

Handling Adaptability, Privacy, and Accuracy in the Design of a Location-Aware Mobile Interactive Gateway

Klaus Marius Hansen
Department of Computer Science,
University of Aarhus
Aabogade 34, 8200 Aarhus N, Denmark
marius@daimi.au.dk

Giuseppe Menta and Beatrice Pregarz
T-Connect S.r.l.
AREA Science Park, Padriciano 99, 34012
Trieste, Italy
{g.menta, b.pregarz}@t-connect.it

ABSTRACT

Context information, and in particular location information, is central to most ambient computing applications. Three central challenges in this context are privacy, accuracy, and availability of location information. Given these challenges, we present an approach to supporting location awareness and guidance for mobile professionals using a *Mobile interactive Gateway (MiG)*. In particular we aim at supporting: control of distribution, adaption to coverage, and control of accuracy of location information. We present preliminary results in the form of a design and partial implementation of a prototype for achieving this goal.

Author Keywords

Location awareness, adaptability, privacy, interaction design

INTRODUCTION

A central need in most ambient computing applications¹ is for applications to be aware of information of relevance in their surroundings. A good example is applications supporting mobile tasks that often need to have information on the task, the location of users and devices, and more. Another central need is for adaptivity in that users in performing mobile tasks often encounter new sensors and actuators with which it is opportune to interact.

The eu-DOMAIN IST project², in the context of which our work takes place, aims at supporting this and more. The eu-DOMAIN project builds a general ambient intelligence service platform aimed at automatic and context-aware offering of mobile web services. The platform will interconnect people, devices, and buildings in an interoperable, heterogeneous network. The two main application domains in

¹This paper uses the term “ambient computing” to interchangeably denote ‘ambient intelligence’ [1], ‘pervasive computing’, and ‘ubiquitous computing’.

²<http://www.eu-domain.eu.com>

the project are *facility management* and *healthcare provision*. Through domain expert and user involvement a number of scenario-based visions of the use of the eu-DOMAIN platform for these two application domains have been developed³. In this paper, we are concerned with the healthcare-related application scenarios of eu-DOMAIN. Our scenarios have taken their outset and inspiration in these.

The rest of this paper is structured as follows: The next section (“Scenarios”) introduces the Mobile interactive Gateway (MiG) scenarios, following which we discuss background in the form of context awareness and security and privacy in ambient computing. Based on this, we derive design challenges, present a design aimed at resolving these, and finally we discuss the design challenges in relation to our design.

SCENARIOS

The actors of our scenarios are nurses and healthcare professionals performing primary care for a number of patients living in different parts of cities (in the eu-DOMAIN project this is in East Birmingham, United Kingdom, in the context of this paper, the setting is Trieste, Italy). Their work is mainly carried out in the homes of patients and is to be supported by the eu-DOMAIN platform. The platform should among others provide needed information through a number of services being delivered by the open and always-connected platform.

Mrs. Sabatini is a nurse manager and nurse. In addition to her daily work with patients, she is responsible for planning the work of other healthcare practitioners. In many situations, she needs to know contextual information, including location, about her team in order to guide herself and the team in providing efficient and effective healthcare. Furthermore, this information should be obtainable everywhere, not only from a desktop computer in the office.

Scenario 1. Mrs. Sabatini is now outside her office because of a general meeting organised in Udine. Unfortunately, ten minutes before 10 a.m. she receives a phone call from Marina, one of the nurses, who is stuck in a traffic jam in the Trieste town centre, who is not able to drive to an old patient who lives outside

³See <http://www.eu-domain.eu.com> for a summary of the scenarios.

the city, near the Slovenian borders and who needs assistance quickly for the injection of a medicine through a phlebotomy. This medicine, in fact, has to be dispensed at a relatively fixed time during the day and one dose is scheduled at 10 a.m. Based on the knowledge of the teams tasks, the location of team members, and available skills, Mrs. Sabatini needs to decide which of them could be asked to replace Marina in relation to their actual and future tasks. Being outside her office, she needs fast and mobile support for obtaining this information.

Scenario 2. Mrs. Sabatini is in the office dealing with daily administrative work and financial matters. All tasks for the day have been assigned to the nurses and the morning passed without any problem. Just after lunch, an emergency call arrives at her office. It is Mr. Ridoni's daughter: her father, an old man suffering from heart disease, is feeling ill and the daughter is worried about the man's condition; she fears a heart attack. In this situation there's no time to waste and the best thing for Mrs. Sabatini to do is to immediately warn the available reference physician and some of her nurses, who know Mr. Ridoni and his health problems. Preferably this should be done in real-time, using indications about healthcare professionals' locations and skills in order to manage quickly the best resources available.

CHALLENGES AND BACKGROUND

Context and Location Awareness

Context awareness in an (ambient computing) application is concerned with acting on information about an entity (person, place, object) in a way that is relevant to the user of the application. An example is using GPS information on an in-car display to guide a driver to a desired location. This example is also an example of *location awareness*, i.e., using information about the location of a device to adapt the applications of that device. This paper is concerned with location awareness.

A large number of *location information providers* are and may be used to gather information about the location of a device. Examples include GPS (for outdoor use), GSM cell-based (for indoor and outdoor use), triangulation of signals from WiFi base stations (for indoor use), and proximity-based location based on the location of fixed radio beacons such as Bluetooth.

Different technologies offer different operational characteristics such as accuracy and speed of reading. As an example, Place Lab [3] does location solely based on proximity of radio beacons (GSM cells, WiFi access points, and fixed Bluetooth devices). Using freely available infrastructure, Place Lab is able to locate device with an accuracy of approximately 30 meters both indoor and outdoor in urban areas. GPS typically offers accuracy of approximately 10 meters. Bluetooth-based location may be more precise but may be hampered by the duration of the time for scanning Bluetooth devices.

Security and Privacy

Information security is concerned with keeping information confident, establishing the integrity of data, and ensuring the availability of data. In ambient computing the problem of providing adequate security is amplified by the heterogeneous, often ad hoc, collection of communicating devices. Since ambient computing may affect our daily lives in many ways, having a sufficient level of security becomes very important.

In particular, *privacy*, i.e., enabling persons to decide themselves when and if information is shared with others, becomes an issue when users are potentially monitored and sensed by a large number of devices capable of communicating this information.

With respect to privacy, ambient computing amplifies existing privacy concerns [4] (paraphrasing [5]):

- *Ubiquity* in that the infrastructure is everywhere, potentially affecting all aspects of our lives
- *Invisibility* in that the infrastructure is not directly visible to users
- *Sensing* in that all that we do may be input to the infrastructure
- *Memory amplification* in that any interaction with the infrastructure may be stored and retrieved

Not surprisingly, privacy concerns are often seen as a major obstacle to actually deploying ambient computing.

Design Constraints

Based on the above discussions, we arrive at the following design constraints and goals of our Mobile interactive Gateway with respect to location information:

- *Control distribution.* Allow end users to control distribution of location information. Users should be able to allow as well as disallow distribution of location information
- *Adapt to coverage.* Dynamically roam among available sources of location information provision. In highly mobile use, provide means for distributing functionality when needed
- *Control information distributed.* End users should be able to control which information is distributed how. Users should be able to distribute their location with another accuracy than that provided by the location infrastructure

A MOBILE INTERACTIVE GATEWAY (MIG) DESIGN

System Design

The MiG system platform is a Windows Mobile PDA platform (currently running on a Siemens/Fujitsu Pocket Loox 720). The overall system architecture is a client-server one in which the MiG connects to an eu-DOMAIN server to handle non-local data such as querying the location of other MiGs or downloading needed software to the MiG.

The MiG runs in Java on top of the Knopflerfish⁴ implementation on the Open Services Gateway initiative (OSGi⁵). OSGi is an open specification for delivering services to local networks and devices. Examples of uses of OSGi are in cars for controlling and coordinating multimedia equipment, in industrial automation, and in service gateways for home automation. Services are provided on OSGi-enabled gateways through *bundles*, Java runtime components that may be installed, started, stopped, and uninstalled during runtime. This is key to supporting adaptability in the MiG platform. Examples of bundles for the MiG platform is bundles for communication with GPS devices and bundles for communication with the eu-DOMAIN server.

The bundle for communication with GPS devices is an example of the need for specific bundles for implementing interaction with location information providers. Currently, we are implementing support for GPS, GSM-based location (based on cell ids), and fixed Bluetooth radios in the form of BLIP Systems hardware⁶. The basic idea is that the MiG monitors the availability of location information providers and calculates its location based on this. Note that location calculation is done on the MiG to enable it to control the information about its location that is transmitted⁷.

If the MiG discovers new (location) hardware that it does not yet support, it may contact its associated eu-DOMAIN server and possibly download support for it through bundles provided by the server. This aids in the adaptivity of the platform. An example would be a MiG that becomes equipped with WiFi connectivity and thus may use WiFi-based location methods if appropriate software is downloaded.

Interaction Design

The basic interaction with the MiG is through a web-based interface. This has been chosen since this makes provision of user interfaces for mobile as well as stationary devices technically simple. Technically, this also poses the constraint that the user interfaces should be pull-based (i.e., information flows from the server to the user only if the user requests it) rather than push-based (e.g., information flows from server to user when it becomes available on the server.) Given the current low frequency of location updates of the scenarios, this was deemed reasonable.

In the context of the scenarios introduced above, there is provision for discovering and authorizing new location information providers, managing one's own and others locations, managing details of users, and for interacting with devices in buildings. In the context of this paper, we focus on the user interface for managing locations. The basic nurses' location overview is a map with various additional information on the map. The following principles are observed for central, visualized concepts of the location system:

⁴<http://www.knopflerfish.org>

⁵<http://www.osgi.org>

⁶<http://www.bliptechnology.com>

⁷For GSM location, the telephone operator will always know the location of a GSM SIM card, however.

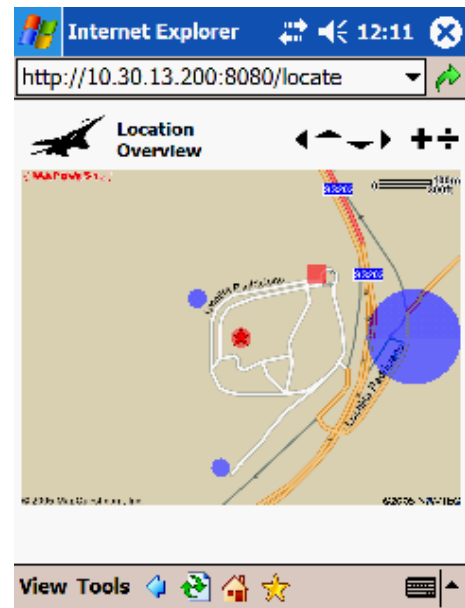


Figure 1. Location Overview. The central translucent dot shows the current position of the MiG. Other dots shows the position of other MiGs. The size of elements indicate the accuracy of the location of the relevant MiG

- *Location* is visualized as dotted “locators” on a map. Initially, the location of the MiG is shown as the centre of the map using red. The controls in the top of the screen may be used to zoom and pan to move the map and show other dots not present at the screen. Other MiGs are shown using blue. Locators are transparent to preserve context of a location
- *Accuracy* is visualized as size of locators and by possibly providing additional, linked material. Linked material provides details of the MiG in question.

Furthermore, the user's preferences provide controls for managing aspects of the MiG's location information publishing. In particular, the user may decide to publish location information just as, worse, or better than the accuracy of the location information if the user decides to publish this information at all. In Figure 1, the user has chosen to publish location information “as is”, i.e., to let other MiGs know that this MiG, e.g., is currently positioned at a precision of 10 meters. If the user had chosen “worse”, then the others MiGs would see this MiG in the form of a larger locator. Indeed it is not possible for the current MiG to decide whether the rightmost, big locator results from a MiG being located with low accuracy or whether its user has decided to publish a less precise location.

DISCUSSION

The current MiG design embodies a general platform for providing applications on a mobile gateway. This paper has considered location, and in particular privacy, aspects of the platform.

Reconsidering the design challenges, *adaptability* is to a certain extent met by the choice of using the OSGi platform at least on a system level. There are most definitely open issues with respect to how the user should interact with (or at least be notified about) the adaptation of the platform to new contexts. Ideally, users should be able to specify high-level objectives (about location information needs) and have the platform discover, install, and use location information providers as appropriate.

The support for *control of distribution* of location data is closely coupled to the extent to which the MiG can deduce location information on itself without relying on communication with the infrastructure that reveals its location. If the location of a MiG needs to be communicated through the infrastructure, then it is possible for the infrastructure to distribute location data in whatever way it wants.

However, even if the infrastructure knows identity and location there are approaches to ensuring privacy (such as mix zones [2]). Our approach follows that of Place Lab [3] by having devices being able to locate themselves using (radio) information from their context. This cannot be done completely anonymous (neither in the case of GSM nor in the case of Bluetooth), but it provides a certain degree of control over who sees location information. In our scenarios, the application *is* to track locations of other devices (in contrast to the typical use of [3]) thus the location information is distributed to the infrastructure (the eu-DOMAIN server), but the user of a device is potentially able to control this distribution.

Control over what is being distributed is up to the application and bundles running on the MiG if distribution of information data may be locally controlled as described above. Currently, the design is to openly support users in setting the characteristics of information that is distributed to others. For professional users this may not always be desirable.

Lastly, it should be noted that what has been presented in this paper is mostly design; implementations of critical parts of the MiG exists, but no evaluations have been made as of yet. The eu-DOMAIN platform and related prototypes will be empirically evaluated in use settings and the MiG location system should be part of this evaluation.

ACKNOWLEDGEMENTS

The work reported in this paper has been supported by eu-DOMAIN project (IST-004420) and an AREA Science Park Individual International Mobility Grant as part of the 2004 Incoming Research Activity Pilot Project.

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