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A User Profile Ontology Based Approach for Assisting People with Dementia in Mobile Environments

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Abstract – **Personalization and context-aware applications have attracted increasing amounts of attention over recent years due to the emergence of pervasive computing applications. Nevertheless, it still remains a challenge to meet the needs of users while they are on the move. This paper introduces a novel approach for providing personalized, context-aware assistance services for users in mobile environments. Central to the approach is the use of ontological user profile modeling which captures various characteristics of a user in order to create a unique set of profile information. In addition, user profiles can adapt to changing user behavior, thus enabling services to respond to evolving user needs and preferences. We describe the overall system architecture of the proposed approach with special emphasis being placed on the user profile modelling and its expected utility based on a typical use case scenario, i.e., using a smart-phone to address the problem of the outdoor mobility of a person with Dementia. A prototype based on the Android OS is used to illustrate the application. The use of everyday technology for a real world problem highlights the potential and utility of our approach.**

I. Introduction

Dementia is an umbrella term which is frequently used to describe a group of illnesses that can cause a progressive deterioration of the cognitive activity within a person's brain. Common symptoms include loss of memory, communication problems and recurring feelings of isolation, confusion and loneliness. Currently, there are approximately 30 million People with Dementia (PwD) and this figure is set to increase further in the future [1]. It is estimated that by 2050, the number of people with this illness will triple in size [1]. This rapid increase has evoked interest in developing assistive technologies that can both enhance a person's quality of life and promote a more independent lifestyle [2]. One of the most common symptoms occurring with PwD is the high rate of memory loss. As a consequence of this symptom, out-of-home mobility can be severely affected. Dementia is viewed as one of the major threats to maintaining a mobile lifestyle and can lead to a person wandering off resulting in confusion, distress and risks.

The current study proposes a personalized architecture with embedded user profile modeling capabilities to support PwD undertaking activities of daily living (ADLs) as they move from one environment to another. The technologies for the proposed architecture are ontology-based personalized service provisioning through a smart-phone.

The remainder of the paper is structured as follows. Section II presents related work in the field of smart-phone based assistive aids. Section III focuses on the design and implementation of a user profile ontology, which is used to provide the necessary user data to support the personalization of smart-phone based care. Section IV introduces the system architecture and discusses the role of each component in a context-aware system. A use case scenario of the proposed approach is discussed in Section V and Conclusions are drawn in Section VI.

II. Background

In recent years, there has been an increased use of assistive, smart-phone based technologies to aid people with cognitive impairments. These have supported areas such as navigation, reminding support and remote monitoring services. Current applications include the use of GPS to track users and determine their location to provide outdoor navigation support back home again (iWander) [3]. Mobile solutions have been used to deliver reminders to users to engage with various activities at scheduled times [4]. Further applications have aimed to improve the quality of patient treatment by enabling the remote monitoring of a user by a caregiver, via an application built into a smart-phone [5].

While these applications aim to enhance the user's quality of life, they fail to provide any form of personalized service. iWander, for example, focuses on tracking a user's location if they have wandered outside of their 'safe zone' and thereafter alerting a carer to assist the user if they are lost [5]. This approach, however, only focuses on the aspect of a user becoming lost and does not include other personalized services such as shopping trip reminders or context-aware guidance. Such activities can enable PwD to live a more normal lifestyle, without their condition hindering task performance. In an effort to overcome these problems, a novel approach to improving outdoor mobility of PwD through the use of a smart-phone application is proposed in this paper. The solution will not only track a user when they venture outdoors, but will also aim to provide context-aware, personalized services adapted to that user at any time. By modeling a user's knowledge and expertise, the service can provide the appropriate level of assistance. Modeling aspects such as user capability (e.g., hearing or vision) can enable the correct form of assistance to be provided. If user preferences or behaviors are modeled,

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location or context-aware based reminders can then be provided. Current work in this field does not focus on these aspects of personalized assistance, therefore highlighting the requirement for this type of service. The solution in this paper is based on an underlying user profile ontology, which collects data about the user and enables a service that is tailored to suit specific needs. This forms the basis of a smart-phone application, which requires minimal user interaction and can subsequently offer assistance when required.

III. ONTOLOGICAL USER PROFILE MODELING

Assistive technologies and applications aim to provide appropriate information to users at the right time. To achieve this 'help on-demand' service provision [6], a system must have a thorough understanding of the environment surrounding an individual; this is known as the context. Context-aware applications supply a user with information relating to their environment. This is then used to enable technologies in the user's environment to adapt to changing situations. While the need for context-awareness is fundamental to creating applications that are adaptable to environments, context alone is simply not enough [7].

As humans have different lifestyles their needs differ and these aspects need to be modeled. As a result, user profile modeling is required to achieve the desired level of personalized service that has the ability to adapt to a particular user. A user profile can be defined as the digital representations of a user and are stored within the modeling and management layer of any context-aware system. While user profile modeling has been widely studied in user interface design [8] and web information retrieval [9], formal user profile modeling for context-aware applications in mobile environments is only a recent effort. For example, user profile models have been developed using ontologies in both GUMO (General User Model Ontology) [10] and UPOS (User Profile Ontology with Situation-Dependant Preferences Support) [11] models. Nevertheless, both do not cover the aspect of personalization in any detail. GUMO focuses on modeling the static user characteristics, but fails to acknowledge the dynamic aspects of a user's life, whereas UPOS focuses on the dynamic situations surrounding a user, but does not provide a comprehensive user profile. To support our approach, we have extended current ontological user profile modeling to address these limitations.

An ontology can be defined as an explicit specification of the conceptualization of a problem domain, which consists of a number of classes (or domain concepts) and properties [12]. Ontological modeling can be referred to as the process of specifying these domain concepts and properties. These concepts are organized into a hierarchical structure in terms of their shared properties to form super-class and sub-class relations [13]. Each defined class may have one or more parent classes (operating via a 'is-a' link) forming a hierarchy of related data. Properties exist in each class, which describe features of that class and any restrictions or rules placed upon them. To provide a user with a personalized service, the system needs to take into consideration a wide range of the user's characteristics such as personal information (including name, age, education history), capabilities (including cognitive, behavioural), interests, preferences and context. Based on these characteristics, a conceptual user profile model has been developed, as presented in Figure 1.

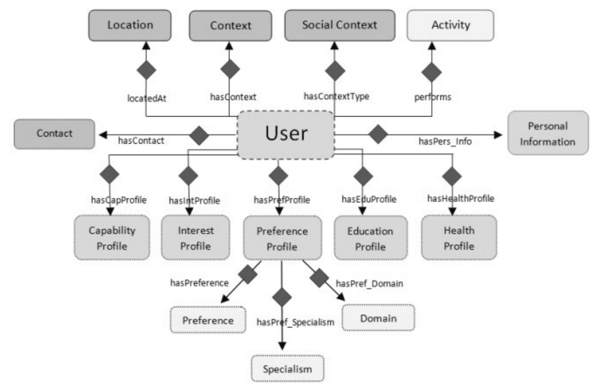

Figure 1. Conceptual level user profile view

As can be viewed from Figure 1, a user profile can be characterised as a number of user-related classes. The five profile classes consisting of *CapabilityProfile*, *InterestProfile*, *PreferenceProfile*, *EducationProfile* and *HealthProfile* are used to describe the dynamic profile aspects. That is, information that will change over time. The *Context*, *Location* and *Activity* classes represent the environment surrounding a user of the application. The *PersonalInformation* class is static and used to initiate the application with basic information. Finally, the properties denote various interrelationships between different profile classes. For example, the *HealthCondition* class could have a property *hasHealthCondition* to determine the state of a user's health and this could be linked to the *Capability* class. This could show that a user has Dementia and therefore infer that they have low levels of memory capability.

We have extended previous user profile ontologies with new concepts, properties and new relationships to capture the relations between the context, applications, users and the dynamics of the user. For example, we added a *HealthProfile and CapabilityProfile* with *Health_Conditions* and *Capability_Levels*. The ontology is represented as a user hierarchy where each class is an aspect of the user. Properties exist within each of the classes (for example, the class *Capability* contains the *hasCapabilityType* and *hasCapabilityLevel* properties). A property describes a class as an instance of another class or a literal, which provides relations between two different classes. This will serve as a base model to be used within our proposed approach and can be further enhanced over time. Based on the conceptual model of the user profile depicted in Figure 1 - a user profile ontology has been created using the *Protégé-OWL* ontology editor[1] and represented in the Web Ontology Language (OWL). Figure 2 presents the user profile ontology in two parts. The user profile ontology consists of classes and properties for describing all user-related information such as

[1] Protégé OWL Web Ontology Editor, available for download online at http://protege.stanford.edu/

Interests, *Preferences*, *Capabilities*, *Personal Information, Context and Health Conditions*, along with their interrelationships.

In the following Section we shall describe the proposed architecture of the system, highlighting the key components which enable a fully context-aware, personalized application.

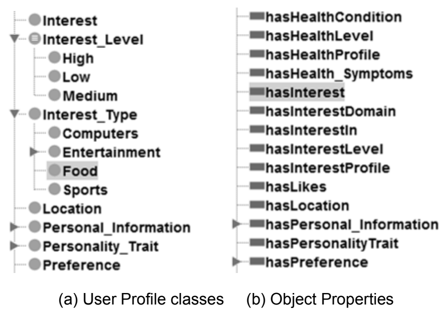

Figure 2. An excerpt of the user profile ontology (within Protégé).

IV. System Architecture

A layered system architecture has been developed to provide personalized services for users as they move from one environment to another, as depicted in Figure 3. The architecture consists of four layers each of which addresses a specific functionality of the system. The domain layer contains three core elements, namely the user, the environment and the application scenario. The user represents any person involved in the use of the application. The environment refers to the context or situation that surrounds a user. The application scenario represents a specific case for each individual, where the functionality of the system will be utilized. The layer above the domain layer focuses on the modeling and management of three areas of the system; the user profile, task and context of a user.

In order to adapt a user profile model to a system, user modeling is required. It is in this layer that we create the user profile ontology, where user information is stored, maintained and updated. Similarly, task modeling and management refers to how activities relating to a particular user are kept and later queried to infer further information. A user's activity may have a specific location, time and context. Context is another key component found in the modeling and management layer. The context refers to the surroundings of a particular user at one specific point in time. It is here that these situations are captured using environmental sensors and this information can then be reasoned to provide some form of personalization according to the situation the user is in. The next layer contains three central components which enable the delivery of a personalized service to the user of the application. This personalization layer contains a user profile learning and adaptation component, a reasoning engine and a knowledge base consisting of a set of personalization rules. Within the system, the user is modeled and their user profile is created and continuously updated according to their changing needs and preferences over time.

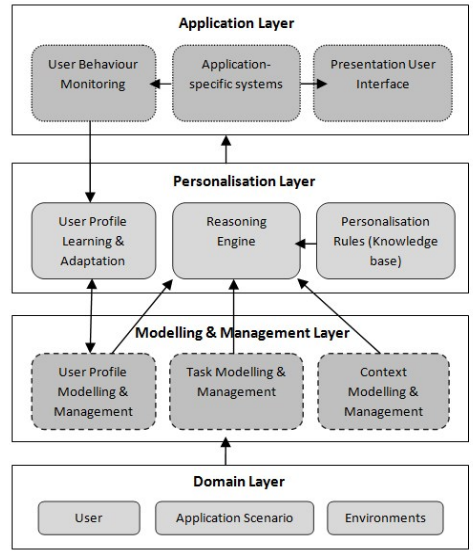

Figure 3. Personalized, context-aware system architecture.

The reasoning engine is a core component of this layer, which takes as its inputs the models of the user profile, the user activities and context. Once it has gathered these models, it makes use of description logic based semantic reasoning capabilities enabled by ontological modeling. By utilizing a user model, a system is able to develop logical, personalized rules that are used to select user preferences, provide reasoning, personalize the output and present the result to the end-user. This set of rules constitutes the knowledge base of the system and thus allows a smart-phone based assistive agent to provide customized support in terms of a user's needs. For example, a user's level of vision is stored in their user profile. This information can be used to tailor the text size of their user interface on their phone to a larger size as a rule states if a user's vision level falls below a certain value, the user interface should adapt accordingly. A user's preferences will change over time. In this case, the learning and adaptation component is activated and user information is fed to the user profile where it is updated and the system adapts continuously. The application can learn these new preferences to enhance the ontology.

The top layer focuses on the delivery of the application via the smart-phone based user interface, the application-specific systems and the monitoring of user behaviors. The personalized information is fed to the application and based on the context the information is presented to the user via the smart-phone user interface. Information is fed back from the user and this in turn enables the user's actions and behaviors to be monitored. This new information is then used as input to the learning and adaptation component, where it is added to the user profile ontology for future reference. By integrating a combination of user profile information and contextual information, the application has the ability to provide individualized services with easier access to personalized information as the user moves between different environments.

V. USE-CASE APPLICATION SCENARIO

The following vignette is presented to convey how the aforementioned context aware service will operate in addition to illustrating the services it will offer. Figure 4 presents two Android user interface illustrations of the proposed application when deployed onto a smart-phone.

Jane is a retired, 68 year old woman who lives by herself and has a mild form of Dementia. Jane's case has affected her quality of living in several ways. She now has trouble remembering how to carry out ADLs, and finds it difficult to navigate to familiar places. All of the information related to Jane's health condition in addition to personal information are modeled and stored within the modeling and management layer of the system within her unique user profile. Jane normally completes a weekly grocery shopping trip every Monday morning. Her smart-phone automatically reminds her via an alert that her weekly shopping is due.

Figure 4. UI snapshots of the application built onto the Android OS.

The smart-phone user interface is presented within the application layer of the system and provides Jane with various personalized options. She accepts the suggested task and within the personalization layer, the reasoning engine and personalization rules work together to infer the best shop suited to Jane's task. Due to her condition, Jane leaves the house and forgets how to find her way to the store resulting in her wandering off in the wrong direction. The phone detects this and offers navigational support to Jane to her destination through the use of GPS technology and coordinates gained from her user profile. When Jane arrives at her local supermarket, her smart-phone uses the underlying user profile ontology to determine what she may want and/or need from her trip. She is presented with food items and can select if these are required or not. In the background, the modeling and management layer will model Jane and her profile and the personalization components will create a shopping list based on her food preferences and shopping history.

Future plans include both implementation and testing on a smart-phone within real-life scenarios. This will enable real users to provide feedback on the functionality, usability and reliability of the smart service.

VI. CONCLUSION

In this paper we have analyzed the characteristics of assistive living in mobile environments in particular in the context of helping PwD to improve their mobility. From the analysis we developed a user profile ontology based approach to address the challenges of providing context-aware, personalized services for people in need in mobile environments. We have described the rationale and design of the user profile ontology. The approach has been applied in a typical use case scenario in which personalized services are provided through a smart-phone. While comprehensive evaluation of the presented approach requires further experiments and implementation, the use case prototyping has illustrated the usage and potential of the approach. Though the approach is discussed in a specific application scenario, i.e., PwD mobility, there is no reason that the approach cannot be used for other scenarios of assistive living.

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