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Building An Interactive Simulator on A Cloud Computing Platform to Enhance Students' Understanding of Computer Systems

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Abstract—Cloud computing technologies have been widely adopted to improve the competitiveness and efficiency of core operations in many enterprises through additional computational resources and/or storage as provided on the underlying cloud platforms. Yet there are relatively few studies on how cloud computing may enhance students' understanding of a specific subject in e-learning systems. In a research project awarded by the Microsoft Research Asia, we successfully developed an interactive simulator aimed to enhance the students' understanding of essential concepts related to computer systems through live animations on a cloud computing platform. Essentially, we propose to integrate the latest technologies of cloud computing and learning objects into an efficient, flexible and interactive simulator to deliver powerful computing services for dynamic simulations of various computer systems specified as "reactive" models of learning objects on the cloud storage. More importantly, through adopting the IEEE learning object metadata standard to represent each key concept/component in different computer systems, our proposed simulator can readily facilitate the sharing and reuse of relevant concepts for future e-learning applications. The system design and prototype implementation of our cloud-based interactive simulator is carefully considered with a thorough evaluation plan to investigate on how learners may benefit from our interactive simulator in various ways. And there are many directions for future extensions.

Index Terms—cloud computing; e-learning systems; interactive simulators; learning objects.

I. INTRODUCTION

In recent years, cloud computing technologies have been frequently used to improve the competitiveness and efficiency of critical operations or services in many enterprises or government units through extra computational resources and/or storage as provided on the underlying cloud platforms. However, there are relatively less work aimed to explore on how cloud computing may enhance students' understanding of a specific subject in e-learning systems. Through careful observations on a foundation year course on Computer Systems in the Faculty of Engineering, the University of Hong Kong over the past decade, we found that many Engineering students encountered difficulty to a certain extent in understanding some essential concepts in computer systems, such as the program execution and the underlying data transfer among the various devices/registers in a specific computer system.

Intrinsically, these concepts are abstract and often involve a complex knowledge structure, and therefore are difficult to understand. Furthermore, most existing simulators for computer systems are text-based and mainly focused on showing the final results after program execution without clearly showing the underlying "operations", and particularly the essential components/concepts involved during such operations. In many cases, students are simply presented with the final result(s) without knowing how such result(s) are produced. Undoubtedly, several existing simulators can only provide a limited set of debugging functions such as monitoring the values of selected registers at a certain step during the program execution. However, without knowing which components, or specifically internal registers, are actually involved in the process, it is totally impossible and meaningless to use such debugging functions for monitoring the changes of values on all the registers in order to better understand the behavior of program execution in the specific computer system. In a recent research project awarded by the Microsoft Research Asia (MSRA), we successfully built an interactive simulator, namely the COMPAD+ simulator as an extended version of the original "learning PAD for COMputer systems" (COMPAD) on a cloud computing platform, that will greatly enhance students' learning of essential concepts related to computer systems through the live animation of program execution for a specific computer architecture.

The original COMPAD simulator [1] was developed as a standalone e-learning application to run on the Microsoft .NET platform on any desktop or notebook computers whereas our enhanced COMPAD+ simulator is newly designed and built on the Windows Azure Cloud platform to provide "anytime and anywhere" simulation services for our students to revise essential concepts on computer systems through web browsers running on their mobile devices such as smartphones or tablet PCs. Intrinsically, our COMPAD+ simulator is platform-independent that can be run on any operating systems including the Android, iOS, Linux, Mac OS, Microsoft Windows, Unix and many others through the web interface. In addition, the design of our COMPAD+ simulator is so generic that it can be readily implemented on any cloud computing platform,

and easily integrated with other existing e-learning systems. Furthermore, the underlying cloud computing platform may quickly provide additional computational resource to boost the performance of our COMPAD+ simulator. To demonstrate the feasibility of our proposal, we carefully consider the system design and build a prototype implementation of our cloud-based COMPAD+ simulator with a thorough evaluation plan to investigate on how novice or experienced learners may benefit from our interactive simulator in various ways. Clearly, there are many interesting directions including the plausible uses of the COMPAD+ simulator to evaluate students' performance for learning analytics such as the learning path optimization method [2] for future investigation.

This paper is organized as follows. Section 2 details the system design of our enhanced COMPAD+ simulator on any cloud computing platform, and provides an empirical evaluation of our implemented prototype with a thorough evaluation plan. Lastly, concluding remarks are given in Section 3.

II. THE COMPAD+ AND ITS EMPIRICAL EVALUATION

The design of our improved COMPAD+ simulator emphasizes on two major aspects: flexibility and scalability. First, our enhanced COMPAD+ simulator is developed such that it can be easily configured to support simulations of various system architectures with different instruction sets and components on any cloud computing platform. Second, for scalability, our learning object metadata (LOM) management system is designed to tackle a potentially large repository of learning objects. To demonstrate the feasibility of our proposal, a prototype of our enhanced COMPAD+ simulator was written in C# and XML files to specify about the resources required for extensive simulations of various computer systems on the Microsoft Windows Azure Cloud platform. The current prototype implementation of our COMPAD+ simulator works on the Motorola MC68HC11 microcontroller using the predefined architecture configuration file and a set of component files. The LOM management system in our COMPAD+ simulator uses the LOM repository available on the cloud storage to store the relevant learning objects and a specific reference file for a clear demonstration.

Figure 2 shows the web interface of our enhanced COMPAD+ simulator to simulate the execution of a specific assembly program on the MC68HC11 computer architecture. After our prototype implementation is completed and tried out by several students, we readily obtain some initial and positive feedbacks from our Year-1 students under the new curriculum [3] in the Faculty of Engineering, HKU. Besides, we plan to provide our enhanced COMPAD+ simulator to all undergraduate students enrolled in a first-year core course on computer systems and also postgraduate students registered in an advanced-level course on high-performance computer systems to try out in both second and summer semesters of 2012/2013. By the end of each semester, a set of carefully designed evaluation forms will be distributed to all undergraduate and postgraduate students attending the courses so as to collect their feedbacks for a detailed analysis.

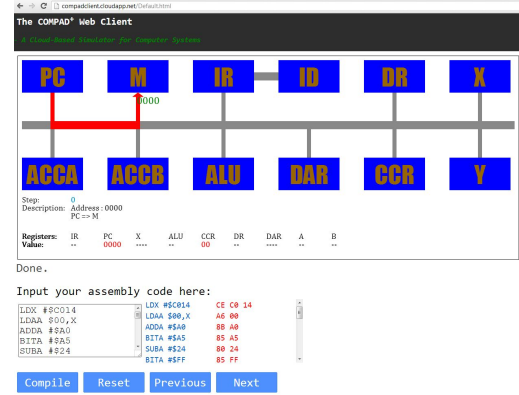


Fig. 1. The web interface of our cloud-based COMPAD+ simulator after inputting an assembly program for a specific computer architecture.

III. CONCLUDING REMARKS

We successfully integrated the learning object metadata (LOM) [4] and cloud computing technologies into our interactive COMPAD+ simulator for users to quickly create and work with related learning objects in the underlying subject area of computer systems. Our enhanced COMPAD+ simulator is so generic that users may reuse or modify the information inside the existing learning objects so as to create learning objects in defining new models. This will help to shorten the development time of relevant course or simulation materials. All in all, this paper reports our on-going work that has initiated many interesting directions for future investigation including the detailed analysis on pedagogical impacts of using the COMPAD+ simulator to enhance students' understanding of computer systems, the possible integration with other existing e-learning systems and the plausible uses of the COMPAD+ simulator to evaluate students' performance for learning analytics such as the learning path optimization method [2] for future investigation.

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