EVALUATION OF VISUAL COMPUTER SIMULATOR FOR COMPUTER ARCHITECTURE EDUCATION

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ABSTRACT

This paper presents trial evaluation of a visual computer simulator in 2009-2011, which has been developed to play some roles of both instruction facility and learning tool simultaneously. And it illustrates an example of Computer Architecture education for University students and usage of e-Learning tool for Assembly Programming in order to realize effective and efficient ICT-based Practical Information Education. Evaluation for the visual simulator has been carried out not only as an instruction facility but also as a self-learning tool. The simulator can be used by teachers in their classroom lectures as well as by students for their making reports (essays). Such evaluated results are based on viewpoints from instruction of internal structure and behaviour in vonNeumann computer, Assembly Programming exercise, some essays by students with the simulator, and relationship between student's examination scores and usage of the simulator. Second half of the paper describes how to organize multiple server system for collaborative learning with the visual simulator.

KEYWORDS

Collaborative learning, multiple server, system, qualitative and quantitative evaluation.

1. INTRODUCTION

People of the world say, an ICT-based Education has become widely accepted from elementary schools to higher educational institutes. Even in Japan, Informatics Fundamentals has been included as one of the menus of University Entrance Examinations. It becomes more and more important for pupils and students to learn computer-related subjects even in not higher education.

Many instructors and researchers have designed and developed some kinds of computer simulators because they seem to be one of the effectively educational tools for the lecture of Computer Architecture and Information Processing. Some of the famous simulators are introduced in the fifth section (parts of Related Works). Such simulators can be used in the practical education. Several of their simulators have been able to illustrate how a computer works graphically and additionally provide some kinds of programming exercise environment. Some of them have been used as visual educational tools of instructors for their learners in classroom lectures. And others have been utilized as e-Learning tools for Programming Exercise through even after school.

It is clearly recognized to be useful and efficient that such simulators have been used in the actual and practical education for more than decade years and they have played ones of significant roles in Computer Architecture and its related lectures. Although such simulators have been providing good effects for Computer Architecture education, there are only a few reports to evaluate the simulators in the practical education and estimate their effects in qualitative and quantitative viewpoints. So we have described trial evaluation of the simulator in qualitative approach as well as quantitative one. The former is based on students' feedback and the later is performed by statistical analysis.

Collaboration and/or collaborative learning are important for users to work together in some kind of effective/efficient environment. We have tried to organize multiple server system for collaborative learning and have implemented collaborated learning environment with visual computer simulator. We will introduce how to organize multiple server system for collaborative learning.

This paper presents an example case of Computer Architecture including usage of our visual computer simulator in the next (second) section. It demonstrates the 2009-2011 evaluation of our simulator in the third section. The fourth section of the paper introduces organization and usage of multiple server system for collaborative learning. The fifth section mentions the related works about our research. And finally the paper summarizes its conclusion in the last (sixth) section.

2. A VISUAL COMPUTER SIMULATOR

A simulator called VisuSim is implemented as a pure Java program to provide two kinds of entries for both Java applet code and Java application one. Each can be selected automatically to invoke the suitable mode of Java program. Namely, for example, VisuSim recognizes its invoking environment and decide to execute as a Java applet in the environment of browser or to work as a Java application in the environment where the Java VM executes in the DOS prompt of Windows, in the command interpreter of Linux and so on. A necessary condition is only to equip the Java VM prepared to execute the simulator. So it is very useful because any executable environment will do, just like Windows, Linux and/or Macintosh.

There are both sides of views for the visual simulator as are summarized below. The first one is a tool to visualize an internal structure and behaviour of computer. It is useful for teachers to show students how a computer works graphically. The second is an e-Learning tool to provide an environment for Assembly Programming exercise.

2.1 Visualization Tool

VisuSim has 8 sets of general-purpose registers, including Stack Pointer, and 256/512 words of main memory. It can simulate computer internal behaviour in a register-transfer level. For example, a teacher of Computer Architecture can utilize it to demonstrate graphical view about von Neumann computer architecture by means of wall-hanging screen and PC projector. The teacher can explain step-by-step actions of internal register and memory with VisuSim. Fig.1 shows an overview of VisuSim which is downloaded from a server and executes on PC.

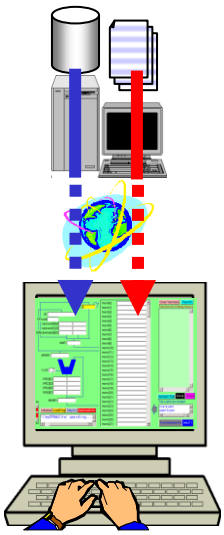

Figure 1. VisuSim on PC

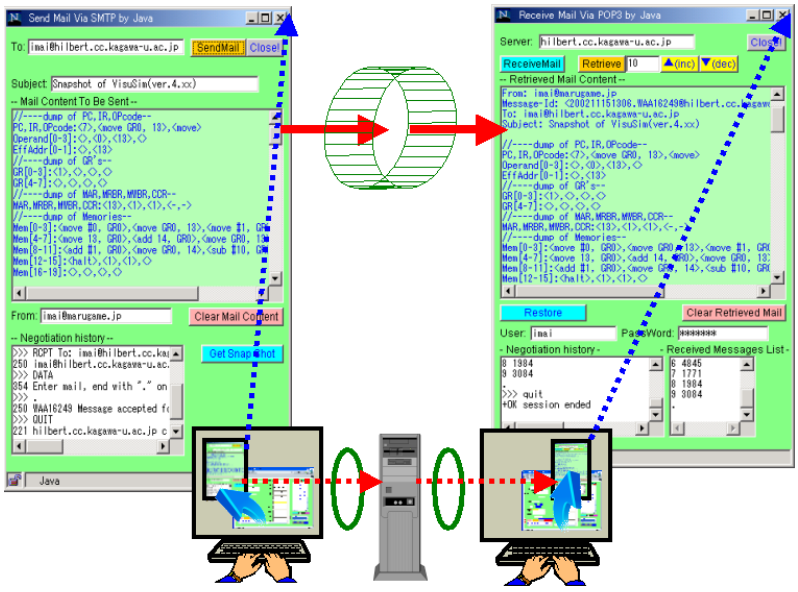

Figure 2. Communication between pair of VisuSim with buit-in e-mail functions

2.2 e-Learning Tool with Communication Facility

VisuSim is utilized for writing essays and answering problems of Assembly Programming exercise. Users (Students) of VisuSim can understand computer behaviour, program processing and well-defined algorithm through verification of assembly program execution. And moreover communication service can be provided between pair of VisuSim with its built-in e-mail function. So it supports effective information sharing between sender and receiver of VisuSim. It is very useful in an e-Learning tool among users in Fig.2.

3. EVALUATION OF VISUAL COMPUTER SIMULATOR

This section describes an evaluation of the visual computer simulator. It presents the detail of essay problems in the lecture, analyzes the scores of students' essays, short test and semester-end examination. And then it shows the relations of them as an evaluation of VisuSim in the relevant year. And it also explains qualitative and quantitative evaluation in the second half.

3.1 Essay Problems for Computer Architecture Education

It is important for students to learn vonNeumann computer architecture as efficiently as possible, because such a theme is positioned as an introductory talk of lecture and its perfect understanding makes more fruitful and expansible for the succeeding education in faculty or graduate school of university. Just like, for example, understanding Pipeline Processing as higher performance technology is a introductory talk for the advanced architecture themes such as Super-pipeline, Superscalar, VLIW and so on. In our university, a semester has only 15 weeks for every lecture and always suffers from lack of time enough to educate several items for students. This is one of reasons to develop our visual computer simulator described in the previous section. From such a viewpoint for lecture, it is necessary to utilize an educational tool for efficient lecture and provide an e-Learning tool for effective exercise environment. Essay problems of Computer Architecture are shown in the following style:

$$(1)\ \sum_{i=1}^{10}(2*i)+10 \quad , \quad (2)\ \sum_{i=0}^{3}A(i) \leftarrow A(0)=1000, A(1)=900, A(2)=50, A(3)=5$$

These are useful to understand Arithmetic Algorithm with iteration, register-register operation, and usage of index-register based indirect address modification. If a student writes such programs and investigate them using our visual simulator, he/she can recognize simple concept of vonNeumann computer architecture.

3.2 Relation between Essay and Two Kinds of Tests for Computer Architecture

In lecture of "Computer Architecture", students are requested to write assembly programs and verify their programs with our visual simulator. At the same time, they also ought to check by themselves whether they understand vonNeumann computer architecture or not. Contents of a short test include some items other than assembly programming or algorithm. So there is not always sure that the students, who used to operate our visual simulator very well, obtain excellent scores in such a test. It can be assumed that the contents of the test have very few factors to relate skill of visual simulator. Under these conditions, there is a result of comparison between Essay's Scores from students and Scores of Short Test by the same students shown in Fig. 3.

There is a certain correlation of Scores between Essay and Short Test. So we can confirm that understanding vonNeumann computer architecture is significantly affected by writing essays with usage of visual computer simulator, VisuSim.

It is also investigated whether there is any relation of Scores between Essay and semester-end Examination or not. It has been not yet a perfect investigation and confirmation to analyze any relation between Essay and Examination yet. We should not exactly mention about a kind of relation between Essay and Examination. So we only show some kind of good correlation of Scores between Essay and Examination as is shown in Fig. 4.

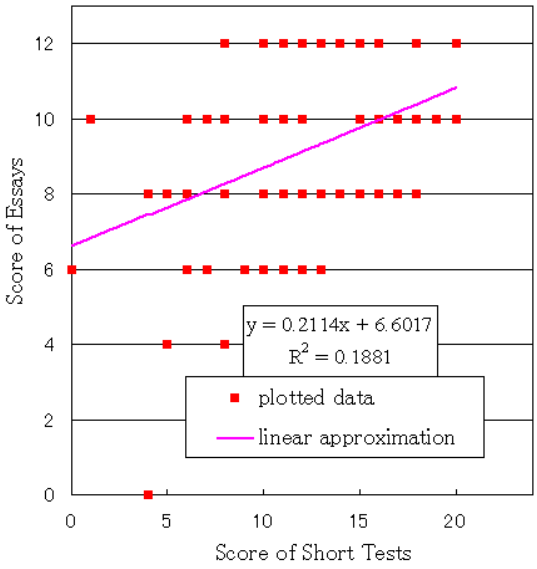

Figure 3. Relation of Scores between Essay and short Test of the same student.

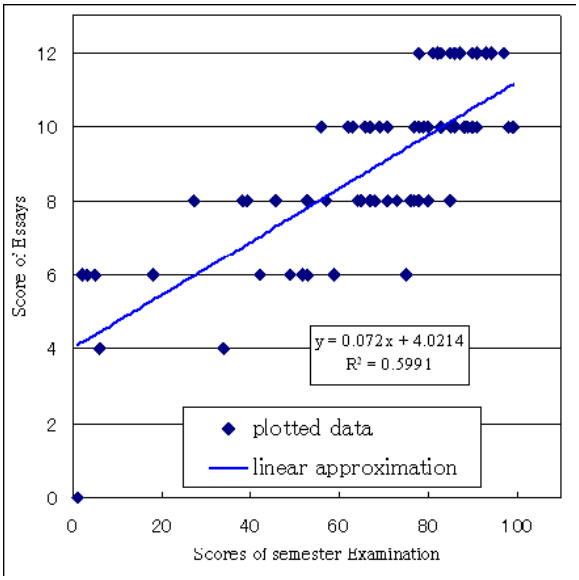

Figure 4. Relation of Scores between Essay and semester-end Examination.

3.3 Qualitative and Quantitative Evaluation of our Simulator

There are some comments and recommendation described in Essays from the students, who learned "Computer Architecture" in 2009. We think that these comments and others scripts are considered to be real and precious evaluation for our simulator. They must be subjective, of course. However, they can be also qualitative evaluation about our simulator VisuSim from the students who were real users of it. Some of positive comments are as follows:

1) It is easy to verify and point out mistakes through step-by-step execution and display the result by VisuSim.
2) I can check change for contents of registers and memory provided by VisuSim.
3) As I use sample programs through VisuSim, it is good enough for me to write new similar ones.
4) It is very important that I can easily understand how a computer works, because VisuSim visualizes interpretation and calculation of my programs graphically.
5) I can recognize characteristics of Stored Programming during writing programs and my essay.

The above positive comments may be considered as positive evaluations for our visual simulator. At the same time, however, there are some of negative comments in the relevant Essays, which are as follows:

6) It is difficult for me to operate VisuSim, so I must help my friends teach me to operate it. Finally I do write my essay only just until deadline.
7) When I modify my program, I have found mistake at the point where program jump from another routine. So I must adjust and shift the according routine.

These are not convenient so that I think it is necessary to be improved. These comments must be considered to be precious recommendations for improvement of VisuSim and teaching methods. We should have a plan to modify our visual simulator from these feedbacks

"Computer Literacy" is an introductory lecture for beginners of "Computer Architecture" at the first year of our university. Table 1 shows the relation of learners' scores between the reports using VisuSim for understanding computer and examinations for "Computer Literacy". The number of learners is 81. The ranks of the scores for reports are classified from A+ to D (ascending order), while the ranks of the scores for examination are "Superior", "Excellent", "Good", "Fair" and "No Good", respectively. Based on this table, we try to evaluate our visual simulator VisuSim by means of test of significance as follows.

Table 1. Distribution of Learners' Scores for Report and Examination

	Superior	Excellent	Good	Fair	NoGood	number
A+	8	13	3	2	1	27
A	2	15	10	4	0	31
B	0	0	3	2	0	5
C	0	0	1	2	5	8
D	0	0	0	2	8	10
total	10	26	17	12	14	81

H0 is a null hypothesis: "using VisuSim is independent from learners' scores of Computer Literacy." A chi-square test is used to decide whether the null hypothesis H0 holds or not. With data of Table 1, the chi-square statistic is

$$\chi^2 = \frac{(8-27\cdot 10/81)^2}{27\cdot 10/81} + \cdots + \frac{(8-10\cdot 14/81)^2}{10\cdot 14/81} = 87.5 \ .$$

By the way, the significance of the chi-square statistic is evaluated for (5-1)*(5-1) degrees of freedom. The chi-square percentile with (5-1)*(5-1) degrees of freedom at the 5% significance level is

$$\chi^2_{0.05}(16) = 26.3 \ .$$

From this result, the null hypothesis H0 is rejected and the alternative is accepted. An evidence of the above analysis indicates that a relation between using VisuSim to understand "Computer Literacy" and the learners' scores of "Computer Literacy" shows a statistically significant dependency. So it is said to be statistically significant that using of our visual simulator is effective to learn "Computer Literacy".

4. COLLABORATIVE LEARNING IN MULTIPLE SERVER SYSTEM ENVIRONMENT

This section explains two types of applications of distributed multiple server system, namely, implementation of collaborative learning environment and distributed surveillance system for emergency communication.

4.1 Collaborative Learning Environment

In order to manage our educational tool effectively, it is indispensable to design and implement a special-purpose information server, which can provide some kinds of information-exchanging environment for the tool and its users. With such a server, the tool can play the very important role to carry out communication among users. Built-in e-mail handlers of the tool realize such communication between users, i.e. a learner and an instructor. Learners using our tool, visual computer simulator, can obtain their necessary information from the special-purpose information server through its communication supporting functions according to their understanding levels. So the information server needs the following three basic functions.

4.1.1 Web Service Functions

They are very much essential to deliver the program (executable) code of Simulator and sample (source) programs for Simulator. They correspond to HTTP-based communication with 3-way hand-shaking procedure. Additionally, They support FTP-based data transferring service.

4.1.2 e-Mail Service Functions

Simulator can support the communication and information-sharing mechanism among users by means of SMTP-based and/or POP3-based facilities. It is necessary for the server to be implemented to provide SMTP-transferring server function and POP3-receiving server ones.

4.1.3 User Management Service Functions

There must be user management functions in the server, not only because of POP3-service but also because of user identification to recognize user's understanding level. The former is necessary to realize POP3-service, while the latter is essential to specify user's level to utilize simulator more effectively.

With these functions, the special-purpose information server prepares necessary and minimal conditions to realize communication supporting and information-exchanging environment for the educational tool and its users.

4.2 Cooperation among Multiple Servers System

The previous information server simply employed one server system for all the users' management, user identification with serial number, so that there were some regulations such as not so good two-way authentication among users, not so efficient information transmission and/or sharing between different level of users, etc.

Now we have employed a new resolution of Cloud Service to group all the users into cluster and assign such a cluster to one server as one of temporary expedients for management of users among multiple servers. Of course, the above palliative treatment is not effective for cooperation among multiple servers. Fig. 5 shows implementation of collaborative learning environment for our educational tool with a distributed multiple server system.

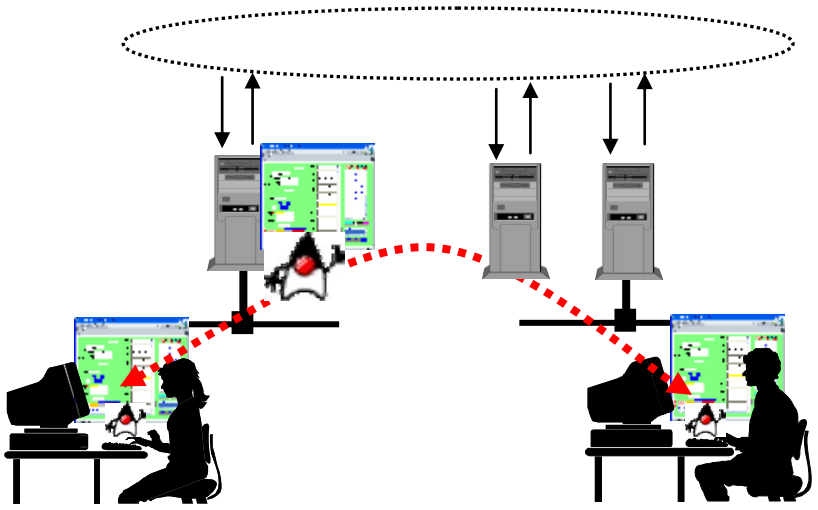

Figure 5. Collaborative learning environment on multiple server system for Visual Computer Simulator

It is necessary to establish more effective methods to organize and cooperate different servers. One of those is to utilize e-mail function of the educational tool and communication facilities between its users. An then all the users of the tool are registered on the shared user database and their mail spool area and users' home directories are created in the shared volume area by means of NIS/NFS or SAMBA (or Network-Attached Storage) facilities.

Flexible user identification is necessary to allow hierarchical user naming. With introduction of LDAP (Lightweight Directory Access Protocol) based authentication, it is very much smooth to manage the users among multiple servers and easy to implement flexible user authority for such servers. Although this is a useful method for user management, it will be suffering from some dangerous intrusion without closed network based characteristics and benefits. Security problems are very much heavily serious and expensive to protect correctly and urgently. Additional facilities such as NAT/NAPT (Network Address (& Port) Translation) mechanism will be implemented into a new information server simultaneously. So that will be one of future problems to be resolved for practical cooperation in a distributed environment.

4.3 Related Works

First of all, visualization is an absolutely necessary keyword and idea to improve the learner's understanding level. For example, when instructors educate their learners about computer, they want to use effective educational tools. These tools are expected to have some kind of function to visualize what is difficult to understand. With such tools, many learners will understand computer in a shorter period than other cases without using visualization tool.

4.3.1 Three Simulator Tools for Teaching Computer Architecture

Yehezkel et al. have pointed out that teaching computer architecture is not an easy task. So they provide three types of simulators with visualizations for different computer architectures. They are (a) EasyCPU for the Intel 80x86 families; (b) Little Man Computer for a general von Neumann computer architecture; and (c) RTLSim simulator for a MIPS-like CPU [1]. They are excellent works, but their GUIs are neither general nor common. It is difficult for beginners to use different GUIs of education tools in the related educational fields.

4.3.2 Simulators over the Network

Llamas-Nistal et al. have designed, implemented and tested a Web-based learning system in pure Java. They have attempted to stay within those standards what are suggested for distance learning, particularly Web-based collaborative distance learning [2]. From their paper, an architecture education of their system seems to be well conceived because of its visualization. Their academic results and opinions from their students who have utilized their system are generally. But the function of simulation is limited for a mid-level or lower computer course, so it seems to be not so useful enough to be applied to assembly programming exercise including recursion.

4.3.3 The MARIE Computer Simulator

Null et al. have prepared MarieSim (a computer architecture simulator based on the MARIE architecture) to teach beginners to study computer organization and architecture. It provides interactive tools and simulations to help them deepen their understanding. The graphical environment for MarieSim is written in Java Swing and seems to be useful in introductory computer architecture[3]. But MARIE employs accumulator-based simple architecture, so that it is not so suitable enough to execute recursive assembly program and moreover the MarieSim is not completely web-based but Java stand-alone application. It is not so convenient.

Secondarily, Web-based educational tools have realized powerful and fruitful results from scientific field to computing one. The second half of this section focuses the following two researches as the related works based on Web-based e-Learning system with effective GUIs.

4.3.4 Integrated Component Web-based Interactive Learning Systems for Engineering

Humar et al. have proposed a strategic approach to integrate already-developed components for development of a web-based learning environment. Although examples from their system only demonstrate how the system can be used with a course on electromagnetism, however, their basic approach must be applicable in other fields of engineering and natural science [4].

4.3.5 A Web-based Educational Environment for Teaching the Computer Cache Memory

Grigoriadou et al. have introduced a Web-based educational environment for teaching the computer cache memory and shown their aims to support and enhance the learning process for such a special and normally-invisible memory. The results obtained from the application/evaluation of such a Web-based environment are to indicate that the simulation and such an approach can effectively support and enhance the learning process [5].

Other related works are listed in the last references, as follows; Moure et al[6] have developed The KScalar simulator not only for ``Computer Architecture Education" but also for normal professional usage. Dr. Chen [7] has designed and (maybe as his trial challenges) implemented an Automated Feedback System for Computer in order to utilize and improve his and other teachers' educational environments. Both of Huey-Ing Lui and Min-Num Yang [8] have originally designed and developed an excellent e-Learning system, which can provided QoL guaranteed adaptation and personalization in e-Learning systems. Djordjevic et al.

[9] have already developed and utilize Web-based Educational System for Computer Architecture Teaching in their university. And finally, we would like to introduce our related work about VisuSim in paper [10].

From the surveys of above described works, we have decided to design a Web-based educational tool with visualization and implement an effective GUI in order to support user-friendly learning process. The following three sections illustrate the detail of our Web-based educational tool for Computer Literacy and Architecture as focusing the characteristics of its GUI.

5. CONCLUSION

This paper describes summaries of a visual computer simulator, some trial evaluation of the simulator, and organization of multiple server system for collaborative learning with the simulator. And it introduces related works for computer simulators and Web-based e-Learning tools. Through the above explanation, our conclusion is summarized as follows:

1) The visual computer simulator has been evaluated in qualitative and quantitative approaches based on users' comments and statistical analysis for relation between essay and two kinds of tests of "Computer Architecture".
2) It is confirmed to be statistically significant that using of our visual computer simulator VisuSim can be effective to learn "Computer Literacy".
3) It shows an overview of distributed multiple server system for collaborative learning with the simulator. Such an environment will be useful and effective for practical education. But there are some problems to be resolved for practical education, just like security and external violation.

REFERENCES

[1] Yehezkel, C., Yurcik, W., Pearson, M., et al. (2001). Three Simulator Tools for Teaching Computer Architecture: Little Man Computer, and RTLSim. ACM Journal of Educational Resources in Computing (JERIC, Vol.1, No.4, pp. 60-80). NY: ACM Press.

[2] Llamas-Nistal, M., Anido-Rifón, L. and Fernández-Iglesias, M.: Simulators over the Network. IEEE Trans. Educ., Vol. 44, No. 2, p.212, CD-ROM folder 09 (May 2001)

[3] Null, L. & Lobur, J. (2003). MarieSim: The MARIE Computer Simulator. ACM Journal of Educational Resources in Computing (JERIC, Vol.3, No.2, Article #1, 29pages). NY: ACM Press.

[4] Humar, I., Sinigoj, A.R., Bester, J. , et al. (2005). Integrated Component Web-based Interactive Learning Systems for Engineering. IEEE Transactions on Education (Vol.48, No.4, pp.664-675).

[5] Grigoriadou, M., Kanidis, E. & Gogoulou, A. (2006). A Web-based Educational Environment for Teaching the Computer Cache Memory. IEEE Transactions on Education (Vol.49, No.1, pp.147-156).

[6] Moure, J. C., Rexachs, D.I., Luque, E.(2002). The KScalar simulator. ACM Journal of Educational Resources in Computing (Vol.2, No.1, pp.73-116).

[7] Chen, Peter M.(2004), An Automated Feedback System for Computer. IEEE Transactions on Education (Vol.47, No.2, pp.232-240).

[8] Lui, Huey-Ing, Yang Min-Num(2005). QoL guaranteed adaptation and personalization in E-learning systems. IEEE Transactions on Education (Vol.48, No.1, pp.147-156).

[9] Djordjevic,J., Nikolic,B., Milenkovic,A.(2005). Flexible Web-Based Educational System for Teaching. Computer Architecture and Organization. IEEE Transactions on Education (Vol.48, No.2, pp.264-273).

[10] Imai,Y., Kaneko,K1., Nakagawa, M.(2006). Application of a Visual Computer Simulator into Collaborative Learning. Journal of Computing and Information Technology (Vol.14, No.4, pp.267-273).