Towards ontology of gameplay: application to game based learning systems

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Abstract

Game Based Learning Systems (GBLSs) constitute an important resource for entertainment and education, they present an efficient technology that uses game principles to engage learners into learning activities. However, several barriers are in the way of the general adoption of learning approaches based on GBLSs, since their design process requires strict and precise specification models to define and communicate gameplay. For instance, until very recently, gameplay is usually specified via natural language rules introducing and generating thus many ambiguous human interpretations and a lack of machine understandable formats. In this paper, we present a formal as well as a semantic formalism based on domain ontology for gameplay specification that offers to game designers a precise model to describe, analyze and communicate gameplay from early stages of development. Moreover this semantic formalism is more machine understandable which could allow more automatic processing and reasoning over the specified gameplay.

Keywords: Ontology, Game Based Learning System (GBLS), Gameplay, GBLS design process.

Introduction

Based on theoretical, practices and real world expertise, GBLS constitute an interesting and stimulating learning environment for learners. Through GBLS, learners become more and more engaged in the learning process, they feel motivated, able to strengthen their cognitive skills, gain satisfaction as well as a sense of achievement and full involvement.

However, their use in real scenarios is limited by several factors that span all over the product life cycle affecting the design, implementation and deployment phases. For instance, gameplay designers suffer from the absence of well defined process and models for gameplay design (Montero Reyno, R et al.2009).

This paper emphasizes the need to have a formal presentation for GBLS gameplay, to design meaningful and engaging GBLSs. The main purpose of this paper is to present a gameplay model that stresses the importance of precisely defining gameplay through a formal model in order to facilitate machine-interpretable definitions of basic gameplay concepts and corresponding relationships.

This paper is organized as follows: In the section 2 we describe GBLSs design problems with particular emphasis on problems related to gameplay design and manipulation as well as how to overcome them. Section 3 presents related works where a formal presentation for gameplay and its corresponding terminology have been provided. Section 4 describes the steps that we followed for the gameplay ontology elaboration and validation. It also highlights the usability of the ontology to help game designers while doing their job. And finally, section 5 presents our conclusions and future works.

Game Based Learning Systems Design Process: Problems and Defects

GBLS is an interactive technology that attracts researchers and professionals interest in various fields. It has been proven to be an effective tool in supplementing conventional teaching methods (Dickinson et al.2011).

However, its use in real scenarios is limited by several barriers that span all over the product life cycle. Indeed, complexity of a GBLS design process, tight development schedules, diversity of development tools and strategies still constitute the major difficulties.

We identify the following requirements:

The first one includes technical problems. Therefore, GBLSs designers suffer from interoperability and communication problems due to the use of different tools and the exchange of heterogeneous data with non-standard formats. They need an appropriate environment allowing the participating actor to curry out, efficiently, his/her tasks either alone or collaboratively.

The same environment should allow the process monitoring. The overall system should be enough flexible and able to cope with business domain changes or IT changes.

Moreover, designers suffer from the absence of well defined process and models for gameplay design (Montero Reyno, R et al.2009; Church 1999). Therefore, gameplay should be presented in a formal way that facilitates its processing automatically and intelligently.

The second one concerns problems of integrating learning outcomes with fun aspects. For instance, learning activities must be sequenced or otherwise structured carefully in the GBLS design process. Learning outcomes need to be integrated as goals from the beginning of the design process. Pedagogy also needs to be formally incorporated into games to promote more effective learning.

The third one concerns the complexity of each step in a GBLS design process and more precisely those related to gameplay design which requires relevant expertise (Djaouti 2011). For instance there are no tools that support novice game designer in doing their job (Mark, j et al. 2008).

In this present paper we will focus on problems related to gameplay design. For instance, lack of gameplay models and formalisms constitutes the major defect. Indeed it should be presented in a formal way that facilitates its processing, automatically and intelligently. Furthermore, gameplay presented in natural language makes it difficult to be analyzed and communicated. So having a formal and standard model that can be used for any game design project, and can be manipulated with any development environment is recommended to facilitate reusability and avoid time as well as money consuming issues.

Moreover, GBLS designers don't have well defined role like the other team members participating in that process (Adams 2009). They must adapt their roles with projects' requirements.

Related Works

GBLS designers still face several barriers at gameplay definition and modeling. We focus in this section on both digital games as well as GBLS gameplay modeling attempts and the associeted terminology to gameplay.

Gameplay Modeling Attempts

Lack of formal models to precisely define gameplay has been for a long time a traditional game design problem. For instance, many studies have pointed out needs to create models in order to explain games mechanics

Indeed, gameplay is considered as the game's core, since it reflects the overall experience during the interaction between a player and the game system. However, there are only very few attempts to present gameplay in a formal way (Montero Reyno, R et al.2009). They have unsuccessfully tried to capture the essence of gameplay in a single representation or diagram. Unfortunately these attempts concern only video games.

A recent approach was reported in (Grünvogel 2005), which considers game design with formal methods that can be used to create a language intended for certain aspects of gameplay. This language is presented with mathematical formalism. Indeed, it can be used to detect connections between game elements. It considers game as a set of objects each of which is able to change its state during the play. The evolution of one's object state is governed by rules (gameplay) and influenced by the players or other objects.

Using mathematical formalism to describe the game system behavior constitutes a very precise specification method. It removes the ambiguity of natural language and makes more precise the description of rules.

Unfortunately, its treatment and manipulation with existing tools constitutes a major challenge. Therefore, a formal model of gameplay is needed to reduce implementation time and errors, which ultimately leads to GBLSs of a higher quality.

In (Heaton 2006), authors present a circular model for gameplay, containing only two fundamental components namely the player and the game. The player is a human who is elected to play. The game is a system that the player interacts with; everything that is not the player is part of the game. All information about the game is conveyed to the player through clearly defined output channels and all the player's actions in the game are carried through clearly defined input channels.

There are usually a relatively set of interactions that are repeated. The changing state of the game constantly prompts new actions from the player. The gameplay typically goes through many cycles of observation and action until an arbitrary endpoint is reached.

This approach presents a formal presentation for gameplay. However, rules which constitute the fundamental concept of gameplay are not taken into account. Moreover, this presentation considers only the human player, or in real scenarios, non human players can also participate in the game.

In order to remove the ambiguity of natural language, authors in (Bura 2005) use Petri Nets to model game systems. They give a first attempt to game design modeling without natural language. Even if Petri Net diagrams can become easier to read and to understand, the final diagram specification is difficult to understand and to scale. Moreover, there are no considerations for pedagogical aspect that characterize GBLS.

In (Montero Reyno, R et al. 2009), authors present an important overview for gameplay modeling. They propose to apply Model-Driven Development (MDD) methodology to game development, raising the level of abstraction towards conceptual modeling of game. In this context, they propose a Meta model that takes into account some concepts of gameplay. Indeed, they propose the use of models as a game design specification tool with abstract and simplified representation of game systems. Proposed models can be independent of the specific technological platform used for implementing the system.

Despites its importance to favor reusability and flexibility of the gameplay design, the proposed solution falls short of GBLS designer's requirements. It cannot be used for GBLS design, because pedagogical aspects are not considered enough.

In the same context, authors in (Djaouti , D et al. 2008) try to present a definition for gameplay. They propose an experimental approach that aims to classify videogames. They develop a tool for indexing and analyzing a large videogames corpus. They define a set of recurrences called "Gameplay bricks." Then, three categories of gameplay bricks are identified. Rules listening to Input and acting on the game elements consequently, named Play bricks. Rules observing the state of the game elements and returning to the player an evaluation of his performance, named Game bricks. And rules that can be classified through the use of some pairs of bricks, named "Meta bricks."

However, used corpus of videogames needs to be extended with adding more kinds of oriented learning systems like GBLSs. Moreover, this approach limits gameplay to rules and actions, but there are other aspects that need to be included as e.g. the game environment (player characters, non player characters…).

Associated Terminology to Gameplay

Gameplay is so difficult to define because there is no single entity that we can point to and say. That's why the Gameplay is considered as the result of a large number of contributing elements.

For instance, rules, actions and outcome, game mechanics, interaction and choice, and the space of possibilities have a close relationship with gameplay. Let us have a look at these concepts, which are clarified by Katie Salen and Eric Zimmerman in their Rules Of play book.

Rules

Constitute the fundamental concept that clarifies differences between game and play. In fact, "Rules are what differentiate games from other kinds of play. Probably the most basic definition of a game is that it is organized play, that is to say rule-based.... Rules impose limits they force us to take specific paths to reach goals and ensure that all players take the same paths" (Salen, K et al. 2003).

Following are the general characteristics that all game rules share (Rules limit player action, Rules are explicit and unambiguous, Rules are shared by all players, Rules are fixed, Rules are binding, Rules are repeatable).

In (Gonzalo 2003), authors identify three kinds of rules. The first kind is manipulation rules defining what the player can do in the game. The second kind is the goal rule that defines the goal of the game. And finally Meta rules which present how a game can be tuned or modified.

Actions and outcome

Play in a game emerges from the relationship between player action and system outcome; it is the process by which a player takes actions within the designed system of a game and the system responds to these actions. The meaning of an action resides in the relationship between the action and its outcome.

Game mechanics

These are the procedures and rules of the game. Mechanics describe the goal of the game, how players can and cannot try to achieve it, and what happens when they try (Salen, K et al. 2003).

Interaction and choice

To play a game is to interact whit it. More specifically, playing a game means making choices within a game system designed to support actions and outcomes in meaningful ways. Every action results in change affecting the overall system. When the player makes a choice in a game the system response is one way to characterize the depth and quality of interactions (Salen, K et al. 2003).

Space of possibilities

A set of possible actions that players explore as they take part in game includes possible actions might a player take in the course of a game (Salen, K et al. 2003).

GBLS Gameplay Ontology Definition

The gameplay design process is one of many other processes to bring GBLSs to life. There are processes related to the artistic design and to the learning design.

Every process has its own specificity in terms of modeling, execution languages, tools and participating actors. That is why we propose to integrate them in a global and coherent system.

Unifying and bridging the gap between the aforementioned processes towards a unified process and a coherent system can be guaranteed using Semantic Service oriented architecture (Raies, K et al. 2013). Indeed it:

- Enables enterprises participating in that process to not only transform internal systems to be more service oriented, but also permits best collaboration amongst them.

- Grants more agile business processes because it reduces the gap between business process modeling and implementation.
- Allows an increased collaboration within and across enterprises (actors belonging to different enterprises).
- Overcomes several problems at run-time as well as at design-time due to the use of different business/learning process modeling languages by the collaborating companies as for example BPMN and IMSLD (Burgos, D et al. 2005).

In this paper we will focus on the process of gameplay design and steps to follow to present a formal model for this process.

GBLS Gameplay Ontology Purpose's

Despite the important number of methodologies to design ontology (i.e., (Grüninger, M et al, 1995) (Lopez, M et al.1999) (Noy, N et al. 2001), all of them consider basically the following steps: definition of the ontology purpose, conceptualization, formalization, and validation.

The major purposes of the gameplay ontology are:

- Having a formal model to provide an automatic treatment and interpretation of the gameplay which can solve communication and interoperability problems.
- Foster opportunities to share knowledge associeted to gameplay among actors and tools participating in the GBLS design process.
- Enable reuse of knowledge related to gameplay design to avoid time as well as money consuming issues.

The proposed ontology is used by services or processes associated to other aspects of GBLS design.

Figure 1 shows the context of using the gameplay ontology.

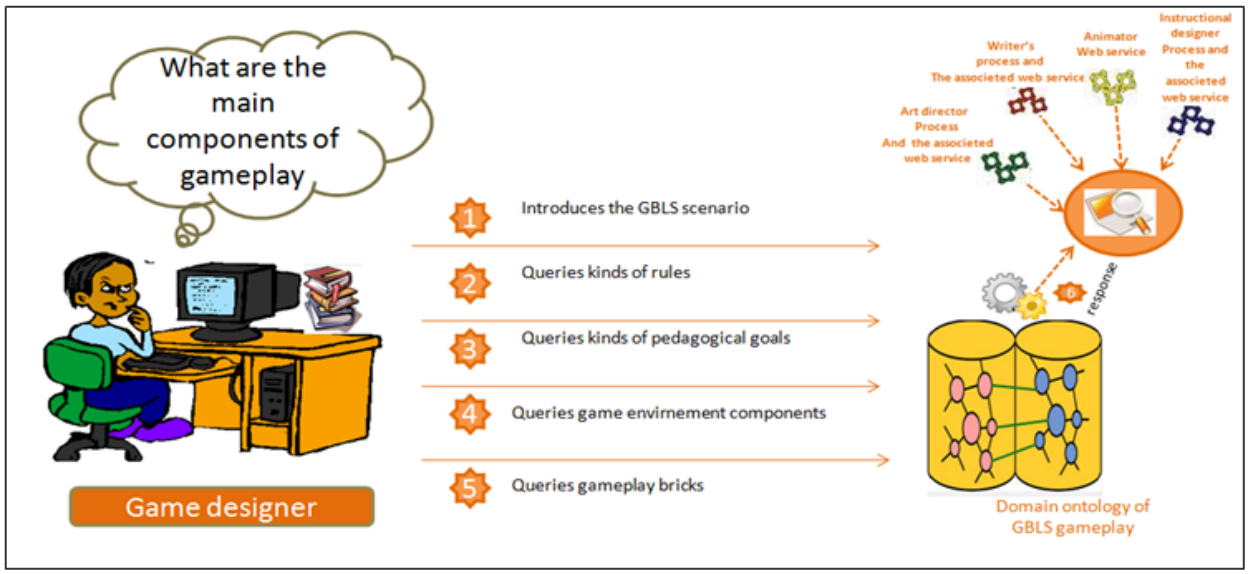

Figure 1. The context of using the gameplay ontology.

For instance, the instructional designer may use this ontology with the LD (Learning Design) service to define the pedagogical aspect of the future GBLS. As he needs goal rules or more precisely the pedagogical goals, we make use of some mapping rules to overcome interoperability problems. Figure 2 presents a mapping rule for associating Learning objectives specified in LD service and pedagogical goals defined throw the gameplay expressed in WSML (Jos de , B et al, 2005).

```
53 axiom pedagogical_goal
54 definedBy
55 ?x memberOf   cognitive_goals and
56 ?y memberOf  affective_goals and
57 ?z memberOf psychomotor_goals
58 equivalent
59 ?A memberOf cognitive_objectives and
60 ?B memberOf affectiv_objectives and
61 ?C memberOf psychomoteur_objectives.
```

Figure 2. A mapping rule for associating Learning objectives and pedagogical goals

Conceptualization

The second step is the conceptualization; it requires the definition of the ontology's scope, its concepts, relations and constraints, it also requires description of a glossary for all concepts and attributes. It represents the knowledge modeling itself.

The conceptualization step starts with the definition of competency questions, i.e., requirements in the form of questions that the ontology must answer (Grüninger, M et al, 1995) :

- What are the main gameplay components?
- Is the pedagogical aspect defined through rules?
- Are actions associated to rules?
- Which are the associated elements of the game environment?
- Which kinds of game bricks can be associated to GBLS?

To answer the first and the second competency question we try to collect related works that describe gameplay components and clarify the relationship between them (Salen, K et al, 2003) and (Gonzalo 2003).

Gameplay is defined through set of rules. Rules are based on actions. They can be Meta rules which defining how a game can be tuned or modified, manipulation rules define what the player can do in the game or goal rules. A goal rules define goals of the game that must be a pedagogical goal or non pedagogical goal.

Additionally, rules define two types of conditions called failure conditions and success conditions. These Conditions generate actions.

Figure 3 shows an UML diagram, of this part of the ontology related to the competency question i. For reasons of simplicity the concept properties are not shown.

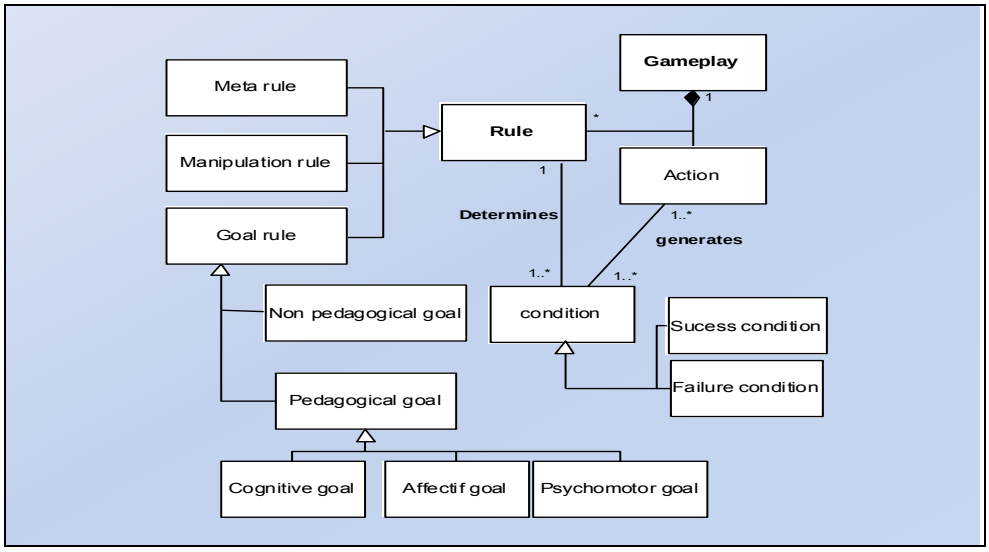

Figure 3. The part of the ontology related to rules of GBLS

To answer the third competency question, we found in literature that rules definition is based on two types of conditions previously mentioned; these conditions generate actions (Gonzalo 2003). In addition, an Action can be authorized or not, and every action performed by a player can affect the score, the state and the level of the game. Figure 4 shows this part of the ontology.

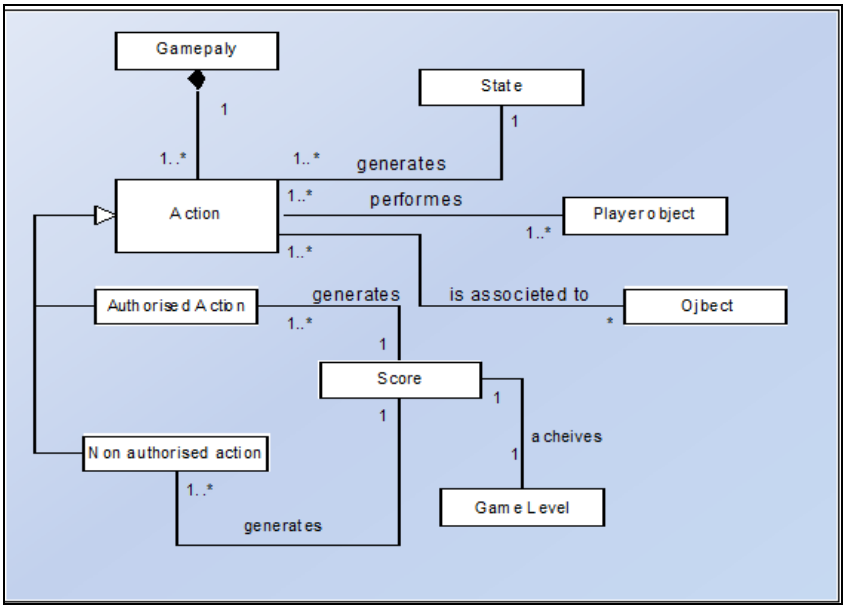

Figure 4 Part of the ontology related to Actions of play

The fourth competency question clarifies an important aspect of gameplay. For instance through gameplay many game objects are described, those objects may be non player objects or player objects. There are two types of player objects as human player and non human player. Figure 5 shows this part of ontology.

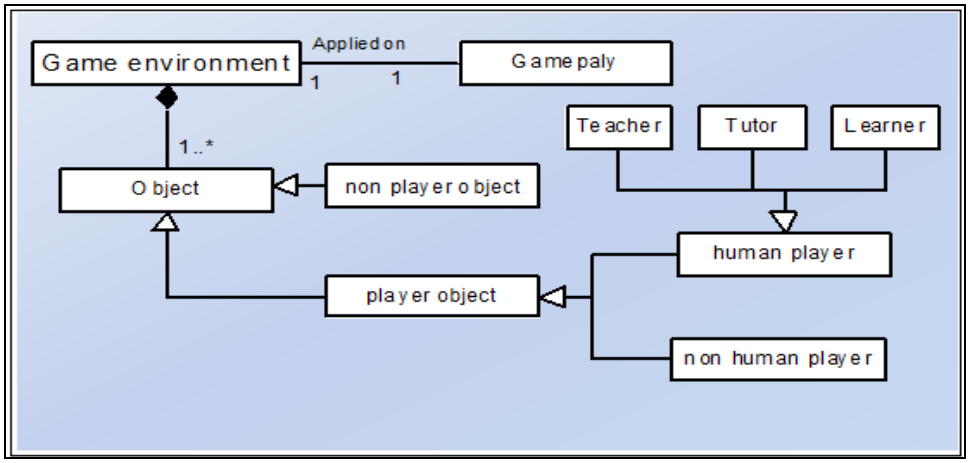

Figure 5. The part of the ontology related to game Environment

To answer to the final question, we adopt related work (Djaouti , D et al. 2008). It defines three types of bricks; play bricks, goal bricks and Meta bricks. In Figure 6 we present relation between game bricks and rules.

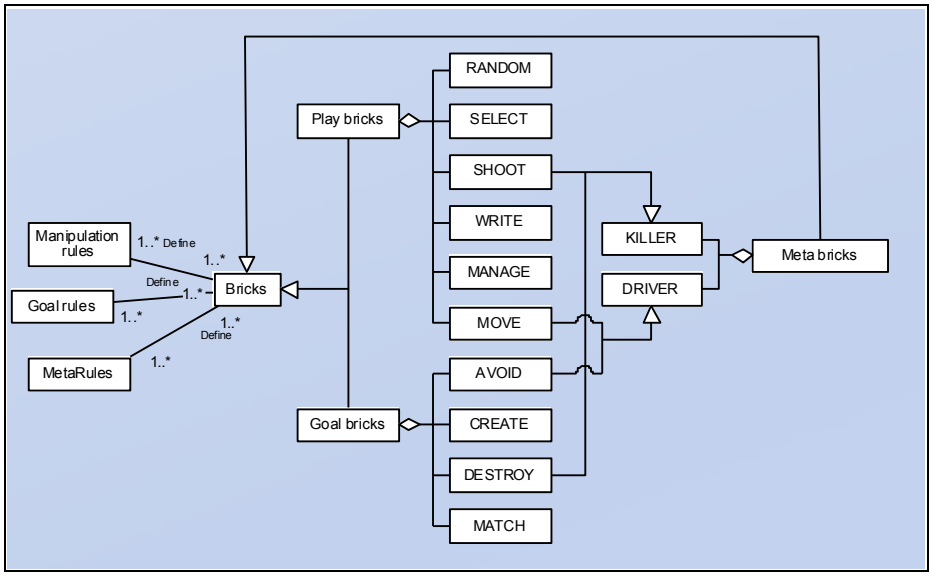

Figure 6. The part of the ontology related to gameplay bricks

Finally, other constraints (axioms) for the concepts and relations were set, such as:

Rules must define at last a condition and its generated action.

- There are only three types of rules manipulation rules, goal rules and Meta rules.
- At least an authorized action must generate a score.
- At least through an authorized action, player achieves an advanced game level.
- The game environment must define at last two kinds of object as player and non player ones.
- Player objects can be human or not human players.
- At least a human player must be defined
- Each rule is associated at last to a gameplay brick.
- Each action is performed by a player object.

- At least three pedagogical goals must be defined through goal rules (Orliac , C et al. 2011; Bloom, B et al. 1956).

Formalization

With respect to the architecture of our future system which is based on SSOA, Web Service Modeling Ontology (WSMO) (Marin, D et al. 2007) constitutes an appropriate environment which provides functionality that covers various related Semantic Web service Tasks in an integrated modeling environment such as the modeling ontology. Figure 7 presents the GBLS gameplay ontology formalized through WSMO Studio.

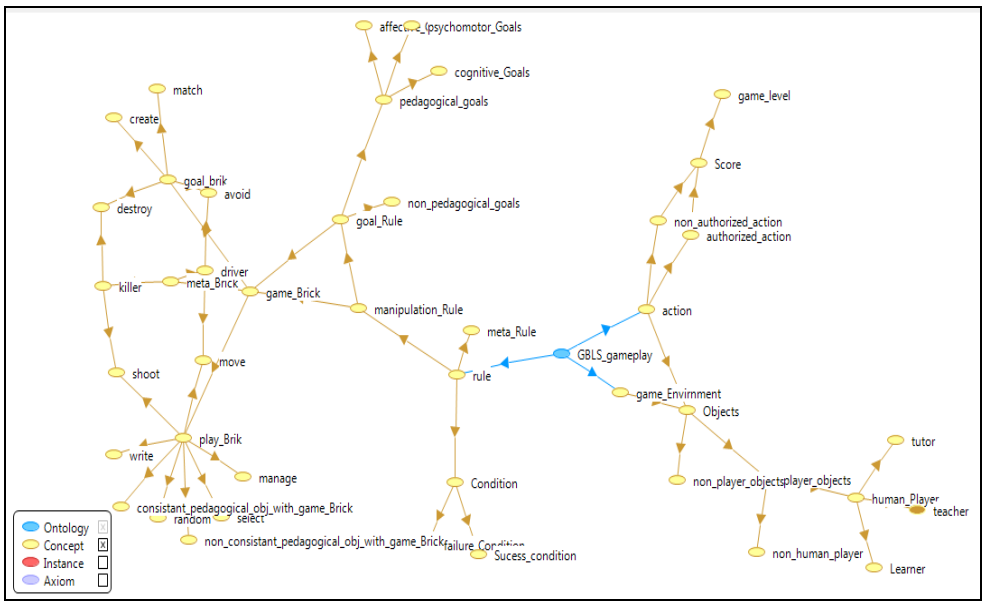

Figure 7. The GBLS gameplay ontology

Experimentation and Validation

To validate the ontology, we create several instances based on a GBLS addressed to kids between 7 and 11 years. The instantiated concepts and information required to design the gameplay for our example are represented in table 1.

For instance, Zombie division (Habgoo 2005) aimed to teach mathematics, for children between 7 and 11 years old, the player is an ancient hero who faces skeletons wearing number. The player can use several attacks, each one corresponding to a kind of division operated on the number linked to the target enemy. The player must take care of matching attacks with opponents through divisions, as enemies cannot be divided without the required attack.

Concepts	Instances
Authorized actions	Choose one weapon Combine(Organize) various weapons Use the same weapon repeatedly
Non authorized action	Using attacks two times repeatedly
Cognitive objective	State the formula of calculate prime numbers
Affective objective	Select the appropriate divisor
Psychomotor objective	Choose the appropriate divisor(weapon) to destroy skeleton
Human player	Ali
Non human player	Skeleton
Game bricks	Destroy, Match, Avoid
Play bricks	Move

Table 1. Glossary of instantiated concepts

WSMO contains an integrated Stratified IRIS reasoner to query the ontology described in WSML. Figure 8 shows a case of queries applied to our ontology to define pedagogical objectives.

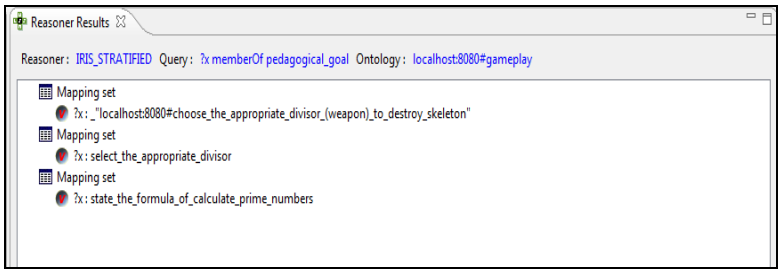

Figure 8. Result of query applied on gameplay ontology that present pedagogical objectives.

Thanks to its generic concepts as rules and actions, the gameplay ontology provides information to all sub processes of GBLS design as the definition of game objects, game environments, pedagogical objectives…

The definition of these aspects can be validated or not with the gameplay ontology. For instance we can find incoherencies between the gameplay specification and the pedagogical content of GBLS as:

- Defining pedagogical objectives that cannot be achieved through actions mentioned by the gameplay.
- Defining pedagogical objectives which are different from gameplay bricks.
- Defining learning scenarios which are not compatible with actions defined in the gameplay.
- Defining learner's abilities' that cannot response to the game level.

Figure 9 shows a case of queries applied to our ontology to define non consistent pedagogical objectives with play brick rules.

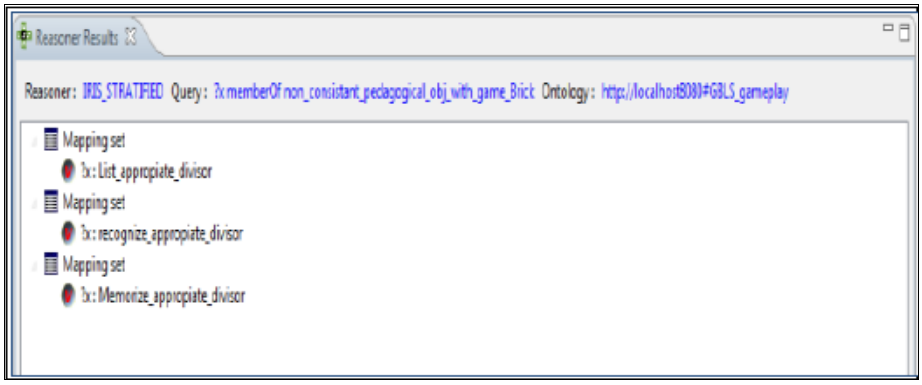

Figure 9. Result of query applied on gameplay ontology that presents non consistent pedagogical objectives with the play brick

Conclusion and Future Work

The principal aim of the work presented in this paper is to define GBLS gameplay ontology. The idea is to lighten and reduce actors' workload, giving them the appropriate presentation of gameplay to produce more attractive and efficient GBLS. This responds to GBLS users' needs and solves many problems like flexibility, modularity, and reusability in one hand. And facilitate machine treatment and interpretation of gameplay in other hand.
Our future work will consist on establishing mapping rules between concepts relating to each GBLS design process.
We will equally focus on development of an assistance process for gameplay development based on an intelligent tutoring system, which is based on actor's context, skills and roles analysis.

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