Education

On Teaching Ubiquitous Computing

Lu Yan • University College London

Ubiquitous computing research has progressed rapidly over the last few years, and real-world applications, especially mobile networking devices, are booming in consumer markets. With rising industry demand and career opportunities, more and more universities are offering graduates ubiquitous computing courses in addition to classical computer science curricula, such as mobile computing and wireless sensor networks.

Here, I outline a graduate-level ubiquitous computing course I taught for final-year master’s and first-year doctoral students in Finland at Åbo Akademi University in 2006. Finland—the home of Nokia, the world’s largest mobile phone maker—has more mobile devices per person than any other country, and its students are very interested in ubiquitous computing technologies. The experiences gained and lessons learned are a good source of information and reference for other educators in this field.

Quick Facts

Course: Systematic Design of Ubiquitous Systems  
Unit: Department of Information Technologies G720-G722  
Institution: Åbo Akademi University (www.abo.fi)  
Instructor: Lu Yan  
Level: Graduate

Teaching component

The course, Systematic Design of Ubiquitous Systems, aims for a good balance between teaching practical system-design principles and introducing the latest research advancements, tailored to meet the graduates’ different career goals.

I first presented an overview of ubiquitous computing and its applications. During the first class, I asked students to write their initial goals and expectations. During the final class, they reviewed their actual progress, revisited their goals, and made action plans.

Ubiquitous computing touches an array of disciplines. In the teaching component, I mainly covered the core technologies and techniques enabling ubiquitous computing, particularly:

- mobile devices and development environments,
- middleware and software architecture,
- mobile networking and wireless sensor networks,
- context awareness and service provisioning, and
- user interfaces, security, and privacy.

Because some topics took less time than allocated and others took longer, we moved adaptively through textbook material, also spending some time on current research issues. To some extent, the speed depended on the students’ maturity and background.
Course project
I believe that the most effective learning comes from experience. So, in addition to classroom lectures, students had to complete a group project.

Considering the students’ different career goals, I offered two tracks for the projects:

• a research track, wherein students wrote a scientific paper, and
• an industry track, wherein students implemented a real-world application.

Both tracks required substantial work, but the choice of the topic was quite flexible. I encouraged students to propose their own projects and complete them before the semester ended.

Here I present some sample projects from the course—two research projects and two industry projects. Roughly half the students chose the research track, and half chose the industry track.

Project 1: RFID technology review
RFID technology has a long history and is part of the past and current technological revolution. In recent years, RFID tags increasingly have been used for tracking, identifying, categorizing, and localizing physical assets and goods in applications such as the supply chain, the medical industry, agriculture, manufacturing, transportation, and the environment.

In this research project, students completed a comprehensive review of the latest RFID hardware and software technology. They studied different application scenarios and opportunities. They discussed the problems facing current adopters and necessary changes. They also explored the latest standards and initiatives.

Project 2: Foundations of context awareness
This research project examined the foundation of context in ubiquitous computing. The students discussed a formal foundation and software engineering techniques for mobile context-aware and context-dependent service derivation and application development, emphasizing the relationships between context and system.

Students implemented a smart kindergarten application as a case study for the proposed foundations of context awareness. The application consists of wireless base stations, mobile sensor nodes attached to the children, and a supervisory application (see figure 1). The children can move freely in a predefined area (that is, the playground), and the supervisor can get the location information for all nodes (visually). When a child leaves the predefined area, the system increases its alertness level and informs the supervisor.

Figure 1. The smart kindergarten application scenario.
Project 3: Real-time temperature monitoring

Temperature monitoring is important in the northern Lapland (inside the Arctic Circle), where the temperature can unexpectedly drop to $-40^\circ$ overnight. The local farming industry is particularly sensitive to temperature change, and it’s crucial that farmers take quick action when the temperature falls too low. Manually monitoring temperature change is time consuming and sometimes dangerous. So, farmers need an automatic solution.

In this industry project, students implemented an automatic temperature-monitoring system using wireless sensor networks, which measured, logged, and transmitted temperature data in real time. The system’s practical deployment also led to the development of a friendly user interface for mobile devices where users can find the current temperature and receive temperature change warnings via short-message service.

Project 4: On-demand mobile peer-to-peer streaming

In recent years, peer-to-peer media streaming has generated interest in both industry and research communities. P2P is an effective way to deliver multimedia content to multiple viewers, and it enables next-generation Internet services such as video on demand, Internet protocol television, videoconferencing, and surveillance. As the Internet becomes more wireless and mobile, P2P terminals are evolving into a mixture of stationary and mobile entities.

This industry project presented a possible path to mobile P2P media streaming by implementing an on-demand P2P streaming mobile application with Nokia smart phones (see figure 2) built over the JXTA overlay. Mobile phones have different computing power, storage capability, communication means, and media format support. So, when implementing a large-scale P2P streaming overlay with mobile phones, students had to address those heterogeneities.

![Figure 2. Students ran the media streaming application in (a) a Java emulator and (b) a Nokia N80 phone.](image)
Evaluation methodology
Throughout the course, I closely monitored the students’ performance and quality metrics. The evaluation considered both the students’ academic performance and their impression of the course, which I extracted from their replies to questionnaires.

A student’s grade had three components: classroom assessment (30 percent), the project (60 percent), and the group presentation (10 percent). During the final session, groups presented their project design and findings to the class. As a peer review process, each group invited other students to provide constructive feedback on their presentation, which led to a good discussion and debate.

I used two questionnaires to elicit student feedback. The course evaluation questionnaire let students provide feedback about the course. It included (but wasn’t limited to) general questions, such as

- What aspects of the course did you most enjoy?
- What aspects of the course did you most dislike?
- How can the instructor improve the course?

The student evaluation questionnaire was a reflection and planning tool for the students. It included (but wasn’t limited to) questions such as

- What’s my expected outcome from the course?
- What’s my actual outcome from the course?
- What’s my long-term goal?
- Did this course help me achieve my long-term goal?
- What other training courses do I need to achieve my long-term goal?
- What’s my action plan for the future?

Lessons learned
Although the overall course evaluation was successful, I encountered limitations:

- Because of the limited available resources, I had to restructure the project groups to maximize the use of experimental equipment.
- During the project stage, I discovered many unexpected hardware and software incompatibilities. For example, most experimental wireless sensor boards were poorly documented, and I wasted a tremendous amount of time hacking the source code and altering system configurations.
- Students tended to propose overly ambitious course projects. Consequently, some projects took almost twice as long to complete than expected (up to six months instead of three months).

Ubiquitous computing courses and research programs are still in the early stages. These kinds of courses usually require students to have background knowledge and skills in several computer science areas, such as communication networks and the Internet, distributed computing, and software engineering. So, at present, most ubiquitous computing courses are open only to graduate-level students. In a future column, I hope to discuss the practice of introducing ubiquitous computing in undergraduate computer science courses that don’t involve complicated problems and in-depth analysis.

Nowadays, there are many more mobile phones in the world than personal computers, and ubiquitous computing is gradually changing the way we live, work, and interact with each other. I expect modern computer science curricula to reflect this trend and prepare students to consider computing from a fresh viewpoint.

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