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An ontology-based approach for representing the interaction process between user profile and its context for collaborative learning environments

Vladimir Luna *, Rolando Quintero, Miguel Torres, Marco Moreno-Ibarra, Giovanni Guzmán, Imelda Escamilla

Instituto Politécnico Nacional, CIC, Mexico
UPALM-Zacatenco, 07320 Mexico City, Mexico

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ABSTRACT

Recent researches about the personalized content generation have focused their efforts on two main topics: the first topic is the user model definition, i.e. the dimensions to be taken into account to represent the user, and the second topic is about the techniques used by recommender systems to provide recommendations according to the user requirements, such as adaptive approaches for context-aware systems, collaborative learning, and recommender systems for mobile environments. In this work, an approach based on ontologies to represent the interaction process between user profile and its context for collaborative learning is presented. We also analyzed the role assignments, permissions, restrictions and the definition of rules that are applied to the user, particularly in the collaborative learning context where the subject is involved. A case study related to the context of a school as well as the defined roles by the occupations in the context of locations is proposed.

1. Introduction

User profiles have played a significant role in adapting search results, if a user profile represents faithfully the interests and preferences of the user; therefore it improves the search process (Ramana & Rao, 2012). There are three main approaches to define a user profile: collect the related knowledge about the user preferences, select a formal language to represent this knowledge, and define a strategy to update the user profile (Eyharabide & Amandi, 2012).

Ideally, users should only receive information that meet their personal needs, but it is not enough to obtain the statistical data about the user, it is also required an explicit description of the user interests to be able to express a wide range of values in an interoperable way. This has led a research works in areas such as user modeling, context modeling and human–computer interaction in context-aware applications (Kuflik, Kay, & Kummerfeld, 2012). One of the main challenges in personalized systems is to provide the "given" information to the "right" user in the "appropriate" time and by the "right" way (Skillen et al., 2012). It is plausible to assume that users do not have the same interests and the same preferences; hence, the results will not be the same for different users in distinct contexts for the same query. Personalized searches are based on modeling the user context, using a user profile that represents the user interests and preferences (Semeraro, Basile, de Gemmis, & Lops, 2007). Recent works in generation of personalized content have focused their efforts on setting the user preferences, the recommendation of the most relevant issues and techniques in context-aware, but they are limited in representing the process of interaction between the user profile and its context.

This has led to use ontologies as a way to provide personalized services through user adaptive models. Ontologies have been recently used as a highly expressive schema to represent user profiles, because they allow us to represent knowledge in structured and expressive mechanism. The user model has been developed to be used in personalized information retrieval systems and personalized applications (de Souza, Siqueira, & Melo, 2011). There are several approaches oriented to collect data for building user profiles, which are presented in Section 2.

In contrast, other approaches do not consider the interaction process between the user and the context in which the user is presented besides the assignment of user roles, the rules of

* Corresponding author at: Instituto Politécnico Nacional, CIC, Mexico.
E-mail addresses: lsotoa10@sagitario.cic.ipn.mx (V. Luna), quintero@cic.ipn.mx (R. Quintero), mtorres@cic.ipn.mx (M. Torres), marcomoreno@cic.ipn.mx (M. Moreno-Ibarra), jguzmanl@cic.ipn.mx (G. Guzmán), ebouchana10@sagitario.cic.ipn.mx (I. Escamilla).

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permissions and restrictions that the context apply to each user. The notion of context has recently been recognized as a key element in information systems development process (Flouris, Manakanatas, Kondylakis, Plexousakis, & Antoniou, 2008). Contextual information is defined as any collected information that is used to enrich the knowledge about the user state, e.g. the physical environment of the user (Abowd et al., 1999; Schmidt et al., 1999).

In this work, we propose an approach based on ontologies to represent the interaction between user profiles and the context of some locations such as government offices, schools, and restaurants. In order to perform the representation of the user profile and the locations contexts, we rely on the representation based on ontologies. Ontologies are formal models and they represent how a person perceives a domain of interest, besides they provide an accurate description, the logic of the meaning of the term, the data structures and other elements to model the real world (Flouris et al., 2008). Since ontologies reflect changes in domains of real world, ontologies should represent changes in the conceptualized domains.

Ontologies are also used to identify and to solve the heterogeneity problems generally at schematic level as a way to set an explicit formal vocabulary for sharing knowledge (Staab & Studer, 2010). When ontologies are used to information integration, it is necessary to generate mappings for linking similar concepts or relations between ontologies and data sources through an equivalence. The foregoing is the mapping process definition (Flouris et al., 2008) and the output of this task is a collection of mapping rules. In practice, this process is manually performed and it is a time consuming activity, which brings an intensive labor and it is liable to errors (Velegrakis, Miller, & Popa, 2004).

This paper is organized as follows: Section 2 presents the related work according to the research issues; Section 3 describes the methodology for representing the interaction process between user profiles and its context, while Section 4 presents the experiments. Finally, in Section 5 the conclusion and future work are outlined.

1.1. The problem statement

In recent years, personalized systems have been using ontologies for semantic representation purposes, automatic knowledge acquisition, and domain conceptualization, for displaying the user model and for the development of interoperable and reusable solutions (Kostadinov, 2007).

Ontologies must evolve according to the user's progress in the system, his objectives and domains of interest to be acquired or updated. However, as the ontology structure evolves, there may be some inconsistencies in the ontology or interoperability problems. Modern research on ontologies is trying to understand the ontology evolution process and address some pending problems such as, how to discover new relevant knowledge, how to describe and apply changes in the ontologies, how to avoid inconsistencies in the ontology and their dependencies and how the management of ontology versions (Kondylakis & Plexousakis, 2013). Ontology evolution is an undisputed necessity in data integration based on ontologies. However, there are few research efforts focused on representing the ontology evolution as a global schema in data integration systems. In most approaches, when ontologies change their data sources relations, the process is susceptible to error generation and time consuming.

By using user profiles the capability of personalization is provided, and they make the results more focused on the requirements and the needs of each user. Each user is different, so the results should be adaptable to every person and every context. However, they have left behind one important aspect, the representation of the interaction between the user profile and the context in which the user is located. In other words, a user profile describes the played role by the user and the rules definition, the restrictions and permissions that the context defines for each user. Therefore, we propose a methodology based on ontologies for processing user profiles and representing the interactions process between the user profiles and the different context that surround the user. As a case study, some user profiles and the context of a school are presented.

2. Related work

In (Calegari & Pasi, 2013) authors define the term "personal ontology", user profile is represented by an ontology and present a method that automatically defines a personal ontology via a knowledge extraction process, this ontology was called YAGO (Suchanek, Kasneci, & Weikum, 2007). Skillen et al. (2012) described the development of user profile ontology for context-aware personalization in mobile environments.

In (Adomavicius & Tuzhilin, 2011), authors argue that the relevant contextual information is important for recommender systems. In (Gallacher, Papadopoulou, Abu-Shaaban, Taylor, & Williams, 2014) several highlights for personalization in ubiquitous environments are presented. Anand and Mobasher (2007) proposes a way to model a user inspired by the human memory models developed in psychology, and the user memories in short and long term. A key point is the definition of a recommendation process that considers the user memories, using a context-aware retrieval system to retrieve relevant information from long-term memory and in combination with information stored in the short-term memory for the recommendation process.

MAPEKUS (Frivolt et al., 2008) is a project originally arisen to design and build domain ontology for scientific publications. The MAPEKUS ontology consists of two ontologies for the user model: (1) a generic user ontology that defines the general characteristics of the user; and (2) a publication ontology that defines the characteristics of the scientific publications domain.

In (Bouneffouf, 2013) the characteristics of user profiles as interest indicators are defined and some approaches to user profile modeling are described. These approaches are the follows: (1) vector representation, (2) connection representation, (3) based on ontologies representation. This model represents the user profile as a concept hierarchy, where each class represents the knowledge in a focus interest area of user profile; and (4) a multidimensional representation.

In (Heckmann, Schwartz, Brandherm, Schmitz, & von Wilamowitz-Moellendorff, 2005) the user profile contents are represented as a structured model with a predefined category called dimensions. The dimensions contain information about personal user data, data sources, data delivery, behavior data and safety data. Similarly in (Golemati, Katifori, Vassilakis, Lepouras, & Halatsis, 2007), a set of dimensions that contain most information that characterizes the user is proposed.

The user profile conceptualization based on ontologies should show the dynamic nature of the user. A subject constantly updates their personal characteristics as preferences, skills, personal information, locations, and personality, among others. There are some research focused on semantic representation of the user model such as GUMO ontology (Heckmann et al., 2005), which is a high-level ontology that benefits user model exchange between different systems. GUMO describes a user with basic dimensions such as contact information, demographic information, skills, personality, among others. GUMO has about a thousand auxiliary groups, predicates and ranges identified and added in the ontology. Some user model auxiliaries are: *hasKnowledge*, *hasInterest*, *hasPlan*, *hasGoal*, *hasLocation*, etc. For example, if a user is interested in studying geography, this dimension is divided into auxiliary part *hasInterest*, predicate part "studying geography" and a range low–medium–high.

Han, Chen, and Li (2013) proposed a method called OUPA for user profile acquisition based on ontologies, where these ontologies are automatically built. This method presents a cluster partitioning simulation together with an automatic user ontologies generation, and a hybrid algorithm is proposed for **k**-nearest neighbor model for user profile maintaining.

Other works in user profiles are based on social networks as Abel, Herder, Houben, Henze, and Krause (2013), where form-based and tag-based user profile generation is presented according to a large set of data collected from social networks. They discussed integrity, consistency and form-based profiles response that users create explicitly in systems like Twitter, Facebook and LinkedIn. Authors developed and evaluated the performance in several user-modeling strategies in recommender systems context.

On the other hand, people learn throughout their lives, from experience, conversations, meetings, etc. The learning process does not only take place within formal educational institutions (García-Peñalvo, Colomo-Palacios, & Lytras, 2012). Learning personalization and related issues are very popular in scientific literature in recent years (e.g. Bodea, Dascalu, and Lytras (2012)). The knowledge is an important role to create learning processes that are key to the development of the knowledge society (Naeve, Yli-Luoma, Kravcik, & Lytras, 2008) and they need to be supported by new learning platforms that are facilitative of collaborative and constructive learning. In the study of Vargas-Vera and Lytras (2008), the concept of personalization is considered in the context of semantic web and ontology research. The main emphasis is given to the management of personal profiles and identities.

One of the problems that they solve is the "cold-start". It occurs when originally there are no valid recommendations for the user that may be suggested to request a feedback. Thus, the queries to this profile may be incomplete. In this case, the ontology is populated with information retrieved from external sources such as user profiles in social networks.

Another point of view in ontology evolution process is found in (O'Brien & Abidi, 2006). They described from natural evolution (biological) that the ontological evolution is not the ontology version control process and their interrelationships, but it preserves the beneficial ontology changes over time by interoperable ontology by merging and aligning tasks.

The role concept in the context of computer-supported collaborative learning (CSCL) has attracted a lot of attention as a construct for facilitating and analyzing interactions (Strijbos & De Laat, 2010). A role and its role-playing depend on the pre-existing values and norms of a group, community, social system or society, and the possibility or power to restrict alleged 'incorrect' behavior. Roles are a key phenomenon not only in CSCL, and not only collaborative learning, but also in learning and in collaboration more generally. Perhaps more importantly, roles help highlight what is unique and valuable about CSCL research and what it has to offer to other fields ranging from psychology and sociology, to education, to computer–human interface design (Hoadley, 2010).

Finally, in (Chen, Chu, Chen, and Chao (2013)) a method for storing user preferences is described. This work presents a user profile ontology based on user characterization. This ontology provides an extendable user model focused on static and dynamic modeling of user aspects. It also considers user interests and several context parameters to include context-aware environments.

3. Methodology

The proposed methodology consists of three stages: Handshake stage, Interaction process stage and Farewell stage (see Fig. 1). The first stage, *Handshake*, corresponds to the presentation of the user profile into the current context (represented by 1 and 2), e.g. the user's workspace, an airport, a restaurant, among others. The *Interaction* stage represents the process of the interaction between the user and their context, i.e. the relationship generation that exists between the user and the context, as the role that the user acquires, permissions and restrictions (represented by 3, 4 and 5). The *Farewell* stage corresponds to the user's context farewell; the user model is updated using the context information such as the context name, the context type, and date, (represented by 6, 7 and 8).

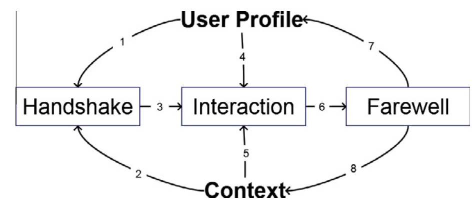

Fig. 1. General framework of the methodology.

Due to the complexity to represent a user profile, an ontological approach to user profile modeling and similarly each context being represented by ontology is proposed. By taking into account the ontology definition, ontologies are formal models about a domain of interest is perceived. They provide an accurate description, the logic of the meaning of terms, data structures and other aspects for real world modeling. According to the assumptions above, relations between a user profile and a context will also be represented in each ontology. The ontologies used in this methodology are described as follows.

3.1. User profile ontology

This ontology describes the basic dimensions of the user, personal information; demographic information such as age, birthplace; preferences, interests, skills, current position, academic degree, among others. As we mentioned above, the user profile is represented by an ontology, Fig. 2 depicts the graph of a fragment of user profile based on ontology.

The user profile ontology represents some of the main characteristics of the user "usr154" such as their name "Juliano Pérez O." Moreover, it presents the details of his enrollment, academic degree, current position, laboratory adscription, academic interests, etc.

3.2. Context ontology

This ontology describes the characteristics of the sites where a person usually visits a site type, location, activities that can be

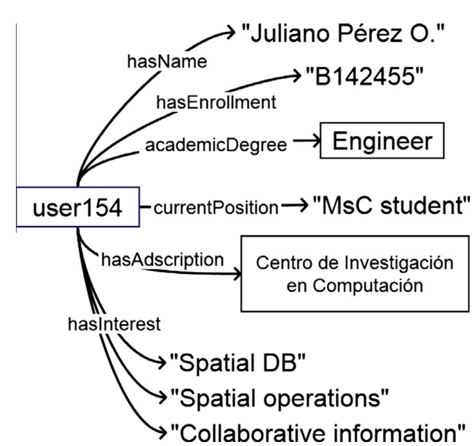

Fig. 2. A graph of a fragment of the user profile ontology.

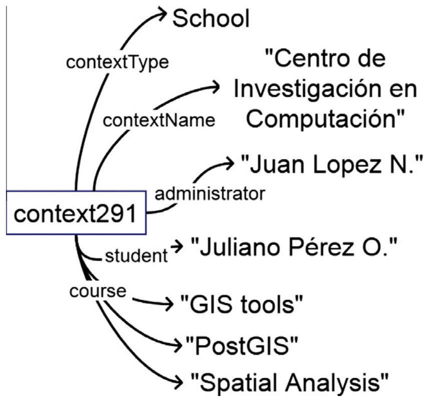

Fig. 3. A fragment of the context ontology graph.

performed, the kind of person who interacts in this context, etc. If we follow a fragment of the context ontology, then the next example presents the "context291" context. Moreover, Fig. 3 shows the graph related to the context ontology. We can appreciate in the fragment of the context ontology (Fig. 3) that it represents information about the context of "Centro de Investigación en Computación" such as context type, registered users and some courses offered in that place.

Therefore, the rules are defined in first-order logic for different types of user. For instance, the rule applied to the user profile *student* would be as follows:

$$isStudent(usr) \rightarrow access(usr, A) \wedge restricted(usr, B)$$

This rule is interpreted as: "if the user is student, then this user has access to section A (e.g. the classroom section) and he is restricted to section B (e.g. the administration area)".

3.3. Handshake stage

This stage represents the first approach that a person has, when he arrives at a site. We assume that everyday life of a person acquires a role depending on the context in which is placed, i.e. if the user is in a restaurant his role could be: dinner, waiter, owner, administrator, etc. On the other hand, if the same user was at the school, then his role would change to student, teacher, administrator or any job in his work place. Similarly, if the user were driving his car, the role would change to driver or passenger. Fig. 4 shows a diagram of the *Handshake* stage, which has as input, the user profile ontology and the context ontology. As output the relations between two ontologies and concepts involved are presented, which will serve as input for the next stage.

Handshake stage makes a mapping between the user profile ontology and the current context by means of an ontology alignment process, in order to find relationships between pairs of concepts in two ontologies previously defined. For example, the relations, *sameAs*, *similar*, *different*, etc., are defined as follows.

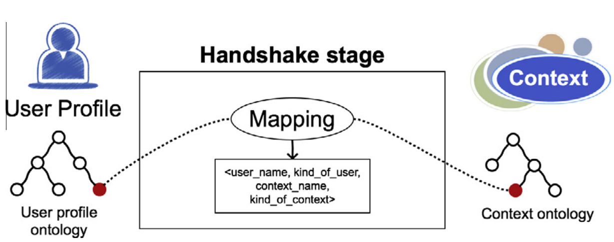

Fig. 4. Handshake stage (logical).

Given two ontologies that present the user profile ontology and the context ontology, then the ontology alignment is defined as the process of creating mappings in the form (C_1, C_2, s), where $C_1 \epsilon USR$ and $C_2 \epsilon CTX$ are concepts from two ontologies and $s \in [0, 1]$ is the estimated similarity between two concepts. Alignment A between two ontologies *USR* and *CTX* is a set of mappings defined as:

$$map(usr, ctx) = \{(C_1, C_2, s) | C_1 \in usr, C_2 \in ctx, s \in [0, 1]\}$$

Mappings may also have the extended form (c_1, c_2, s, r), where r is the type of relation such as equivalence or generalization, or a restricted form (c_1, c_2), where the matching coefficient is not classified (see Algorithm 1).

By taking into account those definitions, the function user_exist receives the label user_name and returns the user identification in the current context. Otherwise, if the user does not exist in the context, then a Boolean value is returned. The function is defined as follows.

$$usr\_exists(usr, context) = \begin{cases} true & U_{id} = isEmployee \\ false & U_{id} = default \end{cases}$$

Algorithm 1. Mapping
Input: A set of labels that represents the basic dimensions of the user $userBasicDimensions = \{name, currentPosition\}$ and the kind of users defined by context $userDefinedByContext = \{usr_1, usr_2, \ldots, usr_n\}$.
Output: A mapping vector VM composed of a flag UE that takes a Boolean value, and a set of input concepts.
If $user\_exists(usr, context)$ **then**
  $usr \leftarrow employee$
else
  $usr \leftarrow defaultUser$
end
return usr

Fig. 5 shows an example of the mapping process between two ontologies. In this case, there are four concepts that match each other; the first one is the user name ("Juliano Pérez") and the attribute 'student' in the context side. Second, the adscription of the user matches with the name of the context: 'Centro de Investigación en Computación'. Finally, in the third and fourth the interest names in the user profile and the 'courseName' that are related to each other with the relation 'similar'.

3.4. Interaction stage

As we described above, the user role changes according to the place where the user is, as a result the rules must also change their states. That is, if the user comes at school with the client student, the rules in this context would give access to take classes and in the same way restrict to enter at the administration area.

3.4.1. Role assignment

It is necessary to consider the user type and the context type, user role assignment, permissions and restrictions that are applied to the user, according to the rules that define the current context. The context defines all the rules that are applied to different user roles, e.g. in the context "school" the user roles are the following: student, teacher, administrator, supplier, cleaning staff, etc. In other words, the context will define the user roles that can interact in this place. In addition, each user role has different rules associated with the user type (see Algorithm 2).

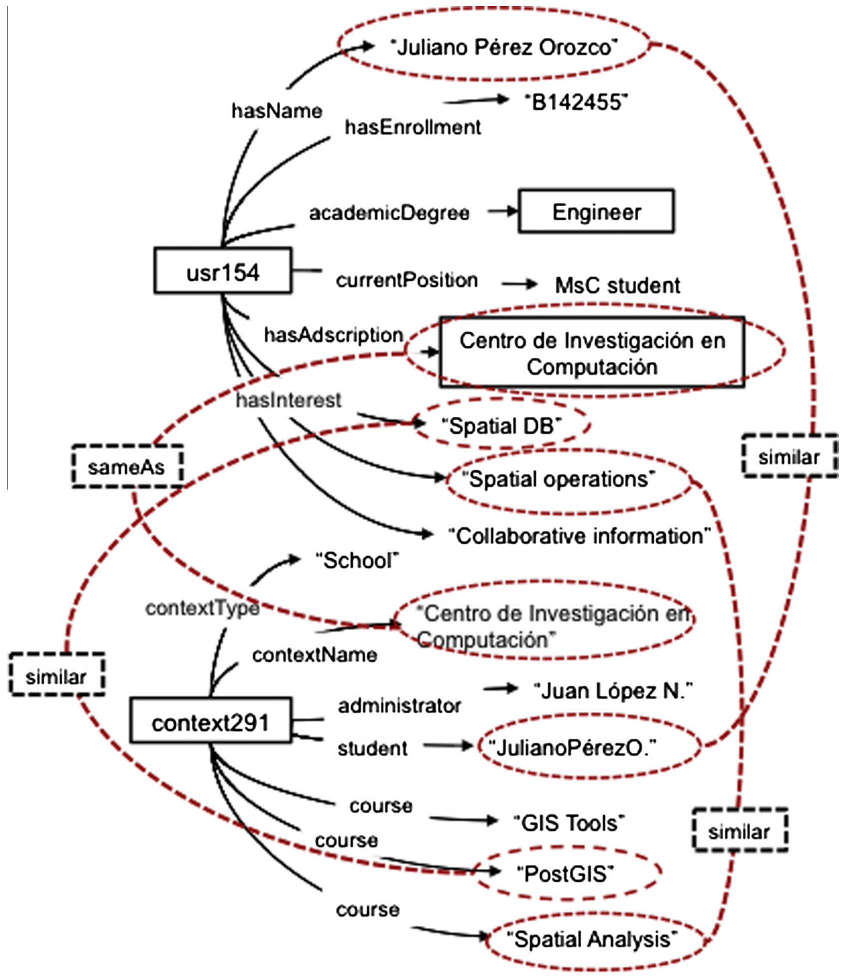

Fig. 5. Mapping process between two ontologies.

Algorithm 2. Role assignment
Input: User-ID: user identification, Applied Interaction Roles
AIR: the interaction roles that user applies to.
Output: Authorized interaction role set ROS to the user.
foreach *interactionRole Ro* ∈ *AIR* **do**
  if *interactionRole Ro* ∈ *contextInteractionRole* **then**
    foreach *positionRole that invokes interaction role* **do**
      if *all constraints are satisfied* **then**
        Insert position role R to ROS
      end
    end
  end
end
return ROS

3.4.2. User rules definition

According to the Semantic Web Rule Language (Horrocks et al., 2004), the rules are defined in the form of an implication between an antecedent (body) and a consequent (head). The previous is interpreted as: always that the specified conditions in the antecedent are held, then the specified conditions in the consequent must be also hold (see Algorithm 3). The context ontology contains a sequence of facts and axioms, where the axioms may belong to several classes e.g. subclass axioms, class equivalence axioms or properties restrictions.

According to the last assumption, one of the associated rules with the user profile "PhD student" is: "any user at the school context with the role of PhD student, gets access to take courses, but he is restricted to enter into the administration area". This rule is written in XML and based on first-order logic as follows:

$$user(usr) \wedge context(school) \wedge student(usr, school)$$
$$\rightarrow takeCourse(usr) \wedge restrictedAccess(usr, administration)$$

As a result, this stage obtains a role description, and the relationships between the kind of context and the user type. Fig. 6 shows as input of the Interaction stage, the user profile ontology and the context ontology. In this stage permissions and restrictions are assigned to the current user profile, depending on the items identified as similar or identical to the previous stage, that is, the user gets access to certain areas of the current context.

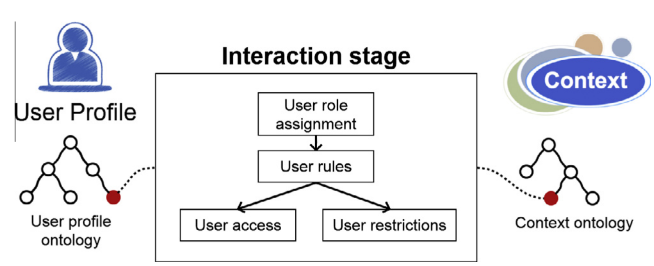

Fig. 6. Interaction stage.

Algorithm 3. User rules definition
Input: User-ID: user identification Authorized interaction role set ROS to the user. Authorized interaction rule set RULES to the user
Output: Rule to user set R2U.
foreach *interactionRole Ru* ∈ *ROS* **do**
  if *interactionRole A* ∈ *contextInteractionRule A* **then**
    foreach *positionRule that invokes interaction role A* **do**
      if *all constraints are satisfied* **then**
        Insert position rule R to R2U
      end
    end
  end
end
return R2U

3.5. Farewell stage

In this stage the interaction between user and the current context is finished Information about the user and the context is evaluated in order to allow updating each ontology. To do this update, an ontology evolution operation is proposed. It implements the changes in the ontologies maintaining the ontology consistency. In Fig. 7 the tasks for updating the ontology are presented (see Algorithms 4 and 5).

Algorithm 4. The ontology evolution
Input: *LC* list of changes, *o* ontology being changed.
Output: An ontology changed *o*.
forall the $c \in LC$ **do**
processChange(c, o)
end
return *o*

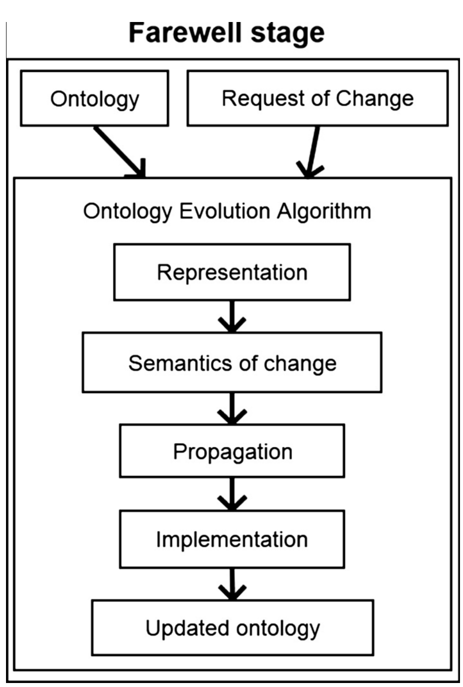

Fig. 7. Farewell stage.

Algorithm 5. processChange
Input: *c* change to process, *o* ontology being changed.
Output: An ontology changed *o*.
  es ← *evolution estrategy for o*
while *generated change gc by es for* $c \in o$ **do**
  processChange(gc, o) /∗ **Semantic of change** ∗/
end
if *c is generated in o* **then**
  processChange(c, o) /∗ **Change filtering** ∗/
end
change ontology o according to c /∗ **Change implementation** ∗/
return *o*

4. Experiments

This section presents the preliminary results of applying the methodology. They are outlined by each stage defined in this work.

To perform the experiments we need both ontologies. The user "Juliano Pérez" are represented in the user profile ontology. The instance "Centro de Investigación en Computación" is represented in the context ontology (see Table 1). Additionally, a summary of the context ontology is depicted, with some data from the context "Centro de Investigación en Computación" (see Table 2).

4.1. Experiment 1

The first experiment deals with the interaction between the user profile of "Juliano Pérez" and the context "Centro de Investigación en Computación".

At the Handshake stage a mapping process is executed to find the kind of user who is "Juliano Pérez". As shown in Fig. 2, "Juliano Pérez" is an instance of the user profile ontology, who has the following characteristics: his academic degree is Engineer, he is a PhD student, he is registered in Centro de Investigación en Computa-

Table 1
Extract of the user profile ontology "Juliano Pérez".

Class Name	Instance	Data
userName	user154	Juliano Pérez O.
currentPosition	currPosition12	PhD Student
Laboratory	Laboratory06	Intelligent Processing of Geospatial Information Laboratory
Interests	interest1	Spatial DB
	interest2	Geospatial operations

Table 2
Extract from context ontology for the instance "Centro de Investigación en Computación".

Class Name	Instance	Data
contextName	context291	Centro de Investigación en Computación
contextType	contextType2	School
	occupation2	Juan López N. (administrator)
	occupation3	Juliano Pérez O. (MsC_student)
Courses	course1	GIS Tools
	course2	PostGIS
	course3	Spatial Analysis
Rules	rule1	$isStudent(usr) \rightarrow access(usr, classroom) \wedge restricted(usr, administration)$
	rule2	$teacher(usr) \rightarrow access(usr, administration) \wedge restricted(usr, systems)$

Table 3
Result of the mapping process (Experiment 1).

Instance 1	Instance 2
user154: Juliano Pérez	occupation3: Juliano Pérez
currPosition12: PhD student	occupation3: PhD student

Table 4
Result of the mapping process (Experiment 2).

Instance 1	Instance 2
interest1: Spatial DB	course2: PostGIS
interest2: Geospatial operations	course3: Spatial Analysis
interest3: Collaborative information	Not found

ción, and more information about this person. So, information that concerns us in this stage, is the user name and his academic interests.

With these data, the mapping algorithm is executed with the user data previously described. The result of this algorithm is a Boolean value that represents if the user is inside the context, i.e. indicates if "Juliano" is a person registered in the context. In this case, "Juliano" is matched with the instance 'occupation3', presented in Table 3.

By considering the above, the next stage defines the rules, permissions and restrictions for the "Juliano" user in that context with the role assigned. The result of the Interaction stage is the following: "The user Juliano Pérez is student at Centro de Investigación en Computación". So, the specifically assigned role is 'Student'. On the other hand, it is necessary to apply the 'rule1' for this kind of user, i.e. the 'rule1' satisfies that the user is a student, and he is a PhD student; thus, "Juliano" has access to classrooms and laboratories, but he has restricted to administration area. Finally, in the *Farewell* stage information described above is updated in the user profile ontology. It is important to mention that privileges that "Juliano" has acquired in the previous context, now they are "switched off". It means that when the user changes his context, his role will be changed too. So, his privileges should also change in this case.

4.2. Experiment 2

The second experiment deals with the interaction between the user profile of "Juliano Pérez" and the same context, but now we take into account the academic interest of the user. The definition of role is a key point in collaborative learning, identifying the academic preferences as well as the type of user; the learning is benefited because the content is adaptable to the user needs and the ability of each one. Moreover, it enhances student satisfaction with the learning experience.

Similarly, as in the previous experiment, a mapping process is executed to find the interests of user "Juliano Pérez". In this case, the interest for 'Spatial DB' is matched with the instance 'course3', and similarly the interest for 'Geospatial operations' is matched with the course 'Spatial Analysis'. It is described in Table 4. An interesting use of this information can be for planning the 'right' course for this type of student.

5. Conclusions and future work

In this paper, an approach based on ontology to represent the interaction process between user profiles and contexts is described. The methodology is composed of three stages: (1) Handshake, (2) Interaction, and (3) Farewell.

As a case study, a school as a context and two different user profiles represented in the user profiling ontology are proposed. This approach analyses the characteristics and preferences of the user and the context models in order to find the relationships generated, when a person interacts in a defined context.

We also analyzed the roles assignments, permissions, restrictions and the definition of rules that apply to each user. This work aims to consider the application of the presented approach in learning environments in order to personalize learning processes according to characteristics of the users.

Future works are oriented toward considering the application of the presented approach in recommender systems, in order to handle as the engine of the processing stage in the relations between user and its contexts.

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