

Practical Positioning Projects: Location Based Services in the Laboratory

Meriel Huggard¹ and Ciarán Mc Goldrick²

Abstract – A novel laboratory environment where final year undergraduate students are tasked with developing unique, innovative and commercially viable location based services is described. This laboratory has been developed and refined over the past five years. In this paper we detail the learning environment created, discuss the student assessment procedures and analyse the course outcomes.

Index Terms – Computer Science Education, Location Based Services, Mobile Communications Laboratory.

INTRODUCTION

Effective wireless communication is the key enabling technology for realising the emerging ubiquitous computing vision. Many highly-effective tools and techniques have been developed for teaching traditional wired networking topics in a laboratory setting; however this is not yet the case in the wireless communications arena. Commercial software has been used to introduce electrical engineering students to the fundamentals of wireless transmission [1], however licensing costs and issues makes it impractical for many to adopt such solutions. Some have found ways to incorporate wireless software development practice into their classrooms [2]; while others have sought to use wireless technologies to enhance and extend their classroom [3, 4]. However these methods do not provide students with practical, hands-on experience of the underlying systems.

One of the key technologies underpinning ubiquitous computing is that of location based services and this should be a fundamental component of any mobile communications syllabus. This paper describes a novel location based services laboratory environment which is a component of a final year undergraduate course given to Computer Science students at Trinity College, Dublin. Students develop solutions using J2ME [5] (running on actual cellular phones) and the Apache Jakarta Tomcat JSP server [6]. The freely available Ericsson Mobile Positioning System (MPS) [7] is used to provide a positioning gateway interface (via a Java API) identical to that available on a live cellular network. Students' applications query the MPS and retrieve the positioning response provided by the network. The technically innovative platforms developed must derive maximum usable information from the longitude, latitude and accuracy data returned. Applications

developed have ranged from three dimensional, position aware game environments to a personal health assistant.

This laboratory has been developed and refined over the past five years and, in this paper, we report on our experience. In particular, the learning environment created is detailed, the course outcomes analysed and an evaluation provided.

COURSE DESIGN PHILOSOPHY

The Mobile Communications course is divided into a number of modules involving a mix of formal lectures and laboratory work. Students begin by learning about the underlying principles of wireless transmission and how these underpin the design of wireless communication networks. This material forms a platform for the subsequent analysis, assessment and implementation of a wide variety of wireless communication systems. Students taking this course are drawn from different degree programmes and have varying levels of exposure to the area so it is important for the instructors to accurately identify the commonality of knowledge for each topic area.

This paper describes one module taken by students on the course; this module seeks to reinforce learning in an enjoyable way whilst encouraging students to become independent, critical thinkers. As such it seeks to imbue the next generation of researchers with a cognisance and awareness of both the capabilities and limitations of modern mobile devices.

The course comprises a mixture of lectures, tutorials and practical classes. The lectures are delivered through a combination of formal, didactic teaching classes in tandem with active learning opportunities where students engage with the material in a deeper, more meaningful way. In the tutorials the students work in small groups to analyse, debate and discuss the topics being considered. To ensure maximum benefit for the students the activities carried out during the laboratory sessions are directly linked to the curriculum objectives for the course.

Independent evaluation of the course is carried out through the centrally administered university student survey system. This uses a standardised, non-course specific range of questions. More detailed feedback is gathered through targeted class surveys carried out by the instructors. Students are also asked to reflect on the nature of their learning during each module of the course. In particular, they are required to provide a critique of the strengths and weaknesses of both the laboratory and learning environment created for each module.

¹ Meriel Huggard, Department of Computer Science, Trinity College, Dublin; Meriel.Huggard@tcd.ie

² Ciarán Mc Goldrick, Department of Computer Science, Trinity College, Dublin; Ciaran.McGoldrick@cs.tcd.ie

The Mobile Communications course aims to:

- provide students with a sound technical basis in current and emerging mobile communications technologies.
- require students to derive and implement solutions to problems in the mobile communications domain.
- encourage students to develop and refine their technical writing and critical appraisal skills in a supportive environment.
- equip students with the capabilities to realize innovative solution platforms from minimal problem domain specifications.

The learning outcomes for this course are that students will be able to:

- recognise and discriminate between the different cognate requirements of mobile communication technologies.
- describe, plan and implement innovative mobile communications services.
- assess and document the infrastructure and functionality of a mobile telecommunications network.
- hold and clearly articulate an informed technical opinion.
- appraise and evaluate the social, cultural and ethical implications of pervasive communications technologies.

The Location Based Services laboratory described herein is a key contributor to the aims and outcomes of this course.

MODULE STRUCTURE

In this module the student cohort are encouraged to create mobile computing environments that challenge the traditional perceptions and boundaries of current thinking. The students are tasked with developing unique, innovative and commercially viable location based services.

Optimized 3-D topographical maps provide the underlying environment. These are then layered with positional and co-ordinate geometry metadata. Position data can include physical, geographic and environmental triggers or cues. The technically innovative platforms developed derive maximum usable information from this metadata through a positioning gateway interface.

During the course of this module the students work in small, mainly self-selected groups of three. The module runs for six weeks and the class have access to a dedicated laboratory for at least two hours each week. Prior to the commencement of the laboratory sessions, students are given a one-hour introductory class where they are introduced to the module design and philosophy. During this session a simple didactic contract is established between the students and the instructors. In particular, the aims of the module are identified and the assessment criteria agreed.

TECHNICAL ENVIRONMENT

As the students taking this module are nearing the end of their undergraduate studies, it is considered essential that the environment in which they work closely reflects that which

they will experience in the real world. The technical environment for this module can be deployed on either a Microsoft Windows or Linux x86 platform. Students may choose to work with the platform on which they feel most proficient. All the software components employed are freely available for download from their respective corporate websites.

Platform

A dedicated laboratory environment has been provisioned for use on this module. It comprises 30 PC's, a dedicated server and instructor screen broadcast capabilities. The laboratory network is completely isolated from the main Departmental and University networks. This allows students and researchers model, investigate and validate technological infrastructures that are unacceptable or forbidden on our main academic networks.

The students are provided with full administrative access to the client PC's in the laboratory. They are also provided with access to an up-to-date repository of the main software packages used for the module. Currently the repository contains: Sun Microsystems Java 2 Platform Standard Edition 1.4.2 and 5.0[8], Sun Microsystems Java 2 Mobile Edition (J2ME) Wireless Toolkit 2.2[5], Ericsson's Mobile Positioning System (MPS) SDK 6.0.1[7], Ericsson's MPC Maptool 3.0.1[9], Nokia's Series 60 SDK for Symbian OS[10], Siemens Mobility Toolkit for Wireless Applications[11], Apache HTTP Server 2.0.53[12], Apache Jakarta Tomcat 5.5.7[6] and the NetBeans IDE[13]. All these packages are freely available for development purposes. Students may install and use any, or all, of these packages on their client PC but must justify their selections to the instructors in light of their implemented services.

Nominally the laboratory environment is exclusively available to the module cohort for 2 hours each week. During this time the instructors are present and guide and assist the students in formulating and executing their proposed services. Students are also free to use the resources, if available, outside the timetabled slot and most avail of the opportunity to do so.

Software

As already described, the module requires small groups of students to conceive and implement novel, commercially viable location based services that will be deployed on, or via, a J2ME device. J2ME is aimed at constrained consumer devices e.g. mobile phones or PDAs, and provides a subset of the full J2SE API. The actual functionality provided by J2ME for a given device implementation is determined by both the Configuration and the Profile.

A Configuration defines a Java platform for a family or range of devices. The standard currently defines two Configurations – Connected Device Configuration (CDC) and Connected Limited Device Configuration (CLDC). A profile can be viewed as an extension or addendum to the Configuration. The Mobile Information Device Profile (MIDP) takes into consideration the display and memory limitations of mobile devices as well as providing API's for

networking, persistent storage, event handling and user interfaces. Students are required to use the CLDC with the MIDP profile, which allows them focus their developmental efforts towards mobile phone devices.

The CLDC and MIDP development and emulation environment is provided by Sun's J2ME Wireless Toolkit (J2MEWTK). This wireless toolkit requires a correctly configured J2SE environment as a prerequisite. The J2MEWTK provides a generic phone emulator which can be used to test and validate client code. The generic phone emulator can be 'skinned' to visually appear as a commercial mobile phone. Phone manufacturers also provide replacement or alternative development and emulation environments that extend the J2MEWTK. The Nokia Series 60 SDK and the Siemens Mobility Toolkit are two such environments. These provide more fully featured, albeit device specific, mobile phone emulators for testing and validating J2ME code.

The Ericsson Mobile Positioning System is a server based solution that allows positioning services be introduced into a GSM mobile phone network. A version of the MPS is made available to developers free of charge via the Ericsson website. This version accurately emulates the behaviour and functionality of a positioning gateway on a live GSM network. In particular the emulator allows students to setup their own local positioning system. Emulation data for the MPS is generated using the Ericsson MPC Maptool. A map, or other area of interest, is loaded into the Maptool. It is then annotated with roads, approximate population densities and mobile phone routes. The MPC Maptool then generates a cell plan for the annotated area and exports configuration files to the MPS Emulator. The Emulator uses this data to provide 'realistic' emulated positioning answers to incoming queries. The format of the positioning response is standards compliant and the MPS supports all request types defined in the Global System for Mobile communication (GSM) standard. The three request types are Mobile Terminated Location Request (MT-LR), Mobile Originated Location Request (MO-LR) and Network Initiated Location Request (NI-LR). The MPC Emulator simulates the part of the MO-LR flow where the positioning answer is sent to the Location Service Client. In summary, a request containing the phone number to be located is sent to the MPS and it replies with the positional data (including the current longitude and latitude) for the device in a standardised format.

Configuration

Configuration of their local development environment on a PC is a task that many students have not previously attempted. Most of our students have advanced through their freshman and sophomore years learning how to program and interact with Java through an IDE but have had little exposure to its inner workings or configuration. This module requires them to quickly grasp these skills so that they can configure the development and evaluation environment correctly.

Installation of the J2SE package is the first task to be completed. This is largely automated by the binary installer package. Next the J2ME package must be installed and

configured. This requires the students to configure some Environment variables and to ensure that the PATH and JAVA_HOME variables are correctly set. At this juncture, the student is expected to successfully compile and demonstrate a sample J2ME midlet to validate that the environment is correctly configured.

Apache Jakarta Tomcat must now be installed. Again this is packaged with a binary installer that makes installation straightforward. Students should ensure that the test servlets load and execute correctly before proceeding.

Next the Ericsson MPS must be successfully installed and configured. The MPS is built using servlet technology and is deployed in a server environment that supports servlet technology e.g. Apache Jakarta TomCat. Installation is straightforward; the MPS comprises a number of jar files that must be moved into the TomCat WEB-APPS library subtree and configured through a web.xml file. Students use the Java Mobile Positioning Protocol API to interact with the MPS, thus ensuring that a detailed understanding of the protocol is not required.

PROJECT DESCRIPTION AND OUTCOMES

The task requirements are presented to the students through a minimal problem domain specification. In 2004/2005 the task was specified as follows:

'Implement a simulation of a commercial service that uses positioning information and makes novel and effective use of a J2ME enabled mobile device as the end-user delivery platform. The MIDP profile should be used.'

The task specification is accompanied by written details on the agreed assessment procedures and module marking scheme together with broad guidelines on how to install and test the development environment.

Initially students are expected to form small groups of three. Each group then meets to discuss the assignment. As marks are awarded for the novelty of the solution proposed, much of this initial session is often spent seeking novel and innovative service ideas. Many groups come up with a range of possible services and must then identify the candidate service that best satisfies the task specification and is most complementary to the group's skill set.

The service design and planning process requires the groups to consider both implicit and explicit system factors as well as the societal significance of their services. Explicit factors include

- the user interface design and how the user interacts with the service.
- service accessibility for all users.
- whether the service runs entirely on the J2ME device or is a client-server architecture which uses the J2ME device as a console.

Implicit factors include:

- the selection of a messaging protocol in a client-server configuration.
- device capability profiling.
- whether the service is a 'push' service.

Groups are also required to assess the ethical and social significance of their service offering. This includes factors such as whether:

- it infringes on any basic civil liberties.
- the general public want or need such a service.
- the service is open to misuse or abuse by state or commercial interests.

Working in small groups, students have developed solutions which span the broad scope of human experience. The minimal problem domain task specification encourages creativity and novelty in both application area and technical implementation. Some of the more innovative student projects in recent years are first described to illustrate this.

Monitoring services

Useful ‘big-brother’ type service offerings include Partner Policing and the Child Chum.

The Partner Police service is a dual functionality system. It allows a jealous spouse track their partner’s location, movements and acquaintances. It provides longitudinal tracking of acquaintances and can be configured to trigger alerts based on frequency of encounter at different classes of venue. Separately, it can also be used by single people to track multiple boyfriends/girlfriends and to send alerts if one of the alternates is likely to encounter or interfere with a current date.

The Child Chum service can be viewed as the next-generation of ‘Tamagotchi’. A J2ME midlet executes on the child’s phone or other tracking device. It is capable of receiving input from, and providing guidance or instruction to, the child. It functions as a child monitoring and tracking service for concerned parents and guardians. A simple expert system can be configured to automatically guide and instruct the child, and to alert the parents if the child encounters difficulties, or is at risk.

Social applications

Social applications of technology are also popular amongst our students. Examples of these include the Osama Shield and the Riot Aggregator.

The Osama Shield is proposed as a terrorist attack alert system. Its purpose is to guide you to safety in the event of an emergency. Individuals in the vicinity of the event area are automatically identified, located and sent personalised instructions guiding them away from the location, and to the nearest safe venue. The system can also automatically notify family or next of kin when the individual is safe.

The relative ease with which Law Enforcement services curb lawful protest was of concern to one group. In response, they proposed the G8 Riot Aggregator. This system guides individuals, or small groups, towards a larger, central protest march. The protestors gradually coalesce from all directions, simultaneously arriving at a protest or conflagration point.

Home and Leisure Services

Other groups focus on home and leisure service offerings. These range from game like environments for children, such as the Hobbit Rescue Service in which you ‘help protect the little people of Middle Earth from the tyranny of evil beings’, to health and well-being offerings, such as a virtual buddy, who encourages you to ‘fight the urge’ when tempted by alcohol or fast food outlets.

SAMPLE STUDENT PROJECT

A brief overview of a representative student project is now provided. The student group proposed a ‘Hobbit Rescue Service’ which they describe as a ‘J2ME based application that manipulates positioning information which is stored in an SQL database and accessed through an Apache Tomcat server’.

The project aims are as follows:

- ‘To protect the little people of Middle Earth from the tyranny of evil beings.
- To guide members of the Fellowship to hobbits in distress.
- To alert members of the Fellowship if they are within proximity of a hobbit.
- To incorporate a stand-by facility enabling members to use the phone for other services e.g. Aragon might want to tell Arwen he won’t be home for dinner as he is busy fighting’.

The students identified that it ‘was important to have clear menu screens and instruction sets that can be easily followed. Human Computer Interaction (HCI) played an important role in designing the interface’. All interaction with the service is via the J2ME menu screens on the mobile phone.

The students provided a map of ‘middle earth’ on which to reference position coordinates. Relative population densities were identified for all the major locations in middle earth – ‘cities and castles were defined as dense urban; villages were defined as urban; hamlets were highlighted as suburban and everything else was defined as rural’.

The students’ solution comprised two distinct components: a J2ME midlet that runs on the mobile telephone. and Java servlets running on an Apache Tomcat Server. The midlet provides both user and administrative Graphical User Interfaces, interaction forms, service lists, user help, alerts and graphical navigation. Users enter login information to a form on the mobile phone screen and submit it. The midlet posts this information (via a HTTP post) to a login servlet. The login servlet queries the database and ascertains if the user exists and if the password is valid. One of three status codes is returned to the midlet: OK, Bad password or Unknown. If the status is Unknown then the user may be offered the opportunity to register. Once login is successfully completed, the user is presented with a menu of options:

- Directions: The directions option allows the user to find the position of certain hobbits.

- Proximity Alert: The proximity option sounds an alert if the user is within a certain distance of a hobbit. It can also be configured to alert the user to the impending arrival of a ‘pack of marauding Orcs’.
- Equipment: The user can select equipment for the quest e.g. Rope, Stretcher, Sword, Bow & Arrow.
- Standby: Allow the user to use the phone for other services during the quest.

To enable this functionality the students provided RescueLogin, PositionServlet, DistanceCalculator and CompassBearing servlets, in addition to the RescueServices midlet. The midlet interacts with these servlets to establish the location of the user, other hobbits or Orcs, and to compute and establish distances and bearings to these entities.

EVALUATION

When assessing the quality of student learning it is essential to consider the information gathered from individual students as well as the global statistical data gathered from the class. As the module described above relates to a practical laboratory environment, the evaluation carried out focused on the quality of the learning and technical environment created.

In Trinity College, Dublin the University Quality Office offers to carry out independent surveys of courses and modules at the requested of the course instructors. These surveys are administered centrally and include almost thirty closed response questions where students must indicate the extent of their agreement/disagreement with a number of statements regarding the course. Students are also asked to list two positive and two negative aspects of anything to do with the course or module. The numerical survey results are then analysed and returned to the instructor together with any associated student comments.

The instructors also carried out a survey to assess how student's viewed the relationship between the course objectives, learning outcomes and technical environment. Students were also asked to provide qualitative feedback along with the final report on their work.

The results of these separate evaluations are given below; these indicate clearly that the students feel that the environment created significantly enhances their learning experience.

Quantitative

The independent quantitative evaluation criterion used may be grouped into the following classes (using a similar methodology to that of Ramsden [14]): Good Teaching, Clear Goals, Appropriate Workload, Appropriate Assessment and Emphasis on Independence. The results are summarised in Figure 1. This includes a separate class for non-course specific questions that do not fit the above criteria.

The students were also given a questionnaire relating to the course objectives. This showed that 82% of students agreed that ‘Creating a novel application that makes maximal use of the positioning information available’ was a feature of both the module and its assessment criterion. Over 75% of the

students also agreed with the statements that the course ‘Encouraged them to think critically’ and to ‘Provide a clear rationale for their design methodology’. While 68% of the students felt that ‘Building a working prototype was a key component of the course’.

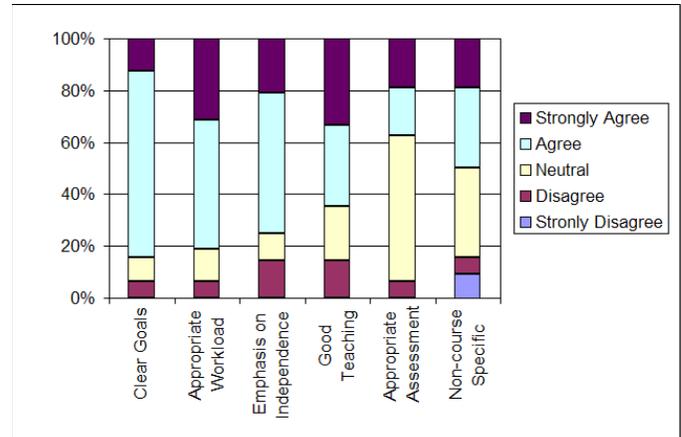


FIGURE 1
SUMMARY OF INDEPENDENT QUANTITATIVE EVALUATION

Qualitative

The qualitative results presented in this section are drawn from the final reports submitted by each group of students at the end of the module. Each group was required to reflect on all aspects of their learning on the module; in particular they were required to comment on the strengths and weaknesses of the learning environment created. They were asked to address the following questions on the module structure and design:

- Which individual features of the module were enjoyable, motivational or appealing?
- Did you find the approach adopted in this module appropriate and relevant to your course of study?
- How do you feel you benefited from taking this module?
- What do you feel can be improved about the technical environment?
- Which parts of the learning environment need to be refined for future module presentations?

Students were very enthusiastic about the fact that they were working with real world development tools such as the Ericsson Mobile Positioning System. They felt that this made the project much more relevant and enjoyable, motivating them to work on the problem in a way that they had not done before. This was also evidenced by the fact that many groups requested access to the laboratory outside of the scheduled hours.

Several groups opined that the emphasis placed on the novelty and commercial viability of the proposed location based services gave them much greater freedom and control over the design of their assignment than they had experienced on other courses. They also felt that this quest for novel applications discouraged plagiarism. Student ownership of the process was also clearly evident in the final assignment reports

submitted: many created their own logos and graphics and discussed ways in which their finished product could be refined to improve its marketability.

One group of students stated that the module brought together many of the concepts they had studied and discussed in class. They felt that it allowed them to see how the different technologies can be combined to form effective location based services.

Some of the groups were of the opinion that the examples provided were insufficient for their needs. The sample code demonstrated one means of interfacing with the positioning gateway; it was not intended to provide students with a prescriptive template for developing their own applications. Some students seemed conditioned to expect highly directional advice and guidance.

CONCLUSION

Wireless communications functionality is proving to be the key enabling technology for the platforms of tomorrow; as such they will affect the way we all live, work, learn and play. With the advent of geographically and spatially aware knowledge based services it is important that researchers innovate and seek to maximally exploit the personalisation and profiling capabilities of evolving systems. The novel laboratory environment described herein seeks to provide graduates with hands-on experience and technological awareness of both the capabilities and limitations of modern mobile devices.

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