Knowledge Modeling for Educational Games

Miroslav Minović[1], Miloš Milovanović[1], Dusan Starcevic[1], and Mlađan Jovanović[2]

[1] Faculty of Organizational Sciences, Laboratory for Multimedia Communications, University of Belgrade
{mminovic,milovanovicm,starcev}@fon.rs
[2] Faculty of Electrical Engineering, University of Belgrade
mladjan@rcub.bg.ac.rs

Abstract. Use of educational games during teaching process does not represent a new topic. However question "How to address the knowledge in educational games?" is still open. The purpose of this paper is to propose a model that will attempt to establish the balance between knowledge integration into game on one side, and its reusability on other. Our model driven approach is relying on use of Learning Objects (LO) as constructing pieces of knowledge resources which are specialized for educational game design purpose. Presented models contribute to methodology of educational games development in a way that they embrace principles of learning and knowledge management early in design process. We demonstrated applicability of our models in design case study, where we developed educational game editor where educator can easily define new educational game utilizing existing knowledge, assessment and multimedia from repository.

Keywords: Knowledge modeling, Educational game, MDA, Metamodels.

1 Introduction

There is a promising role of digital games in education process. Traditional forms of teaching and passing knowledge lose their strength daily, due to development of technology and different motivational factors for the upcoming generations. Digital game-based learning is a novel approach applying at universities' courses and lifelong learning. In search for new role of universities in changing context of education, gaming is becoming a new form of interactive content, worth of exploration [1]. Features of games that could be applied to address the increasing demand for high quality education are already identified as [2]: clear goals, lessons that can be practiced repeatedly until mastered, monitoring learner progress and adjusting instruction to learner level of mastery, closing the gap between what is learned and its use, motivation that encourages time on task, personalization of learning, and infinite patience.

Use of educational games during teaching process does not represent a new topic. Since the need for new forms of education has been recognized by the researchers in this area, new problem arose. The main issue in this area of research is "How to address the knowledge in educational games?" At this moment, development of educational games includes knowledge integration during game development process. This

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approach establishes strong coupling of game context and integrated knowledge which further disables reuse of that particular knowledge. In order to increase knowledge reuse, there is a need for a certain level of separation from the game. That extraction, on the other hand, can lead to poor integration with game context, which disrupts the flow of the game. Finding the right balance is essential regarding this matter.

Finding the right way to model the knowledge for use in educational games presents an important issue. Video games teach players certain skills and knowledge [3,4]. The problem arises when there is a need to teach specific matter such as subject curriculum at universities etc. Integrating that kind of knowledge, while still making game interesting and playable presents a big challenge. The purpose of this paper is to propose a model that will attempt to establish the balance between knowledge integration on one side, and its reusability on other. Our model driven approach is relying on use of Learning Objects (LO) as constructing pieces of knowledge resources which are specialized for educational game design purpose. Learning objects represent a small, reusable pieces of content relevant for learning (for example, an online exercise; a coherent set of introductory readings on a specific topic; or an assessment test) [5]. Reusability of LO represents using LO in different courses, by different teachers and learners [6]. In this case LOs can be reused in different educational games as well as other eLearning forms, online classes, tests etc.

The paper is structured as follows. In part 2, we give a brief discussion about this area of research and survey of research result regarding this matter. Next, we give a description of the proposed approach inspired by model-driven development that represents a basis of this work. Detailed description of our metamodel is a subject of part 4 of this paper. An example of application of the described metamodel, is described in part 5. Part 6 gives a conclusion and issues in respect to our future work.

2 Games in Education

The essence of e-learning lies in knowledge management [7,8]. The ever-increasing importance of knowledge in our contemporary society calls for a shift in thinking about innovation in e-learning.

In the context of e-learning, ontologies serve as a means of achieving semantic precision between a domain of learning material and the learner's prior knowledge and learning goals [9]. Ontologies bridge the semantic gap between humans and machines and, consequently, they facilitate the establishment of the semantic web and build the basis for the exchange and re-use of contents that reaches across people and applications [10].

It is important to be able to separate content from expression within a LO in order to be able to clearly distinguish two important types of questions: those dealing with the meaning that has to be conveyed by the LO, and those dealing with how meaning is to be expressed [11].

On the other side, main purpose of educational games is to teach and pass knowledge. That is why a majority of educational games is focused mainly on knowledge. Different skills and knowledge can be taught differently. Some games are using well-known, popular environment and set of rules, adapted for purposes of education - for example, the educational game based on “Who wants to be a millionaire?” quiz [12]. It uses all elements of the TV show, but questions are chosen by the teacher.

Some games are developed with certain subject matter in mind, like games for teaching electromagnetism called Supercharged! [13] or a fantasy adventure game for teaching the basic concepts of programming [14]. In some cases, the modification of popular games (game modding) was used for teaching computer science, mathematics, physics and aesthetics [15]. Game design can be used to achieve similar goals - developing problem solving skills and teamwork [16].

Regardless of the rapid growth of this research field, knowledge modeling for the purpose of educational games is still in its initial phases. While there are many examples of practical work in knowledge modeling and knowledge management, there is very little practical work done in the field of knowledge modeling and integration with educational games. While there are numerous efforts that games can be applied to learning, relatively few attempts can be found where principles of learning and knowledge management were explicitly followed a priori in design [9]. Cognitive modeling and assessment tools have to be incorporated in to educational games, giving insight into learning outcomes and enabling their evaluation. The challenge with these games is also that they are very costly to develop, as they must compete with commercial video games in terms of quality of graphics, challenges, and game play [2].

3 Proposed Approach

Our approach is inspired by the model-driven development, where software development's primary focus and products are models rather than computer programs. In this

Table 1. Mapping Educational Games Concepts to the OMG's MDA Levels

OMG MDA Level	Educational Game Metamodeling Architecture	Description
M3 – Meta-metamodel	The Meta Object Facilities (MOF)	The MOF is an OMG standard that defines a common, abstract language for the specification of metamodels. MOF is a meta-metamodel – the model of the metamodel, sometimes also called an ontology
M2 – Meta models	The Educational Game Metamodel (EGM)	The Educational Game Metamodel provides a common and standardized language about phenomena from various domains relevant to the design of educative games. It is called a metamodel as it is the abstraction of platform specific models.
M1 – Models	Platform-specific Shemas (XHTML, SAPI, SWIXml Schemas...)	Platform specific models of educational game content.
M0 – Objects, data	Content data (XHTML, SAPI, SWIXml files...)	Instances of platform specific models.

way, it is possible to use concepts that are much less bound to underlying technology and are much closer to the problem domain [17].

Table 1 gives an overview of educational game development through MDA levels. It uses a platform-independent base model (PIM), and one or more platform-specific models (PSM), each describing how the base model is implemented on a different platform [18]. In this way, the PIM is unaffected by the specifics of different implementation technologies, and it is not necessary to repeat the process of modeling an application or content each time a new technology or presentation format comes along. The views on game content from different levels of abstraction can be derived by *model transformations*. In MDA, platform-independent models are initially expressed in a platform independent modeling language, and are later translated to platform-specific models by mapping the PIMs to some implementation platform using formal rules. The transformation of the content models can be specified by a set of rules defined in terms of the corresponding higher level metamodels. The transformation engine itself may be built on any suitable technology such as XSLT tools. Our approach is based on standard technologies such as the Unified Modeling Language (UML) and XML, which are familiar to many software practitioners and are well supported by tools. Therefore, it is not necessary to develop complex solutions from scratch, and it is possible to reuse existing model-driven solutions and experiences from other domains. In our work we rely on existing UML modeling tools, XML parsers and software frameworks, developing only code that extends, customizes, and connects those components according to common and standardized language defined in the Educational Game Metamodel.

4 Educational Game Metamodel

Defining educational game models requires a vocabulary of modeling primitives. Therefore, our metamodel describes basic educational game concepts. Figure 1 shows a simplified educational game metamodel.

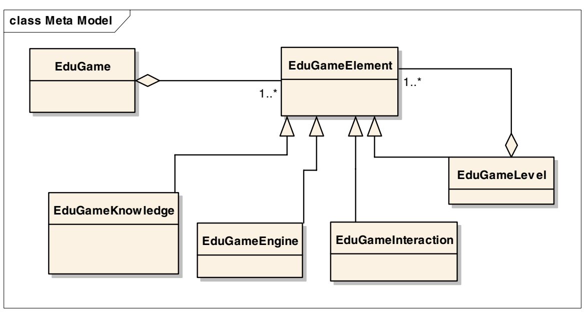

Fig. 1. Educational game basic concepts

The metamodel's main concept is *EduGameElement* which is used as a basis for defining other concepts of educational game. *EduGameKnowledge* defines educational content that aims to convey to players in learning process. There is a need for expertise in science area for managing complexities of the underlying knowledge.

Educational content needs some form of presentation to the user, therefore we introduce concept of *EduGameEngine*. It describes the mechanism used to present knowledge, which, for example, might be the learning tool to generate and answer questions that guide learner through the exploration and discovery of the required science area. *GameInteraction* concept describes communication between player and game. This concept describes interaction at high level of abstraction regardless of specific manifestations. In broad outline, interaction is established using multiple channels of communications, and concept is derived from our existing metamodel of multimodal human-computer interaction [19]. The overall goal is to convey knowledge in interactions rather than static data. *EduGameLevel* comprises previous modeling primitives in order to provide inherent mechanism for game progress as well as creating a sense of achievement. It also allows creating games at multiple scales of knowledge and skills.

4.1 Knowledge Metamodel for Educational Game

In this paper, we will focus on knowledge modeling for educational games. Further development of knowledge metamodel for educational game should provide a good basis for modeling domain knowledge and integration with the game. Model should enable manageable learning path, through the game, as well as knowledge reusability. In addition, model must provide the ability of knowledge assessment and integrating that assessment with the game.

In order to structure domain knowledge, we introduce basic metamodel shown on the Figure 2. *EduGameKnowledge* consists of *EduGame KnowledgeCategory*, which defines hierarchy of knowledge, and contains zero or more domain models.

Domain model represents a specific knowledge area and consists of Domain Concepts, which are self-related. Domain Concept represents a specific unit of knowledge that constitutes a building block of mentioned knowledge area. Relation between Domain Concepts has two important aspects. If concept relates to other concept, than correlation attribute will have value between zero and one (one for exactly the same concept and zero for non-related concepts). Second important relation is prerequisite, which signifies concepts that must be adopted before related concept.

We define *EduGameLO* (Educational Game Learning Object) and *EduGameAO* (Educational Game Assesment Object) to introduce a relation between game and knowledge. One *EduGameLO/EduGameAO* is related with one or more Domain Concepts. Finally, *EduGame Scene* consists of zero or more *EduGameLO* and zero or more *EduGameAO*. Inspiration for using the name *Scene* came from the field of movies. As in movies, scene represents an integral set of constituting parts that are presented to the viewers as a whole. In educational games domain, scene represents a composition of learning materials and assessments, that have a specific educational purpose, but its presentation depends on many different factors. Adequate interaction with learner required from us to develop another part of our framework, targeting Game Interaction [20].

Major benefit of our metamodel is that construction of educational games is driven by “learning scenario”, which actually defines domain concepts and learning path that learner should adopt. Less experienced educator can construct educational game, simply relying on domain model developed by experts in specific knowledge area, utilizing already established relations between concepts for given domain model.

On the other side, established relation enables us to create transformations on lower MDA levels, in order to automatically generate *EduGame Scene*. Educator can define "learning scenario" (or use existing one from repository), and educational game will be generated (by use of game template from repository). *EduGame Engine* can generate adequate *EduGame Scene*, by choosing Learning and Assesment Objects, and pass it to *EduGameInteraction* for presentation to learner.

Next model (Fig. 2) gives in more detail specification of Learning and Assessment Objects. Although learning and assessment is often overlapping, in our model we distinguish between Learning Object and Assessment Object. In this way, we can achieve separated management of learning and assessment paths, as well as easier manipulation by computers. Specific nature of educational games leads us to separation of LO and AO. In order to keep learners motivation high, game should provide a sense of achievement. Learner should be provided with a challenge adequate to his current knowledge state, which is established by use of AOs. Game platforms enable implementation of assessment objects which are different than in classical eLearning (for example mini-game inside the game which will verify acquired knowledge or skills). Finally, for learner this separation does not have to be so clear, since advanced educational games should mix these two concepts and blur the separation line between them. Further, *EduGameLO* can be Simple or Complex type. Simple LO can be: *TextEduGameLO*, *PictureEduGameLO*, *VideoEduGameLO* or *AudioEduGameLO*. *ComplexEduGameLO* represents any combination of Simple Learning Objects as well as combination with other Complex Learning Objects. *EduGameAO* has same specialization, as *Simple* and *Complex EduGameAO*.

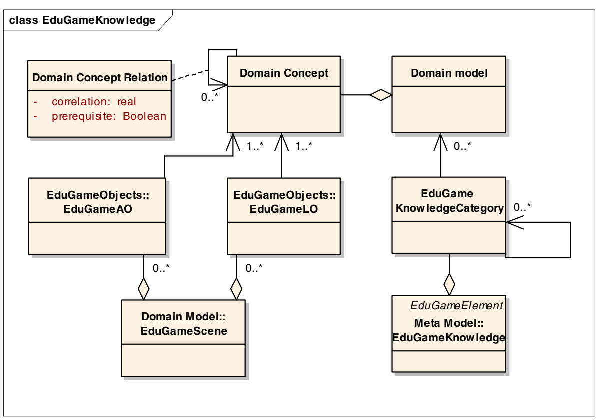

Fig. 2. Educational game knowledge metamodel

We decided to continue specializing simple AO into *Question, Simulation, Puzzle* and *Mini-game*. *Question* covers all standard question types for knowledge assessment (like multiple-choice or free-text question). *Simulation* represents a specific kind of assessment, where learner has some kind of mini-model for manipulation and has to use it in order to solve a given problem. *Simulation* is particularly convenient for skill assessment. *Puzzle* refers to a group of tasks described as logical assignments or logical hurdles. *Mini-game* is assessment object in a form of a game. Important characteristic of every assessment object is to provide *EvaluationPoints* value (for example, at implementation level this can be valued between 0 and 100) in order to enable verification of knowledge. *Complex EduGameAO* can be aggregation of Simple EduGameAO (mini-game for example).

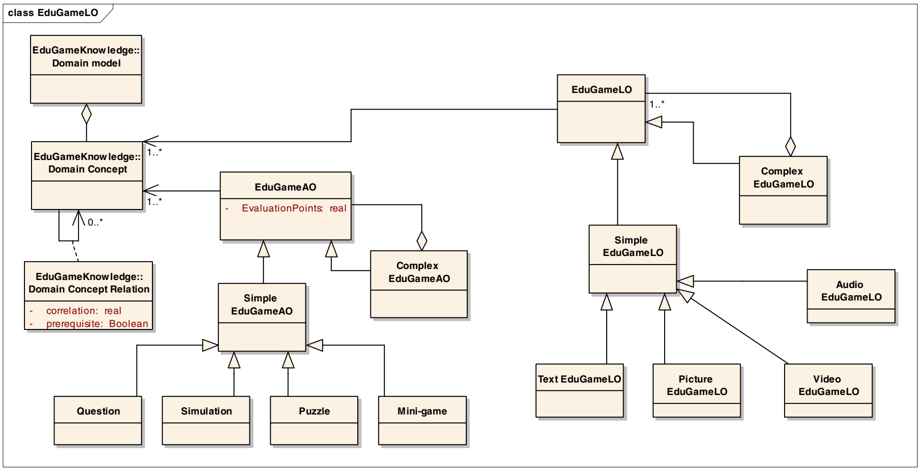

Fig. 3. Educational game Learning Object and Assessment Object metamodel

In next section we will present our design case study, where we developed educational game editor as a proof of concept, based on our metamodels.

5 Design Case Study

We have applied our approach in designing pilot project educational game editor, where educator can easily define new educational game, utilizing existing knowledge, assessment and multimedia from repository. For now, we provided support for adventure game type. For this specific game type, we use a 2D game environment.

The main idea is that learner has to solve all given quests inside adventure game world. In order to complete the quest, player (learner) must pass all assessment objects successfully. First, educator defines a map, which presents a game world environment. Upon that, he defines game regions and relations among them, and proceeds with detail definition of each region, where he can use existing learning objects or create new one for specific domain concept. Assessment objects can belong to a region, too. Also every *region* contains Non Playing Characters (NPC) that act as enemies, partners and support characters to provide challenges, offer assistance and support the storyline. After the creation of regions, we can make different avatars, assign them different abilities, and make quests and assignments for future players.

The result of the process described is a uniquely structured XML document [21], which EduGameEngine uses for interpretation and presentation to learner.

Figure 5. shows how user see interpreted adventure game, implemented as Java Applet. By advancing through the game, and by solving the quests, the player gains knowledge and learns new concepts.

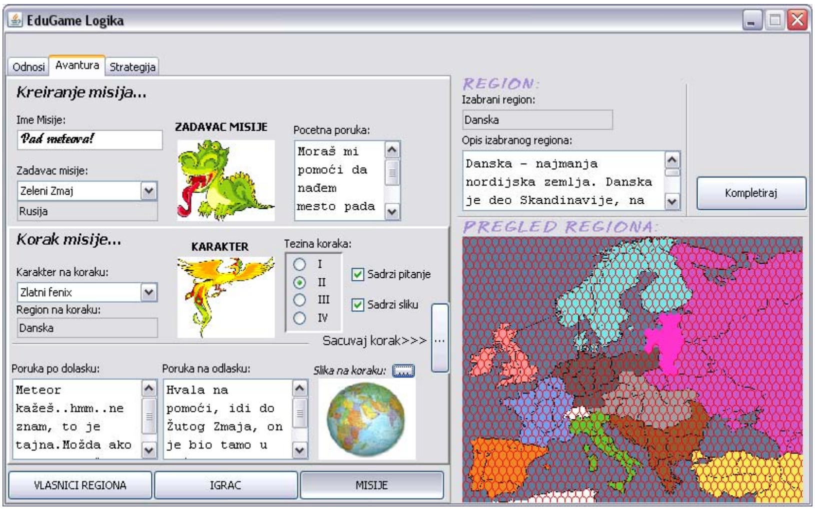

Fig. 4. Graphical editor for educational games definition

Fig. 5. Web client game interface

6 Conclusion

This paper describes our research in knowledge modeling for educational games. Extending our previous work on Educational Game Metamodel [22], this article provides further details of this approach and introduces a knowledge metamodel that enriches learning by creating platform for seamless integration between knowledge and game.

Presented models contribute to methodology of educational games development in a way that they embrace principles of learning and knowledge management early in design process. Together with metamodels for game interaction [19], this presents a step toward a unified framework for development of educational games.

We demonstrated applicability of our models in design case study, where we developed educational game editor where educator can easily define new educational game utilizing existing knowledge, assessment and multimedia from repository.

Further development will be focused on implementing XSLT transformations in order to automate Learning Scene generation. The main idea is that educator defines “learning scenario” with concepts that learner should adopt during the game, and game engine will perform the rest of the job, e.g. select adequate LOs and AOs, produce Learning Scene and present it to the learner.

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