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Dynamic context-aware personalisation in a pervasive environment

Sarah Gallacher*, Eliza Papadopoulou, Yussuf Abu-Shaaban, Nick K. Taylor, M. Howard Williams

MACS Department, Heriot-Watt University, Riccarton, Edinburgh, UK

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ABSTRACT

In the development of ubiquitous and pervasive systems, it is understood that mechanisms are required to take adequate account of user preferences. This paper presents several key challenges for personalisation in pervasive environments and introduces the Daidalos solution developed as part of a European research project, Daidalos. The Daidalos personalisation system architecture goes beyond customary simplistic preference management to provide two aspects of dynamicity: first in the establishment of user preferences, where learning mechanisms are used to refine and update preferences when the need arises; second during the application of preferences whenever the context of the user changes. The paper discusses how this system meets the outlined challenges and details how the system has been evaluated.

1. Introduction

During nearly two decades since Mark Weiser described his vision of future ubiquitous computing [1], much research has been focused on advancing towards this goal. Devices such as mobile phones, laptops and PDAs allow us to take computational technology with us wherever we roam, and network technologies such as wireless access allow us to remain networked far beyond the reach of physical cables. As the user navigates through their mobile environment they require ubiquitous access to an expanding array of surrounding services and resources. To meet this requirement, the notion of pervasive computing [2] has emerged. The result is a new and exciting set of challenges.

With a potentially large collection of resources and services vying for the user's attention and requiring some level of management, this presents one of the major challenges for pervasive computing. To meet this challenge, it is generally understood that mechanisms must be provided which will alleviate the user from some of the detailed interaction and decisions required in order to manage such a system. For this reason personalisation has become an important component in the management of pervasive resources and environments, helping to satisfy the current needs of individual users.

In a pervasive environment personalisation is the set of processes that adapt the environment and the services in it to fit the user's needs. This results in different user experiences for different users, or for the same user in different contexts. The level of personalisation provided is dependent on the user information held by the personalisation system.

Several guidelines exist for the management of user information, often referred to as the *user profile*. W3C provides CC/PP (Composite Capabilities/Preference Profiles) Structure and Vocabularies [3] outlining profile management guidelines within a web environment. Similarly ETSI provides guidelines [4] for user profile management within a mobile communications environment. As yet, no guidelines exist for user profile management within a pervasive environment. The more static

* Corresponding author. Tel.: +44 0 131 451 4170; fax: +44 0 131 451 3630.
E-mail addresses: s.gallacher@hw.ac.uk, ceesmm1@macs.hw.ac.uk (S. Gallacher), ceeep1@macs.hw.ac.uk (E. Papadopoulou), ya37@macs.hw.ac.uk (Y. Abu-Shaaban), nkt@macs.hw.ac.uk (N.K. Taylor), mhw@macs.hw.ac.uk (M.H. Williams).

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approach to profiles and their management, described by W3C and ETSI, does not correspond with pervasive environments and their dynamic nature.

Of particular importance are user preferences that are invaluable when determining how pervasive environments and resources should be optimally adapted. If we have a richer and more accurate preference set it follows that personalisation can reflect more accurately the user's wishes. However, the establishment and maintenance of a rich and accurate preference set is a non-trivial task and indeed several major challenges need to be addressed. A successful personalisation system should provide support for preference creation and maintenance, alleviating the user of such tasks where possible. Equally important are the mechanisms to apply personalisation at the correct time.

This paper describes the Personalisation System implemented within the Daidalos project, which aims to provide all round support for preference establishment, management and application in a pervasive computing environment. Daidalos [5] is a European research project, a major aim of which was to deliver dynamically adaptive, personalised services in a pervasive environment to static and mobile users. The project was divided into two phases. In the first phase a prototype was developed that successfully demonstrated basic personalisation based on static, manually entered user preferences [6]. Such personalisation was applied in the selection of services and their customisation during instantiation. The second phase focused on the implementation of a more ambitious Personalisation System, which provided enhanced personalisation based on dynamic preferences that are established and managed on behalf of the user through monitoring and learning techniques. In addition such preferences are applied dynamically (based on user context) to constantly tailor the environment to the user as they navigate through it. This paper describes the final architecture developed in this second phase.

The next section looks at the main challenges of providing preference management in pervasive environments and Section 3 provides a brief overview of related work. Section 4 describes Daidalos preferences and Section 5 goes on to introduce the Daidalos Personalisation System highlighting the two dynamic aspects of preference learning and preference application. Section 6 discusses how the Daidalos solution meets the challenges outlined in Section 2. An evaluation of the Daidalos Personalisation System is presented in Section 7 and finally Section 8 provides a conclusion.

2. Challenges

Providing a universal and dynamic solution to pervasive personalisation is no trivial task. Numerous factors and issues must be considered. The following sections highlight several of the most taxing challenges.

2.1. Generic personalisation

Within a general pervasive system, personalisation is required at two levels. First it is required to tailor the internal services (and their behaviours) that are part of the pervasive system infrastructure—so-called "enabling services". Second, it is required to tailor external services – third party services – to behave in accordance with the user's preferences. Daidalos third party services can have a number of personalisable parameters (e.g. volume, font size) whose values need to be set in accordance with the user's *personalisable parameter preferences*.

In the case of the Daidalos platform, personalisation is required in the following internal processes:

(1) Service filtering and ranking. When a service request is made, relevant services are discovered and the optimum ones are selected to meet the user's needs. Discovered services may need to be filtered (i.e. services that do not satisfy the user's preferences are removed from the list) and then ranked (the list is ordered) based on criteria specified by the user's *filtering* and *ranking preferences*.
(2) Session adaptation. During service runtime, more suitable services may become available. If this occurs, the session may be re-composed to include the new service, based on the user's filtering and ranking preferences.
(3) Network selection. As with services, there can be a variety of different networks available e.g. LAN, WLAN, GPRS, Bluetooth, etc., and for a given type of network one may have different network providers. During network selection the available networks are ranked based on some criteria specified by the user's *network preferences*.
(4) Virtual Identity (VID) Selection. Virtual identities are used to protect the real identity of a user [7]. The user can masquerade behind any number of VIDs each with different access rights and attributes. To minimise user interaction the most appropriate VID can be selected on behalf of the user based on their *privacy preferences*.

One can see from the above that the personalisation system must be able to deal with preferences used in a range of different processes throughout Daidalos enabling services and third party services. Where possible this should be done in a generic way to reduce duplication of preference management processes.

2.2. Finding the balance between explicit and implicit personalisation

Personalisation is often referred to as being one of two types: explicit personalisation or implicit personalisation. The distinguishing feature is the process for establishing and maintaining user preferences. Explicit personalisation relies on user preferences that are created and managed manually by the user. In contrast, implicit personalisation provides mechanisms