Developing an Innovative and Pen-based Simulator to Enhance Education and Research in Computer Systems

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Abstract

The recent advance in pen-based computing and mobile devices empowers many innovative e-learning systems with increased interactivity and improved features. In this paper, we proposed an innovative and pen-based COMPAD simulator to enhance both education and research in computer systems. Being model-based, our proposed system is adaptive and different from many commercially available Windows-based emulators that are customized for specific computer architectures. Besides, our COMPAD simulator allows learners to flexibly modify any part of a program through pen-based inputs, and instantly visualize the computed results. In this way, the COMPAD simulator can support not only education but also research such as instruction scheduling in computer systems. To demonstrate the feasibility, we built the COMPAD-PRO as its prototype for empirical evaluation. After all, this work stimulates many interesting directions for further exploration.

1. Introduction

Due to the fast development of mobile devices such as smart-phones, sub-notebook, tablet and ultra-mobile personal computers (UMPCs) [7] in recent years, pen-based computing has stimulated many innovative applications of e-learning technologies [2] with increased interactivity, more adaptive styles for user interface [9] and more sophisticated features such as personalized learning profile or history, possibly with the use of intelligent character or symbol recognition techniques [4]. Besides, the Microsoft Center for Research on Pen-Centric Computing [6] provides a common repository with interesting projects and published results to foster the exchange of ideas between practitioners or researchers in pen-based computing for education, especially under the theme of Mobile Computing in Education (MCE). There were several attractive projects including the AlgoSketch [6], the MathPad^2[3] and Music Notepad [6] that clearly demonstrated the innovative uses of pen-based input to facilitate detailed explanation or interactive discussion in algorithm design, mathematical problem-solving, and musical composition wherever appropriate.

From our past years of observation, with the use of command-line or Windows-based emulators customized for specific computer architectures such as the Motorola MC68000 family of microprocessors, many students in schools of Engineering or other disciplines may often encounter difficulty in understanding or visualizing the essential operations performed for program execution. A key drawback of the interface of such emulators is difficult-to-use, demanding the students to memorize and key in commands for checking or setting the environment or variables for program execution. In view of the ample opportunities opened up by pen-based computing and mobile devices, we proposed a innovative and pen-based COMPAD simulator to enhance both education and research in computer systems.

This paper is organized as follows. Section 2 reviews the system design of our proposed COMPAD simulator. Its prototype implementation and empirical evaluation will be explained in Section 3. Lastly, the concluding remarks are given in Section 4.

2. System Design

The COMPAD is a visual simulation tool that clearly shows the internal registers, memory and more importantly the data flow of the computer architecture. Essentially, it is a very flexible, model-based and also pen-based simulator that supports the program execution on various computing systems. Given an assembly source program, possibly inputted via the stylus pen of tablet PC or selection of commands from its drop-down menu, and the underlying execution

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model specified in several configuration (or schema) files, the simulator can quickly show the key events such as changes in registers or memory, and lastly the computed results through a dynamically generated sequence of animation. The speed of the animation can be flexibly adjusted by the end users. The pen-based input may naturally increase the interactivity of the system with the users since they can easily modify any part of an assembly program on the screen, and instantly visualize the generated results.

Figure 1 gives the system design of our proposed COMPAD simulator in which the core function is provided by the COMPAD simulation engine. The simulation engine reads in the 3 configuration files as the architecture configuration, the instruction-set configuration and the execution model as required for any specific computer system, and then interpret the inputted source program to generate the sequence of attractive animation to highlight the significant events occurred for registers or other key components of the underlying computer system during the program execution.

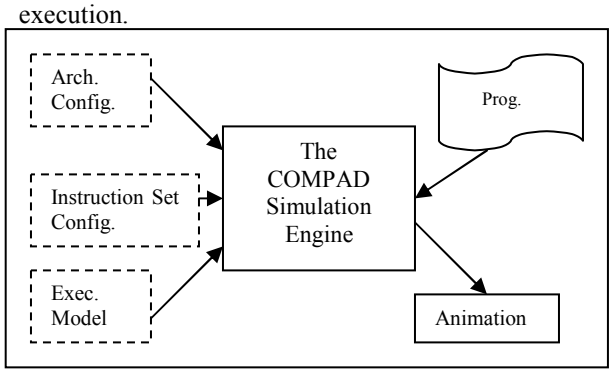

Fig. 1 – The System Design of the COMPAD Simulator

Whenever a part of the program is updated, an interrupt request will be produced to enforce the COMPAD simulation engine to regenerate the part of animation codes being affected so as to ensure a faster response time and therefore higher interactivity with the end users.

3. Prototype Implementation and Evaluation

To demonstrate the feasibility of our proposal, we implemented a prototype named COMPAD-PRO using the C# programming language on the Microsoft .NET development platform since our prototype was intended to be executed on the pen-based mobile computing devices such as the tablet or ultra-mobile PCs. The current prototype implementation consists of approximately 3,800+ lines of source codes, including around 2,300 lines of C# codes for the COMPAD simulation engine and the interface for the assembly program input and animation, and the remaining 1,500+ lines for the 3 configuration files involved. It took 4 man-months for the design and implementation of our COMPAD-PRO simulator.

Figure 2 shows the user interface of our COMPAD-PRO simulator. It consists of tabbed window display on the left side for the input of assembly program and the display of register values. The middle area displays the generated animation with a "speed" button for end users to flexibly adjust an appropriate speed of the animation. The bottom part is the message window that shows the key events or operations during the animated program execution.

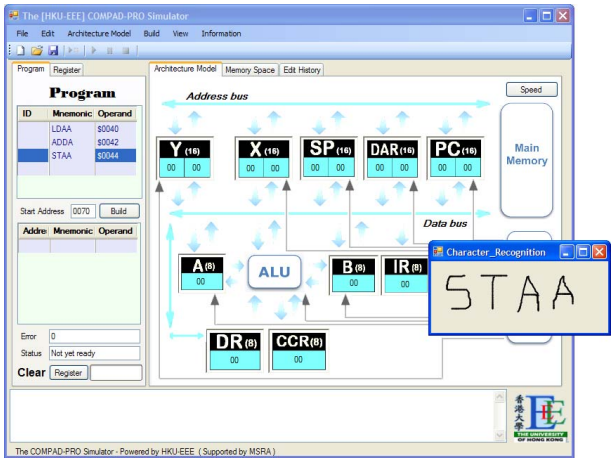

Fig. 2 – The User Interface of the COMPAD Simulator

By the end of the Spring semester, we would come back to conduct a thorough evaluation with both questionnaire and interviews to investigate whether our simulation tool can really promote the learners' interests and possibly their performance as well after a longer period of uses. After some careful analysis, a detailed report about the evaluation results will be published in October, 2009.

4. Concluding Remarks

In this paper, an innovative and pen-based COMPAD simulator is proposed to enhance both education and research in computer systems. Being model-based, our proposed system is adaptive and different from many commercially available Windows-based emulators that are customized for specific computer architectures. Besides, our COMPAD simulator allows learners to flexibly modify any part of a program through pen-based inputs, and instantly visualize about the

computed results. In this way, the COMPAD simulator can support not only education but also research such as instruction scheduling in computer systems.

The simulator has been tested by different users who gave us fairly positive feedbacks. Around the middle of February 2009, the simulator was released to motivate the students' learning interests, and facilitate their understanding on the operations of modern computer systems in the Department of Electrical and Electronic Engineering, the University of Hong Kong. More importantly, our proposed COMPAD platform was useful not only to support undergraduate or postgraduate teaching, but also to facilitate research discussion. We had spent 4 man-months to work on the simulator and thoroughly tested the prototype. A project website was set up for the students to download the simulator software or any updated schema files for the concerned computer architectures.

Clearly, our proposal of adaptive and pen-based simulator for computer systems has opened up many interesting directions for further investigations. First, the current implementation of our COMPAD-PRO simulation engine to generate attractive animation is still computationally intensive, thus with inadequate performance when our simulator is executed on sub-notebook or ultra-mobile PCs with slower processors running at 800Mhz or below. Hence, optimizing our implementation is a task certainly worth investigating so that our simulator can be executed with reasonable performance on other mobile computing devices such as the Apple™ iPod Touch or even smart-phones. In addition to facilitate the teaching of more advanced undergraduate or postgraduate courses in computer systems, it is interesting to study how to include other new or more sophisticated computer architectures into our existing prototype. Last but not least, it is exciting to explore how to improve our COMPAD simulator to provide better animation and visualization so as to support the research study such as instruction scheduling in computer systems.

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