

Creating Passion for Augmented Reality Applications - a Teaching Concept for a Lab Course

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Abstract. We introduce a project-based concept for teaching Augmented Reality (AR) applications in a lab course. The key element of the course is that the students develop a stand-alone application based on their own idea. The complexity of Augmented Reality applications requires software engineering skills and the integration of AR specific solutions to occurring problems.

The students work self-responsible in a team with state-of-the-art methods and systems. Moreover they gain presentation and documentation skills. They define and work on their individual goals and challenges, which are assembled in a final application. The identification with the goal of the group creates passion and motivation for creating the AR application.

Beside of the teaching concept we present some of the students' applications in this paper. Furthermore we discuss the supervision effort, our experiences from the supervisors' view and students' feedback.

1 Introduction

Augmented Reality Applications are gaining more and more attention in the last view years. Augmented Reality (AR) is no longer found only in research laboratories. The first commercial applications are already available. AR is used for advertisement purposes or navigation systems. The car manufacturer BMW presents the Mini Cabrio with an AR print advertisement¹. Another AR application is the Virtual mirror provided by the sunglass company Ray-Ban, which enables the user to virtually try on sun glasses². Also navigation systems like Wikitude³ augment the street with virtual navigation information shown on mobile devices. These are only the first steps. AR has a very high potential for the future. Therefore it is very important to teach AR in universities in order to educate the next generation of students, which is able to work in the field after finishing their studies.

We present in this paper the concept of our project-based Augmented Reality lab course first introduced in the winter term 2009. The lab course gained support form the excellence initiative at the university as "Leuchtturm Praktikum" in winter 2009. This initiative awards courses which are very hands-on and which use state-of the art

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¹ <http://www.mini.de/de/de/webcam/index.jsp>

² <http://www.ray-ban.com/usa/science/virtual-mirror>

³ http://www.wikitude.org/category/02_wikitude/wikitude-drive

technology. The AR lab course aims to teach the various aspects that must be considered in order to create an Augmented Reality (AR) application. These aspects concern low-level as well as high level implementation and therefore cover the full bandwidth of challenges in building an AR application. The students are taught on the usage of modern software development toolkits and off-the-shelf hardware to program their own stand-alone AR application during the semester.

Students do not necessarily need preliminary knowledge in Augmented Reality but it is an advantage. The fields of study of the students during the last two semester were Computer Science and Computational Science and Engineering. The course is a major part of their semester as students get 10 ECTS points while 30 points are recommended for each semester.

Earlier AR courses which are offered already since ten years at the Technical University of Munich (TUM) were more exercise based [1]. The newer, project-based concept of the AR lab course, introduced in this publication, fulfills also the requirements from the official university module description⁴. The students should gain the following skills during the lab course:

- The competence to apply state-of-the-art methods and systems
- The ability to work goal-oriented and in teams
- Skills to present and document the results

The project-based concept of the course provides a broad range of experience in building Augmented Reality Applications. Those issues range from tracking infrared as well as paper-based markers, to sending data over network connection, to controlling Bluetooth devices. Also non-technical skills are addressed like the development of the application idea and concept as well as the design of the graphics. The students gain knowledge in interpersonal skills like team work and project management. They build the applications in groups from the first idea to the final application, which can be demonstrated at the end of the term. Building a time schedule with project milestones, splitting the work, and putting all individual parts together are also essential parts of the student work.

2 Related Work

Some teaching concepts are briefly reviewed in the following paragraphs due to their importance or inspiration. Maxwell did a survey of different computer vision and image processing courses [2]. He mentions all courses to teach the students well known algorithms by using real-world images and problems. From the survey it is clear that satisfying results are important for the motivation of the students. Analog to this observation we also want to lead the students to build successfully applications that will be demonstrated in public at our chair for one week at the end.

Essa and Brostow [3] aim also for the high motivation of students for creating digital video effects in small projects in order to teach the syllabus of the course. Their

⁴ https://drehscheibe.in.tum.de/myintum/kurs_verwaltung/cm.html?id=IN2106

target group are undergraduate students with only preliminary or no knowledge in the required fields of image processing. They attract always a high number of students (21-30) with their course offer. This course is also a good example for attracting students while teaching the contents in order to reach an appealing goal.

Another interesting group based teaching concept is applied by Pang [4]. He challenges the students by letting them develop own games using game development engines the students had to program in an earlier stage of the course. The students are faced with other students implemented features and their documentation of the code. This teaches the students important aspects of programming applications in a self-awareness process. In order to build AR applications we rather use commercial game development software. There are too many aspects in building an AR application such that this concept could apply here.

3 Teaching Concept

In order to teach the students the various skills of an (AR) software engineer we involve the students from the beginning of the lab course. In order to do so we pay attention to several aspects of the lab course introduced here:

Group Based Working We separate the students into groups incorporating three to five students. This group finding process takes place in the second session of a semester since there is normally some fluctuation in the first week of the course. The group building phase is important for the further process of the lab course. It is mainly influenced by the availability of the students for the different days during the week, and their native language. Although experience and knowledge in different fields of computer science are good criteria for building groups we attach more importance on having all group members sharing the same day within the week to discuss topics and support each other. These regularly meetings are very important at the beginning of the course such that the students start to share the same vision of their final application. Later on, the students can start arranging their time in a self responsible way.

Own Ideas We offer the students the possibility to develop applications based on their own ideas. Instead of predefined tasks the students have to make the decision what application they like to implement. The brainstorming of the teams takes place after the group building phase. The students have to design own project drafts and discuss these concepts among their group members. Well-known computer games are the main source of inspiration and we guide these discussions such that the students do not drift away in too detailed discussions. Finally the process of idea creation ends in a presentation of the idea from each group to the whole class.

The process of creating own ideas and the possibility to implement them is a key element in our lab course. We expect a high motivation of the students in order to realize their own ideas.

Self Responsibility Besides other goals, the students, which will finish our university should be independent of supervision, self-confident, experienced and have the ability to

adapt to new fields in computer science quickly. In our lab course we aim for those goals and we want to have the students mainly acting in a self-responsible way. Besides the shared working day during the week the groups are given no restrictions when to meet and work. The students have to organize their group in a self-responsible way which includes finding their own role within the team. Besides three introduction lectures to the programming environment, the tracking framework and appropriate documentation we give no additional input to the students. We rather let the students get in touch with the provided hard- and software as early as possible, so that they can start gathering experience by themselves. As supervisors we offer office hours for the students. If there are any questions they can contact us and we give them feedback about their actual work. We are also available to discuss possible future steps so that the projects are not diverging but still leave the final decision open to the students.

Documentation Besides the technical challenges, which the students have to face, they are advised to document the final application as well as their personal work. The application documentation follows the guidelines for the “Game Design Document” given by McGuire and Jenkins [5]. The Game Design Document is a framework for communicating the concept of a game to a publisher. At the same time it should document the development of the described application and therefore it should always incorporate the status of the application. The personal documentation follows no strict framework but should include a more detailed description about the personal work of the group member, the task given inside the group, the problems faced and the solution. This documentation is part of the basis for the student’s grade.

Presentation Presenting the work is also part of the lab course. Each student has to present his or her own role within the team at the beginning of the lab course. At the end of the semester a short, private presentation to the supervisors should expose the students task within the semester and the problems he or she personally had to face. The short private presentation is also a basis for the student’s grade. In addition to the private presentations the students give one final, public presentation, followed by a public demonstration of their applications. We let the students have the presentations to learn how to communicate own ideas and applications. Especially the final presentation should have the character of a product presentation in order to convince the publisher similar to the “Game Design Document”.

4 Course Contents

Designing an AR application involves several challenges. The students learn in our lab course about various aspects one has to consider and should find own ways of handling certain problems, as far as possible. The most important aspects are listed here.

Tracking The students are provided with a rigidly mounted infrared tracking system⁵ consisting of four cameras, that cover a space of about nine square meters, the application area. A single, ceiling mounted camera, can be used in addition for marker based

⁵ <http://www.ar-tracking.de>

tracking using our own tracking library⁶. Although the students are provided with these systems they have to choose the appropriate one for their application. This involves considerations about the advantages and disadvantages of the single computer vision based systems for their application. Later on, they have to deal with the complexity of calibrating these systems until the systems are usable for their application. This involves calibration of cameras, room and rigid bodies and absolute orientation or hand-eye calibration. One group came also up with the idea of integrating a different vision-based tracking system. Although they used our tracking at the end it was interesting to see the increasing motivation of the students, driven from demands our provided systems could not met.

Visualization The main application is developed using 3DVia's Virtools⁷, a rapid prototyping and development environment. Virtools allows to concentrate on designing the higher level application. This approach is in contrast to many lab courses where students program in a lower level language C/C++/C#, JAVA, etc. For their application the students can make use of the visualization techniques that are already incorporated but they can also program own elements, e.g. pixel shaders. This enables the students to deal on a higher level by choosing among appropriate techniques. They can experiment how to create an immersive perception of the virtual elements placed within the real world using drop shadow, reflectivity, alpha blending, etc. of the virtual objects. In addition the occlusion of real world elements, e.g. moving robots, should be considered such that they are correctly overlaid with 3D graphics.

Modeling By designing their own AR application the students also have to take care of an appropriate look of the virtual objects. Since downloading models from the Internet is in many cases not sufficient the students learn to create own models and animations or editing of already existing models. A challenge the students have to face is the importing/exporting of animations from different file formats such that the models can be used from the rendering engine in the end. If models with a high number of polygons are used the model has to be adjusted such that the rendering engine is capable of showing the model for the AR application in real time.

Interaction We provide the students with hardware interaction devices like the Wii remote or infrared finger tracking. Using the Wii remote is of high motivation for the students although in all cases there was no time for a complete integration of this device into the final application. Nevertheless the students start to think about meaningful interaction concepts besides normal keyboard controls. In case of the finger tracking some limitations of the hardware led the students to come up with only few simple gestures for controlling their application.

5 Students' Applications

In the following we describe several projects, which were developed during the courses in winter 2009 and summer 2010.

⁶ <http://www.ubitrack.org>

⁷ <http://www.3dvia.com/products/3dvia-virtools/>

5.1 ARace

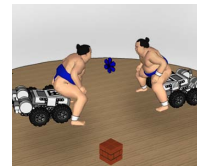
ARace is an augmented car racing game for two players. Two robots with markers on top, representing the virtual racing cars, control the virtual game 1(a). The robots are tracked by a camera mounted on the ceiling. The game is played from the robot's perspective using radio cameras mounted at the front of each robot. This view is augmented with the virtual cars, the race course and some special items (speedup, rockets, etc). An augmented view can be seen in 1(b). The goal is to drive as fast as possible four laps or to hunt down the other player before he can finish the race⁸.



(a) ARace



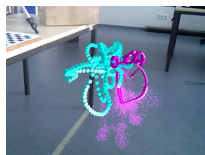
(b) ARace



(c) Sumot



(d) Ragnarök



(e) AR Painting



(f) Treasure Hunt

Fig. 1. Screen shots of the different projects developed during the AR Lab Course. The games shown in figures 1(a) to 1(c) were developed during the winter term 2009. Figure 1(d) to 1(f) show results of the lab course in the summer term 2010.

5.2 Sumot

In the augmented reality game Sumot two Lego Mindstorm robots, equipped similar to the ones in ARace, fight in a Sumo arena, trying to force the opponent out of a ring, see figure 1(c). The players are not limited to using only physical forces: They are equipped with several imaginary weapons, which freeze the other ringer or to steal him hit points which affect the physical representation (the robot). The winner is the player who passes the other sumo ringer out of the ring.

5.3 AR Painting

AR Painting is inspired by the 'Tagged in Motion' project from the 'Jung von Matt' group⁹. The graffiti artist Daim used an ARToolKit based drawing application for draw-

⁸ A video of ARace <http://www.youtube.com/watch?v=BXG115JU35o>

⁹ http://www.jvm.com/de/ideas/\#/4/_111/jung-von-matt-tagged-in-motion/

ing in different color, brightness and line thickness. The students developed an application with several extended three dimensional drawing tools to choose from. Depending on the chosen tools the user can either draw a ribbon, a tube, use an arbitrary shape or use a particle based spraying tool. The user wears an video-see-through HMD showing the graphics, which is tracked by an infrared tracking system. The application is based on a finger tracking device to have an immersive human-machine interaction so that the user can directly paint using his own fingers by applying certain gestures.

5.4 Treasure Hunt

The goal of this AR game is to find a treasure hidden in a swamp. Each player controls a robot, which is represented as a pirate in the augmented view. This time the robots are tracked using the infrared tracking system and again they are equipped with radio cameras. In order to find the treasure, the players need to collect parts of a treasure map, which are physical blocks standing in the arena. These blocks have to be transported by the robots. One player can only carry one hint at the same time. There are also virtual obstacles like bananas and spiders, which can be placed to hinder the other player.

5.5 Ragnarök

Ragnarök is a game basically featuring the idea of capturing the flag, with some interesting additional ideas. In this game, the robots represent different opposing parties wanting to capture the flag of the opponent. The players perspective is the camera mounted on top of the robots. The AR aspect is mainly realized by making it possible to add so called "towers" to the game arena by dropping physical red square markers. These towers protect the own flag, but they can be shot by the opponent. An interesting aspect of the game is the possibility to change the environment where the "fight" takes place. Possible environments are, medieval, alien terrain or futuristic urban environment.

6 Discussion and Evaluation

The following section will include the experience the supervisors had during the lab course as well as the evaluation of the course.

6.1 Supervision Effort & Supervisors' Experiences

The structure and grading of the lab course changed between the first time (winter term 2009) and the second time the course was conducted. This had to be done due to the enormous amount of time the supervisor had to spend with the students and due to the increased number of students in the summer semester 2010.

Winter 09/10 In winter 2009/2010 the supervision effort was enormous, although only 6 students did attend the lab course 3 supervisors did spend at least 5 hours each week supervising the students, not including individual questions to a specific supervisor. The positive aspect of this approach is, that it was easily possible to see the students' effort and grade them accordingly. The official presentation as well as the overall status of their projects was not taken too much into account.

Summer 2010 For the summer semester 2010 it was decided to change the supervising approach simply due to the fact that each supervisor is also involved in industry projects and the number of students increased from 6 to 13. Therefore it was decided that each supervisor is responsible for one group and the grading of the group will be more objectively measurable. This approach first of all resulted in a more accurate planning of the tasks the students had to perform as well as in more organizational effort that had to be done beforehand. During the semester the division into groups and the introduction of office hours resulted in a more controllable timetable and all together could be considered less time consuming.

6.2 Students' Feedback

This section will cover the evaluation of the lab course given in the summer semester 2010. The following diagrams were created on the base of 13 evaluations, meaning all students did participate in the evaluation process. The evaluation is realized by the student representatives of the Computer Science department each semester. The evaluation uses the same standardized questionnaire for all lab courses in our department.

Figure 2(a) shows that the content that was chosen, was experienced as not too difficult as well as not too easy, but just right by 11 out of 13 students. The practical relevance was rated high from 6 students (Figure 2(b)). As already been said, this lab course has a free mind, everything that is suitable in the research field of AR can be integrated, thus those results, especially Figure 2(b) simple reflects the practical relevance of AR in todays society. Figure 2(a) shows how much the students would recommend the lab course to other students.

Concerning the opinion on the supervisors: Figure 2(d) to Figure 2(h) show that the effort and time that was contributed by the supervisors before and during the lab course was greatly appreciated by the students. In all aspects the course received a better rating than the overall average of all lab courses at the computer science department (indicated by the line at the bottom of the image).

Figure 2(i) shows the evaluation of the organization of the lab course. The mixed results again are due to the wide bandwidth of opportunities as well as the rather big changes that were made during the first and second semester. Problems that were occurring are: not available software (Maya), problems with the delivery of additional hardware (Lego NXT and additional workstations). The overall impression of the lab course in Figure 2(j) shows that the idea and the realization of the lab course was received good by the students, although the time they had to invest into the lab course was considerably.

Also in the evaluation there was an part with open questions. Table 1 to table 3 show the questions as well as the answers of the students.

7 Conclusion

Conclusively it can be said, that the evaluation results show exactly what was anticipated by us. Most students accept and like the possibility of an open and free environment, they do not need to be patronized, and being under supervision all the time. It has

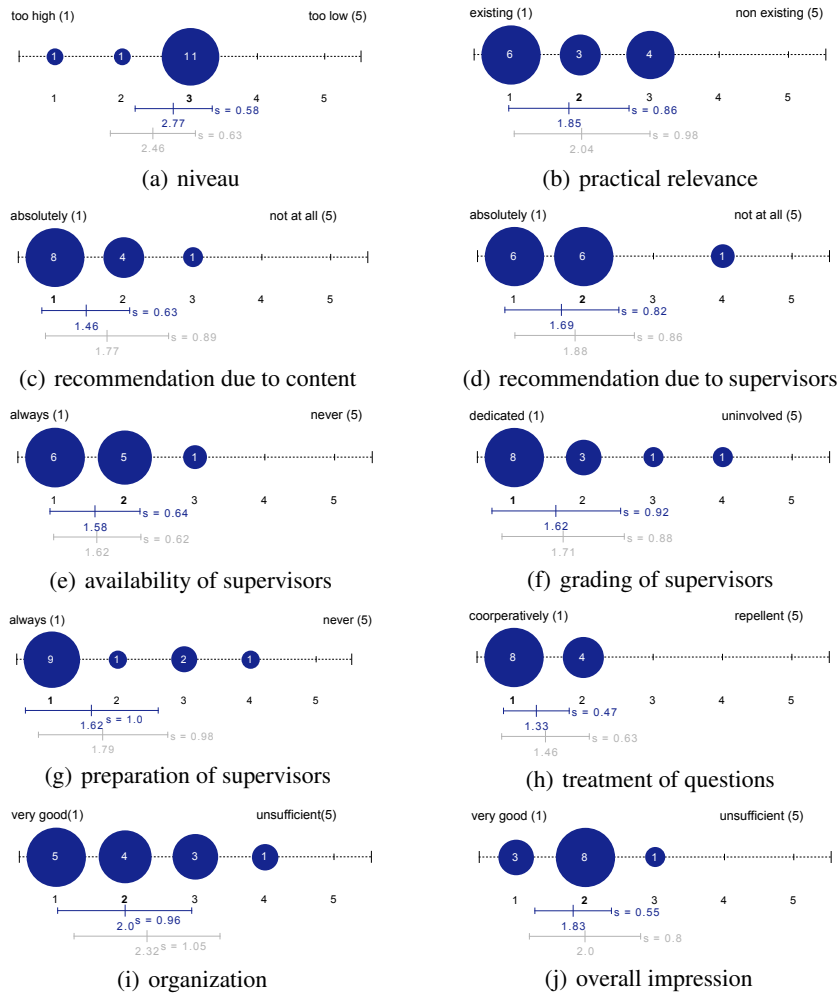


Fig. 2. Evaluation Results

Content			
Content I liked		Quality of the lab course	
different fields	2 statements	good	5 statements
producing a working product	1 statement	appropriate	1 statement
total statements	3 statements	total statements	6 statements

Table 1. Statement on the content

Preparation			
Preparation I liked		Could have been done better	
introduction to all the different topics	3 statements	better introduction into Virtools	3 statements
introduction to a specific topic	2 statement	more introduction sessions	1 statement
total statements	5 statements	total statements	4 statements

Table 2. Statement on the preparation

Organization			
I liked		Could have been done better	
practical examples of tools	1 statement	more supervision	1 statements
independent working	1 statement	mini deadlines	1 statement
availability of tutors	1 statement	availability of hardware	1 statement
total statements	3 statements	total statements	6 statements

Table 3. Statement on the organization

to be said though that this concept might only be valid in certain study areas, where it is necessary to solve problems with all sort of tools, and no strict solution is given beforehand. Although it shows that the field of Augmented Reality is a good playground for students to (self)learn different techniques while having a clear, touchable and last but not least fun goal.

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