

Automatic acquisition, processing and analysis of data system, using the AHP multi-criteria method

Sorin Borza, Carmen Simion,

¹**Abstract**—In this paper, an automatic system of taking over the data of the environment and their automatic transformation in GIS Data, for some intelligent map's generation, is presented. Also, the system allows, by using the multi-criteria method AHP, an objective analysis of the factors that will be taken into account during the system. These factors will be taken over automatically by using the LabVIEW Software and with the help of the acquisition board that will be connected to the computer. By using the same LabVIEW software, the factors will be memorised in an ACCESS type database. The database will be connected to the Geomedia Professional Software, with the help of which an intelligent map will be generated automatically. The system allows, not only the automatic collection of data, but also their memorization and the generation of GIS elements and an objective analysis of the collecting points of data could provide a concrete answer regarding the most and least polluted points. As a novelty element, the paper allows the analysis of the polluted factors using the multi-criteria AHP method in such automatic taking-over storage and data generation system. Also, in this paper, an economic analysis of the used system will be made. In the first part of the paper, the general aspects of the paper will be presented. In the second part, the object oriented technics of the realization of the virtual apparatus and of the data transfer in the Access database. In the third part of the paper, the AHP method will be presented. The fourth part will present the physical realization of the module system of automatic taking over data, the analysis of the polluting factors taking account the AHP method, the automatic generation of the object-oriented classes needed for the elaboration of the intelligent maps.

Keywords— databases, virtual instrument, object oriented, GIS.

I. INTRODUCTION

The development of human society has led to a negative anthropic and technogenic impact on the air quality, resulting in a significant series of adverse effects on human health, flora, fauna and ecosystems in general. In urban areas, the environmental dimension, the economic and the social one interfere the most [7].

F. A. Sorin Borza *Faculty of Engineering, Sibiu University "Lucian Blaga", 10, Victoriei Bd, Sibiu, 550024, România* (e-mail: sorin.borza@ulbsibiu.ro).

S. B. Carmen Simion . *Faculty of Engineering, Sibiu University "Lucian Blaga", 10, Victoriei Bd, Sibiu, 550024, România* (e-mail: carmen.simion@ulbsibiu.ro).

Four out of five European citizens live in urban areas and their quality of life is directly influenced by the state of the urban environment. A high quality of the urban area also contributes to reaching the priority of the revised Lisbon strategy, which is „to make Europe a more attractive place to live and invest”. The attractiveness of the European cities will enhance growth potential and also job generation, and therefore cities will be key factors for the implementation of the Lisbon Agenda. In the case of urban habitats, transportation is “guilty” for more than 50% of NO_x, particles (PM) and volatile organic compounds (VOCs), over 25% of CO₂ emissions and 80% of the noise level.

The U.S. Environmental Protection Agency's (EPA) Clean Power Plan, proposed in June 2014, would limit carbon pollution from existing power plants [8].

Vehicular air pollution has been recognized as a major anthropogenic activity responsible for deteriorating air quality in urban areas. One of the major traffic related air pollutants which have serious health effects is carbon monoxide (CO). One of the major components of traffic related air pollution is carbon monoxide (CO) that results from the incomplete combustion of fuel. CO does not participate in secondary atmospheric reactions but has approximately 210 times more affinity for the hemoglobin (Hb) than oxygen (O₂). Carbon monoxide enters the bloodstream through lungs and form Carboxy hemoglobin (COHb), a compound that inhibit blood capacity to carry oxygen to organs and tissues. Though studies have ruled out any possibility of detectable increase of genetic damage in blood cells due to moderate air pollution levels [9].

The automatic taking over and the analysis of the data using the AHP method (Analytic Hierarchy Process) and of generating the element's classes necessary to elaborate the intelligent maps consists of hardware components: sensors of the acquisition board, apparatus used for measuring the polluting factors and also, of software elements, like: LabVIEW, Geomedia Professional, Access Database, figure 1.

The data will be taken over, with the help of the sensors or with the help of the specific apparatus which will be connected to the computer. In the case in which the data will be taken over by the help of the sensors, the IEPE (Integrated Electronic Piezoelectric) sensors were used, the acquisition board NI 9234, NI Mseries. In the case in which the taken over data by the specialized apparatus, the Drager Pac III apparatus has been used for the measurement of the monoxide carbon

and the sound level meter EXTECH 407780 for the sound measurement. The Drager Pac III apparatus is equipped with a sensor for the concentration measurement of the monoxide carbon. The values showed on the display apparatus are represented in parts on a million (ppm), these values must be multiplied with 1,16, and the resulted value represented in mg/m^3 . The virtual apparatus will be made using the compute, by the help of the LabVIEW software. The multi-criteria analysis will be realized by a virtual apparatus. Another part (branch) of the system will allow the data memorization in the ACCESS database for their following use in the class generation process (features classes) used for the elaboration of the intelligent maps.

II. OBJECT ORIENTED PROGRAMMING IN LABVIEW

In object oriented programming with LabVIEW [5], a class consists merely of a user defined data type together with methods that can be applied to values of that data type. Once could say that object oriented programming in Labview allows the developer to create object oriented wires. Object orientation in Labview means the following:

1. Simple Inheritance. Neither multiple inheritance nor interfaces as in Java.
2. Strict encapsulation. Data of a class are always private. Public or protected data do not exist.

As in other object oriented languages, a derived class may overload an abstract method of its base class. However, the override method must have exactly the same input and output parameters as the respective method of the parent class.

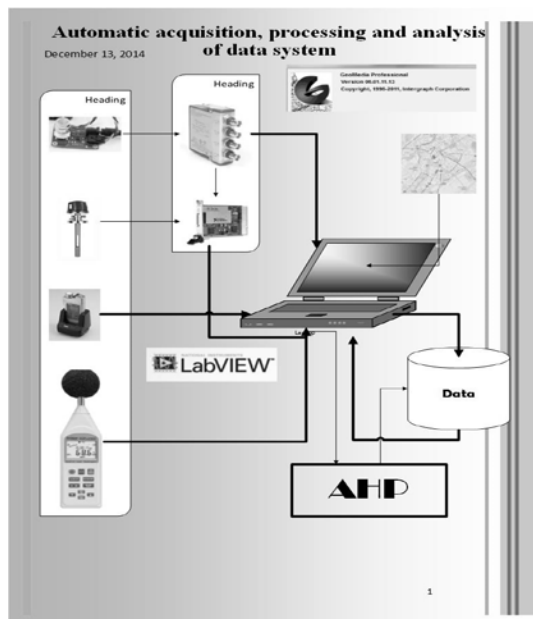


Fig. 1 The System presented in this paper

In object oriented programming for Labview [6] are three fundamental consequences.

1. Objects contain only data and no active code. Agents do not exist.

2. Labview does not have classical variables. For the same reason, in Labview has no equivalence to the concept of a *constructor* and a *destructor*. There are neither constructors nor destructors.

3. Objects can only be accessed "by value" and never "by reference".

The fundamental differences between object programming in Labview and conventional object oriented languages prevent a straightforward *implementation* of design patterns that are based on the idea of objects as entities. However, many of those design patterns are useful for designing control systems.

III. ANALYTICAL HIERARCHY PROCESS (AHP) METHOD

Analytic Hierarchy Process (AHP) is used for decision making when a decision (choice of some of the available alternatives, or their ranking) is based on several attributes that represent criteria [1]. Solving complex decision problems using AHP method is based on their decomposition in a hierarchical structure whose elements are goal (objective), criteria (sub-criteria) and alternatives. An important component of the AHP method is a mathematical model by which priorities of elements are calculated (weighted), for elements that are on the same level hierarchical structure. AHP was successfully used in environmental impact assessment for determining of weights for impact categories in paper [3]. In paper [4] AHP was used for verification of results gained by quantification of environmental aspects and impacts.

Summary of AHP method consists of converting subjective assessments to the relative importance of the criteria scores and weights. The method, developed by Saaty [1] proved to be the most common form of multi-criteria analysis. AHP input data are answers to questions such as "How important is criterion A relative to criterion B?". This results are compared in pairs, resulting are in scores and weights. For each pair of criteria required comparing the importance of the two, associating a score as follows (Table 1):

TABLE 1 PAIR OF CRITERIA

Definition	Intensity of importance
Equally important	1
Moderately more important	3
Strongly more important	5
Very strongly more important	7
Extremely more important	9
Intermediate values	2,4,6,8

Numbered intermediate values can be used to define nuances among the five basic formulation. Of course, if it is considered that B is very strongly more important than A, when the opposite is true, so A is assigned the value of 1/7 compared to B. Therefore, since it is assumed that judgments

are consistent with respect to all pairs and all the criteria are "equally important" to themselves, the total number of evaluations will be:

$$\frac{1}{2} \times n \times (n - 1)$$

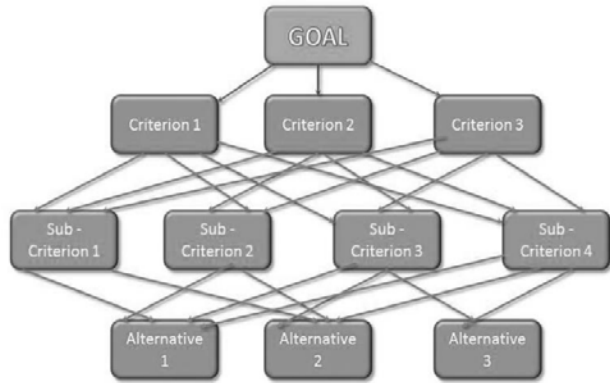


Fig. 2 General hierarchical model in AHP

Application of AHP method can be explained in four steps:

1. Setting a hierarchical model of decision problems in order with goal on the top criteria and subcriteria at lower levels, and alternatives at the bottom of the model (Fig. 1);
2. At each level of hierarchical structure each elements of the structure are compared in pairs, whereby the decision makers express their preferences with the help of appropriate scale which has 5 degrees and 4 sub-degrees of verbally described intensities and the corresponding numerical values for them in the range from 1 to 9 (Table 1);
3. Local priorities (weights) of criteria, sub-criteria and alternatives at same hierarchical structure level are calculated through appropriate mathematical model and afterwards they are synthesized in total priorities of alternatives;
4. Implementation of the sensitivity analysis for final decisions.

The matrix A has special features (all of it's rows are proportional to the first row, and they are all positive and $a_{ij} = 1/a_{ji}$ is true) and because of that only one of it's eigenvalue differs from 0 and is equal to n .

If the matrix A contains inconsistent estimates (in practical examples almost always), weight vector w can be obtained by solving the equation $(A - \lambda_{max} I)w = 0$ with prerequisite that $\sum w_i = 1$, where λ_{max} is the largest eigenvalue in matrix A . Because of matrix A properties $\lambda_{max} \geq n$, the difference $\lambda_{max} - n$ is used in measuring consistency. With consistency index $CI = (\lambda_{max} - n)/(n-1)$ measure of consistency can be calculated:

$$CR = CI/RI$$

$$A = \begin{bmatrix} 1 & a_{12} & \dots & a_{1j} \\ a_{21} & 1 & \dots & a_{2j} \\ \vdots & \vdots & \ddots & \vdots \\ a_{i1} & a_{i2} & \dots & a_{ij} \end{bmatrix}$$

Fig. 3 Matrix A

The next step is to determine the set of weights that are most consistent with the estimates of the relative importance of the criteria. This can be done in several ways. In the method developed by Saaty [2], the calculation of the weights is based on a relatively complex mathematical apparatus, using matrix algebra tools. The results are values associated to eigenvector of maximum eigenvalue matrix.

The calculations are quite complex, so it is necessary to use a dedicated program.

But in practice, we provide a simple method of calculation, which gives the same result with two decimal places:

- Calculate the geometric mean of each row of the matrix.
- It calculates the sum of the geometric mean.
- Normalized geometric mean.

IV. RESULTS AND DISCUSSION

The system allows both measurements using dedicated equipment, and with the help of sensors and acquisition board. Measurements can be performed with the help of the mobile laboratory.

Monitoring points were established to evaluate the impact of road traffic on environment and implicitly on people.

By example, in the system, concentration measurements of carbon monoxide can be achieved using MG-811 sensor. Also this sensor is good for measurement CO concentration. This is an onboard signal conditioning circuit for amplifying output signal and an onboard heating circuit for heating the sensor. The MG-811 sensor is basically a cell which gives an output in the range of 100-600mV (400—10000ppm CO₂). The LMC662 is used as the amplifier because of its ultra-high input impedance. According to the datasheet of MG-811, this sensor require an input impedance of 100-1000Gohm. This sensor need one analog input and one digital for connect the sensor to Arduino Mega Microcomputer. The Arduino Mega is a microcontroller board based on the ATmega1280. It has 54 digital input/output pins (of which 14 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started.

The block schema is presented in figure 4.

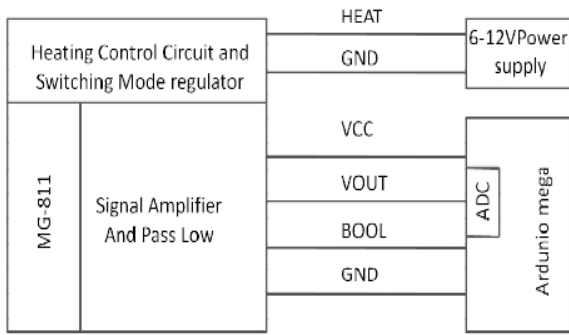


Fig. 4 The block schema of connection, sensor to microcontroller

The data obtained through hardware presented will be analyzed in Labview software. This permitted:

- Easy used Arduino digital input/output, analog input, I2C, and Serial Peripheral;
- Interface from LabVIEW;
- I/O engine sketch to load on Arduino;
- Communication wireless via XBee or Bluetooth;
- Loop rates: USB tethered (200 Hz) and wireless (25 Hz);
- IDE arduino sketch and LABVIEW toolkit VIs help to specification functionality.

The panel of this virtual instrument is shown in figure 5.

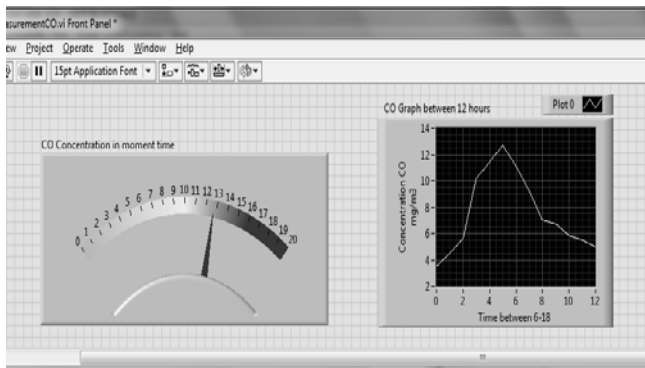


Fig. 5 The panel of CO concentration part of the system of automatic acquisition, processing and analyze data

Furthermore, we will present one of the most important parts of the automatic acquisition, processing and analysis of environment data system, which is the analysis of the AHP multi-criteria method implemented within the system. The virtual instrument created in this system is based on objected-oriented programming. The input data is processed by using the LabVIEW functions. With the help of these functions the data is memorised in a database, in order to be further used in the realization of the objected classes for the generation of the intelligent maps of the Geomedia Professional Software.

The system allows measurements for the diverse polluting chemical factors, like: NO_x, PM10 dust and ozone.

The multi-criteria analysis that we will further present it is based on real measurements of the NO_x, PM10 dust and ozone made in 4 different points from Sibiu: Union square, Alba-Iulia street, DN 1 306 km and the Sub Arini park.

The virtual apparatus projected for the realization of the

multi-criteria analysis works as follows:

- A subjective appreciation of the importance of each point stated above is made depending on the number of vehicles, number of people that are found in that concrete point at a certain time. The comparison matrix of pairs is realized, the weight of each observation point is calculated, the priority vector Lambda, CR and CI are being calculated. The block diagram are presented in figure 6.

- Depending on the measurements made for each of the polluting factors, the virtual apparatus will calculate the weight of each polluting factor from the observation points taken into account, figure 7.

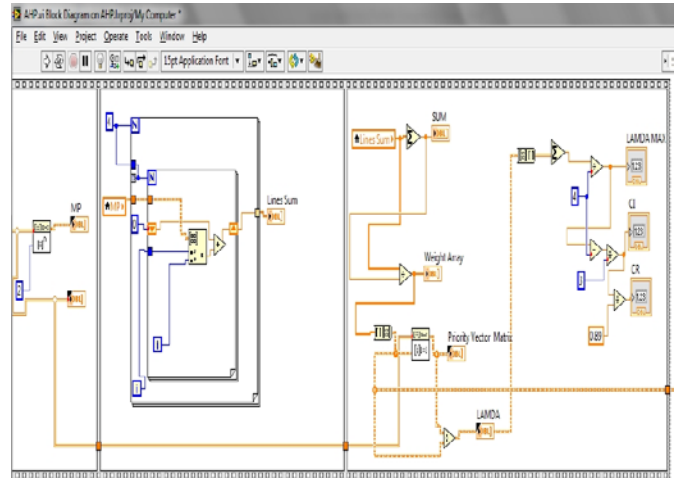


Fig. 6 The diagram of VI for measurement points in AHP analysis

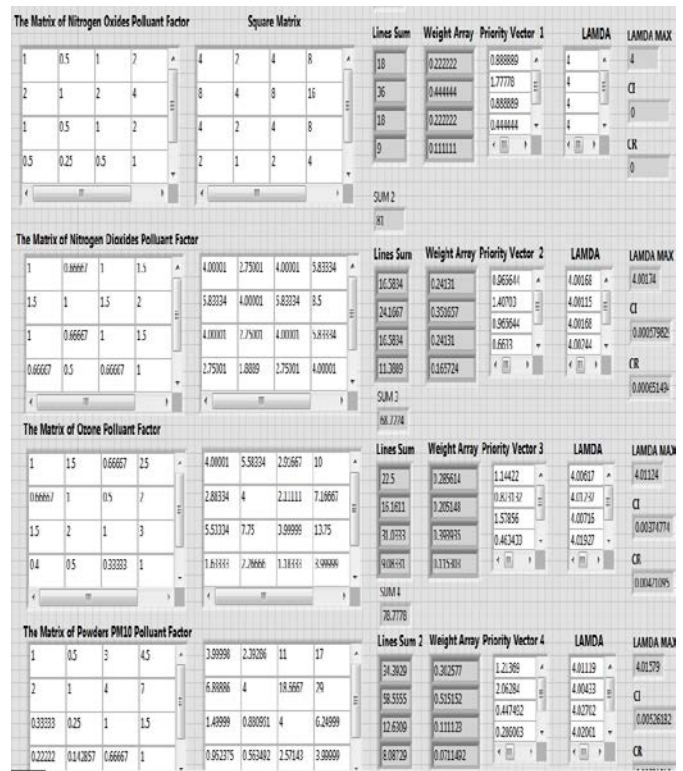


Fig. 7 The panel of VI for all pollutant factors

- Finally, the matrix of polluting factors is obtained. This

will be multiplied with the observation point's weights matrix. The virtual apparatus allows the determination of the most and least polluted observation point, depending on the subjective appreciation made upon them and also, depending on the weight that each polluting factor has in the observation points. The final results are presented in figure 8.

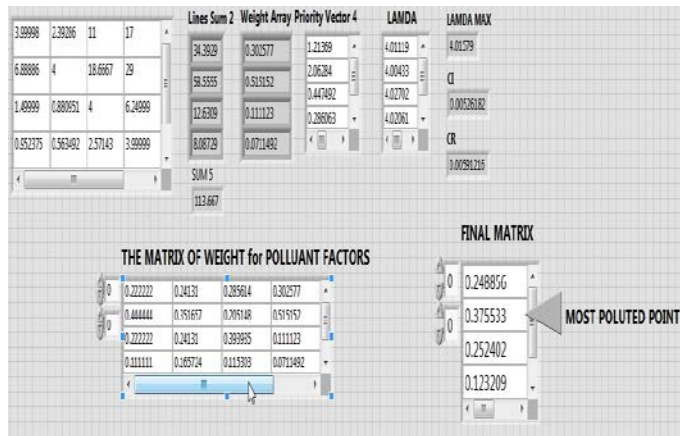


Fig. 8 The matrix of weght for pollutant factors and final matrix with results

For the presented example we can observe that the most polluted point is DN 1 306 km, followed by Alba Iulia street, Unirii Square and, as expected, Sub Arini park.

The presented system allows the automatic memorization of data measured and processed in ACCESS database. This is very important for the GIS Maps generation. The ACCESS table in which the data is saved is in this way projected, as for it to hold the specific object class attributes, which will be presented in the map that will be generated using the Geomedia Professional Software, in figure 9.

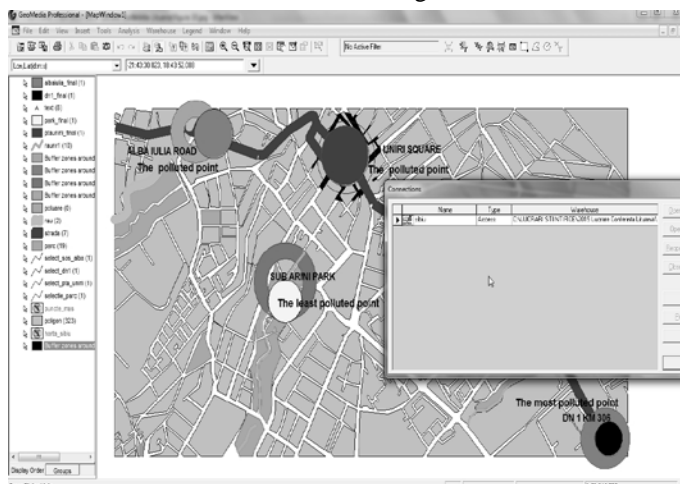


Fig. 9 The map with the observation points and database connection

V. CONCLUSIONS

The automatic system for the taking over, processing and data analysis allows obtaining the object class attributes used

for generating the intelligent maps.

The data are taken over and processed using the objectual technology and the implemented functions in LabVIEW. Plus, the system offers the possibility of the data analysis through sensors, microcontrollers, acquisition boards and specific apparatus, which is highly unused in the current literature. The multi-criteria analysis is made depending on the user's will. The elaborated system is very important because of the fact that it excludes the intervention of the human factor in the acquisition process, taking over and data memorisation.

In the future the system will be extended by using other analysis methods, like for instance the TOPSIS method or other optimization technics based on genetic algorithms. Also, it is very important the automatic generation of the pair comparison matrix, depending on the factor's values

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