Consistent Modelling of Users, Devices and Sensors in a Ubiquitous Computing Environment

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Abstract. This paper describes the use of an accretion-resolution user modelling representation to model people, places and objects. We explain the motivation for the key properties of the representation, especially those of particular importance for ubiquitous computing: firstly, for flexibility in interpreting the typically noisy and potentially conflicting evidence about users’ locations; secondly, to support users in scrutinising their user model, the processes that determine its contents and the way that it is used in the ubiquitous computing environment.

A novel and important aspect of this work is our extension of the representation beyond modelling just users, using it also to represent the other elements such as devices, sensors, rooms and buildings. We illustrate our approach in terms of models we have been building for a system which enables users to gain personalised information about the sensors and services in a ubiquitous computing environment. We report experiments on the scalability and the management of inconsistency in modelling of location, based on accretion-resolution.

Key words. modelling location, modelling pervasive computing environments, scrutability, user control, user model representation

1. Introduction

User modelling has an important role in ubiquitous computing. It is essential for important forms of the personalisation of user environments: it is user models which will be the repositories of information that might be collected about a user from ubiquitous sensors. Modelling the user’s location is central to much ubiquitous computing work.

This is reflected in the large amount of work on mechanisms that can be used to determine a user’s location. Many of these operate invisibly, from the early active badges (Want et al., 1992) to the now common radio-based sensors like Wi-Fi and Bluetooth, low cost radio-frequency tags and associated RFID readers as well as ultrasound devices as in the Cambridge BAT (Addlesee et al., 2001) and in the Cricket system (Priyantha et al., 2000). In addition, many other sensors, such as cameras, pressure pads and microphones may sense people. To model a person’s location, a system must interpret the data from such sensors to model aspects of the user that are associated with location.
We want to model the user’s location, activity and other relevant aspects of context in a manner that is consistent with the other information a system holds about a user in a user model. We introduce our approach in terms of two, closely related, target classes of scenario: the first is a personalised user interface that enables each user to see all elements of the ubiquitous computing environment, especially the invisible ones; and the second is to support one person in locating another person.

1.1. THE INVISIBILITY SCENARIO

Alice walks into her house, and pauses at the mirror in the foyer, checking her hair. Then she asks for any messages and it lights up, displaying messages that her children have left for her. She walks into the lounge room and the new release of Monsieur Camembert begins playing. Later, her father enters the house. He is visiting for a few days and staying at the house. For him, the mirror in the foyer behaves only like a conventional mirror. He is rather irritated at the music coming from the lounge, but is then surprised when it changes to a recording of his grandchildren’s recent band concert. (He does not like this music but has always tried to indicate that he does.)

This scenario illustrates the invisibility goal of ubiquitous computing environments, where devices should fit so well and operate so naturally, that the experienced user, like Alice, finds that they blend into the environment. Another goal of invisibility is that the computing elements in the environment should be unobtrusive. This is the case with the sensors that are needed to detect Alice for the mirror and music in the scenario to operate.

This naturalness and unobtrusiveness can pose problems. It may be impossible for people even to be aware of facilities available to them. Once Alice knows about the mirror and how to activate it, it may provide a natural and convenient hands-free interface. However, for the new user, even locating the interface may pose real problems. We can expect this to be a long term issue of importance because invisibility is one of the fundamental goals of pervasive computing design.

There are also problems in unobtrusiveness of sensors, such as those used in well-known ubiquitous computing projects, like the Georgia Tech Aware Home (Kidd et al., 1999) and the Microsoft Easy Living Project (Brummit et al., 2000), as well as many others. This is in conflict with privacy principles such as those of Langheinrich (2001), which require that people be able to determine what sensors operate in an environment and what they do with the information they collect. It also is at odds with the observation (Ackerman et al., 1999) that many people want to control the use of personal data, especially where that data can be linked to their identity. This makes it important that a user model representation in this environment supports such scrutiny.

Another important aspect of the scenario relates to the personalisation of services and facilities available. In the scenario, the mirror’s hidden services were not available to Alice’s father. The different choices of music delivered are an example