UKACC International Conference on Control 2012
Cardiff, UK, 3-5 September 2012

Survey and Evaluation of Simulators Suitable for Teaching for Computer Architecture and Organization

Supporting Undergraduate Students at Sir Syed University of Engineering & Technology

Raza Hasan
Computer Engineering Department
Sir Syed University of Engineering & Technology
Karachi, Pakistan
raza_6@hotmail.com

Salman Mahmood
Computer Engineering Department
Sir Syed University of Engineering & Technology
Karachi, Pakistan
salmanm@ssuet.edu.pk

***Abstract*— Advancement in computer system hardware makes it difficult to meet the demands of teaching computer architecture and organization. Visualization of different architectures enhances the learning process among students by using simulators. This paper attempts to give a survey on the following simulators (1) Electrical Numerical Integrator and Computer (ENIAC) was the first electronic digital universal computer built at Pennsylvania University in 1944-1946., (2) The Visible Virtual Machine (VVM) based on Little Man Computer (LMC) which is general for von Newmann computer architecture, (3) MARS an Education-Oriented MIPS Assembly Language Simulator, (4) Logisim for simulating digital logic circuits and (5) SPIM for MIPS Assembly Language Simulator that are going to be taught in the course Computer Architecture and Organization by the faculty members. Also, evaluate the selected simulators according to the criteria established in the course meetings.**

Keywords-component Computer Architecture and Organization; Simulation; Evaluation; Electrical Numerical Integrator and Computer; The Visible Virtual Machine; MARS; LOGISIM; SPIM;

I. INTRODUCTION

Computer-based graphical simulators are widely used in universities to support the teaching of computer architecture [1].These range from relatively simple, visual simulators to advanced, complex simulators for research and product development. One area where software simulators have become almost indispensable is in undergraduate computing courses [2].These simulators are often used to aid student's understanding of complex technologies which are difficult to conceptualize and visualize without the help of graphical animations that the modern simulators can offer [1].

Advancement in computer system hardware makes it difficult to meet the demands of teaching computer architecture and organization. Visualization of different architectures enhances the learning process among students by using simulators. Rather making a comprehensive simulator that can cater the requirement for the course, available simulators can serve the purpose as they can save time resource, ease of use, capacity to learn the concepts to fullest which are delivered in the course, can be accessed anywhere and anytime by the students. Finding the appropriate simulator for the course is a difficult task. Similar study was also conducted [3].

The paper describes the evaluation process followed before the induction of simulators in the course. The paper is organized as follows: Section II gives the teaching strategy followed in the course. Section III describes the criteria for which the simulators were selected. Section IV introduces the evaluation process. Section V describes the questionnaire design. Section VI concludes the results and Section V concludes the paper.

II. THE TEACHING STRATEGY

There was a lack of giving students the exposure of different architectures visualization through graphical representation. Instead, they receive the theoretical aspect of internal structure and components of the computer, how the instruction are being executed and handled by different architectures. This problem can be handled by the use of simulators.

For the batch 2010, currently enrolled in their 5th Semester, the course Computer Architecture and Organization was restructured to two hours of lectures and two hours of laboratory work per week whereas before it was only three hours of lectures per week. This way the gap between theoretical and practical work was removed.

III. CRITERIA FOR SELECTING SIMULATORS

As advised by **Chairman** *Computer Engineering Department* **Dr. Syed Misbahuddin** of *Sir Syed University of Engineering & Technology* the simulators that need to be the part of the course should possess certain properties and should be tested by the instructors before it is included in the laboratory work. The characteristics that a simulator should possess are usability, availability and topics covered in the lectures.

IV. EVALUATION PROCESS

Although simulator imitates a device near to reality but it is necessary to evaluate its effectiveness to which it can be inducted into the course as a teaching aid and to support the learning of the students.

A. Methodology

The evaluation of the simulators was based on the criteria discussed earlier. For evaluation both qualitative and quantitative methods was used. For qualitative method Opinion survey using 5-point Likert scale and having open ended questions as well. For quantitative method describing the data numerically measure of center and location technique was used to interpret the data gathered from the survey.

B. Participants

The participants were composed of eight faculty members teaching the course of Computer Architecture and organization. Among eight, two were Assistant Professors and two were Lecturers who are responsible to give lectures in the lecture room. Two Research Assistant and Junior Lecturer assisting any one of the above in the Laboratory was also included in the survey.

V. QUESTIONNAIRE DESIGN

The opinion survey questionnaire was given to the faculty members (Sample Size N=8). Each survey was conducted for each simulator making it five surveys consists of four parts. Part A consists of the information about the participant's profile; Part B consists of the information for the simulator usability and the recommendations was taken from []. Part C consists of the information for the simulator availability. Part D consists of the information relevance to the course contents covered by the simulator which was further divided into four sub categories: *Fundamentals of Computer Architecture, Memory System Hierarchy, Communication and Interfacing and Processor System Design.* Values for likert scale in the questionnaire used is as follows 1= Strongly Agree (value = 2) 2= Agree (value = 1) 3= Not Sure/Not Applicable (value = 0) 4= Disagree (value = -1) 5= Strongly Disagree (value = -2)

In the first part, questions 1 to 5 focus on the profile of the respondents. As the respondents type was homogenous so the profile was drawn with close ended questions.

In the second part, questions 6 to 19 focus on the simulator usability. This part of the questionnaire is to achieve the usability of the simulator that needs to be included in the course. To achieve information about the simulator usability the faculty members were asked to evaluate from 1 to 5 their satisfaction and the simplicity about the simulator.

In the third part, questions 20 to 22 focus on the simulator availability. This part of the questionnaire is to find out that the simulator can be used anywhere anytime and on different platforms. To achieve information about the simulator availability the faculty members were asked to evaluate from 1 to 5 their satisfaction.

In the fourth part, it is divided in four categories related to the course contents and the topics that the simulator covers. First category *Fundamentals of Computer Architecture*, questions 23 to 28 focus on the fundamental concepts of computer architecture. To achieve information about these, faculty members were asked to evaluate from 1 to 5 their satisfaction. Second category *Memory System Hierarchy*, questions 29 to 36 focus on the performance issues. To achieve information about these faculty members were asked to evaluate from 1 to 5 their satisfaction. Third category *Communication and Interfacing*, questions 37 to 40 focus on the communication between the peripherals and interaction between the components. To achieve information about these faculty members were asked to evaluate from 1 to 5 their satisfaction. Fourth category *Processor System Design*, questions 41 to 45 focus on the substrate of processor logic implementation. To achieve information about these faculty members were asked to evaluate from 1 to 5 their satisfaction.

VI. RESULTS

Below are the summary of the evaluation based on the opinion survey:

A. Qualitative Analysis

Five opinion surveys were conducted. All before the start of the semester and total of eight faculty members participated in the survey. Figure 1 shows the criteria on which the survey was conducted. The strongly agree/agree and the strongly disagree/disagree results are aggregated and the results are presented below

Simulator	Criteria	Strongly Agree + Agree (%)	Strongly Disagree + Disagree (%)	Not Sure (%)
ENIAC	Usability	86.6	5.4	8
	Availability	100	0	0
	Fundamentals of Computer Architecture	62.5	27.1	10.4
	Memory System Hierarchy	19	64	17
	Communication and Interfacing	53.1	28.1	18.8
	Processor System Design	75	20	5
VVM	Usability	98.2	1.8	0
	Availability	100	0	0
	Fundamentals of Computer Architecture	97.9	2.1	0
	Memory System Hierarchy	45.3	31.3	23.4
	Communication and Interfacing	96.9	0	3.1
	Processor System Design	85	7.5	7.5
MARS	Usability	99.1	0.9	0
	Availability	100	0	0
	Fundamentals of Computer Architecture	100	0	0
	Memory System Hierarchy	75	6.3	18.7
	Communication and Interfacing	100	0	0
	Processor System Design	92.5	5	2.5
Logisim	Usability	100	0	0
	Availability	100	0	0
	Fundamentals of Computer Architecture	33.3	66.7	0
	Memory System Hierarchy	25	75	0
	Communication and Interfacing	0	100	0
	Processor System Design	60	40	0
SPIM	Usability	100	0	0
	Availability	100	0	0
	Fundamentals of Computer Architecture	100	0	0
	Memory System Hierarchy	100	0	0
	Communication and Interfacing	75	6.3	18.7
	Processor System Design	100	0	0

Figure 1.

The survey indicates that the usability and availability was high for the simulators under examination. Different simulators cover different architectures and depending upon the

architecture they cover few concepts high as compared to others. As logisim is a specific for simulating digital logic circuits so it has low percentages in Part D as it covers fewer concepts related to the course as compared to the others. The survey indicates overall, faculty members agreed of the above simulators to be fulfilling the criteria to be included into the course.

B. Quantitative Analysis

Qualitative analysis givens an opinion of the faculty members about the simulators usability, availability and the relevance of contents covered in the course. As the questionnaire consists of ordinal data in likert scale and the result was aggregated in percentage upon the members agreed upon and disagreed upon. To check the discrepancies with the parts of the questionnaire measure of center and location technique was used such as mean, median and mode. Due to the nature of the data collect was ordinal median gives the best measure of the *middle.* Due to the range of scale used for the data collection was between -2 to 2 so the mean values came in negative range. Below are the values

Simulator	Criteria	Mean	Median	Mode
ENIAC	Usability	1.136	1	1
	Availability	2	2	2
	Fundamentals of Computer Architecture	0.688	1	2
	Memory System	-0.36	-1	-1
	Communication and Interfacing	0.345	1	1
	Processor System Design	0.702	1	1
VVM	Usability	1.458	1	1
	Availability	1.6	2	2
	Fundamentals of Computer Architecture	1.523	2	2
	Memory System	0.283	-0.25	-0.5
	Communication and Interfacing	1.19	1	1
	Processor System Design	1.078	1	1
MARS	Usability	1.332	1	1
	Availability	2	2	2
	Fundamentals of Computer Architecture	1.398	1	1
	Memory System	0.923	1	1
	Communication and Interfacing	1.345	1	1
	Processor System Design	1.178	1	1
Logisim	Usability	1.555	2	1.5
	Availability	2	2	2
	Fundamentals of Computer Architecture	0	-1	-1
	Memory System	-0.25	-1	-1
	Communication and Interfacing	-1	-1	-1
	Processor System Design	0.8	2	2
SPIM	Usability	1.42	1.25	1
	Availability	2	2	2
	Fundamentals of Computer Architecture	1.833	2	2
	Memory System	1.5	1.5	2
	Communication and Interfacing	1.283	1.5	2
	Processor System Design	1.15	1	1

Figure 2.

The values of corresponds correctly to the percentage of the qualitative analysis. It was seen that the aggregate percentage of strongly disagree/ disagree increases made the effect of the quantitative values towards negative. The value of median in decimal was calculated as there are two median values so adding the both values and divided by two. Rest of the percentage of the qualitative analysis correspond the values of median for the quantitative analysis.

VII. Conclusion & Future Work

Use of simulators in studying Computer Architecture and Organization help the students in understanding the concepts delivered in the classroom. The strategy adapted in the study discussed the usability, availability and the course contents covered by different simulators before inducting them into the laboratory work. Survey was conducted between faculty members and evaluated using qualitative and quantitative analysis.

The evaluation, based on the criteria laid by the faculty members and also the input from the department chairman, as no simulator covers all topics so combination of simulators were surveyed depending upon different architecture and the topics covered in class room. The overall result was satisfactory and it was decided to include all of the simulators in the laboratory work.

In future, survey on simulators would be conducted and see what are the difficulties faced by the students and what students benefited from use of simulators.

Later evaluation will be conducted on the knowledge grasped by students from the use of simulators by comparing the past results of students when there was no laboratory work conducted in comparision to the current result of the students and will see if there is any significant difference in the behavior of the students learning process.

Acknowledgment

The authors acknowledge the encouragement, support and guidance given by Chairman Computer Engineering Department **Dr. Syed Misbahuddin** to prepare Lectures, Laboratory manual and selecting simulators.

Special thanks to all other faculty members for helping during the research and giving their valuable suggestion and guidance.

References

[1] B. Chalk, “Evaluation of a cache memory simulator to support the teaching of computer architecture”,3rd LTSN-ICS Annual Conference, August 27-29, 2002, Loughborough, UK. URL: http://myweb.lsbu.ac.uk/~chalkbs/research/research.html

[2] Mustafa, B.; , "Modern computer architecture teaching and learning support: An experience in evaluation," Information Society (i-Society), 2011 International Conference on , vol., no., pp.411-416, 27-29. URL: http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=5978481&isnumber=5978433

[3] Nikolic, B. Radivojevic, Z. Djordjevic, J. Milutinovic, V. , "A Survey and Evaluation of Simulators Suitable for Teaching Courses in Computer Architecture and Organization," *Education, IEEE Transactions on* , vol.52, no.4, pp.449-458, Nov. 2009 DOI:10.1109/TE.2008.930097
URL: http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=4967893&isnumber=5291647.