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SERIOUS GAME DEVELOPMENT FOR EDUCATORS - A SERIOUS GAME LOGIC AND STRUCTURE MODELING LANGUAGE

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Abstract

Serious games play an important role in education. The interplay of education and gameplay induces to higher motivation of players and enhance their learning success. Serious games development implies programming knowledge and didactical knowledge. However educators are not able to develop such games on their own due to lack of programming and game design skills. In our research, we focus on a solution that allows educators with no programming skills to still create didactically sound serious games by providing a visual design tool and model driven development techniques that allow the generation of games from visual models. In this paper, we describe the first steps towards this goal, the design of the Serious Game Logic and Structure Modeling Language (GLiSMo). Therefore, we identified requirements for the development of serious games and derived language elements from them. We show the feasibility and applicability of GLiSMo by modeling an exemplary serious game scenario.

Keywords: Domain specific modeling language, serious game, model driven development, visual programming, requirements.

1 INTRODUCTION

Serious games are applications combining educational content with gameplay by integrating learning objectives into a game-like environment. Computer games keep up the player's motivation to continue playing, and hence learning, throughout the game. So, the more fun the game is, the more the players will learn, since they use the game more often and intensively. This characteristic is highly sought after in educational contexts, making serious games a big asset for didactics [1]. It has been shown, that offering new learning contents through a game not only induces higher motivation, employing serious games can also yield higher learning success than presenting material in a classical, non-computer based, way [2].

Tailoring the serious games to specific learning objectives poses a challenge for educators, as existing serious games generally do not allow adapting the content to the educators' own purposes. Therefore, to tailor serious game content, the development process must be either handed over to a professional game developer, which is associated with high cost, or the serious game must be developed by the educators themselves. However, only few people having the proper didactical background to tailor the learning objectives to the students' need also have the programming knowledge and game design skills allowing them to develop didactically and technically sound serious games [3-5]. In this paper, we argue for an approach to enable didactical experts, i.e. educators, to develop serious games adapted to their own learning content.

To address this problem we develop a tool allowing educators to visually design their serious games, which is based on model driven development techniques that allow the generation of software from visual models. In this paper we describe the first step towards this tool, the development of the underlying domain specific modeling language for the design of serious games. As the foundation of our design research, we have conducted an in-depth literature review to identify requirements for the development of serious games. Unfortunately, existing research on those requirements is very sparse, literature mostly focuses on influencing factors in serious games, which directly or indirectly affect the motivation and learning success of players. Based on these influencing factors, we have deducted 24 requirements for the development of serious games and derived the language elements for our domain specific modeling language from them.

This paper is organized as follows: section 2 gives a brief introduction to model driven development and lists its advantages for educators. In section 3 our literature review concerning the derivation process of serious games requirements is described. Section 4 gives an overview of existing modeling

languages for educational game development followed by the presentation of our serious game modeling language GLiSMo. In section 5 we demonstrate our language by modeling an exemplary serious game scenario. Finally conclusions are given in section 6.

2 MODEL DRIVEN DEVELOPMENT

Model Driven Development (MDD) is a methodology in software engineering, which consists of techniques for automated generation of software code from formal models. Domain-Specific Modeling Languages (DSMLs) are formal languages designed and implemented for a specific domain to formalize the application structure, behavior and its requirements. In our case the domain is serious gaming, the elements of the DSML include elements needed to include game-related functionality as well as elements representing didactical concepts. In MDD, applications are modeled at a higher abstraction level instead of writing code in a programming language. The necessary generation of source code is handled by the so-called transformation engine and generator that render the model into compilable code. Consequently, all changes made to the software will be made by updating the model [6].

Model Driven Development for serious games has several benefits for educators. The use of a DSML allows educators to focus on creating models representing their didactical goals and frees them from the task of programming or worrying about technical details. This higher level of abstraction of dealing with models instead of source code allows easier maintenance and documentation of games, which is highly desirable for any educators [6]. To further support the non-technical expert, in our case the didactical expert, a visual serious game editor can be developed based on the DSML. Such a visual editor would allow the creation of even complex serious games by just dragging, dropping and connecting visual elements on a canvas. To systematically develop the GLiSMo modeling language, we follow the approach as described by Mernik et al. (2005). They argue for a process comprised of the following five phases to develop a domain-specific language: (1) Decision, (2) Analysis, (3) Design, (4) Implementation and (5) Deployment. In the first two phases the problem domain is identified, analyzed and domain knowledge is gathered. In the design phase the DSML is developed by defining the syntax and semantics of the language. In the following implementation phase the associating transformation engine and generator will be developed. Finally in the deployment phase the DSML will be used [7].

This paper describes the first three phases of this development process. We have identified and analyzed the domain of serious games and gathered domain knowledge by deriving requirements for our language. This derivation process will be depicted in the following section. Finally the design phase is executed in section 4.

3 DERIVING REQUIREMENTS FOR A DOMAIN SPECIFIC MODELING LANGUAGE FOR SERIOUS GAMES

During our research we have found little related work dealing with modeling languages for game based learning, which will be described in section 4.1. To identify requirements for the development of a domain specific modeling language for serious games an in-depth literature review was conducted. To identify publications covering requirements for serious games or domain specific modeling languages for serious games, we searched the ScienceDirect and IEEE Xplore Digital Library databases using the individual search strings "*serious game requirements*", "*game based learning requirements*" and "*domain-specific language serious game*". In our search, we did not find any publications explicitly dealing with requirements for serious games or a DSML specifically designed for serious games. However some publications mentioned influencing factors in serious games, which directly or indirectly affect the motivation and learning success of players/learners. As no publications directly listed requirements, we decided to adapt our approach and derive requirements for serious games from the influencing factors mentioned in literature and use these requirements as the foundation for designing GLiSMo. We hence compiled a list of these factors adapting our search strings to *"serious games OR digital game based learning"*. After filtering the 1246 papers found this way by analyzing their title and abstract, 107 papers remained for detailed analysis. After having read these papers we identified 18 publications mentioning influencing factors for serious games. Table 1 shows an overview of the identified influencing factors. The factors are clustered into seven categories, namely: (i) learning, (ii) restriction, (iii) communication, (iv) assistance, (v) goals, (vi) adaptation and (vii) representation.

Table 1. Influencing factors in serious games

Category	Influencing factor
1. Learning	Learning objectives [8, 9]
	Didactical model or approach [10-15]
	Transfer of learned skills [13, 14]
	Situated and authentic Learning [13]
2. Restriction	User freedom [8, 16]
	Learner control [13, 16]
	Rules [8, 16, 17]
3. Communication	Communicate with environment [18]
4. Assistance	Intermittent and immediate feedback [12, 13, 15, 19, 20]
	Assessment and measurement of progress [14, 21]
	Rewards and achievements [13, 22]
	Help and support [13, 14]
5. Game Goal	Solvable Problems [8, 15, 21, 22]
	Clear and understandable problems [15]
6. Adaptation	Accommodating learner's styles [13]
	Adjust to skill of the player [18]
	Challenging with ideal amount of difficulty [16, 17]
7. Representation	Multimodality [14, 16, 23]
	Immersion [10, 11, 24]
	Curiosity and Surprise[16, 21, 22]
	Identity [11, 20]
	Objects and characters [17]
	Virtual world and location [8, 16, 17, 21, 25]

3.1 Learning

The first category *learning* describes influencing factors that relate to the didactical concepts of serious games. It is said that a serious game should base on *didactical models or approaches* to effectively achieve learning success [10-15]. A serious game based on learning theories has to incorporate three different types of learning processes which determine the way player objectives are designed: associative (task-centered), situational (social aspect) and cognitive (constructivist) objectives. This means:

Requirement 1: A serious game must provide object-focused interaction-mechanisms and could give the possibility to learn/play in social groups.

Furthermore it is said that the ability to practice and drill learned contents is an important characteristic of serious games [10-15]. This leads to the following requirement:

Requirement 2: A serious game should convert a difficult learning objective into repeated game tasks to enhance knowledge retention.

Another influencing factor is the design of *learning objectives*, which should be constructed in a way that all actions in the game will lead to fulfillment of these objectives [8, 9]. In order to introduce new learning objectives to the player a serious game has to communicate problems and learning centered content. To do this a serious game has to have different mechanisms to communicate directly to the player. Objectives can be introduced by NPCs, objects or the game itself. Technically there have to a facility to show text in the game, a dialog system for NPC interaction and an event handling system. The derived requirement is:

Requirement 3: A serious game must have player-world interaction mechanisms to introduce learning objectives to the player.

Another influencing factor is the *transfer of learnt skills*. This again is divided in transfer of learnt skills i) from previous task to a following task, ii) real world to serious game world and iii) serious game world to real world [13, 14]. Serious games should provide a progressive way of incremented use of

new skills. This requirement has a deep impact on level and objective design. From this the following requirement is derived:

Requirement 4: A serious game should provide a progressive way of incremented use of new skills.

The last influencing factor in this category is *situated and authentic learning*. This describes the ability of the learner to relate the in-game world to the real world [13], which leads to the requirement:

Requirement 5: A serious game must provide players virtual worlds they can relate to and match to the represented content.

3.2 Restriction

The second category deals with *restriction* in serious games as well as for the player. *User freedom* is one influencing factor, which describes the player's degree of freedom of action within the game [8, 16], whereas *learner control* highlights the ability to self-explore the environment based on individual pace and experience [13, 16]. The following requirement is:

Requirement 6: A serious game must provide game mechanics to enable the player to have control over his gaming experience and to explore the virtual world.

Rules are an important component of serious games and determine what the player is allowed to do and not. Furthermore they provide the player with the necessary information on how to win the game and define guidelines on how to engage in tasks. This makes rules essential to good gameplay. Rules must be dictating building parts of the player environment [8, 16, 17]. This induces the following requirement:

Requirement 7: A serious game must base on game rules.

3.3 Communication

The third category *communication* contains one influencing factor named *communicate with environment*, which describes the ability to interact and talk with other characters within the game or with other players. The derived requirement is:

Requirement 8: A serious game should allow the player to communicate with characters within the game.

3.4 Assistance

The fourth category combines influencing factors that deal with *assistance* within serious games. Serious games should challenge the player with problems that can be solved by exploring information in the virtual world. The player needs information from and of the virtual world that helps him orientate and solve problems and get feedback of the player's state and progress. Feedback needs to be specific to the three different types of learning processes. Through *intermittent and immediate feedback* the learner gets reflection on what has been reached so far during game play. It is a key aspect of interaction and influences the motivation of the player [12, 13, 15, 19, 20]. This leads to the following two requirements:

Requirement 9: A serious game must have a feedback system to give feedback on user actions.
Requirement 10: A serious game must have a Graphical User Interface (GUI) system to show texts and textures.

Another kind of feedback is *assessment and measurement of progress*, which informs players about their level of performance, e.g. by showing scores [14, 21]. Furthermore the learners' motivation will increase by giving *rewards and achievements* [13, 22]. To maximize player motivation and minimize frustration an achievement-system will encourage players in fostering their learning experience and can strengthen replayability. Furthermore it is said that assessment is one characteristic of serious games, which contribute to learning [26]. So, the following requirement is derived:

Requirement 11: A serious game must have a system to assess and measure learner's progress.
Requirement 12: A serious game must have a system to manage achievements.

It is also said in literature to give additional guidance during learning with *help and support* strategies [13, 14]. This can be supported by the feedback system described in Requirement 9.

3.5 Goal

The fifth category *goal* describes influencing factors that deal with the design of tasks and their goals. All tasks must start with a problem which has to be solved. These goals should be *solvable*, so that the player is able to complete the task [8, 15, 21, 22]. Furthermore each task should have *clear and understandable problems* [15]. Goals represent the end-state of a solved problem. Goals must be designed in a way that enables players to gain insight in the steps necessary to achieve them. Goals need to be achievable by the player at his current state of learning. This indicates the need for well-designed tasks and leads to the requirement:

Requirement 13: A serious game must have solvable, clear and understandable goals.

3.6 Adaptation

Adaptation is the sixth category of influencing factors in serious games, which is also crucial for the contribution to learning [26]. This contains *accommodating learner's style*, which means that the game needs to adapt to different learning types [13]. This makes a diverse learning-objective and task design necessary and induces this:

Requirement 14: A serious game should accommodate to learner's style.

Another influencing factor is *adjust to skill of the player*, which describes adjustment to player-specific learning behavior. Serious games need to adapt to players' learning behavior and their current skill state. Serious games need a system to measure players learning progress and playing style to minimize frustration and to ensure a balanced player specific learning challenge.

Requirement 15: A serious game must have a system to measure players' learning progress and adjust to learner's skill.

The last influencing factor in this category is *challenging with ideal amount of difficulty*. It is said that the game must have the possibility to adjust the difficulty of tasks, so that enough challenge is given to increase learning success [16, 17]. The derived requirement is:

Requirement 16: A serious game must have different difficulty levels to solve tasks.

3.7 Representation

The last category contains influencing factors dealing with *representation* in serious games. *Immersion* means, that a player has an increased sense of presence within the game, leading to higher motivation to succeed in the game [10, 11, 24]. Serious games differ from other games in their content-specific nature. This indicates that players must have a high amount of intrinsic motivation and engagement to the specific content. Both of these factors are necessary for the game to be effective. This leads to the following requirement:

Requirement 17: A serious game should have game world which reflect the content they represent.

The presentation of content knowledge within a serious game with a combination of visual, auditory, haptic, and other sensory modalities is called *multimodality* and is another influencing factor leading also to higher motivation [14, 16, 23]. In order to ensure an authentic learning and gaming experience content needs to be represented through sensory modalities. This induces the following requirements:

Requirement 18: A serious game must have the ability to display videos.
Requirement 19: A serious game must have the ability to play audio.

Through incorporating the players identity into the virtual world serious games can establish a personal relationship with the player. This can strengthen the player's motivation to engage in the game [11, 20]. This induces the following requirement:

Requirement 20: A serious game should have a character to which the player can identify to.

Objects and characters are integral part of the virtual world and can hold information or objectives for the player. Furthermore the player is able to interact with them [11, 20]. The derived requirement is:

Requirement 21: A serious game must have objects and characters.

Curiosity and surprise is one of the primary factors that advance learning. Exploring is based on curiosity and serious games need to foster the player's motivation and curiosity to explore [16, 21, 22]. This indicates the need for the following requirement:

Requirement 22: A serious game must have virtual worlds that are authentic and exciting for the player with curious and surprising elements.

Virtual world and location in serious games need to be designed in a way so the player can get insight in the state of the world. As virtual worlds are limited in time and space, there are no consequences for player decision which can foster motivation to explore [8, 16, 17, 21, 25]. The derived requirements are:

Requirement 23: A serious game should have a virtual world parallel to the real world without having consequences on the real world.

Requirement 24: A serious game must have a virtual world limited in space and time.

4 GLISMO: SERIOUS GAME LOGIC AND STRUCTURE MODELING LANGUAGE

GLiSMo is a serious game modeling language, which allows designing the structure as well as the logic of a serious game. The structure describes how a serious game is built, whereas the logic characterizes the behavior of a serious game. We have designed our language based on the raised requirements from section 3. Our idea was to analyze all requirements individually and derive language elements which support the fulfillment of these requirements. During this process we have noticed, that the requirements 2, 4, 7 and 13 can only be fulfilled by the educator, who designs the game, as they have no direct influence via structure or logic elements. The educator has to consider these requirements during the game development.

4.1 Existing Serious Game Modeling Approaches

As mentioned earlier, only little research concerning modeling languages for serious games can be found in current scientific literature. Tang & Hanneghan (2008) propose a domain specific modeling language for serious game design allowing data and visual modeling. They describe data modeling as the definition of objects, flows and processes and visual modeling as the positioning of in-game components within the game world [27]. Considering our serious games requirements from section 3, this language does not fulfill the following requirements: 9, 11, 12, 13, 14, 15, 16, 18 and 19. Especially requirements relating to assessment and adaptation in serious games are crucial and not supported by this language.

Gomez-Rodriguez et al. (2011) present another solution named GAM-ING, which is based on INGENIAS, an Agent Oriented Software Engineering methodology. As stated by the authors the main focus of their work is to allow the specification, design and development of actors, scenes, context, light, cameras, and environment of a serious game by using different types of meta-models [28]. Nevertheless the following requirements are not met by GAM-ING: 7, 9, 10, 11, 12, 14, 15 and 16. Furthermore this solution is rather complex for non-technical educators.

The story-flow language designed by Marchiori et al. (2011) aims at developing narrative educational games based on game storyboards, which are represented by a visual language. This language allows to model potential actions of players and their consequences to give an abstraction of the story-flow, which can be automatically transformed into playable 2D educational video games [29]. As stated by the authors, this language is only for narrative educational games focusing on the description of the game behavior and thus does not allow the design of a game world. This induces that this language does not meet the following requirements: 3, 5, 6, 8, 17, 22, 23 and 24.

The presented modeling languages have several weaknesses and disadvantages by not meeting our requirements for serious games. This induces the need for a DSML for serious games, which language elements should be derived from the requirements described in section 3. In the next section we introduce GLiSMo our domain specific modeling language for serious games.

4.2 Serious Game Structure Modeling

Serious game structure modeling contains the layout of the game world, which characters and objects are included, how the User/Player interaction takes place. In the following sections, GLiSMo's

structural elements will be described. The *Serious Game Root* element, present once for each game modeled, plays a special role, as it is the point of origin for all other elements. This means that all elements directly or indirectly connected to this serious game root element belong to one serious game.

Acts and Scenes: The requirements 5, 17, 22, 23 and 24 relate to the virtual world design in serious games, which must be authentic and limited in space and time. From these requirements we have derived two language elements called *Act* and *Scene*. Serious game root elements can have one or more acts, which have similarities to levels in common games. They represent a major part within the story having one or more goals and are divided by one or more scenes. A scene describes a specific place within the game world. This can be for example a room within a building or grassland. Scenes have three attributes called *name*, *position* and *scale*. The name attribute contains a name describing one specific scene within the game. The position and scale attributes contain the coordinates and size of that scene within the game world. These attributes are also present in the following Object, Character and GUI Manager elements.

Objects: Requirements 1, 3, 5 and 21 describe the need for player and game world interaction. This includes also the presence of objects in the game world with which the player can interact with or which are used as decoration. Therefore we have designed the element *Object*. This element represents all kind of objects within the game world, i.e. doors, boxes, trees or other special objects that will enhance the skills of the player. A scene can contain several objects.

Characters and Inventories: The requirements 3, 20 and 21 highlight the need for characters in serious games. The derived *Character* element represents on the one hand the player itself. On the other hand it represents all social beings within the game world. This can be humans, animals or any other living beings representing a Non Player Character (NPC). A character can be defined for the whole game, for acts only or in the scope of a specific scene. Besides the default attributes the character element contains the attribute *isNPC*, which determines if a character is controlled by the player or not. Considering the requirements which demand a player and game world interaction we also introduce an *inventory* element for storing objects taken by the player. These objects can be used at a later time within the game progress. Each character can have one or more inventories. An inventory contains the attribute *objectList* which stores all collected objects of the character.

User Feedback and Rewards: The requirement 9 emphasizes the importance of a feedback system for serious games, to give feedback on players' actions. Therefore we have derived the element *feedback manager*, which manages the textual feedback given to the player. Each time a player accomplishes a task the evaluation of his performance will be shown through the feedback manager.

Requirements 11 and 12 relate to the assessment and measurement of user performance including the management of achievements and rewards. To motivate the user to continue playing the game, good learning performance should be rewarded. Therefore, we have derived the element *Reward Manager* which manages the scoring and rewarding within a serious game. This element contains two attributes *scoreList* and *rewardList.* The scoreList consists of all completed tasks and the associated scores. Analogously, this applies to the rewardList, too.

User Interface Management: Requirements 18 and 19 demand the ability to play videos and audios within serious games. For this purpose we have derived two language elements named *Audio Manager and Video Manager*, which allow the playback of audio and video. Audios and videos can be played as intro and outro of a game, an act or a scene. Furthermore, specific actions or events can also trigger the playback of audio or video. The video manager contains the attributes *videoSrc,* which references to the video file, and *isLoop*, which tells if the video is played in a loop. Analogously, this applies to the audio manager with its attributes *audioSrc* and *isLoop.* The *GUI Manager* follows from the requirement 10, which tells that a serious game must be able to show texts and textures. It is used to display buttons, textboxes, scores or the game menu. Besides the default attributes it additionally has *content*, which contains text or a reference to an image.

4.3 Serious Game Logic Modeling

Serious game logic modeling characterizes the behavior in terms of how does the game react on specific actions performed by the player, or events occurring during game play. The logic also describes the assessment of player actions and the game adaption according to the adaption results. Just as described in section 4.2 for the structure modeling, we have derived the logic modeling elements from the serious games requirements.

States: To define the boundaries of a logic model, we denote the *initial-state* by a black circle; *final-states* are represented by an encircled black circle. This follows the notion already known from UML activity diagrams.

Actions, Assessments and Adaptation: Requirements 3, 6 and 8 describe the need for a mechanism to enable the player to interact with the game world. Therefore we have derived an element called *action.* This element has different types, e.g. *select object*, *take object, use object, put object, discussion with character,* representing different interaction methods in the game world.

Requirements 9 and 11 demand, that a serious game must have assessments. A prerequisite for assessment is the existence of tasks. Therefore, we have introduced the element *task*, which represents different tasks, i.e. multiple-choice questions. The associated *assessment* element evaluates the result and initiates processes to give feedback and achievements to the player.

Requirements 14, 15 and 16 describe the need for an adaptation method for serious games. The intention is to monitor the player's learning progress and adjust the learning content and its difficulty to the player's skills. This can be done by simply letting the player select the difficulty level at start and based on this selection a predefined game content will be presented. Another way is to provide different tasks with various difficulty levels and dynamically chose the right task on the basis of previously scored points.

Information and Control Flow: To manage the information and control flow, we use so called *streams*, a continuous arrow, to connect the elements. To make a progress along the control flow the player must execute the described actions. To send *events and messages* between elements a dotted arrow will be used. Furthermore *fork and join* as well as *branch* elements are used to manage parallel and branched flows.

5 EXPLORATION OF A MULTIPLE-CHOICE LEARNING SCENARIO

To give a first evaluation of GLiSMo's feasibility to model structure and logic of a serious game we describe a multiple-choice task as an exemplary learning scenario including. The scenario takes place at a company where the player character is representing a trainee. He finds himself in a hall, which is connected to two rooms. One is an office with a NPC, furniture and a computer, the other is a storeroom with a box which contains four computer parts. Furthermore, the NPC holds the key for the storeroom. The first goal is to talk to the NPC and learn about the task. The task is to repair the computer. Therefore the player should get the key from the NPC, open the storeroom and get a specific computer part from the box. This computer part has to be handed over to the NPC, which will check if the correct part was brought. If this is incorrect, then the NPC will give feedback telling him to go back and bring the right part. As soon as the task is accomplished correctly, this scenario ends. Fig. 1 shows the structure model and

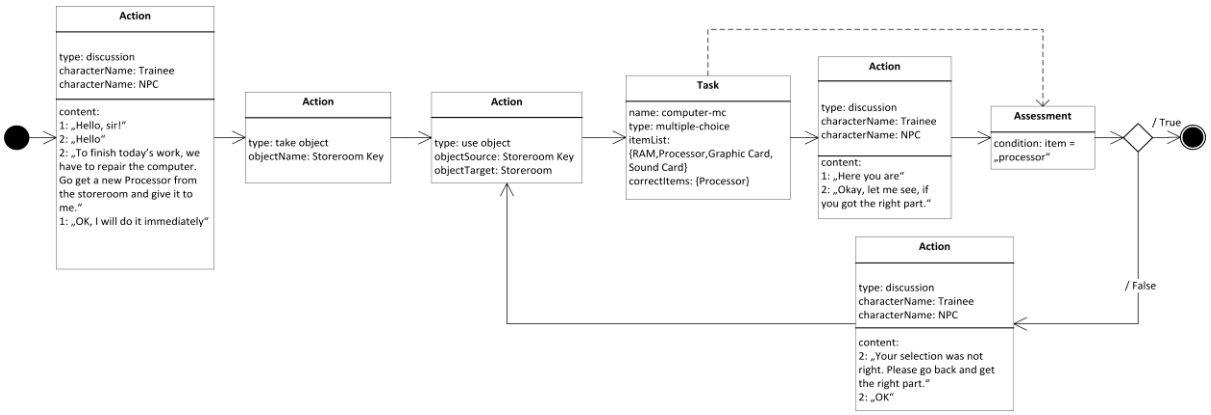

Fig. 2 the associated logic model of this described scenario. As this is just a demonstration, the position and scale attributes are not mentioned in this example.

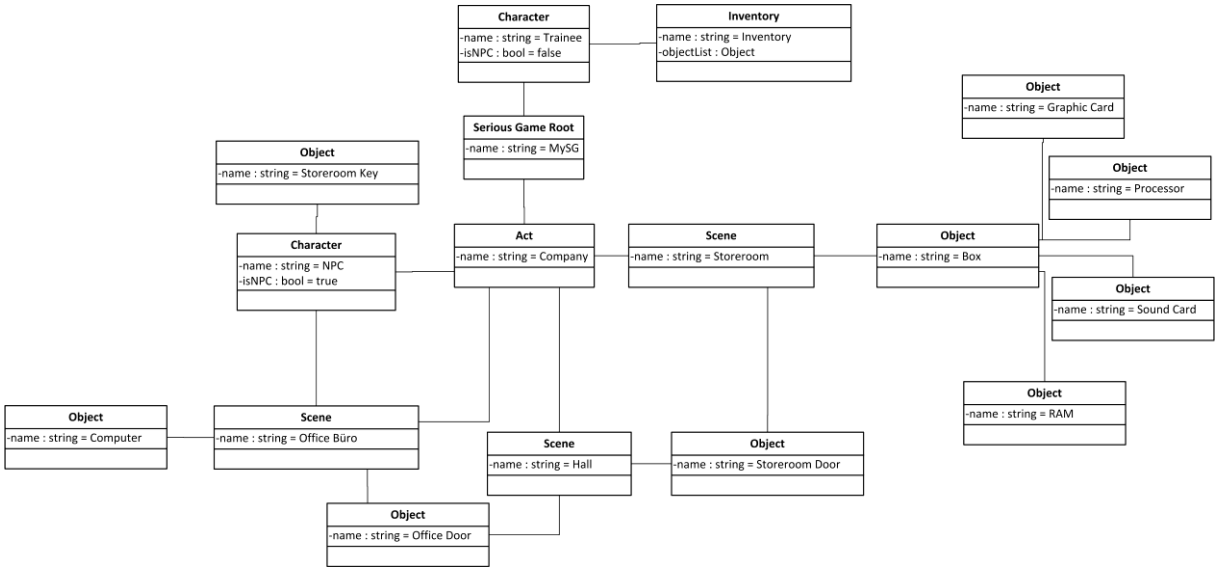

Fig. 1. Structure Model of an exemplary serious game scenario

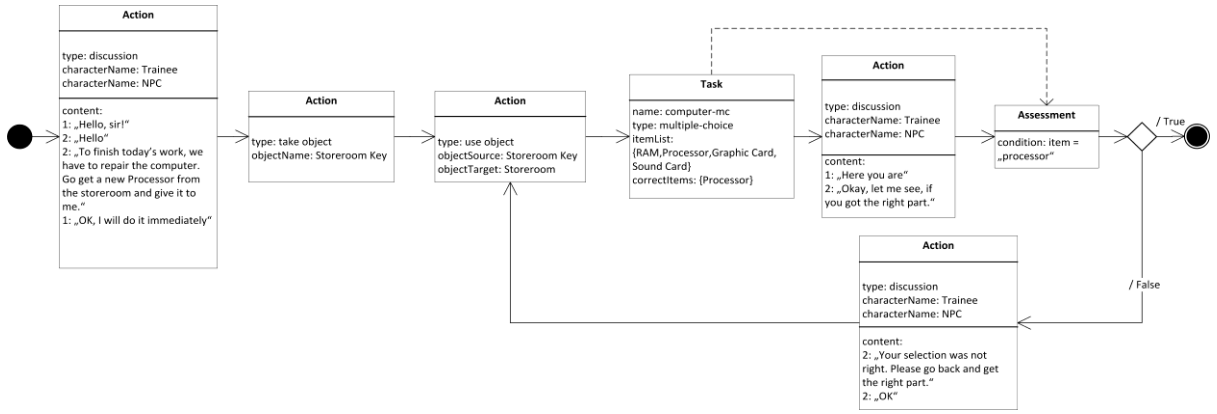

Fig. 2. Logic Model of an exemplary serious game scenario

6 CONCLUSION AND FUTURE WORK

Supporting educators design serious games through model driven development techniques is a very promising approach. In this paper we proposed our first steps towards a domain specific modeling language for serious games (GLiSMo), which enables non-technical domain experts without programming and game design skills to model serious games. We identified several requirements for serious game development and from them we derived the language elements for GLiSMo. We showed the feasibility and applicability of GLiSMo by presenting an exemplary serious game scenario modeled with our language. Future work includes the extension of the modeling language with more elements supporting different tasks and assessment methods. Furthermore GLiSMo must be evaluated with educators to determine its usability, by letting educators model serious games. In parallel a visual design tool for GLiSMo will be implemented, including a software code generating component, to model and develop serious games.

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