AC 2011-2161: INTEGRATION OF MOBILE DEVICES INTO COMPUTER SCIENCE AND ENGINEERING CURRICULUM

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Integration of Mobile Computing into Computer Science and Engineering Curriculum

Abstract

The area of Mobile Computing has been growing tremendously in recent years. A major aspect of this growth has been the addition of networking technologies, operating systems, and database management systems to mobile devices. Today, mobile devices might be one of the most pervasive pieces of electronic equipment in our society. A recent study has estimated the total number of subscribers of mobile phones in the world to be three billion. As the use of mobile devices within society is quickly expanding, mobile learning (m-learning) has emerged as a potential educational environment to support learning. Mobile devices can be integrated into classroom teaching to promote excitement in learning.

The three aspects of Mobile Computing are mobile communication, mobile hardware and mobile software. The first aspect addresses communication issues in ad-hoc and infrastructure networks as well as communication properties, protocols, data formats and concrete technologies. The second aspect focuses on the hardware, i.e. mobile devices or device components. The third aspect deals with the characteristics and requirements of mobile applications[10].

Widespread use of mobile devices makes an opportunity for the computer science and engineering programs to integrate the use of mobile devices into their curriculum in order to enhance and promote new ways of teaching and learning. Since young people are very excited about these devices, mobile devices can be used as motivators for attracting and retaining students in the computer science and engineering fields. Educators now must come up with innovations on how to integrate mobile devices into their curriculums.

This paper is a study of different approaches that are used by different colleges and universities around the world to integrate Mobile Computing into their computer science and engineering curriculums.

Introduction

Mark Weiser, who is often considered to be the father of ubiquitous computing, classified computing into three eras: the mainframe era, where each mainframe was shared by lots of people; the personal computing era, where each person had their own machine; and the ubiquitous computing era, or the age of calm technology, when technology recedes into the background of our lives.[1] Weiser envisioned ubiquitous computing as a setting where people would conveniently have effortless access to computational and communicative technologies[41].

The ultimate goal of ubiquitous computing is to place computers everywhere in the world and provide ways for them to connect, communicate, and work together.[1] The need for ubiquitous computing has been a key factor for the increasing growth in Web and Internet technology, wireless communication, and portable computing devices. The field of mobile computing is the

merger of these advances in computing and communication with the aim of providing seamless and ubiquitous computing environment for mobile users.

Wireless communication infrastructure and portable computing devices together have laid the foundation for a new network computing paradigm, called mobile computing, which allows the users to access information and collaborate with others while on the move.

In the past years, the capabilities of cellular communication have tremendously improved. This improvement has brought smart phones, which combines the functionalities of a cellular phone and personal digital assistant (PDA). Smart phones featuring more power, memory, and functions are becoming smaller, lighter and are providing us with a wide variety of services, such as media streaming, mobile payment, mobile ticketing and software downloading[2]. Smart phones are very popular among users since they are capable of supporting third-party applications. Currently, so many third-party applications or files on the internet can be easily downloaded onto powerful smart phones by users. The popularity of handheld mobile devices, such as PDAs and smart phones is growing. China has more than 842 million mobile users. It is estimated that in 2011, it will have 95 million smart phone users[3]. According to a study by ComScore in 2010, there are over 61.5 million smart phone subscribers in the United States out of 234 million total subscribers[4]. Smart phones are one of the most ubiquitous portable technology devices available.

The widespread use of mobile devices suggests that this field of study cannot be ignored in education or training. Similar to web-based learning, the development of mobile learning is another method to deliver learning materials into daily life. The rapid development in mobile, wireless, and sensor technologies provide new possibilities for augmented learning activities.

Application of Mobile Devices in Education

Mobile learning is an active area of research. The following discussion explores the work that has been done in different parts of the world to integrate mobile devices into education:

The combination of Mobile devices and wireless communication with electronic measurement and control provides an enormous potential for education in the area of technology and science. "Mobile devices are everywhere and mobile learning (m-learning) has emerged as a potential environment to support learning."[5] Almost all the university students in US own a mobile phone. Mobile devices can be directly integrated in the classroom activities to enhance and promote new ways of teaching and learning.[5] A key benefit of m-learning is its potential for increasing productivity by making learning available anytime, anywhere. The following are some studies that have been done on the use of mobile devices in education:

A study was done in private colleges in Cyprus to determine the general knowledge of faculties on mobile technologies and their willingness to integrate m learning into their classes. "This study revealed that educators, who played the major role in the implementation of mobile devices in the teaching and learning process, appeared to have limited knowledge on the subject. On the other hand, faculty with technical backgrounds seemed to have the basic knowledge for the technology behind mobile devices, even though they lack capabilities to integrate it into the

curriculum."[5] This study indicates that for successful m-learning integration, a series of informative seminars on mobile devices (hardware/software), service providers, and infrastructure is needed for higher education educators in different fields of study.[5]

Kenneth Hoganson has done a study on the use, effectiveness, and acceptance of graduate computer science course lectures recorded and formatted for mobile devices. The result of his study indicates that students find viewing lectures and participating in live remote lectures by using a laptop to be the most effective, and prefer that mode of participation even when recordings are available for popular mobile devices[6]. Their students' interest in interacting during class over mobile broadband on a mobile device is significant but modest.[6]

In developing countries, mobile phones have a much higher penetration rate than laptop and desktop computers. In China, as of July 2008, a survey reported 84.7 million computers are connected to the internet compared to 592 million mobile phone numbers. An increasing number of users access the internet using their mobile devices. China's higher-education institutions have to manage the number of graduates that grew from 830,000 in 1998 to 3,068,000 in 2005. [7] Africa faces similar challenges. For example, Nigeria's universities can accommodate only 20 percent of applicants for higher education.[8] In developing countries, where the number of mobile device are more than laptops and PCs, the use of mobile devices for learning has been explored.

Shanghai Jiao Tong University in China has developed a mobile learning system that streams live lectures to the student's mobile devices. The system takes care of compressing the video and audio data efficiently so that it can be live-streamed while maintaining high visual quality of slides. Since the system is live, the students can interact with professors during lecture. Their system was evaluated in two classes, with about 1,000 students each. The feedback was mostly positive[7].

The University of Sydney, has developed a mobile learning system for syndromic surveillance and diagnosis. This system can assist farmers and veterinary students to study surveillance and diagnosis of farm animal diseases in the field. Their experimental evaluation shows that their system can meet the requirements for their specific training application.[9]

Mobile Computing Courses in Computer Science / Computer Engineering

The field of mobile computing is quite broad and presents challenges in many areas. The area of mobile computing is multidisciplinary in nature, and it involves many issues in computer science, computer engineering, and electrical engineering[10]. The industry is constantly involved in the development of technology and products to solve issues with mobile computing and communication. There is a big demand for engineers and computer scientists with experience in the development of technology and products to solve challenges of the future. In order to enhance the education and careers of the future computer scientists and engineers, it is essential that mobile computing concepts be integrated in the computer science and engineering curriculum. The ACM/IEEE Computer Science Curriculum 2008[11] lists Mobile Computing as an elective course under the "Net Centric Computing" Body of Knowledge. Also, the ACM/IEEE Computer Engineering Curriculum 2004[12] lists Embedded Systems as a Body of Knowledge and

also lists Wireless and Mobile Computing under "Computer Networks" Body of Knowledge. It is essential for both computer engineering and computer science undergraduate students to be exposed to the concepts of Mobile Computing. Table 2 provides a study of Mobile Computing course offerings of selected universities in the world. In the United States, course offerings of thirty three universities were studied. From this study, it can be seen that universities are using five models to integrate mobile computing into their computer science and engineering curriculums:

1. Offering undergraduate courses on Mobile Computing
2. Offering graduate courses on Mobile Computing
3. Integrating Mobile Computing concepts into their traditional courses
4. Combining model 1, 2, and 3
5. Offering Mobile Computing as an area of research to their graduate students

Model 1 is used by several universities such as Stanford University which is offering an iPhone and iPad Application Programming course, University of Maryland which is offering Mobile Environment and Android, and Zhejiang University which is offering a Smartphone Development course based on Android. The majority of universities that have graduate programs are offering graduate courses on Mobile Computing. Some universities are using the third model and integrating mobile computing concepts as modules in their existing courses, as seen by the University of Guelph. The University of Bridgeport, Carnegie Melon University, and Massachusetts Institute of Technology are offering Mobile Computing as an area of research to their graduate students, therefore employing Model 5. In the Computer Science Department at Carnegie Mellon University, Mobile and Pervasive Computing is an area of research, and this department offers a graduate course in Mobile and Pervasive computing, which is cross-listed both by the school of Computer Science and the Department of Electrical Engineering. Also, the department offers a course in Wireless Networking that focuses on topics at the physical and link layers.[13] At Stanford University several courses are offered on wireless communication in the CS and CE departments at graduate and undergraduate levels. They also offer an undergraduate course called iPhone and iPad Application Programming (CS 193). The material for this course is available for others to use.[15] Several universities are offering mobile phone development courses through their continuing education program. University of Washington is offering professional certification for iPhone development.

Center for Mobile Education and Research

At The University of Guelph, they have established a center for mobile education and research. In this center, they have developed an academic kit[33]. This kit contains 20 weeks of teaching material for integrating mobile devices into a computer science curriculum, including lesson slides, labs, tutorials, quizzes and assignments[32]. This academic kit offers material for a full course on mobile application development, as well as teaching modules for software engineering, web services, game design and development, information security, and operating systems[32]. They have integrated BlackBerry devices into their computer literacy course.[32]

Utah Valley University

Utah Valley University (UVU) is a state institution with 23,840 students. UVU is located in Utah County which has a population of over 430,000 residents. The Computer Science department at UVU offers a Bachelor's Degree in Computer Science with four areas of specialization, including Computer Science (traditional), Computer Engineering, Database Engineering and Computer Networking. The Bachelor of Science in Computer Science program was one of the first Bachelor of Science programs implemented at UVU in 1993. The program's goal has been to provide a quality program that meets accreditation standards while providing the students with a skill set that allows them to succeed in computing careers. The curriculum content for the Computer Science degree is based on the 2008 ACM Curriculum Report. The Computer Science degree at UVU is accredited by Accreditation Board for Engineering and Technology (ABET) in 2002 and currently has more than 500 students.

To integrate Mobile Computing concepts into our curriculum, we decided to use the second model by offering an undergraduate course on Mobile Computing. This course was offered as a junior level elective course for the first time in the Fall 2010 semester. Offering this course as a required course was not an option for us, so not every student is going to be exposed to this material. In this class, students designed, implemented, tested, and debugged iPhone programs. There were twenty six students in this class, and students commented that their experiences with the class were very positive. The textbook chosen for this class was "Beginning iPhone 3 Development: Exploring the iPhone SDK" by Dave Mark and Jeff LaMarche since the hardware used in this class was the iPod Touch. The material from Stanford University accessible through their website has been used as a supplementary material to develop teaching materials for this class.

Table 1 – A Survey of Universities with Regard to Mobile Computing Offerings

Universities	Country	Mobile Computing Undergraduate Courses in CS	Mobile Computing Undergraduate Courses in CE	Graduate Course in CE/CS	Comments
Carnegie Melon University[13]	U.S.		1.Embedded Control System. 2.Embedded System design. 3.Special Topics in Wireless Network. 4.Embedded Real Time Systems. 5. Digital Wireless Communications	1.Wireless Sensor Networks 2.Wireless Networks 3.Mobile and Pervasive Computing 4.Mobile Hardware for Software Engineers.	Mobile and Pervasive Computing is an area of research
Stanford University [14]	U.S.	1.Wireless Networking 2. iPhone and	1. Intro. To Wireless Personal Communication	**CS:** Advanced Wireless Networks **CE:**	

		iPad Application Programming course (CS 193)[15]		1. Wireless Communication 2. Wireless Networks 3.Mobile and Wireless Networks and Applications 4. Wireless Sensor Networks Concepts and Implementation	
University of Utah[16]	U.S.	None	None	CS: 1.Embedded System Design 2. Advanced Embedded System design 3. Embedded System and Kinetic Art	
University of Washington[17]	U.S.	Software for Embedded Systems	Embedded System Design	1. Special Topics in Embedded Systems. 2.Topics in Ubiquitous Computing 2. Advance Topics in Ubiquitous Computing	UW through continuation education branch offers 3 courses on i-phone development and offers professional certification for iphone development.
Utah State University[18]	U.S.	None	None	CS: Topics in Mobile Systems	
Massachusetts Institute of Technology [19]	U.S.	None	None		In Computer Science Department research field on Computer Networks: Mobile and Wireless Computing Course on iphone development in Continuing Education
Ohio State University[20]	U.S.	N/A	None	None	
University of Maryland[21]	U.S.	Mobile Environment and Android	N/A	None	
Harding	U.S.	Mobile	N/A	N/A	

University[22]		Computing			
Washington University in St. Louis[23]	U.S.			Embedded Computing Systems	
University at Buffalo[24]	U.S.	None	N/A	1. Realtime & Embedded Systems 2. Wireless Networks Security 3. Wireless Networking & Mobile Computing 4.Secre Wireless Sensor Networks	
University of Bridgeport[25]	U.S.		Embedded System Design	1. Mobile Communication 2. Satellites/Wireless Communication Systems 3.Intr. to Wireless Sensor Networks	Wireless and mobile computing and networking area of research
University of Central Florida[26]	U.S.	Wireless Security and Forensics	Embedded Computer Systems	CE: Satellite Communications	
University of Michigan Ann Arbor Campus[27]	U.S.	None	None	Mobile Computing	
Duke University[28]	U.S.	None	1.To Embedded Systems 2.Wireless Communication Systems	Wireless Networking and Mobile Computing	
Elon University[29]	U.S.	Mobile Computing	N/A	N/A	
Jadavpur University[30]	India			Wireless and Mobile Networking	
University of Texas at Arlington[31]	U.S.	None	None	1. Embedded Computer Systems 2. Pervasive Computing & Communication 3. Advanced Wireless Networks & Mobile Computing 4. Advances in Sensor Networks	
University of Guelph[34]	Canada	Integrated Mobile Devices in their CS1 course. (BlackBerry)	N/A	Hardware/Software Co-design of Embedded Systems	They have integrated Mobile Computing concepts as modules into

					several of their undergraduate courses.
Zhejiang University[35]	China	Smartphone Software Development Course based on Android	N/A	N/A	
Utah Valley University[36]	U.S.	Mobile Phone Programming	N/A	N/A	Using material from Stanford University
Northern Kentucky University[37]	U.S.	None	N/A	CS: None	
John Hopkins University[38]	U.S.	1. Network Embedded Systems and Sensor Networks 2. Wireless Networks and Mobile Computing Fundamentals	None	CS: 1. Network Embedded Systems and Sensor Networks 2. Wireless Networks and Mobile Computing Fundamentals	
Rochester Institute of Technology[39]	U.S.		CS & CE: Data management in Pervasive Computing	CS & CE: 1. Principles of Wireless and Mobile Computing Architecture and Design. 2. Pervasive Computing Architecture and Design.	They have developed a lab called Pervasive Computing Lab
Colorado State University [40]	U.S.	CS/ ECE: Embedded Systems	ECE: Wireless Communication	CS/ECE: Hardware/Software Design of Embedded Systems CS/ECE: Mobile Computing[10] ECE: Advanced Topics in Embedded Systems	
Seton Hill University[42]	U.S.	None	N/A	None	Leverages the power of mobile devices to store and deliver recorded lectures, syllabi, HW, tests, ..

University of Missouri-Columbia[43]	U.S.	None	CE: Computing for Embedded Systems, Real Time Embedded Computing, Intr. To Wireless Communication Systems.	CS: Wireless Embedded Systems	In Computer Science Department research field on mobile networking, Wireless sensor network
Christian University in Texas[44]	U.S.	None	N/A	N/A	
Cornell University[45]	U.S.	Introduction to Mobile Application Development.	Modern Computing Devices: Smart Phones to Super computers. Embedded Systems.	CE: Mobile Communication Systems	
Princeton University[46]	U.S.	None	N/A	None	
Rice University[47]	U.S.	Mobile and Embedded System Design and Application Mobile Wireless Services Project	Mobile & Embedded Systems Mobile Wireless SRVC Project	CE/CS: Mobile and Wireless Networking CE/CS: Security of HW Embedded Systems	
University of Berkely[48]	U.S.	Introduction to Embedded Systems	Embedded System Design: Models, Validation, and Synthesis	N/A	
Brown University[49]	U.S.	Introduction to Embedded Real-Time Software Game Development Seminar: Android and Core Techniques	None		

Summary and Concluding Remarks

Integration of Mobile Computing concepts in undergraduate computer science and engineering has started in many universities worldwide. The computer science programs are addressing the mobile communication and mobile software development aspects of Mobile Computing while Computer Engineering programs are addressing the mobile hardware and mobile communication aspects. For example, the Rochester Institute of Technology has developed a course called Principles of Wireless and Mobile Networks. A number of universities in the U.S. are offering courses in the area of Mobile Computing.

When should mobile computing concepts be introduced into computer science and engineering curriculum? Some computer scientists believe that it should be introduced as early as CS1, which is the approach taken by the University of Guelph[34]. This university believes that the concepts should be introduced slowly as modules in different traditional courses. Introducing the mobile computing concepts early in the program energizes the students. Some believe that it should be offered as a senior level required course. The second option might be harder to implement, since adding a new course to the curriculum is not an easy task, as often times eliminating another course would be necessary. Offering it as an elective course is not a good option either, since every student is not going to get this experience. It seems that adding the concepts slowly as modules to existing courses is a good solution for integrating the mobile computing concepts into the computer science and engineering curriculums.

As the computing industry is constantly involved in the development of technology and products to solve issues with mobile computing and communication, tomorrow's computer scientists and engineers must be educated on the mobile computing concepts. As educators, teaching mobile computing today is vital to giving our students the tools they need to build tomorrow's hardware and software. It is crucial that mobile computing topics be integrated into computer science and engineering curricula.

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