

A Framework for Mobile, Context-Aware Trails-based Applications: Experiences with an Application-led Approach

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Abstract. The *Hermes* project is addressing the development of a generic framework to support the design and implementation of mobile, context-aware applications. Our initial focus is on trails-based applications. This paper discusses our experiences with an application-led approach to framework development and presents the issues encountered to date. Remedies for the issues are proposed as a step towards enhancing the benefits of application-led ubiquitous computing research.

1 Introduction

The development of ubiquitous computing applications poses numerous challenges to software developers. Issues inherent to the ubiquitous computing paradigm must be tackled during each application development effort, meaning that developers repeatedly encounter the same or similar issues, regardless of the application under consideration. These issues range from low-level programming issues to high-level usability issues.

Hermes [5] (<http://hermes.dsg.cs.tcd.ie>) is a software framework for mobile, context-aware trails-based applications which will support developers by providing generic components containing structure and behaviour common to all trails-based [4] applications. Mobile, context-aware applications are those that run on devices such as PDAs and mobile phones, and have an awareness of the physical and social situation in which they are deployed. A trail can be thought of as a collection of locations, together with associated information and activities, and a dynamically reconfigurable recommended visiting order. Trails underpin a wide range of useful applications for a mobile user who has a set of activities that may or should be carried out throughout the day at different locations. Combining the trails concept with mobile, context-aware technology creates opportunities for innovative activity-based application development. Examples of trails applications that are both mobile and context-aware include courier management systems, basic route planners, treasure hunt games and student support systems.

The *Hermes* framework will facilitate the development of a diverse range of realistic trails applications. This research is relevant to the field of ubiquitous applications development as a whole because we consider trails applications to be archetypal mobile ubiquitous applications which exhibit the ubiquitous computing characteristics described in [2].

This paper presents our experiences to date with following an application-led approach to framework development. The remainder of the paper is as follows. Section 2 contains a description of our framework development approach and work to date. Section 3 describes the issues we encountered. Section 4 suggests remedies to these issues. Section 5 contains a summary.

2 Framework Development Approach

The *Hermes* framework is being developed using the “Three Examples” technique for framework evolution described by Roberts et al [14]. We began the process by specifying requirements for three mobile, context-aware trails-based applications. These are listed below in order of increasing complexity as regards ubiquitous computing issues addressed:

- 1) Student support system for new students at Trinity College Dublin.
- 2) Trails-based mobile treasure hunt game.
- 3) Delivery courier support system.

We have implemented a student support system called Oisín which provides campus-wide trails including both compulsory tasks such as registration and optional activities such as visiting college buildings. The trails are based on and affected by environmental and personal context and are automatically dynamically reconfigurable. We have recently initiated a period of application testing involving a user trial preceded and followed by written questionnaires and interviews.

3 Issues and Experiences

This section contains the issues encountered by the *Hermes* development team during the design, implementation and initial user testing of Oisín.

3.1 Lack of Interdisciplinary Expertise

Lack of Psychological Expertise

As the user trial is based on a questionnaire design, the data produced depends entirely on the quality of the questionnaire employed. Our experience illustrates that computer scientists are typically not the people best qualified to conduct user trials. For example, some of our questions proved confusing to the test subjects, even though those tested thus far have a computer science background. These questions yielded no data,

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leaving our data sets incomplete as a result of our own short-comings in the area of questionnaire design.

Lack of Graphical User Interface (GUI) Expertise

Poor GUI design has prevented the collection of data on application features we are interested in. An objective of our trial is to gauge user opinion on Oisín's dynamic trail reconfiguration behaviour. We wish to ascertain whether or not users feel the decisions made by the application on their behalf are appropriate and timely. However, we found that the implementation of the trail adaptation behaviour was deficient from a GUI perspective. This resulted in cases where the users did not notice that the trail had been reconfigured, due to the lack of appropriate notification. It is apparent to us that although the dynamic reconfiguration decisions may make sense, the user can be turned off the concept if the GUI is not designed in a manner which maintains the user's feeling of control.

3.2 Social Computing

The social attraction of the application was overlooked when developing Oisín, most notably in terms of the hardware form factor and the social acceptance of the devices used. Users of Oisín are required to carry a GPS receiver and a PDA, which are connected by a cable. The GPS receiver requires line of sight to satellites so must remain in the user's hand. The PDA requires two hands to operate. This leads to a very difficult to manage deployment platform.

We also found that repeated consultation with a PDA attracted inquisitive and sometimes disparaging glances from passers-by. We accept that levels of social acceptance of such devices vary from country to country but believe our experience to be representative of the general case in our environment. This factor coupled with the difficult to manage form factor has lead to a negative social impact on system users, resulting in negative comments in our user trials.

3.3 Implementation issues

Implementation issues arose that detracted from getting unbiased results on potentially more important aspects of the research. In our experience, two main implementation issues affected our results: 1) limited resolution and unpredictable error of our chosen location system and 2) resource limitations of mobile devices.

Oisín uses a GPS receiver to obtain location data. During user trials the location data was only accurate to twenty meters, resulting in user location being inaccurately displayed on the map. This confused users and caused the application to make incorrect reconfiguration decisions. This inaccuracy is attributed to the urban environment in which Oisín operates, where GPS functionality can be lost because buildings occlude signals or scatter them in multipath reflections.

The conflict between the limited processing power of the mobile device and the calculations required by the dynamic reconfiguration algorithm caused a delay each time a trail reconfiguration decision was made. Delays in the order of 30 seconds were experienced while the application updated the user's trail. During this time the application was "busy" and could not be interacted with, leading to user frustration.

3.4 Application Scenario Choice

A motivating factor in our decision to implement a student support system as the first prototype application was ready access to a pool of test subjects. We intended to use two classes of students on their first day at college. However, due to delays in equipment acquisition it was not possible to meet this deadline, meaning that another application scenario had to be defined. We sent subjects on an information gathering trail around Trinity College's historical artefact displays and art galleries. We observed that subjects exhibited a lack of motivation when following the trail as doing so is not necessarily in their interest. They were purely participating in a user trial, unlike the first day students that would have followed a different trail involving activities such as registration and compulsory lectures.

4 Ideas for Remedies

This section puts forward possible solutions which may overcome the difficulties we have encountered.

4.1 Interdisciplinary Involvement

Psychology

There is an area of psychological research known as psychometrics [12] that is concerned with the design of tests and questionnaires and the compilation and evaluation of their results. Psychometric knowledge is required in order to validate that a user trial is suitable for gathering the type of data required by a development team. It is asserted that "metrics for designing and evaluating pervasive systems are still lacking" [7]. Our approach of gathering user trial results via questionnaires is a common one and increasing the quality of such questionnaires should be a goal of researchers in this area. In parallel with the development of applications we foresee a need for the development of a standardised questionnaire for measuring user-perceived quality of context-aware mobile applications. This could provide data for an evaluation of users' experiences under various conditions and across a range of independently developed applications. Such evaluation techniques can only be developed in conjunction with experts in the area of psychology. For this reason we recommend the inclusion of such experts in the development of ubiquitous computing applications.

GUI

"A frustrating interaction with a computer system can also leave a user feeling negatively disposed toward the system and its makers." [9]. This finding suggests that when evaluating an application via a user trial, the ease of use of the application's interface can colour the results of questionnaires.

It is essential that experts in the field of human-computer interaction are consulted on design issues where possible at an early stage of development. For example, when we consulted Human Computer Interaction (HCI) researchers they were able to advise us on how to reduce the feeling of lack of control regarding trail adaptation by making a small number of improvements to the user interface.

4.2 Social Computing

Device satisfaction and social attraction need to be considered when selecting hardware. Neither of these factors featured in our hardware requirements. We are

preparing new hardware requirements for the next prototype application featuring a subset of factors from [10], which we believe have the most significant social computing impact for our class of application:

- 1) **Familiarity.** Is the form of the device one that is familiar and appropriate for the context of its use?
- 2) **Appeal.** Is the device something that the user is comfortable being seen using?
- 3) **Disruption.** Does the device disrupt individuals' natural social behaviours?
- 4) **Pervasiveness.** Is the device mobile or otherwise convenient to use in social settings?

The above considerations have led us to begin evaluating and researching the possibility of basing future applications on mobile phones. It should also be an aim of context-aware applications to produce more socially intelligent applications that adapt not just to physical context such as location and time but to a users social environment providing for a more positive social impact.

4.3 Overcoming Implementation Issues

The main implementation issue hindering our user trial is an inaccurate positioning system. Other researchers have also encountered this issue [1]. The failure of systems beyond our control to supply accurate contextual information highlights a general problem with context-aware mobile application evaluation. Because context-awareness clearly distinguishes ubiquitous computing applications from other mobile applications, the ability to evaluate how applications react to context changes is critical in a test environment. To make this possible a test environment in which developers have some degree of control over available context for the purpose of logging and reasoning about applications correctness and for the purpose of enabling repeatable experiments is required.

A possible approach to achieving such control is to use a simulated environment. Similar efforts in the area of ubiquitous computing are now emerging with immersive 3D games engines being used to simulate the physical environment [3,6,11]. These test environments are designed to simulate different aspects of ubiquitous computing environments. The GeoNotes project [6] modified a games engine to output a player's position via the Context Toolkit. UbiWise [3] modelled mobile devices in the environment and Morla et al. integrated network simulation into a virtual environment [11].

Trinity College Dublin's Knowledge and Data Engineering Group are working towards a ubiquitous computing simulator combining aspects of all these previous works called TATUS [13]. TATUS allows for easily configurable interactive 3D virtual environments to be built using a games engine. Context is exported from the virtual environment to the software under test, simulating the software running within the virtual world. An environment like TATUS with the addition of standardised context acquisition interfaces would be useful for the development of context-aware mobile applications. Such an environment could provide a level of control not easily attainable in the real world and would have even more utility when collaborative context-aware applications are considered. A TATUS-like simulator could allow multiple researchers to si-

multaneously test the interactions between different devices in a ubiquitous computing environment.

4.4 Application Scenario Choice

To avoid having to carefully select trial subjects so that they are motivated for the particular application under consideration, we are turning our attention towards investigating how the properties of the application itself influence user motivation. Opportunities for creating engaging applications exist in the computer gaming field. Games have a motivational appeal that distinguishes them from other forms of computer interaction [8]. Games provide a sense of control, opportunity for strategy and discovery of information. These qualities are desirable in an application that will be evaluated by user trial. For these reasons we are currently working on the next prototype application which is a mobile, context-aware trails-based treasure hunt game.

5 Summary

This paper discusses issues we have encountered to date with using an application-led approach to ubiquitous computing research. We learned that experts from the fields of psychology and HCI should be involved to validate the work done in those areas. We also suggest increased consideration of the social issues surrounding ubiquitous computing. Finally, development of virtual environment-based ubiquitous computing simulators may aid evaluation of prototype applications.

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