Computing Education on Cloud

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Abstract - Guided by the vision of engaging diverse student populations, especially students from the underrepresented groups, in an increasingly computationally empowered workforce, we launched a “Computing Education on Cloud (CEC)”. The CEC project aims to deliver critical computing education as cloud services, which can be accessed anywhere, anytime, by any registered user with minimum requirement of resources. In this paper, we identified three categories of critical computing education and describe the solutions towards some challenging issues in delivering open courseware in the identified categories as cloud services.

Keywords: Cloud Computing, Computing Education, Open Courseware, Education as a Service

1 Introduction

The National Science Foundation (NSF) has launched a funding program that is called Computing Education for the 21st Century (CE21), which aims to “build a robust computing research community, a computationally competent 21st century workforce, and a computationally empowered citizenry” [1]. Being both educators and researchers in computing, we share the same vision of the NSF CE21 program on engage diverse student populations, especially students from the underrepresented groups, in an increasingly computationally empowered workforce.

As stated in the NSF CE21 Proposal Solicitation, innovation in computing technology has driven economic development and produced strong growth in computing jobs [1]. However, the increasing demand in computing job market has exacerbated the shortfall of workforce in computing, which in turn poses a big challenge for computing education. The divergence between the demand for computing professionals and productivity of computing education can be illustrated using cloud computing technology. A research from IDC predicts that the cloud will generate nearly 14 million new jobs worldwide by 2015 [2]. In the state of Georgia, Silver lining, a cloud computing company is in the process of adding 900 new jobs in Atlanta [3]. However, very few institutions of higher education provide courses on cloud technology. Taking the state of Georgia as an example, only a handful of all Georgia public institutions offer cloud computing related courses.

We believe that one of the major reasons for the difference between the demand for computing professionals and productivity of computing education is the lack of resources, including, but not limited to, faculty expertise, teaching materials, computing equipments, lab space, and best practice. In order to solve this dilemma, we propose this “Computing Education on Cloud (CEC)” project that aims to deliver critical computing education as cloud services, which can be accessed anywhere, anytime, by any registered user with minimum requirement of resources. We start the project by identifying the following categories of computing education that are critical but often missing from a typical computing curriculum due to resource constraints: 1) emerging computing technologies (such as cloud computing, big data computing, and mobile computing); 2) algorithmic thinking (problem solving skills that are essential to a computationally competent workforce and computationally empowered citizenry); and 3) computing security (critical to addressing a fundamental problem that a large population of computing technology creators lack deep understanding of computing security challenges and technologies). We further set the primary goal of the CEC project to be the producing of open courseware, which can be delivered as could service, for each of the three identified categories. Each courseware contains a group of units that cover different aspects of the corresponding category. A courseware unit is a collection of the following items: unit description, learning objectives, lecture notes, recorded lectures, simulation tools, lab manual, cloud lab environment, assignments, and assessment questions. All the items of a courseware unit will be hosted on our cloud platform and accessible at user’s PCs, Laptops, or mobile devices anywhere and anytime. The second goal of the CEC project is to evaluate the effectiveness of the open courseware from different perspectives, including user population, courseware adoptions, learning objectives, student success, and reviews by peer institutions.

2 Computing Educational Perspective of Cloud Computing

Cloud Computing is a computing model that enables rapid on-demand provisioning of computational resources that are hosted remotely through the Internet as services. Typical types of computing resources that can be delivered as cloud service include computing infrastructures, computing platforms, and computing software. Correspondingly, the three typical cloud services are Infrastructure as a Service...
(IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS).

IaaS can be further divided into Server as a Service, Storage as a Service, and Network as a Service. Computing educators can leverage IaaS to set up required computing environment for various educational needs. For instance, Linux server with proper setting can be obtained from cloud as service in order to satisfy the needs of variety of computing courses, such as Operating Systems and System Programming. More complicatedly, a virtual Beowulf cluster can be set up from multiple virtual servers with the Network as a Service, which is a very cost effective way to build a lab environment that promotes parallel computing. In the next section, we will describe how IaaS is used to deliver necessary lab environment for computing security courseware in the CES project.

PaaS delivers highly scalable run-time platform as cloud services. Prominent examples of PaaS include Google App Engine [4] and Windows Azure [5]. Teaching the development of web applications or web services is an important component in a computing curriculum. Instead of setting up traditional LAMP environment as the run-time platform for the corresponding courses, computing educators can instruct students to deploy their web applications to Google App Engine if using Java technology or Windows Azure if using C#. By using PaaS in teaching, a computing curriculum is able to put more emphasis on building scalable software, which is an essential skill that any computing graduate should have nowadays. In the next section, we will focus on how the CES project leverages Big Data computing platforms as cloud services to deliver critical computing education on emerging technologies.

SaaS have been evolved as a popular model for delivering software, especially business applications, such as business intelligence, CRM, and HR applications. In the CES project, we will use SaaS as the model to deliver the produced open courseware. Especially, we will design a suite of software services to help students to develop algorithmic thinking skills, as described in the next section.

3 The CEC Project

The major activities of the CEC project are the production of a set of open courseware units that cover the critical computing education in the following identified categories: emerging computing technologies (such as cloud computing, big data computing, and mobile computing); algorithmic thinking (problem solving skills that are essential to a computationally competent workforce and computationally empowered citizenry); and computing security. Each courseware contains a group of units that cover different aspects of the corresponding category. A courseware unit is a collection of the following items: unit description, learning objectives, lecture notes, recorded lectures, simulation tools, lab manual, cloud lab environment, assignments, and assessment questions. All the items of a courseware unit will be hosted on our cloud platform and accessible at user’s PCs, Laptops, or mobile devices anywhere and anytime.

Producing courseware as cloud service for each identified category has its own challenges to overcome. For instance, the courseware unit for teaching Big Data Computing in the category of emerging computing technology requires provisioning big data computing platform as cloud service, so that the end user without local access to high throughput server clusters can simply access big data computing platform hosted on our cloud from any browser or mobile application. In order to address this challenge, we set up an experimental cloud platform using KVM [6] and Rackspace [7]. This cloud platform, which is called cloud@cs.Kennesaw.edu, integrates multiple servers and workstations in the Cloud Lab at the Department of Computer Science. Furthermore, as a proof-of-concept, we created a big data computing platform and provisioned it as a cloud service. The big data cloud platform includes a Hadoop cluster and a Cassandra database ring. Figure 1 demonstrates that our big data computing platform can be simply accessed from an Internet browser. We will use the same approach to provide cloud services for platforms that are needed for cloud computing, mobile computing, and computing security labs.

Algorithmic thinking is a fundamental method for problem solving in this era of computing. It concerns how to take a vague problem and turn it into a set of interpretable steps. Cathy Davidson, a Ruth F. DeVarney Professor at Duke University, argues that our education needs to start emphasizing the 4th R (Reading, wRiting, aRithmetic, algoRithms) in kindergarten, even preschool [8]. We believe that equipping K-16 students with solid algorithmic thinking
skills is a necessary and effective way to broadening the participation in computing. However, due to the intrinsic nature of solving complex problems, it is common that students feel subjects involving algorithmic thinking are challenging to learn. In order to address this bottleneck, we plan to produce cloud services that provide step-by-step animation for a wide range of typical algorithms. Users can access our cloud services from Internet browsers or mobile applications to interact with an animated process, which can help them to understand every details of the algorithm in a visible and intuitive way.

Figure 2. Eight Knowledge Area of Cybersecurity

Although the need for equipping computer science majors with comprehensive knowledge in cybersecurity has been long recognized in literature [9, 10, 11], it is far from a norm that an institution of higher education expands its CS curriculum in cybersecurity. The major challenge of preparing computing majors with comprehensive knowledge in computing security lies in the fact that security issues are widely spread in different aspects of computing, such as networking, databases, operating systems, web, software applications, and cryptography. Therefore, teaching computing security is not a matter of adding one or two new courses. Our approach to address this issue is that we first form a comprehensive view of cyber security by identifying eight knowledge areas (M0-M7) in a layered model of cyber security as shown in Figure 2. Each knowledge area contains a list of security topics, each of which consists of corresponding security issues and solutions. Then, for each cyber security topic identified in figure 3, we design and implement a group of courseware units as cloud services. For example, in the knowledge area M2-Wireless Network Security, the following three courseware units will be produced: M2.1-Wireless LAN’s security, M2.2-Wireless Personal Area Network security, and M2.3-Handheld device Security; in the knowledge area M7-Web Security, the following three courseware units will be produced: M7.1-Input validation vulnerability and mitigation, M7.2-session vulnerability and mitigation, and M7.3-storage vulnerability and mitigation. Finally, we view a typical CS curriculum as a “motherboard” and plug in all cybersecurity course units in the “motherboard” to form an expanded version of CS curriculum with added value on cyber security as shown in figure 3. In this way, an institute of higher education can easily plug these units in their existing computing curriculum without requirements on extra resources.

Figure 3. Illustration on how computing security courseware units fit a typical computing curriculum

Most of the cybersecurity courseware units require a server environment with proper software installations as the lab settings. We will again leverage the cloud computing technology to deliver the required lab environments as services. More specifically, for each relevant cybersecurity courseware unit, we will configure a server with proper hardware setting and necessary software installation and save the server image. The users of cybersecurity courseware will then be able to provision as many identical servers as needed from the image on the cloud.

4 Final Remarks

Cloud computing is reshaping the information technology landscape. As computing researchers and educators, we need to not only consider how to incorporate cloud computing technology itself in the computing curriculum, but also rethink how critical education could be delivered to diverse populations in a more effective way by leveraging the promises the new technology brings. The described Computing Education on Cloud (CEC) project is such an effort that aims to deliver critical computing education as cloud services, which can be accessed anywhere, anytime, by any registered user with minimum requirement of resources.

We identify the following three subject areas are critical but often missing from a typical computing curriculum due to resource constraints: emerging computing technologies, algorithmic thinking, and computing security. The major
activities of the CEC project are then the production of open courseware covering these areas that can be delivered as cloud services. In this paper, we describe the solutions that address some challenging issues in delivering the proposed courseware via cloud.

As an important component of the CEC project, the evaluation of the produced courseware services will be conducted from multiple angles, including user population, courseware adoptions, learning objectives, student success, and reviews by peer institutions. Feedback provided by multi-factor evaluations will helps us to continuously refine our courseware services. Therefore, this paper is also serving as a call for collaboration and participation in the CEC project.

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5 References


