea of combining formal and informal languages to exploit the best of both worlds [11],[12] have been investigated by others before. A coupling of semi formal (UML) and formal methods (VDM-SL) is found in [11] where the author investigates the mapping potential between VDM++ and UML. [12] Describe a tool for specifying and analyzing natural language properties of UML models, resulting in generation of the corresponding formal specification language 'Promela', which can then be formally analyzed by the model checker 'Spin'.

However a systematic approach with help of formal and semiformal methods in the requirement engineering of iLMS is yet to be explored as a research area. Considering this, in this paper we propose a Requirement Analysis Model of iLMS using UML and VDM-SL.

III. MODULES OF iLMS

iLMS is intended towards making web- based learning more flexible, autonomous and adaptive to the needs of each student. Conventionally, iLMS provides individualized tutoring to the learners with help of five components or

modules, i) student model ii) domain model iii) tutor model, iv) communication model and v) interface model. Fig.1 represents a 4 layered generic architecture of iLMS. The first layer is the core layer of iLMS and its features are inherited from the traditional ITSs. The Second layer represents the web architecture which models how the system is deployed across the web. The third layer is the web interface layer that represents how the users interact with the system. The learners who use the system form the last layer. Fig.1 shows a generic architecture of iLMS.

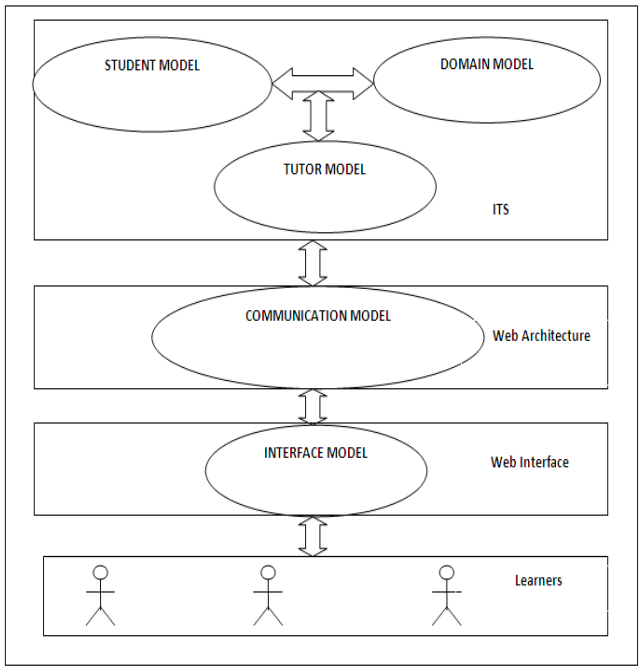

Fig. 1 the generic architecture of iLMS

A. *Module For Domain Model*

It is also known as the expert model. It refers to the topics and curriculum being taught and facts and rules of that particular subject domain, i.e. the knowledge of the subject experts. This model tries to abstract what the learner should learn in the course and what goal should be achieved in that course, so these are very hard to model. It assumes that knowledge can be described in terms of facts and principles that can be learned in an incremental fashion. Therefore, developing complex representations of such knowledge heavily depends on the teacher's expertise in that domain. In this paper we focus on some basic principles of Domain modeling, which is implemented in our iLMS named "CompTutor". We consider a course as sequence of Learning Objects (LO) where each LO has the following properties:

i) The topic should have unique identifier
ii) The topic name should be defined.
iii) Keywords are identified and stored in a separate list
iv) Every keywords are hyperlinked that point towards the LO that describes it
v) Prerequisite are identified in terms of keywords
vi) Examples are stored separately; each example should define two parts: one, what is the difficulty to solve the problem without the new knowledge and two, how the new knowledge is used to solve the problem.
vii) Tables, diagrams, image are stored separately.

Fig. 2 shows how *CompTuto*r provides an authoring interface to accomplish these tasks. This interface helps the author to deliver the content, prerequisite, keywords, images in accordance with the requirement of the domain model. Once the submission of this page is done, the author is requested to identify the 'keywords' from the content. Then all the keywords including prerequisites are asked to link with their corresponding LOs. In case there is no available LO for a keyword, the author is requested to provide a short note on that keyword which may come as a pop-up help for the learner. Then finally the author should provide a set of multiple choice questions for an assessment test. The author can also specify some domain rules in these question–answers, like any particular selection of wrong answer may infer a common misconception on a particular concept or keyword.

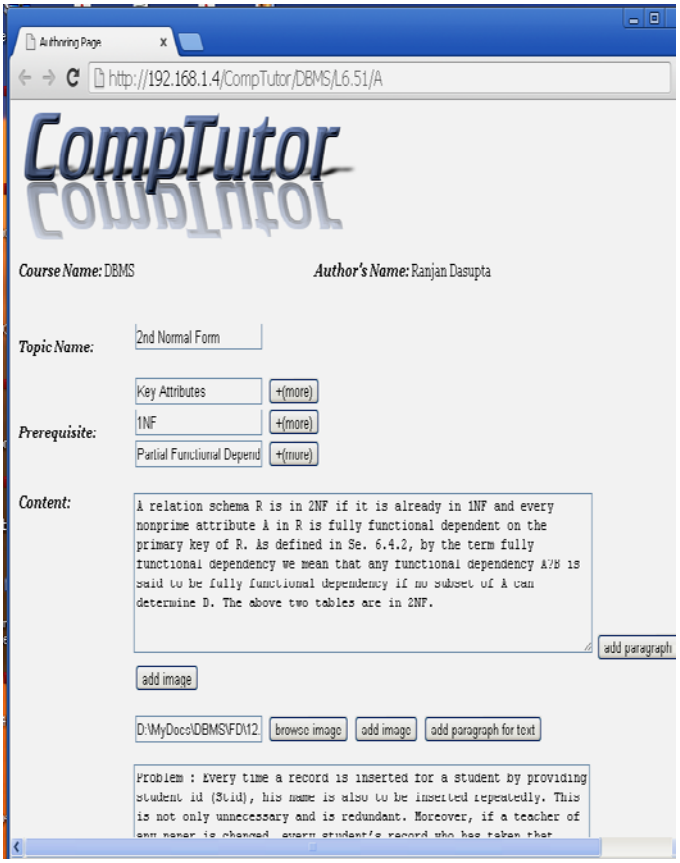

Fig.2: Authoring interface of CompTutor

B. *Module for Student Model*

Student modeling is the core of WiLMS architecture. What distinguishes WiLMS or iLMS from LMS is the goal of being able to respond to the individual student's learning style to deliver customized content and instruction. According to [3], student model mainly focuses on three tasks.

i) It must gather data from and about the learner. This data can be either explicit, obtained by asking the student to provide static information or to solve specific problems, or implicit, by tracking the students navigation and other interactions with the system.

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ii) It must use that data to create a representation of the student's knowledge and learning process. This often takes the form of "buggy" models that represent the student's knowledge in terms of deviations from an expert's knowledge [5]. The system then uses this model to predict what type of response the student will make in subsequent situations, compares that prediction to the students' actual response, and uses that information to refine the model of the student.

iii) The student model must account for the state of the student's knowledge to help the tutor model in selecting optimal pedagogical strategies for presenting subsequent domain information to the student. One of the biggest challenges is to account for 'noisy' data, the fact that students do not always respond consistently, particularly when their knowledge is fragile and they are uncertain about the correct responses[4].

In CompTutor we take the student's preference information at the start of each session. We define session as the time between when the learner initiates an interaction with an topic (LO) and when the learner completes atopic and goes to the next topic or exits th system. In CompTutor the student model stores the information about learners preference for the entire session. The learner may select from the two available levels of beginners and advanced. In beginners level the helps and hint will appear and more hypelink will be available than the advanced level. The learner may select any one of the learning style between example followed by the concept or concept followed by example. The learner may select some keywords from the prerequisite list for her recapitulation. Fig.3 shows the CompTutor interface to accomplish these tasks.

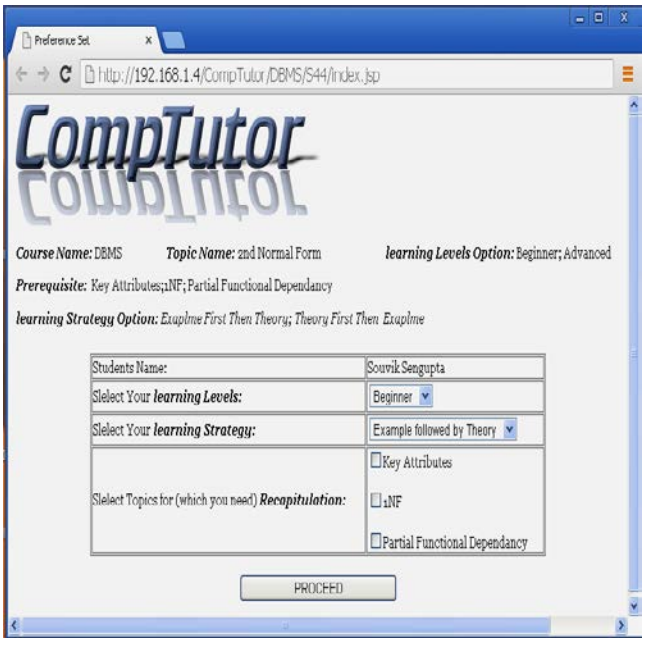

Fig.3: Setting Learning Preference in CompTutor

C. *Module for Tutor model*

The tutor model is also known as instructional model or pedagogy model. It is a representation of the methods that is used in the WiLMS to provide customized information to the learner. This model designs and regulates instructional interactions of the system with the students. It deals with pedagogical issues [4] i.e. how to teach, in what order, typical mistakes and remediation, typical questions a student might ask, hints that one might offer to a student who is stuck This concept is more related with the way in which the learner seem to approach the problems in their face to face interaction with the teacher in real world. According to [6] the tutor model should have the following properties:

i) It should analyze the student model and interpret the type of knowledge that the student possesses
ii) It should define the actions that the student can perform to achieve the goals in a correct way
iii) It should adjust the pedagogy style in accordance with learner's preference and need.

In CompTutor we focus on three important tasks of tutor modeling namely sequencing, navigation and learning style. Firstly we provide attachment of the recapitulation part at the beginning of the course in addition to the standard sequence decided by the author and present it to the learner. The knowledge of required recapitulation for individual learner can be fetched from the learner model or learner herself can set the preference. We use a set of keywords identified as 'hitch -words' for that particular learner on that learning session for this purpose. The tutor model can also decide to re-launch the course to the learner after evaluation of the assignment; it can then alter the sequence by adding/ removing some LO based on the learner experience recorded with this course.

Secondly, we can control the navigation by adjusting the hyperlinks with in the context. The domain model provides all possible hyperlinks for the keywords but the tutor models adjust the links based on the knowledge level of the learner.

Finally, in case of adapting learning style we provide two simple alternatives, 'concept first then example' and 'example first then concept'; whichever suitable is chosen by the learner.

Fig.4 shows how CompTutor adapt to a personalized sequencing and navigation for the learner. In this particular case we can see that the definition of "partial functional dependency" has come before the start of the topic "2nd normal form". This is because the learner has opted for a recapitulation on this topic. The link of the next button is dynamically created that points either to start the specified topic or to any other recapitulation topic as preferred by the learner. The recapitulation topic presents only a brief narration about the keyword without any link or example. However if the learner wants more, she can get the complete LO on that topic by clicking on the 'more details' button.

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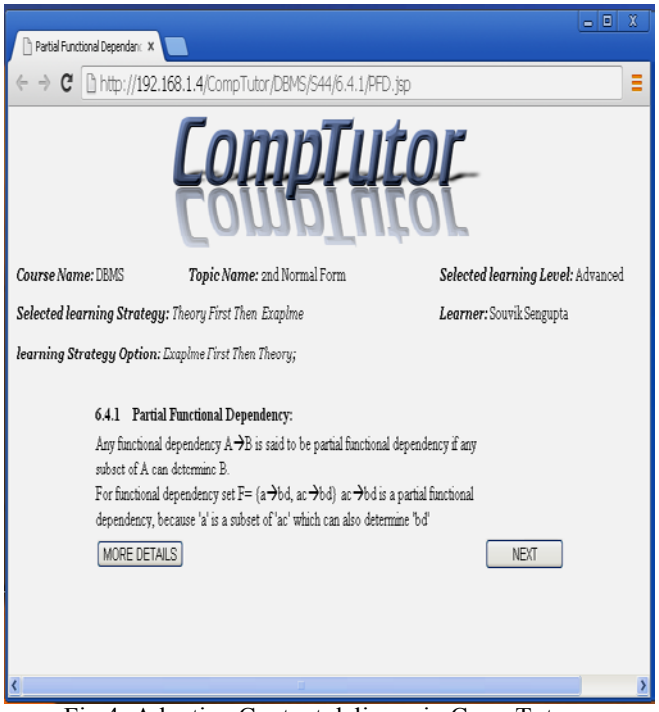

Fig.4: Adaptive Content delivery in CompTutor

D. *Module for Communication Model*

This model differentiates ITS from standard iLMS. In order to achieve the intelligent behavior of the system communication model distributes the logic of student model and tutor model across different levels of the web architecture. For example the learning experiences of the students at different nodes with in an Institute are collected in a local server and then we apply some logic to understand the common pattern and mistakes on a particular course. Knowledge from all such local servers at different sites is then collected to a central server to analyze the student model and tutor model. Then the course can be updated to adopt this feedback. This change will be reflected from the next time any local server launch the course from the central server. The distributed deployment of CompTutor helps us to store and analyze the students' information at different levels of the architecture. In order to focus only on functional requirements, this part is not included in this paper.

E. *Module for Interface Model*

The user interface model controls the interaction between the student and the system, as depicted in Fig.1; it translates between the system's internal representation and an interface language that is understandable to the student [7]. This model is also responsible for other user's (Teacher, Author, Admin) interaction with the intelligent system. The rich variety of hypermedia based web interfacing techniques is used in this model. In this paper we displayed some interfacing related to domain model [fig.2], student model [fig.3] and tutor model[fig.4] but detail modeling of interface as a module is not included in this paper to limit our Requirement Analysis Model within the context of functional requirements only.

As seen from the above discussion that iLMS grasp the essence of ITS in terms of adaptivity within the context of LMS. The elicited software requirements may not have one-to-one mapping to the said modules. So from the software engineering perspective it is essential to build the domain model (DM) of the system for a better understanding of the requirements. The domain model is required to depict the essential structure of the system by identifying the key entities and their relationship. In our approach we use Conceptual Class Diagram to represent the DM of iLMS. Fig.5 illustrates the domain model of iLMS.

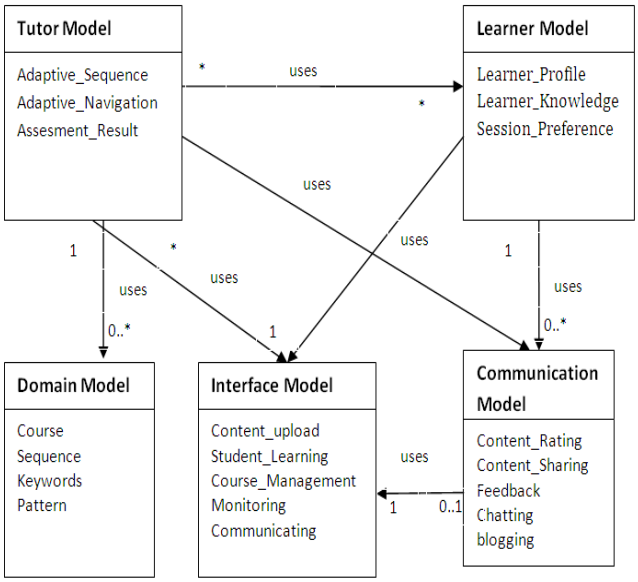

Fig.5: Domain Description using Conceptual Class

IV. REQUIREMENT ANALYSIS MODEL

In software engineering 'models' are abstract representations of a system that simplifies the system for better understand the problem ("analysis model") or the solution ("design model"). Requirement Analysis Model defines 'what' in contrast to design model which defines 'how'. It captures user requirements in a technology-independent way, using concepts from the problem domain. Analysis model represents the system in a higher level of abstraction and often use conceptual views [see fig.5]. Specification using analysis model contains the expected functionality that a software system must provide, described through typical user-system interactions but it does not represent interactions among actors, neither a complete business model. In this paper we develop a Requirement Analysis Model based on the requirements taken from the system CompTutor.

A. *Characteristics of a Good Requirement Analysis Model*

- The model must be able to capture information, behaviour (operations) and presentation (inputs and outputs) of the system.
- The focus is on the logical structure of the system ; it should not make implementation decisions
- Defined structure should be stable, robust, maintainable and also extensible

- The model must be independent of the implementation environment, i.e., any change in the implementation environment should not affect the logical structure of the system.

Modeling using UML implies that diagrams are normally easily comprehensible for both analysts and stakeholders.
Hence it is widely accepted and a common tool for requirement engineering, but we find that it is very hard to achieve the above goals in a Requirement Analysis Model if we rely entirely on UML. In the next two subsections first we discuss on the merits of demerits of different UML diagrams from the perspective of Requirement Analysis Model and then we discuss the importance of using VDM-SL in requirement analysis.
Use case diagram provides a comprehensive summary of the whole software system in a single illustration and useful in elicitation and documentation of functional requirements at an early stage. Being a user-centered technique, use cases ensure validity of the system under development by capturing the requirements from the user's point of view. So it is the natural choice to depict the system description at a higher level of abstraction.
Similarly activity diagrams are equally important to represent the flow of the activity within the system. We can also allow displaying multiple conditions that drives the activity at a very high level of abstraction . So we prefer use-case and activity diagram for Requirement Analysis Model and we observe that some other types of UML diagrams are not that helpful in higher level abstractions.
Class diagram is a static diagram and it is used to model static view of a system. The static view describes the vocabulary of the system. The problem of using class diagrams in analysis model is that the data types of higher level abstraction are not particularly suited for class diagram as they are closer to implementation. This is why we have used Conceptual Classes in Domain description [see fig.5]
Similarly the sequence diagram captures the time sequence of message flow from one object to another. But the identification of object is also a challenging like classes at the higher level of abstraction. Moreover in iLMS, our goal is to develop the specification such that we can identify the functionalities from the perspective of the different models, like domain model, student model, tutor model etc. As a consequence use of class and object at the higher level of abstraction is not very useful.
State-chart diagram is useful to model dynamic nature of a system. They define different states of an object during its lifetime and the states are changed by events. Its specific purpose is to define state changes triggered by events. The problem of using State-chart in analysis model is that, the identification of events of a web based system at higher levels of abstraction is highly risky job to do as it will confine the implementation idea. We argue that activity diagram is a safer approach to model the dynamic aspect at the higher level of abstraction as they deal with activity states which can be abstracted very early.

B. Advantage of Using VDM-SL

Use case diagrams are easy to construct but as the narrations are written in natural language, the lack of formality in the definitions leaves ample chances for ambiguity, miscommunication and misunderstandings while capturing the early requirements. Also they are created before objects and classes, use cases ignore the encapsulation of attributes and operations into objects. We use VDM-SL to fill these gaps. It is used to define an early structure of the system (in terms of state) in terms of the basic components of iLMS like domain model, student model or tutor model. On the other hand, we use activity diagrams to define the structure of a work flow using the logic of the activities, but higher level abstraction of activities fail to provide the required level of formality in the conditional expressions. Taking all these in view, in our approach we VDM-SL along with UML to handle these issues more efficiently.
Vienna Development Method (VDM) is widely used as a formal method at different stages of Software Development Life Cycle. We use its specification language VDM-SL as tool in our Requirement Analysis Model. VDM-SL support data type's abstraction at different levels so we can use it in a better way than the class diagrams to sketch the system in the higher level of abstraction. It allows deriving a detail model from a higher level model, which also makes extensibility easier to achieve. As a higher level VDM model can logically deduce the lower level VDM model, the traceability of requirements is achieved automatically. Another important advantage of using VDM-SL is that we can verify it early before taking any design or implementation idea. We create a state-model captured from the VDM specification in order to verify the consistency checking of the model.[discussed in sec. 5]

V. A CASE STUDY BASED ON THE REQUIREMENTS OF COMPTUTOR

The author creates and uploads learning objects (LO) that have prerequisites, keywords, content, diagrams, example and questions. Keywords are automatically assigned with hyperlinks pointed to other LOs and external entities. Authors crate course as a sequence of LOs with different levels and learning styles. The student model captures information about the students that includes her personal information, knowledge base, performance history etc. It also asks the student for selecting the level of hardness, choice of learning style and any additional LO as prerequisite if required. The tutor model, based on the data available from the student model, preferred learning style and level of hardness prepare an adaptive sequencing and navigation plan that is best for that individual learner. The entire learning activity is monitored by the system and the student model is updated on observable events. Learner's performance is evaluated by an assessment made by the tutor. The result of the assessment is used to update the student model. If the result is not adequate then the learner is provided with the same topic but the content is differently arranged(sequencing and navigation) based on the new data available from the student model.

For the above requirements we next create an analysis model which comprises of three components i) use case diagram, ii) activity diagram and iii) VDM-SL specification. Fig 6 shows how different stake holders like learner, teacher and author are connected with the use cases. It also depicts how LMS agent is responsible for controlling

the automated tasks of student model and tutor model, on behalf of the system.

A. *UML Diagrams*

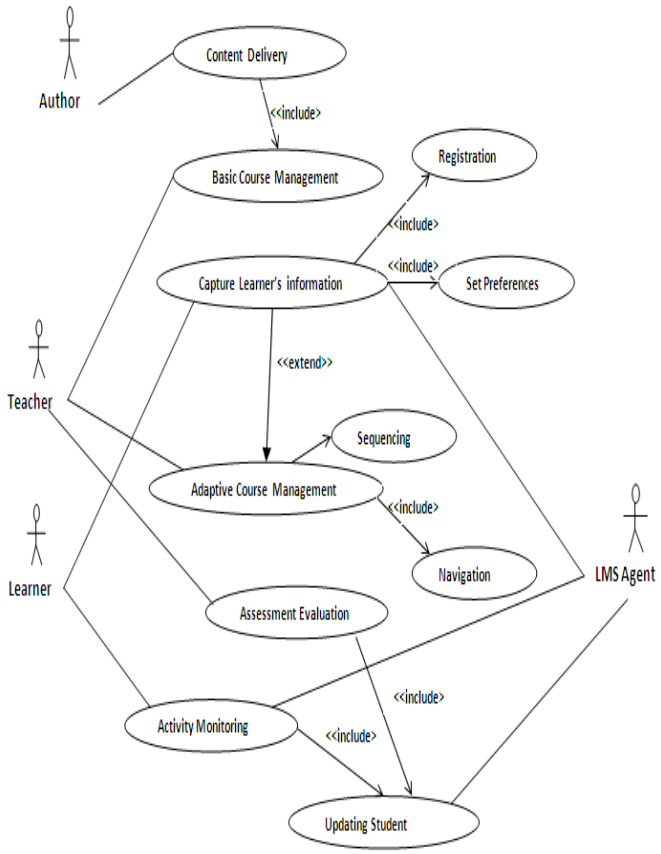

Fig.6: use case diagram of the case study

The activity diagram depicts the flow of activities of the system as shown in fig.7. It complements the use diagram by illustrating the dynamic flow of the activities to achieve the use cases. In this example, Learners first enroll for the course by providing some static information. The authoring activity by the author can be started independently. Learners perform their study in learning sessions, which is monitored by the system agent. The student model stores this session information. Teachers evaluate the assessments. The agent then decides whether re-launching of the LOs is required or not. If required the tutor model initiates modified contents by setting an adaptive learning style, adaptive sequencing and adaptive navigation. On the other hand after the assessment is evaluated as satisfactory result the session ends. In any case the student model is updated with the performance record and with any observation made by the monitoring activities.

B. *The VDM-SL Specification:*

Types:
String: set of char
Link:: text: String
target :String
Links:: set of link
keywords: set of String
Learning_Object::L id : String

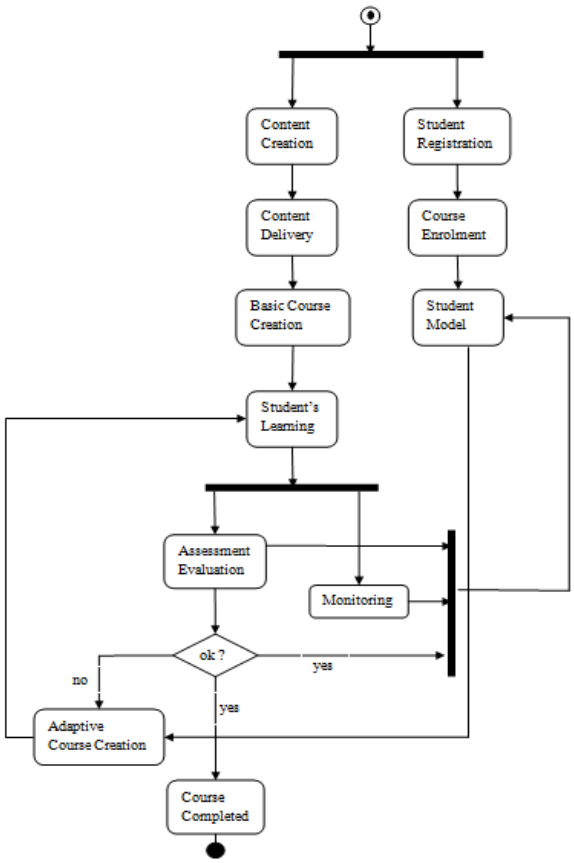

Fig.7: Activity diagram of the case study

heading: String
content: String
links: Links
keywords: Keywords
QA: Assessment
Learner_Profile :: Sid: String
Name: String
email: String
Learner_Knowledge:: course_completed: set of String
Assessment_score: token
hitch_ words: Keywords
LO_Sequence: set of String
Assesment:: question : String
Answer : String
Result:: course_id: String
score: token
Learning_style:<example_first|theory_first>
Learning_level:<advanced|normal>
Status: <in|out>
Observation : token
Session_Info:: LL: Learning_level
LS: Learning_style
Lid: String
RC: Keywords
Learning_flag: Status
Student_model::
LP: Learner_Profile
LK: Learner_Knowledge
SP: Session_Info
Tutor_model::
LP: Learner_Profile
AS: LO_Sequence

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```
                AN: Links
Domain_model::
                keywords: Keywords
                course: set of Learning_Object
State of  WiLMS
Stm: set of Student_model
ttm: set of Tutor_model
Dm: set of  Domain_model
Invariant
Hitch intersect skill is null
Domain keywords is sum of lo keywords
Operations

enrolment : String* String * String ==> ()
enrolment (id,name,mail)==
pre  id ∉ {s.LP.id|s∈Stm}
post stm=stm ∪
mk_Student_model(mk_Learner_Profile(id,name,mail),_,_
)

set_prefernce: Learner_Profile * Learning_style *
Learning_style ==> ()
set_prefernce(lp,ll,ls)==
pre  lp.sid ∈ {s.LP.id|s∈Stm}
post
mu(ss, ss.LL→ll ^ ss.LS→ls) |∃ ss∈ { s.SP|s∈Stm •
s.LP.id= lp.sid }

sequencing: Domain_model* Student_model==>
Tutor_model
sequencing(d,s)== return t
pre s.SP.RC ⊆ d.keywords
post  s.SP. RC ⊆t.AS

authoring: String * String * set of String * set of String *
assessment==>Learning_Object
authoring(h,c,l,k)==

learning:Studentmdel ==>()
learning (sm)==
pre sm.SP. Learning_flag=on
post sm.SP. Learning_flag=off

navigation: Domain_model* Student_model==>
Tutor_model
navigation(d,s)== return t
pre s.LK. hitch_ words ⊆ d.keywords /
s.LK.coursecompleted
post  s.LK. hitch_ words ⊆t.AN

assessment: Student_model * Assesment==>
Student_model
assessment(sm,as)==return lm
pre  as ∈ {s.QA|s∈ Learning_Object • sm.SP.lid= s.lid }
post lm.LK. Assessment_score=eval(as) ^ lm.LK.hitch_
words=judge(sm,as)

monitoring: Student_model ==> set of Observation
monitoring (st) == return  ob
post ob= observe(st)

update_studentmodel: studentmodel * set of Observation
==>()
update_studentmodel(sm,ob)==
pre ob <> nil
end
```

The above VDM specification provides a formal way of representing the system. All the structures of the data required for this higher level specification are defined within the 'types' block. The state of the system is defined by its three state variables, which are, student model, domain model and tutor model. The dynamic behavior of the system is described by its operations. Every operation is defined with help of a pair of pre and post condition. In this above example some of the operations use functions, such as eval(), observe(), judge() etc. but we have not included the function definitions in the specification for the sake of simplicity.

VI. MODEL CHECKING

One of the major advantages of using formal specification in the Requirement Analysis model is that we can check for satisfying certain conditions of completeness and consistency. In our case study we will first build a state transition model from the specification and then define the rules for completeness and consistency.

A. Developing A State Model From VDM-SL

It is obvious that the state transition model cannot deal with all possible operations on every state of the system as it will lead to state space explosion problem; also not all the operations result in a state transition. We have identified five different states of the system and ten different operations to represent the state-transition model of the system [see fig.8]. The system is in 'initiated' state when the initial resources are initialized that is when the authoring and the enrolment operations are performed by the system. The system is in 'terminated' state after the successful completion of a learning session. After the initiated phase, learning preference is set by the learner and the system goes to the 'customized'. The tutor model can perform operations like sequencing, navigation and learning style on this state to create customized contents and instructions and the state goes to 'delivered' state. When the learner initiates learning and the system initiates monitoring on this state then we call it an 'active' state. The assessment is performed on this state and unsatisfactory result may bring the system back to the 'customized' state with an adaptive content. The exit operation will bring the system to the terminated state. Fig.8 shows this model and Table1 shows the meaning of the symbolic representations.

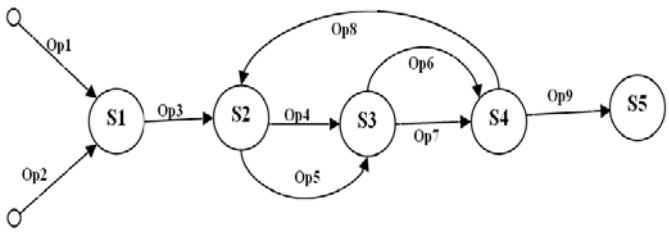

Fig.8: State Transition Diagram of the case study

Table 1: Symbol Narration of the State Model

Symbol	Meaning
Op1	authoring
Op2	enrolment
Op3	preference-set
Op4	sequencing
Op5	navigation
Op6	learning
Op7	monitoring
Op8	assessment unsatisfactory
Op9	exit
S1	initiated
S2	customized
S3	delivered
S4	active
S5	terminated
○	start

B. Checking Completeness and Consistency

In order to verify the system we need to perform completeness and consistency checking on the model. Let OP is the set of all operations that we can perform with the system in different states. Q is the set of different states of the system. We define the end state to be distinct from the other states as we cannot perform δ is defined as transition function and $\perp$ is used to represent end state.

$OP=\{op_1 ..op_n\}$;

$Q=\{q_1..q_n\}$;

$\delta: Q * OP \rightarrow Q' \cup \perp$

Completeness checking: The theory of completeness demands that no state can be isolated. We can write it formally as:

$\forall q \in Q \ \wedge q' \in Q \cup \{\perp\} \ \exists op \in OP \bullet \delta(q,op) \rightarrow q'$

Consistency checking:

i) Domain checking:

Operations are defined as: op: X → Y where X is the input domain and Y is the output domain. Operations in VDM-SL are often partial functions as not for the all possible value from X, Y value is defined. So we have to check that all operation should satisfy the rule:

$\forall x \in dom(X) \ \exists \ y \in dom(Y) \bullet op(x) \rightarrow y$

The pre condition of each operation makes sure that $x \in dom(X)$

ii) Subtype checking:

The obligation of subtype checking arises due to the liberty of the operations to access and even change the state variables. The consistency check is easy if the operations use the state variable as a whole because it can be done by simply checking the output result of the operation. The challenging part is to check consistency when the operations use only a subtype of the state variable. For example if we change the learner profile (subtype of Student model) in any operation then whether invariant rules based on Student models hold or not.

Invariant= <set of state variables, set of expression>
Inv={A,E}
X is the set of all variables used in operations
We define invariant as a function that maps the state variable with an expression, which must hold true:
Inv: A→E
We use the ► symbol to represent subtypes, ie., b►a means b is a subtype of a.
We assume b is used in the operation op then we can check
$\forall a,e \ a \in A \ \wedge b \in X \wedge b \blacktriangleright a$ conforms(b,e,op)= true

VII. CONCLUSION

In this paper we propose an integrated approach for developing analysis model for intelligent Learning Management System. We have taken a case study of the 'CompTutor' system that we have implemented. The core area of the intelligent part of the system, comprised of Student model, Domain Model and Tutor Model, are discussed and analysed. The Requirement Analysis Model in software specification is very helpful in postulating the overall structure of the system at a very early stage. The use of UML and VDM-SL combination in developing such model is beneficiary because it always enhances qualities like understandability, extensibility, traceability and verifiability. In this paper we discussed about understandability and verifiability in Requirement Analysis Model. As VDM is a proven way of using formal method in software development, this work can be extended by creating the design specification of the system and compare it with the Requirement Analysis Model to check for extensibility and traceability. This is the future scope of this work.

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Web2.0 and Informal learning: Overcoming Challenges and Creating Possibilities

S. Mellett, Dr. E. O'Brien, G. Vlckova

***Abstract*—**This paper explores learning in Small and medium enterprises (SMEs) particularly with respect to an individual's ability to develop their range of training and learning options incorporating eLearning and in particular Web. 2.0 technologies and communities of practice. Appreciation is given to how learning, whether formal or informal, currently and actually occurs within companies and how the use of Web2.0 tools and resources could allow for better learning outcomes. Based on research findings showing that the majority of training is informal this paper will examine how Web2.0 can facilitate and document the informal learning outcomes. It is widely acknowledged that there is a direct correlation between training and business success. In addition to looking at the learning that takes place in companies this paper also examines the barriers to training in SMEs and how Web2.0 can help overcome these barriers.

***Keywords*—**eLearning, Web2.0, informal learning, Small and medium enterprises

I. Introduction

Previous research carried out in the area of training and SMEs suggests that the main constraints for not carrying out training include time, place, quality and cost (European Commission, 2000). The author feels thatWeb2.0 should be a feasible and cost effective solution for SMEs. Although some countries are currently lagging behind other countries in the utilisation of eLearning, improved broadband access, popularity of social networking, Web 2.0 and ICT usage and in particular smart phones most individuals and SMEs have accessed the technology and skills required to avail of eLearning opportunities. This paper will look at formal and informal learning in companies and in turn examine the barriers that exist to formal training. The paper goes on to discuss how eLearning can overcome these barriers to training. The paper finishes with details of a course developed for both individuals and companies for using Web2.0 and collaborative practices to support and enhance informal learning.

II. Definition of SME

For the purposes of this research small to medium size businesses are defined in accordance with EU guidelines. In addition to the staff headcount ceiling, an enterprise qualifies as an SME if it meets either the turnover limit or the balance sheet limit, but not necessarily both (European Commission, 2009). The unit of analysis is SMEs in Ireland employing 250 or fewer employees. 99% of all companies in Europe are SMEs.

III. Definition of eLearning

For the purpose of this study eLearning is defined using the European Commission definition as '*the use of new multimedia technologies and the Internet to improve the quality of learning by facilitating access to resources and services as well as remote exchanges and collaboration'* (eLearning Europa, 2005).

Web 2.0 technologies, are online tools which allow users to interact with each other in some way by sharing information, opinions, experiences, knowledge and interests.

IV. Learning in SMEs

Many researchers have emphasised the importance of organisational learning and correlated the importance of learning with companies that want to compete successfully (Birdthistle, 2004; Handy, 1992; Kaufman, 1992 and Lucas *et al*., 1996, PUII 2007b). Although continuous staff training is vital to the success of any company, many SMEs have limited resources and experience difficulty in sending staff on training courses as well as keeping up with funding for competence development.

Learning in SMEs is 80% informal, unconscious learning. It is the unofficial, unscheduled, impromptu way people learn to do their jobs. This experience is one of the most important sources of informal learning in companies, followed by interaction with co-workers, publications, Internet, Intranets and attendance at conferences are the main means used to acquire informal learning. SME personnel strongly prefer informal ways of learning new things or improving their efficiency with daily tasks. These techniques are often not thought of as "learning" but thanks to Web 2.0 Technologies and Net Collaborative Practices, these activities and the information gathered can be transformed and shared as structured informal learning to contribute to the knowledge development of SMEs.

The focus on Web2.0 for learning should be re-evaluated and made more attractive to innovators in the learning system. Informal learning is the most common type of learning and is

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also quite often carried out via eLearning. Within Irish SMEs the majority of training is job specific, however informal training and attendance at tradeshows were considered the most used method for staff training. Courses, seminars and training provided by outside consultants and internal personnel rated low. Ireland had a higher than average rate of trade show visits and attendance at courses and seminars when compared with its European counterparts and also compared positively for study visits, job rotation and tutoring/mentoring. Half of European SMEs considered competency development activity a key part of the overall business strategy. The main drivers to train in SMEs included firm specific factors, competitive factors and external factors such as legislative issues.

Companies need to look at why the majority of the training budget is spent on formal learning? How can informal learning be managed, leveraged and enhanced to get the most out of it?.

V. FORMAL AND INFORMAL TRAINING

SME learning is essential to enable the company to respond and cope with market changes and conditions (Beer et al, 2006; PUII 2007b). Training can be broken down into two categories: formal and informal. Formal training is structured and entails a defined curriculum with specific training goals and evaluative criteria as established from the beginning (Birdthistle, 2004). Examples of formal learning include seminars, workshops, and structured courses, both face-to-face and online courses. Grebow (2002) defines informal learning as learning that happens when knowledge has not been externalised or captured and exists only inside someone's head, so that to get to that knowledge you must locate and talk to that person (Grebow, 2002). Informal learning is typified by being shown how to do something by a work colleague – peer learning using prior learning. Examples of informal learning in eLearning include instant messaging, a live one-to-one sales meeting or a chat room in real time. Goss and Jones (cited in Birdthistle, 2004) outlined a number of factors controlling informal learning – senior management's attitude towards training and learning, the culture within the organisation, and the dynamic and complex environment in which the company operates.

Many researchers agree that informal learning methods are the preferred option in many SMEs (Chaston et al, 2001; Field, 1998; Gibb, 1997; Kerr and Mc Dougal, 1999; PUII, 2005).

One advantage of informal learning is that it allows quicker access to information, however, informal learning is by its nature more reactive than proactive, and therefore does not address the long term needs of the SME. Some online social learning groups are examples of informal eLearning e.g. LinkedIn, forums, Facebook, Twitter, CoPs, feedback and Blogging. These sites not only facilitate informal learning but also document it. Formal learning provides a more structured means for SMEs to acquire the new knowledge and skills that will help them to manage and adapt to change. It also improves the organisation structure and culture by allowing easier access to knowledge resources. The disablers of formal learning strategies are the constraints facing many SMEs. They are unable to train due to lack of resources, lack of awareness among SME management can result in training needs not being identified and a difficulty in sourcing suitable training (Birdthistle, 2004, Pye, 2000).

VI. BARRIERS TO TRAINING IN SMES

SMEs encounter numerous obstacles when it comes to planning and organising training. These include a lack of in-house resources, lack of facilities internally for onsite training, poor ICT infrastructure and an inability to articulate training needs (PUII, 2007b).

The barriers can be broken into 3 groupings:
1. Organisational barriers
2. Individual barriers
3. Environmental barriers

1) Organisational Barriers Facing SMEs

The primary barriers facing SMEs is lack of resources, including financial, staffing and time to carry out the training. Many SMEs do not have a dedicated training person or a human resource department and very few have a training plan in place. Managers in SMEs are unable to carry out training needs analysis and therefore are unaware of what training is required or how to source it. There is a lack of a training culture which leads to a reluctance to carry out any training that is not mandatory. The benefits and return on investment on training are unknown to many managers. From a technical perspective poor broadband access and an unsuitable IT infrastructure are also prohibiting factors for training in the workplace. Another reason for poor adoption of ICT in training was lack of knowledge of what is available and lack of quality assurance. The development time and cost of developing their own eLearning solutions were excessive.

2) Individual Barriers

As there is a lack of training culture many individuals are unmotivated and not encouraged to undertake training courses. Individuals also lack resources, they may not have free time to carry out training and may not get time off work for training. Individuals may not have a PC at home and if they do not have access to a PC at work, training can be impractical. Individuals require a certain environment to train including access to computer, internet and software. Many individuals lack computer experience and require training on the basics of IT and web navigation. From an eLearning viewpoint, individuals may be unaware of the range of courses available to them. When they do undertake eLearning they may have a feeling of isolation if the eTutor is not responding, if they experience navigation difficulties, information overload or if they are not getting any feedback they may fall behind in coursework. Other inhibiting factors included poor content, lack of quality

and assessments that were constructed poorly. The individuals may also have little formal education or it may be a long time since they undertook training and are unaware of the skills required for training including motivation, time management and discipline.

3) Environmental Barriers

Many SMEs and individuals feel that there are not enough incentives from government and support organisations in place for carrying out training. There is a lack of knowledge of eLearning programs and an unawareness of the barriers facing SMEs and individuals to undertake training. Support from SME managers and co-workers is very important to ensure a suitable environment for training. Poor communication between individuals and managers leads to lack of awareness on the training needs and requirements.

VII. Strategy for eLearning

For eLearning to be successful in SMEs a balance must exist between the individual employee, the behaviour and culture of the SME, and the environment. The three skills required are the social, cognitive and behavioural skills of the Social Cognitive Theory.

a) Social Skills

SMEs' learning culture needs to change to accommodate eLearning. SME managers can provide a supportive training culture by allowing time off during work hours for eLearning to take place, providing the skills necessary to carry out training, and offering incentives for taking eLearning courses. On a broader scale, enterprise support groups and governments can offer incentives by demonstrating the ROI of eLearning and advertising the range of courses available. Tax incentives and training grants could also help assist with the financial barriers of eLearning in SMEs.

b) Cognitive Skills

Synchronous and asynchronous learning improves interaction of student-teacher and student-student. Regular contact with eTutor and other students will help relieve the feeling of isolation of eLearning. Important skills required by the eTutor, to engage, encourage, invite and support the students can also encourage participation in eLearning. Web 2.0 makes it easier to produce, document and store information which makes it easier to tailor training to individual and SMEs resources, this is vital to the success of eLearning adoption. The eLearner must have ICT and web skills before undertaking an eLearning course. The eLearner also requires certain personality traits including good time management, ability to request assistance, maturity, self discipline and motivational skills in order to be able to complete a self study course. Individuals that may experience personality and physical difficulties are given more choices by using eLearning.

c) Behavioural Skills

Incorporating eLearning into the overall company strategy and providing resources to facilitate this process may help SMEs remain competitive. Networks or clusters can provide support for SMEs and assist in the adoption of eLearning. Industry support groups could build awareness of eLearning and aid in the building of cooperatives for technology and information sharing among clusters. eLearning allows learning to be carried out in an efficient and effective manner. Learners can control when and where they carry out their learning. It reduces the cost of training to SMEs with remote offices by allowing them train employees concurrently and also reduces both direct and indirect costs. The ROI of eLearning is higher and easier to track and the delivery of training is consistent.

The most significant factors identified in phases one, two and three that negatively impact the implementation of eLearning in SMEs are as follows:

- Lack of training culture within SMEs – most of the training that was carried out was mandatory training.
- Lack of appropriate software and contents – most of the commercial eLearning software is targeted to large enterprises or higher education. Customised solutions are expensive, and standardised solutions are unsuitable for many SMEs.
- The attitude of managers – Managers are unsure of the benefits of eLearning, they are unaware of what is available or what exactly eLearning is.
- Lack of time - many SMEs have neither the time nor resources to dedicate to eLearning.
- Lack of access to sufficient bandwidth to ensure high quality training, especially user-friendly tools and quality content. SMEs do not have the time or the resources to solve technical problems or learn sophisticated user tools.
- The availability and access to ICT. Many of the computers in SMEs may not be linked to the internet or employees may not have access to computers.

VIII. Factors to Consider When Implementing eLearning

eLearning works best in SMEs that already regularly organize and participate in formal and informal training. At a national level, the government needs to run systematic and collective marketing initiatives with enterprise and employment groups to promote the content of eLearning programs. eLearning should be further integrated into part of the learning within SMEs without entirely replacing traditional methods of training. eLearning is not a 'one size fits all' approach, therefore a variety of learning methods are required to suit the individual tastes.

To be successful in incorporating eLearning, SMEs should look at similar companies where it has been implemented, and learn from their successes and mistakes. eLearning should be used in cases where it is more effective than traditional

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methods and in line with company goals and objectives. Employees must have the necessary cognitive skills for eLearning or get training to acquire them. Furthermore, a supportive learning environment and self discipline will help to ensure the success of eLearners in SMEs.

The effective use of eLearning requires a cultural change within SMEs. Managers and staff need to become aware of the benefits and the variety of courses offered by eLearning, including reduced travel time to course location and anytime/anyplace learning. The interaction of teachers and students and students-students is very important in the success of most eLearning. Students should do work through student led discussion, web resources, peer assistance and analysis of case studies. The role of the eTutor is different than in tradition learning, it includes administration, coach, assessor and subject expert. The best practice delivery techniques include peer learning, group work, mentoring, problem solving, networking and use of ICT support tools.

The key technological factors in implementing eLearning include access to resources, integration and usability of the learning environment in addition to flexibility to serve current and future andragogical needs. The software used for eLearning needs to be easy to use and must integrate with the existing ICT infrastructure, thereby avoiding extra expenditure. The European project ARIEL revealed that SMEs expect faultless, easy to use and self-explanatory software with high practical use to cut down on the integration, implementation and delivery process.

The issue of accreditation and certification is also important to eLearning to ensure confidence with course material and for educational advancement of employees. The ARIEL study revealed that SMEs prefer providers they feel they can trust either because of previous long-term successful business relations, or because the institution has a good reputation for certified training.

However, in order for an eLearning strategy to be sustainable there must be a detailed strategy in place. The following results were found to be the most appropriate in developing training strategies in SMEs:-

1. Identification of training needs and objectives. This is a vital step, yet many SMEs reach their first obstacle here, as they are unsure of what their needs and objectives are or how to go about finding out what they are. Many SMEs do not have a dedicated Human Resource or training individual. Training is often carried out in a reactive instead of a proactive manner. As shown in the research there is a link between training and production therefore it is important for the SME manager to learn how to identify their training needs and objectives.

2. Engaging Employees – employees need to take responsibility for their own training needs and see it as their responsibility. The research showed that there are many barriers to employees engaging in eLearning, but, where it is linked to their day to day tasks and they can see the benefits of it, it is most successful.

3. Time constraints – employees and SMEs are often lacking time and dedicate little time to training. It was found that informal methods for training are more widely used in SMEs.

4. Courses and learning content – the most important areas for training in SMEs are those related to the core activities. Other areas that are important for training are those that will give the SME competitive advantage. The primary activities of the company including management, accounting and language skills are also important.

5. Tutor support and integrating eLearning with traditional learning – the research has shown that the learning is more successful when there is more contact with the tutor and also a combination of face-to-face, online or telephone interaction with students and tutor.

Based on these points it is clear that a successful, sustainable eLearning solution is one that is integrated with the goals, objectives and resources of the SME and where there is engagement from staff.

IX. WEB2.0 AND INFORMAL LEARNING

Web 2.0 technologies allow users to interact with each other in some way by sharing information, opinions, experiences, knowledge and interests. They are widely used unconsciously in informal learning. Some features of Web 2.0 tool and services, like blogs, wikis, discussion lists, chat, internet forums, RSS Feed and other social media resources can be used as informal learning resources.

The Net Knowing 2.0 project (NK) funded with support from the European Commission aimed to enable entrepreneurs, managers and supervisory staff of European SMEs:

- to use Web 2.0. technologies and net collaborative practices to obtain informal learning.
- to learn how to put in place sustainable informal learning strategies in their companies that are based on knowledge sharing supported by Web 2.0 and net collaborative practices.

The objective of the next section is to detail the objectives addressed by the courses developed in NetKnowing 2.0 project and the corresponding contents and methodologies. The training courses were established to assist with the use of Web 2.0 Technologies and to facilitate it in daily work and job posts of enterprises and organisations at corporate level. In other words the purpose of this part of the project was to build a training program that would provide the competences that, in the experience of the partners:

• the employees of SMEs (and organisations) need to be able to use the opportunities offered by "web2" to learn new knowledge and improve their work related skills;
• the high/medium directive staff of human resource/training responsibles of SMEs (and organisations) need to be able to facilitate the informal learning at corporate level supported in Web 2.0, Networking and Shared Knowledge Management.

These identified competences have been the basis for building the training program and didactical contents of the Basic and Advanced course previewed as part of main results of the project. During the previous partner's common work to determine and describe these competencies, 3 main competence areas have been identified:
1) Learning
2) Technology
3) Social

Accordingly, the main characteristics of the training structure program from the NetKnowing2.0 project are as follows:
• Two different levels, one for each course, corresponding two different targets and aims, according that what has been explained above.
• Three different modules in each course: the first more theoretical, about concepts and strategies; the second focused on the optimum use of Web 2.0 for the purpose of Informal Learning from the different perspective – individual and corporate level; the third one centered on behaviour and networking techniques.
• A set of complementary didactical resources (case studies, documents and info, links, exercises).

In the NetKnowing 2.0 Project, two target audiences have been identified, according to their degree of responsibility in the human resources development of SMEs:
• The employees
• The responsiblility of human resources, training coordinators, team's supervisors or managers who intend to be able to recognise and support informal learning in their business and workplaces.

The training program comprised two courses:

1. the "Basic", aimed at all employees,
2. whilst the "Advanced" is for training and facilitators, supervisors, team coordinators, managers.

A pre-requisite level of digital literacy (web browsing, e-mail, simple use of Office tools) will be assumed in both cases. Intended participants who do not have this pre-requisite should acquire it first.

The basic course title: *How to acquire informal learning by using Web 2.0 and Networking?* refers to individual abilities and behaviours. This course is a self-learning course focused on how to obtain and share informal learning by networking practices and by the basic use of most popular Web 2.0 tools.

It is a basic introductory level course, which aims to train entrepreneurs, freelance professionals, technical staff and managers of SMEs on how Web 2.0 technologies, social networking and collaborative practices can be used to understand how to acquire and share informal learning.

The contents are as follows:
The first module of this course will give an understanding of the basic concepts related to informal learning. Web 2.0 technologies, are online tools which allow users to interact with each other in some way- by sharing information, opinions, experiences, knowledge and interests.
They are perfect to support informal learning.

In the second module the main features of Web 2.0 tools and services, like blogs, wikis, discussion lists, chat, internet forums, RSS Feed and others social media, as well as their utility as informal learning resources will be explained.

The third module will discuss the importance of networks. Belonging to networks carries obligations and responsibilities as well as advantages. In the third module the key to maintaining a desirable behaviour in networking activities and the basic rules of Netiquette for social media will be conferred.

In each unit it will be possible to find theoretical contents explaining in a simple way in multimedia format, as well as complementary resource like links, documents, storytelling and exercises to allow the trainee find out more and to go deeper on a particular topic of the course.

Taking into account that the Basic Course is conceived for self learning delivery, two kind of exercises will be offered:
1. Questionnaires multi-choice options. Once finished, will be possible to see the correct options/answers.
2. Open exercises with questions to be answered by the trainees in an electronic form.

It will be possible for the trainee to "share and see answers", to access to the answers given and shared by others trainees. This is an optional feature.
The advanced *course "How to implement informal learning strategies based on Web 2.0 in our company or organization*""
Is an advanced level course developed for training in implementing Web 2.0 strategies and technologies, collaborative learning techniques and the principles of knowledge management, in order to convert daily work and the spontaneous activities of informal learning into corporate knowledge and training resource for companies and organizations. "

One of the reasons that informal learning represents around 80 percent of all learning activity is that the learning need can often arise quickly and unexpectedly. To execute the organizational operations efficiently a quick and effective response is required. Informal training and learning could in this context be organized in minutes. An important aspect is that such forms of learning are available, accessible and they

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should be supported by the company/organization management.

Accordingly, the advanced level course is focused on the implementation of Web 2.0 and structured informal learning systems based on the application of knowledge management practices in SMEs.. Essentially, it covers two important areas:
1. How to convert the knowledge obtained from daily work practices, networking activity and spontaneous informal learning into corporate knowledge stored in a structured informal training system supported by Web 2.0 technologies, social and collaborative learning principles and techniques of shared knowledge management;
2. How to combine them with formal learning to implement continuing training strategies in SMEs and how to integrate these approaches in a sustainable LLL strategy.

The course has been designed to be delivered via blended learning. This means that trainees can use this course for self-learning but online learning is most effective when delivered by trainers experienced in the subject.
The expected target audience for this course includes:
- Managers
- Human Resources officers
- Training officers
- ICT Experts willing to know how introduce these tools in the companies
- Trainers (internal or external)
- University Students of Business
- Future entrepreneurs

The Advanced Course will train these people to be facilitators of informal learning in the companies/organisations. And it is supposed that they will need to use the contents of the modules, case studies, tools, when they go back to in companies access to the course to facilitate informal learning in the enterprises.

The modules for trainees will be developed in the similar framework to the Basic Course, and they will be available on the e-Learning Suite. But will be adapted to the user, because in this case the aim of this module will be for consultation purposes, to reinforce the trainer's explanations and to revise and use after the course, if the trainees need. It will also contain a connection to the CoP or other links.

The course is conceived to be delivered in blended learning format that means part will be in face to face sessions, and another part in the form of on line tutor based training.
It contains theoretical explanations and didactical resources, including documents, case studies (storytelling / best practices) that could be useful for enterprises.

It could also be important that trainers and trainees engage in learning through the use of technology and of social networks like the virtual Communities of Practices (CoP) and become more familiar with technology by using it. A simple manual of the CoP will be developed for the trainers, and another for the trainees (students).
An additional resource is the Web 2.0 Toolbox that facilitates access to information, demo versions, and social software manuals useful to support informal learning, both at a personal and corporate level. Both are composed of 3 main modules, divided in units with specific themes.

X. Conclusion

This paper looked at learning in SMEs, it explained the difference between formal and informal learning. It is clear from this paper that the majority of training in SMEs is informal and social learning allows SMEs an easy means to formalise this. This paper outlined how the tools and resources in Web2.0 has a great potential to improve the quality of learning by facilitating access to resources and services in addition to remote exchanges and collaboration thereby reducing some of the constraints and barriers to training in SMEs. This paper outlined a basic and advanced course developed by the NetKnowing2.0 project to assist companies in the use of Web2.0 to enhance and assist informal learning in SMEs. Web2.0 can assist SMEs in overcoming the barriers to training and capture the knowledge obtained through informal learning.

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ARIEL website http://www.ariel-eu.net/

Sinead Mellett, University of Limerick, Sinead holds a BA in Business Studies, an MSc in Technology Management, a Specialist Diploma in Teaching, Learning and Scholarship and is currently completing a PhD in the area of eLearning and Small and Medium Enterprises Sinead has a number of years' experience working on international research in the area of learning and small and medium enterprises. She has carried out consultancy and research with partners in Canada, Portugal, UK, Spain, Germany, Romania and other European countries.

Dr. Emma O Brien is a tutor and a research fellow in the University of Limerick. She teaches on the MA in technical communication and e-learning and is a distance learning tutor for the Atlantic university alliance. She has co-ordinated and participated in many European projects in the area of e-learning for SMEs. She is a member of the editorial board for the journal of technology enhanced learning and has many publications in this area.

Gabriela Vlckova has the master's degree from the field of business, marketing and economics. Since 2007 she has been working in the field of training and education, actively involved in management and implementation of European projects. Her professional background as well knowledge and skills she obtained during the professional carrier and studies allows her to be involve in activities related to the entrepreneurship and SME's, sustainable personal development or innovative methods of learning with focus on ICT. From 2009 she has contributed to activities of testing, implementing and validating the ECVET system in Czech Republic.

22nm NMOS device with lowest leakage current, optimized using Taguchi Method

Afifah Maheran A.H.[1], Menon, P.S.[*1], I. Ahmad[2], S. Shaari[1], H. A. Elgomati[3]
[1]Institute of Microengineering and Nanoelectronics (IMEN), Universiti Kebangsaan Malaysia (UKM), 43600 Bangi, Selangor, Malaysia
[2]Centre for Micro and Nano Engineering(CeMNE), College of Engineering, Universiti Tenaga Nasional (UNITEN), 43009 Kajang, Selangor, MALAYSIA
[3]Applied Research & Development Organization (ARDO), Libya
[*]e-mail: susi@eng.ukm.my

Abstract – In this paper, the optimization of process parameter using Taguchi orthogonal array method was performed in finding the lowest leakage current on designing a 22 nm NMOS transistor. The invention of NMOS transistor was used the new combination on planar device of high permittivity (high-k) material and metal gate which are titanium dioxide (TiO_2) was used as the high permittivity (high-k) material instead of silicon dioxide (SiO_2) dielectric whereas tungsten silicide (WSi_x) as a metal gate was deposited on top of the high-k dielectric layer. The device's design fabrication, characterization and optimization were performed using an industrial-based numerical simulator. The L9 orthogonal array was utilized four control factors and two noise factors which total up to 36 simulation runs. The functional objective is to obtain I_{LEAK} values using signal-to-noise ratio (SNR) in Smaller-the-Better (STB) characteristic. The optimization results in the attainment of the I_{LEAK} mean value of 1.22954 nA/μm. This value is lower than the prediction value given in the International Technology Roadmap for Semiconductors (ITRS) 2012.

Keywords- **Taguchi orthogonal array method, 22 nm NMOS transistor, high-k/metal gate, leakage current.**

I. INTRODUCTION

Demanding for greater integration, higher performance with lower power dissipation motivates the scaling of complementary metal-oxide-semiconductor (CMOS) devices. Smaller devices can be implemented in a smaller area of integrated circuits (IC) and this leads to increasing the number of transistor-per-wafer. However, the downsizing dimensions of transistors resulted the reduction of the silicon dioxide (SiO_2) layer thicknesses as gate dielectric until 2 nm which is increasing of gate leakage current [1]. The introduction of high permittivity (high-k)/metal gate transistor is the best candidates in replacing the SiO_2/poly-gate where it is believing to solve the leakage current crisis [2]. And also, by replacing high-k dielectrics to replace SiO_2 as a CMOS gate is one of the major challenges for further downscale in order to keep planar CMOS devices still on track [3]. The device characteristic prediction made by the International Technology Roadmap for Semiconductors (ITRS) gives a good reference in CMOS scaling development.

With that motivation, the mathematicals analysis were aid in to design the device by optimizing the fabrication's process parameters to find the best combinations in achieving the target .The optimization of the fabrication process parameters was performed using Taguchi's orthogonal array method in order to obtain the minimum leakage current (I_{LEAK}) according to the ITRS prediction. In the optimization process using Taguchi method, the signal-to-noise ratio (SNR) was used where it measures the quality of the orthogonal arrays. Many design parameters are studied simultaneously using only a small number of experiments with added noise factors in order to get the optimal process parameters [4]. To find the lowest leakage current, the best analysis in SNR is the Smaller-the-Better(STB) where the objective is to gain the lowest leakage as could.

In this experiment, an L9 orthogonal array was implemented where it consists of four process parameters which are the Halo implantation dose, Halo implantation tilting angle, Source/Drain (S/D) implantation and the compensation implantation. The Sacrificial Oxide Layer (PSG) annealing temperature and the Borophosphosilicate Glass (BPSG) annealing temperature were selected as the noise factors. The aim of the work is to minimize the I_{LEAK} of the device by minimizing it as small as possible in reference to the ITRS 2012 prediction for 22 nm gate length NMOS transistor where the accepted maximum value for I_{LEAK} is 100 nA/μm [5].

II. MATERIALS AND METHODS

A p-type silicon substrate with <100> orientation is used and P-well region using Boron as a dopant with a dose of $3.75x10^{12}$ ions/cm^2 is produced. The silicon wafer is then annealed at 900°C in a Nitrogen environment followed by dry oxygen in order to ensure that the boron atoms are being spread properly in the wafer. The Shallow Trench Isolator (STI) was produced by oxidized in dry oxygen followed by a low pressure chemical vapour deposition process (LPCVD) and then a photo resist deposition took place to achieve the trench depth. Finally, to complete the trench, a sacrificial oxide layer was grown and then etched followed by a sacrificial nitride layer.

The next step was to implant with boron dose of $6.98x10^{12}$ ions/cm^2 to perform N well active area. Later on, a Halo implantation took place in order to get an optimum performance for the NMOS device where indium was implanted with a dose of $20.45x10^{12}$ ions/cm^2. The dosage was varied in order to get the optimum value. Then the high-k material, TiO_2 (dielectric permittivity =80) was deposited for a final thickness of 2 nm and was adjusted to produce a 22 nm gate length [6]. Tungsten silicide (WSi_x) as a metal gate was then deposited on the

top of the bulk device to produce the gate contact point as desired [7].

Side wall spacers were formed at each of the source and drain regions respectively where it functions as a mask for the source and drain implantation. Then, there are source-drain implantations where Arsenic was firstly implanted with a dose of $28.2x10^{12}$ ions/cm^2, followed by phosphorous with a dosage of $1.5x10^{12}$ ions/cm^2. The next process was the development of 0.5 µm Borophosphosilicate Glass (BPSG) layer that acts as a pre metal dielectric (PMD) [8].

After that, the wafer undergoes annealing process at a temperature of 850°C. The next process was compensation implantation by phosphorous, with a dose of $7.8x10^{12}$ ions/cm^2. Lastly, aluminium layer was deposited on top of the structure and then it was etched accordingly to form the metal contact for the device. Then, the transistor undergoes electrical characteristic measurement using ATLAS simulation module in order to study the leakage current of the device with reference to ITRS 2012.

A. Taguchi L9 Orthogonal Array Method

The L9 Taguchi orthogonal array method is used to optimize the device's process parameters for the best combinations in order to achieve high device performance with a small number of experiments [9]. There were total of 36 running simulation performed which consists of four process parameters at three different levels and two noise factors purposely to make the process parameters insensitive to the design. All the values of the process parameters and noise factors are listed in Table 1 and Table 2 respectively.

TABLE 1
PROCESS PARAMETERS AND THEIR LEVELS

Factor	Process Parameter	Unit	Level 1	Level 2	Level 3
A	Halo Implantation Dose (10^{12})	Atom/cm^3	20.40 (A1)	20.45 (A2)	20.50 (A3)
B	Halo Implantation Tilting Angle	Degree	33 (B1)	35 (B2)	37 (B3)
C	S/D Implantation Dose (10^{12})	Atom/cm^3	28.20 (C1)	28.25 (C2)	28.30 (C3)
D	Compensation Implantation Dose(10^{12})	Atom/cm^3	7.75 (D1)	7.80 (D2)	7.85 (D3)

TABLE 2
NOISE FACTORS AND THEIR LEVELS

Symbol	Noise Factor	Level 1	Level 2
		°C	
X	Sacrificial Oxide Layer (PSG) Annealing Temperature	900 (X1)	903 (X2)
Y	Borophosphosilicate Glass (BPSG) Annealing Temperature	855 (Y1)	858 (Y2)

III. RESULTS AND DISCUSSION

The results of the I_{LEAK} were analyzed and processed using Taguchi method in order to get the minimum possible value in designing the 22 nm NMOS device.

A. *Analysis for 22nm NMOS Device*

The Taguchi implementing analysis for I_{LEAK} which is specified in the orthogonal array table was simulated and listed in Table 3 for different noise factor combinations.

TABLE 3
I_{LEAK} VALUES FOR NMOS DEVICE FOR DIFFERENT NOISE FACTOR COMBINATIONS

Exp. No	Leakage current (nA/µm)			
	X1Y1	X1Y2	X2Y1	X2Y2
1	3.66497	3.72880	3.66717	3.73102
2	5.20185	5.28127	5.20497	5.28442
3	2.92172	2.96522	2.92351	2.96704
4	4.69349	4.76058	4.6963	4.76342
5	3.32754	3.39326	3.32953	3.39528
6	0.97236	0.98938	0.97300	0.99003
7	2.28422	2.31073	2.28563	2.31216
8	2.87639	2.93385	2.87814	2.93562
9	1.22586	1.241213	1.22667	1.24295

Since the experiment target is to get a minimum leakage current, therefore the leakage current is optimized using signal-to-noise ratio (SNR) of Smaller-the-Better [10]. The SNR (Smaller-the-Better), η_{STB} can be expressed as

$$\eta_{STB} = -10\log_{10}\left(\frac{1}{n}\sum_{i=1}^{n} y_i^2\right) \quad (1)$$

where n is number of tests and y_i is the experimental value of the leakage current. By applying the formula given in Eq. (1) the η_{STB} for the device was calculated as resulted in Table 4. The parametric combination level of the process and noise factors is also listed in Table 4.

The performance of the device characteristic is evaluated by the SNR analysis value. In general, in SNR analysis, the best performance of the device is observed when the SNR has the highest value. Therefore, the optimal level of the process parameters is the level with the highest SNR [11].

TABLE 4
SNR FOR THE LEAKAGE CURRENT AND THEIR MAIN EFFECTS

Exp No.	SNR (dB)	Process Parameter			
		Factor A	Factor B	Factor C	Factor D
1	168.64	1	1	1	1
2	165.61	1	2	2	2
3	170.62	1	3	3	3
4	166.51	2	1	2	3
5	169.47	2	2	3	1
6	180.16	2	3	1	2
7	172.77	3	1	3	2
8	170.73	3	2	1	3
9	178.17	3	3	2	1

Referring to Table 4, row 6 resulted the highest SNR value of 180.16 dB which is indicates that the process parameter in this row gives the best insensitivity for the response characteristics. Since the experimental design is

orthogonal, the effect of each process parameter on the SNR at different levels can be separated out.

The value on each levels of the process parameters on SNR (STB) for the experiments is summarized in Table 5.

TABLE 5
SNR RESPONSE FOR THE LEAKAGE CURRENT

Factor	SNR (Smaller-the-Better)			Total Mean SNR
	Level 1	Level 2	Level 3	
A	168.29	172.05	173.89	171.41
B	169.31	168.60	176.32	
C	173.18	170.10	170.95	
D	172.09	172.85	169.29	

The factor effect graph for the SNR (STB) of the experiment is shown in Figure 1. The dashed horizontal lines in the graph represent the values of the overall-mean of the SNR (STB). Referring to the graphs, from the left, the slopes correspond to the Halo implantation dose (Factor A), followed by Halo implantation tilting angle (Factor B), S/D implantation dose (Factor C) and lastly Compensation implantation dose (Factor D) respectively.

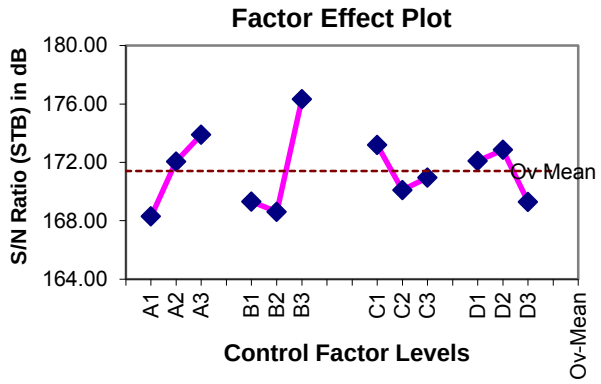

Figure 1 SNR (Smaller-the-Better) graph

B. Analysis of Variance (ANOVA)

In order to discover the selected process parameters that gives effect to the device characteristic, Analysis of Variance (ANOVA) was used in this experiment. The result of ANOVA for the device is presented in Table 6. The factor effect percentage on SNR was selected to indicate the priority of a process parameter to reduce variation. The high percentage value of a factor effect on SNR donates to the highest influence on the I_{LEAK} with respect to the noise parameters.

TABLE 6
RESULTS OF ANOVA

Factor	Factor Effect on SNR (%)
A	25.16
B	56.15
C	7.82
D	10.87

The results clearly shows that the Factor B, which is Halo implantation tilting angle with 56.15% has the greatest influence in discover the minimum I_{LEAK} of the NMOS device. This means, by adjusting even a few degree of Halo implantation tilting angle, the I_{LEAK} value gives a lot changes compare to others process parameters. By that reason, varying the tilting angle must be took more attention compare to the others.

IV. CONFIRMATION OF OPTIMUM RUN

Table of SNR (STB) is a good reference in order to finalize the fabrication's process parameters, in achieving the target. Based on Table 5, the SNR (STB) values of each level for process parameters is selected as the levels was expected to achieve the target which is minimum I_{LEAK}. As a result, for the Halo implantation dose (Factor A), level 3 with value of 173.89 dB was selected, for Halo implantation tilting angle (Factor B) was level 3 by 176.32 dB, while for Factor C which is S/D Implantation at level 1 with SNR of 173.18 dB and last but not least is Compensation implantation at level 2 with SNR of 172.85 dB. The best setting of the process parameters for a NMOS device that affects the I_{LEAK} which is suggested by Taguchi method is A_3, B_3, C_1, D_2 and this is summarized in Table 7. These final parameters were then simulated with the noise factors to get the final I_{LEAK} values as noted in Table 8.

TABLE 7
BEST SETTING OF THE PROCESS PARAMETERS

Factor	Process Parameter	Level	Best Value (atom/cm^3)
A	Halo Implantation Dose	3	$20.5\text{x}10^{12}$
B	Halo Implantation Tilting Angle	3	37
C	S/D Implantation Dose	1	$2.82\text{x}10^{12}$
D	Compensation Implantation Dose	2	$7.8\text{x}10^{12}$

TABLE 8
RESULT S OF BEST SETTING PARAMETER WITH ADDED NOISES

LEAKAGE CURRENT (nA/μm)				
I_{LEAK} 1 (X1,Y1)	I_{LEAK} 2 (X1,Y2)	I_{LEAK} 3 (X2,Y1)	I_{LEAK} 4 (X2,Y2)	I_{LEAK} (Mean)
1.22023	1.23625	1.22281	1.23885	1.22954

After the optimization approach, the value of SNR (STB) of the I_{LEAK} for the developed of 22 nm NMOS device shows that it was resulted the mean of 1.22954 nA/μm. The lowest I_{LEAK} value obtained is 1.22023 nA/μm which is much lower that the value of 100 nA/um that predicted by ITRS 2012.

V. CONCLUSION

As a conclusion, the mathemathical anaysis tools of Taguchi method is a reliable technique in optimizing the process parameters of a 22 nm planar NMOS transistor utilizing high-k/metal gate technology in order to achieve the optimum solution with reference to the ITRS 2012. Leakage current was kept as minimum as possible to increase the speed of the device and maintaning the performance. The best process parameter value that gives the minimum I_{LEAK} for Halo implantation, Halo implantation tilting angle, S/D Implantation and Compensation implantation $20.5\text{x}10^{12}$ atom/cm^3, 37°, $2.82\text{x}10^{12}$ atom/cm^3 and $7.8\text{x}10^{12}$ atom/cm^3 respectively. While the noise parameter values for PSG and BPSG

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annealing temperature are 900°C and 855 °C respectively. The lowest I_{LEAK} value of 1.22023 nA/μm was attained upon Taguchi optimization.

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Automatic evaluation of correctness and originality of source codes

Daniel Pohuba, Tomáš Dulík, Peter Janků

***Abstract*—This paper introduces a system for automatic evaluation of correctness and originality of source codes submitted by students enrolled in courses dealing with computer programming. Automatic correctness checking consists of searching for plagiarisms in assignments submitted earlier and checking the correct implementation of algorithms. User interface is implemented as a Moodle module using its Plagiarism API. The complete system is published with GPLv3 license; therefore other learning institutions can use it as well.**

Keywords—Moodle,plagiarism,automatic checking, source code

I. Introduction

Manual checking of submitted source codes is often a menial, repeating and a very time consuming work. This can lead to an unnecessary workload of the teacher and subsequently to a lower quality of programming courses. Many of the repetitive tasks can be automated, thus giving the teacher more time to discuss with students or further enhance the course.

On the other side are the students, many of who are always trying to do their assignments with as little work as possible, often resorting to plagiarism. Automation of searching for plagiarism is even more beneficial, since in some cases it can be very hard or overly time consuming to find a plagiarism manually, e.g. when a student copies a source code from last year.

This paper describes a system for automatic evaluation of correctness and originality of source codes.

The main objectives were to:

- Create a local system for evaluating correctness of programs in an arbitrary programming language that can handle both unintentional errors in the programs and intentional attacks against the host OS.
- Create a local system for checking plagiarism in source code of several programming languages, e.g. C/C++, Java, PHP…
- Create a Moodle module that will use the above mentioned systems.
- Create a set of sample assignments for every supported programming language.

This paper begins with a short description of technologies used and a description of how the new system is divided into its main subsystems. Their implementations and details are further listed in the following chapter. Finally the benefits of using this system are stated.

II. Used Technologies

A. Moodle

Moodle is a Course Management System (CMS), also known as a Learning Management System (LMS) or a Virtual Learning Environment (VLE). It is a free web application that educators can use to create effective online learning sites. Moodle is widely used on universities to make study materials more easily available and to assign various types of projects to theirs students. Since version 2.0 it offers a Plagiarism API specially developed to allow a creation of a new type of module. Using this API, a module is able to get a submitted file, text or other type of submission uploaded through some of the core modules. This file can be then checked for plagiarism or processed with other systems. [1]

B. YAP

YAP (Yet Another Plague) is a system for plagiarism control made at The University of Western Australia. The last version, YAP3, is used in this project. YAP system is divided into two main parts. First of them is tokenization and it consists of these steps:

- Comments and string-constants are removed.
- Upper-case letters are translated to lower-case.
- A range of synonyms are mapped to a common form.
- If possible, the functions/procedures are expanded in calling order.
- All tokens that are not in the lexicon for the language are removed.

The result is a .token file with indices of tokens from the lexicon.

Second part is comparison with other submissions. YAP3 uses an algorithm designed for this purpose called Running Karp-Rabin, Greedy String Tiling (RKR GST) [2].

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III. System Description

The resulting system is divided into three main parts: anti-plagiarism module for Moodle, YAP subsystem for originality checking and APAC subsystem for automatic evaluation. Their connection can be seen in Fig. 4.

Moodle module acts as a user interface for the whole system. After installing, teachers can see settings for the whole system in assignment settings. Files submitted by students are automatically submitted for plagiarism control to YAP and for automatic evaluation to APAC. Even though the plagiarism API supports several of the core modules, this module only communicates with the *Assignment (mod/assign)* module since it is used in courses with programming assignments for submitting files.

YAP subsystem accepts the files submitted by students, tokenizes them and performs the originality check. Furthermore, it saves the files as a zip archive for APAC. YAP takes all the submitted files as a whole by concatenating their contents. Results are then periodically sent back to Moodle.

APAC subsystem then takes the submission and, based on the used programming language, tries to compile it. If the first stage is successful, APAC runs the program to record its behavior.

IV. Implementation

A. Moodle module

The user interface of the whole system is implemented in the Moodle plagiarism module called "Yap anti-plagiarism". It takes advantage of the plagiarism API introduced in Moodle v. 2.0. This API connects core modules with custom modules. This module can be used only with the new Assignment core module. Custom plagiarism module has to implement predefined methods in a class that extends plagiarism_plugin class located in lib.php file. Some of the more important functions and features they provide are described in this section.

In Fig. 1 we can see a new submission that is not yet checked. After the files are checked by YAP and APAC, their results are automatically sent back directly to this module and saved in the Moodle database. Fig. 2 and Fig. 3 show a submission with results: similarity in percent and a checkbox visualizing whether the submission has been marked as a plagiarism by a teacher, or a message that no plagiarism was found. These shorter results can be seen either directly in the submitting page of the Assignment module or in a page showing a list of all submissions. Students themselves can see only a limited portion of these results, specifically the percentage of the highest similarity and APAC results.

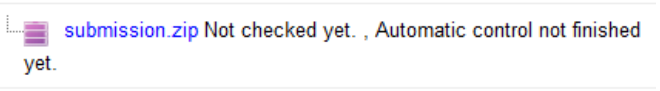

Fig. 1. Submitted files without available results

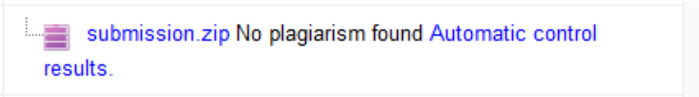

Fig. 2. Submitted files after being checked with negative results shown

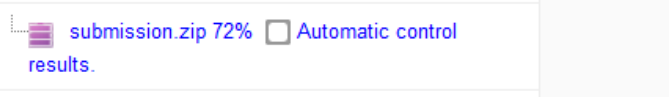

Fig. 3. Submitted files after being checked with positive results shown

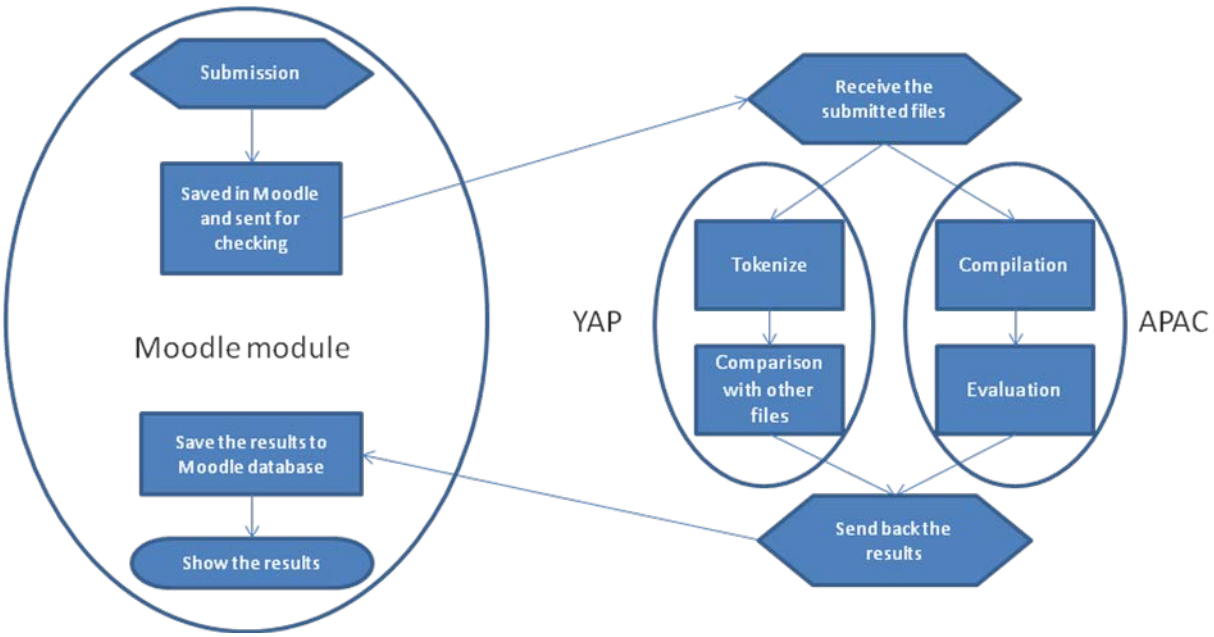

Fig. 4. Connection of the subsystems

After clicking on one of these links a detail is shown. The detail consists of two tables. First table shows one or more found similar submissions. Each matched submission shows similarity, the other user, list of uploaded files from both users, and a checkbox for marking the submission as a plagiarism. After clicking on a checkbox, a JSON request is sent; therefore no form submitting or manual saving is required.

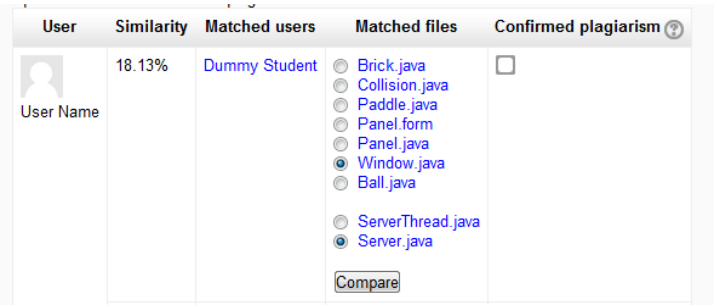

Fig. 5. Detail of a suspicious assignment

The aforementioned list of submitted files can be used to open a built-in source code comparator by checking one of the radio buttons for a file from each submissions and clicking the "Compare" button. Source code comparator uses a SyntaxHighlighter 3.0 JavaScript plug-in. This feature allows the teacher to find out if the similarity is truly a plagiarism, without unnecessarily downloading, opening and comparing both files. This option is available only when student submits uncompressed files. An example is shown in Fig. 7

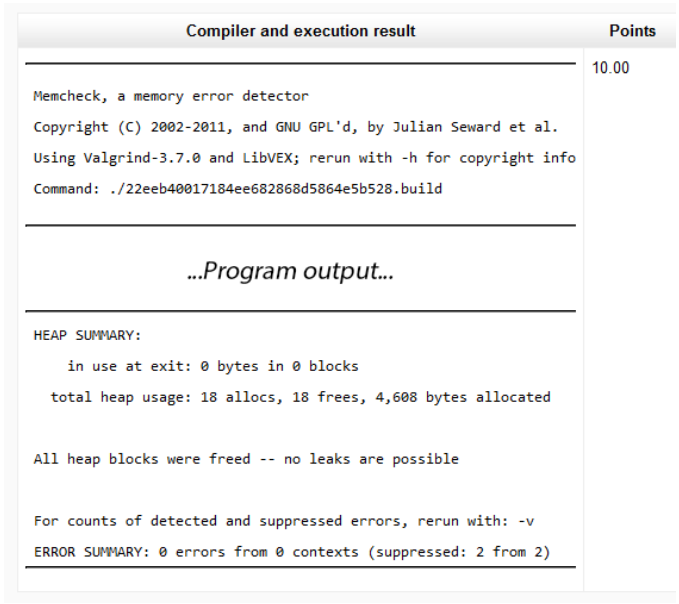

Fig. 6. APAC results – execution & compiler results and points

Second table in the submission detail shows results from the APAC subsystem. First column shows output from a compiler followed by a list of results from execution of the program. If the submitted program is in C/C++, these results also contain an output from Valgrind Memcheck, warning about memory leaks.

Final third column shows points that can be used for final grading. Base idea of the score calculation is based on comparing output from the base program and output from the students' program for each test vector. Score is calculated from the maximum points defined in the test vector; therefore score parameter equals maximum points.

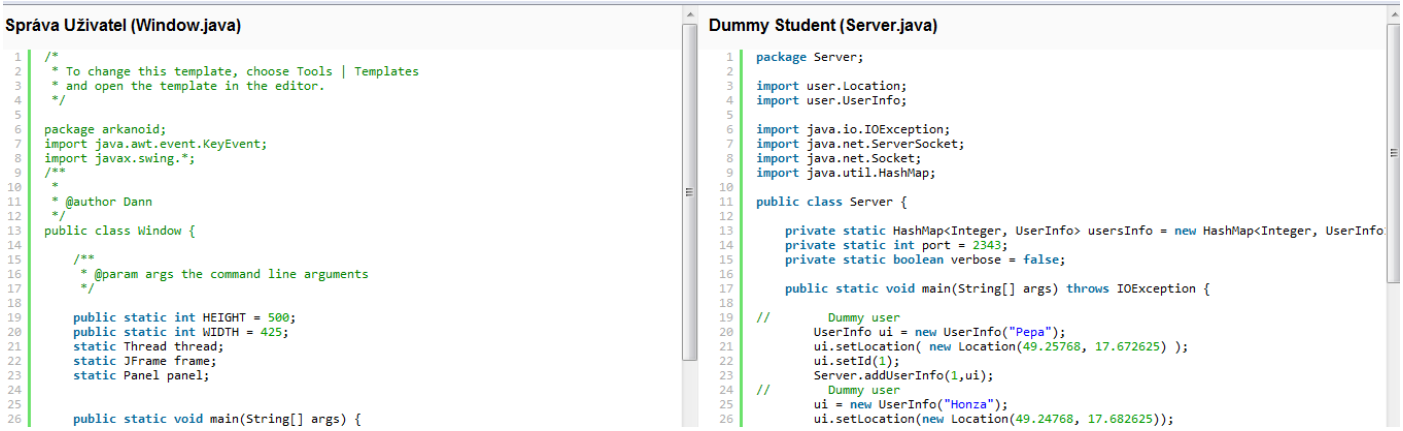

Fig. 7. Comparison of two submitted source codes

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Rules for points:

- If the student has some compilation errors, final score is 0.
- If the student has more than 2 warnings, score is decreased by 10%.
- Similarity of the output has a weight of 50% for C/C++, otherwise it is 90%.
- If submission language is C/C++, found memory leaks have a weight of 40%, so if Valgrind finds any memory leaks, score will be decreased by 40%.

Levenshtein distance is used to calculate the similarity of the outputs. StringUtils' implementation of the algorithm from Apache Foundation was used.

B. *YAP Controller*

Yap Controller acts as an interface between Yap anti-plagiarism module for Moodle and YAP system. Its main purpose is to receive files submitted in Moodle and sent by the Yap module, call YAP and APAC and then send back the results. Because of mostly unpredictable time complexity of these processes, these steps are done asynchronously. At first, the controller calls a tokenizer to process the files; secondly, APAC is called using its REST API. Results of APAC are saved in a database described in the following subsection; YAP uses a file based system for storing all of its data. All these results are periodically gathered and sent back to the Moodle module which saves them in its own tables in Moodle database.

C. *APAC*

APAC system was created in Java EE 7, a modern rapid development platform. One of the requirements for this system was to create a sandbox environment for execution of a potentially dangerous student programs. After some research, Linux Containers with its powerful frontend Docker was chosen as a backend technology for the sandbox. Docker containers are managed by REST API from Java. Docker containers use Control groups' policy to limit resources such as memory and CPU usage. After exceed this limits, the running process in a container is killed.

Main purpose of APAC is to submit new jobs to job queue for evaluation. This was implemented as a simple servlet. Currently it is dependent on a shared database with the YAP component.

Shared database is very simple, it contains two tables. First table is for storing results of execution and the second table for storing assignment configurations.

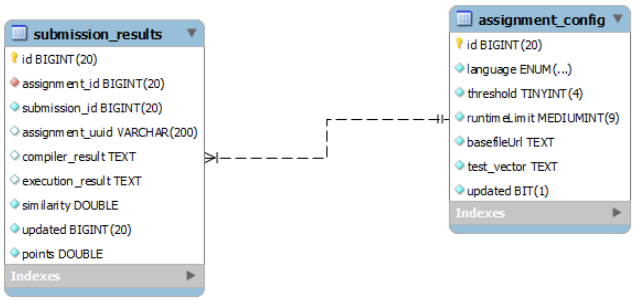

Fig. 8. Database ER Diagram

V. APAC Submission Evaluation

This section describes the pooling, compilation and evaluation of the submission in APAC subsystem in detail.

The whole process begins after YAP Controller creates a partial record in the shared database and calls the APAC using its API. Task submission process is illustrated in the Fig 9.

Before creating a new job, request parameters are checked. If parameters are wrong, the submission process ends. If the request is correct, APAC fetches assignment data from a database. Next step in the process is a check if the base program was updated. If base program was updated, program sources in zip are downloaded from the url stored in database. After successfully downloading the zip file, it is extracted and sources are compiled.

After successful compilation, APAC execute the program for all the defined test vectors. Program is executed outside the main queue. When execution is done, test vectors outputs are updated to the latest execution outputs and updated flag is set to false.

As a next step, a job is created with parameters of submissionIds from request. Job is added to JobRepository, waiting for evaluation.

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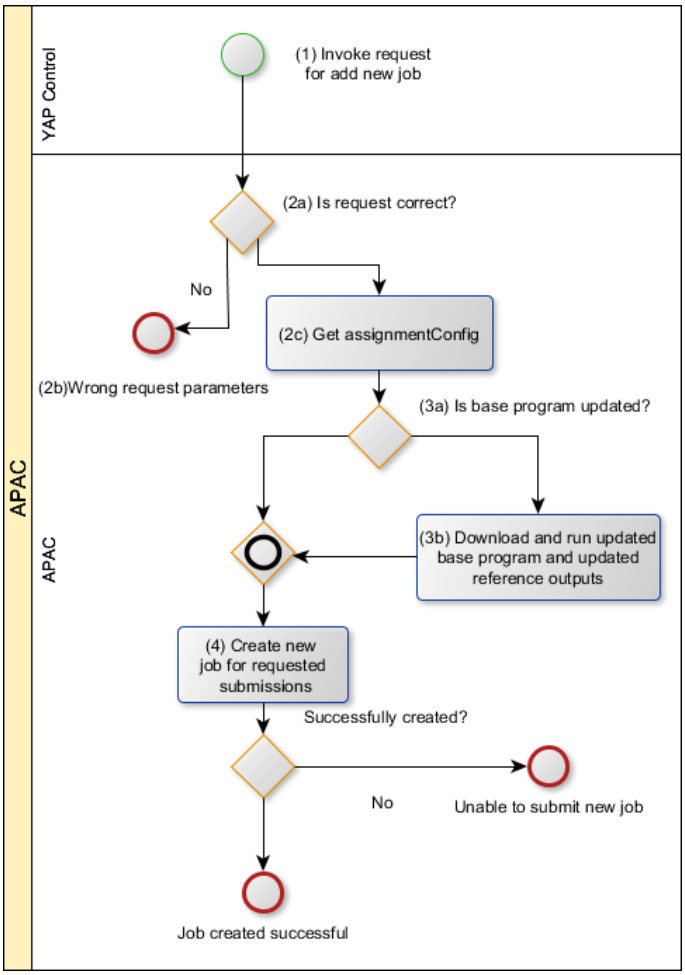

Fig. 9. Batch submission process overview

When a job gets to the top of the queue, AssignmentItemReader method readItem is invoked. Method readItem pulls out parameters of a job, which contains ids of submission and id of the assignment config. All needed data are fetched from the database. AssignmentItemReader creates an entity which is suitable for AssignmentItemProcessor. AssignmentItemProcessor contains all the required logic regarding the compilation and execution of students programs. Simplified compiling and execution process is illustrated in the Fig 10.

Process item starts by loading the zip file for the submission, which is copied from YAP working directory to APAC working directory and its name is defined by an id of the submission from Moodle.

If a zip file was found, UUID for the submission is generated. This UUID is a name for the submissions' temporary workspace. Found zip is extracted to this directory. Next step is a compilation of the source code. Compilation output is saved in all cases. If compilation was successful, execution process will be started.

Compilation uses external tools for each supported language. For C and CPP it is gcc, which internally choose C or CPP compiler. For Java ant compiler was used.

As a first step of the evaluation process is to get a free sandbox container. Container management is implemented as a simple pool. So if no container is available, current thread will be waiting on a semaphore.

Container Pool Management is implemented as a singleton. During initialization it checks how many containers are running. If this count is lower than the count defined in configuration file, new sandbox containers will be created.

Allocated container is then inspected. In Docker terms inspected means getting details about the container. List of containers and all other Docker management API is available via REST API. Java client to Docker REST API was created with Jersey library which provides a fluent API to fetch responses from RESTful services. Responses are in json format, so for deserialization the Gson library was used.

From these details an SSH connection properties are created. Because Docker and LXC generally do not provide easy access to run something inside the container, we used the SSH protocol for execution purposes. JSch was used as an SSH client.

Every Docker container has a private address and a container images built with our Dockerfile have also 22 port exposed. It is accessible from the host system but not from another location.

The submitted program is run for each test vector. Test vectors with arguments are stored as a json string, so it is deserialized and an execution command is built from the list of arguments.

Binary files and input files have to be transfer to the container. For this purpose the SCP protocol is used. If the files were transferred successfully, a command build by the Command Builder is executed inside the container. JSch provides an API for fetching the output from the commands' execution. This output is stored in a submission entity.

After processing all items in the batch, items are submitted to the AssignmentItemWriter. AssignmentItemWriter calculates the final score for each submission by comparing the output with the base programs' output. Outputs are compared per test vector and each test vector has defined maximum points. After calculation of final score results are written to database.

VI. Benefits

The resulting system will dramatically increase the quality of teaching and the quality of our IT graduates. The increase of quality of teaching is backed by the facts stated in the following paragraphs.

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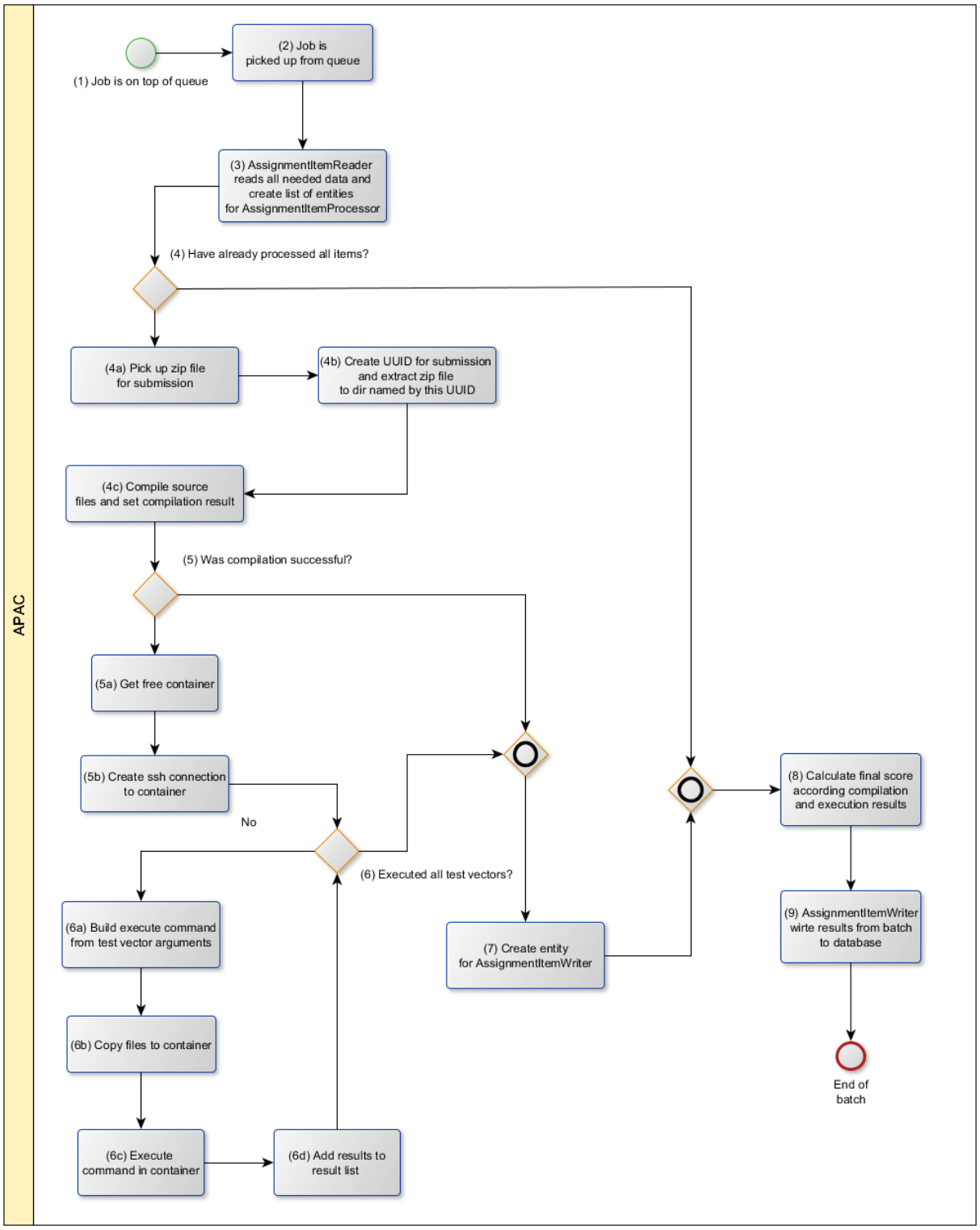

Fig. 10. A schema of submission processing

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Currently at FAI TBU, the teacher has to download each program submitted by students in Moodle, compile it and test it for various input data.

In courses that teach or use programming languages C, C++, Java, Pascal, PHP or Matlab, there are up to 250 students per course.

In each of these courses, students solve several (8, on average) assignments. If we assume 100 students per course on average (full-time and combined form students), then 100 x 7 [courses] x 8 [assignments] = 5600 submissions that teacher has to check. If checking one submission takes 5 minutes, the total time spent is 466 hours, which is almost 3 man-months. By automating this work, the teacher can spend the saved time consulting with students, making new study materials, etc.

Increased quality of absolvent's of the mentioned courses is given by the fact that the automatic system will make them create independently written and functionally correct programs. Currently, part of the students relies on the fact that:

- the teacher is not able to find plagiarism of a source code submitted long ago (e.g. a program submitted a year ago)
- the teacher does not have enough time to test the program with all possible inputs
- the teacher forgives submissions of only partially fulfilled assignments

By removing these factors, the student will learn to follow the assignment specification with care for details, exactly as it is required in real IT projects.

VII. Conclusion

The aim of this paper was to introduce a new system for automatic evaluation of correctness and originality of source codes. Solution for this project has two main outputs: new module for Moodle and APAC, a deployable application on a backend server. The new system is available on GitHub under GPLv3 license. Project page on GitHub currently contains three repositories: APAC, YAPMoodle and DockerClient. APAC and YAPMoodle have been already described in this paper. DockerClient is Java REST client extracted from APAC for control Docker API. Currently it supports only API which was used in APAC. GitHub project page can be found on:

https://github.com/apacrepo

Thanks to the GPLv3 license, the system can also be used for other learning institutes.

In this version, the whole system is dependent on Moodle database. In future versions, we plan to make APAC as a standalone system, which will contain also an anti-plagiarism subsystem based on NoSQL database. APAC will expose more robust API allowing connecting with more systems, not only Moodle. API for simplified support of other programming languages is also planned. The system is currently being used and improved in two programming courses on TBU.

(1) Acknowledgment

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The importance of school education in maintaining of local dialect - case study from the Czech Republic

Helena Kiliánová, Ivo Machar, Vilém Pechanec, Jan Brus, Olga Vránová

Abstract - The aim of research, the results of which are presented in this paper, was to determine the role of school education and current level of maintaining of the Haná dialect in primary school children. The research was conducted in 2012 using standard methods of educational investigation at primary schools in Náměšť na Hané and Horka nad Moravou, situated in the Haná ethnic region around Olomouc City (eastern part of the Czech Republic). Based on a questionnaire survey investigation method in combination with structured interviews, the research referred to a total of 492 respondents from both primary schools. Statistical evaluation of the presented research results showed that the traditional Haná dialect is unknown to and unused by most children living in the Haná villages (78.5 %) of today. With regard to the investigated sample of almost five hundred elementary school pupils, the trend resulting from the frequency histogram chart indicates that active use of the Haná dialect fades away with decreasing age of children. A statistically significant relationship was demonstrated between the use of the Haná dialect in children and their parents. Pursuant to the research results, it is thus very likely that education in family and the example set by parents is the main factor positively affecting the preservation of active knowledge of this folk dialect within the investigated group of children. The interpretation and conservation of traditional folk culture should be supported more significantly by schools as well, particularly through the inclusion of education related to the cultural and historical heritage into the school curricula.

Key words - Cultural-historical heritage, primary school, use of folk dialect by children.

I. Introduction

Haná is one of the most distinct ethnographic regions in the Czech Republic and its folk culture used to be exceptionally rich [1]. The Haná dialect constitutes an essential part of the region's non-material cultural heritage. Interference of different dialect groups often tends to form neutral, so-called general dialects [2], of which the general Haná dialect is an example. A paper [3] confirms a certain unification of the originally locally diversified Haná dialect into general Haná dialect and a decline in old local differences within the originally more colourful dialect.

The years ensuing 1989 marked a distinct restoration of efforts to preserve the Haná dialect. Recent years saw the publication of books written in the Haná dialect [4]. Despite these positive isolated events, most regional ethnographic scholars agree that the knowledge and active usage of the Haná dialect has slowly been dying out, particularly in the youngest generation. It is therefore teachers particularly, who are considered "guardians of the folk culture and dialect in Haná" and whose work with children is irreplaceable in this respect [5]. Scholarly papers dealing with the existing level of dialect knowledge in primary school pupils appear only sporadically [6].

The authors of this paper therefore incorporated the issue of primary school pupils and their relation to the Haná dialect into a more complex study focusing on the ways in which primary school pupils perceive the Haná landscape, conducted in 2012. This paper presents results of the study whose aim was to ascertain the present level of active usage of the Haná dialect by children who fall into the age category of primary school pupils.

II. Material and methods

The study was conducted in April 2012 and used standard methods of educational research according to [7] at primary schools (PS) in Náměšť na Hané and Horka nad Moravou located in the northwestern part of Haná in the vicinity of the town Olomouc. The municipality Náměšť na Hané has 1993 inhabitants and a total of 190 respondents participated in the research at the local PS. Pupils from Náměšť na Hané and the surrounding municipalities of Drahanovice, Lhota pod Kosířem, Kníničky, Střížov, Ludéřov and Olbramice attend the school. The municipality of Horka nad Moravou has 2300 inhabitants and 302 respondents from its PS participated in the study. The school is attended by local children as well as children from the municipalities of Skrbeň and Chomoutov.

To achieve maximum research objectivity, a minimum number of pupils representing a sufficiently representative sample of studied respondents had to be estimated. The estimate used the nominal data research method represented by the formula:

$$n = \frac{t_\alpha^2 . p.(1-p)}{d^2} \qquad (1)$$

where n is the required sample, t_α is the reliability coefficient α for the selected level of significance, p is estimated relative frequency of the studied attribute and d is the required relative accuracy ranging between 3 – 4% (i.e. 0.03 – 0.04). Upon p = 0.1 (i.e. 10% based on personal experience of the authors), the calculation yields the number 216. To conduct the survey with 95% reliability and the usual 4% accuracy level, a statistical sample of a minimum 216 respondents was necessary. A total of 492 respondents from both primary schools were used, which is more than double the minimum required number of respondents necessary to ensure statistical data validity.

A close-ended question method was used in the questionnaire survey conducted among second stage primary school pupils (6^{th} – 9^{th} grade). The key advantage of close-ended

questionnaires is the simple statistical analysis of data obtained, as respondents' answers do not stray from the designed questions. Upon consulting teachers of both schools, a structured interview method was employed among first stage primary pupils (1^{st} – 5^{th} grades), who were interviewed by their own teachers. This method is comparable with the questionnaire method and at the same time provides young children with the maximum degree of comfort when answering questions asked by a well-known teacher, which generally does not distort the obtained data much.

To determine the reliability degree of the questionnaire data obtained, a comparison of data obtained from two equal samples, formed from the basic sample as a representative selection, was conducted. The concordance rate between respondent responses in both randomly generated samples was expressed using Cohen's coefficient:

$$\kappa = \frac{p_p - p_0}{1 - p_0} \quad (2)$$

where κ is the Cohen's coefficient, p_p is the observed concordance rate and p_o is the expected concordance rate. Statistical significance of the calculated coefficient κ was calculated by standardized normal variable using a criterion according to the following formula:

$$u = \frac{\kappa}{\sqrt{\frac{p_0}{n.(1 - p_p)}}} \quad (3)$$

where u is the value of the standardized normal variable and the remaining symbols correspond to those in formula (2).

When comparing the results obtained from the respondents from both schools, the data was statistically analyzed using a two-sample *t*-test in Minitab program, version 15.1.1. Normal distribution of the set was assessed visually using a data distribution diagram.

Chi-square [8] determined possible dependency between the collected nominal data, always between the "active usage of the Haná dialect" phenomenon and selected phenomena which may influence the knowledge of dialect in children. Reliability testing of the null hypothesis was conducted at significance level α = 0.05. The chi-square criterion was calculated using the following formula:

$$\chi^2 = \frac{(P - O)^2}{O} \quad (4)$$

where P is the relevant field of the contingency table and O is the value of expected frequency. The calculated chi-square value is an indicator of the difference between reality and the formulated null hypothesis. To assess it, the number of degrees of freedom in the table must be determined according to the following relation:

$f = (r\text{-}1).(s\text{-}1)$ (5)

where r is the number of rows and s is the number of columns in the table. For the calculated number of degrees of freedom we compare the calculated value of test criterion with its critical value as expressed in statistical tables.

III. Results

The calculated value of Cohen's coefficient 0.813 for the obtained survey results may be considered satisfactory with respect to a concordance between the randomly selected respondents and with respect to the reliability of the research methods applied. Standardized normal variable of 6.21 upon significance level of 0.01 is higher than the critical value (2.58) for the two-way test. It may be stated that the calculated coefficient indicates a statistically significant concordance between respondent replies in the conducted survey and structured interviews. Analysis of the obtained first degree classification research data provided data for clear graphic data depictions (Figures 1 and 2).

The relationship between the respondents' age category and their knowledge of the Haná dialect is apparent in the frequency histogram of the studied attribute "active usage of the Haná dialect" (Fig. 1). The trend indicated in the graph (although not a correlational relationship) shows that active usage of the Haná dialect diminishes with decreasing child age in the studied sample of nearly 500 primary children. With respect to the ongoing efforts to retain the living dialect in rural society, this information is far from positive. A tentative assessment of variability (and thus the informative value of the information) using nominal analysis of variance, the results range within the interval from zero to 0.74, which is a relatively high variability, probably due to the considerable range of age categories in the studied respondent set.

Assessment of differences in the data obtained in both schools using the *t*-test did not prove a statistically significant difference between data from both schools (calculated value of $T = 1.24$, critical table value $P = 2.006$, significance level $\alpha = 0.05$). It may be concluded that 21.5 % of children in the studied population sample of 492 rural school children in the Haná region use the Haná dialect actively at present. Most children in the studied representative set (78.5%) do not use the dialect actively – see Fig. 2.

In the course of interpretation of second degree classification data, the chi-square between active usage of the Haná dialect and (1) the sex of respondents, (2) education of respondents' parents and (3) parent usage of the Haná dialect was tested for the contingency table of data obtained by the survey and structured interviews. The conducted tests revealed that active usage of the Haná dialect in children is not statistically significantly dependent on the first two factors. The sex of respondents and the education of their parents (primary, secondary and tertiary education categories) are not statistically related to the dialect usage in children. Only assessment of the relationship between Haná dialect usage by children (on one hand) and by their parents (on the other hand) revealed that the calculated value of the tested criterion chi-square $\chi^2 = 6{,}614$ was higher than the critical value (5.991). A statistically significant dependence was thus documented only between the usage of the Haná dialect by children and their parents. This finding is supported by the most frequent choice of answer to the question "Where do you speak the Haná dialect most often?", which was answered "At home with family" by 94% of respondents familiar with the dialect.

IV. Discussion

The farmer class in Haná region became extinct primarily during the forced agricultural collectivization in 1948-1960 [9]. The traditional, generally deep piousness of the Haná people has been preserved in the landscape memory in the form of numerous historical landscape structures [10].

The cultural heritage which generations of our ancestors left us contains an immense potential for future development. Imbuing children with a positive relationship to their cultural heritage is vital for a healthy development of a knowledge society, as long-term experience with educational projects shows [11]. Education which encourages a positive relationship to the cultural and historical heritage should inspire primary school pupils in their formative years with a keen interest in the environment in which they live (municipality, region) and make them aware of its cultural, historical and natural values. This may precondition children to become adults who perceive their home landscape and the folk culture traditions as valuable assets which must be actively protected, cultivated and developed [12].

Some primary schools in the Czech Republic have implemented a number of pilot projects presenting our cultural and historical heritage under a project of the Faculty of Education of Charles University in Prague. This project [13] aimed to establish a new interdisciplinary topic of "Educating Towards Appreciating Cultural and Historical Heritage".

The education process should stress the importance of the cultural and historical heritage at the local level, as it is the context of their residency (municipality) where the most intense relations to places and people may be formed in children [14]. On the contrary, a loss of the youngest generation's relationship to home landscape and of their awareness of the local cultural and historical heritage leads to a gradual devastation of historical elements in the landscape as well as to a moral devastation as such [15].

In this context it is highly significant that in the past it was the role of primary school teachers to maintain people's awareness of their cultural and historical heritage. These efforts on the part of Czech teachers may be traced back to the late 19th century. The Ethnographic Czech-Slavic Exposition organized in Prague in 1895 inspired wide-spread efforts to document and collect folk spiritual and material mementos [16]. Within the ethnographic region of Haná, which is the focus of this paper, village school teachers and secondary school professors became actively involved in the collection and presentation of folk culture artefacts in the form of so-called regional unions and exhibitions already in the 1880s. Teachers played an important role in the establishment of national history museums in the Haná region – e.g. Jan Havelka, professor at the Slavic Grammar School in Olomouc [17].

Statistical assessment of results of the presented research revealed that most children living in Haná villages (78.5 %) are not familiar with the traditional Haná dialect and do not use it. It is interesting to note that 21 % of these children have parents, of whom at least one speaks the dialect. It would be a suitable topic of further research to try to analyze reasons which motivate the parents' decision not to speak the Haná dialect when communicating with their children at home.

Children who use the Haná dialect actively represent a minority and tend to use the dialect mostly in communication with their parents and siblings at home. Needless to say that most children – active Haná dialect users – do not speak a "pure" form of the traditional dialect of Haná farmers, as was used in the first half of the 20th century, but rather a spoken and heavily modified form of standard Czech in which dialectic elements are widely applied [18].

It is therefore more than probable that family upbringing and parental example represent the key factors which positively influence retention of active usage of the Haná dialect in the studied sample of children. The presented research was not sufficiently extensive enough to allow us to identify unambiguous and statistically significant development trends in active usage of the Haná dialect in the entire ethnographic region of Haná. It cannot be ruled out that the belief held by most seniors living in Haná villages [19] that the Haná dialect is quickly disappearing may unfortunately be nearing the truth.

V. Conclusion

As results of the presented research indicate, the key role in retaining the knowledge of the Haná dialect in children is played by families. The question arises whether school education has a realistic change in influencing the situation. The fact remains that teachers, who would offer children activities related to traditional folk culture in the course of curricular and extracurricular educational activities, are rarely encountered. It is obvious that the times of agrarian country, as known in the early 20th century [20], are long gone. Knowledge society which is built on modern technologies stresses different priorities in school education other than the knowledge of a traditional folk culture. Nevertheless, traditional folk culture formed the lives of a vast majority of our ancestors. Education focusing on knowledge and the understanding of traditional folk culture is therefore education enabling people to understand their very own past.

Acknowledgement

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FIGURES:

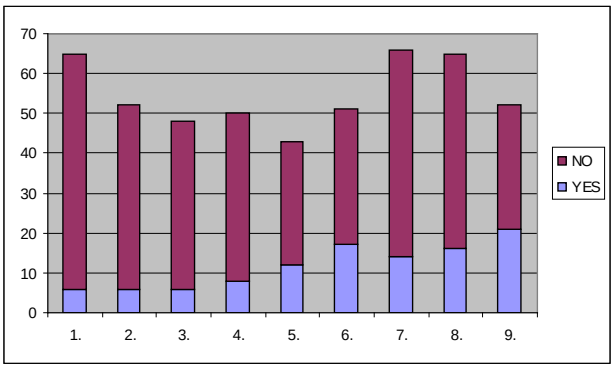


Fig. 1: Frequency histogram – active usage of the Haná dialect by primary children (vertical axis – absolute number of respondents; horizontal axis – primary school classes; column YES – respondents who are familiar with the Haná dialect and use it actively; column NO – respondents who do not speak the Haná dialect)

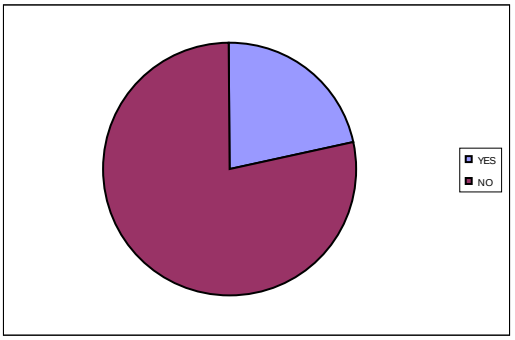


Fig. 2: Relative representation of the number of children in the studied respondent sample (n=492) who use the Haná dialect actively (sector YES) and those who do not speak the Haná dialect (sector NO)

Comparison of the Communication Skills of Students and Managers

J. Vrchota, J. Kubecová

***Abstract*—** This article aims to compare the level of communication skills between managers and university students in the bachelor and master program. The issue was investigated in a sample to sample 221 managers and 376 university students. Communication is seen as one of the key managerial competencies crucial to the success or failure of the manager. In the research, two samples were tested by using Wilcoxon test. At significance level 0.05 it was not statistically demonstrated that both groups were different. This contribution was supported by GA JU 079/2013S.

***Keywords*—**competence, communication, manager, student

I. Introduction

COMMUNICATION is an activity carried out by the majority of executives and managers more than 80% working time (Wiemann, 1980). Through the right communication are set tasks, is used to motivate, to inform, it provides feedback, praises, evaluates and also contributes to the achievement of the objectives set (Monge, 1992; Savignon, 1985). The communication is very fragile, may be affected by participants of conversation, the overall milieu, the context, but especially corporate culture and conditions, which are formed by the organization. Communication can be described as a basic social human need and like any human needs it can be a source of motivation, but also frustration, if it is not possible to satisfy this need. In the business world, communication has always had to provide information based on which we are willing, whether consciously or unconsciously, to modify our emotions and our opinions (Randhawa, 2007). This is also true for communication inside organizations. Inside the organization, communication permeates corporate behaviour, information systems, strategies and styles of leadership and management (Woodrufe, 1990).

In this article, communication is seen as one of the key managerial competencies (McGaghie 1991, Belz, 2001), the competencies are understood as the ability to pursue a particular activity or work (Kubeš, 2004). For example, according to the Armstrong (1999) definition, competences are the basic skills, capabilities necessary for the good performance, work and this definition is very similar to the definition of C. K.Prahald a G. Hamel (1994). These authors see the competence as everything that is required of the humans to be able to effectively perform position or role emphasizing above standard performance.

Very important part of communication is feedback, which should be preferentially used many times in everyday tasks and reminders (Plamínek, 2005). It always depends on the supervisor and staff member whether the communication will have the desired effect or not. In these cases it is very useful to base the communication on open questions and not to be afraid to ask for other people´s opinions. But for a manager, it is necessary to learn to assess communication according to the effect not only according to the response. These conclusions published Troth (2012) as the main reason for contributing to the team´s development.

In organizations, there are two types of communication - formal and informal. The second one is used by the head of a small team and it is more about the views of other team´s members and about teamwork. In contrast, formal communication is applied in larger organizations where managers normally do not come into the contact with all staff. Communication is also constrained by different standards and rules that are set up for information processes and systems. For all multinational companies fast and clear communication means key role, managers have to deal mainly with language and cultural barriers many times caused by different geographical locations. And all of these aspects act against fast and effective decision-making, which is necessary in today's global world.

II. Methodology

The aim of this paper is to statistically verify the assumption that managers achieve the same or higher level of communication compared to students, is correct. Communication within the framework of research is to understand not only the ability to convey specific information, either verbally or non-verbally, but there is also taken into consideration ability to take information and actively listen and other aspects that were considered in the questionnaire survey where respondents were tested by questions. The survey is focused on the larger spectrum of competencies (performance, cooperation, decision making, responsibility, independence, and others) minimum 8 questions were directed to each competency (allegations) that were under test jumbled to avoid prejudging the outcomes. The degree of concurring opinion with individual allegations in the questionnaire was assessed by using a five-point scale. The questions in the questionnaire were formulated based on the recommendations of practitioners and even then adjusted according to the results of the pilot. Both groups (managers and students) were submitted

to identical questionnaires in order to access the results consistently. Communication is evaluated on the basis of questions aimed at the skills: to summarize and to convey important information, the ability to estimate an appropriate method of communication and a willingness to communicate, as indicated Poon (1991).

In context of the calculation null hypothesis was formulated that the competences of managers and students agree on the analysed data and the alternative hypothesis was that the competences of managers achieve higher performance level than the students' competences. Getting Data was carried out in the context of dissertation study from 221 managers through a questionnaire survey with the participation of the South Bohemian Chamber and CzechInvest, followed by 376 university students. Data was tested using a Wilcoxon test (Freund 2010, Friedrich 2010) and its variant. This is a two-sided non-parametric test, which is mostly used when it is not satisfactory assumption of normality of data. As the moderate breach of normality for samples larger than 30 does not have a major impact on the results.

Let the X_1, ..., X_n a Y_1, ..., Y_m are two independent random samples from two continuous distribution whose distribution function may differ only by moving. $x_{0.50}$ a $y_{0.50}$ are labeled as the median of the first and the second layout. It is always tested the hypothesis that the distribution function of both layouts are identical, in other words, that the medians are equal. In contrast of alternative that the first of the medians $x_{0.50}$ of managers is higher than the second one. (Budíková 2010, Freund 2010, Friedrich 2010)

$H_0 = x_{0.50} - y_{0.50} = 0$ *against* $H_A = x_{0.50} > y_{0.50}$ (Friedrich 2010)

In the first phase, all the (n + m) values X_1, ..., X_n and Y_1, ..., Y_m are arranged in ascending order of size. As the whole process of test takes place electronically using statistics software Statistika ver. 10, this step is not written in the contribution because it is only a lapidary operation.

Furthermore the total order of values X_1, ..., X_n are detected and indicated as T_1. The sum of values in order of students Y_1, ..., Y_m is indicated T_2.

The next step is to calculate the test statistics for U_1 and U_2, while it is still true that $U_1 + U_2 = mn$ (Friedrich 2010)

$$U_1 = mn\frac{n(n+1)}{2} - T_1 \text{ , } U_2 = mn\frac{m(m+1)}{2} - T_2$$ (Friedrich 2010).

If it is true that statistics $\min\{U_1, U_2\} \geq$ preformed critical value for the selected range of both selections and chosen level of significance, then the null hypothesis about the identity of the compared groups reject on the significance level $\alpha = 0.05$. *As* for both samples in all tested cases it is applied, that *n, m* are higher than 30, it is approached to the asymptotic variant of Wilcoxon test (Mann-Whitney test), which is used for *n and m* larger than thirty. Where $U'_1 = \min\{U_1, U_2\}$. (Budíková 2010, Wonnacot 1995)

$$U_0 \frac{U'_1 - \frac{mn}{2}}{\sqrt{\frac{mn(m+n+1)}{12}}}$$ (Friedrich 2010)

Critical values for right field alternative W= $<k_2, n>$ non-negative values k_1 and k_2 are accurately given in the literature. Reject H_0 on significance level α if $U_0 \in W$ (Freund 2010, Friedrich 2010).

III. Results

Using Wilcoxon test (Mann-Whitney U test) on the chosen significance level $\alpha = 0.05$, where *X = the communication skills of managers* and *Y = communication skills of students* are tested hypotheses: $H_0 = x_{0,50} - y_{0,50} = 0$, $H_A = x_{0,50} > y_{0,50}$. Results of the test in program Statistika are logged in Table 1.

Tab 1: Mann-Whitneyův U test

	The Sum of the Managers	The Sum of the Students	U	Z	p-value
Communication	2419038	3994534	1450894	1.478496	0.139276

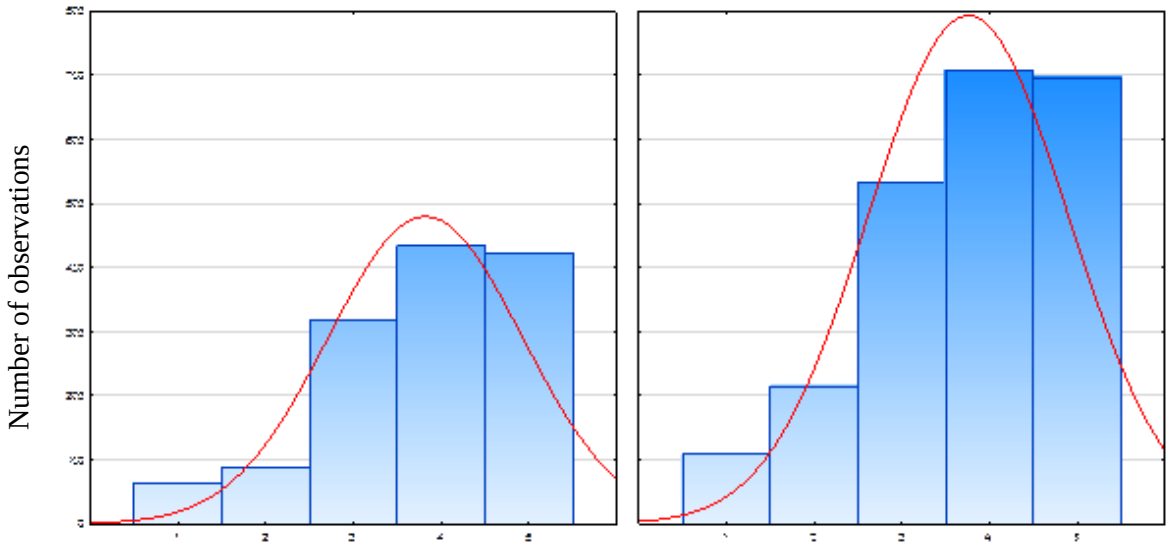
Source: authors

0.1393 > 0.05

p-value > α

The final p-value is higher than α so it could not be on the basis of the data reject the null hypothesis at a significance level 0.05. The test results are also demonstrated in Figure 1, where it is clear that the top of both curves is identical in the area 3.5 points. The test results are also demonstrated in Figure 1, where it is clear that the top of both curves is identical in the area 3.5 points. In the right part of the graph there is shown curve of students and in the left part there is the curve of managers.

Figure 1: Communication curves



Source: authors

IV. Disscusion and Conclusion

According to the findings in the scientific literature, it has not been compares the communication skills of university students with managers yet. However, it can be assumed from the study of Wiemann 1980, where the significant differences on the level of communication skills between university student and working people were detected. These results are in contrast to this research, where different levels of students and managers with regard to communication skills could not be demonstrated. It should be noted that almost 30-year-old research was focused solely on verbal communication. Other studies have already only compared the level of communication between different groups, such as Ghoshal (1991), which attempted to general measure the level of communication skills of managers in the international organizations. He came to the conclusion that there are some differences between the heads of individual departments (not with respect to age and education - as he expected), mainly with regard to willingness to communicate. Employees working in finance achieve the lowest level of willingness to communicate, which largely justifies their introverted character. Other studies in this area of research are carried out on students in 2001 by Donald (2001), the students were compared with each other within the individual years of study. Slight increasing communication skills were presented depending on the year of study. These results of Donald (2001) are in accordance with marginal findings of this research. A similar survey was carried out by Sandeen (1968), but the evaluation of the level of communication is always specific and therefore there is the level of communication between these studies incomparable.

Communication skills will continue to play a very important role in the management and leadership of staff, where they will be an integral part of the motivation techniques, control and information. This interdependence of communication skill with the performance of management functions was describe by Luis Garicano and Yanhui Wu (2012), or Koubek (2003), they understand the communication skills at the forefront of management performance factor. The results show a very good student preparation of business high school for leading positions with regard to the communication skills.

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