A FRAMEWORK FOR DEVELOPMENT OF E-LEARNING SYSTEM FOR COMPUTER PROGRAMMING: APPLICATION IN THE C PROGRAMMING LANGUAGE

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This paper describes a framework for development of e-learning system for computer programming. The proposed framework includes not only the necessary course materials and the corresponding tests and exercises, but also offers an integrated environment to test written programming codes. The described approach corresponds to recent trend in distance education by providing massive open online course for unlimited participation and accessible through the Internet. The modern capabilities of ICT and database are integrated to support the learning process in a user friendly environment. The functionality of the e-learning framework is composed of five basic modules for learning content, testing, exercises, questions and answers, and help module. The described framework is implemented in developed e-learning system for C programming language. The e-learning system was tested in real educational environment and was very well accepted both of...
students and teachers. The preliminary results show applicability of the system leading to improvement in the acquired knowledge and C programming skills. This was confirmed by decreasing the number of students failed on the C programming exam.

1 Introduction

E-learning systems have noticeable impact on both of researchers and practitioners. The term of e-learning system is used describes various information systems that facilitate learning and teaching. Due the progress of information and communication technologies e-learning became a focus of the modern education society. Using of the multimedia tools in the learning content adds new dimensions to the traditional educational methodology (Borissova & Mustakerov, 2009). In recent years e-learning and distance learning are increasingly growing and cover different educational topics. Educational systems are those that encourage e-learning and its application contribute to substantially improvement of the quality of education. Open educational resources and online learning try to help in providing of scalable solutions to address the education gap in society, independently of a geographic location. One of the main requirements for successful application of e-learning systems is their usability. This indicator requires providing the learning systems with interactivity and feedback directed to specific goals while overcoming any factor of nuisance that interrupts the training stream.

Recent trend in distance education is to provide Massive Open Online Courses (MOOC) that allows unlimited participation and open access through the Internet, thus making higher education more accessible (Atiaja & Guerrero, 2016). The MOOC as an innovation, influence on the public academic attention and also have impact in the evolution of e-learning and especially on the higher education worldwide.

In computer science, the skills are essential element in education on software engineering. The courses for computer programming are characterized by large amount of exercises that students are expected to practice intensively in order to develop good programming experience (Lam et al., 2008). Many efforts are needed to acquire experience and to master techniques of writing computer programs. This requires providing the students with specific for computer programming tools – editor, compiler or integrated development environment (IDE) (Cedazo, 2015). Computer programming skills can be viewed as core competencies of the students from computer science and many efforts have to be done in developing of supporting learning systems with ability for assessment (Alruwais et al., 2016). That is why, it is important to provide at least a combination of a virtual learning environment and ability for self-testing. In this respect, many researchers have attempted to design and
develop individualized learning environments based on specific learning styles. Combining the advantages of online digital media with traditional classroom methods, the blended learning systems could be achieved via face-to-face instruction with computer mediated instruction (Mesh L. (2016).

Various problems have been developed using C language, making it the right choice for many engineers and scientists not only because the powerful commands and data structure, but also because it can easily be used for system-level operations (Etter, 2012). The design, development and application of learning tools and systems are essential to improve the learning outcome. Many authors attempt to improve the learning of C programming using the capability of modern technologies as.NET platform to perform the communication between the system and the compiler of C language using redirect technology (Wang et al., 2008). For checking the knowledge about the statements in a C programming and algorithms comprehension some FLASH animations or Java applets could be used to visual representation (Han et al., 2008).

In contrast to the other authors, the proposed framework for development of e-learning system for computer programming is based on freeware is easy accessible tools as HTML, JavaScript and free student’s edition and cross platform Ch environment\(^1\). The proposed framework for e-learning gives the opportunities not only to follow the learning content, but also to get feedback and provides self-testing during the education process. The learning system can be used to facilitate the conduction of official examination. The existence of the module for writing and testing of program codes allows the students to verify the ability to writing the codes. The rest of the paper is structured as follows: architecture of the proposed e-learning framework and its basic modules, description of the basic functions of developed e-learning system, discussion and conclusion.

2 A framework for e-learning system development

This section describes the proposed framework for the e-learning system composed of the basic learning modules and represented via proper architecture. The aim of e-learning system for C programming language is to assist the learners in the educational process. That means to provide not only the courseware to the domain of C programming, but also to give some tools to assess knowledge in the learning process. Taking into account the advantages of Web-technologies, the proposed learning system is based on client-server technology and relies on web browser accessibility. The proposed e-learning system for computer programming can be represented as interactive computer-based information system that combines the computer capabilities, Internet.

\(^1\) http://www.softintegration.com/
and database to support the learning process in a user-friendly learning environment. The e-learning system is composed of three-layer architecture – user interface (presentation layer), functional logic (functional layer) and data access logic (data layer) as shown in Fig. 1.

![Diagram of the e-learning system](image)

**Fig. 1 - Architecture of distance e-learning system for C programming**

The *learning content* module is composed of different multimedia information as text and hypertext, images and video consistent to the particular lectures. This module also provides an alphabetical index of terms, allowing quick access to their detailed description in the lectures by appropriate hyperlinks. The teaching material should be generated dynamically to help the students to navigate different learning topic through hyperlinks.

The *exercises* module contains instructions for programming tasks corresponding to the learning content of units. In this module the students can write and test different program codes as the programming skills cannot be obtained without programming practice. This allows the students to set breakpoints, to run a program step by step, to watch and change values of variables in stacks during its execution, etc.

The comprehension states of the learners can be measured by tests during learning via *testing* module. To estimate the students’ knowledge, the learning system integrates self-testing combined with an automated evaluation. The assessment part of the testing module should be capable to evaluate the quality of learners correctly. The module for questions and answers is composed of a separate text file from which the selected item is loaded when activated the testing module. The right answers of testing questions can be stored to be available in process of forming the current and total scores of tests. The relation
between learning content and self-assessment module is of great importance because it facilitates the e-learning process and influences on increasing of learning motivation. Computer programming has essential practical context and the assessment of programming learning performance is challenging. Different online assessment system could be used to count total scores used to define the final estimation (Harley & Harley, 2011; Mustakerov & Borissova, 2011; Wang et al., 2012). In self-test assessment mode, test module should be able to mark errors and provide a feedback to students for deficiencies in their knowledge. This self-test assessment mode allow the users to see what they do well and what they need to improve. Multiple choice questions are easier to use with technology than short or essay question, but learners can answer the questions more quickly and respectively the number of questions and the coverage of the curriculum can be increased (Farrell & Rushby, 2016).

The Questions and Answers (Q&A) module provides frequently asked questions and answers of these questions. This module is composed of a separate database (questions repository) from which different themes can be selected and loaded. The Q&A module could be viewed as additional information based on the students’ questions and teachers’ answers in respect of the learning content.

The Help module contains information about the organization of the course and its usage rules. The structuring of the learning system in modules allows easily maintenance the courseware management and future updates.

The user interface allows interacting with the specialized modules for learning content, exercises, testing, questions and answers, and help. The second layer is responsible to provide functional logic between requested unit from the lectures, tests, exercises, questions & answers and corresponding learning content. The data layer provides the needed access logic in accordance to the selected module. The e-learning system should be based on asynchronous learning method to facilitate the uses of online learning resources information sharing outside the constraints of time and place among a network of users. This facilitates the learning process in traditional education, distance education, and also the continuing education.

3 Description of main system functions

This section provides information about the required modules for realizing the functionality of the e-learning system. The developed e-learning system is self-contained and presents all learning content online. The basic horizontal navigation menu of the system allows links to the main modules: 1) module for learning content, 2) module for testing, 3) module for exercises, 4) module for Q&A and 5) module for additional helpful information (Fig. 2). The content of lectures differs from the original approach of presentation proposed by
developers of the C language – Kernighan and Ritchie (Kernighan & Ritchie, 1988). This approach is widely accepted for teaching and learning of programming in C, although it is not the easiest for beginners in programming. From didactic point of view more appropriate for beginners is presentation of learning content with gradually increasing difficulty – starting from allowable symbols, keywords, etc. (Fig. 2). The learning content is divided into two main parts – for novice programmers and for students which have some programming experience (Bogdanov & Mustakerov, 2004). The first part presents the main language symbols and elements illustrated by examples. Each new element is introduced by formal description, explanation, examples and exceptions. The syntactical description for language elements in the beginning can be used as reference by any C programmer. Passing the first part, the students will have the basic knowledge to write and test some simple C codes.

The second part covers all insights of ANSI C and also could be used for reference and from more experienced C programmers. Each educational unit includes learning material as lecture text and code of examples (based on learned to that point language elements), and is accompanied by appropriate explanations. Integrated part of the learning process is the assessment.

Fig. 2 - Screenshot of the part of first lecture content
Assessment encourages the learning and provides feedback on learning for both students and teachers. Assessment is perhaps the best way to identify the learners needs, so the testing module essential. It is composed of questions with multiple options to choose from. This type of assessment is quicker in delivery, gives more specific and directed feedback to learners and can provide greater curricular coverage.

The module for testing is composed of two main parts. The first one is intended to store the questions and answers while the second one aims to calculate the testing scores and to form the final result. Due the used JavaScript language, minimal resource is needed. JavaScript functions interact with languages such as CSS and HTML via document object model. Through Ajax technology, the Web page is updated without reloading the whole page via requesting and receiving data from a server in the background. Loading of module for testing is based on `open(method, URL, async)` to point the method and web address of the file on a server accessible through `XMLHttpRequest` object. The “async” parameter specifies whether the request should be handled asynchronously or not. `XMLHttpRequest` as an API can be used by JavaScript to transfer and manipulate data to and from a web server using HTTP, establishing an independent connection channel between a webpage’s client-side and server-side. When the file is loaded, the test can be started (Fig. 3).

The answers of questions are realized by radio buttons. The second part of the module test checks whether the answers are correct and calculates the current test score and also provides an overall assessment of the answers to
the questions so far (Fig. 3). The chosen topic on the left pane defines the questions to be loaded in the right pane. The questions are visualized through a table template where form template is used for processing of data. For processing of questions’ answers data, the JavaScript is chosen as a flexible and expressive scripting language, which makes it possible to implement the interactive asynchronous Web applications by Ajax technology. In the contexts of the current e-learning system for C programming, the JavaScript function, which processes the current and total score of the test, is listed below:

```javascript
function getScore()
{
    if(check==0 && parent.conttest.tpass[0]==0)
    {
        Score = 0; da[0]=" "; da[1]=" "; da[2]=" ";
        var A1=eval("an1[0]");
        var A2=eval("an1[1]");
        var A3=eval("an1[2]");
        var Answers = new Array();
        Answers[0]  = [A1, test.question1];
        Answers[1]  = [A2, test.question2];
        Answers[2]  = [A3, test.question3];
        for (i=0; i < ansNum; i++)
        {
            var currQuestion = Answers[i][1];
            if(!currQuestion[0].checked && !currQuestion[1].checked && !currQuestion[2].checked)
            {
                alert("Изберете отговор за всеки въпрос!"); return 0;
            }
            for (j=0; j<currQuestion.length; j++)
            {if (currQuestion[j].checked && currQuestion[j].value == Answers[i][0])
                { da[i]="*"; Score++; break; }
            }
        }
        Score = Math.round(Score/ansNum*100);
        if (Score <33) Score= 0;
        else if (Score <67 & Score>=33) Score= 4;
        else if (Score <100 & Score>=67) Score= 8;
        else if (Score==100) Score= 12;
        if(parent.conttest.TotalScore>0)
            TotalScore=parent.conttest.TotalScore;
        document.test.score.value= " "+ Score;
        document.test.totalscore.value= " "+ TotalScore; check=1;
        parent.conttest.tpass[0]=1;
        stat(test);
    }
    else window.alert("Тестът вече е изпълняван!");
}
```

The self-testing process can be more useful if after the student has marked his answers, the correct answers are shown. They are presented in a pop-up window and are marked with asterisk (*) as shown in Fig. 3. This pop-up window is generated via JavaScript function on the fly when the button current test score is activated. This function does not allow going back to questions that are already passed but the test can be repeated from the beginning as many times as it is needed. Because the students are able to see their answers that resulted in errors, they have the opportunity to go back to the learning content.
to understand what knowledge they have missed. The self-assessment allows the students to estimate their acquired knowledge on any computer and at any place (provided there is Internet connection).

The testing module is realized following the proposed conceptual approach for development of educational Web-based e-testing system (Mustakerov & Borissova, 2011). This module can be adjusted to perform different levels of test difficulty and can be used also for official student examination if the test run is limited to single run for given time period and total questions score are sent to the tutor. The programming skills cannot be obtained without programming practice. Testing codes is an absolute prerequisite for success in programming and any developed e-learning programming course requires availability of tool for writing and testing of program codes. This tool can be implemented as a module in the e-learning system (Rehberger et al., 2013; Cedazo et al., 2015).

The main problem is that C programs have to be linked to appropriate libraries and compiled to get the executable code. Only after execution of this code, the programmer will be able to assess the correctness of the program. An alternative approach for exercising of C programming is to use some specially designed tools for professional programming with proven effectiveness. The developed of e-learning system for the C programming language is based on Ch environment for C programming. This environment extends C for scripting and shell programming and provides many options needed for quick start in learning of C programming. The free student’s edition also provides an easy to use cross platform Integrated Development Environment (ChIDE) (Fig.4).

Fig. 4 - GUI of ChIDE for exercises on C programming
The use of ChIDE gives the opportunities the students to create a solution C code or edit the developed one according to the received feedbacks. The users can set breakpoints, run a program step by step, watch and change values of variables in different stacks during the program execution, etc. This is due to the comprehensive facilities of ChIDE for editing, debugging or running of C programs. Advantage of ChIDE is the ability to set the user interface among over 30 local languages. This environment can be downloaded for free from any student or teacher and can be used for training of C programming skills.

4 Results and discussion

The proposed online learning system for C programming language is based on modular architecture and can be modified and extended with additional modules. The selection of content of learning and testing depends on users’ preferences. Each of the learning units can be accessed separately, as they are independent of each other. Since the different system modules are accessible via simple and intuitive navigation menu, the usage of the described e-learning system requires only basic knowledge for using of Web browser. The incorporated modules in the learning system give the opportunities not only to follow the learning content, but also provide opportunities for self-testing to verify the gained knowledge. The used module for writing and testing of program codes allows setting of breakpoints, running a program step by step, watching and changing values of variables in stacks during execution.

The described e-learning system for C programming language was tested in a course of higher education during one semester. Two ways of system using are included in testing: 1) in classroom teaching where learning content of the system is presented by the teacher and 2) distance education using the support provided by the described e-learning system. At the end of the semester, all students pass test for C programming language syntax and coding. The results of examination after completing the courses are compared with those of students not using system and following the traditional way of teaching using learning content presentation based on Kernigan & Ritchie (Kernighan & Ritchie, 1988). The testing results for all groups of students are shown in Table 1.
The results show, that the students in distance education have a little better results compared with the students that are present in-class during the educational process and using e-learning system. For example, the excellent results from students in distance education exceed the excellent results from the in-class teaching with about 4% (41.2% vs. 37.5%) while the fail results are less with about 1% (1.96% vs. 2.8%). This could be explained with the better motivation of the self-learning students. The testing also show that students in distance education have better results than in class learning students (80% vs. 68.75%). This might be explained with existence of a better motivation of the self-learning students. Another visible fact is that the gender of the students does not impact essentially on the final exam results, i.e. the ambition to learn has nothing to do with sex of students. The comparison between in classroom teaching by e-learning system using and traditional way of teaching (without e-learning system) show higher excellent scores (about 11 %) and about 4 % more fails.

Overall, the testing results show the learning system applicability for both of students in distance education and for in classroom teaching. The improved final results demonstrate the capability of the system to assist the students to write correct programming codes which is the ultimate goal of C programming course.

To get feedback for system usage benefits, an anonymous evaluation of system from the students was held at the end of the semester. The evaluated components are learning content, exercises and tests. The student’s satisfaction varies in different modules as follows: for learning content 89 %, for exercises 89.3 %, and for tests 98.2 %. The overall satisfaction from the usage of the e-learning system for C programming language reaches more than 90 %. This gives confidence that the developed system really helps the learning process and
especially writing the correct codes. This is due not only to the well-structured learning material, but also as a result of appropriately organized modules to verify the acquired knowledge. Using of asynchronous communication and online learning contribute to the minimal requirements of hardware resources and ability to use at the student’s pace. The conducted testing with described e-learning system demonstrate an improvements of student’s skill and knowledge level over a specific topic, facilitate the exchange of ideas and feedback between students and teacher and creates a meaningful learning experience for the students.

Conclusion

This article describes a framework for development of e-learning system for computer programming. The proposed system architecture is composed of three-layer: 1) user interface, 2) functional logic, and 3) data. Due the modularity, some modification, expanding, and maintenance can be easily realized. The proposed e-learning system is platform-independent as it is compatible with web browsers and relies only on the availability of Internet. The proposed architecture is used to develop e-learning system for C programming language. A distinguish feature of the described e-learning system is the possibility to be used independently for study of the course on C programming language or to be incorporated in some existing learning management system. The Internet allow students to acquire knowledge and skills in C programming at a convenient for them time and place by using the functionality of the described distance learning system.

The preliminary testing of the system in real teaching process shows that is very well accepted both by the students and by teachers. Structuring of learning content in a way known from other procedural programming languages unlike the widely accepted approach from Kernighan & Ritchie, contributes for easier perception of the C programming language specifics. The learning content and system functionality will be tested continuously in real educational environment and analysis of the results will be used in order to improve it.

REFERENCES


