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Pervasive Computing and Tomorrow's Computer Scientists

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Reinvigorating the Discipline:

Pervasive Computing and Tomorrow's Computer Scientists

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EDITOR'S INTRO

Declining enrollments in computer science and related fields are a global concern. This issue's column, by Mike Hazas and Rebecca Marsden of Lancaster University in the UK, describes the novel Lancaster Headstart program that uses the excitement of pervasive computing to attract students into computer science. Your comments and suggestions for this column are welcome. Please contact me at midkiff@vt.edu. *—Scott F. Midkiff*

Starting in the first half of this decade, the number of students enrolling in undergraduate computer science degree programs in the UK has significantly declined.[1] Similar trends have been observed in the US and other countries.[2] Although it's difficult to predict future industry needs for computer scientists in terms of either quantity or expertise, some computing education experts argue that the number of computing employment opportunities in the UK will outstrip the number of national computer science graduates by the end of the decade.[3]

Certainly, we could characterize the recent sharp drop in enrollment as a side effect of the dot-com bust, but small surveys and focus group interviews have indicated that the limited take-up is also due to the perceptions that computer science is nerdy, is too narrowly focused to prepare students for multidisciplinary jobs, and involves repetitive or mundane tasks lacking in creativity.[4]

Practitioners and educators in pervasive computing would beg to differ: the study of modern computing is a multidisciplinary endeavor that includes engineering (software, hardware, and mechanical), interaction methods, creative design, ethnography, and sociology. With technology becoming evermore embedded, wireless, and ubiquitous, it fundamentally impacts our everyday lives. How, then, should we communicate computing's increasing importance to young people making decisions about their undergraduate study?

QUICK FACTS

Course: Headstart Program
Unit: Computing Department
Institution: University of Lancaster
Course Directors: Rebecca Marsden, Mike Hazas
Level: Secondary school
URL: www.comp.lancs.ac.uk/headstart

BACKGROUND AND AIMS

One thing higher education institutions can do is host residential summer programs that give in-depth, hands-on experience to students nearing the end of secondary school. This gives them a feel for undergraduate life and the chance to interact with peers and academics with similar interests and to deepen and broaden their knowledge in a field they might be considering for undergraduate study. In the US, such programs typically span multiple weeks and involve an integrative design project (for example, Rose-Hulman Institute of Technology's "Operation Catapult," www.rose-hulman.edu/catapult).

In the UK, Headstart (www.headstartcourses.org.uk) is a national scheme for talented students entering their final year of secondary school. Headstart applicants can choose from courses at a number of hosting universities—in 2007, 28 institutions offered Headstart courses. Courses typically last about four days, but their composition varies. Some have a broad focus on science and engineering, whereas others might focus on a particular field or be tailored specifically for female or minority students.

Lancaster University's Headstart is a focused course held in July, centered on the theme of "ubiquitous computing." The course aims to

- expose students to the diversity of topics and interdisciplinary approaches in the field and
- give students hands-on experience with developing mobile and pervasive technologies.

The course should balance these two aims while also provisioning for the over-

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arching aims of the Headstart program, which include

- visiting a local company,
- sampling undergraduate life,
- meeting academics and recent graduates, and
- receiving career advice.

Fitting all this into a three-and-a-half-day program is quite a challenge.

COURSE STRUCTURE AND OPERATION

We use several course components to satisfy our focus subject aims as well as those of the Headstart program (see the "Course Highlights" sidebar). First, a set of multidisciplinary workshops give students a snapshot of the breadth of modern computing. Past examples include a seminar on computer science innovation from a business standpoint, a workshop on developing multiplayer networked games on mobile phones using Python, and an interactive tutorial on installation art incorporating embedded sensing.

Second, a central component of the course is the design project (discussed further in the next section). At the course's beginning, we divide the students into predetermined teams. (We found that not allowing students to form their own teams is crucial—otherwise, students who happen to be from the same school might stick together and dominate their team, rather than getting to know students from other schools to create balanced teams.) On the first day, we present the teams with the project goals and give them about three hours per day to work on the projects. An academic staff member and three graduate students supervise the project time. On the course's final day, each team creates a 15-minute presentation and demonstration, given in front of all attendees and a panel of three judges (see figure 1). Each member of the winning team receives a prize; in previous years these have been iPods.

The third component of the Lancaster Headstart program focuses on information about university courses and careers in technology. We offer short sessions that discuss the procedure of applying to university and what technology-based courses at university entail. The Headstart attendees particularly enjoy the question-and-answer session with recent computing graduates; they seem to identify closely with our graduates and consider the graduates' firsthand opinions to be honest and relevant to their own impending career decisions.

Computing in industry is a fourth course component. This involves an afternoon trip to Coniston in the Lake District. Coniston Launch is a company operating solar-electric passenger boats on Coniston Water; the company has links with several departments at Lancaster University. We also like to encourage our Headstart course's industrial sponsors to come and talk to the students. For example, in 2005, Intel Research in Cambridge provided partial sponsorship, and James Scott, one of their senior researchers visited Lancaster and spoke about ubiquitous computing-themed research at Intel.

Social and recreational activities make up the course's final component, which is meant to give students a taste of undergraduate life. In addition to staying in the residence halls on campus, students can spend an evening at the sports center, participate in a pub quiz (sans alcoholic drinks, of course), and watch (preapproved) DVD films on a projector system in a lecture hall. And, as you might expect of undergraduates-to-be, the students seem to enjoy just hanging out in the residence halls in the evenings and chatting.

Even though we host relatively small groups of students, the course's operation is complex and requires many support staff. These include two resident

COURSE HIGHLIGHTS

- Tutorial on prototyping ubiquitous systems
- Development of networked interactive applications on mobile phones using Python
- Workshop on innovation in computing
- Interactive and/or live performance art using embedded sensing
- Group design project
- Informational sessions on applying to university and studying for technology-based degrees
- Onsite company visit: Coniston Launch in the English Lake District
- "Grapevine" session: question-and-answer with a panel of recent computer science graduates
- Social events: sports center evening, quiz night, film evenings
- Seminar on how to use "bad ideas" in brainstorming activities
- Overview of pervasive computing research by an industrial sponsor

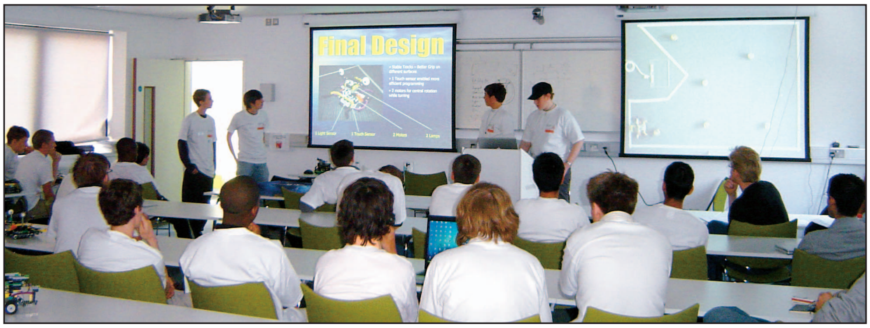

Figure 1. In the final presentation, each team argued the rationale for their solution with respect to the design goals and then demoed the performance of their solution. The right projector displays a live video feed of their robot's efforts to remove cans from the arena.

EDUCATION & TRAINING

MINDSTORM DESIGN PROJECT CHALLENGES

Challenge 1

- Build and program a robot that will remove empty aluminum cans from an arena (for example, see figure A). The cans will be arbitrarily placed (standing up) in the arena.
- The aluminum cans will be empty.
- The arena will be marked out with white masking tape on black carpet or flooring.
- The geometric center of your robot must not go outside the arena.

Challenge 2

- Your robot should remove the aluminum cans while navigating around obstacles.
- Obstacles can include other robots or stationary, heavy, and rigid things.

Challenge 3

- Your robot will periodically send over infrared a unique code that identifies it. You will be given the program blocks to do this.
- Of the six teams, there will be one that you are hunting (your prey) and one that is hunting you (your predator).
- Your robot should try to force its prey out of the arena; likewise, your robot should resist being forced out by its predator.

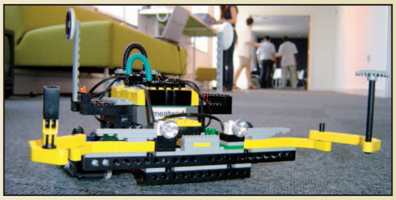

Figure A. Example of a final design: The wide bracket in front eases the collection of cans.

graduate students who stay with the attendees in the residence halls, three graduate supervisors to assist and advise during the workshops and project sessions, a record keeper who takes photos and video and documents the course using a blog, a resident Headstart supervisor (normally a teacher from a secondary school appointed by Headstart UK), the local course coordinator (a Computing Department staff member), and several Lancaster University professors, lecturers, and senior researchers who conduct the workshops and judge the design project presentations. Compounding the complexity is the close level of supervision of the students, which is legally required because most Headstart participants are under 18 years of age. All of this essentially means that running the course is a 24-hour job, which requires ample people on hand to deal with unexpected situations and to allow adequate downtime for staff.

DESIGN PROJECT

The design project aims to demonstrate pervasive computing's approach of detecting real-world phenomenon (via sensor data), processing it (often using embedded computers instead of conventional ones), and then using actuators (sound, displays, or motors) to achieve a desired effect. In this way, students learn that modern, practical, and relevant computing is really about a lot of small devices that aid people in some way and with which people can interact in various environments. Often we use computers without giving them a specific, cognitive focus as we undertake our daily activities (for example, communicating via text message or listening to a pocket MP3 player). Students are already familiar with this type of casual interaction with nonconventional computing devices—perhaps even to a more personal degree than pervasive computing researchers are. So, students tend to find pervasive computing concepts and ideas convincing and appealing.

However, deciding on the design project's technical content and requirements is rather tricky. We can't assume that students have any computing background, much less experience with any particular programming language. When we first ran the course in 2005, we had timetabled 7.5 hours of project time. We opted for an open-ended design project centered on paper-based conceptual prototyping. Notwithstanding the project's abstract nature, we encouraged students to follow the steps of the engineering design process. The teams came up with innovative pervasive application scenarios that they illustrated using Wizard of Oz demonstrations. Despite this success, some of the students felt they hadn't grappled enough with technical content. They commented that deeper subject matter and building something "real" in their design project would have been more rewarding. As educators who normally adopt a practical approach to teaching computer science, we too felt that something was missing.

For Headstart 2006 (www.comp.lancs.ac.uk/headstart/2006), we increased the allotted project time to 9.25 hours and adopted the Lego Mindstorms Robotics Invention System as a teaching tool. (In mid-2006, Lego released Mindstorms NXT, which has new sensor, actuator, and connectivity capabilities and uses a LabView-based programming environment. See http://en.wikipedia.org/wiki/Lego_Mindstorms_NXT for more information.) Mindstorms was specifically designed for educational purposes.[5]

Although the three design challenges (see the related sidebar) might not represent typical pervasive computing applications (particularly the more adversarial yet undeniably fun third challenge), we used Mindstorms to stress the recursive "input/processing/output" aspect of pervasive computing. The Mindstorms controller unit (the thing that gets programmed) is a good example of an embedded device—complete with the power, computational, and peripheral limitations common in pervasive computing. Each group ran their batteries flat at least once, and groups observed the limits of the sensors, the processor, and the actuators. The students also became acutely aware of the challenges of overcoming the difficulties human programmers have trying to express complex algorithms as computer programs that run on an embedded microprocessor.

Pervasive computing device requirements stand in contrast to the device requirements in robotics, where size, cost, and power consumption are typically not as much a concern. As such, after being given the design challenge, each team had an hour to plan their solution's approach and come up with a list of resources needed—sensors and actuators were in limited supply. The teams didn't have to meet all three design challenges. However, they could address the different challenges by reusing design components, and we made it clear to the students that judges would look more favorably on projects that addressed all three challenges. To make the programming tasks accessible to as many students as possible, we opted for RCX Code, the GUI-based programming environment that came with consumer versions of the Mindstorms sets.

The projects were wildly successful; many group members worked extra hours in the evenings to revise their mechanical designs (see figure 2), improve their firmware algorithms, and polish their presentations and demos. Several students commented that they found the RCX Code programming environment too limiting. This year we're considering using community-developed Mindstorms programming languages such as NQC (Not Quite C, http://bricxcc.sourceforge.net/nqc) for students who wish to use a more powerful language.

HISTORY AND CURRENT DEVELOPMENTS

Student attendance in the course has varied from year to year. In 2005 (the first year we ran the course), we had 14 students, and in 2006, the number went up to 26. Survey respondents (14 in 2005, 20 in 2006) in both years were generally positive, with 56 percent and 35 percent rating the projects as "excellent" and "good," respectively. All responding students reported that our Headstart program influenced their choices about undergraduate study and careers; 76 percent would consider computer or software engineering as their first choice. For many (66 percent), Headstart helped them make a firm decision regarding the field within computing or engineering they wanted to focus on. For a small proportion of the respondents (10 percent), their experience in the program helped confirm that they didn't want to study an engineering-related subject.

We seem to have achieved our course goals in that none of the students characterized computer science as nerdy or repetitively boring. Some cited simply being more interested in other subjects (such as film). But interestingly, a small number didn't feel confident they could grapple with the "technical aspects" of computer science and engineering. By this, we assume they were referring to computer, electrical, or mechanical system design.

However, in pervasive computing, we know that technical approaches vary widely in their nature, and the greatest leaps forward come from a synthesis of approaches. This year we aim to represent more of these approaches by including sessions on human-computer interaction or sociology. By familiarizing them with the concept of a user study or ethnomethodological approaches to understanding people and technology, we hope to give students a better idea of the breadth of technical approaches needed to understand computing in the present day. P

ACKNOWLEDGMENTS

Over 25 members of Lancaster University (staff and students) work to make our Headstart program a success, and we can't name them all here. However, we especially thank Matt Faulkner and Lorna McKnight (resident graduate students); Mark Lowton (record keeper); and Ben Green, Martyn Welch, and Andrew Stone (project supervisors). Paul Coulton conducts challenging yet accessible hands-on sessions on programming mobile phones; these have been very well received by the students. We also thank our industrial sponsors who provide financial support and a good collaborative spirit: Intel Research, Cambridge (in 2005 and 2006), and Microsoft Research, Cambridge (in 2007).

Figure 2. Team members collaborate on an iteration of their design. They're aiming to engineer a stable, speedy robot using a low center of mass and a relatively low gearing ratio.

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