Education & Training

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A Multiplatform Methodology:

Developing Mobile Device Applications

Hassan Artail

EDITOR'S INTRODUCTION

In this column, Hassan Artail describes a senior and graduate course on pervasive computing taught at the American University of Beirut. The course features a strong programming component that includes three different platforms for developing mobile applications. Please let me know your comments and suggestions for future columns. — *Scott Midkiff*

When the Electrical and Computer Engineering Department at the American University of Beirut decided to launch a computing course on mobile computing devices, I designed a course to meet industry requirements and to introduce students to the major platforms used to build practical applications. I dedicated much of Pervasive Computing Systems and Applications, EECE 679, to teaching mobile device application programming through code demonstrations and in-class application building. The course also covered front-end mobile device technologies and back-end infrastructures.

Today, many pervasive computing courses focus on research and theory. Those that do deal with developing mobile applications often limit their coverage to a specific platform. This course covers practical and theoretical pervasive computing, lets students acquire hands-on application-building experience in multiple platforms, and acquaints students with recent developments in related technologies and research.

I initially offered the three-credit-hour course in the spring of 2004. In this first offering, 23 students enrolled (15 graduate and eight undergraduate). I offered the course again in fall of 2004, and 48 students enrolled (20 graduates and 28 undergraduates). The course includes a mix of lectures, code demonstrations, and student presentations. The lectures constitute about 40 percent of the course time and cover various topics. The remaining class time covers code demonstrations, which involve building applications in the lab.

LECTURES

The lectures cover various pervasive computing topics, organized into the following six major categories.

- *Mobile device technologies, operating systems, and development environments.* We discuss and compare several device models, including PDAs that run the Palm OS, Pocket PCs that run the Windows CE (WinCE) operating system, and Java-enabled mobile phones.
- *Programming languages and their characteristics.* We use Java (for the Java 2 Micro Edition (J2ME) environment), C# (for Microsoft's .NET Compact Framework), and C (for the Palm OS programming environment).
- *Wireless communication protocols and technologies.* Topics include cellular communication, IEEE 802.11 (Wi-Fi), Bluetooth, infrared, and GPRS (General Packet Radio Service).
- *Higher-level protocols.* These include voice over IP, WAP (Wireless Application Protocol), and associated technologies, such as WML (Wireless Markup Language), and WTP (Wireless Transaction Protocol).
- *Modern advances and trends in mobile computing technology.* Subjects cover smart identification, wearable computing, and mobile commerce.
- *Wireless privacy plus security protocols and technologies.* WTLS (Wireless Transport Layer Security) is an example of a covered subject in this area.

The course uses *Pervasive Computing* (Springer 2003) by Uwe Hansmann, Lothar Merk, Martin Nicklous, and Thomas Stober, as its textbook.[1] Although this text covers a reasonably broad range of subjects, it lacks the desired depth for many of them. Additionally, the limited lecture time doesn't allow for going into a lot of depth. How-

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ever, the lecture material gives students sufficient technical information to become conversant in the course topics and to identify areas of interest for research or development.

CODE DEMONSTRATIONS

The code demonstrations introduce students to design and coding concepts in application interface programming for handheld devices. Chiefly, the code demonstrations have three main objectives. First, they aim to introduce and familiarize students with the features of Java, C#, and C within the framework of mobile device programming. Second, the demonstrations explain sample programs that show how to build applications for implementing functionalities involving user interface components, data storage and handling, socket and HTTP communication, and multithreading. Finally, I introduce application configurations and deployment details using the code demonstrations. The examples are topic-centric. So, similar examples that discuss the same topic but use all three platforms (J2ME, Palm OS, and WinCE) are presented consecutive in the same 80-minute lecture or in successive lectures. This approach lets me highlight the differences in implementations, required development effort, functionalities provided, and interoperability issues. Most code examples that I present come from three books, which I put on reserve in the library:

- Paul Tremblett's *Instant Wireless Java with J2ME* (McGraw Hill Osborne 2002),
- Kris Jamsa's *Instant Palm OS Applications*, (McGraw Hill Osborne 2001), and
- Andy Wigley, Mark Sutton, Rory MacLoed, Robert Burbidge, and Stephen Wheelwright's *Microsoft .NET Compact Framework* (Microsoft Press 2003).

To get students started with their development projects as early as possible, my graduate assistant and I give most of the code demonstrations in the semester's first half. We do this in parallel or after I discuss existing handheld devices' characteristics and the relevant development tools' details. In parallel with this, the graduate assistant provides fast-track sessions on the programming languages we use.

The demonstrations cover design and user interface programming, which concerns forms and their elements, user interaction, and navigation and flow between forms. They also cover implementing local databases on a device and interacting with a remote database, MySQL, via a wireless network and sockets. Additional subjects include communication between devices as well as between devices and HTTP servers.

DEVELOPMENT PLATFORMS

I chose the development platforms covered in the class largely on the basis of market trends and advances in wireless application development. The course's applied section focuses on the three platforms: J2ME, Palm OS, and WinCE. I selected J2ME because of its popularity among wireless application developers. The Evans Data Corporation's 2004 worldwide survey, "Wireless Development Survey," indicated that 40 percent of wireless developers use J2ME while another 24 percent are evaluating it for future use. Developers primarily use J2ME to build applications for wireless phones, but they also use it to build applications for PDAs. As for Palm OS and WinCE, Forrester Research's 2004 report, "E-Commerce Forecast for the US," indicated that WinCE and Palm OS accounted for 48.1 and 29.8 percent, respectively, of worldwide PDA shipments in the third quarter of 2004.

We installed the required software on laboratory computers to let students readily work on projects and follow along while building and deploying handheld and server applications. Primarily, we focus on the three integrated development environment (IDE) packages: Microsoft's Visual Studio .NET 2003 for developing WinCE applications, Metrowerks' CodeWarrior for developing Palm OS applications, and Sun's Open Network Environment Studio 5 Mobile Edition for developing J2ME applications. For testing and deployment, students depend mostly on the emulators that come with the three development environments, although some used their own mobile phones and PDAs in addition to three Pocket PCs that I borrowed from a Dell distributor.

The lectures on J2ME and J2SE (Standard Edition) cover the application life cycle from design to deployment. I discuss the IDE and how to install it, the mobile information device profile, and the structure of mobile applications. I use J2ME to demonstrate and develop mobile applications (clients) and J2SE to develop server applications. Other Java technologies that I discuss include Java servlets, which require the Tomcat servlet container for interaction with Web servers. The application demonstrations cover user interfaces, event handlers, multithreading, sockets, local data structures, interfacing with remote databases, and interactions with Web servers.

The lectures on Palm OS include an overview of CodeWarrior and its resource constructor, a companion application for designing user interfaces graphically. I discuss the Palm OS Emulator and ROM images and show students how to set up projects and how to develop and deploy executable PRC (Pilot resource database) files. The application topics almost completely duplicate those of J2ME, with the exception of multithreading, which Palm OS doesn't support.

QUICK FACTS

Course: EECE 679, Pervasive Computing Systems and Applications
Department: Electrical and Computer Engineering
Institution: American University of Beirut
Instructor: Hassan Artail
Level: Upper-division undergraduate and graduate

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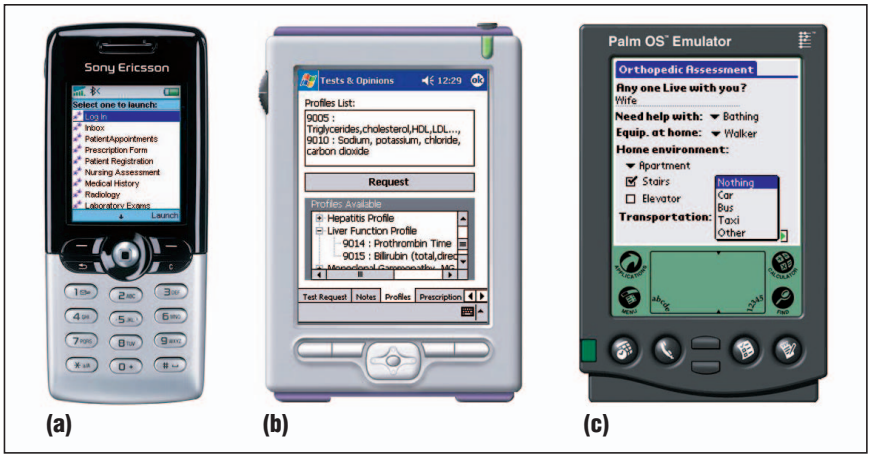

Figure 1. Three hospital information system screens: (a) a wireless phone (J2ME) form showing the main menu, (b) a Pocket PC form listing profiles for medical lab tests, and (c) a Palm orthopedic assessment form.

For Windows CE, I cover the .NET Compact Framework architecture and the available functionality and capabilities. I review Visual Studio .NET and its utilities, including the integrated Pocket PC emulator. I chose C# (among the varied choices for programming language) to introduce students to a new language increasingly gaining in popularity. Most of the application topics coincide with those of J2ME and Palm, although Visual Studio .NET substantially simplifies the application development process and lets students develop Pocket PC applications relatively quickly.

In addition to IDEs, the course also covers other technologies. MySQL is an open source database server that I introduce in class with tutorials on how to set up database tables and perform simple queries. I use MySQL to demonstrate client-server applications and data synchronization between handhelds and a database server. I also discuss the Tomcat HTTP server and demonstrate how to set up Web modules and deploy Java servlets.

DEVELOPMENT PROJECTS

The course requires three development projects, which aim to provide students with hands-on experience in developing pervasive applications. These three projects constitute 45 percent of the course grade. I expect the groups to run applications on the emulator packages, the actual mobile devices, or both. For each project, the students must develop and demonstrate the same application for all three of the course's platforms. In spring 2004, I asked the students to develop a forum application to let mobile device users join one or more online communities, where they help each other answer technical questions relating to given subjects and also contribute information. In fall 2004, I asked students to build a hospital information system. I based this project on actual requirements specifications from the American University Hospital, which call for enabling doctors and nurses to access and alter patient data from their mobile devices.

Requirements

The first project requires students to develop a stand-alone application. This demonstrates their ability to design a user-friendly interface. I give students a requirements specification document that describes the required forms and their functions. This project is worth 10 percent of the grade.

The second project lets students acquire hands-on experience with implementing applications that employ local and remote data-handling functionality. Specifically, the application lets users work on buffered data when the device is disconnected from the network and later synchronize this data with the database. The design model includes the client device, a man-in-the-middle server, and the database server. The server in the middle receives requests from devices, translates them to SQL, and sends them to the database. The server then formats the returned data and sends them to the device. As in the first project, students must implement the project for all three platforms. This project introduces many new concepts and technologies, so it's worth 20 percent of the grade.

The third development project (worth 15 percent of the grade) concerns peer-to-peer communication between devices and interfacing to a Web server. The implementation must let a device query another device regarding topics related to the project's subject. Students must design a high-level protocol (exchange messages) to let devices interact and exchange data. This project also involves communication with a Tomcat HTTP server, which lets the device retrieve content from the Internet.

Figure 1 shows three screenshots of the hospital information system application, one for each platform. The Java-enabled mobile phone has a much smaller screen, so the form design in the J2ME environment (see Figure 1a) differs drastically from the ones for Palm OS and WinCE. This results in more forms and using different groups of controls. For the Pocket PC, students can create more appealing user interfaces (see Figure 1b) with far fewer forms. Most students had some experience in C# and were comfortable with Visual Studio .NET. Finally, for the Palm emulator device (see Figure 1c), the created forms resemble, from a design perspective, those of Pocket PCs. The screen sizes for the two devices are comparable and both offer touch screens that let users interact with form controls by tapping them.

Difficulties

Students faced several difficulties while working on the development projects. For example, CodeWarrior and Visual Studio .NET required student accounts to have administrative privileges. We discovered this when the linker failed to build applications properly and generated ambiguous messages. We resolved this by creating an account for the class with selected permissions to enable reads and writes to given folders.

During the second month of the spring 2004 semester, we discovered that the trial version of CodeWarrior, which came with the Palm OS programming book, limited the application's size to 5 Kbytes. Until we purchased an official copy, students had to divide their applications into smaller subapplications to work around the size limitation.

Because we had access to a limited number of mobile devices, most students had to rely on emulators.

Finally, the course required students to work with multiple programming languages and use advanced programming concepts. Students had varying levels of skills relative to these areas, so I asked the graduate assistant to give fast-track lab sessions during the first few weeks to cover the basics.

RESEARCH PROJECT

The course's research project requires students to research current pervasive computing issues. Students select a topic of interest, identify an area of improvement or contribution, and investigate the idea through simulation or analysis of empirical data. The project aims to promote the students' research and writing skills, introduce them to research topics and advances in pervasive computing, give them an opportunity to explore ideas of personal interest, and improve their presentation skills.

Groups of three or four students work on a research project. To help them get started, I give them more than 20 journal papers covering approximately six research areas to read and select a topic from. I ask each group to read, summarize, and analyze at least six additional papers that relate to their topic. Next, group members must brainstorm ideas for proposed improvements of methods, approaches, or designs. I advise students to use analysis, simulation, or objective benchmarking to support their proposals.

The research project constitutes 20 percent of the semester grade, and groups must submit four reports (a field survey, the project idea, a progress report, and a technical project summary) and give class presentations.

Students completed the following projects in spring 2004:

- realities in context-aware mobile computing,
- a benchmark of security algorithms on handhelds,
- Web services caching in mobile ad hoc networks,
- distributed computing for mobile devices,
- securing mobile ad hoc networks,
- m-commerce security: a case study, and
- mobile database synchronization scalability.

GRADING AND STUDENT PERFORMANCE

For the spring 2004 offering, students performed relatively well on all aspects the class, including the development projects, the research project, and exams. However, during the fall 2004 term and driven by the fact that the projects were to be demonstrated in the presence of officials from the hospital, many groups delivered outstanding projects that received many praises.

Before the projects are due, I give students a list of grading criteria:

- *Project 1:* Diversity in the use of controls, form layout, navigation and flow between forms, design intuitiveness, and user information.
- *Project 2:* Design of on-device persistent data structures, forms data management, middle server design, MySQL database tables design, and synchronization between the data structures and database tables.
- *Project 3:* Implementation of the high-level communication protocol among devices, design and integration of the Web server's Java servlets, communication between handhelds and the Web server, and automation and integration of communication functionality.

The first development project, having to do mainly with developing the user interface, is relatively easy. The second project requires interaction with a database server plus network programming, so it's the most involved. By the time students reach the third project, they're experienced. Additionally, the third project extends part of the second one, making this project the easiest. The projects' relative difficulty is reflected in the students' scores. The averages and standard deviations of grades in the three projects are 84.2 (7.4), 78.9 (7.2), and 88.5 (5.0), respectively. Each grade is itself an average of the individual grades given on the three applications written for the three platforms.

For the research project, I base most of the grade on the final report because it represents the final product. I grade this report on the basis of criteria meant to reflect originality and effort. The "caching of Web services in mobile ad hoc networks" project was particularly strong. The group of students performed a thorough survey of related work, proposed a model for caching in devices within a manet (*m*obile *a*d hoc *net*work), and performed extensive simulations using Scalable Networks's QualNet simulator (www.scalable-networks.com). The group presented results that validated the model and showed its strengths. After receiving favorable reviews, a local conference published the written paper.

In addition to assessing the development and research projects, I tested students on their understanding of the material that was covered during the

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STUDENT FEEDBACK

In a student evaluation of course outcomes at the end of the spring 2004 semester, I asked students to rate the quality of certain aspects of the course by responding to a questionnaire with the following statements:

- I acquired detailed knowledge of the Java 2 Micro Edition, Palm OS, and .NET Compact Framework environments.
- I became proficient in the three programming languages: Java, C, and C#.
- I learned advanced topics in mobile device programming, including data handling, communication with devices and servers, and security.
- Learning by example through code demonstrations enabled me to learn the concepts and tools more efficiently.
- The development projects enabled me to develop hands-on experience and skills in building complete and practical mobile device applications.
- I learned about the characteristics and capabilities of current mobile device platforms and models, and I am able to associate them with applications and markets.
- I gained a broad understanding of the architecture and inner workings of the Palm OS, WinCE, and Symbian operating systems.
- I gained a good understanding of communication protocols and standards for mobile devices, including GSM, General Packet Radio Service (GPRS), Bluetooth, and infrared (IrDA).
- I acquired a general knowledge of related protocols and standards, such as WAP (Wireless Application Protocol) and voice over IP.
- The material that was presented in class was current and useful for my career.
- I learned about current research in this field both through the research project assignment and through the presented material.

Students responded to each statement using a scale of 0 (strongly disagree) to 5 (strongly agree). Figure A shows the average results that highlight the course's strengths and weaknesses, as seen by students. From the results, I can make several observations. For example, the mix of platform architectural overviews, product specification reviews, code demonstrations, and explanations of the platform, language, and tool details gave students a nearly complete picture of the pervasive computing field. Also, code demonstrations effectively helped students grasp many concepts, learn new tools, and develop using three languages in a relatively short time period. Finally, because members of most groups took turns in working on the three platforms, some students didn't have an opportunity to explore some of the advanced subjects in mobile device application development.

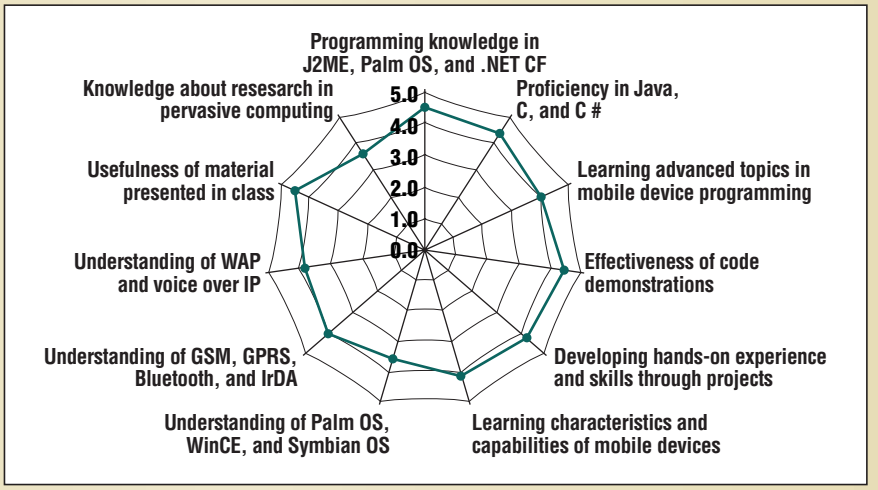

Figure A. Results of the student assessment questionnaire.

lectures and during the code demonstration sessions. Students took a midterm exam and a final exam that were worth 15 and 20 percent of the course grade. The means and standard deviations for the class on the midterm exam and final exam were 82.6 (10.6) and 77.4 (12.7).

Judging from the students' performance on the projects and their answers to a feedback questionnaire (see the related sidebar), the course appears to have met its objectives. Most importantly, I aimed for students to become skilled in developing wireless applications for three platforms that are present in most mobile devices. Many of the students (mostly undergraduates) thought the course load was very high. So, I waived the research project for undergraduate students in the fall 2004 offering. With respect to the projects, I concluded from the scores that students learn better by working on each platform as a group. Because of this, in the course's second offering, we strongly encouraged the students to work in a group and not individually on the three development projects. P

ACKNOWLEDGMENTS

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