A reference profile ontology for Communities of Practice

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A reference profile ontology for communities of practice

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Abstract: Communities of Practice (CoP) integrate people in a group in order to learn in a collaborative way. It is necessary to establish in these communities a formal and standardised representation of the knowledge and interests that emerge from CoP. With this scenario in mind, this paper presents a reference ontology for a user profile representation in a CoP Framework (CoPF). The main idea of this framework is to provide virtual CoP for collaborative learning by using semantic web technologies. This work proposes a foundational ontology for a general profile to be used as a guideline to build a computational CoPF, which is semantic web compliant. In this paper we summarise a first proposition of the CoPF ontology development focusing on the ontological user profile. We also present the methodological aspects of the ontological CoPF and also illustrate a case study applying the ontological user profile.

Keywords: CoP; communities of practice; ontologies; collaborative learning; semantic web.

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1 Introduction

Normally the member's profile in most any virtual community is related to personal and professional information, as well as interests that may identify a usage and behaviour profile in the context of service-oriented applications, especially in recommendation systems (Rich, 1983; Donath, 1999; Kobsa, 2007; Sosnovsky and Dicheva, 2010). The traditional formalisation of a profile in this context is used to define not only the identification and preferences of the users, but also (a) their expertise in a specific area of interest; (b) the relevance of their contributions in collaborative interactions and (c) the evolution of their learning, which is promoted by interactions.

These three aspects may be captured, in group learning interactions, by making use of Communities of Practice (CoP) as a support for knowledge management (Wenger et al., 2002). In order to achieve this level of knowledge management, the member of a community needs to register and share his knowledge and practice, and therefore his intellectual evolution in the community domain along with his practices.

CoP is defined as communities of people who share the interest regarding an issue or a problem and learn from regular interactions (Wenger, 1998; Wenger et al., 2002). This contact among community members may occur virtually or in person in order to enable the exchange of knowledge. This exchange, once put into practice by other members, may help them in finding solutions and the best practices, thus promoting group learning (Terra, 2005).

The representation of the user profile is an important matter when the subject concerns information filtering and recommendation systems. The issue is traditionally approached by studies in the domain of user modelling, which is well established in literature of Perrault et al. (1978), Rich (1979), Rich (1983) and Kobsa (2001). The usual approach to user modelling is to collect different types of information concerning users, which is described by users' interests and also traces of behaviour seized from their interaction with the system. From a static and syntactic point of view, this is enough for information retrieval systems and product recommendations based on consumer characteristics.

A user profile definition generally reflects only the user's momentary interest regarding a particular subject in a specific domain. Some authors (Poo et al., 2003; Carreira et al., 2004) claim that every expression in the user profile represents a characteristic obtained directly from the user and/or eventually inferred during interaction on the web. The data is stored in a traditional database including user identification, interests and preferences that is held in a static way (Poo et al., 2003; Rousseau et al., 2006).

However, in the knowledge sharing among groups of people who learn collaboratively, it become necessary to establish a standardised and formal representation of interests along with tacit/explicit knowledge present in a community. We regard this under the hypothesis of the Semantic Web as the main pattern of collaboration.

The issue we want to address in this work is about the static and linear user representation in traditional user modelling systems. Instead of a limited vocabulary such as keywords, an ontological representation of the user's profile will allow inference to be employed, permitting the discovery of new interests. Using ontologies to represent profiles will also grant communication with other ontologies.

Nowadays an increasing number of ontologies are available on the web representing data and the web itself. If by one hand the manipulation of this kind of heterogeneous information is quite complex, by the other, the web is crucial in carrying out information by sharing and reusing it through these multiple ontologies.

This paper presents an ontology for modelling user profiles in the context of CoP as being part of a larger work that proposes an ontological framework for building CoP. A first model was applied on a learning context in order to give us the first idea about the concepts and properties of the ontology (Ribeiro et al., 2011). Our goal is to use a profile reference ontology in order to establish a sufficient knowledge standard for modelling CoP. This approach can detect *expertise* in its environment and automatically (or at least semi-automatically) link together participants and other communities related to an issue, as well as the practice that can solve it. It is also a fundamental step that an application or domain ontology could be instantiated to build CoP for specific domains.

This paper is organised as follows: Section 2 presents a brief overview of the ontological CoP framework and summarises the methodological aspects of its specification. Section 3 presents more details about our proposal of an ontological user profile for CoP. In Section 4 we present an application scenario concerning the use of the ontological user profile. Some related works are shown in Section 5 and conclusions and further work appear in Section 6.

2 The ontological communities of practice framework

The proposed Communities of Practice Framework (CoPF) is built on three meta components: the CoP component, responsible for the relationship among people with common interests, with emphasis on the CoP life cycle; the Virtual Environment component, which provides technological collaboration tools needed by the community; and the Activity Component, which serves as a link with previous layers through the management activities of CoP and the relationship between the use of collaborative tools and the CoP life cycle.

The information and issues addressed within the community in the CoP component are defined from some sources of knowledge related to the CoP concept. The main concepts are: *Domain* (knowledge, interest and preferences), the *User and Community Profiles*, the *Collaboration Records* and the *Membership* and *Technological Collaboration Tools*. Figure 1 shows the generic model to represent the main concept classes proposed in our CoPF*: Interest Domains, Profiles, Collaboration Records, Activity* and *Web Tools*. The Interest Domains should consider the collective construction of the knowledge, perhaps by a group of editors/mediators and predefined domain ontologies. Such ontologies can also be used within the web community built by the participants themselves (using mediators) and/or otherwise generated semi-automatically. The Interest Domains also integrate the repository of ontologies and address broader issues, unifying concepts around community domains.

As depicted in Figure 1, the main class in the CoPF is the *CoP class*, which represents the main concept of CoP. Therefore, the CoPF is modelled from a CoP definition taking into account the three structural characteristics of a CoP (Wenger et al., 2002), Domain, Community and Practice, which are represented by the following CoP associated classes:

Interest domains class: The areas and fields of interest related to subjects and themes dealt with CoP are the main topics covered in this concept. It is a high-level concept, defined by a *Profile* in the creation of a CoP, which could be described by elements in the user profile and CoP domain, both based on domain ontologies. This ontological representation is suitable to ensure the context validity (when the ontology can be verified by experts) and then used as a reference for searching and recommendation.

Profile class: Represents both a CoP user and the community itself. The CoP profile describes the discussed topics, the way of work, expectations, goals and motivations of the CoP creation. The *Profile class* is detailed in Section 3 and it represents static and dynamic information, allowing continuous development and renewal of CoP maintenance. The descriptive text on static profile is produced by the CoP moderator or by the user himself, while the dynamic part will be inferred from CoP interactions among its members. There is also the possibility to retrieve some personal data from a *FOAF URI*.

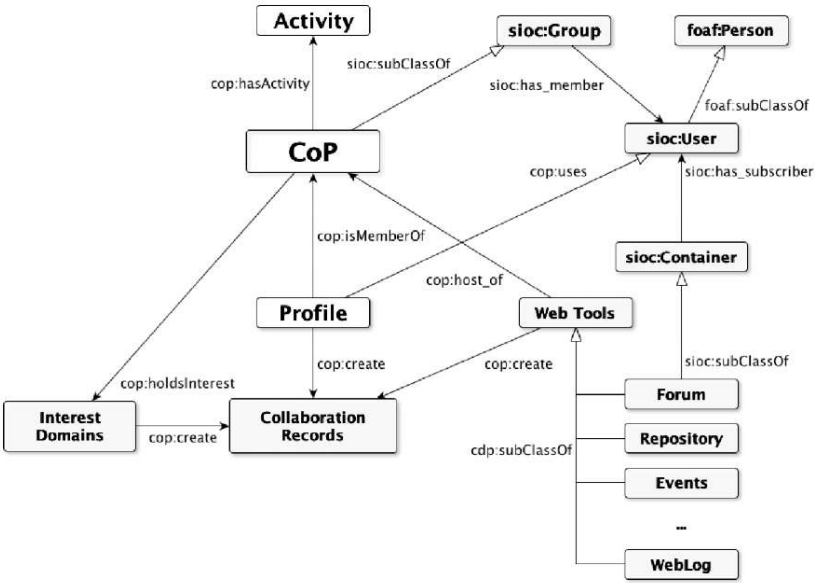
Web tools class: Describes the technological collaborative tools available in CoP. It is defined based on a structure relating CoP activities with the interaction of its members. This component implements an interface with a generic set of web collaborative tools and can be interpreted as an abstract class in order to instantiate multiple tools with their attributes and characteristics.

Collaboration records class: Keeps the historical record of interactions from an individual using the tools in CoP such as recording information on which tools used, checking the involved CoP, author's records, collaboration contents (explicit knowledge) and the areas of interest associated with the record.

Activity class: The practice of CoP lies in the outcomes developed by the CoP which is distributed in *Activity, Web Tools, Profile* and *Collaboration Records* classes. In our point of view, we realise that user and community competence (Skills) are related to the type of activity and Roles played by the user in CoP. In order to map the practice (and best practices) in CoP, we need to formalise the relationships among *Activities, Roles, Skills* and some sort of *Evaluation* of the outcomes. Therefore, we have adopted a definition of activity from the model of an activity system proposed in the Activity Theory of Engestrom (Engestrom et al., 1999), which is appropriate to describe the relation between individual and community in collaborative activities.

The proposed CoPF also includes some complementary classes in order to represent shared concepts from several existing ontologies such as FOAF (Brickley and Miller, 2010) and SIOC (Bojars and Breslin, 2010). The main idea in this framework is to reuse multiple domain ontologies in order to represent the conceptual classes described in this specification.

Figure 1 The overall ontology for the CoP Framework. Round rectangles represent the classes of the ontology (concepts) and the edges represent the relationships (properties) between classes. Edges with straight line arrows represent the properties specific to our CoP ontology, while triangle heads means the concept hierarchy. We use different 'namespaces' to represent distinct ontologies, such as '*cop:*', '*sioc:*' and '*foaf:*'



2.1 Methodological aspects of the ontological CoP framework

This work takes into account the definition of ontology as a framework for representing concepts (things or ideas about things) (Gruber, 1995; Guarino and Giaretta, 1995) and the relationships that exist between those concepts (Uschold and Gruninger, 1996). This definition is suitable for domain ontologies to describe things and also for higher level ontologies. According to Guizzardi et al. (2010), the concept of ontology in the semantic web context is about an engineering artefact associated with a formal structure of concepts and relations among concepts. Both concepts and relations can be constrained by a set of axioms.

Our ontological framework is mainly based on a foundational ontology instead of traditional domain ontology. Domain ontologies could perhaps present some semantic interoperability problems when related to open and dynamic scenarios, such as the semantic web (Guizzardi et al., 2010). In general, such scenarios need a domain-independent commonsense theory through methodology and complementary language based on foundational ontologies (Smith, 2003; Guizzardi, 2005; Brinkley et al., 2006).

As stated by Gangemi et al. (2002), foundational ontologies can be seen as axiomatic theories upon domain-independent high-level categories such as objects, attributes, events, parthood, dependences and spatio-temporal connections.

A first step towards our ontological CoPF model was to select some well established CoP and user profile ontologies from the context of general user modelling (Pease et al., 2002; Heckmann et al., 2005; Yudelson et al., 2005; Kobsa, 2007), CoP representation (Vidou et al., 2006; Tifous et al., 2007), formal learner profile (Isotani et al., 2009) and web community representation (Bojars and Breslin, 2010; Brickley and Miller, 2010). From these works we have selected and adapted some base concepts required to high-level CoP representation.

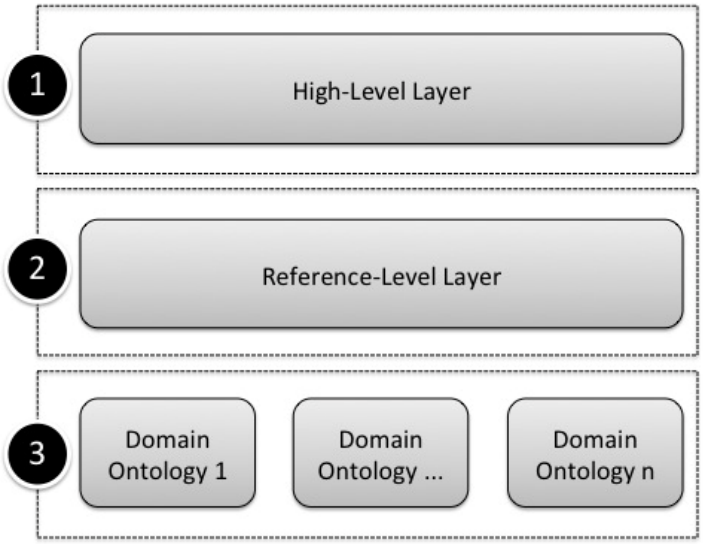
The next steps in our definition are based on a top-down approach, proposing foundation ontology in order to select important wide-ranging concepts organised in three layers: a high-level layer, a reference layer and a set of domain ontologies in the domain layer. Figure 2 shows an abstract overview of the granularity involved on the process of ontology engineering.

The first layer (number 1) employs all the high-level concepts and relationships we need to represent the CoP domain structure in some metadata schema including our CoP ontology illustrated in Figure 1. For instance, in this level we bring together the SIOC and FOAF metadata through their semantic and domain restricted values in order to make our framework interoperable and to associate the community participant's social profile.

The second layer (number 2) represents a reference ontology for application profiles. We defined a set of axioms that can infer individuals in ontologies such as their instances and some concepts that represents only the context of CoP. Our reference ontology is based on the theory of Brinkley et al. (2006) and Burgun (2006), which represents a domain according to knowledge representation principles belonging to ontologies and may build extensions, specialisations or instantiations to other specific domain ontologies.

Finally, the third layer (number 3) represents the domain ontologies that compound the third party applications with classes that are not present on the ontological framework and that belong to specific domain related to the CoP contents. It is, for instance, the case of the *Interest Domains* that is related to multiple domain ontologies in order to represent specific domains of in CoP.

Figure 2 Ontological CoP framework through a three layer level abstraction



3 Description of the ontological CoPF profile

The participant's profiles (*Profile class*) are made up by some basic information *properties* that define their personality. We propose a description in two levels of details: static profile and dynamic profile. Essentially, this dichotomy is established based on explicit and implicit models by Rich (1983) that allows users to provide individual pre-defined data and the system complements it with inferred user data by monitoring its behaviour.

The work by Schubert and Koch (2003) also introduces distinction between the explicit and implicit profiles. The explicit profile contains identification information (username, role, personal settings, etc.), social-economic information (age, gender, hobbies, etc.), reviews (products, standpoint, items of information) and information on relationships with others and comments/opinions (text, images, videos and others). They classify the implicit profiles in a transaction profile (transaction logs, purchased products related to product metadata), an interaction profile (user click-streams, page views, etc.) and external data (information obtained from weather forecasting, local news, events, credit analysis and more).

In our proposal, the static profile represents information provided traditionally by the user as his personal and professional data, interests, curriculum vitae and so forth. In short, the basic information that grants the definition of entries as a 'yellow pages' service. The dynamic profile consists on information captured from its interaction with the community at all levels of knowledge, such as files and posts, practices, contributions in problem-solving activities and through the use of collaborative tools.

The diagram in Figure 3 illustrates the main concept classes defined as reference in the user's profile ontology. A *Profile* has an *Identity, Interactions, Interests, Roles* and Skills. In the static context, all these concepts can be informed. In the dynamic context, the information is permanently added derived from interactions with the members of communities, as well as from interactions with the tools within the community.

In the following sections we detail each one of the classes of the CoPF profile.

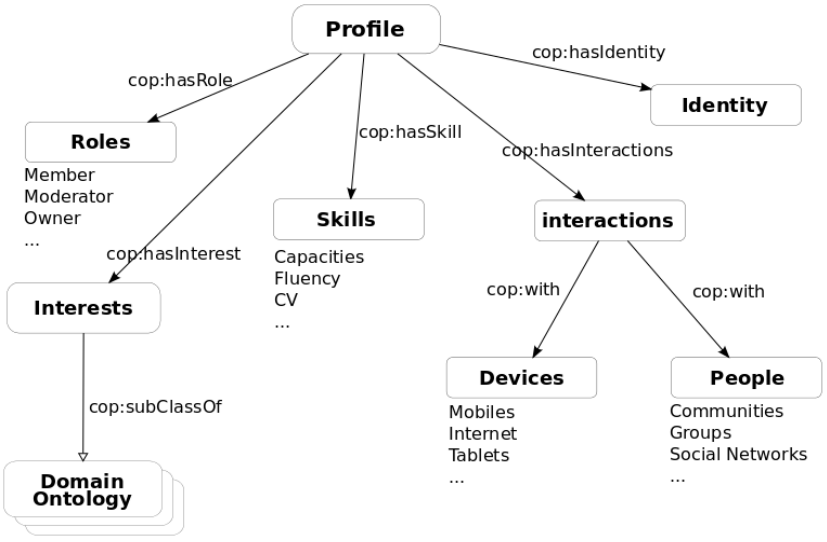
3.1 CoP:Roles

Roles can be immediately assigned to users in the creation of a CoP. The creator of the community has features and privileges that are formalised in the *Owne*r role, which is assigned to the creator immediately during the CoP creation. All guests interested in this community are registered as *Members*. Other roles can be negotiated and awarded for participation as, for instance, the definition of *Moderators* or *Animators* for the community. Each role defines a form of action/interaction in the community, but it can also hold some types of competence, expertise and skills in their field of activity/interest. In this case, the concept of role works as a repository of specific parameters in the instantiation of a domain ontology.

In a general sense, a role has been defined as a collection of necessary features, interests, expectations and behaviours in relation to a particular system (Constantine, 2006). In a narrower point of view, the role of a user can be represented by its performance in the context/environment according to the characteristics and criteria of action/ interaction. This means that the characteristics of its performance are influenced by the context. Within the CoP, the definition of roles can standardise the use and the choice of collaborative tools according to the activity developed in the community. In this case it is important to keep a record of patterns of interaction related to each type of user or each type of role assumed in a specific collaborative practice.

As an example, in order to illustrate this context-dependent approach, we can relate the role in CoP to some activity contexts. The most general domain provides the basic set of roles of *Owner*, *Member* and *Moderator*. This set can derive and instantiate other behaviours such as 'Guest', 'Beginner', 'Regular', 'Leader' and 'Senior' as for instance, in training areas or working groups. The domain of *e-learning* can instantiate 'Teachers', 'Tutors', 'Specialists', 'Students', 'Monitors' and others.

Figure 3 The user Profile Ontology in the *CoPF*. As in this figure, the edges with straight line arrows represent the specific properties for our reference ontology that are labelled with their properties. The terms in each class illustrate some possible instances of individuals



The following OWL[1] examples illustrate the contexts (*#basicContext* and *#eLearningContext*) as subclasses of the ROLE concept:

```
<!-- Sample code for "basicContext" representation as subclass of COP:Role-->
<SubClassOf>
    <Class IRI="#basicContext"/>
    <Class abbreviatedIRI="COP:Role"/>
</SubClassOf>
<SubClassOf>
    <Class IRI="#basicContext"/>
    <DataExactCardinality cardinality="1">
        <DataProperty IRI="#hasBasicRole"/>
```

```
        <Datatype abbreviatedIRI="xsd:string"/>
    </DataExactCardinality>
</SubClassOf>
```

Thus, it is possible to link the CoPF roles throughout the data types that define the contextual roles:

```
<!-- Sample code for roles datatype definitions -->
<DataPropertyRange>
    <DataProperty IRI="#hasBasicRole"/>
    <DataOneOf>
        <Literal datatypeIRI="&rdf;PlainLiteral">Member</Literal>
          ...
    </DataOneOf>
</DataPropertyRange>
<DataPropertyRange>
    <DataProperty IRI="#hasElearningRole"/>
    <DataOneOf>
        <Literal datatypeIRI="&rdf;PlainLiteral">Monitor</Literal>
          ...
    </DataOneOf>
</DataPropertyRange>
```

The following example illustrates a community member with some associated roles, depending on the context they belong.

```
<DataPropertyAssertion>
    <DataProperty IRI="#hasBasicRole"/>
    <NamedIndividual abbreviatedIRI="COP:https://profiles.google.com/103478
23764498384736263847"/>
    <Literal datatypeIRI="&xsd;string">Member</Literal>
</DataPropertyAssertion>
<DataPropertyAssertion>
    <DataProperty IRI="#hasElearningRole"/>
    <NamedIndividual abbreviatedIRI="COP:https://profiles.google.com/103478
23764498384736263847"/>
    <Literal datatypeIRI="&xsd;string">Monitor</Literal>
</DataPropertyAssertion>
```

3.2 CoP:Interests

The profile presents a relation of interests (*Interests*) representing the user's preferences and knowledge about a domain. Traditionally, interest has been represented by lists of keywords or by using folksonomy through tags (Szomszor et al., 2008) and incremental (Sieg et al., 2005) or collaborative categorisation.

In our CoP Framework, the set of *Interests class* related to the *Profile class* contextualises a set of domain ontologies related to the community in which the user belongs. These ontologies represent the characteristic that defines a domain CoP (Wenger et al., 2002), i.e. the explicit knowledge that brings together community members in collaborative learning. Therefore, the set of user's interests in the proposed *framework* can be inferred through its links with several domain ontologies (*dynamic model*), besides the predefined set of the user tags (*static model*).

In this model, the *Interests class* can be adapted both to represent community contextual interests as to set metrics in order to evaluate the context proximity. These metrics will be used for representing the several posts, embedded files, comments and any communicative interaction in the CoP. An example of a possible instantiation from the reference ontology Profile would be an adaptation of a weighted hierarchy of interests, as represented by the community context and illustrated in Figure 4.

Reference ontology models the *Interests class* as a subclass of domain ontologies *(Interest Domains* class in Figure 1). The basic idea is to link CoP to external domain ontology and promote the construction of shared ontology from interactions among members.

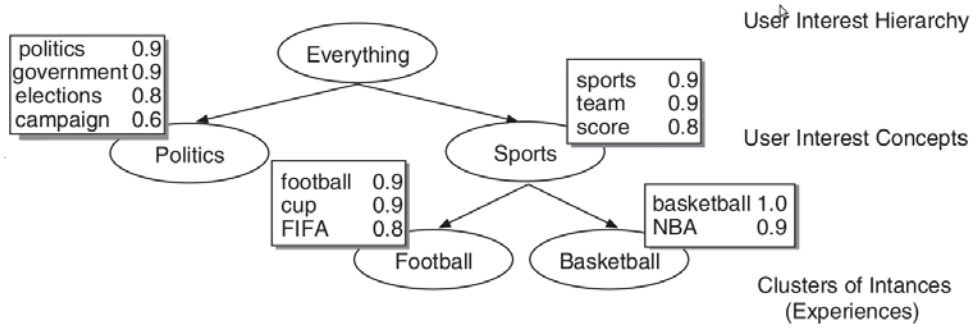
The following example points out these issues. The first assertion shows a user that *holds Interest* on the subject 'Artificial Intelligence', with no further details apart from the *Artificial-Intelligence* tag. The second property links the interest in 'Football' to an external ontology regarding Sports represented here by *sptcsem* Ontology.

```
<ObjectPropertyAssertion>
    <ObjectProperty abbreviatedIRI="COP:holdsInterest"/>
    <NamedIndividual abbreviatedIRI="COP:https://profiles.google.com/104438
298068522195023"/>
    <NamedIndividual abbreviatedIRI="COP:Artificial_Intelligence"/>
```

```
</ObjectPropertyAssertion>

<ObjectPropertyAssertion>
    <ObjectProperty abbreviatedIRI="COP:holdsInterest"/>
    <NamedIndividual abbreviatedIRI="COP:https://profiles.google.com/104438
298068522195023"/>
    <NamedIndividual abbreviatedIRI="sptcsem:Football"/>
</ObjectPropertyAssertion>
```

Figure 4 Example of an ontological representation from a community domain context according to Godoy and Amandi (2006)



3.3 CoP:Skills

The *CoP:Skills* class represents the skills and competencies that the participant has in CoP. This level of details provides important information for the recommendation of people, expertise and the discovery of relationships between communities through related skills.

The human resources management area has a basic and typical concern when it comes to finding the right person for the job or position. Normally the area is also responsible for planning the development of certain skills in case of gaps in the company. Intellectually speaking, finding a proper team for a project or a group of teachers for an appropriate course also derives from such an issue: the skills management. A human resource system maintains a database with the specific skills or expertise of the individuals with some interface for maintenance and research.

Generally, competence is related to a collection of knowledge that people need in order to solve specific problems (Dutra et al., 2000; Fleury and Fleury, 2001; Perrenoud, 2001). Our work is based on Fleury's definition (Fleury and Fleury, 2001), where competence is connected to the identity of an individual and his educational and professional background so that the framework can identify relationships in the practices used for a given field and the skills and/or knowledge that the user has mobilised for his implementation.

From the *CoP:skil*ls class it is possible to instantiate an application ontology representing a set of skills demonstrated by participants in a community. This for example, could be an OWL scheme representing the user's curriculum vitae along with an ontological structure that classifies an area of expertise that could be instantiated by this class.

From this representation, the recommendation of CoP can filter the domain from the skills of its participants or recommend participants according to the dominant skills in a community. By taking advantage of this standardised structure it can still relate to topics of interest (*the CoP domain*) with schemes to solve problems or actions carried out to respond to challenges from the community (*the CoP practice*). In addition, it is possible to recommend experts and to make dynamic yellow pages available that can be updated from a topic posted by an individual in order to fill in its list of skills.

3.4 CoP:Interactions

The *CoP:Interactions* class defines the type of support for multiple platforms that represents intra and inter-community relations. CoP members need to share domain knowledge and practices in pursuit of their common goals, but they also keep explicit and implicit relationships with other communities and individuals and also interoperate across multiple technological platforms. Therefore, *users* who have *Profiles* in a CoP maintain interactions *(Interactions*) with devices *(Devices*) and individuals *(People*) through a relationship *cop:with*.

Relationships between individuals can be described directly through the property *foaf:knows* as of means to join members of the same community or from other communities. When it comes to the social domain of the individual, it simply refers to the interactions that exist among the various communities in which the user unites identity by using an *OpenId*[2] or from an *owl:sameAs* relationship to integrate various sites of the same user.

When the matter concerns the context of recommendation on communities, it becomes important to define a more specialised type of interpersonal relationship that may involve more particular kinds of interaction. This applies to the possibility of instantiating an ontology through the FOAF property *foaf:knows*, *rel:acquaintanceOf*, etc. A recommendation algorithm may, for example, infer that two individuals are collaborators or colleagues through this class Interaction. If a community has a document that uses the relation Interaction *CoP:with* People, which can be described by the *foaf:know*s property, the recommendation may include the skills and interests from the relationship of users and their communities.

The same happens for *Devices* when considering the use of various devices by the same individuals who have *foaf:knows* or *rel:acquaintanceOf* relationships. Some axiom of inference can establish the use/preference of specific protocols in order to identify a profile from mobile behaviour in such cases.

3.5 CoP:Identity

As seen in the work of Donath (1999), user profile and social reputation are very important to define the user's identity in order to anticipate needs and user behaviours in a virtual community. The understanding and evaluation of interactions in these communities depend on the user's identity, which is also important to motivate people to actively participate in community discussions.

The Identity component of the Profile class is not only composed of information's regarding the user's personal/ academic/cognitive characteristics, but also by the interactions in the community through membership feature.

The user's identity is defined in a traditional way in this class through a simple identification by using personal details such as name, surname, business and residential information. Many FOAF properties can be summoned at this level as a representation of OpenId (*foaf:openid*), associating an Identity URL.

Thus, it is possible to establish information about the users from any document or resource semantically linked by any other means of knowledge (e.g. RSS, Atom and vCard). Private information can also be aggregated to this class such as date of birth, gender, marital status and more.

The following example illustrates an excerpt of the user's identity representation. Here we use both, SIOC and FOAF, in order to enrich the description and to follow the user's connections.

```
<owl:NamedIndividual rdf:about="&COP;https://profiles.google.com/1044382980
68522195023">
     <foaf:givenName rdf:datatype="&xsd;string">Joao Luis</foaf:givenName>
     <foaf:lastName rdf:datatype="&xsd;string">Tavares da Silva</foaf:last-
Name>
     <foaf:openid rdf:resource="&COP;https://profiles.google.com/1044382980
68522195023"/>
     <sioc:email_sha1 rdf:datatype="&xsd;string">joaoluis.tavares@gmail.com
</ns:email_sha1>
     <sioc:member_of rdf:resource="&COP;Digital_Habitats_for_Education_co-
urse"/>
</owl:NamedIndividual>
```

4 Instantiating a CoP in an educational scenario

This Section presents an example of the instantiation of the ontology proposed in an educational domain. The ontology was built using the ontology editor and knowledge-based framework Protege.[3] This example represents CoP, its members with its profile and interactions in the community. One can encounter CoP associated with a group of people related to a course context. The CoP can identify the 'Digital Habitats for Education' course in the domain (*Interest_Domains*) of 'Permanent Education' that uses a pool of collaborative tools and virtual learning environments (*WebTools*). The CoP class may also be associated with a topic in the course, an area of knowledge or even an academic unit.

Its members include students, teachers and tutors in the context of a class and also external users of a public CoP. Each one described as ontology individuals.

The ontology relations are modelled using *Object* and *Data* Properties. An individual is defined through his/her Google *OpenId* by using the data property *foaf:givenName* filled with, for example, the value 'Joao Luis' and has a relation with the object property *isMemberOf* with the CoP individual 'Digital Habitats for Education'. The member is associated to the individual Teacher through the object property *CoP:hasRole* and *CoP:holdsInterest* with the individual Football (Soccer) as illustrated in Figure 5. These relations allow a reasoner tool to infer that an individual is member of any class that has axioms related to their object or data properties.

Figure 6 illustrates the CoP practices through the (*Activity*) model. This practice is related to the academic activities concerning the unity of knowledge provided by the teacher/tutor. An activity example is represented by a *Task* 'Mastering_ the_Subject' which has a Goal 'Question_and_ Answers'. In order to reach this Goal, the Task uses some *Resources* ('Exercise_List' and 'Main_Book'), which have as a resulting metric an *Evaluation* ('High_grade').

The *Interest_Domains* are instantiated as a library of domain ontologies suitable for various user groups and domains. These ontologies are external to the *CoPF*. An illustration of the *Interest_Domain* related to a user Post in a Forum ('Virtual_Communities') is depicted in Figure 7. A CoP member *Person* plays a *Role* from the type *eLearningRole* 'Teacher' in the community and all the interactions are registered in the *Collaboration_Records*.

Figure 5 A partial description of a member in the CoPF modelled in the Protégé (see online version for colours)

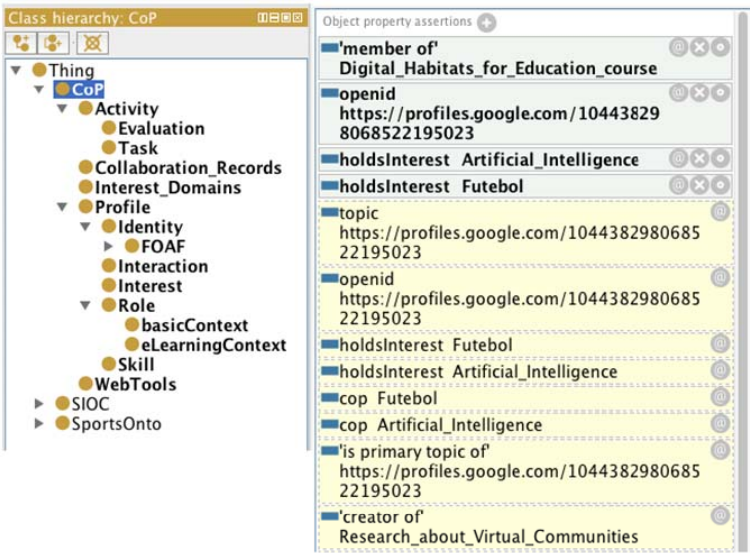


Figure 6 A partial representation of an activity model in the CoPF. The triangular arrows represent the hierarchy of concepts whilst the dotted lines correspond to the *Object Properties* between individuals

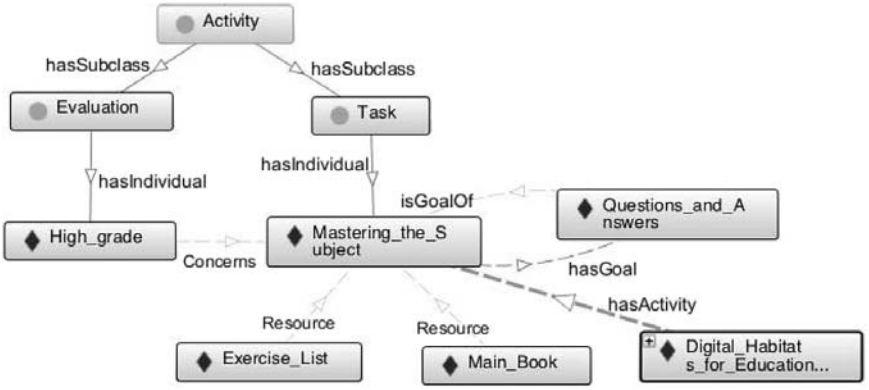
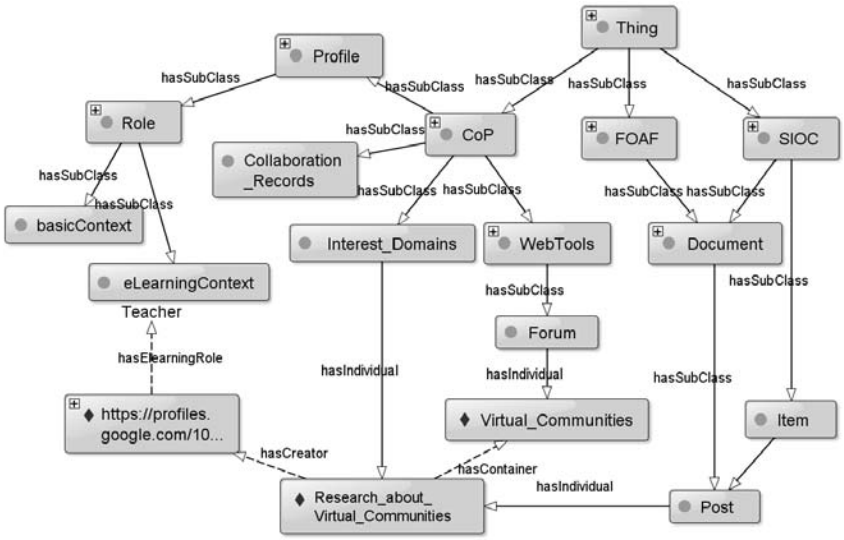


Figure 7 A partial CoPF representation illustrating how user interactions are carried out in our ontology



The Following OWL fragment presents an example of the description of the individual Register_1 from the *Collaboration Record* class. Each individual from this class describes a single interaction inside CoP. The Object Property assertions describe that the scope of this interaction is for the *Digital Habitats for Education* community and is related to the (https://profiles. google.com/10443829) user over the *Exercise_List* activity individual. The Data Properties describes that this interaction was made at a certain *time* and that it was a *post*. If there where to be any other interactions, then new individuals in the *Collaboration Record* class should be built.

```
<Declaration>
    <NamedIndividual IRI="#Register_1"/>
</Declaration>

<ObjectPropertyAssertion>
    <ObjectProperty abbreviatedIRI="COP:hasActivity"/>
    <NamedIndividual IRI="#Register_1"/>
    <NamedIndividual abbreviatedIRI="foaf:https://profiles.google.com/104438
29..."/>
</ObjectPropertyAssertion>

<ObjectPropertyAssertion>
    <ObjectProperty abbreviatedIRI="COP:hasActivity"/>
        <NamedIndividual IRI="#Register_1"/>
        <NamedIndividual abbreviatedIRI="COP:Exercise_List"/>
    </ObjectPropertyAssertion>
<ObjectPropertyAssertion>
    <ObjectProperty abbreviatedIRI="COP:hasInteraction"/>
    <NamedIndividual IRI="#Register_1"/>
    <NamedIndividual abbreviatedIRI="COP:Digital Habitats for Education"/>
</ObjectPropertyAssertion>

<DataPropertyAssertion>
    <DataProperty IRI="#post"/>
    <NamedIndividual IRI="#Register_1"/>
    <Literal datatypeIRI="&xsd;string">Research_about_Vitual_Communities
        </Literal>
</DataPropertyAssertion>
<DataPropertyAssertion>
    <DataProperty abbreviatedIRI="sioc:last_activity_date"/>
    <NamedIndividual IRI="#Register_1"/>
    <Literal datatypeIRI="xsd:date">1982-04-23T18:32:52</Literal>
</DataPropertyAssertion>
```

5 Related works

According to Donath (1999), the definition of *User Profile* in terms of internal identity and social reputation is part of the community formation. While the internal identity is defined by the user, the convention is that the social reputation is an extension of the user profile. According to Josang et al. (2007), reputation can be defined in terms of what is said or believed about a person or object. Therefore, both the authors consider that the social reputation uses the same kind of information stored in the user profile, but under the point of view of other users. For this reason, we take into consideration the interactions that occur among members in the community in our proposal.

The *User Modelling Meta-Ontology* (UMMO) (Yudelson et al., 2005) is a general ontology for user modelling applied in defining a uniform interpretation of user models distributed in web environments. The UMMO general model is presented in several dimensions that define the characteristics of the user, such as *BasicUser Dimensions, Emotional States, Characteristics* and *Personality*. The *Basic UserDimensions* defines personal traits like professional, demographical, emotional and psychological among others. Among them is the definition of role *(Role*) as a structuring tool in the user profile.

The UMMO aims to generalise the concepts in the broader aspects of user activities (*Who, What, Why* and *How*) offering a taxonomy and a partonomy of concepts about user modelling. In our point of view, UMMO is not properly to represent a user profile in the context of CoP since we need to infer interactions and collaborations in order to build the user's dynamic profile.

The *General User Model Ontology* (GUMO) (Heckmann et al., 2005) is another initiative towards a basic user modelling. GUMO focuses on the basic user dimensions such as Emotional States, Characteristics and Personality. Therefore, the GUMO approach aims at a regular and uniform interpretation on distributed user models including

very specific concepts like the user's age, current status, place of birth, heart rate and so forth, or very broad preferences such as specific wines, sports or reading.

The GUMO grants us a huge taxonomy to identify the user in depth, but does not handle with relations on objects, documents, web tools or other users in the context of community interactions as necessary. In our approach, we are in search for upper level concepts about the user description that may be taken as a kind of reference to integrate domain ontologies.

There are two works that rely on the use of ontological dimensions on educational contexts: an ontology for the learner profile in specific educational CoP (Vidou et al., 2006; Tifous et al., 2007) and a formal description towards group formation from a learner profile ontology (Isotani et al., 2009).

In the 'O'CoP' ontology (Vidou et al., 2006), the user model is aimed at a learner profile whereas learning is a main activity in CoP. Therefore, the *Actor* concept in the ontology is associated to a learner. They present a meta-model of a generic Learner Profile that represents the learners' cognitive characteristics in a learning activity. This model is composed of a learner's *Static Information* relating interests, preferences, professional and academic information; the *Objectives* and *Incentives* that represent the learner behaviour in learning activities and the learner's *Skills and Capabilities* and his *Knowledge Assessment*. Our proposal seeks out the same focus on user representation in terms of knowledge but not so specific in a learning domain. We search for a more general view on user activities and roles in CoP and also the semantic web interoperability with the communities and social networks of another user.

The work by Isotani et al. (2009) deals with group formation using a Learner Profile (specifically the knowledge on content, personality, attributes and programming styles). The authors in this context are working on the role for an ontology for content, roles, goals and strategies for group formation on problems and tasks (goals/contents) that require certain specific related skills (roles). However, the ontology of the work covered in this profile only lists goals and roles that are needed for the learning activity. This is a seminal work about a larger formal representation of collaborative learning activities which focuses on group formation. The aspects of their work do not take into consideration a specific user model inside a Community of Practice, although the formal specification on the tasks, goals and roles are very close to our ontological activity model.

Dicheva et al. (2005) relates the ontology-based applications, which have to deal with two types of knowledge: subject domain and structure. They use a domain ontology to represent the basic domain concepts and a structure ontology to define the logical structure of the content. Nevertheless, the authors are concerned about the content in online resources (such as papers, workshops, research groups, etc.) in a Web portal with no focus on the description of this portal or on context profiling. Our approach does not only describes the concepts regarding hierarchical classes of meaning, but it also portrays the necessary structure for a Web site for CoP and which types of relationships we must cope with in order to cover all aspects of the CoP interaction activities.

Two semantic web projects, the *Semantically-Interlinked Online Communities* (SIOC) (Bojars and Breslin, 2010) and the Friend of a Friend (FOAF) (Brickley and Miller, 2010) are also used as standards for communities and user representation. The FOAF vocabulary represents people and their social networks through their relationships and information using the web. Certain classes, for instance, are related to personal identification, such as *name* and *organisation*, as well as more technical classes like *Agent* and *Person*. Properties such as *topic-interest* and *knows* are also important to be taken into consideration, due to their important semantic inference and social characteristic. The SIOC project allows the integration of information from the online community providing a Semantic web ontology for representing data from the social web in RDF.[4] The SIOC vocabulary is an open format used for expressing user-generated content in an interoperable way.

Different from the SIOC and FOAF approaches, our proposal does not intend to describe only the site or personal identification, but also aggregate all interaction events and user contents in the CoP profile. It will integrate what we call a 'dynamic profile' as in adding/commenting a post forum, a file, an image, a video, searching for context/person, adding articles, editing profile info or posting blog contents, which will trigger a capture for such posting details into Collaboration Records. This activity will generate more entries into interests, skills or interaction components in the profile that will be linked to the contents in the Collaboration Records. Furthemore, our proposal takes into account these services by Kobsa (2007) in our model.

Both GUMO and UMMO offer no more than a taxonomy of concepts related to the description of the user. In the context that we are working on, it would not be enough to conceptualise the various terms that describe the user. Our ontological profile captures the social structure in which the user is interacting and describes his contextual profile according to the various communities in which he participates. At the same time we describe the social learning environment in which it fits in order to permit contextual inferences of the structural and knowledge level in the community.

6 Conclusions and future works

Current works that rely on semantic web proposals have used ontologies to represent almost any knowledge component in order to model user, domain, adaptation and communication information on the web. The main goal of these works stands for a better reusability and interoperability of the web systems and the standardisation of knowledge. Nevertheless, this interoperability is limited due to the lack of content in the Semantic Web specific educational applications and the lack of structure in the community-authored content of web 2.0 (Sosnovsky and Dicheva, 2010).

In this paper we address some of these issues by presenting an ontological user profile used in the CoPF, as a foundation for the semantic web application, capable of being aggregated on the context of collaborative learning activities.

The CoPF ontology enables a formal annotation of the profile and contents of the CoP and its members through a three-layered structure. Two higher layers are based on foundational ontology structures in order to become reusable when describing most any CoP, as well as the contents of the ontology itself. The lower layer relies on specific domains to CoP that agrees to instantiate other domain ontologies which can be imported into the CoP Framework.

We have presented in particular in this paper a general profile reference ontology to represent CoP along with its members and its related activities. Regarding the interoperability aspects we count on a top-level ontology with FOAF and SIOC vocabularies. For the reusability aspects, while GUMO and UMMO provide ontological user models in a narrow sense or in a very general broad view, our purpose attempts to simplify the ontological representation by keeping it domain independent and extensible through the integration of specific domain ontologies.

As a future work, we need to refine the higher level ontologies to evaluate the concepts and relations and to validate the ontology engineering approach over the reference ontology layer. Nevertheless, the next step in a larger CoPF project is to build agent interfaces in order to provide communication among multiple communities by using a semantic web approach. These agents will consequently gather their knowledge from the proposed ontologies.

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Notes

1 Web Ontology Language (see http://www.w3.org/TR/owl-ref/).

2 http://openid.net/

3 http://protege.stanford.edu/

4 Resource Description Framework (see http://www.w3.org/TR/2004/REC-rdf-mt-20040210/).