ADAPTIVITY IN STORY-DRIVEN SERIOUS GAMES

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ABSTRACT

Learning is an important part of our society and the search for good learning tools and environments is an ongoing debate. Serious Games are often suggested as they are able to promote active and reflective learning (Conle 2003, Eisner 1997). However efficiently creating effective serious games is hard. On one hand they should be tailored to the learner's needs in every possible way, on the other hand they should tell a story that goes hand in hand with the content taught. Therefore changing the content directly results in a need for changing the story. Doing this without breaking the narrative can be very hard. In this paper a model for representing stories is suggested that allows for selecting the best learning path based on inferences made about the learner with the Knowledge Space Theory.

KEYWORDS

Serious Game, Learning, Knowledge Space Theory, Story, Adaptivity

1. INTRODUCTION

…to a particular person, the meaning of an object, event, or sentence is what that person can do with the object, event, or sentence. (Barsalou 1999, p.77)

Supporters of the serious game movement argue that serious games are able to promote active and reflective learning (Conle 2003, Eisner 1997) while at the same time providing motivation. The narrative of serious games strongly influences the efficiency of the learning experience. A story that is integral to the learning content of the game and does not only serve as some kind of sugarcoating carries the learner's motivation and aids in comprehension (Dickey 2006, Rieber 1996, Laurillard), as meaning can only be developed "bottom up via embodied experiences" (Gee2007, p. 105). A well developed story can provide a context for the content and thereby provide the learner with an opportunity to collect embodies experiences, which allow him in the long run to gain a more abstract knowledge about the topic. Such a story is however neither easy to design nor to implement, especially for serious games.

When utilizing the computer as a learning tool only making use of its multimedia support does not exploit its full potential, instead its potential to adapt to a learner should also be integrated. However adapting the content in a learning game with a story that is interweaved with the content poses the problem that one cannot simply exchange the content anymore. Instead the whole story needs to change without breaking the narrative.

In this paper we address this problem by combining the Competence-Based Extension of Knowledge Space Theory (KST) in combination with a flexible data structure for presenting storylines.

2. COMPETENCE-BASED EXTENSION OF KNOWLEDGE SPACE THEORY

The Knowledge Space Theory (KST) was first suggested by Doignon and Falmagne in 1985 with the original objective to assess knowledge efficiently and adaptively on a purely behavioristic basis (Falmagne & Doignon 1985, Falmagne et al 1990). It was later extended (Albert) to allow the prediction whether a learner can solve a given problem correctly by separating observable performance, i.e. test item solving behavior, from the underlying competencies (Hockemeyer 1997, Albert & Kaluscha 1997) whose dependencies are represented through prerequisite relationships. A function defines the relation between problems and performance. This made it a viable tool for determining the best learning path for a learner.

Extended Knowledge Space Theory deals with a set Q of assessment problems, a set L of learning objects (LO) and a set S of skills relevant for solving the problems and taught by the LOs. The relationship between assessment problems and skills can be formalized by the skill function (Hockemeyer 2003), which associates each problem with a collection of subsets of skills, which are sufficient for solving the problem. Learning objects are additionally assigned a set of skills they teach, allowing for suggestions of learning paths.

Consider the set of skills $S = \{w, x, y, z\}$

w) Resolving brackets
x) Addition of natural numbers
y) Multiplication of natural numbers
z) Application of the precedence rule $\cdot$ before $-$

and the set of problems $Q = \{a, b, c, d\}$ and

- $a{:}\,7 + 2$
- $b{:}\,4 \cdot 3$
- $c{:}\,7 + (2 \cdot 3)$
- $d{:}\,4 + 6 + 2$

Which lead to the skill function s, where

- $s(a) = \{\{x\}\}$
- $s(b) = \{\{y\}\}$
- $s(c) = \{\{x, y, z\}, \{w, x, y\}\}$
- $s(d) = \{\{x\}\}$

Looking at the example we can observe two aspects of the competence-based extension of KST: First, some tasks can be solved through different skill sets, for example the calculation $7 + 2 \cdot 3$ can either be solved by a student who can resolve brackets correctly or by a student who knows the precedence rule. Addition and multiplication are required for both solutions. Second, not all combinations of skill sets are possible, as there is no problem that only requires the knowledge of z. Instead, every problem where z needs to be used, also requires knowledge about x and y, which are hence called prerequisites of z. Those dependencies cannot only be induced indirectly from the assessment of skills to problems, but also explicitly. When talking to teachers or other domain experts for example one might realize that addition is a prerequisite for learning multiplication. This ordering on skills is called competence structure.

Formally this competence structure can be represented through a surmise system where each skill is assigned collection of subsets of skills, called clauses. Learning a skill then requires knowledge about all skills in at least one of its clauses. Based on a surmise system, adaptivity can be realized by deriving the current competence state from patterns in answers to assessment problems. The fringe of the competence state is the set of all skills which distinguish the knowledge state from its direct neighbors in the competence structure (Hockemeyer 1997). The next learning object is then chosen to deal with a skill from the fringe.

3. MODELING A FLEXIBLE STORY

KST is a useful presentation for knowledge that can drive adaptive systems. But in order to guarantee that tailoring the selected problems does not break the narrative, an additional structure is required, which defines dependencies and mutual exclusions between the quests that make up the story. This structure should also support different ways of storytelling:

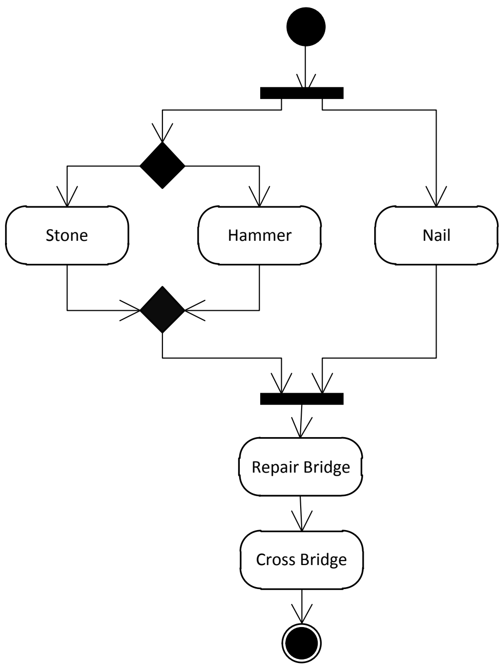
- Linear stories where only one quest is available at a time and the next quest follows as soon as its predecessor has been solved.
- Non-linear stories where the player can pursue more than one quest at a time, which gives more freedom of choice to the player but disallows repeated playing of a quest.
- Exploratory stories where more than one quest can be pursued at a time and quests that were available once stay available.

We present this data structure as a directed graph consisting of quests and various types of "play conditions" used to connect quests:

- SEQ for linear progression through a number of quests
- AND for requiring all predecessors of a quest
- OR for requiring at least one predecessor but still allowing other predecessors to be solved
- XOR for requiring exactly one predecessor, mutually excluding other predecessors
- NOOP for optional side quests

These directed graphs can easily be displayed as an UML Activity Diagram, as seen in Figure 1.

Figure 1. Filled diamonds represent "OR", filled rectangles "AND" connectors in this extract of a story where the player needs to gather tools to repair a bridge.

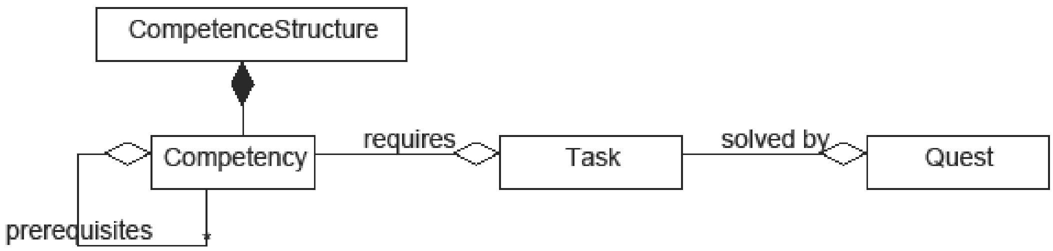


4. INTERPLAY BETWEEN KST AND STORY STRUCTURE

During the game the story structure is used to guarantee a consistent narrative. Every time a player solves a quest it is used to determine which quests should be available next. Whenever some quests are mutually exclusive the system uses the fringe of KST to determine which of them should be taken next based on the problems required to solve it (Figure 2). For example two quests are available, one that requires subtraction and another that requires multiplication. If student A has already proven that he knows addition and subtraction, the game would provide him with a quest that trains multiplication, which the system assumes to be in his zone of proximal development. For student B who hasn't mastered subtraction yet, the quest where subtraction is practiced will be selected. The fringe also contains competencies, that have been learned recently. Therefore if a third quest featuring addition would be available the system could also decide to repeat this content for student A.

In non-linear or exploratory games the quests are activated, which can for example be seen by highlighting them on the map, making available new dialogs or simply adding them to a quest journal. The player can then decide on his own, which quest he wants to pursue next. In linear games this decision is taken over by the system, again applying KST.

Figure 2. UML-diagram presenting the connection between Competency Structure and Story Structure. Each quest is assigned with tasks that are pursued to solve the quest.



5. CONCLUSION

In this paper we presented a model which allows for macro-adaptivity where not only the difficulty of the task, but also the type of task presented are selected according to the learner's skills, while at the same time keeping the story aligned with the content to be taught. The model is applicable to multiple types of games including adventures, role-playing games, and also simulations.

While the data structure allows for the creation of quests that can be solved with two different sets of skills it is not possible to determine which of the skills the learner actually used to actually solve it. This makes it very hard to determine his competence state. These findings call for further research to analyze the current competence state despite ambiguities.

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