Personalization and Multi-user Management in Smart Homes for Disabled People

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Abstract

Dependent people have a great variability in their needs and levels of motor and/or cognitive handicap. Hence they call for personalized services, especially when interacting with their environment. In smart homes, the Semantic Matching Framework (SMF) provides an appropriate middleware for delivering personalized assistive services in line with the disabilities of a user. SMF is a system based on the Web Ontology Language (OWL) as a modeling language to define ontologies for modeling and reasoning on the user environment and its profile. This paper first, details the adopted approach to personalize a smart home to people with special needs. Then shows how SMF support and manage multiple-users.

1. Introduction

Research on Smart Home is becoming an important trend [1-6], [7]. It is at the crossroad of research in pervasive computing, ambient intelligence, machine learning, databases, mobile computing, robotics, and multimedia. In general, the aim is to maximize comfort and productivity of the inhabitants while minimizing costs (installation, operation and maintenance). At the same time, there are huge needs in healthcare to maintain at home dependent people. We are convinced that smart spaces and smart homes can dramatically improve the autonomy of people with disabilities in real-life habitats with assistance and remediation through technology [14] [15] [16] [17].

Due to the great variability in handicap levels and needs of dependent people, personalization is a key issue. Personalization in smart spaces often focuses on customizing the interface of a terminal (screen color, font size, etc.) and adapting environment's services to the user preferences [12] [13]. But personalization for dependent people is indeed a very complex task with tricky issues which should involve several disciplines (ergonomics, occupational therapy, design, engineering, medicine, etc.). Semantic Matching Framework (SMF) is a framework for personalization based on the environment's infrastructure and the user's capabilities. It has been designed with experts in Psychology and computer science. SMF adapts the environment's services to users having disability. It takes into account the specific characteristics and needs of dependent people through the user centered design. As people with disability have a complex needs, the adopted personalization approach is based on the *Handicap situation* concept.

1.1.   Handicap situation

According to Fougerollas [10], disability is not only a physical deficiency, but it results mainly from the inadequacy of the environment infrastructure to fulfill the user needs. This defines the "***handicap situation***" which indicates that disability doesn't design the individual, but mainly represents the inadequacies of the living environment in regard to the user's capabilities.

The main key is how to identify the differences between a person having severe disabilities and a one without a disability in terms of daily activities? Or even which deficiency of the user is causing the handicap situation and what are the environmental elements becoming

an obstacle for the user? And, how can an ubiquitous environment compensate, partly or totally, disability of each person. Each of these questions is strongly dependent on human behavior that should be supported by any assistive system.

The SMF role is defining the user limitation capabilities (the accessibility rate of each user) and provides adapted process to personalize the service delivery.

2. Semantic Matching Framework

SMF aims to deliver assisted services according to the user's capabilities and preferences. The core functionality of SMF is based on semantic matching between the user model and the environment model (Fig. 1). The user model characterizes user factors, for instance his name, his preferences and capacities, those factors are defined as user's attributes. The environment model describes environment factors it specifies devices (e.g., doors, windows, sensors, etc.), defined as "effectors", each effector contains a set of characteristics defined as environment's attributes, for instance: required force to open the door, the door size, etc. These factors are quantified to formalize the relation between the user's attributes and the environment's attributes which brings out the handicap situation for each user on his daily living activities.
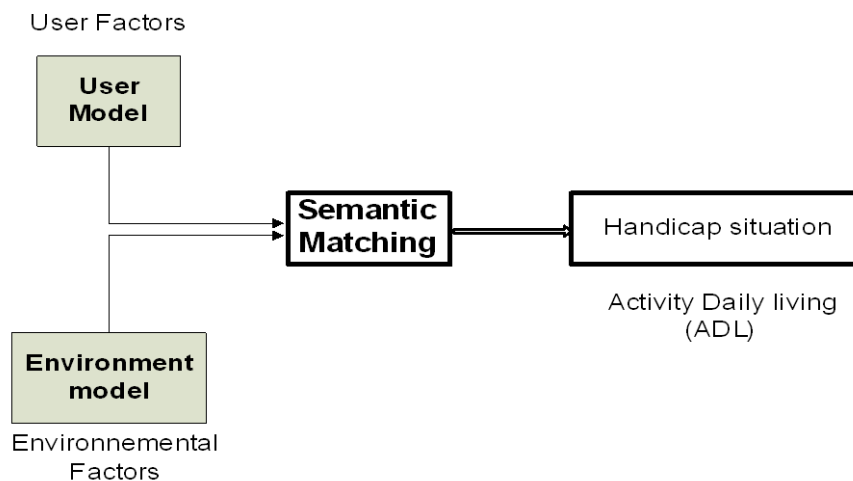

Fig 1. SMF structure

Using a reasoning process SMF Analyses the user's capabilities and the environment characteristics, then infer all handicap situations that helps to deliver personalized services. The reasoning uses a set of first order logic rules that involves the user and environment characteristics defined above. The rules define all the cases that provide a handicap situation.

Example: the following rule defines the matching between the attribute "Stairs" of the environment y and the technical aid "Wheelchair" of the user x

$$HandicapSituation(x,y) \longleftarrow Environment(y,"Stairs")\textbf{and } Users(x, "Wheelchair")$$

It means, when we have a context where the environment contains a stairs and a user is using a wheelchair, this context provides a handicap situation.

3. Data representation

An ontology (Fig. 2) describes the semantic of both models (user and environment models). This uniform description helps the different models to understanding each other. Elements of user and environment models are implemented by classes and subclasses, (ellipses in Fig. 2), or by attributes (rectangles in Fig. 2). A class or a subclass contains a set of attributes or subclasses. An instance of the user model or the environment model is called a **profile**. It is implemented as an instance of a class where the attributes correspond to instance variables. For instance in figure 2, the class "tap cold water" is a subclass of the classes "bathtub" and "wash basin". Those classes are subclasses of the class root "Environment". The class "taps cold water" contains two attributes "Required hand force" and "Required hand workspace". The effectors Tap coldwater is defined as follow: Environment (Indoor (Bath Room (Bathtub (Tap Coldwater (Required hand force= 5, Required hand workspace=10))))).

The matching algorithm computes a relationship between the attributes of both models. This relationship brings out the handicap situation for each user in a given environment.

The use of ontologies in this context requires a well-designed and compatible ontology language with supporting reasoning tools. The Web ontology languages OWL is the best candidate. OWL [11] is an ontology language for the Semantic Web, developed by the World Wide Web Consortium (W3C) Web Ontology Working Group. The user model and the environment model are defined as OWL classes. The following table defines the corresponding representation on OWL of the different entities of our ontology
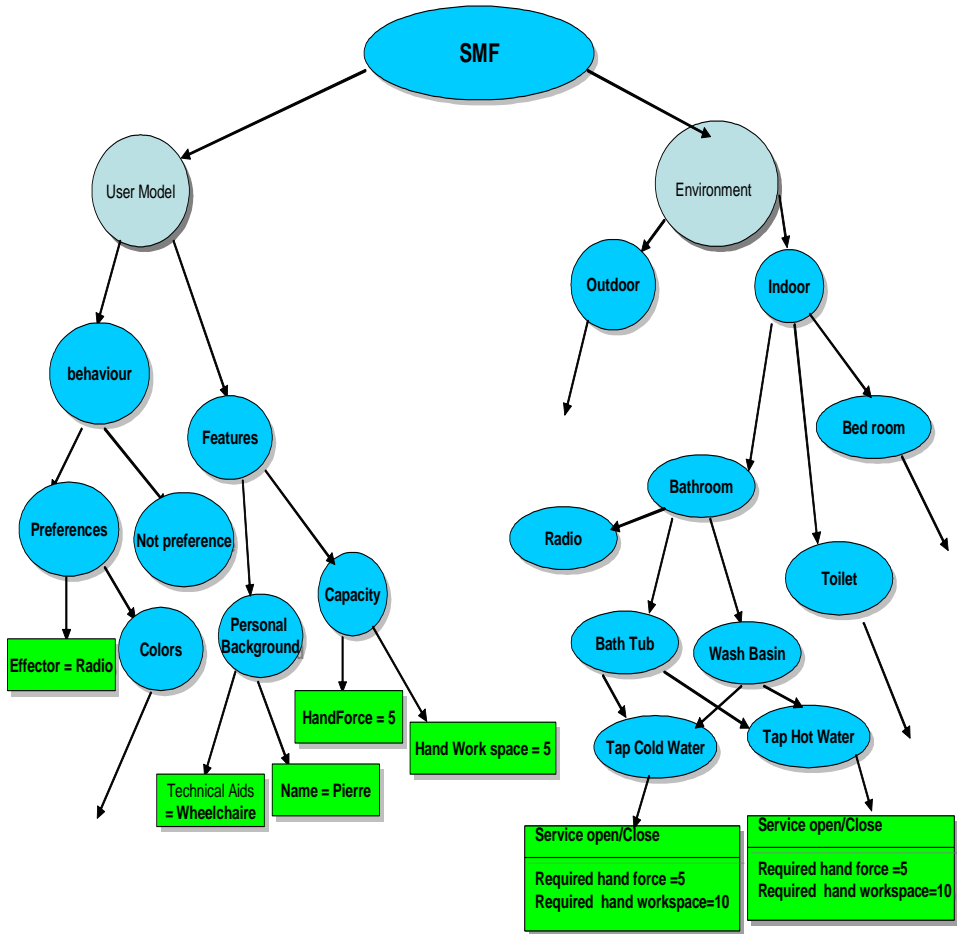

Fig 2. The SMF ontology

Table1: SMF ontology on OWL

Ontology element	OWL representation
User model	<owl:Class rdf:ID="*Users*"/>
Environment model	<owl:Class rdf:ID="*Environnement*"/>
Attributes	<owl:DatatypeProperty> **Or** <owl:ObjectProperty>
User Profile	<Users rdf:ID="*Pierre*">
Environment Profile	<Environnement rdf:ID="*Salon*">

4. Semantic Matching Framework architecture

The SMF framework is composed of several collaborating components (Fig. 3): a knowledge base ontology (KBO), an instantiation manager, inference reasoner, and a query engine. It operates with external data (user profile and context manager) and provides tasks and services.
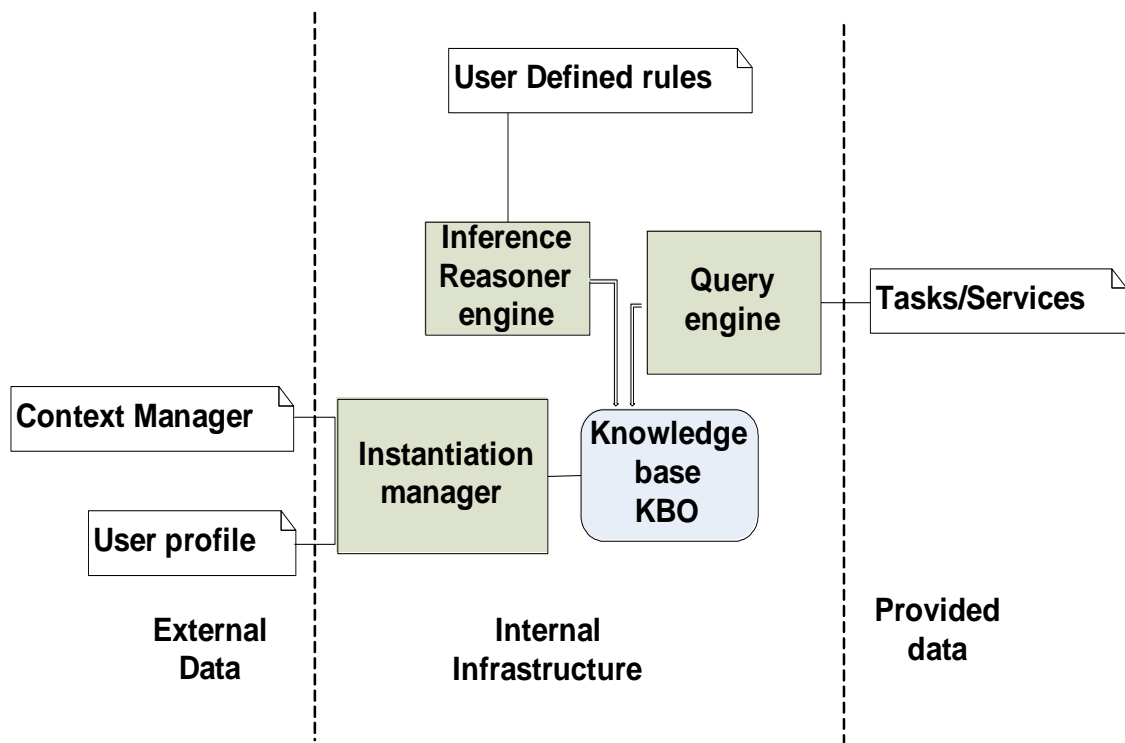

Fig 3. The SMF architecture

Once a user is detected as well as his location, (see fig.3), the client application in the Framework exchanges information with the instantiation manager module in order to update the KBO which contains the user and environment instances (called profiles).
The Inference Reasoner Engine module, using the program rules, iteratively processes the KBO instances and performs the matching between the users and effectors that lead him to

the handicap situations. The Query Engine module, using declarative queries, extracts services that do not lead the user to handicap situation from the updated KBO.

5. Reasoning

The reasoning process is leaded by the inference reasoning engine module. It is based on the following algorithm

```
Input: (E,R)(t)
Output: É
Let V, an empty vector
Do:
É = Reasoner ((E,R),(t))
V=(R,E)(t)
t=t+1
Until V=(E,R)(t)
```

The algorithm has as input the environment context at time t, which is defined by the matching rules R and the environment instances E. The environment instances gather the set of users and effectors in the environment. The environment context can change by adding or removing rules or by changing the environment instances. Each time the environment context is modified, the algorithm runs the reasoner.
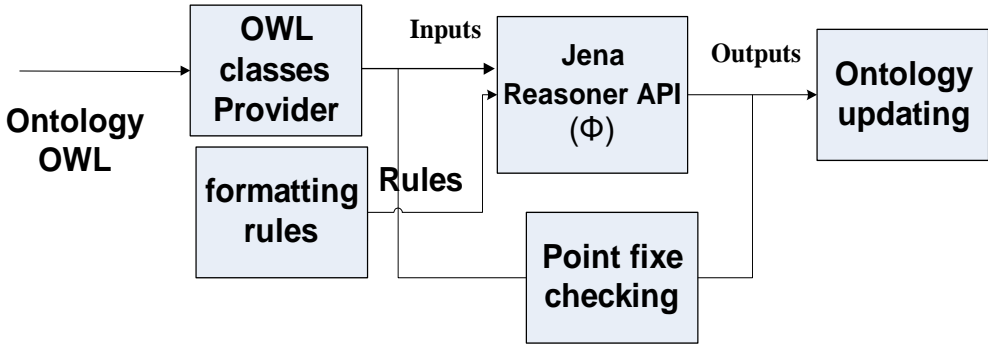

Fig 4. Architecture of the inference engine module

The algorithm extracts the environment context from the ontology as OWL classes (Fig. 4). The matching rules are formatted as Jena rules standard [19]. The inference engine is started using the reasoner API of JENA (Φ). The result (output) is checked with the Inputs (point fix checking). If they are different, the reasoner runs again, otherwise the reasoner stops. This result is then used to update the ontology.

6. Multi-User Management

SMF supports several users in the same time. It uses "Session" to manage multi-user. Steps of one user session are shown in Fig. 5. The first step is user authentication (1). An access decision is taken according to his profile. If the user is not allowed to access to the environment's services, it is then sent back to the final state of the diagram. An

unauthorized user is informed why he was denied access (2). If he gets permission, two concurrent threads are started: one for the discovery of services and the other for the user localization. Then both threads are joined to proceed to the step Inference reasoning. The user profile will be sent to the Knowledge Base Manager module (4) Through the Initiator Manager module (3). Then the Knowledge Base Manager creates, for that user session a thread (5), which sets up and loads the profile in the KBO (6). As soon as the user leaves the environment, the User Identification module inform the initiation manager of the state of the user (7) which forwards it to the Knowledge Base Manager (8) in order to stop the thread from that session (9) and updates the KBO (10). The final step is service delivery. If another user enters in the environment, the same process is triggered concurrently, and a new user session begins to carry out the various phases of the services delivery process.

7. Experimentation

We built a smart environment demonstrator in Handicom lab (Fig.6). This demostrator integrates the context aware Framework (CAE) [18], the Service Management Framework [8], and of course SMF. The CAE manages contextual situations such as user mobility in the environment, detection of critical situations. The Service Management Framework manages the provision of services and service discovery. The demonstrator is a client-server architecture. Mobile handhelds (PDA, Tablet PC…) are used as clients. Their low processing capacities advocated for a thin client approach. So clients mainly convey inputs and outputs between the user and a remote server.
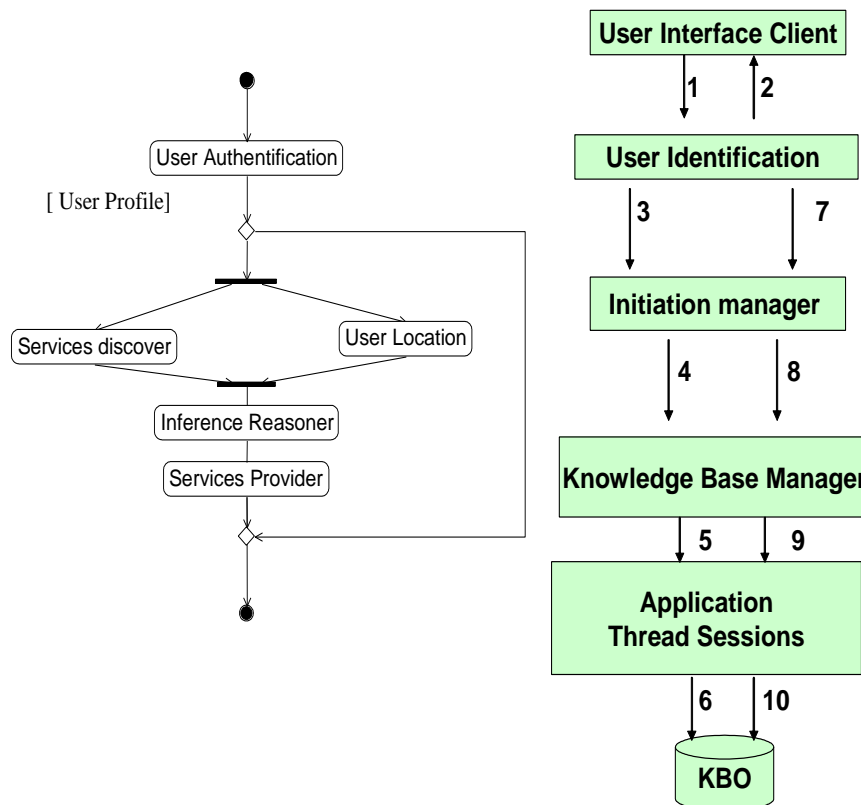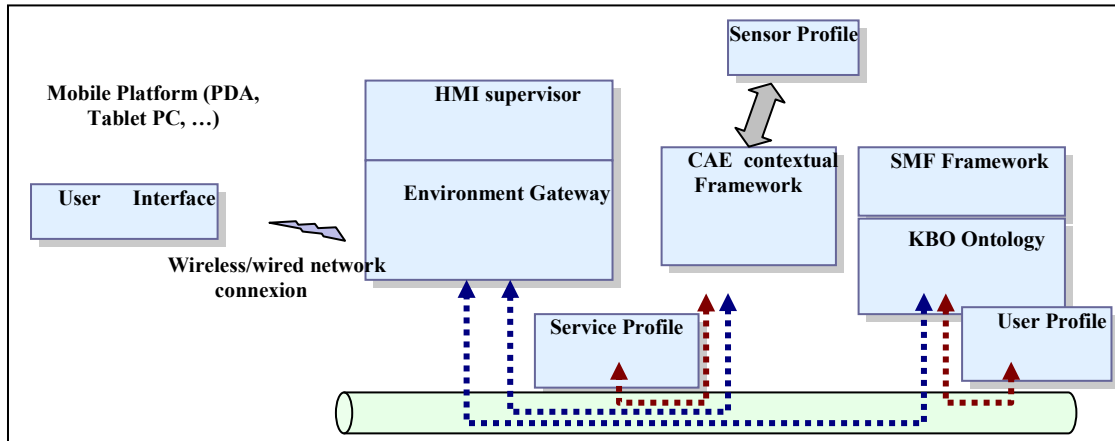

Fig 5. Multi-user management

Fig 6. The demonstrator architecture

8. Results

In order to evaluate the performance of the SMF according to reasoning response time with multiple users, we varied the number of rules and the number of user instances in the KBO. The system was implemented with Java runtime platform 4.2 on a 2.4 GHZ processor with 1.0 Gbyte of RAM running on Windows XP. The response time of the Reasoner is expressed in milliseconds (ms). Figure 7.a shows the values for a set of 10 rules with the number of users varying from 10 to 60. In opposition in figure 7.b, the number of Users is fixed to 10 while the number of rules varies from 10 to 60. Changing the number of rules does not have much impact on the reasoning time as we can see in figure 7.b (from 1050 ms to 1250ms when we change the number of rules while keeping the number of users to 10). We can observe that, the reasoning response time increases considerably when we vary the number of users (from 400 ms to 1200 ms) w. So, in order to improve the response time of SMF, we should decrease the number of user instances in the Knowledge base KBO, for instance eliminating the instances of users who have left the environment.

9. Conclusion

In this paper we have presented SMF, a framework for semantic matching, to personalize the smart home services to dependant people. SMF is based on the detection of handicap situation on this environment. Particularly we defined the multiple user management where each user is assigned to a session, and the design of a session is based on threads implementation. We have evaluated the performance of the system on multiple users context, the system time response depends closely on the number of user's session. Based on tracking the user's activity at home, we are aiming to automatic user recognition to avoid the authentication phase.
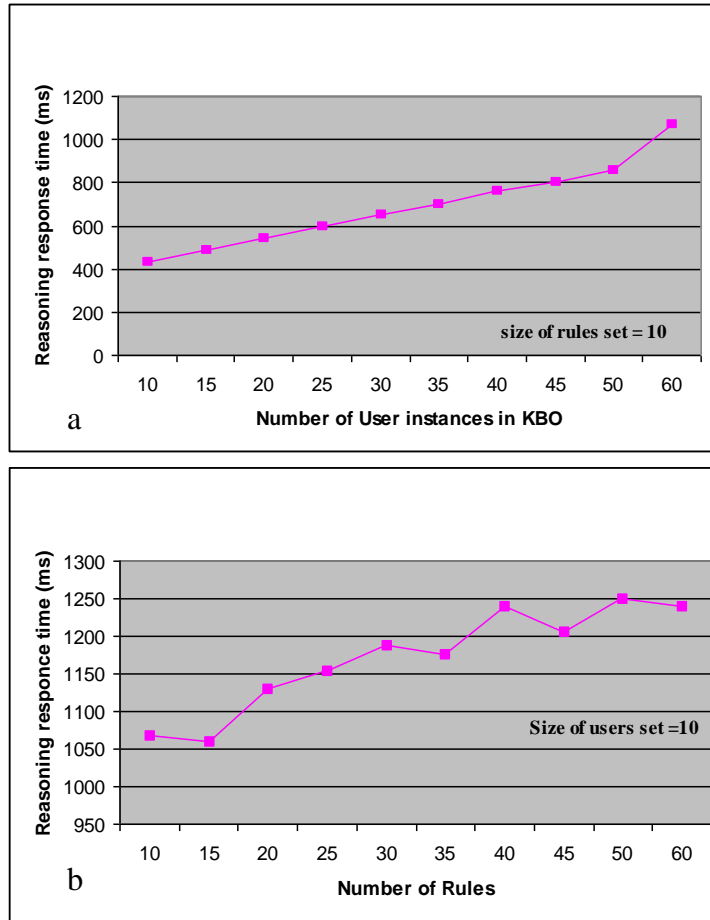
Fig 7. The performance of the Reasoning process

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