Learning Control Network Programming with the *Bouquet* Cloud Compiler

Kostadin Kratchanov, Buket Yüksel, Tzanko Golemanov, and Emilia Golemanova

"And just like everything else important in your life, Bouquet CNP development environment is cloud-based"
- Re-phrased from the video on [29]
"Primitives + Control Network = Control Network Program"
Claimed in Sec. II C

Abstract**—**The ultimate goal of this paper is to introduce a cloud development environment for Control Network Programming (CNP) called *Bouquet*. However, our route to that goal is not strait. We address a number of related objectives and use the corresponding conclusions. We discuss the distinguishing features of CNP and deduct the summarizing maxim **"Primitives + Control Network = Control Network Program"**. Then we analyze the types of CNP development environments paying special attention to the most advanced CNP IDE, *SpiderCNP*. We address the reasons for devising a cloud compiler, and include an extended review of cloud IDEs and their advantages. Finally, we are at a position to explain the principles and some design and implementation details of the *Bouquet* cloud CNP environment. All these issues are considered within the context of teaching and learning – teaching major concepts of computer science and mathematics with the help of CNP tools, and learning CNP by students, programmers, and researchers.

Keywords**—**Control Network Programming, CNP, cloud IDE, cloud compiler, online compiler, learning system.

I. INTRODUCTION

Control Network Programming (CNP) is an unusual programming style. It is especially advantageous for solving problems which exhibit one or more of the following traits: the problem description or its procedural solution have a natural graph-like representation, involve nondeterminism or randomness, are based on search. Distinguishing features of CNP are discussed in Section II.

We have been successfully using CNP as a tool for simulating various computational models and algorithms in our Computer/Software Engineering curricula at undergraduate and graduate levels. Other areas where concepts such as computation, search, inference, nondeterminism and randomness are fundamental, and where CNP could be a great teaching tool, are Computer Science, Mathematics, Industrial Engineering, Robotics, and others. A short summary of our teaching experience with CNP is given in Sec. II E.

We need a CNP programming environment in order to create, modify, compile, and run CNP applications. Such a powerful IDE (with embedded graphical editor) is *SpiderCNP*. This report focuses on describing a much simpler, light-weight, online cloud CNP compiler which we call the *Bouquet* compiler. (Bouquet is the English equivalent of the name of the programmer most involved in the development of this compiler, Buket). Being run in the cloud, this approach is not only 'trendy' but in fact frees a user from the burden related to installation, maintenance and updating the tool. This is especially important for a user who wants to learn the basics of CNP and use it for running demos or creating their own small-size CNP applications. Generally, our students belong to this class of user, together with other students, researchers or programmers whose aims are to get basic awareness of CNP and its possibilities but are not yet its heavy users.

II. DISTINGUISHING FEATURES OF CNP AS A NEW PROGRAMMING PARADIGM

A. Introduction to CNP

The name **Control Network Programming** or **CNP** can be deciphered as 'programming through control networks'. It is a combination of the declarative and imperative programming styles. A 'program' consists of two fundamental parts. The first one is called a **Control Network** (**CN**). It can be considered as a declarative description of the problem at hand and is an explicit system of graphs called subnets. The arrows of the subnets are labeled with sequences of simple actions, called **primitives**. The primitives are defined separately or taken from existing libraries simple procedures.

In CNP, other synonymic names for the computation process would be inference or search. The goal is to find a path from the initial node of the CN to a final node, possibly going in the process through invoked subnets. The execution of a primitive might result in failure in which case the system executes primitives backwards, restoring the state of the data, and attempts another path. The passing of the control through the CN is thus highly intuitive and easily understandable.

Some major resources describing the technical details of CNP are [5]-[9]. How CNP can be applied for solving

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different types of problems is demonstrated in [10]. The computation/inference in a CN program is based on search. Therefore, the built-in powerful tools for user control of the computation can be used to implement heuristic search strategies in an unusual, non-procedural manner [11]-[13].

B. *CNP distinguishing features*

We describe CNP as a new programming paradigm extending and integrating declarative programming, imperative programming, and programming rule-based systems. As all other programming paradigms CNP is universal – that is, it can be used for implementing any algorithm. However, it is especially effective when solving problems which can be naturally represented in a graph-like manner, and/or whose descriptions exhibit nondeterminism and declarativeness.

As we mentioned already, the CN can be looked at as a declarative description of the problem to be solved. Typical illustration of this viewpoint is the CNP solutions to the Animals classification problem in [10], the Map traversal problem in [7], the non-recursive heuristic solutions to the same problem in [13] as well as its iterative and recursive solutions in [7] and [13], the iterative and recursive solutions to the Wolves and sheep problem in [10], etc.

CNP can be successfully used for typical procedural solutions as well. Such an example is the SelectionSort algorithm in [10]. Here, the CN is an explicit graphical representation of the program control (as understood in imperative programming). In other words, in CNP the program control is extracted from the imperative program and made explicit. The actions on data are defined in the simple and well-understood primitives. This helps for easier understanding, creating, modifying, or verifying the algorithm.

In both cases of considering a CN as a declarative problem description or as an explicit description of the control in a procedural solution, CNP can be also described as a type of graphical programming. Indeed, the CN (being the leading principal part of the CN program) is a recursive set of graphs. Depending on the development environment used this net (the CN) may be actually seen and edited in a graphical editor, or may be coded textually using our simple language for describing graphs called *Spider*.

'Executing' the CN is a kind of search. CNP has been equipped with powerful means to control this search – namely numerous system options and control states [7],[8],[12]. Some of these can also introduce randomness. This makes CNP a very powerful tool for realizing a great number of search approaches. Especially interesting and unusual are implementations of algorithms based on local search, as the execution of the CN is in fact a particular type of local search itself. This approach is called non-procedural implementation [11]-[13]. It does not involve writing any search algorithm in the usual sense – a behavior equivalent to the corresponding search algorithm is achieved 'automatically' trough the built-in search control tools.

C. *Primitives + Control network = Control network programming*

Back in 1975, Niklaus Wirth proclaimed: "Algorithms + Data Structures = Programs" [1]. First of all, this applies to structured, imperative programs. In 1979, sighting logic programs Robert Kowalski responded: "Algorithms = logic + control" [2]. Modifying the famous Wirth's statement, Zbigniew Michalewicz added in 1992: "Generic Algorithms + Data Structures = Evolution Programs" [3].

Here we notice and proclaim: **"Primitives + Control Network = Control Network Program"**.

Our statement has a very direct and literal meaning: a Control Network (CN) program consists of two parts: definitions of primitives, and a CN using these primitives. Physically, a CN programming (CNP) project includes two main files – one that contains the primitive definitions, and a second one with a textual representation of the CN. In more detail this will be discussed in the following sections.

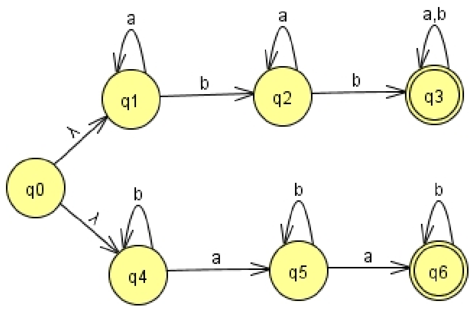
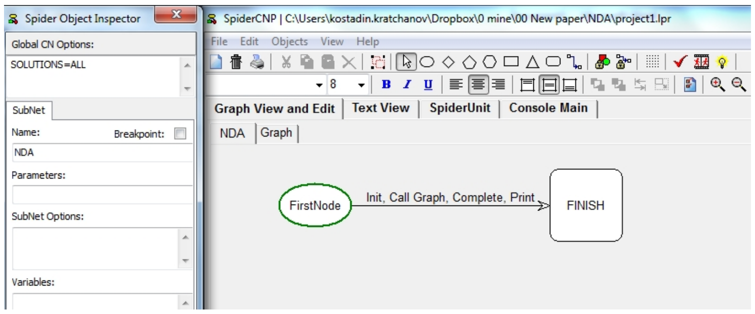


Figure 1 NDA

A note is needed. We apologize to the data for somehow neglecting its importance. The data does exist and is important. We refer to the first major component of a CN program as "Primitives". To be maximally precise, we should've called it "Data and Primitives". The primitives act on data. The data is usually declared in the same file where the primitives are (or in other project modules used). However, for simplicity, we'll keep the shorter name "Primitives". It is understood by default that there is data processed by these primitives. Generally, in CNP one focuses more on the computation control rather than on the data. As a matter of fact the control is explicit, and is presented graphically by the CN.

D. *An exemplary CNP application*

As an illustration, we show here the CNP simulation of a


Global CN Options: SOLUTIONS=ALL

Name: NDA

Figure 2a The *NDA* main subnet

nondeterministic automaton which accepts strings over the alphabet {a,b} that include exactly two a's or at least two b's (Problem 1.4b from [4] but implemented as an NDA). The graph of this NDA is shown in Fig. 1 (screenshot from *JFLAP*). The CN of the CNP implementation consists of two subnets. The main subnet called *NDA* is shown in Fig. 2a, and the subnet *Graph* - in Fig. 2b. The screenshots are from the *SpiderCNP* programming environment discussed below. An exemplary dialogue with the user is given in Fig. 3c. This CNP example is used in the PhD course Theory of Computation and the undergraduate course Discrete Computational Structures II at Yaşar University.

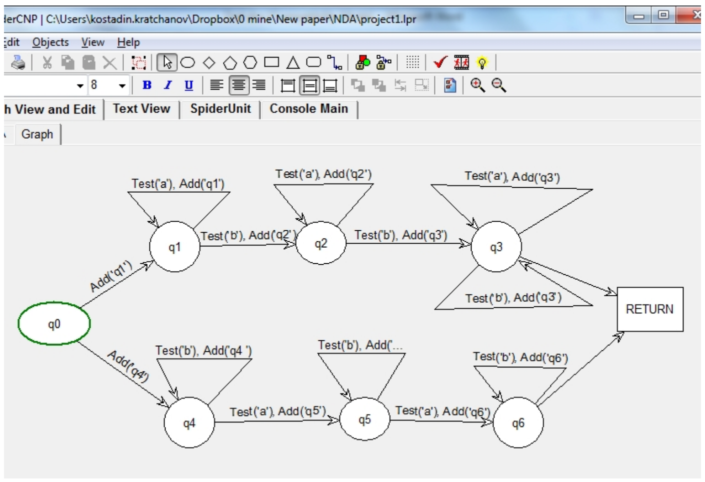
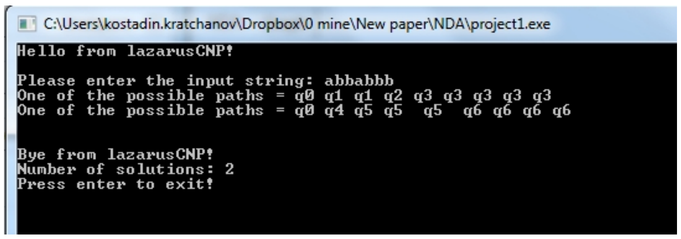


Figure 2b The *Graph* subnet


C:\Users\kostadin.kratchanov\Dropbox\0 mine\New paper\NDA\project1.exe

```
Hello from lazarusCNP!

Please enter the input string: abbabbb
One of the possible paths = q0 q1 q1 q2 q3 q3 q3 q3 q3
One of the possible paths = q0 q4 q5 q5  q5  q6 q6 q6 q6


Bye from lazarusCNP!
Number of solutions: 2
Press enter to exit!
```

Figure 2c Console

The following primitives are used in the CN. Primitive *Init* performs some initialization and prompts the user to enter the input string. Primitive *Test(c)* completes successfully if the current input character equals *c*. Primitive *Add(n)* adds the string *n* as the name of the current node into the solution path. Primitive *Complete* checks if there are additional symbols in the input string that have not been read and used. Using this primitive in the main subnet ensures that no unused symbols have remained in the input string. Finally, primitive *Print* displays the solution path.

E. CNP in education

At Yaşar University, we have been systematically using CNP for three years in teaching the courses of Artificial Intelligence (4th year undergraduate) and Theory of Computation (PhD.) in our Computer/Software Engineering curricula, and we have found it to be a very useful tool in simulating various models and algorithms. Other possible areas include Formal languages and automata, Compilers, Algorithm analysis and design, Concepts of programming languages, Discrete mathematics, Logic, Digital design, Algorithms and data structures, and more.

In general, it is the prevailing view of the educators in areas such as computer science and mathematics that students tend to have substantial difficulties in apprehending the ideas behind nondeterministic and randomized (also referred to as stochastic) computation models and algorithms. CNP can be a great instrument to help understanding and getting confident with these concepts [17],[18]. In fact, our experience and surveying results strongly suggest that understanding and using CNP for our students (who have already developed a strong procedural way of thinking) is substantially easier than Prolog.

III. Programming environments for CNP

To practice CNP, i.e., to create, edit, compile, and run CNP applications one needs an appropriate development environment. A number of such environments have been created.

A. SpiderCNP – a CNP IDE for graphical programming

The most powerful one is *SpiderCNP* [14]. It has two versions. They are integrated as a tool in the *Delphi* and *Lazarus* IDEs, respectively. A fundamental advantage of the chosen approach is the possibility to use all the features and tools of the larger encompassing environment and the latest versions of the programming language around which the IDE is built. This programming language is also used to program the primitives. The installation process consists of three steps: install the *Delphi* or *Lazarus* IDE, then run a simple installation program that installs *SpiderCNP* as a tool of the IDE, and finally fix some settings.

Delphi is a sophisticated, ambitious, advanced professional environment which, of course, is an important advantage of this approach. However, this is also its main disadvantage when using it in teaching. The IDE is rather expensive, free academic versions are very difficult or impossible to obtain, updates in the IDE are difficult for the same reason. The second disadvantage is the size of the software product and correspondingly the difficulties in its installation. Difficult installation was the single most important drawback of the CNP approach identified by the students in their surveys and comments during the first year of using CNP in teaching.

In our opinion the switch to the *SpiderCNP* version based on *Lazarus* (called also *LazarusCNP*) brought essential advantages. *Lazarus* is a free product; it is pretty easy to download the latest version of the product, and much easier to install it. The IDE is also quite advanced and stable. We have been using *LazarusCNP* for two years and it is our most advanced and well-tested CNP development environment.

Although the installation still requires the same three steps, it now takes less than 5 minutes, and all the components to install are free. The corresponding installation instructions and download files are available at [19].

Before discussing the CNP IDE further we need to understand the architecture of a CNP application.

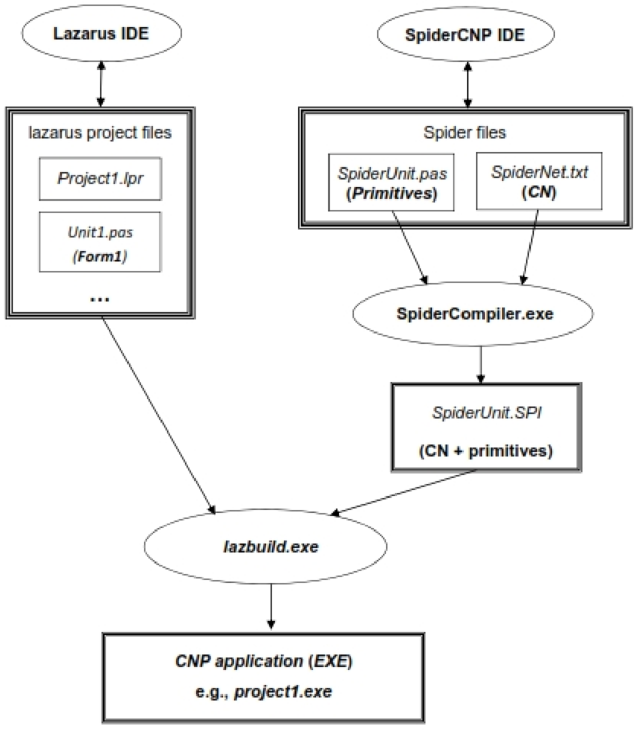


Figure 3 Structure of a CNP application

B. Architecture of a CNP application

There are two types of applications in *Free Pascal* (also known as *OO Pascal*) which is the core of *Lazarus*: console applications and window applications. Correspondingly, we have the same two types of CNP applications. Console applications are simpler; the I/O is realized through a DOS-type console. Such an I/O console is shown in Fig. 2c. The I/O of a window application is performed through various built-in or user-defined windows. This allows the creation of applications with more attractively looking and modern I/O. In practically all cases of teaching applications the console I/O is enough and even easier to follow. The online CNP compiler that we will be describing further in this report allows console applications only. Therefore, we will introduce the structure of a CNP application for the case of console applications only (although the differences are minimal). It is shown in Fig. 3.

A CNP application is created as a *Lazarus* project. All the files of the project (i.e., the CNP application) are placed in a folder. As we know, a CN program consists of two fundamental parts: primitives and CN. The file with the primitives is *SpiderUnit.pas*. Technically, it is an *OO Pascal* file in which the primitives are defined as procedures. The file may contain also definitions of global data. The CN is specified in the text file *SpiderNet.txt*. It describes the CN in textual form using a very simple language for specifying nets called *Spider* – see [6],[10] for a description of this language.

The CNP compiler (called *SpiderCompiler.exe*) uses the above two files (the CN and the Primitives) to produce a Pascal program as its object file *SpiderUnit.spi*. This program includes directly a copy of the definitions of the primitives and the global data. The behavior of the program corresponds to that of an interpreter that would execute the CN according to its semantics. The CNP compiler has been developed using ideas similar to recursive decent.

As any *Lazarus* project, the project folder contains some other files. The only one important for our description here is *Project1.lpr*. A CNP user may well survive without knowing about it, but if (s)he wants to change the initial and concluding text in the output, the user may do corresponding modifications there.

All *Lazarus* files included in the project, as well as the *SpiderUnit.spi* file, are used by the *lazbuild.exe* file (which is part of the *Lazarus* IDE) to create the file *project1.exe*. This executable file is the CNP application. It can be called (executed) from inside the IDE, or directly as a stand-alone executable file.

The general view of the *SpiderCNP* IDE can be seen in Fig. 2a. In the main window, the user may switch between displaying the CN (graphical view or textual view; the latter is the file *SpiderNet.txt*), primitives (file *SpiderUnit.pas*), or console (file *Project1.lpr*). Normally, the CN is studied and edited in the graphical view. However, if preferred, the textual file may be modified (currently, for a given project, only one of these options is possible). The textual view of the *Graph* subnet shown graphically in Fig. 2b, is given in Fig. 4.

Clearly, the most distinguishing feature of *LazarusCNP* is the existence of graphical editor of CNs. The CNP IDE has many other features, including tracing the execution within the graphical editor on the graphical view of the CN.

Working with a CNP project means creating and modifying as needed the three components (files) described: CN, primitives and *project1.lpr*.

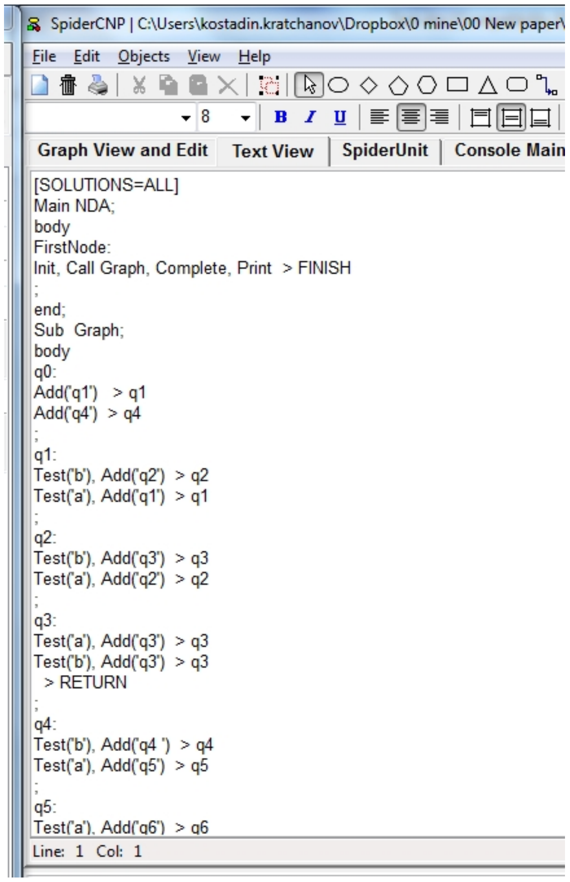
C. Possible principles for designing a CNP development environment

Historically, the first CNP were run using **interpreters** which interpreted the CN. However, for over fifteen years all CNP environments use a **compiler** (e.g., [5]) – an approach which we found to have substantial advantages.

As we emphasizes earlier, a CN program consists of primitive definitions and a CN. For representing the CN we have always used the simple *Spider* language mentioned before. The second question arising is how to specify/program the primitives.

It is possible to use a **special, defined by us programming language for primitives** which, in a way, will make CNP self-contained. We have decided against this approach, however, as it will imply constant improvements, extensions, and modifications to the language and the corresponding environment, for which we must be responsible, together with the corresponding documentation, installation files, etc.

Following the approach we have chosen, we must **integrate our CNP development environment with the external IDE** of a programming language. As already mentioned, our main CNP development environment, *LazarusCNP* is integrated as a tool inside the *Lazarus* IDE. Therefore, a CNP developer can avail of all the powerful features of *Lazarus*. Also, a developer working in *Lazarus*, can in principle create a 'regular' *Lazarus* project (e.g., in *OO Pascal*) using CNP only for subtasks where CNP would be most effective. Naturally, this approach also has drawbacks, the major one being the necessity to obtain, download and learn the basics of *Lazarus*. This disadvantage is not so severe as *Lazarus* is freely available and well maintained; however it still exists. For example, we need to have *Lazarus* installed in our teaching labs.


SpiderCNP | C:\Users\kostadin.kratchanov\Dropbox\0 mine\00 New paper\
File Edit Objects View Help
8
Graph View and Edit
Text View
SpiderUnit
Console Main
Line: 1 Col: 1

```
[SOLUTIONS=ALL]
Main NDA;
body
FirstNode:
Init, Call Graph, Complete, Print  > FINISH
;
end;
Sub  Graph;
body
q0:
Add('q1')   > q1
Add('q4')  > q4
;
q1:
Test('b'), Add('q2')  > q2
Test('a'), Add('q1')  > q1
;
q2:
Test('b'), Add('q3')  > q3
Test('a'), Add('q2')  > q2
;
q3:
Test('a'), Add('q3')  > q3
Test('b'), Add('q3')  > q3
  > RETURN
;
q4:
Test('b'), Add('q4 ')  > q4
Test('a'), Add('q5')  > q5
;
q5:
Test('a'), Add('q6')  > q6
```

Figure 4 Textual view of *Graph* subnet

An alternative promising approach is to develop a **'stand-alone' CNP environment** which does not depend directly on any specific external development environment. However, in contrast to the approach with a specially design programming languages for coding the primitives which was mentioned above, a natural and highly appealing approach would be to use primitives programmed in different programming languages and eventually developed in different IDEs. This idea is aligned with the modern-day idea of language interoperability [20]-[24]. The idea could be implemented on the base of any of the two major groups of managed languages – the .NET SLI compliant languages and JVM compliant languages [25],[26]. Creating such a light-weight and highly-flexible CNP development environment is in our plans for the near future. In particular, being able to write primitives in a language of the student's choice is a highly desired feature of a CNP environment used in teaching. The learners of CNP come from different backgrounds, have different personal preferences, and would like to be able to use the language they feel most confident with. A main idea behind creating the declarative-driven approach of CNP is that 'programming' can be done by any user, including those with very limited or even non-existing experience in programming.

Finally, we can develop the previous approach even further by using a **cloud CNP development environment** the core component of which is a cloud CNP compiler.

A short survey of cloud compilers and development environments follows. The sections afterwards describe our current working CNP cloud compiler called *Bouquet*.

D. Cloud IDEs and compilers

It is widely accepted that cloud computing is undoubtedly one of the biggest buzzwords in the technology world today. According to Fast Company [27], the cloud is a vast network of low-cost, high availability computing resources. Almost 60% of companies are already in the cloud and an additional 20% are planning to do so within the next 12 months. Cloud computing refers to application service provisioning where typical client server software is run at a remote location. Such services are given popular acronyms like 'SaaS' (software as a service), 'PaaS' (platform as a service), 'IaaS' (infrastructure as a service), 'HaaS' (hardware as a service) and finally 'EaaS' (everything as a service) [28].

Cloud computing has well-known advantages and challenges which we are not going to address here in general. Instead, we discuss below the advantages and limitations of cloud IDE's, simpler development tools, and compilers.

Software development, and in particular its most important component – compiling - can also be shifted from being performed on a user's physical computer into being done in the cloud using available remote software resources. The result of this approach is the so called cloud development environments (most developed ones are referred to as **cloud IDEs**). Some authors use the phrase online environment/platform or online compiler – this is technically correct but does not emphasize well enough the nature of a cloud application – it is not simply contents available from the internet but it is actually an integrated resource/service available remotely, most often from a dynamic website. A cloud development environment may include much more than a single compiler – editors, libraries, online execution facilities, user storage, etc.

For some reason lifting the code production into the cloud is happening later than many other types of business and other applications. Advancement in cloud compiling and cloud IDEs is a comparatively recent development, an emerging technology.

Some of the most interesting representatives of currently available cloud development environments are [29]-[44].

They have different features. Some are simple and free; many of the best ones are (as it should be expected) paid and highly professional. Some sites support many (e.g., 60) languages, others are highly specialized and focus on one particular programming language or tool. Some allow for the execution of the compiled object program on the cloud server or even for the deployment of the compiled embedded code into a particular device. Some IDEs also allow the developed code to be deployed into cloud platforms such as Windows Azure, Amazon Cloud Services, or Heroku.

Jimenez, founder of [32], summarizes: “The online IDE is one of the final frontiers of apps ported to the web. I would like to be able to develop from any computer or operating system and have the same experience without having to install software or install anything.”

The following advantages of cloud compilers may be identified (not all sites possess all advantages).

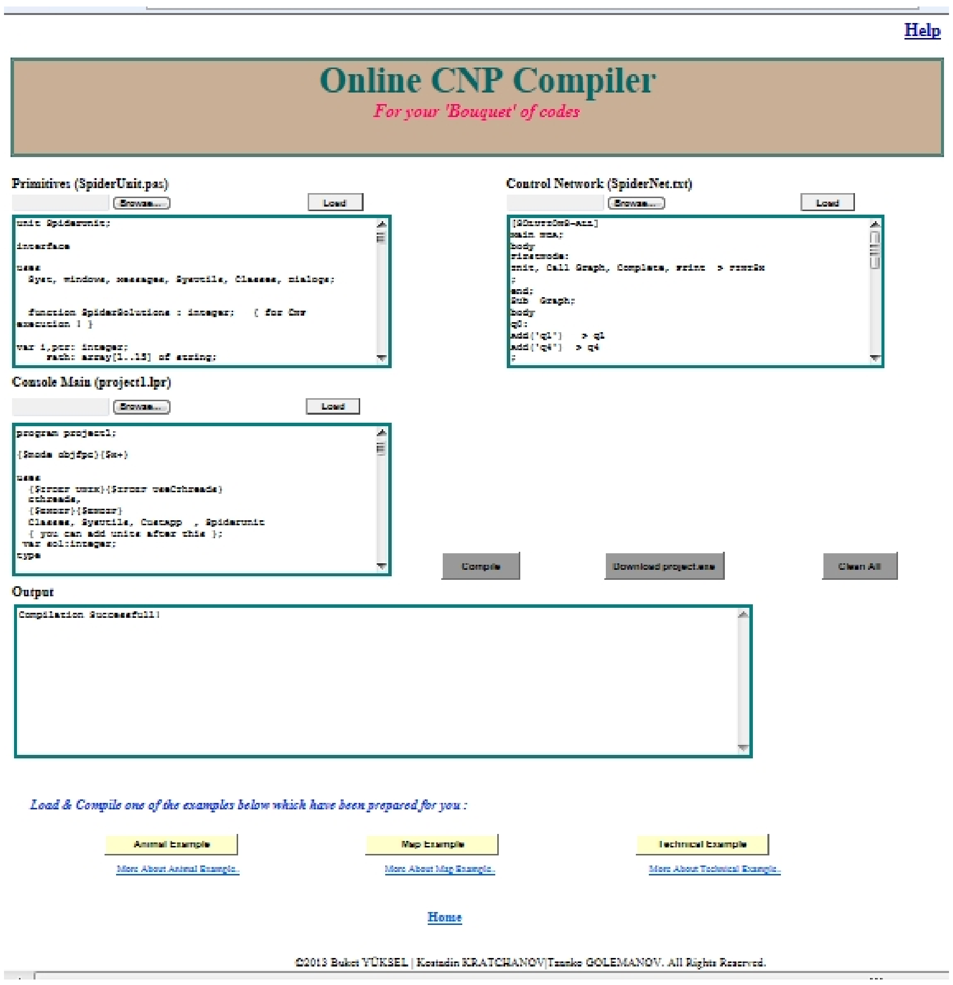
It can be frustrating to have to install volumes of software just to write a little bit of code. Cloud IDEs keep it simple by making all these tools available in the cloud with the click of a mouse. Some cloud IDEs come equipped with almost every tool, library, etc. that the code developer may ever need. With an online IDE, one can get their projects up and running faster than ever by skipping over tedious installations, and getting right down to the programming of the project itself.

The local computer is not loaded with large-size software, neither is computer time and other resources used for compilation and other related tasks.

Cloud IDEs allow the code to be accessed and edited from just about any computer worldwide, freeing the programmer from the need to have constant access to a single computer where all the tools and files are. Typically, cloud IDEs are cross-browser and device-friendly. They have been tested across all modern desktop and mobile web browsers like Internet Explorer, Firefox, Chrome, and Safari. With support for touchscreen interaction one could write code all from their mobile or tablet device. It is possible to log into one’s online IDE with a smartphone or tablet, edit the code, test it and send it off to a client in a matter of minutes.

A developer is now able to program for a wide selection of devices, without actually needing to go out and purchase them. They can write for Mac, Windows, Linux or even an iPhone or iPad without spending the money on buying one of each.

A cloud IDE can integrate features that can hardly be achieved by a compiler installed on a local computer.


Help
Online CNP Compiler
For your 'Bouquet' of codes
Primitives (SpiderUnit.pas)
Browse...
Load
Control Network (SpiderNet.txt)
Browse...
Load
Console Main (project1.lpr)
Browse...
Load
Compile
Download project.exe
Clean All
Output
Load & Compile one of the examples below which have been prepared for you :
Animal Example
Map Example
Technical Example
More About Animal Example.
More About Map Example.
More About Technical Example.
Home
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```
unit SpiderUnit;

interface

uses
  Syst, windows, messages, Sysutils, Classes, dialogs;


  function SpiderSolutions : integer;   { for Cnr
execution ! }

var i,ptr: integer;
      rach: array[1..15] of string;
```

```
[SCnrrrCmS-Arr]
main SNA;
body
firstnode:
init, Call Graph, Complete, print  > result
;
end;
Sub  Graph;
body
q0:
add('q1')    > q1
add('q4')  > q4
;
```

```
program project1;

{$mode objfpc}{$H+}

uses
  {$IFDEF UNIX}{$IFDEF UseCThreads}
  cthreads,
  {$ENDIF}{$ENDIF}
  Classes, SysUtils, CustApp  , SpiderUnit
  { you can add units after this };
 var sol:integer;
type
```

```
Compilation Successfull!
```

Figure 5 The *Bouquet* cloud CNP compiler

The remote server can be more powerful (in terms of speed, storage and memory) than a local computer. The compiler, editor and other components may be most advanced and possess most useful and increasing the developer’s productivity features. E.g., the cloud compiler may include advanced code optimizing features, the editors may support features such as autocomplete, syntax checking, multiple cursors, keyboard shortcuts, etc. Live editing might be supported where you can see real-time updates as you tweak your code. Advanced tracing may be included, even simulating the state of data. Powerful latest popular and non-standard libraries may be made available. The software components on the cloud-based site will be kept up-to-date at any time.

You can have a user account at the cloud IDE – a central depository and a virtual console. You can forget about Dropbox, USB sticks, external drives — with a cloud IDE central depository your code is always accessible online. You can access files directly from your folders on the IDE or from Dropbox, Google Drive, Amazon S3, etc. You can keep a revision history. You do not have to compile into local native images or re-download pre-compiled native images.

An especially important feature is the possibility to easily share your code and collaborate. Some cloud IDEs enable developers around the world such as teammates or peers to edit the same code and chat together in real time.

Some IDE's allow the developer to integrate with many other services that are important within the development life cycle. Thus the user can work with the tools they know and like, or even develop and integrate their own extensions.

Some sites offer for download local servers that can automatically synch with the cloud workspace.

Of course, cloud IDE's also have shortcuts and limitations – some of them are inherent, other relate to the fact that the technology is only emerging. One of the major issues is security – both in relation to the user code, and in relation to the integrity of the servers of the provider. Another issue is the client-server communication, in particular during the editing. Usage of graphical tools such as graphical editors or complex graphical I/O in the developed programs might be a serious challenge. Reaction to errors on the server and auto-safe functionality are another issue to address.

E. Cloud IDE's and learning systems

It is often claimed that online IDEs and compilers are a perfect learning tool for students and other persons learning programming with a particular programming language or tool. Some of the systems mentioned in the previous subsection have been actually created mainly as a learning tool.

A cloud IDE is easy to be used by students. They can create their codes all from the comfort of their browsers. All the heavy lifting has been done by the creators of the cloud IDE, so students and learners can just focus on writing and learning code. A cloud IDE is a natural sandbox for learning a programming language. You can write code in the computer lab and pick up where you left off at home. You can learn programming by visualizing code execution, use advanced editors, etc.

Many of the other assets which cloud IDEs demonstrate and we discussed in the previous subsection, can be considered as essential advantages from the viewpoint of learning systems.

It is also natural to integrate a cloud IDE/compiler within an integrated learning system. In addition to the IDE, an integrated learning environment may include reference guides, online interactive tutorials, pdf and video tutorials, demos, tests, problems, projects, other resources, etc.

Cloud IDE sites often include blogs and forums. You can easily get help from the programming community as well as from other students and learners.

In addition to teaching and learning, cloud IDEs may be used in training courses and certification, recruitment, programming contests, and similar activities.

IV. The *Bouquet* CNP cloud compiler

Following the modern trends in 'lifting' compilers into the cloud described above, and first of all understanding the substantial advantages of cloud IDEs, we have developed two online CNP compilers. One of them is the subject of [45]. The second one, called *Bouquet* compiler, is introduced below. It can be accessed at [46].

The general view of the cloud compiler is shown in Fig. 5. The data that can be seen are from the NDA application described earlier in Sec. II D (where *SpiderCNP* was used).

The webpage includes three input and one output forms. An input area exists for each of the three files that specify a CNP application: *SpiderUnit.pas* for the primitives, *SpiderNet.txt* for the textual representation of the CN, and the console file *project1.lpr*. These files were discussed in Sec. III B.

In order to compile a CNP application we must enter (e.g., write or copy) the corresponding files into the three input windows. We can also use the *Browse* button under each form. Three exemplary applications are prepared in advance and their files can be loaded with the click of a single button – the Animals classification, Map traversal, and the Technical example. These are the major examples used for introducing CNP in [5]-[7],[9],[10], as well as in teaching CNP at university.

When the three input files of an application are ready, the user can activate the *Compile* button. This triggers the following sequence on actions. A project folder with a partially random name is created on the virtual server. The randomness of the folder name allows multiple independent users to work simultaneously with the cloud CNP environment. A new CNP project is created in that folder. The input files from the forms are uploaded into the project folder. Then compilation/building is started by executing the file *SpiderCompilerCloud.exe* on the virtual server. This file is a cloud version of *SpiderCompiler.exe* (see Fig. 3). The generated name of the project folder is given as an argument to *SpiderCompilerCloud.exe.* In addition to the application executable file, a second output file, *CompResult.txt* is produced which contains details of the compilation and is most useful in the case of errors. Finally, *lazbuild.exe* is run which in absence of errors generates the CNP application executable file *project1.exe* and saves it in the application folder in the cloud. The user can now push the *Download project1.exe* button and download the executable file of the CNP application to their local computer. Execution of the application file directly in the cloud is not offered due to the security policy of the cloud services provider.

In case the CNP compiler or the *Lazarus* builder encounter errors, corresponding messages will be displayed in the output window. The text displayed is a filtered version of *CompResult.txt.* After fixing the errors the user can initiate compilation again.

Currently the *Bouquet* CNP environment is hosted using Amazon Elastic Compute Cloud (Amazon EC2) web services [47]. We found this advanced but still convenient and user-friendly cloud services platform suitable and attractive. However, this is a paid service and we will have to find an alternative solution in the future.

The cloud CNP environment is installed on a remote virtual server (rented from Amazon WS). Windows 2008 R2 server with IIS7 is installed on the virtual server instance. The application is coded in ASP.NET and C# using web forms with code behind. Setting properly the server configuration actually proved to be probably the most difficult part of developing the CNP compiler as allowing an executable file (the CNP cloud compiler) to run on the server was a hard job.

V. Future Development

As an emerging technology, today's online compilers are certainly not without their limitations. Most online compilers have yet to integrate reliable version control capabilities which are necessary on production projects, as well as to enhance their integrated auto-save functionality to temporarily make up for lost ground, for example when the internet connection is lost.

Bouquet is more than just a compiler, more precisely – it is a simple development environment. It is, however, still not a cloud IDE. It is missing many of the advanced features of cloud IDEs discussed in Sec. III D and E. Development continues.

The first most important feature that needs further research and improvement would be the possibility to use the graphical editor in the cloud version of the environment.

Another important task is to integrate the cloud environment into an advanced learning system for studying and improving skills in CNP. Such a system is currently under development.

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