An OWL-Based Ontology to Represent Interactions of Students in Educational Virtual Worlds

Tito Armando Rossi Filho
Programa de Pós-graduação em Informática na Educação,
Universidade Federal do Rio Grande do Sul (UFRGS)
Porto Alegre, Brazil

Aliane Loureiro Krassmann
Programa de Pós-graduação em Informática na Educação,
Universidade Federal do Rio Grande do Sul (UFRGS)
Porto Alegre, Brazil

Liane Margarida Rockenbach Tarouco
Programa de Pós-graduação em Informática na Educação,
Universidade Federal do Rio Grande do Sul (UFRGS)
Porto Alegre, Brazil

Patrícia Alejandra Behar
Programa de Pós-graduação em Informática na Educação,
Universidade Federal do Rio Grande do Sul (UFRGS)
Porto Alegre, Brazil

Abstract

While several studies in the last decade explore the potential benefits of virtual worlds in education settings, less attention has been given to the research of solutions to help overcome implementation barriers. One of the existing areas of concern is related to the difficulties on the exploitation of data obtained from educational virtual worlds. This paper proposes an OWL-based ontology to address a solution to the problem of inconsistency of databases that record information about student interactions with learning objects within these environments. The steps that have been followed for the development of the ontology are described, guided by Stanford's 101 model. To discuss the feasibility and exemplify the ontology, an instance of an existing virtual world interaction is presented. The conclusion is that the proposed ontology can be helpful to researchers and development groups as it delivers a reusable model to gather data in a uniform way.

Keywords: virtual worlds; ontologies; student interactions

1. Introduction

The adoption of three-dimensional Virtual Worlds (VW) is being considered an educational trend, as they provide new opportunities and challenges for technology-enhanced learning, enabling interactive knowledge construction while motivating and engaging students. They are immersive in three dimensions (3D) and can be multi-user, thereby supporting collaboration, group activities and the development of novel and interesting simulations, animations and visualizations (Allison et al., 2010). Soto and Allongue (1997) states that VW allows users located in different geographical areas to perform complex tasks jointly.

In addition, VW allows contact with learning activities based on situations that mirror the real context in which school knowledge should be employed (Tibola et al., 2014) and the integration of Learning Objects (LO). Wiley (2003) highlights that LO amplifies the access to information and increases the possibilities of learning, besides being well accepted in scholar environments due to the fact that they provide a pleasant learning experience.

Despite the numerous advantages, and although some experts predicted the effective adoption of VW (Yoon & George, 2013; Gregory et al., 2015), the frequency of use of these systems for teaching and knowledge sharing is still limited. Muñoz-Cristobal et al. (2015), argue these limitations are due, among other reasons, the absence of authoring tools for teachers and the non-possibility of VW's learning object reuse on other platforms. Beyond that, there is also usually the lack of a common structure for databases that receive information about user's interactions with LO in the environment. This creates a problem of inconsistency, e.g. data captured in the same VW by different researchers from a same population of students, besides disabling the reuse of database models.

As the data about students' interactions can be very useful for teachers and researchers, allowing them to understand their behavior and improve the VW, a solution to overcome this problem is strongly desirable. One of the possibilities is called data integration, what can be defined as the combination of data from different sources. However, if the terminologies used are not the same, this can lead to inconsistency and does not solve the problem of reusability. Bernstein and Haas (2008) emphasize data integration as being frequently the most expensive and bigger challenge in Information Technology (IT).

Ontologies appear as a solution for problems related to terminology, e.g. someone can use the term "zip code" while somebody else uses "postal code" (De Troyer et al., 2003), and can describe possible concepts and relationships between these terminologies, as in the case of Domain Ontologies (Bille et al., 2004). With ontologies, a system is specified at a conceptual level and no longer at the implementation level (De Troyer et. al, 2003). Gali et al. (2004) assert that ontologies are important to apply at integration solutions because they provide a shared and common understanding of data that exist within a problem domain.

Therefore, standardizing VW interaction terminologies using a Domain Ontology would enable the gathering and integrating a larger amount of data with the same nomenclature, perhaps with the same database structure, facilitating data consistency and reusability, with the flexibility that is inherent to ontologies. Furthermore, data mining techniques and the so-called Big Data are increasingly being researched at educational systems and could be reinforced by this perspective, allowing to analyze more data at the same time with less effort.

Based on these assumptions, this study addresses the proposal of an OWL-based Domain Ontology aimed at creating a reference model of interactions with LO commonly used at educational Virtual Worlds. The goal is to create a reusable model that teachers and developers could take into consideration while designing these environments and planning interaction strategies, to avoid inconsistency problems and with this having more time to focus on other issues, as the quality of resources.

The article is structured as follows: section 2 brings the theoretical background and related works, at section 3 the methodology is presented, and section 4 presents the ontology proposal. Finally, at section 5 the obtained results are discussed, and at section 6 the conclusions are presented.

2. Theoretical Background and Related Works

A Virtual Reality (VR) system places the participants in an immersive 3D world. According to Slater and Sanchez-Vive (2016), a minimal VR system can be delivered by a computer and a display, and at very last, with the participant head being tracked by a Head Mounted Display (HMD) device, so that image and audio depending on head-position and orientation. The definition of Virtual World (VW) adopted in this research is related to VR: a computer-based simulated 3D environment where users occupy and interact with them by using avatars (Rico et al., 2011).

One of the most promising application fields for VW is education (González et al., 2013). According to Freitas et al. (2010), these systems allow more complex interactions and encourage learner empowerment through an increased level of interactivity. Reisoglu et al. (2017) highlight its ability to render impossible, costly, and even dangerous real-life events in a safe and cost-effective manner.

An illustrative example of educational VW can be seen in Figure 1, which is a genetics laboratory developed at the University of Leicester (UK), using Second Life platform. In this application, initially, an embodied pedagogic agent shows the students avatars around the laboratory, describing the pieces of equipment as well as specific health and safety issues (Rudman et al., 2010).

Figure 1. Genetics Virtual Laboratory. Source: Rudman et al. (2010)

However, VW implementation requires a technical effort that is not always available in educational institutions. In order to facilitate this work, the reusability could be explored, but the lack of common structures and terminologies of VW databases hinder this process, besides creating a problem of integrity and inconsistency. It also prevents the application of IT techniques as data mining, which requires a great amount of consistent data.

In this sense, Soto and Allongue (1997) stress that the use of ontology appears to be suitable in order to provide a necessary minimum set of common symbols and concepts for VW design. Thompson (2011) asserts that with ontologies the development and implementation of VW tend to become quick and easy, so the teacher can focus on other aspects of the quality and the meaning of the VW. Bille et al. (2004) highlight other advantages, as better fitting the requirements of end-user, the development process can be shortened, and the communication among VR-specialist, the domain expert, and the end-user experience can be improved. In addition, the maintenance will become easier as modification can be made at the conceptual level (De Troyer et al., 2003).

The Domain Ontology, in the context of VW development, is the ontology describing the VW that someone wants to generate (Thompson, 2011). According to Messoud et al. (2015) ontologies are a trend to model semantic information of virtual environments, as they define a common vocabulary for domain-users (researchers or experts in a particular area) who need to share information in a particular domain. It includes interpretable machine definitions of basic concepts and relations among them. Qin and Hernández (2004) suggest that coupled with new IT; such representation allows direct conversion into implementation models.

Some researchers have already investigated the use of ontologies within Virtual Worlds context. Bille et al. (2004) presented a system called VR-Wise to automatically derive VW environments by generating VRML (Virtual Reality Markup Language) code from conceptual specifications, in a way that a domain expert can design a VR application without having to know how to build VR primitives. Trescak et al. (2010) proposed a system to automatically generate a 3D VW from multi-agent system specification, that is, from a formal description of activities taking place in the system modeled by an organization. The framework named Virtual World Builder Toolkit (VWBT) generates the VW layout and situates 3D objects there.

Eguchi and Thompson (2011) created a way to align VW with the semantic web, extending this concept towards a “semantic world,” defining URLs anchors inside the VW which can be shared and teleport the user to a specific X-Y-Z location. Messoud et al. (2015) created the SVHsIEVs framework to do the integration of semantic layer in VW, which is distributed according to two levels, the first being global and the second being the virtual objects, where geometry concepts and more abstract information need to be incorporated in its description.

In the present study, it is proposed an ontology to overcome limitations in VW adoption while providing common terminologies and standardizing the relations among objects and avatars. The Domain Ontology is developed in Web Ontology Language (OWL) and focus on the interactions of students within the environment, concerning the objects of the VW itself, Non-Player Characters (NPC) or Embodied Pedagogical Agents (EPA), and the available Learning Objects (LO).

OWL is considered an extension of the Resource Description Framework (RDF), supporting a richer vocabulary. Although it is primarily a machine-readable language, an OWL ontology can be diagrammed using entity-relationship diagrams, such as the Unified Modeling Language (UML) class diagram (Rodriguez, Bollen and Van de Sompel, 2007). Hu and Qu (2007) suggest that although relational databases are based on closed-world and ontologies use open-world notations; there usually exist some approximate correspondences between them; for instance, an attribute in a relational database schema may correspond to a property in an OWL ontology. According to the authors, an entity relation would heuristically match a class in ontology, while a relationship relation would heuristically match an object property.

These assumptions come in agreement with the main objective of this research, which is to deliver common structure for databases modeling, in order to enable the capturing of more consistent data from students' interactions. According to Gali et al. (2004), it is easier to change ontologies classes and relations than database tables. The authors have shown that this conversion can be automatized with IT techniques, described as follows.

In the research of Gali et al. (2004), it is presented a set of techniques to provide a mapping of an OWL ontology to a relational schema and the corresponding instances to data. In the approach entitled OWL2DB the OWL data is mapped into tables of a relational schema and the queries are translated into SQL queries. In a more recent work, Balderas et al. (2017) propose using Virtual Web Query Language (VWQL), a Domain Specific Language (DSL) which allows to retrieve objective indicators from interaction logs of students from an OpenSimulator VW-based game environment, aiming to analyze learner behavior and interaction, generating reports with the requested data.

In this research, the focus is not to automatically deliver or generate VW, as in the studies of Eguchi and Thompson (2011), Bille et al. (2004), Trescak et al. (2010) and Messoud et al. (2015). It is modeling interactions within VW as in Balderas et al. (2017), but by using the technology of OWL-based Domain Ontology to design the conceptual structure and with the singularity of considering Learning Objects. Also, it is not mapped in an automatic way to database structure as in Gali et al. (2004), but it is one of its future works.

3. Methodology

The study described in this paper basically follows the method developed by Noy and McGuinness (2001), in which seven steps are defined to support the process of building an ontology. This method, called "Ontology Development 101", was selected due to its simplicity and applicability to the type of solution to be modeled. The method has been developed by Stanford University, and its authors describe that it is aimed to be used for declarative frame-based systems and has a list of steps in the ontology-development process.

In order to conduct this study, the following research question has been set up: how to standardize VW interaction terminologies using a Domain Ontology? Looking for responses the following objectives were defined: i) develop a Domain Ontology aiming to be applicable for an educational VW and ii) evaluate, on a preliminary basis, the feasibility of the developed Domain Ontology through an instantiation in an existing VW. What follows will describe details of procedures to meet these objectives.

3.1 Objectives and Scope

As declared by Gali et al. (2004), the key ingredients that make up an ontology are a vocabulary of basic terms, semantic interconnections, simple rules of inference and some logic for a particular topic. So as a starting point, it was defined a set of characteristics the envisioned ontology should have in order to comply with the defined research objective, what became the basic specifications. As indicated in Figure 2, the scope included the following:

a. Basic properties of Learning Objects: it will be helpful to reuse the designed LO on other regions of the same VW or even on other VW, and should basically include the subject, its category (e.g. video, audio, experiment), language, target audience, etc.

b. Most potential interactions of students with Learning Objects: the ontology must consider, based on the known types of LO in Virtual Worlds, what a student, while inside the environment, is able to do. It basically should include touching and colliding with objects.

c. Most potential interactions of students with the VW itself: besides interacting with the LO, the ontology should consider other events that could be interesting for researchers, such as the interaction with sensors to identify the location of the student in the virtual environment.

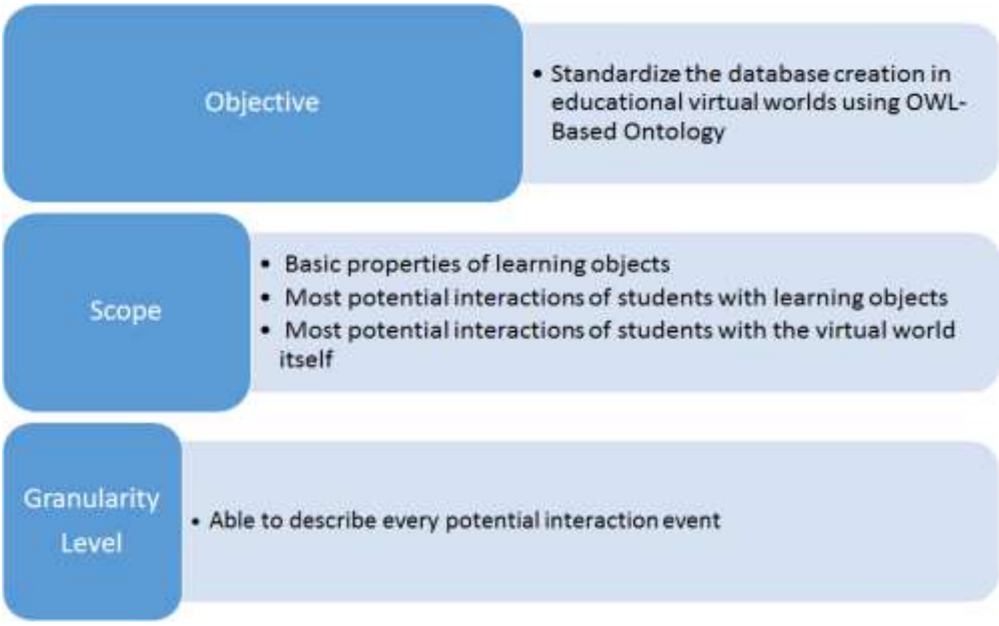

Figure 2. Basic Requirements for the Ontology

In the process of ontology construction, additionally to the objectives and scope, as listed in Figure 2, another requirement is the granularity level. Granularity can be defined as a detailed description of a domain or as the availability of terms in a lower background in the semantic hierarchy (Shamdasani et al., 2011). So a high level of granularity could mean an "atomic" grade of detail, while a low granularity would result in something like a summary of data. For the proposed ontology it is required a relatively high granularity in order to enable meaningful data mining and efficient data sharing, as indicated by Quackenbush (2004). In this sense, the ontology should be able to describe the exact time when a specific student activated a specific button of a certain LO of a specific room in the Virtual World.

3.2 Development of the Domain Ontology

The first step of Stanford's guide is to determine domain and scope of the ontology. Basically, some questions need to be answered to help make sure the ontology to be developed is correct. This process is more detailed than what was previously presented and adds one important element to the ontology scope: the types of questions the information in the ontology should provide answers. The questions and their respective answers can be found in Table 1. As mentioned by Noy and McGuinness (2001), the answers to the questions may change during the design of the ontology, so it is necessary to return to this step to review it.

Table 1. First Step in the Ontology Construction

Item	Definitions
What is the domain that the ontology will cover?	The domain of students' interaction with learning environments built in Virtual Worlds.
For what we are going to use the ontology?	It will be used to standardize the definition of databases that will record data related to the interaction of students while immersed in Virtual Worlds. It will make easier the gathering of data obtained from different developers. Also, it will be used to standardize a library of developed learning objects, in order to help developers to search and use (reuse) learning objects that may fit their needs.
For what types of questions the information in the ontology should provide answers?	- What are the types of Learning Objects in a typical Virtual World? - What are the typical elements of a Learning Object of a Virtual World? - What are the relationships between elements of Learning Objects and typical Learning Objects? - What are the necessary characteristics of the Learning Objects? - What are the potential types of interactions between avatars and elements of Learning Objects? - What are the potential types of interactions between avatars and the Virtual World itself? - In what specific time each student accessed each specific educational resource in the Virtual World?
Who will use and maintain the ontology?	Members of a same research and development group. The community of users to take advantage of a common ontology.

At Step 1 is defined the domain and scope of the ontology

The second step of the guide is to consider reusing existing ontologies, searching for existing libraries of ontologies, such as Ontolingua and DAML. For this process, it is not important the formalism of the existing ontology, but the ideas built into the hierarchy of classes and the relations among terms, as well as the concept properties. It was identified at Swoogle (DCMI, 2012) an ontology that was used to describe the learning objects properties.

Table 2. Third and Fourth Steps in the Ontology Construction

Item	Definitions
What are the terms we would like to talk about?	Learning Objects Types: video, image, slides, text, experiment, audio, questionnaire, web link Interaction with VW: avatar status (standing, running, etc.), avatar position Interaction with LO: touch, collide
Based on top-down, bottom-up or a combination, define the classes and hierarchy	Top-down hierarchy: - Interaction - Collide: physical contact between student avatar and object in the VW - Touch: intentional contact of student avatar's hand on a VW primitive - NPC Interaction: action performed by NPC to support learning processes - Avatar - Student Avatar: avatar that represents the student - NPC (Non-Player Character): avatar that represents a pedagogical agent, instructor or guide - Object - Learning Object: object designed for learning purposes - Environment Object: object in the VW not designed for learning purposes

At Steps 3 and 4 important terms of the ontology are enumerated, the classes and classes hierarchy are defined.

As a preparation for defining classes and hierarchy of the ontology, it was listed all relevant terms that might be needed to describe. This step is called "enumerate important terms in the ontology." It was actually just a starting point to describe the interaction within the Virtual World.

In the fourth step, the classes and their hierarchy have been defined. It was followed the top-down approach, starting with the most general concepts of the domain: interaction of the avatar with the environment, the interaction of the avatar with the LO and the Learning Objects themselves.

Table 3. Step Five of 101 Guide to the Ontology Construction

Item	Definition
"intrinsic" properties	Interaction: interaction type Avatar: avatar status, NPC ID Object: title, owner, description, date of creation, physical size, file format, version, instructional method, subject, source, time extent, version, number of sub parts
"external properties."	Interaction: absolute time, accessed Learning Object Avatar avatar location, NPC interaction type, student avatar ID Objects: accessed learning object, target audience, educational level, Virtual World address
Parts	table of contents accessed part
relationships with other individuals	Interaction has Objected, Student Avatar has Interaction, NPC has NPC Interaction

At Step 5 the properties of classes (slots) are defined

Furthermore, in the properties of the last step of classes (slots) were defined, as well as their faces.

According to Noy and McGuinness (2001), facets are different features each slot can take. In other words, they describe the formats the instances can have. For example, the instance of title for the slot object refers to the name of the object and is associated with a string format.

4. Virtual World Ontology

By applying the initial six steps of Stanford's guide, as described in the previous section, it was obtained the first input of the proposed methodology: the base ontology for the application. Figure 3 shows the ontology, including its classes, subclasses, and relationships. This ontology was built using an online collaborative development environment and free solution, called WebProtégé. It is an ontology editor and knowledge acquisition tool for the web which is actively used for several projects (Tudorache, 2011).
The seventh and last step of Stanford's guide is to create individual instances of classes in the hierarchy for each educational Virtual Worlds. Since in a VW the objects are created before the actual interaction of them with the avatars, the instantiation process needs to be accomplished in two phases: first the instance of "VW Object" classes and later the instance of "Interaction" and "Avatar" classes.

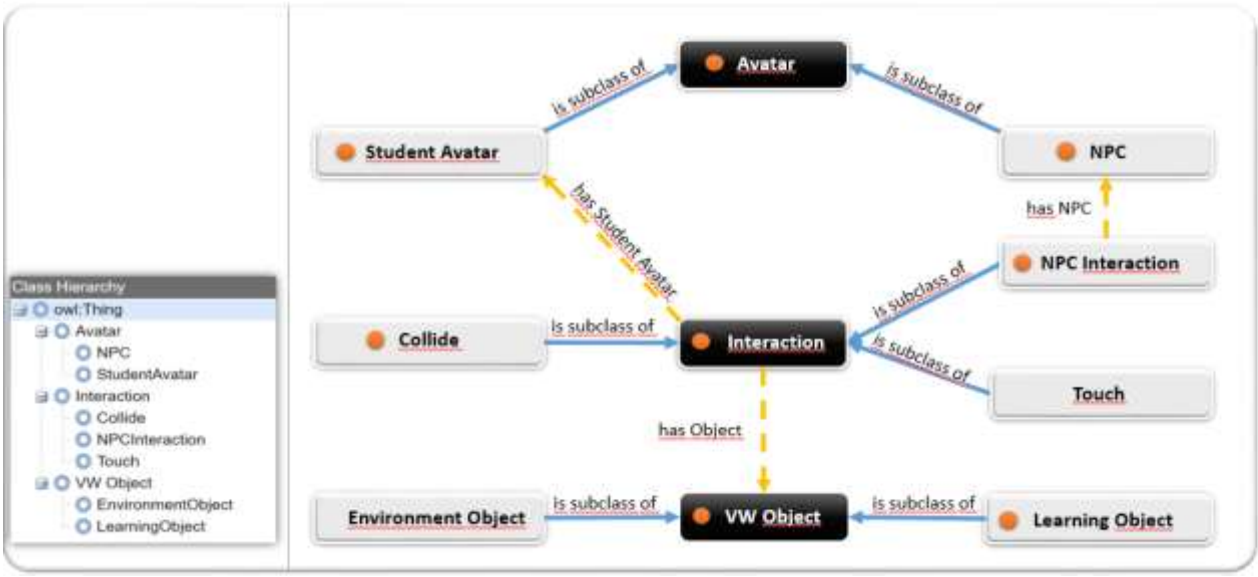

Figure 3. Proposed OWL-based Domain Ontology for Educational Virtual Worlds interactions

The instantiation of VW objects should be part of the design phase of the Virtual World. Even not being the focus of the proposed ontology, the VW developer may take in advantage the existence of previous instances of VW objects. For example, if there is a need for designing a Learning Object related to Electricity subject, the VW developer can check in existing instances of LO whether it was already implemented in the past and whether there were instances of interactions to this LO.
In the case of a new instance of VW object, the VW designer has to assign values for all properties that are considered important to characterize it. The following properties should be considered mandatory: title, subject, instructional category (video, audio, experiment, etc.) and target audience. Others may be

considered mandatory depending on the application context.

At the next phase of instantiation, the objective is to complete the knowledge base of the ontology, by assigning values to the properties of classes. In this case, the creation of instances should be made while the students use the Virtual World. Therefore, for each event of interaction, there should be a set of instances. The suggested mandatory properties are: absolute time (date and time when the event occurred), accessed LO, accessed subpart of LO and type of interaction.

5. Results and Discussion

To discuss the feasibility and exemplify the Domain Ontology proposed, in this section an instance of an existing Virtual World interaction is presented, along with suggestions on how to use the ontology to design the interaction and the database structure.

It was used the VW of an applied research project (acronym AVATAR), which focuses on Physics teaching for secondary education, built on OpenSimulator VW platform. Figure 4 shows the screen of a student avatar interacting with an experiment of electromagnetic waves. At the moment shown in the Figure, the avatar has just touched a button with the option that refers to the waves reflection phenomena, resulting in the simulation of the movement of propagating electromagnetic waves when they hit a wall.

Figure 4. Student Avatar interacting with a Learning Object

Figure 5 shows the first level of instantiation: the LO properties. In this case, the LO accessed by the student is the Experiment1, which was created on June 11, 2017 and has the title Wave Phenomena. The owner of Experiment1 is Teacher1; this LO has been created for secondary education level, to secondary students as the target audience. The LO also has the properties of VW location, being Region5 and Room2, and it is divided by the subparts refraction, reflection, and diffraction.

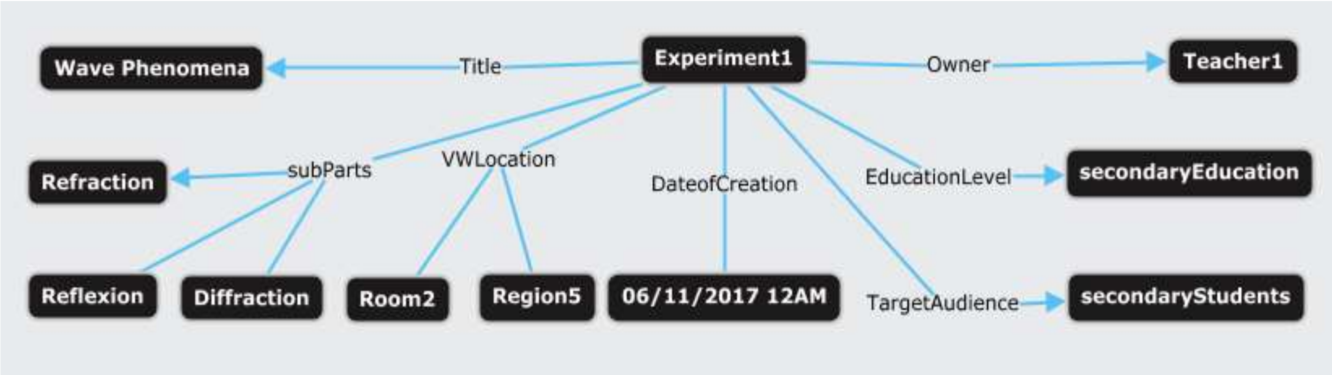

Figure 5. Instantiation of LO using the proposed Domain Ontology

This specific model would help to store LO with similar properties at databases, enabling to search, for example, for LO aimed at X target audience, or the ones created by owner Y.

Figure 6 presents the LO interaction, which belongs to the second phase of instantiation. The green items represent the classes, and the blue items represent the properties of those classes. In this case, the interaction of type Touch occurred at 12 AM of June 21, 2017, between the avatar of Student1 and the LO Experiment1, being a reflection the accessed subpart of LO.

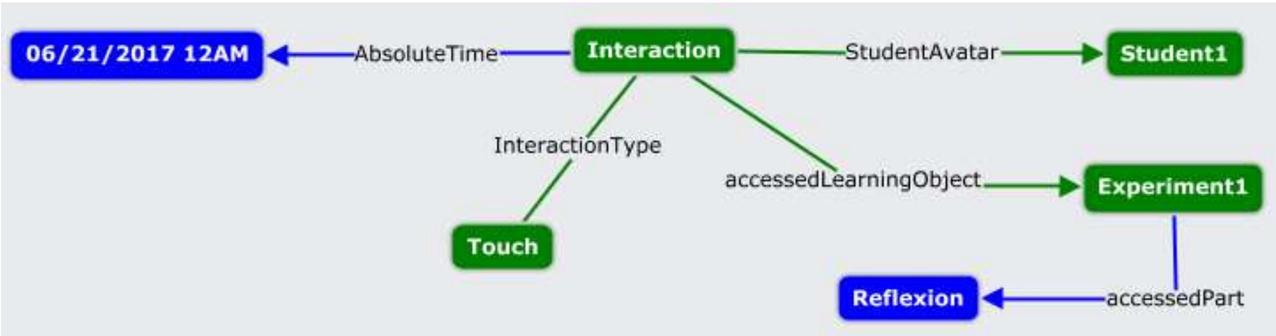

Figure 6. Instantiation of interaction with LO using the proposed Ontology

With the LO interaction instantiation in mind, it is possible to design and create the database structure that will receive these data from VW. Figure 7 shows a table from MySQL database where the mentioned interaction could be recorded. This modeling would apply to the previous level of instantiation, just changing the attributes of the columns.

#	Nome	Tipo	Agrupamento (Collation)	Atributos	Nulo	Predefinido	Extra	Acções
1	absoluteTime	datetime			Não	None		Muda Elimina Primária Único Índice Spatial Mais
2	StudentAvatar	varchar(90)	utf8_general_ci		Não	None		Muda Elimina Primária Único Índice Spatial Mais
3	InteractionType	varchar(90)	utf8_general_ci		Não	None		Muda Elimina Primária Único Índice Spatial Mais
4	accessedLearningObject	varchar(90)	utf8_general_ci		Não	None		Muda Elimina Primária Único Índice Spatial Mais
5	accessedPart	varchar(90)	utf8_general_ci		Não	None		Muda Elimina Primária Único Índice Spatial Mais

Figure 7. Database model of interaction with LO using the proposed Ontology

To actually register these data first it would be necessary to configure the VW sensors to send that information to the database. For the current research project, it is used a PHP Hypertext Processor (PHP) page to provide the middle process, receiving commands from objects of the VW, processing, formatting and inserting it into MySQL tables. It is a very agile and transparent process, so the data is captured within milliseconds.

Another instantiation at the second level is a result of the interaction with the VW itself. Figure 8 presents the moment when the student avatar had the interaction inside the VW. It occurred on June 21, 2017, in the location with the coordinates X 2.6, Y 2.0, Z 1.0, and from Student1 avatar, with ID EW54AW4EF.

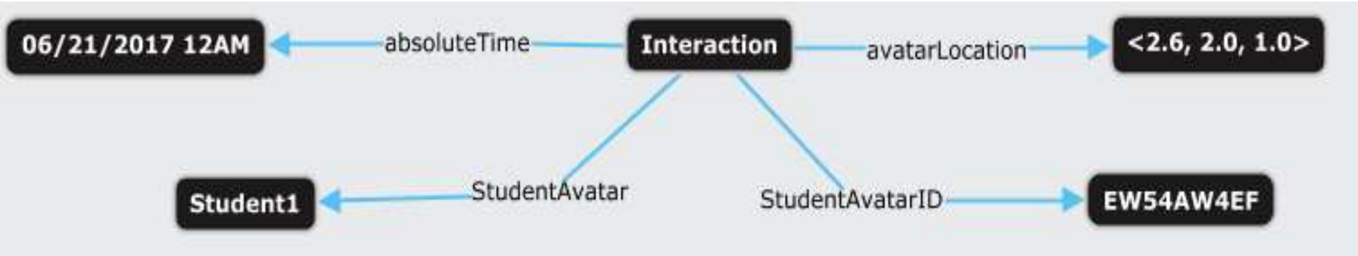

Figure 8. Instantiation of VW interaction using the proposed Domain Ontology

In view of that, it is possible to assume that the proposed Domain Ontology fulfill the basic requirements listed in section 3 (Figure 2) - to create a model to standardize database creation, in the scope of LO basic properties, and of most potential interactions of students with LO and with VW itself. The ontology was feasible to use in an existing scenario, to model other LO or interactions with similar properties, encompassing a good part of VW possibilities.

6. Conclusion

Ontologies have gained wide popularity as an information model that can be used for many purposes, including enterprise integration, database design, information retrieval and information interchange (Gali et al., 2004). In this way, an ontology can help overcome the obstacle of Virtual World databases inconsistency, standardizing VW interaction possibilities and terminologies. Data retrieved from consistent databases can help teachers detect learner difficulties at an early stage; hence to take the necessary steps to better support students throughout the learning process (Balderas et al. 2017).

In this work it was proposed an OWL-based Domain Ontology aimed at creating a reference model of student interaction with LO commonly used at educational Virtual Worlds, to avoid the inconsistency problem with a reusable model that teachers and developers can take into consideration while designing these environments and planning interaction strategies.

With the proposed Domain Ontology, the gathering of a larger amount of consistent data becomes possible, enabling to analyze student interaction in a uniform way, using, for example, data mining techniques as clustering and association. As ontologies facilitate communication between people and information systems, with the flexibility of Domain Ontologies, it will be easier to adjust the prerogatives to develop better VW for educational purposes. This could also allow teachers that are not so familiar with VW technologies to understand its operation, thus helping on expanding its utilization to more educational institutions.

The design and implementation of this ontology have given the authors a valuable feedback and topics for further research. For example, it is intended a validation of the Domain Ontology by experts in the field, extracting suggestions of improvements necessary to align the proposal and turn it more complete, functional and realistic, confirming whether it is really a reusable model. Also, a system that automatically maps the ontology and transforms it to database structure is desirable to automate and shorten the process. It could also have an interface that enables the generation of reports from VW activity, easily delivering students interactions data to the teachers.

This paper contributes with new possibilities to educational Virtual Worlds using the advantages of ontologies, helping on overcome the barriers to its widespread adoption, as reusability and data accuracy.

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