Interactive Technology and Smart Education

Enriching adaptation in e-learning systems through a situation-aware ontology network

Ana Marilza Pernas Alicia Diaz Regina Motz José Palazzo Moreira de Oliveira

Enriching adaptation in e-learning systems through a situation-aware ontology network

Ana Marilza Pernas
Centro de Desenvolvimento Tecnológico, Universidade Federal de Pelotas, Pelotas, Brazil and
Instituto de Informática, Universidade Federal do Rio Grande do Sul, Porto Alegre, Brazil

Alicia Diaz
LIFIA, Universidad Nacional de La Plata (UNLP), La Plata, Argentina

Regina Motz
Universidad de La República, Buenos Aires, Argentina, and

José Palazzo Moreira de Oliveira
Instituto de Informática, Universidade Federal do Rio Grande do Sul (UFRGS), Porto Alegre, Brazil

Abstract

Purpose – The broader adoption of the internet along with web-based systems has defined a new way of exchanging information. That advance added by the multiplication of mobile devices has required systems to be even more flexible and personalized. Maybe because of that, the traditional teaching-controlled learning style has given up space to a new way of learning, which is more flexible and adequate to the learners needs. The purpose of this research is to go further into the semantic modeling of adaptive web based learning systems. Particularly, the paper focuses on those learning systems that consider in their definition the awareness of student's context in order to properly react to the student needs.

Design/methodology/approach – In this paper the authors introduce a semantic model of the student context in terms of an ontology network. This semantic model is explored in order to detect the "current situation" of students when they are navigating into e-learning environments. The final objective is to enrich the adaptation functionality of e-learning environments, being able to evaluate context data from personal profile, learning domain and technological situation.

Findings – In order to evaluate the semantic model defined, examples of detected situations are shown in accordance to specific e-learning scenarios.

Originality/value – The paper covers definition of a flexible and modularized model by using ontology networks, which can be easily modified to incorporate new knowledge data, aiding the modeling of concepts from different learning environments.

Keywords Ontology, Context, Situation, Situation-awareness, E-learning systems, Adaptation, Computer based learning

Paper type Conceptual paper

Interactive Technology and Smart Education
Vol. 9 No. 2, 2012
pp. 60-73

1741-5659
DOI 10.1108/17415651211242215

This work has been partially supported by Conselho Nacional de Desenvolvimento Científico e Tecnológico – CNPq, Brazil, and by Coordenação de Aperfeiçoamento de Pessoal de Nível Superior, CAPES, Brazil. This work was also funded by: the PAE 37279-PICT0 2203 which is sponsored by the ANPCyT, Argentina.

1. Introduction

The broad adoption of internet and the multiplication of mobile devices have increasing the exigency of the adaptation functionality in web-based learning systems, aiming at becoming more attractive and aware of the students' needs. Researches on the field of computer-assisted learning focus on the development of mobile, adaptive and personalized learning environments (Nino *et al.*, 2007; Ogata and Yano, 2004).

Adaptation is a key feature for improving education support on the web, being the personalization one of the most significant promises for distance learning. Adaptation and context awareness are applied in different kinds of applications, being e-learning applications an example of such initiatives (Yu *et al.*, 2007; Tetchueng *et al.*, 2007). Context awareness does not necessarily imply adaptation, but an adaptive system, in general, needs to be aware of the user context for properly reacting to. Additionally to a variety of systems that propose a context awareness character, in this work we extend the capabilities of web-based adaptive learning systems by means of the detection of learner's context and its underlying situations.

The context in this work is defined by all data that influence and are influenced by the user. Therefore, a contextual data could be a computational device, a location (room, building or laboratory), an objective or an available learning object, i.e. a raw data. On the other hand, a situation can be defined as an interpretation of a set of contextual data, relating each one of them in order to provide some information that is valid in a specific time interval. For example, a learning situation could be a student developing a learning task using a notebook at home. This situation is only valid in the precise moment when it occurs, with specific instances of contextual data.

Consequently, our hypothesis is that the analysis of the situation lived by the student when she is using the e-learning environment is useful to improve the learning process. The environment should automatically recognize the student situation and then suggest actions to be followed. These actions should be adapted according to the leaner needs.

To accomplish this hypothesis, the learning system has to identify and combine information coming from different sources in order to determine the student context. In order to achieve this, we developed a semantic model of contextual data to get a better notion of the student context. The semantic model has to take into account: where the student is; what computational device is she using; what is she doing; the student educational path; her educational goals; in which topics she has knowledge; among other topics. If these context data was analyzed in a given period of time, it is possible to discover the student's situation.

In our prototype, this model is developed through the context ontology network, which model the context by means of contextualizing the student device, location, profile and learning domain. In applying ontology networks, a number of well-known ontologies are related to new domain ontologies, aiming at developing a more flexible and expressive system. One of the advantages provided by the network is the better understanding of the relations among the participating ontologies, their concepts and properties. But also the ontological approach is useful to have better mechanism for deducing the student situation.

Still in the developed context ontology network, we define concepts which are responsible to reason upon the student situation, organized into the situation ontology.

In our vision, knowing the student situation, it is possible to suggest actions more adapted to her actual necessities and the development of the current task.

The remainder of this work is organized as follows. The next section presents a background on ontology networks and situation-awareness. In the Section 3 we show our conceptual model, defining the context ontology network. The Section 4 shows our mechanism, based on rules, to infer over student contextual data. Some related works on the topics of context and context-aware systems are presented in Section 5. We finalize the paper in Section 6 with our conclusions and future works.

2. Background

In this section we introduce important concepts related to the main areas covered by this paper: ontology networks and situation-awareness.

2.1 Ontology networks

According to d'Aquin *et al.* (2006), ontologies on the web cannot be treated as standalone artifacts, because they are related to each other in ways that might affect their meaning and are inherently distributed in a network of interlinked semantic resources. Thus, the authors define an ontology network as a collection of ontologies related together via a variety of relationships. An ontology network differs from a set of interconnected single ontologies, due to the fact that in it the meta-relationships among the different ontologies involved are explicitly expressed (Suarez-Figueroa *et al.*, 2009). Some of these relationships are:

- "Dependencies and imports" are the simplest kind of relationship and occurs when in order to define its own model, an ontology requires to refer the definitions included in another ontology.
- "Versioning" relates to the activity of keeping track of the different versions of an ontology.
- "Alignment" refers to put different models in correspondence by declaring which of their entities should be considered as being the same, or as being more general than the others.
- "Modularization" an ontology is the modularization of another when it is a division in the whole ontological model, being self-contained and maintaining its interlinked components, which can be considered independently but that participate each in a specific aspect or sub-domain of the ontology.

Allocca *et al.* (2009) formalize ontology network relationships in the descriptive ontology of ontology relations (DOOR) ontology. DOOR models the main abstract *ontologyRelatedTo* relationship which is then specialized in more specific relationships: *includedIn*, *similarTo*, *isAlignedTo*, *disagreesWith*, *agreesWith* and *isTheShemaFor*. Díaz *et al.* (2011) identifies a new relation among ontologies, named *usesSymbolsOf*, which happens when the properties from an ontology involves individuals from another ontology.

Currently, ontology networks are seen as a new ontology engineering concept, which is being increasingly applied, instead of custom-building new ontologies from scratch. Distributed and collaborative methodologies of ontology design, such as DILIGENT (Vrandecic *et al.*, 2005) and the NeOn project approach

(Suarez-Figueroa *et al.*, 2009), allows the design of local models based on a core model which integrates the local ones.

Intuitively, defining an ontology network is to select a set of networked ontologies, by identifying the different kinds of relationships between the networked ontologies. However, create a knowledge model through an ontology network implies to define metadata information about the networked ontologies. Ontology metadata refers to the information which is attached to the ontology itself, not to its content and is critical in ontology networks. This ontology metadata would cover ontologies provenance, purpose and the relations with other ontologies and semantic resources (Rohrer *et al.*, 2011).

2.2 Concepts on situation-awareness

In a situation aware environment, a situation is defined as a set of contextual characteristics that are invariable in a defined time interval (Weißenberg *et al.*, 2006). It corresponds to the set of semantic relationships that are valid for a given instant or that are stable on a time interval.

According to O'Brien (2009), some key information must be included in situation definition:

- the events that can participate in situation detection;
- whether and under what conditions an event is consumed;
- context during which the situation detection is relevant; and
- the semantic conditions that must be satisfied in order to detect a situation.

An event in situation-aware systems consists on occurrences in the environment, resulted from a direct user action or not, which will determine the system's reaction. Different types of events can be defined and, depending on the event, a new situation can be started. In e-learning environments, an event could be: the change of a learning object being used; the selection of some topic; the change of network speed or sending some work to be evaluated. Each one of these events has to be constantly monitored in order to be aware of the student's actions and develop adaptations.

The conditions to raise an event are dependent on the system. In this work, the conditions could be simple actions, like the login in the e-learning system, or compound actions, like the fact that the student has opened a learning object, given a previous act of had started an activity.

Context may be referred to as "any information that can be used to characterize the situation of an entity where an *entity* can be a person, a place, a physical or computational object" (Schilit *et al.*, 1994). In the model described in this work, the relevant context in a situation in expressed by specific values instantiated in the context ontology, identified by the semantic rules. In the Section 3 the contextual entities are showed in distinct ontologies.

The semantic conditions could be understood as the rules that form a situation or, more simply, all axioms and restrictions existent in the knowledge model. After, in Section 4, we describe some rules to calculate the semantic conditions that define a situation.

3. Ontology network for e-learning systems

In this section, we describe the definition of a context ontology network that is underlying in an e-learning system that supports an adaptive strategy based on the automatic detection of the student's situation. This ontology network covers the different domains to be considered to conceptualize the context data:

- the student domain, with information related to the student's profile and his/her preferences and behavior in using the e-learning environment;
- the learning domain, which describes the learning objects and the educational resources available to the students; and
- the technological domain, with information related to the available devices and places (resources) that surround the student.

As we identify these three different domains as relevant context data to be conceptualized, our proposal was to develop each one in a separate ontology network, combining them in a network of ontology networks, called context ontology network. The context ontology network was defined by the meta-relationship among the cited ontology networks, as shown in Figure 1. Each one of these ontology networks has they own internal structure, do not interfering in the others except by the inter-domains relations (shown in Figure 1 by the continuous line). The dependence (relationship dependsOn) among the student ontology and the device, location, content knowledge and instructional design occurs because the student is contextualized in the space according to the activity being developed, the learning object being accessed, the computational device being used and the current location. The next subsections describe separately each ontology network.

3.1 Learning ontology network

The Learning ontology network has the objective of structuring the learning content and all concepts related with courses and disciplines. In its content, the network represents the taxonomy of terms, to which the learning objects are related. Besides, the network needs to represent the instructional design defined by the tutor to be followed in a discipline.

The Learning ontology network is formed by the following ontologies:

- *LOM-lifecycle* (IEEE Learning Technology Standards Comitee, 2002). Intends to conceptualize contextual metadata related to the history and current state of learning objects, having concepts like: status, version, contributor and creator.

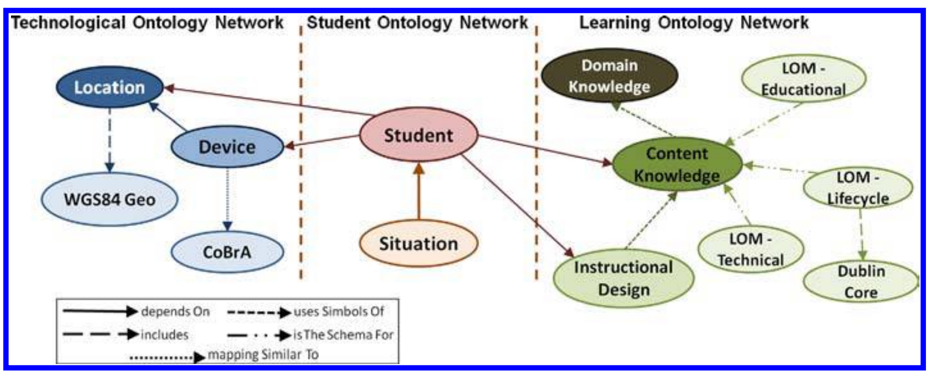

Figure 1.
The context ontology network

- *LOM-technical* (IEEE Learning Technology Standards Comitee, 2002). Identify technical requirements to install and correctly reproduce (access) learning objects.
- *LOM-Educational* (IEEE Learning Technology Standards Comitee, 2002). Conceptualize the learning objects, identifying types, interaction type, level of difficulty and type of intended users.
- *dc-elements* (DCMI, 2010). Dublin Core metadata set of elements.
- *Content knowledge* (Muñoz *et al.*, 2004). Structure learning objects, courses and disciplines.
- *Domain knowledge* (Muñoz *et al.*, 2004). Consists on a taxonomy of knowledge terms.

The intra-domain relationships, presented in Section 2.1, that form the learning ontology network are: *includes*, *useSimbolsOf* and *isTheSchemaFor*. As we can see in Figure 1, the LOM-lifecycle ontology includes concepts from the Dublin Core ontology, like creator and publisher.

The relationship *usesSimbolsOf* is identified in Figure 1 between the ontologies content knowledge and domain knowledge, because the content knowledge ontology defines properties that determine the domain area covered by a learning object, which take values from individuals of domain ontology. Still in Figure 1, the relationship *isTheSchemaFor* happens among the content knowledge ontology and the LOM-technical, LOM-educational and LOM-lifecycle ontologies because the LOMs ontologies serve as the metamodel for the development of the content knowledge ontology.

About the concepts and relationships of the ontologies contained in the learning network, they are shown in details in Figure 2. In Figure 2, a "Topic" is related itself to determine the student learning path (topics already studied) and pre-requisites, as defined by Muñoz *et al.* (2004). Indeed, a "Course" customizes a "Discipline" to a specific public of learners (instances of "Student"). Every "Learning Object" is related with some term present in the "Taxonomy", having one or many "Keywords" and being created by one or many "Contributors". The "Instructional Project" is responsible for structuring a "Discipline", defining a set of "Activities", each one with its learning "Objective", to be developed by the students.

In Figure 2 and in the following figures, the letters "d" and "r" represents, respectively, the domain and range of values in the relationship.

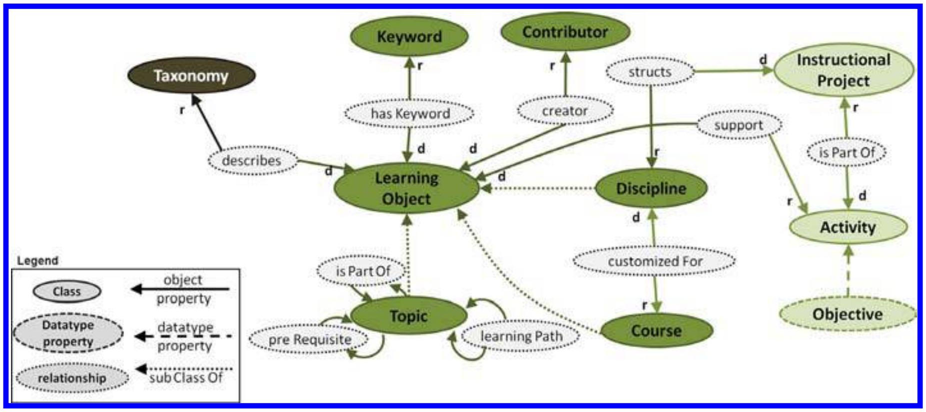

Figure 2.
The learning ontology network

3.2 Technological ontology network

The technological ontology network is responsible for managing technological and location data. It is made up of the following ontologies:

- *WGS84 geo positioning* (W3C Semantic Web Interest Group, 2009). Consists of a vocabulary for representing latitude, longitude and altitude information.
- *CoBrA* (Chen, 2003). Full ontology to support context-aware systems in smart spaces.
- *Device*. Contains information about the student's current device.
- *Location*. This ontology represents the places (e.g. at home, at library) where the student can be located and, for each local, its geographical localization.

The technological ontology network is formed by the intra-relationships *includes* and *mappingSimilarTo*. In Figure 1, the location ontology includes the WGS84 ontology structure because the WGS84 ontology defines all concepts and relations needed to define the geo localization of some point. According to Díaz *et al.* (2011), the relationship *mappingSimilarTo* occurs if there exists an alignment from one ontology "O" to another ontology "O′" and this alignment covers part of the vocabulary of "O". This relationship occurs between the Device and CoBrA ontologies because a set of concepts from the Device ontology (e.g. mobile, display screen, among others showed in the Figure 3) is aligned with the device module of CoBrA ontology.

We opt to represent location data with the technological network because the information related with the geospatial point where the student is located is sensed through the network connection. Thus, we classify also as technological information.

Figure 3 shows the concepts and relationships presented in the technological network. It consists of two simple ontologies because they are based strictly on context data that can be sensed by the student connection without installing any piece of software in the client size. The locations (home, university, libraries) are defined as "Points", having data type properties related to latitude and longitude. Besides, each "Device" has a corresponding "Display Screen" and is classified as "Fixed" or "Mobile", having a "Low" or "High" "Network Connection".

3.3 Student ontology

The student ontology conceptualizes preferences (cognitive learning style and navigation type), learning trajectory, competences and goals of the learner (Muñoz *et al.*, 2004). The "Cognitive Learning Style" is defined based on the four dimensions of

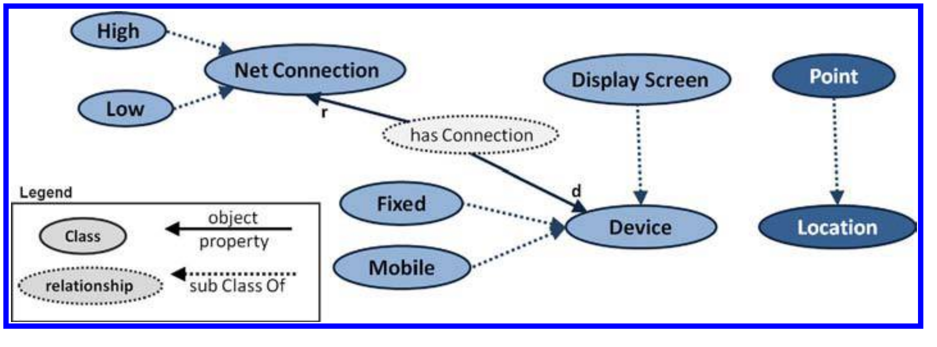

Figure 3.
The physical ontology network

cognitive learning style identified by Felder and Brent (2005), which are: perception (sensorial/intuitive); input (visual/auditory); processing (active/reflective); understanding (sequential/global). The "Navigation type" specifies how the learner prefers to navigate in the learning content: or following a pre-defined order; or freely navigating in the complete hierarchy of contents. The concepts and relationships of the student ontology are shown in Figure 4.

3.4 Situation ontology

After structuring the context data related with the three relevant domains (student, learning and technological), it is important to apply some mechanism to situation evaluation. Thus, our proposal is to use the situation ontology, responsible to reasoning about the student's current situation.

To define the situation ontology we tried to extend other situation ontologies. Among the ontologies researched the most appropriate was the ontology proposed by Baumgartner *et al.* (2010). However, it was difficult to represent e-learning situations just extending this ontology because that assigns situation to things (objects), having attributes and relations not applied to a real person. Thus, to better represent situations in e-learning environments it will be necessary to create new concepts and change others.

The situation ontology defined in this work is shown in Figure 5. An "Action" of the student is responsible to generate an "Event", which could be classified as an "Internal" or "External" event, depending if it was generated directly by an external action

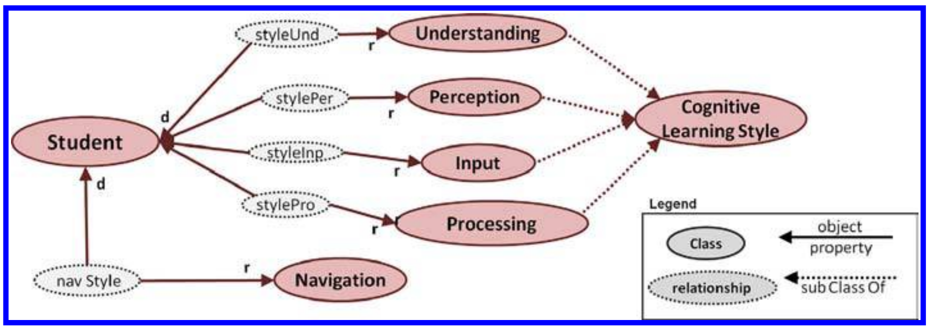

Figure 4.
The student ontology

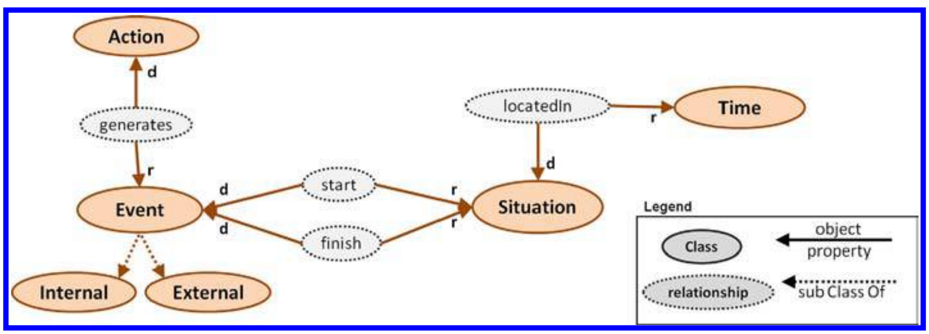

Figure 5.
The situation ontology

(the changing of type of learning object being accessed) or some internal rule was analyzed (the changing has occurring in learning objects of same activity). Each "Situation" is started or finished by an "Event". In general, the same action that generates the start event will finish the earlier situation. All "Situations" have to be located in "Time", which represents the period of time in which the situation was valid (with a specific set of context data values).

Finally, Figure 6 shows the complete context ontology network.

3.5 Network of ontology networks

The concepts of the context ontology network are shown in a simplified way in Figure 6 (to a better visualization, we omit some concepts and the relationships already presented in the previous figures).

The student network represents the learning trajectory and competences through the relationship between the learner and the learning domain. It can be seen in Figure 6 by the inter-domains relation *hasKnowledge*. About the learner goal, by default the main goal consists in finishing a course. So, the inter-domains relation *finalGoal* has to be defined between the concepts "Student" and "Course". When accessing the e-learning environment, the student *isUsing* some computational device and is always located in some point of the space. In the course of time, the student can be doing different activities in the e-learning environment, executing a number of actions in navigating on the learning content. According to these actions, different situations can be configured in the e-learning environment.

As presented in Section 3.1, the LOM-technical ontology identifies technical requirements related with the installation and reproduction of learning objects. The knowledge of these requirements is important when adapting the learning content according to the student's available resources. For example, if the learning object requires a minimum of display resolution and the student is using a Smartphone with

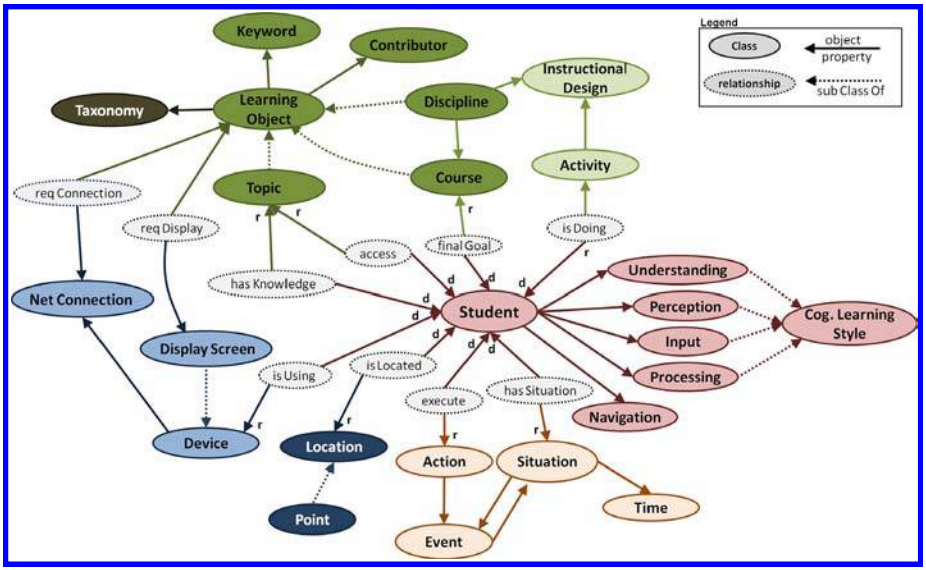

Figure 6.
Relationships among concepts from student, learning and technological ontology networks

low resolution, possibly is better to recommend another learning object that could be appropriately presented in the device used by the student. Thus, as shown in Figure 6, the learning objects can require a specific network connection speed and/or display resolution to be appropriately presented.

The defined context ontology network was encoded using the web ontology language (OWL) (Bechhofer *et al.*, 2004), sublanguage OWL-DL, through the software Protégé (http://protege.stanford.edu/). The relationships inter-networks were defined with OWL-DL resources *owl:subclass* and *owl:import*.

4. Reasoning over situations

The reasoning over student's situations is made by exploring the relationships and individuals instantiated in the context ontology network. However, the formalism that underlies OWL is not sufficiently expressive to permit reasoning over ontology individuals, which is necessary to situation detection. Thus, we choose to define the inference rules in semantic web rule language (SWRL), which allow instance reasoning. SWRL consists on horn-like rules in the form of an implication between an antecedent (body) and consequent (head), and its meaning specifies that whenever the conditions specified in the antecedent holds, then the conditions of consequent must also hold (Horrocks *et al.*, 2005).

The rules are defined inside the context ontology language and reason over the current values of instances existent in the network. The valid values defined in the relationships will make the difference between a situation *S01* or *S02*. For example, if we want to state that "A student is using a notebook", "She is at home", "She is reading an example in the topic of Computer Graphics" we need to access instance data related to the student device, geographical localization and the learning object being used now:

Rule S_01: Student(?x) ∧ isDoing(?x, Study) ∧ access(?x, ?y) ∧ p7:isPartOf(?y, Computer_Graphics_1) ∧ isLocated(?x, p5:Home_1) ∧ isUsing(?x, ?z) ∧ p3:MobileDevice(?z) → hasSituation(?x, S_01)

It is possible to explore a broad notion of context in defining the rules, using more relationships of the context ontology or creating new ones, depending on the kind of situation that needs to be detected. For example, if we have a learning scenario like:

> Anne is following a regular Computer Science course. It is 13h PM and she is connected to the environment through a tablet device in transit, going to the university by train, before her Data Base Systems class programmed to 14h PM. So, she is solving an exercise given by her teacher.

This scenario can be detected by the following situation rule:

Rule S_02: Student(?x) ∧ styleInp(?x, Visual) ∧ styleUnd(?x, Sequential) ∧ isDoing(?x, Exercise) ∧ access(?x, ?y) ∧ p7:isPartOf(?y, Data_Base) ∧ hasLocation(?x, Train) ∧ isUsing(?x, ?z) ∧ p3:MobileDevice(?z) ∧ p3:hasNetConnection(?z, p3:Bad) → hasSituation(?x, S_02)

The first situation detected is important to fix the actual attributes of the student and "understand" the changing context. The system will continue to store and analyze the student's actions, trying to detect the occurrence of events that will define a new situation.

Thinking on the assumption that Anne tries several times to hit the response of this exercise, but she cannot find the correct answer. The system can evaluate

Anne's action and deduce that "she is not achieving good results in her activity". Thus, each situation detected has to take into account the previous situation and the events detected. A following situation detected could be defined by the rule:

Rule S_03: Student(?x) ∧ previousSituation(?x, S_02) ∧ isDoing(?x, Exercise_01) ∧ DoingBad(?x,Exercise_01) → hasSituation(?x, S_03)

After detecting that Anne is having some problem with the exercise, the system can recommend adaptive actions to be followed by her. For example, by analyzing Anne's profile the system will discover that her cognitive learning style is visual. So, the system can recommend her to access some learning object that shows graphics and diagrams that could help her with this activity.

5. Related works

Context may be explored in several ways in order to discover situations. Barwise and Perry (1983) propose a situation theory to formally describe real situations. Closer to computer science, McCarthy (1993) propose to apply situation calculus to describe situations as formal objects. Another example are the conceptual spaces, explored by Padovitz *et al.* (2004). In this last work, ontologies are proposed due to their efficiency already observed in representing context (Strang and Linnhoff-Popien, 2004; Bettini *et al.*, 2010).

Ontological representations of situations were presented in works like O'Brien (2009) and Baumgartner *et al.* (2010). The situation ontology of O'Brien (2009) was made to support situation-awareness for highly mobile people (HMP), where the aspect of location is very important. Thus, many of the concepts in the situation ontology were created to detail location aspects. On the other hand, the situation ontology of Baumgartner *et al.* (2010) was proposed to be extensible to different applications. This ontology is applied to situations in road traffic, presenting complex spatio-temporal relations to represent locations and time. Unfortunately, it was difficult to apply this ontology to the educational domain without modifications, since we model real persons with specific profiles and relations with the environment. In order to represent learning situations, we take some concepts from Baumgartner *et al.* (2010) ontology and define new ones.

Another related work that explores context in e-learning environments is presented in Tetchueng *et al.* (2007). The authors propose to model adaptive and context-aware learning scenarios. Thus, they built several scenarios based on a common learning scenario, and then transform these scenarios into a computer based hierarchical task model. Different from our work, the main challenge is not the automatic detection of the student's situation, but the pre-designing of generic scenarios to deal with learning situations for problem-based learning.

The research presented in Zhan *et al.* (2007) proposes an ontology to represent the situations experienced by students while using educational software. However, the objective is to deduce different emotions felt by students while crossing different situations in the learning environment. In our work, the emotions of the students are not evaluated but aspects related to learning resources, computational devices and locations are evaluated to detect the right resource in the right situation.

6. Conclusion

This paper enriches the possibilities of adaptation in e-learning environments, taking into account the learner's context and situation. As the main contribution, we developed a model to represent the knowledge implicit in a learning situation, which is related with the students, learning and technological domains. This model was developed according to the methodology defined by ontology networks, consisting on a network of ontology networks. By using ontology networks we looked for a flexible and modularized way to represent a learning context. In this research we also present a mechanism of rules to reason over the student's context data.

After developing the network and inferring the situations, we conclude that this structure can be easily modified to incorporate new knowledge data, allowing to model concepts from different learning environments. Our final objective is to suggest adaptive actions regarding the student's current learning situation. At present, we are working on this final objective, implementing the context ontology network and testing the situation detection over a real e-learning environment.

References

Allocca, C., d'Aquin, M. and Motta, E. (2009), "Door – towards a formalization of ontology relations", *International Conference on Knowledge Engineering and Ontology Development*, INSTICC Press, Setúbal, pp. 13-20.

Barwise, J. and Perry, J. (1983), *Situations and Attitudes*, MIT Press, Cambridge, MA.

Baumgartner, N., Gottesheim, W., Mitsch, S., Retschitzegger, W. and Schwinger, W. (2010), "BeAware! Situation awareness, the ontology-driven way", *Data & Knowledge Engineering*, Vol. 69, pp. 1181-93.

Bechhofer, S., van Harmelen, F., Hendler, J., Horrocks, I., McGuinness, D., Patel-Schneider, P.F. and Stein, L. (2004), "OWL web ontology language reference", W3C Recommendation, available at: www.w3.org/TR/owl-ref/

Bettini, C., Brdiczka, O., Henricksen, K., Indulska, J., Nicklas, D., Ranganathan, A. and Riboni, D. (2010), "A survey of context modeling and reasoning techniques", *Pervasive Mobile Computing*, Vol. 6 No. 2, pp. 161-80.

Chen, H. (2003), "CoBrA device ontology", V. 4, available at: http://cobra.umbc.edu/ontologies-2003-11.html

d'Aquin, M., Gangemi, A. and Haase, P. (2006), "Definition of ontology networks", *NeOn Book – NeOn Methodology in a Nutshell*, Chapter 2, available at: www.neon-project.org/nw/NeOn_Book

DCMI (2010), "Dublin Core metadata element set", Dublin Core Metadata Initiative, version 1.1, available at: http://dublincore.org/documents/dces/

Díaz, A., Motz, R. and Rohrer, E. (2011), "Making ontology relationships explicit in a ontology network", paper presented at V Alberto Mendelzon International Workshop on Foundations of Data Management (AWM 2011), Santiago, Chile.

Felder, R.M. and Brent, R. (2005), "Understanding student differences", *Journal of Engineering Education*, Vol. 94 No. 1, pp. 57-72.

Horrocks, I., Patel-Schneider, P.F., Bechhofer, S. and Tsarkov, D. (2005), "OWL rules: a proposal and prototype implementation", *Journal of Web Semantics*, Vol. 3, pp. 23-40.

IEEE Learning Technology Standards Comitee (2002), "Draft standard for learning object metadata", IEEE 1484.12.1-2002, available at http://ltsc.ieee.org/wg12/files/LOM_1484_12_1_v1_Final_Draft.pdf

McCarthy, J. (1993), "Notes on formalizing context", *13th International Joint Conference on Artificial Intelligence* (*IJCAI'93*)*, Chambery, France*, pp. 555-60.

Muñoz, L.S., Palazzo, M. and de Oliveira, J. (2004), "Adaptive web-based courseware development using metadata standards and ontologies", *International Conference on Advanced Information Systems Engineering* (*CAiSE*)*, Riga*, pp. 414-28.

Nino, C.P., Marques, J., Barbosa, D.N.F., Geyer, C.F.R., Barbosa, J.L.V. and Augustin, I. (2007), "Context-aware model in a ubiquitous learning environment", *5th IEEE International Conference on Pervasive Computing and Communications Workshops* (*PERCOMW'07*), pp. 182-6.

O'Brien, P. (2009), "An ontology for mobile situation aware systems", *Australasian Journal of Information Systems*, Vol. 15 No. 2, pp. 45-72.

Ogata, H. and Yano, Y. (2004), "Knowledge awareness map for computer-supported ubiquitous language-learning", *2nd IEEE International Workshop on Wireless and Mobile Technologies in Education* (*Wmte'04*), p. 19.

Padovitz, A., Loke, S.W. and Zaslavsky, A. (2004), "Towards a theory of context spaces", *2nd IEEE Conference on Pervasive Computing and Communications Workshop* (*PERCOMW'04*), pp. 38-42.

Rohrer, E., Motz, R. and Diaz, A. (2011), "Web site recommendation modeling assisted by ontologies networks", *Cadernos de Informática*, Vol. 5 No. 1, pp. 49-68.

Schilit, B., Adams, N. and Want, R. (1994), "Context-aware computing applications", *Proceedings of the Workshop on Mobile Computing Systems and Applications, Santa Cruz, CA*, pp. 85-90.

Strang, T. and Linnhoff-Popien, C. (2004), "A context modeling survey", paper presented at Workshop on Advanced Context Modeling, Reasoning and Management 6th International Conference on Ubiquitous Computing (UBICOMP), Nottingham, England.

Suarez-Figueroa, M., Gómez-Pérez, A., Poveda, M., Ramos, J.A., Euzenat, J. and Le Duc, C. (2009), "Neon deliverable d5.4.2. Revision and extension of the NeOn methodology for building contextualized ontology networks", Technical Report, NeOn Project.

Tetchueng, J.L., Garlatti, S. and Laube, S. (2007), "A didactic-based model of scenarios for designing an adaptive and context-aware learning system", *IEEE/WIC/ACM International Conference on Web Intelligence*, IEEE Computer Society, Los Alamitos, CA, pp. 723-6.

Vrandecic, D., Pinto, S., Sure, Y. and Tempich, C. (2005), "The DILIGENT knowledge processes", *Journal of Knowledge Management*, Vol. 9 No. 5, pp. 85-96.

Weißenberg, N., Gartmann, R. and Voisard, A. (2006), "An ontology-based approach to personalized situation-aware mobile service supply", *Journal of GeoInformatics*, Vol. 10, pp. 55-90.

W3C Semantic Web Interest Group (2009), "WGS84 geo positioning: an RDF vocabulary", available at: www.w3.org/2003/01/geo/wgs84_pos

Yu, Z., Nakamura, Y., Jang, S., Kajita, S. and Mase, K. (2007), "Ontology-based semantic recommendation for context-aware e-learning", *Ubiquitous Intelligence and Computing*, Lecture Notes in Computer Science, Springer, New York, NY, pp. 898-907.

Zhan, Y., Xu, L. and Mao, Q. (2007), "Ontology based situation analysis and encouragement in e-learning system", *Technologies for E-learning and Digital Entertainment, Hong Kong, China*, pp. 401-10.

About the authors

Ana Marilza Pernas is Assistant Professor of Computer Science at the Federal University of Pelotas (UFPel), and a PhD Student at Federal University of Rio Grande do Sul (UFRGS), with a doctoral stage in Telecom et Management Sud – Paris. She graduated in Computer Science in 2003 and obtained an MSc degree in Computer Science at the Federal University of Santa Catarina (UFSC) in 2004. Her research interests are conceptual modeling, semantic web, ontologies and information systems. Ana Marilza Pernas is the corresponding author and can be contacted at: ana.pernas@inf.ufrgs.br

Alicia Diaz has been a Professor at La Plata Nacional University (UNLP) since 1992 and has also been working for LIFIA since 1988. Nowadays, she is a member of its Board of Directors. She graduated as Licentiate in Computer Science in 1992 and obtained a PhD in Computer Science at Université Henry Poincaré-Nancy I (France) in 2005. She is the author of more than 50 research articles mainly in the area of hypermedia, object-oriented programming, data bases and knowledge management. At the moment, she is leading a research group which is working in the field of computer-supported cooperative work (CSCW) and semantic web.

Regina Motz holds a PhD in Computer Science from the Technische Universität Darmstadt, Germany (2004) and a Master's in Computer Science from Universidade Federal de Pernambuco, Brazil (1990). She obtained her degree on Computing Engineer Systems at the University of the Republic Uruguay (1988). She currently serves as Full Professor at Institute of Computing Faculty of Engineering of the University of the Republic, Uruguay.

José Palazzo Moreira de Oliveira is Full Professor of Computer Science at Federal University of Rio Grande do Sul – UFRGS. He has a Doctorate degree in Computer Science from Institut National Politechnique – IMAG (1984), Grenoble, France, an MSc degree in Computer Science from PPGC-UFRGS (1976) and has graduated in Electronic Engineering (1968). His research interests include information systems, e-learning, database systems and applications, conceptual modeling and ontologies, applications of database technology and distributed systems. He has published about 160 papers and has been the advisor of 11 PhD and 51 MSc students.