GAME BASED LEARNING MODULE „Z-BUFFER“ ON A COURSE IN COMPUTER GRAPHICS

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Abstract: Interactive multimedia simulations combined with computer game elements can be successfully applied as a new type of educational resources for teaching today’s generations of students. This type of game-based learning modules (GBLm), has been designed by the author. This work describes one type of GBLm, which we used in the subject Computer Graphics for the teaching unit, “Z-buffer” in order to facilitate the learning process. During designing and creation of the teaching unit for GBLm we used one of constructivist teaching methods – concept maps.

Keywords: educational games, game based learning, Z-buffer algorithm, concept maps.

1. INTRODUCTION

In the education process with the use of today’s modern multimedia technologies and Internet a lot of teachers usually use interactive simulations for students’ training and practice. However, since the game environment is becoming more and more complex, educational games can be very useful in providing by-ways leading to the teaching material concepts, which are difficult to acquire by traditional methods. The use of interactive learning enables students to handle data and geometric shapes in order to check and practice mathematical principles, which is confirmed by Prensky’s most successful game project, Monkey Wrench Conspiracy [1].

Educational games attract students’ attention in a simple way. Research in this field shows that this phenomenon is a result of an emotional connection between a game and a student. The emotional connection is established due to combining of a number of various sources, such as graphics and sound, which provides for a high interactiveness level between the computer and student [2]. Educational games and interactive simulations can enable a student to acquire knowledge in a specific field through playing a game successfully. Educational games are very popular among younger children and adolescents, and For the mentioned reasons, in this work we tried to make easier for students to learn abstract educational material and to improve their results on the final exam with the use of one type of such software.

Section 2 gives an overview of new ways of students’ interaction with amusing and modern learning systems that are today used in technical science and maths lessons; Section 3 presents a teaching unit in which amusing learning environment is implemented – „Z-buffer“.

Section 4 describes the methodology of the use of concept maps, realized thorough game based learning modules – GBLm. Section 5 includes the used interface design, application of levels in GBLm, as well as the way of concept maps usage through levels; finally, Section 6 illustrates the results recorded by students after the use of GBLm on the course in Computer Graphics.

2. RELATED WORK

Having in mind the big power of multimedia type contents, in today’s education process there is an increased use of specific types of multimedia applications for amusing learning, i.e. educational games. Through this type of educational material today’s teachers are trying to present teaching material to students in the simplest and most interesting possible way. If we start from the fact that playing games and competing are the oldest human characteristics, this adds even more significance to the use of educational games in education systems. A combination of dynamic simulations and educational games on courses in physics for teaching a new generation of students is used by teachers of the Norwegian University of Science and Technology (NTNU). Bjarne A. and Tor I. Eikaas [3] present in their work „Game play in engineering education: concept and experimental results“ the main design and a series of online learning resources based on dynamic simulations which give significance to the use of games on engineering courses in the future.

Sweller and Mayer, relying on cognitive load theory [4, 5], suggest that complex tasks, procedures and complex problem solving can be best understood if taught as mutually connected units. On the other hand, concept maps are the tools used to build relationships among concepts. These tools have been used in educational environments to better connect the relationships among theory and practice as well as among other concepts covered in a course. These tools also help the learners build relationships between previous knowledge and newly introduced concepts, encouraging meaningful learning rather than rote learning (memorizing concepts, no relationship to previous learning) [6].

As in any discipline, in Computer Engineering, students start learning the basic concepts of the discipline in their first year studies. Gül Tokdemir and Nergiz Ercil Çagiltay [7] propose to use a concept map to built connections between the concepts taught in Introduction to Computer

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Engineering course. While preparing the concept map, they applied a new paradigm called “Goal-Question-Concept” inspired from a well-known GQM (Goal-Question-Metric) method of software engineering field. Programming is hard to learn both for complex concept and skills. To overcome these disadvantages, a new teaching strategy, named as “concept map-based anchored teaching”[8], was proposed by Liu Li, Haijun Mao and Licheng Xu. With the anchor as core, students launched inquiry learning and incorporated detailed syntax into a real application, which meant the construction of application skills and problem-solving abilities. To support concept leaning, concept map was assigned to students for better understanding of the concepts relationships.

3. BACKGROUND

After analysing the final exam results during examination periods in the subject Computer Graphics at the College of Electrical Engineering and Computing Science Professional Studies in Belgrade, we came to the conclusion that results of one group of questions were much more different than the others. Performing an analysis we discovered that the questions referring to the field of hidden surface techniques and especially Z-buffer algorithm, taught on the course in Computer Graphics, had an unusual ratio between correct, incorrect and „I don’t know” answers. The answers to these questions were in the following proportion: 34% of correct, 33% of incorrect, and also 33% of „I don’t know” answers. The proportion of answers to other questions was usual for test-type questions and answers, and it was the following: 46% of correct, 17% of incorrect and 29% of „I don’t know” answers. Although students had the same learning materials for exam preparations for all fields, the difference discovered for this teaching unit showed that this field was quite complex and abstract for students. It was therefore necessary to take some steps in order to improve the approach to learning regarding this teaching unit, and improve the final exam results on the other hand. Of all the algorithms for finding visible surface, Z-buffer algorithm is maybe the simplest and is thus used most frequently. Starting from the facts that this teaching unit is simple and that, on the other side, the students’ results are worse for this than for other fields, we began searching for an answer to the question how to offer students teaching material that will be understandable for learning.

For every pixel on the screen this algorithm keeps a record on the object depth in the scene in relation to an observer, plus a record on intensity of the color used for the object description. In the situation when a new polygon is to be presented, the value of depth and the value of color intensity are calculated for each pixel positioned within the borders of that polygon. If the value of the polygon pixels is closer to the observer than the value in Z-buffer, the recorded values of depth and values of color intensity are replaced with the previous values in the buffer [9,10]. Calculation of Z value for every point on a scan line can be simplified by using the fact that some polygons are planar. Z-buffer is often implemented with 16 to 32-bit integer values in hardware, but software (as well as some hardware) implementations can use values with movable points. Although the Z-buffer algorithm demands huge memory space, it is easy for implementation. The procedure for placing pixels in the Z-buffer algorithm:

\[
\text{Procedure SetPixel}(x:Xres; y:Yres; z:Zres; v:Value)\
\text{Begin}\
\quad \text{If } z > \text{depth}[x,y] \text{ then}\
\quad \quad \text{Begin}\
\quad \quad \quad \text{depth}[x,y] := z;\
\quad \quad \quad \text{screen}[x,y] := v;\
\quad \quad \text{End;}\
\text{End;}\
\]

4. PROPOSED METHODOLOGY

4.1. Concept Maps

Knowledge structure is regarded as an important component of understanding in a subject domain, especially in science [11,12]. The knowledge structure of experts and successful learners is characterized by elaborate, highly integrated frameworks of related concepts [13,14], which facilitate problem solving and other cognitive activities. A knowledge structure, then, might well be considered an important but generally unmeasured aspect of science achievement. Concept-mapping techniques are interpreted as representative of students’ knowledge structures and so might provide one possible means of tapping into a student’s conceptual knowledge structure [14,12].

During designing and creating of a teaching unit a lecturer may find concept maps very useful. Global, „macro-maps” can also be made, showing the main ideas we want to present during the entire course, or specific „micro-maps”, showing the structure of knowledge for specific fields. Concept maps are graphic tools for organizing and presenting knowledge. They comprise concepts presented in regular geometric shapes, and relations among them are marked by lines that connect them [15]. Connecting words or expressions are written on the lines and they determine the relationship between the concepts. A concept is defined as a regularity discovered in phenomena or objects, or data on stated phenomena and objects. Ideas comprise two or more concepts connected by words or expressions into a sensible unit (Figure 1).

![Fig. 1: Concept map](image)

In the sense of graphics, concept maps include:

- Concept

- Sub-Concept

- Connecting lines and words

- Sub-Concept
With the use of advantages of the concept map technique, in the subject of Computer Graphics we created a concept map for the teaching unit Z-buffer, with the aim to reduce the items presented in this unit to main concepts and to connect them in the simplest possible way.

4.2. Game Based Learning Modules

Computer Graphic students start the learning process from learning computer techniques and algorithms for generating two- and three-dimensional graphical objects. This subject is very good for teaching through games. Such games can be used by both beginners and those who want to improve their skills. While playing learner gets theoretical knowledge and an experience of graphics algorithms. If he is really interested in this game he will go to external information (books, Internet) and in that way study advanced graphics algorithms.

After performing an analysis of existing Internet simulations and applications used in the teaching process, we came to the conclusion that it is necessary to introduce some of those contemporary teaching resources in the course in Computer Graphics, so that students could learn the planned material in the best possible way. We consider that the main objective of computer techniques in games is awakening interest in computer graphic. Thus the game concept should be based on two components:

- learners must get the course information through it’s interpretation in game world;
- learners must see the result of his algorithm in a game context;

The concept is based on a Role Playing Game (RPG) genre. Also, besides placing game interface into modules we have also applied basic game elements, such as: result, time and difficulty levels. These new modules, which include game elements, represent research multimedia learning applications and are intended for Computer science students (Net-generation), we named game based learning modules (GBLm).

The purpose of learning through the game is to enable students to learn the rules and check them in practice on the example of all graphics algorithms. Multiple repetition of tasks with performing the same operation increases the probability of learning characteristics and use of particular operation. Quality evaluation whether an operation is acquired or not is performed through visual indication of the number of successful and unsuccessful tasks (score) with the same operation, and comparison with preset criteria. The model of the game based learning module - GBLm is shown in Figure 2.

Entire design and architecture of GBLm was made in ActionScript 3.0 object oriented program language supported in the package Adobe Flash CS3. Construction of the game interface demanded a longlasting and extensive analysis, whose main objective was adjustment of the environment and the ways of task implementation to affinities, formerly acquired knowledge and age of end users (students from 18 to 20).

5. GBLm IMPLEMENTATION

The innovative way of checking knowledge with multiple answer computer tests served us as the main idea for the way in which teaching material could be given to students for solving. With the use of techniques for the first class innovative testing select/recognize, we came to the idea that answers in the multimedia interactive learning module can be given as a series of image fields on which a student should click. Since the buffer we use in the Z-buffer algorithm uses 16 bits, the task of this module is to determine the value of each bit, i.e. contents of the registry in various situations presented in the task.
The correct answer to fill the content of one bit is one of the proposed answers presented to students in the form of squares to be selected. These squares, i.e. offered answers, are presented in two ways. In the first level of the module answers are offered in the form of a 13-square column (type 1, Figure 3). Answers in the second level are also offered as an array, but in the form of a five-square row (type 2, Figure 3). This row with offered answers is not constantly visible, but is shown only when the given bit is selected as a sub-menu in the menu list.

5.1. Module interface

The visual presentation of the module interface is adjusted to the type of student it is intended for, i.e. to teenage students. We used motives of contemporary applications, as well as motives of the graphic interface Aero on operating systems Windows Vista and Windows 7. The graphics is adjusted to provide for students to enjoy in visually attractive effects of brightness, transparency and reflexion, the characteristics of the new “fancy” technology. In the functional sense, the interface of the GBLm „Z-buffer“ comprises 6 thematic fields (Figure 4):

- The field in which the problem task is presented visually – field 1,
- The field which presents solution to the task – field 2,
- Offering assistance – field 3,
- Description of the algorithm operation – field 4,
- The task text – field 5,
- The field for main playing information – field 6.

5.2. Various difficulty levels in the module

The learning module named „Z-buffer“ has been made on the basis of a concept map created for this teaching unit, which is shown in Figure 5. Since two main concepts are given in the concept map (the depth and color test concepts), which are to be learned by students through this module, we presented them as two levels with different solving difficulty. Solving the task that presents operating of the Depth test is shown in the module as the easier level, i.e. level 1.

5.1.1. Level 1

The task at level 1 demands from students to determine a pixel whose value will be written in the depth buffer. The student should select the appropriate square within the active field, which is determined by the current position of the scan line arrow (Figure 6). Observed from the aspect of concept maps, solving of the task at level 1 is reduced to recognizing concepts of the depth test operation.

5.1.2. Level 2

At level 2 students are requested to determine the color of the screen buffer on the basis of the displayed order of squares and the legend of color transparency given in the lower right corner of field 1. A student can select as an answer one of the offered colors that appear as a sub-menu when a specific bit is selected in the screen buffer. To determine the resulting value of the color in case that squares have a certain level of transparency, the field 3 gives a part with colors whose transparency can be
changed interactively, which helps in determining the value of the resulting color. The concepts to be recognized by students at this level are given in the picture of the lower concept map (Figure 7).

Testing of learning efficiency with the use of GBLm was performed during the summer semester 2009/10 for the teaching unit „Hidden surface techniques“ on the course in Computer Graphics. The research included first year students at the College of Electrical Engineering and Computing Science Professional Studies in Belgrade. On the lectures of the said course students were informed about the principle of the „Z-buffer“ algorithm operation. The professor presented the teaching unit with the use of a classic method, with blackboard and without modern teaching resources such as a projector, Power Point presentation etc. After the lectures on the distant learning system – Moodle, students also obtained GBLm „Z-buffer“ as additional material for exam preparation. After that, a pedagogical experiement was carried out, and it consisted of monitoring students’ activities in the period prior to taking the exam, and analyzing of the results they accomplished on the final exam.

The sample included 183 students, and 4 predefined groups were monitored: $P_I$ (the group which did not attend the lectures and did not use GBLm), $P_I$ (the group which did not attend the lectures, but used GBLm), $P_I$ (the group which attended the lectures but did not use GBLm), $P_I$ (the group which attended the lectures and used GBLm). Characteristics of the results distribution on the final test are shown in Table 1.

<table>
<thead>
<tr>
<th>Groups</th>
<th>Correct answer</th>
<th>Incorrect answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_I$</td>
<td>11.5%</td>
<td>13.1%</td>
</tr>
<tr>
<td>$P_I$</td>
<td>14.8%</td>
<td>11.5%</td>
</tr>
<tr>
<td>$P_I$</td>
<td>18.0%</td>
<td>4.9%</td>
</tr>
<tr>
<td>$P_I$</td>
<td>23.0%</td>
<td>3.3%</td>
</tr>
</tbody>
</table>

Table 1. Characteristics of the results distribution on the final test

The total accomplishment of students who used GBLm regardless of whether they attended the lectures or not (the second and fourth row in Table 1, $P_I + P_I = 37.8\%$) was better than the accomplishment of students who did not use GBLm (the first and third row in Table 1, $P_I + P_I = 29.8\%$). On the other hand, the difference between the arithmetic means in incorrect answers given by the groups that used GBLm and those that didn’t use it was very small - 3.2%. It means that students in the groups that didn’t use GBLm gave incorrect answers to the same extent as students in the groups that used it, which shows that students of that group were not interested in the given teaching unit regardless of the way of presenting the teaching material.

Total percentage of correct answers given by groups that used GBLm and attended lectures ($P_I = 23.0\%$) in comparison with all other groups shows that these groups recorded best results, which still gives high significance to classic lectures supplemented with this kind of the modern module GBLm.

5.1.3. Help Window

For both levels in GBLm there is a help window which is closed in usual circumstances. If students need help during the task solving they can request it at any moment with the use of this window. The window contains a definition needed for understanding the task and gives an answer at the moment when the student doesn’t know what to do next. The content of the help window is actually the key thing, i.e. concept a student should learn at each level. An example of the open window at level 1 can be seen in Figure 8.
Results on the final exam showed that the generation of students that had a chance to use GBLm (generation 2009/10) acquired the teaching unit „Z-buffer“ more successfully than the generation of students who didn’t use such teaching material (generation 2008/09). Proportion of results accomplished by these generations can be seen in Figure 9. On the basis of the result proportion we can conclude that the generation 2009/10 increased the number of correct answers by almost 50%, by eliminating a big number of „I don’t know“ answers. The use of GBLm, besides increasing the level of knowledge in the given teaching unit, also gave a lot of students confidence in the acquired knowledge.

7. CONCLUSIONS AND FUTURE WORK

Documents related to education in many countries emphasize the significance of learning technical sciences through the technique of „discovering“, with the use of amusing interactive multimedia applications. A result of such learning is that students establish interaction in order to recognize the main concepts of the learning topic and their mutual connection, with amusing environment which reminds them of playing a game. Students’ capability of making conclusions on the basis of playing games was checked in this work by test questions on the final exam of the course in Computer Graphics for the teaching unit „Z-buffer“. The effort students had to make using GBLm in the learning process showed that its usage helped students to better understand and acquire given material with minimum time spent. Students’ playing games in GBLm lasted only 3 minutes on average, and the result on the final test for this group of questions improved by almost 50%. This was the reason for which the authors of this work decided to make and apply GBLm in other teaching units of the course in Computer Graphics in the future as well.

The presented results and conclusions drawn in this work give big significance to the use of GBLm for fields that are abstract and hard to understand, especially having in mind that Net-generation students are not quite interested in classic way of learning.

REFERENCES


