Creating an Ontology for the User Profile: Method and Applications

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Abstract— **User profiling is commonly employed nowadays to enhance usability as well as to support personalization, adaptivity and other user-centric features. Insofar, application designers model user profiles mainly in an ad-hoc manner, hindering thus application interoperability at the user profile level, increasing the amount of work to be done and the possibility of errors or omissions in the profile model. This work aims at creating a user profile ontology that incorporates concepts and properties used to model the user profile. Existing literature, applications and ontologies related to the domain of user context and profiling have been taken into account in order to create a general, comprehensive and extensible user model. This ontology can be used as a reference model, in order to alleviate the aforementioned issues. The model, available for download, is exemplified through its application in two different areas, personal information management and adaptive visualization.**

***Index Terms*—user profile, ontology, user modeling, context**

I. Introduction

The continuing progress in network technologies and data storage has enabled the digitization and dissemination of huge amounts of documents. The need for more effective information retrieval has lead to the creation of the notions of the semantic web and personalized information management, areas of study that take advantage of the semantic context of the presented information and the user to facilitate the information storage and retrieval process. The notion of user profiling has been introduced in order to record the user context and personalize applications so as to be tailored to the user needs.

Ontologies have been proven an effective means for modeling digital collections and user context. They can be a very useful tool, because they may present an overview of the domain related to a specific area of interest and be used for browsing and query refinement. Ontologies model concepts and relationships in a high level of abstraction, providing rich semantics for humans to work with and the required formalism for computers to perform mechanical processing and reasoning.

Using an ontology to model the user profile has already been proposed in various applications like web search [9], [12] and personal information management [7]. However, up to this point, ontologies modeling user profiles are application-specific, with each one having been created specifically for a particular domain. Taking into account the continuing incorporation of ontologies in new applications, there is an emerging need for a standard ontology that will model user profiles; this standard ontology will facilitate the communication between applications and serve as reference point when profiling functionalities need to be developed.

This work presents such an ontology for modeling user profiles. The purpose was to create a general yet extendable ontology that will be able to adapt to the needs of every application, maintaining at the same time a general common structure so as to satisfy portability and communication between different applications. After a brief overview of existing work in the area of profiling in relation with ontologies, the method for creating the user profile ontology is presented, followed by a presentation of the ontology itself. Examples of the application of the model in two domains are provided in the following section. The last section presents the conclusions and briefly outlines future work.

II. Related Work

In the last few years the need for software systems to automatically adapt to their users has been recognized in many application areas and the research on user profiling and context has spread into many disciplines which are concerned with the development of computer systems that are to be used by heterogeneous user populations [8]. Context in [13] is categorized in human user context and surroundings context and may also be categorized according to persistence (permanent and temporary) and evolution (static and dynamic). Elaine Rich [15] identifies a three dimensional space of user models: 1) canonical vs. individual user model, 2) explicit vs. implicit user model and 3) long-term vs. short-term user model.

Another important issue is that a user might be found in various contexts. Thus, a context-aware system has to infer which context the user is in a given moment in time, and consequently adapt the system to that context [14] [15].

According to [23], a user model contains all information that the system knows about the user. It is generally initialized either with default values or by querying the user. Users in some cases are grouped in “stereotypes”, like “woman” or “computer scientist”, according to particular characteristics which are application specific.

An overview of methods for building a user profile are presented in [15] and [16]. User modeling issues and guidelines are presented in [8], concentrating on modelling of user knowledge, plans, and preferences in a domain. It focuses on stereotype (as opposed to *individual*) profiles. The need for a profile that supports reasoning is also stressed out in [15].

The goals listed above can be achieved through the use of ontologies. Ontologies in the form of hierarchies of user

interests have been proposed in [9]. Gauch at al. [10] also proposed a system that adapts information navigation based on a user profile structured as a weighted concept hierarchy. The user may create his/her own concept hierarchy and use it for browsing web sites. A user model can also be built using an ontology schema. Razmerita et al. [11] presented a generic ontology-based user modelling architecture applied in the context of a Knowledge Management System.

In the field of ontology design, efforts have been made by several research groups to facilitate the ontology engineering process, employing both manual and semi-automatic methods. Semi-automatic methods focus on the acquisition of ontologies from domain texts. In [2], for example, a framework is proposed with this objective; it incorporates several information extraction and learning approaches, in order to face the discovery of relevant classes, their organization in a taxonomy and the non-taxonomic relationships between classes. Comprehensive surveys of existing methodologies can be found in [3] and [4]. Throughout the ontology creation process, the designers may take into account a set of ontology design criteria, such as clarity, coherence and extensibility [5].

III. ONTOLOGY CREATION ISSUES

As seen form the previous section, ontologies as a notion have already been introduced in the context of user profiling. The ontologies used however in relation with user profiles are mostly limited to taxonomies of user interests. Bearing in mind that for most applications profiling is not restricted to user interests but also encompasses other user characteristics (such as education, expertise and computer literacy level), our purpose is to incorporate them in a user profile ontology. This section, after a brief definition of the ontology concept, presents description of our method for creating the ontology.

A. Ontology Definition

As defined in [1], an ontology is a formal explicit description of a domain, consisting of classes, which are the concepts found in the domain (also called entities). Each class may have one or more parent classes (is-a or inheritance links), formulating thus a specialization/generalization hierarchy; a class has properties or slots (also called roles or attributes) describing various features of the modeled class, and restrictions on the slots (also referred to as facets or role descriptions). Each slot, in turn, has a type and could have a restricted number of allowed values, which may be of simple types (strings, numbers, booleans or enumerations) or instances of other classes. Classes may have instances, which correspond to individual objects in the domain of discourse; each instance has a concrete value for each slot of the class it belongs to. An ontology together with a set of individual instances of classes constitutes a knowledge base.

B. Ontology Creation Resources

For the creation of the ontology we adopted a top-down approach; firstly selecting important general concepts, which were later enriched and specialized. The focus of the ontology is the static profile of the user, his/her more or less permanent characteristics and not the dynamic ones, like his her current position.

Gruber's design criteria [32] (clarity, coherence, extensibility, minimal encoding bias, minimal ontological commitment) were taken into account during the creation process. In order to create a simple yet extensible and adaptable model, user profile information models maintained by various applications, like [34] were gathered and examined; general ontologies like the ones presented in [29] were also taken into account.

At this point no automatic concept extraction has been used, as the information in the available profile models did not contain high level concepts but rather instances of possible concepts and slot names Consequently, the ontology designers team proceeded by analyzing the semantics of the profile models and suggesting concepts that would adequately model them. Table I exemplifies this procedure by presenting how certain information from the ICQ [34] user profile were mapped to ontology constructs.

TABLE I. ICQ USER PROFILE EXCERPT AND ITS TRANSLATION INTO USER PROFILE CLASSES

ICQ Profile Category	ICQ Profile Property	Modeling in the Profile Ontology
Home	Street Address	
	Zip	Slots of the "Living Conditions" class
	City	
	State	
	Country	
Place of Birth	City	
	State	Slots of the "Person" class
	Country	
Personal Info	Homepage	Slot of the "Person" class
	Gender	Slot of the "Person" class
	Age	Not necessary, may be calculated by the date of birth
	Date of Birth	Slot of the "Person" class
	Zodiac Sign	Not necessary, may be calculated by the date of birth
	Spoken Languages	Could be added as Instances of the "Education" class

User profile models sourced from bibliography were also considered and concepts from these were appropriately adapted and included in the ontology. Information from bibliographic sources was exploited for selecting the basic set of upper level classes.

Tazari et al [18] suggest the following concepts as important for user profiling: User identity, characteristics, capabilities, universal preferences, state of the user, application-specific preferences. Other concepts like current activity, current terminal, location, motion state and orientation are mentioned, but have not been included in this ontology as they refer to a dynamic profile. They also propose a group of parameters concerning personal information (name, birthday, address, bank account, and credit card), general characteristics (physical factors: weight and height, physical disabilities and abilities: reading, speaking and writing), education, occupation, interaction-related information, expertise and user state.

Interests ([9], [10], [20], [23]) and preferences [8], [23] are considered of particular importance for most applications that

incorporate profiles. Interests are in some cases organized in hierarchies of concepts [9], [10]. Abilities, both physical and mental also seem to be relevant [24]. For example, the ability of a user to mentally rotate two or three dimensional objects affects the interpretation of a picture [17]. The gender factor also has been proven to affect the performance of different users while interacting with the same system [19].

User expertise, either computer-related or related to another domain is a concept necessary for many profiling applications [23]. Defining a universal and adequately objective expertise measure with clearly defined categories is not an easy task [25] and is out of the scope of this work. However, by studying the existing literature, properties relevant to user expertise and competence have been identified and included to the user model ontology. The ontology is described in the following section and is available in Protégé and RDF format in [23].

IV. ONTOLOGY DESCRIPTION

This section presents a brief description of the user profile ontology. The ontology may be extended through inheritance and the addition of more classes, as well as concept instantiation according to the needs of a specific application. As a result, it may be used for the representation of both stereotype profiles (i.e. user profiles that represent a specific user category, like "computer expert" or "woman") and individual ones.

This ontology presents information that is mostly static and permanent. More dynamic characteristics like the current position of the user when moving are currently not included. The temporal aspect of some of the ontology classes has been taken into account however. The ontology allows the existence of multiple instances of classes that represent characteristics that may change with the passage of time, like living conditions for example. These classes include a period representing the validity period of their instances, for example, "Living Conditions: New York, 12/3/2003 – 18/8/2007".

TABLE II. USER PROFILE ONTOLOGY UPPER LEVEL CLASSES

Class Name	Class Description
Person	Basic User Information like name, date of birth, e-mail
Characteristic	General user characteristics, like eye color, height, weight, etc.
Ability	User abilities and disabilities, both mental and physical
Living Conditions	Information relevant to the user's place of residence and house type.
Contact	Other persons, with whom the person is related, including relatives, friends, co-workers.
Preference	User preferences, for example "loves cats", "likes blue color" or "dislikes classical music"
Interest	User hobby or work-related interests. For example, "interested in sports", "interested in cooking"
Activity	User activities, hobby or work related. For example, "collects stamps" or "investigates the 4th Crusade"
Education	User education issues, including for example university diplomas and languages
Profession	The user's profession
Expertise	Includes all kinds of expertise, like computer expertise
Thing	Living things or Non Living Things the user may posses or otherwise be related to, like a car, a house, a book or a pet

Table II presents an overview of the proposed ontology upper level classes and Figure 1 the class hierarchy of the ontology as displayed in Protégé.

The "Person" class is the central one in the ontology, as it contains all the user profile characteristics. These may be of simple type, like the user "name" or "date of birth", or may be instances of other ontology classes, like "physical characteristics", "contacts", etc.

The rest of the classes are used to describe the complex user characteristics. "Living conditions", "Contact", "Education", "Expertise", "Activity" and "Profession" include a set of slots describing the respective aspects of the user's life as well as a time period which represents the duration of that particular aspect. For example, a user may have had a "Contact" of type "friend" from 1989 to 2004. The slot "person" of the "Contact" class has as type an instance of the class "Person". This way, relations between different users may be modeled as well.

"Interest", "Preference", "Ability", "Characteristic" and "Thing" contain only three slots: "type", "name" and "score" (or "value" in the case of "Thing"). "Thing" has two sub-classes, "Living Thing" and "Non Living Thing" as modeled in the WORLDNET ontology [30] [31]. In the case of interests, apart from the "type" slot, which is a String, a slot named "interest type" of type "Interest" has been added to allow the creation of interest hierarchies, as the ones suggested in [9] and [10]. Table III shows an example.

TABLE III. AN EXAMPLE OF HOW AN INTEREST HIERARCHY MAY BE MODELED WITH THE USER PROFILE ONTOLOGY

Interest hierarchy	"Interest" Instances (Type, Name)
Business	(<Root>, Business)
Investing	(Business, Investing)
Stocks & Bonds	(Investing, Stocks & Bonds)
Sports	(<Root>, Sports)
Basketball	(Sports, Basketball)
Professional	(Basketball, Professional)
College & University	(Basketball, College & University)

User expertise according to [26] may be defined as a combination of three dimensions: *breadth*, the extent or variety of different tools, skills and knowledge the user may posses, *depth*, the completeness of the user's current knowledge of a particular domain, and *finesse*, which refers to innovativeness and creativity. Breadth and depth are developed over time through a combination of study and hands-on use, whereas finesse is more related to the user's personality. These properties are included in the user ontology as slots.

The notion of "experience atoms" is introduced in [25]. They are defined as elementary units of experience as a result of activity in a particular domain. Experience atoms may be expressed in the user ontology as individual instances of the "Expertise" class.

Experience refering to the use of computers is very often related to duration and frequency of usage [28]. A

questionnaire of perceived user expertise in a series of end user computing related sub-domains is used in [27] in order to calculate the expertise level of the user by the combination of the scores supplied by the user in each question. The idea of assigning a score or level to expertise is expressed through the "score" slot in the "Expertise" class.

It should be mentioned here that in the case of the "Expertise" class, the aim was to collect from the existing literature user characteristics that may serve as indications or factors during the assessment of the user expertise level. The definition of the expertise levels themselves and the expertise measures are application-specific and out of the scope of the current work.

To sum up, the "Expertise" class has been created as a container for both expertise measures and expertise scores in order to accommodate the particular needs of individual applications that make use of profiling. The following section provides two examples of such applications and how the user ontology may be used in each case.

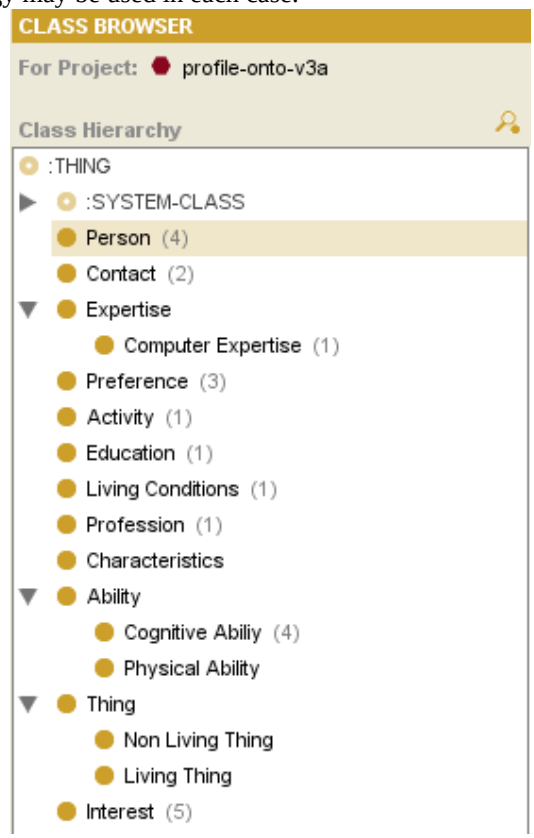

Fig. 1 The User Profile Ontology as displayed in Protégé

V. CASE STUDIES/EXAMPLES

In order to demonstrate the adaptability of the proposed user profile ontology, two case studies will be presented, one related to personalized, adaptive visualization and the other to personal information management.

A. Personalized Visualization

A context-related research is being developed in the framework of digitizing the Historical Archives of the University of Athens, Greece. The corpus of the above-mentioned archive is very large (more than 4,000,000 documents) and consists of documents issued in the University since its foundation (1837).

Currently, the Historical Archive can be visited by anybody -members of the University or not- who is interested in searching for information relative to the contents of such an Archive. Visitors submit requests to the Historical Archive staff, which subsequently undertakes the task of locating the relevant documents and presenting them to the visitors.

In the above-mentioned framework, a novel information retrieval system is being developed in order to render the corpus available directly to its users.

Users who come to the Historical Archive to retrieve information vary in multiple ways. For example, they have different educational levels, ranging from users who only completed elementary or secondary school to users who possess postgraduate degrees (MScs, PhDs) in various scientific subjects. They also have differences in their experience using the computer, ranging from those who are beginners to the ones very experienced and computer-skilled.

Regardless of their computer expertise, users have been found to have different ways for foraging the information they are interested in, and these differences depend on individual preferences and existing knowledge. Individual differences constitute a major factor that influences the user profile. Apart from personal preferences and existing knowledge, cognitive abilities, specific aims and tasks to be solved, the gender, the age, the profession and the living environment of the user constitute properties of individuality, which is a fundamental part of the user profile. Moreover, the steps a user performs while trying to reach the information needed, the -so called- "history" of the user, plays an important role in sketching out his/her profile and deciding which visualization system suits him/her best, so as to employ this system the next time s/he returns to search for information. Important properties related to the user profile are listed in Table IV.

TABLE IV PROPERTIES OF THE USER CONTEXT

User Context Property	Values
Education	Primary
	Elementary
	Higher
University relation/role/title	Faculty members
	Administrative personnel
	Student
	None of the above or no relation
Information Retrieval Knowledge	Perfect
	Medium
	Novice
Aim	Research
	Publication
	Personal Information
Age	Integer
Gender	Male/Female
Profession	Instance of "Profession"
Living environment	Instance of "Living environment"
Abilities	Visual memory
	Arithmetic memory
	Color recognition
	Mental rotation
	Motor skills

Apart from the user profile, the visualization environment proposed for the information search in the Historical Archive takes into consideration both the system context and the

document collection context. Tables V and VI list representative properties of the system and document collection contexts.

In order to select the most prominent visualization method for each case, the values for all properties of the user, system and document collection context are computed and, subsequently, the computed property list is matched against the feature profile of each available visualization method. Matching is performed through a set of *rules*, which each rule indicating whether a particular feature of a visualization method is considered to be helpful, impeding or neutral for a specific context characteristic. For example, the rule

(user_context, spatial_memory, yes) =>
(metaphor, landscape, 70)

states that if a visualization is to be performed for a user having spatial memory, then methods employing the landscape metaphor are considered as "strong candidates" (as indicated by the *score value* 70), since the particular user's ability allows him/her to exploit the visualized items' spatial placement so as to perceive the visualization more effectively [21]. Score values are drawn from the range [-100, 100] with positive values being used for "helpful" features and negative values being used for "impediments". For more information on the visualization method selection algorithm, the interested reader is referred to [22].

TABLE V. PROPERTIES OF SYSTEM CONTEXT

System Context Property	Values
Input devices	Mouse Keyboard Joystick Specialized input devices (3D mouse, glove, etc.)
Output devices	2D monitors 3D monitors Head mounted displays
Other hardware equipment	Processor Memory Graphics

The user profile is represented in the system via the user profile ontology. An example of such a user profile, also available as an Instance in the profile ontology available in [23], is the following.

A female (*gender)* 20 years old *(age)* student *(profession),* Maria Papadopoulou *(name),* wants to retrieve information about the Department she is studying in. She wants to write an article to publish in the Department's newspaper *(activity)* about the evolution of the Department of Informatics and Telecommunications as far as teaching in it is concerned. She is very experienced in using the computer *(computer expertise: high)* and in searching for information, mainly though the Internet (*web search expertise: high)*. She uses a PC with traditional I/O devices (*system context: mouse, keyboard, 15΄΄, 2D monitor*). She has already visited the Historical Archive in the past and according to her previous interaction she likes exploring 3D environments *(registered preferences-history).*

The system collects the above contextual information and matches it against the features of all available visualization methods. The method found most appropriate for the contexts at hand is selected to perform the visualization.

B. Personal Information Management

As part of the EU DELOS Network of Excellence, the TIM project (Task-centered Information Management) is studying the potential for users to store files, email, etc, indexed by personal ontologies. Design and implementation of the prototype tool OntoPIM [7] is still in early stages but several key issues are already apparent.

TABLE VI. PROPERTIES OF THE DOCUMENT COLLECTION CONTEXT

Document Collection Context Property	Values
Categories of documents	Criterion of categorization Number of elements Relation between categories
Text documents	Full text Image Manuscript only Meetings' minutes
Metadata	Author Title Type Date of issue Department of issue Keywords Categories
Collection origin	Static Dynamic

OntoPIM relies on the use of a *Personal Ontology* that describes the user's domain of interest. The ontology is personal in the sense that it reflects the user's view of the domain(s). It is used to assign semantics to the information contained in the user document repository in order to be able to retrieve this information more easily. With the use of the *Semantic Save*, it provides the user the possibility to store any object of interest according to its semantics, i.e. to relate it to the concepts of the Personal Ontology, where an object may be an e-mail, a document, a picture, or any other type of data.

Bearing in mind that every user has his/her own domain of interest, personalization issues are very relevant here. OntoPIM proposes the creation of an initial library of ontologies suitable for various user groups and domains. These ontologies should be created beforehand after an elaborate user study.

There are cases, of course, that some final tuning will be necessary to adjust the ontology template in order to accurately reflect user characteristics and interests. This can be done both manually (by the user) and automatically (by the system), employing a user profiling mechanism. The ontology presented in this work may be used to model this user profile.

The profile ontology may, to some extent, be populated automatically with user information that is available within the file system. This may include:

- Chosen language and time-zone. These could give information about the user nationality and living conditions. Dialing codes and IP addresses can be also used for determining the users' location.
- Current file structure. If the user has created a more elaborate file structure than that already provided by the

operating system to store his/her files, then it could also be a source of new concepts. A dictionary of synonyms could be used here to make the matching more effective. The user could also be prompted to indicate folder structures that contain documents relevant to his/her interests or activities. For example, if the user has a folder named "Articles" with sub-folders like "basketball" or "gardening" used to further categorize the documents, these concepts may be used to populate the "Interest" Class of the profile. The file content could be used as well to support this concept extraction.

- The system can also scan address books in order to retrieve contact information and populate the "Contact" class with instances.
- Calendars and to-do lists may be used to identify user activities.
- The web cache and bookmark/favorites structure could also be a possible source for deriving interests and preferences. The user can also be prompted, through an appropriate questionnaire to provide information concerning his/her personal data, interests, preferences, contacts, etc.

As an example available in [23], Elias Daradimos (*name*), 29 years old (*age/date of birth*) is a network administrator (*Profession*). The OntoPIM user profile extraction mechanism identifies him as a resident of Athens, Greece (*Living Conditions*) and creates a list of his contacts names and e-mails (*Contacts*). By examining application preferences and system settings, asking him to fill a questionnaire, and by scanning indicated parts of the file system, the mechanism concludes that the user is interested in electronics, airplanes, motorbike mechanics and movies (*Interests*).

VI. Conclusions and Future Work

This work is an attempt to create an ontology that incorporates concepts and properties used to model the user profile. Existing literature, applications and ontologies related to the domain of user context and profiling have been taken into account in order to create a general, comprehensive and extensible user model. The model, available in [23], is also presented through two examples in two different areas, personal information management and adaptive visualization.

As this model focuses more on static user characteristics, it is our future aim to study the incorporation of dynamic and temporal characteristics in order to cater for a wider range of applications that include profiling. Furthermore, the acquisition of the profile properties for individual users through questionnaires is investigated, in order to compliment the user profile ontology with a means to populate it.

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