ADAPTING STEREOTYPES TO HANDLE DYNAMIC USER PROFILES IN A PERVASIVE SYSTEM

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ABSTRACT
In developing ubiquitous or pervasive systems it is essential that the complexity of the underlying system is hidden from the user. To achieve this, the system needs to take many decisions on behalf of the user. This can only be done if the system knows what the user would prefer, i.e. it maintains a set of user preferences for each user. This is a laborious task for the user to perform manually and research is focussing on the use of machine learning to assist the user in creating and maintaining an acceptable set of preferences. This paper describes how stereotypes can be adapted for use in pervasive systems to help build up user preferences while maintaining user privacy through the use of virtual identities, and how these can be modified to match the changing preferences of the group of users who select this stereotype. The paper also introduces the notion of group identities and shows how the same approach can be used to handle these in the Daidalos pervasive system.

KEY WORDS
Pervasive, user preferences, personalization, stereotypes, learning

1. Introduction

In 1991 Weiser [1] predicted that the environment around the user will soon be filled with microscopic devices, mobile or stationary, that will aid the user in his/her everyday life. Since then with the developments in communications and in technologies such as sensors, motes [2], specks [3], etc., this is rapidly becoming a reality. This growth will be accompanied by an even larger expansion in the services available to the user, and the result will soon become unmanageable. This is the problem that pervasive computing [4] seeks to address by developing an intelligent environment to support the user and enable him/her to control and manage this situation.

In order to hide the complexity of the underlying system from the user, the system needs to take many decisions on behalf of the user. This can only be done if it knows what the user would prefer, i.e. it maintains a set of user preferences for each user and uses these to personalize the decision making processes within the pervasive system. This is one of the major assumptions underpinning most pervasive system developments, including the Daidalos pervasive system [5]. Daidalos is a European Integrated Project whose aims include the development of a pervasive system that will provide the appropriate infrastructure to support a wide range of personalized context aware services in a way that is easy for the end-user to manage and use.

The establishment of user preferences for each user for such a system is a non-trivial task since it is laborious for the user to create manually. To assist in this process, some pervasive systems monitor the user's behaviour and employ machine learning techniques to create and refine the set of preferences for each user.

In addition stereotypes provide a useful technique for creating an initial set of preferences for a user. However, for pervasive systems the preferences need to be context-dependent and take account of user privacy – in this case through the use of virtual identities. This paper discusses how such stereotypes may be implemented in pervasive systems, and how they may be adapted to change with time for groups of pervasive system users. These ideas have been implemented in the Daidalos pervasive system which will be demonstrated in April 2008.

The notion of a group virtual identity is introduced and it is shown how the same approach can also be used to handle dynamic preferences associated with these

The next section provides a brief overview of personalization in pervasive environments and how this affects some current systems. Section 3 briefly discusses user preferences in the Daidalos pervasive service platform. Section 4 describes the way in which stereotypes and learning are used in Daidalos while section 5 discusses a problem with virtual identities. Section 6 deals briefly with dynamic stereotypes and section 7 introduces the notion of group identity and shows how the same approach can be applied to dynamic preferences associated with group virtual identities. Section 8 describes the status of implementation and concludes.

2. Personalization and Pervasive Environments

A pervasive system needs to be able to take decisions on behalf of the user, taking account of the needs and priorities of the user in the way in which the system behaves. These needs and priorities are captured in a set of user preferences which will, in general, be context-dependent. The term *personalization* is used to refer to the set of processes used to create, maintain and apply user preferences in decision making. In pervasive systems the scope of such personalisation is quite wide and extends beyond the usual forms of personalization, e.g. [6]. Some examples of this are given in the next section. However, the most significant problem facing the developers of pervasive systems is the creation and maintenance of an adequate set of user preferences for each user.

Early pervasive system developments such as the Intelligent Home [7] and Blue Space [8] implemented personalization with context awareness although they relied on user input of preference information rather than the use of learning, resulting in minimal sets of user preferences. Other projects such as Microsoft's Easy Living project [9] and MIT's Intelligent Room project [10] paid little heed to user preferences but concentrated instead on context information – producing a context aware rather than a personalized approach. .

However, it was soon realized that some form of assistance was needed in gathering and maintaining user preferences. For this reason the Adaptive House [11], GAIA [12] and MavHome [13] have made personalization an important goal in order to produce effective and acceptable pervasive systems that attempt to meet individual user needs with minimal user intervention. Gathering preference information is achieved by monitoring the user's behaviour and using machine learning techniques to identify new user preferences. The Synapse project [14] also makes use of machine learning techniques but combines this with user control to provide more accurate personalization.

One of the main drawbacks of the above systems is that the machine learning techniques employed are all offline algorithms, which means that there may be a significant delay before the system adapts to changing preferences. On the other hand the pervasive systems developed by projects such as Ubisec [15], Spice [16] and Mobilife [17] all make use of online learning algorithms that can respond rapidly to changes in the user's behaviour patterns and update the set of user preferences in real time. However, these have another disadvantage in that they do not distinguish between temporary changes in user behaviour arising from particular transitory circumstances and established user preferences derived from long-term behaviour patterns.

Daidalos [5] is a European research project which aims to develop an infrastructure that is able to integrate a range of heterogeneous networks and devices and to create a pervasive service platform on top of this, which protects the user from the complexity of the underlying infrastructure while providing personalized and context aware services with minimal user intervention. The research is being conducted over a five year period and is divided into two phases with slightly different objectives.

In the first phase simple GUIs were used to allow the user to set up new user preferences or update existing ones, while in the second phase these are supplemented by the use of stereotypes to create initial preferences and a combination of online and offline learning techniques to create new preferences or refine or adapt existing preferences as the user's needs change with time.

This combination has the potential to provide significant advantages over some of the other pervasive systems that have been developed.

3. Creating and Maintaining User Preferences in Daidalos

The basic functionality contained in the Daidalos pervasive service platform includes the following six main functions:

- Service Discovery and Selection
- Service Composition
- Session Management
- Personalization and User Preference Management
- Context Management
- Security and privacy

The user preferences for these functions will, in general, be context-dependent. These user preferences may take the form of a set of rules or possibly a neural network or Bayesian network. All three formats are being investigated although this paper is concerned only with the case where the user preferences are represented as a set of rules.

In Daidalos the various different decision processes within the pervasive system that may be personalized and for which user preference rules need to be maintained, include the following:

- *Service selection*. When a user initiates a request for a service through the service browser, there may be a number of different alternative ways in which that request can be satisfied. This will depend on the possible candidates that are available and might be used to satisfy this request. The Service Discovery component will find the possible options, and then use the user preferences (which may depend on a variety of factors such as the user's location, time of day or current activity) to *filter* the possibilities (i.e. remove options that definitely do not satisfy the user's preferences) and *rank* them so that the best possible choice can be made.

- *Service personalization*. The behaviour of individual services (including both third party services and services internal to the pervasive service platform) can be personalized to meet the user's needs by passing appropriate values for parameters. For example, if the user is receiving a telephone call, the volume could be adjusted automatically according to user preference depending on where the user is located (at home, at work, in the car, in the street).
- *Call/message delivery and redirection*. This concerns the ability to connect or redirect incoming telephone calls or messages to different devices. This will depend on the user's preferences which may in turn depend on where the user is located, the time of day and possibly on the identity of the caller. For example, preferences can be set up so that when the user is at home, business calls can be redirected to the user's home telephone during working hours and to a voicemail service outside of working hours. Personal calls on the other hand can be redirected to the user's mobile phone if the user is free – otherwise to another member of the family. If the user is in his/her car, an incoming call may be directed to the car phone if the caller is deemed to be important enough. And so on. This was studied in detail in the first phase [18].
- *Identity Selection*. User preferences may be used to assist in the selection of virtual identities to protect the privacy of the user. This is an area that is currently being investigated in the second phase and will be reported on in due course.
- *Network Selection*. In a pervasive environment, as with services, there can be many different network possibilities. On the one hand there may be different network technologies e.g. WLAN, LAN, GPRS, etc., while on the other hand for each technology there may be different providers. User preferences are used in the process of selecting the appropriate network to meet the current needs of the user.

Each of these areas of personalization has its own set of preference rules for each user. Furthermore, there is a separate preference rule for the selection of each type of service or the setting of each personalizable parameter for a service. The format adopted for such rules is a simple "if-then(-else)" format. The condition part is a general Boolean expression which may involve checks on context attributes such as location. Each then-part or else-part may be either an action or a nested if-then(-else) statement. An example might be:

IF location = "home" AND status = "free"
THEN SET volume TO 10
ELSE SET volume TO 5

The main challenge for personalization in Daidalos is to create and maintain a user profile comprising a set of user preference rules, which adequately reflect the user's needs and priorities. While some preferences are more difficult to capture than others and there will always be situations in which some of the preferences will not be correct, the aim is to correctly forecast what the user would prefer as much of the time as possible.

In the first phase a simple approach was used to capture user preferences which relied on the user to set these up manually using an appropriate GUI. However, in general, this is not practical as the user soon becomes bored and gives up without completing the task. For this reason in the second phase machine learning techniques are being used to assist in building up the profile for a user. These learning mechanisms will help to create and maintain user preferences. As the user interacts with his/her environment through the various services, devices, etc. the user actions performed and the context in which they are performed are monitored. These actions will be processed by both offline and online learning mechanisms to provide improved preferences for all personalisation tasks. A mechanism is provided which informs the user of decisions taken on his/her behalf and allows him/her to intervene if necessary. If the user does intervene and override a decision, this fact is recorded together with the current context of the user and fed back into the learning system. Monitoring such negative interactions is crucial as it allows learning mechanisms to identify any new patterns in behaviour or changes to existing ones.

4. Use of Stereotypes

To assist the user in creating an initial profile, one can provide a number of stereotypes. A stereotype corresponds to a user who may have a typical pattern of behaviour and for which a typical set of user preferences may apply. This idea is helpful in the case of individual services where different stereotypes can be identified – for example, through cluster analysis on the options selected. By selecting a stereotype for a service, the appropriate set of user preferences will be loaded into the user profile, thereby enabling the user to create a user profile fairly rapidly.

Stereotypes are commonly used in recommender systems with preferences such as "users who like X also like Y" but have also been used in a range of other applications, including ubiquitous systems (e.g. Youngster). One problem with stereotypes in pervasive systems is that the preferences are generally context-dependent (for example, "If the user is at home then the user prefers the cheapest network option"). Thus one needs to deal with context-dependent conditions such as "if the user is at home", "if the user is at work", etc. Obviously one cannot use actual physical locations for this purpose but need to map these to concepts such as "home", "work", etc. For this purpose an ontology has been developed for user preferences for the subset of personalisation functions in Daidalos, and this is used in conjunction with the context management system to create appropriate conditions.

But the use of stereotypes on their own is not sufficient for two reasons. Firstly, although the set of user preferences in the stereotype will generally provide a reasonable fit for the user's needs and priorities, it rarely provides an exact one. In general one would expect that the set of preferences would need to be tweaked to some degree to suit the user. Secondly, for various reasons some user preferences will change with time – for example, new and better services will become available or the user's needs may change. By combining the use of stereotypes with machine learning, the nett effect of this is that the user is able to create an initial profile very rapidly and the system will then adapt the profile gradually with time as observation of the user's reactions to decisions lead to refinement of his/her preferences.

5. The Problem of Virtual identities

In order to protect the privacy of the user a system of virtual identities is used. Each user may have any number of virtual identities. These may depend on the user's role (doctor on duty, doctor on call, parent, participating in sport, etc.), their location (at home, at work, in car, in town, on the golf course, abroad, etc.) or even their current activity. They may be viewed as a set of different user names, which the user may use for different purposes. All services (both third party and system services) that the user may use can only see the user's virtual identity and whatever subset of personal information the user allows, apart from the Security and Privacy component where the virtual identities can be tracked to real identities for the purposes of accounting.

This does create some problems both for the initial set-up and for the subsequent learning of user preferences since in principle each virtual identity should have its own set of user preferences. However, if one does this then one will find that for services that are common to two or more virtual identities (e.g. making a telephone call), the same preferences may need to be learnt again and again. If the learning subsystem identifies a change in a user preference when the user is using one virtual identity, this cannot be transferred to any of the other virtual identities used by the user. The system has to learn it afresh for each separate virtual identity where it arises. This inevitably leads to user frustration.

The solution to this problem that was adopted here was to allow the user to specify to the Security and Privacy subsystem that any particular set of virtual identities should share the same user profile. This subsystem then created an appropriate set of indirections so that the user profiles for each of these virtual identities pointed to the same set of user preferences. Thus without revealing any associations between virtual identities to the Personalization subsystem, the latter could create and update user profiles in such a way that any changes to the user profile for one virtual identity were immediately reflected in the profiles for other associated virtual identities.

6. Dynamic Stereotypes

The initial approach adopted focused on the use of machine learning to adapt the profile of the individual user to refine the user's preferences or change them to suit their changing needs. However, a similar approach can be used to modify the stereotypes themselves if it becomes clear that these can be improved or need to be revised.

In order to achieve this, whenever a user selects a particular stereotype, a link is set up from the preference rule in the user's profile pointing to the stereotype structure from which it was copied. In addition a count is maintained in the stereotype of the number of users who have used this stereotype. Then whenever a user makes a change to this preference rule, a message is sent to the stereotype recording the change. The message is effectively anonymous to ensure the privacy of the user. This can be achieved through the use of a group virtual identity (see section 7) associated with the stereotype service.

The system administrator can then set an appropriate condition - depending on the number of times users have used the stereotype and the proportion of those who have modified the same part of it. When this condition is met, the stereotype rule can be modified in one of two ways:

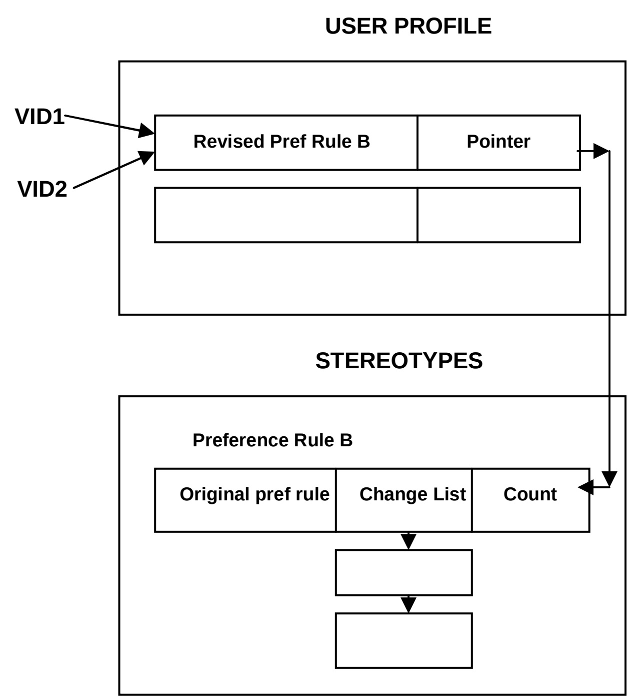

Fig. 1 Relationship between VIDs, preference rules and stereotypes.

- If the changes made by the users are consistent, then the rule can be updated with this change.
- If the changes are not consistent, this component may be removed from the rule provided that it does not reduce it to an empty rule.

This can either be done automatically or a recommendation can be sent to the system administrator who can take the final decision.

7. Group virtual identities

One extension to this system of virtual identities which has been considered within the Daidalos pervasive system is the notion of a group virtual identity. This is a virtual identity that is shared by a group of people for a particular purpose. A typical example where this might be useful is where a company might set up a group virtual identity for its employees to use when accessing a particular software package. For example, suppose that the company uses a particular CAD package but due to licence restrictions (or some other reason) it needs to control access to it. By creating a group virtual identity which has access to the package and disallowing any other virtual identity to access it, the company can control and monitor access.

Now, a group virtual identity is no different from any other virtual identity in that it has a set of user preferences associated with it. These may relate to how it is selected or to the parameters associated with it. When a user uses the group identity, the user preferences associated with it are applied.

In a way this is similar to a stereotype in that when a stereotype is selected by a user, the appropriate rules are applied. In the case of a group virtual identity, when the group identity is selected the appropriate rules are applied. However, one important difference between the two is that when a stereotype is selected by a user, the preferences associated with it are copied into the user's profile and can be adapted by learning to suit the user. In the case of a group virtual identity the preferences are not copied into the user's profile and although they may be changed temporarily for each user, no permanent change is made by any individual user.

Once again one can apply learning to this by monitoring and recording whatever temporary changes users make to the preferences while using this identity. Temporary changes to the preferences by the users are not stored in the group virtual identity profile but are fed back and stored in the same way as changes are handled for stereotypes. As in the case of stereotypes the system administrator can set up appropriate conditions which, if met, result in the preferences associated with the group virtual identity being updated. The individual users are once again anonymous and the update to the preferences associated with the group virtual identity only occurs if on a sufficient number of occasions these are updated by the user using the identity at the time.

When a preference associated with a group virtual identity is updated in this way (either automatically or via the system administrator), this will have an effect on the next user and all subsequent users who will use it. The preferences that will be used will be a new copy of the group virtual identity preferences that will contain the newly changed preference. Note that this is different from a stereotype in that when the group virtual identity is updated all users benefit from the update whereas for a stereotype only new users selecting the stereotype will benefit from the update.

Another difference between stereotypes and group virtual identities relates to the handling of context. Because the stereotype is adopted by the user, the context of the individual user can easily be taken into account in the learning process. In the case of group virtual identities context information is more difficult to isolate considering that the group virtual identity will be used concurrently by more than one user. Nevertheless it is still possible to produce useful context generalisations. If available, using context inference, an "at home" location or an "on the road" location instead of specific addresses or coordinates, can be used to generalise a location condition in the preference enough to be able to capture and update more preferences under a group virtual identity. However, even without context inference one can produce useful adaptations with learning.

For example, suppose that the aforementioned company operates on two sites, producing different kinds of products at each, but it sets up a single group VID for both sites to access the CAD package. Any employee using the group VID could be at either of the two sites or at another location (home, customer's site, or somewhere else). It may be that users at one site have different preferences from the other or that if the user is outside the company premises, they may have different preferences again. By monitoring usage over a period one may identify such patterns and change the preferences associated with the group virtual identity to fit better with the different user preferences for different locations.

8. Conclusion

This paper is concerned with some aspects of the problem of creating and maintaining user preferences for each user in a pervasive system. Because this is a laborious task to perform manually, both stereotypes and machine learning are being used to assist in creating and maintaining an acceptable set of preferences. These preferences are generally context-dependent which provides additional challenges.

This paper describes how user preferences are used in the Daidalos pervasive system and how stereotypes and learning are used to support them. It describes the problem of maintaining user privacy through virtual identities and its effect on stereotypes and learning, and presents the solution adopted in Daidalos. It describes how the same learning process can be used to adapt stereotypes to match the changing preferences of the group of users who select this stereotype. This idea enables stereotypes to adapt to changing requirements on the part of the users or to new services becoming available. The approach could be extended to allow stereotypes to be split to create sub-stereotypes that give better coverage of different user groups.

The same approach can also be applied to group virtual identities. Although there are a number of differences between the two, a similar strategy can be applied to handle them. Once again learning is used to refine the preferences associated with the group virtual identity to better fit the needs of the users using it or to adapt to new or updated services becoming available.

The initial ideas on personalization and user preferences in the first phase of Daidalos were implemented in a prototype of a pervasive service platform which was demonstrated at the end of the first phase (early 2006). A redesign of these ideas with the addition of stereotypes and learning as described in this paper has been implemented in a revised Daidalos prototype which is currently being integrated with the lower level infrastructure to support the pervasive platform, and will be demonstrated in April 2008. This implementation incorporates stereotypes although it may not include group virtual identities.

Acknowledgements

This work was supported in part by the European Union under the FP6 programme (Daidalos project) and will be developed further under the FP7 project Persist.. The authors also wish to thank all colleagues in the Daidalos project developing the pervasive system. However, it should be noted that this paper expresses the authors' personal views, which are not necessarily those of the Daidalos consortium. Apart from funding the Daidalos project, the European Commission has no responsibility for the content of this paper.

References

[1] M. Weiser, The computer for the 21st century, *Scientific American*, *265*(3), 1991 94-104.

[2] Crossbow Technology: Sensor Technology, http://www.xbow.com.

[3] D. K. Arvind, Speckled Computing, *Proc. Nanotech 2005*, Anaheim CA, USA, 2005, Vol 3, 351-354.

[4] M. Satyanarayanan, Pervasive computing: vision and challenges, *IEEE PCM*, *8*(4), 2001, 10-17.

[5] M. H. Williams, N. K. Taylor, I. Roussaki, P. Robertson, B. Farshchian and K. Doolin, Developing a Pervasive System for a Mobile Environment, *Proc. eChallenges 2006 – Exploiting the Knowledge Economy*, Barcelona, Spain, 2006, IOS Press, 1695 - 1702.

[6] D. Pacey, E. Dempster, M.H. Williams, A. Cawsey, D. Marwick and L. MacKinnon, A Toolkit for Creating Personalized Presentations, *Proc. IEEE/WIC International Conf on Web Intelligence*, Halifax, Canada, 2003, IEEE Computer Society Press, 550-553.

[7] V. Lesser, M. Atighetchi, B. Benyo, B. Horling, A. Raja, R. Vincent, T. Wagner, P. Xuan and S. Zhang, XQ., The Intelligent Home Testbed, *Proc. Anatomy Control Software Workshop (Autonomous Agent Workshop)*, 1999, 291-298.

[8] S. Yoshihama, P. Chou and D. Wong, Managing Behaviour of Intelligent Environments, *Proc First IEEE Int. Conf. on Pervasive Computing and Communications (PerCom '03)*, 2003, 330-337.

[9] B. Brummit and S. Shafer, Better Living Through Geometry, *Journal on Ubiquitous Computing*, *5*(1), 2001, 42-25.

[10] S. Peters and H.E. Shrobe, Using Semantic Networks for Knowledge Representation in an Intelligent Environment, *Proc. IEEE Int. Conf. on Pervasive Computing and Communications*, 2003, 323-329.

[11] M. C. Mozer, Lessons from an Adaptive House, in D. Cook and R. Das (Eds.), Smart Environments: Technologies, protocols and applications, J. Wiley, 2004, 273-294.

[12] B. D. Ziebart, D. Roth, R. H. Campbell and A. K. Dey, Learning Automation Policies for Pervasive Computing Environments, *Proc. 2nd Int. Conf. on Autonomic Computing (ICAC '05)*, 2005, 193-203.

[13] M. G. Youngblood, L. B. Holder and D. J. Cook, Managing Adaptive Versatile Environments, *Proc. 3rd IEEE Int. Conf. on Pervasive Computing and Communications (PerCom '05)*, 2005, 351-360.

[14] H. K. Y. Si, A Stochastic Approach for Creating Context-Aware Services on Context Histories in Smart Home, *Proc. ECHISE2005*, Pervasive 2005, 2005, 37-41.

[15] J. Groppe and W. Mueller, Profile Management Technology for Smart Customizations in Private Home Applications, *Proc 16th Int. Workshop on Database and Expert Systems Applications (DEXA'05)*, 2005, 226-230.

[16] C. Cordier, F. Carrez, H. Van Kranenburg, C. Licciardi, J. Van der Meer, A. Spedalieri, J. P. Le Rouzic and J. Zoric, Addressing the Challenges of Beyond 3G Service Delivery: the SPICE Service Platform, *Proc. Workshop on Applications and Services in Wireless Networks (ASWN '06)*, 2006.

[17] M. Strutterer, O. Coutand, O. Droegehorn and K. David, Managing and Delivering Context-Dependent User Preferences in Ubiquitous Computing Environments, *Proc. Int. Symp. on Applications and the Internet Workshops (SAINTW '07)*, 2007.

[18] E. Papadopoulou, M. H. Williams, S. M. McBurney and N. K. Taylor, Redirecting Communication in a Pervasive System, *Proc. eChallenges 2006 – Exploiting the Knowledge Economy*, Barcelona, Spain, 2006, IOS Press, 1689-1694.