SERIOUS GAMES ON MULTI TOUCH TABLES
FOR COMPUTER SCIENCE STUDENTS

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Abstract: Within the project IGaDtools4MINT one of our goals is a pedagogical redesign of the introductory phase of CS studies. This paper describes an approach to develop and use serious games on multi touch tables to support collaborative learning processes at university. After giving a short overview over the context of the project, we briefly describe the educational and technological concepts behind the development process. As an example a multi touch application for learning resolution in propositional logic through collaboration and competition is introduced.

1 INTRODUCTION

The goal of IGaDtools4MINT is the development of a concept which contributes to the increase of the percentage of women as well as to a reduction of the drop-out rate in STEM subjects. The concept is based on the analysis of existing best practice measures and is supposed to lead to a comprehensive catalogue of measures. By this means gender-equal didactics and an opening of the faculty culture for diverse women and men is intended.

To take concrete measures a pedagogical concept with four steps was developed, which should gradually guide students from school to university:

1. Foster interest in CS for school students by providing a students' lab for CS
2. A preliminary CS course for freshmen
3. Supporting students with problems during CS courses at university
4. Integrating gender and diversity aspects during regular teaching at university

Within this, the development and use of serious games is located in step one and three. The presented multi touch application about resolution in propositional logic for example targets at university students with problems during the corresponding lecture.

2 MOTIVATION

2.1 Games in Education

While regular university courses might tend to fulfil the cliché of boring learning environments, there is a plethora of pedagogical approaches, which aim at making learning more interesting, more personally relevant and more fun. One way to achieve this is based on the usage of games.

Combining learning with gaming results in the concept of serious games, which aim at more than mere entertainment: They have an educational purpose, including teaching, training and informing its players, wrapped up in an entertaining environment (Michael and Chen, 2005).

Generally games have several aspects that make them suitable for educational purposes. Depending on the game design, serious games offer great possibilities for motivating students, promoting collaborative learning or arousing enthusiasm by using competitive elements (Hakulinen, 2011). Nevertheless it has to be kept in mind, that games, just as any other concept for motivation, are not an all-round solution and not all students can be motivated by using games, though their attitude generally is positive (Whitton, 2007).

2.2 Using Educational Games in CS

Concerning the field of computer science education the interactive learning style invites to use serious

games for algorithm teaching. Algorithms are often complicated and abstract concepts. Ergo, working with algorithms is a very challenging task for lecturers and students (Shabanah and Chen, 2010). To support the process of algorithm learning algorithm visualization is an established measure (Shaffer et al., 2007). Based on the theoretical findings of this learning approach, which is often rather passive, serious games can be used for interactive algorithm learning in computer science. Shabanah and Chen specifically highlight the benefits of using serious computer games for algorithm learning: Computer games are popular, interactive and competitive and they utilize entertainment and simplify assessment (Shabanah and Chen, 2009).

Yet, there are several different ways of using serious games in computer science education (Wallace et al., 2010):

- Playing games
- Implementing (certain aspects of) games
- Implementing a computer player for a game

While the first point is applicable for serious games in all fields, it is often neglected by computer science education as it focusses on the remaining two points. Nevertheless there are also games in which the student is the player and not the programmer.

Subsequently this paper focusses on serious computer games for computer science education where the learning of algorithms is supported by playing multi touch games.

3 RELATED WORK

3.1 Educational Background

3.1.1 Learning Models and Taxonomies

When developing games for educational purposes, several different theories can be used as guidelines for designing the learning environment:

- Blooms revised Taxonomy
- Gagnes nine events of instruction
- The Felder-Silverman learning model
- The Engagement Taxonomy

Blooms revised Taxonomy provides us with a hierarchical system for classifying learning objectives in six categories (Bloom, 1984).

With the instructional design theory "Nine steps of Instruction", Gagne provides a scheme to purposefully pursue the formulated learning objectives within the learning process (Gagne et al., 1988).

Furthermore the Felder-Silverman learning model helps us to design these steps with respect to different learning styles. This certainly has its limits within learning environments which are designed for collaborative learning, but the model helps to avoid neglecting any of these styles. One of the findings of Felder and Silverman was that most people comprehend graphical representations of certain information better than textual representations (Felder and Silverman, 1988).

This leads to using the Engagement Taxonomy during the development process (Naps et al., 2002). This taxonomy was proposed to "better communicate learners' involvement in an education situation that includes visualization" (Naps et al., 2002) and defines "six different forms of learner engagement with visualization technology" (Naps et al., 2002). For developing a collaborative serious game the research by Korhonen et al. is of great interest, as it has shown, that "the amount of discussion in collaboration is […] different between engagement levels, and increases as the engagement level increases". This research was based on the Extended Engagement Theory, which introduces more fine grained steps (Korhonen et al., 2009).

3.1.2 Intrinsic and Extrinsic Motivation

When trying to motivate students to play a learning game, two different categories of motivation should be considered that were described by Malone: Intrinsic motivation and extrinsic motivation. While extrinsic motivation is induced by external stimuli, like additional points for an exam, intrinsic motivation arises from the activity of playing the game itself (Malone, 1980). A strong positive correlation between a learning activity's potential for intrinsic motivation and the activity's learning effect is assumed (Schiefele and Schreyer, 1994).

Malone describes several heuristics for designing motivating serious games. Some characteristics are decisive for individual learning without a group: curiosity, challenge, control and fantasy. The interaction of learning in groups is targeted by different aspects like collaboration, competition and recognition (Hejdenberg, 2005). These aspects were considered when designing the different gaming modes.

3.1.3 Collaboration and Competition

Concerning the aspect of working and learning in groups, one can find slightly differing definitions for

collaboration and cooperation, although both terms are often used synonymic. Subsequently collaboration is used as the general concept of "working together", whereas cooperation specifically means situations where a division of labour takes place.

Some important positive effects of collaborative learning can be summarized as follows (Straub, 2001); (Arvaja et al., 2003):

- Being more involved into the topic.
- Process the learning content more actively.
- Support in joint critical thinking.
- Become aware of own thinking processes.

As multi touch tables inherently support collaborative work (Khaled et al., 2009), there are plenty of possibilities to use these benefits for learning processes within serious games. Still it is important to foster the process of collaboration to promote its positive effects, as learners do not necessarily interact with each other, just because the environment provides the possibility (Krejns et al., 2003).

At this point the aspects and dimensions of collaboration, identified by Meier et al., help to structure and address the different components of collaboration (Meier et al., 2007):

- Communication
- Joint information processing
- Coordination
- Interpersonal relationship
- Motivation

Opposing this, the motivating concept of competition can be divided into two categories as well: Competitive elements and social competition (Vorderer et al, 2003).

In this context competitive elements refer to situations within the game in which the player faces a certain necessity to act in a suitable way. Social competition refers to the competition between the learner as a player and an opponent, who can be either virtual or human. According to Koster, it is still an open question, whether social competition is efficient to raise motivation (Koster, 2005).

3.2 Algorithm Visualization

Against the background of the described theories, algorithm visualization is a promising way of teaching and learning algorithms in computer science education.

This approach is being used by many educators and thus a plethora of different algorithm visualizations can be found today. As Shaffer et al. found out, the quality and distribution across the topics of computer science is highly heterogeneous

(Shaffer et al., 2007). They collected over 350 visualizations and categorized them according to their subject. The vast majority of algorithm visualizations (ca. 292) deal with concepts that are addressed during basic data structures and algorithms lectures at university. Only a small fraction of the remaining minority deals with mathematical algorithms (four examples), so the algorithm visualization within a serious game about resolution in propositional logic tackles a relatively unexplored area.

Yet, visualization of a mathematical algorithm does not max out the potential for the learning process. As the analysis by Hundhausen et al. pointed out, the learners' activities are of greater importance for the learning process, than the content of the visualization itself (Hundhausen, 2002). Furthermore many studies indicated, that complex issues are remembered the better the more active learners participate in the topic (Prince, 2004).

One approach that considers these aspects is Algorithm Visualization using Serious Games (AVuSG) by Shabanah et al. With this concept an algorithm is represented in four forms: as a *text*, as a *flowchart*, as a *game demonstration* and as a *game*. For each of these representation forms the learners pass through a learning process of three consecutive steps: the *viewing process*, the *playing process* and the *designing process*.

Throughout these processes the learner starts with viewing algorithm text, flowchart and demo, before becoming active in playing the game. Subsequently a creative creation process can follow in which the student develops his or her own algorithm text, flowchart, demo and game (Shabanah and Chen, 2009).

The next step in development is to transfer this concept for serious games to multi touch tables.

3.3 Multi Touch Tables in Education

So far multi touch learning applications can be found primarily within the K-12 education sector with focus on elementary schools. Examples for this are projects like the multi touch learning software for mathematics called MEL-Vis (Tyng et al., 2011) or the Multitouch Education Table (MET) by George et al., which features numerous virtual card game suites e.g. about geography for elementary school students or mathematics for class 7 to 12 (George et al., 2011).

But as multi touch tables encourage students to experiment more with a problem and its solution (Piper and Hollan, 2009), the technology can be

regarded as suitable for learners of all ages, especially as the usage of tables as interactive objects additionally promotes collaborative working by naturally providing space for an ideal group size of four learners (Schneider et al., 2010).

Besides the, up to now, rather limited target group, it seems that multi touch tables are used quite seldom for computer science education. This is insofar astonishing as the technological development of multi touch tables or similar equipment is a highly popular topic in computer science research. But it seems that computer science education researchers have paid relatively little attention to this so far.

4 SERIOUS GAME PROTOTYPE

4.1 Circumstances

As a basis for our applications we use the SMART Table by Smart Technologies. Initially two different prototypes of serious games about Dijkstra's algorithm were developed, which made only limited use of the multi touch features of the table. Subsequently the described prototype about resolution in propositional logic was developed with respect to the benefits of multi touch user interaction. Current work in progress concentrates on developing a multi touch learning environment about sorting algorithms.

4.2 Game Design

The application was designed with nine different usage modes, which can be divided into three categories: *Learning*, *Playing* and *Creating*.
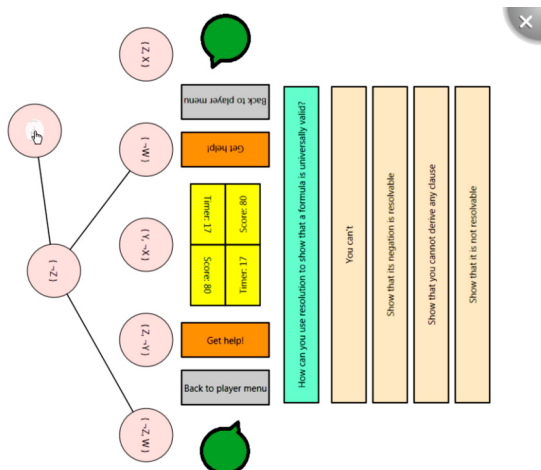

Figure 1: A screenshot of the cooperation mode.

Learning modes are primarily designed for students who were only briefly introduced into the topic of resolution or need to brush up their knowledge. For this, four different *learning modes* were designed to form the viewing process:

- *Animation mode:*
  Using this mode gives learners a first insight into the execution of the resolution algorithm.
- *Feedback mode:*
  Within this mode learners have the possibility to execute the resolution algorithm on their own while receiving feedback to deepen their understanding of the algorithm.
- *Quiz mode:*
  In this mode learners can explore the context of resolution in propositional logic by facing questions about the topic.
- *Formula mode:*
  This mode gives leaners the opportunity to construct an equivalent conjunctive normal form for a given logical formula to discover the steps that lead from logical formulas to resolution clause sets.

The *playing modes* are designed for long-term use of the serious game. These four modes target at players who already know the algorithm basics, but can still profit from further practice:

- *Collaboration mode:*
  Round-based score-keeping challenge a team of players to play against time. This mode can also be used by a single player.
- *Cooperation mode:*
  For this mode players have to split up into teams with different responsibilities (execution of the resolution and answering questions) to score as a group while playing against time (see figure 1).
- *Competition mode:*
  In this mode two opponents play a round-based duel by working with the same clause sets.
- *Tactical mode:*
  This mode offers the possibility of competition in duels with a wider tactical range by introducing a set of bonus actions to the gameplay (see figure 2).

The ninth mode, the *creation mode*, was implemented to realize the designing process. This allows students to create own clause sets, which can be saved and used within the game.
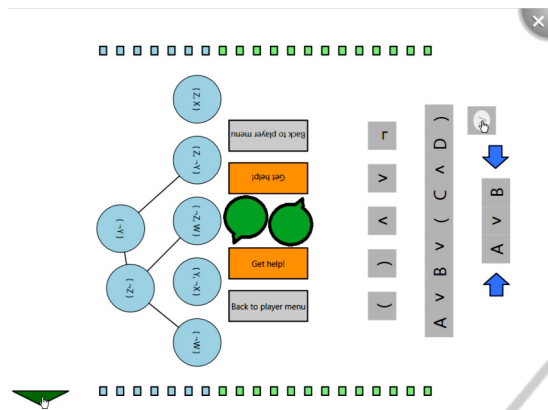
Figure 2: A screenshot of the tactical mode.

4.3 Implementation

The software was developed with respect to heuristics concerning application design for tabletop displays (Apted et al., 2009):

- Interface elements are rotatable.
- Touchable elements are easy to select.
- Elements are movable to all areas of the table.
- Movable elements can be quickly removed or rearranged to avoid clutter.
- The tabletop space is used efficiently.

Besides this, the aspect of extensibility was considered as well. The serious game comes with a predefined set of challenges and tasks, but users are free to contribute their own clause sets, questions and formulas. Besides the creation mode, new content can be integrated directly into the document structure of the software as XML file.

5 EVALUATION

To obtain first feedback about the prototype an informal evaluation was conducted with participants of the e-learning lecture at RWTH Aachen University. Within this evaluation students had the possibility to test this and other applications for 90 minutes. During the whole evaluation there were always several students actively involved with the game and several more were watching.

Feedback was collected by talking to the students while they were performing tasks and by collecting written feedback. The outcomes were directly integrated into the development process. In general a positive attitude towards the serious game was stated and it was seen as a motivating approach on the subject. Some students explicitly mentioned cooperation and competition mode as fun to play.

For any further conclusions a formal, quantitative evaluation of the serious game is urgently needed.

6 CONCLUSIONS

We described our work of designing a theoretically profound serious game prototype for multi touch tables in the area of higher computer science education. The present outcomes indicate this to be a motivating and engaging approach to familiar topics of computer science lectures. Consequently we will be pursuing this way further.

7 FUTURE WORK

In the long run it is planned to integrate serious games and other pedagogical approaches that differ from regular courses into the first semesters of computer science studies at university. These offers will be an optional enhancement of the regular learning methods. Thus it is crucial to design the future learning environments to be engaging, motivating and easy to use.

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