Making large, encompassing projects with individual, well-identifiable components work in VR classes

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Abstract: In this paper we present our experience applying a new multi-layered project design method to a course on Virtual Reality. We contrast this approach with traditional project methods, based on their respective advantages and disadvantages. We also present the results of the VR course, which was focused on the topic of navigating Virtual Environments. In order to investigate navigation techniques, the students developed a testbed application, including a complete virtual environment built specifically for testing various navigation tasks. The students then developed a toolkit of navigation techniques, developing several new techniques, and evaluated their usability in the developed testbed virtual environment.

Keywords: Virtual Reality, Education

1   Introduction

While the Virtual Reality (VR) hype may have ended some time ago, the name and the ideas encapsulated within attract many students to Virtual Reality course offerings. Students come with ideas of what they expect in such a course; rarely do such expectations match what is offered. There seems to be no definitive method of teaching Virtual Reality. The ubiquitous lectures format can be used and text books to the subject now exist, such as [BC03, SC03], providing a structure for the course. However, it seems most educators, who are also researchers in this field, are not content with the text books available and instead create their own content. The lectures are given from the instructors own experience, with the lectures being the students main source of information. Other educational methods could be implemented, but they are not often seen in VR education. There is, however, an even more pervasive commonality to VR courses, project work.

The VR field seems to have embraced the constructivist approach as the only way in which students truly learn about VR [BA98]. In this paper we categorize the most prevalent of the various constructivist approaches into two designs. Although it is not the only component, we identify the two designs by the size of the working groups, i.e. projects where students work either on *individual* or small group projects and projects where all the students work on a single *large* project.

In this paper we present our experience with a course using a unique combination of individual and group project approaches. We discuss how this approach combines positive aspects of both and why we believe it is a good method of defining projects in VR courses. This approach was developed to attempt to maximize diverse factors, the most prevalent being: student motivation, successful completion of the project, inter-student help, support, and learning success. The paper shows portions of the resultant project completed students in such a course, demonstrating the high quality project they produced in this framework,

In Section 2 we discuss the advantages and disadvantages of individual vs. large, encompassing projects. We then present our combined approach in Section 3. The discussion is informed by an overview of a concrete course realization. We present our 2005/2006 VR course, the goals for the course, the tasks we set, and the results in Section 4. Finally, we discuss the success of the approach and the results and give details on the students feedback on the course in Section 5.

2 Traditional Project Design

Designing a project that helps the students more effectively learn is not always straight forward. The project work needs to defined in such a way that the students gain the desired learning outcomes. A number of factors involved in defining a successful project. There seems to be two prevalent project definitions, in the VR area and in many similar areas: large encompassing projects and individual/small group projects. The choice between the two options has various impacts on the course design and the students.

In this subsection we discuss our view of the two project definitions' impacts, the options within them, and the factors in making a decision to use them. This discussion is organized around what we feel are the major points in the decision on which approach to use. These points are form a solid basis when looking at our developed project approach in Section 3.

2.1 Division of Work

Perhaps the single largest division in project style one can make is on how the work is divided. Individual projects are the mainstay of VR courses and make this division explicit, as each student should be doing the complete project themselves. If all students have the same project task, ensuring that no students plagiarize may be necessary. Small groups are conceptually similar to

individual projects. Naturally, the division of work within the small group should be present, but experience indicates that the work is often done by one student.

One of the big problems of the individual project in VR is that building a complete VR environment, including interaction, is difficult. This is due to many factors, some of which are: the broad scope of knowledge required, implementation challenges, and the size of a complete project. Having a project completed by a large group makes it possible to successful design and implementation of a fully developed VR project.

Generally, a large project is divided up to have students work on smaller portions of the complete project. As this is the approach often used in industry, the experience of working on such a project affords the student valuable experience. The educational impacts of such a division will be addressed in Section 2.4. Large projects can rarely be divided into completely independent portions. These dependencies often leave students waiting on portions from other students or having to implement what someone else was supposed to. Unfortunately, there is almost always one or two students who fail to complete their portions, either completely or not in a timely manner.

Successful, large group projects generally require project management. This can be performed either by the instructor or a designated student. Having a student or more students doing the project management has its own set of advantages and disadvantages. Issues to consider in this decision are: whether the student is capable of performing in this capacity, what power the student has to enforce deadlines and such, and what the educational impact it has on the student.

2.2   Project Definition and Scope

Another point of contemplation is the decision of what the exact theme, design, implementation, scope, and content for the project will be. The usual solutions are either to have the students decide for themselves or the instructors designate it.

When the students are given the possibility of defining the project themselves, feedback from the instructor is usually needed. The feedback is usually focused on the plausibility of the project. The students typically have to define projects early in the semester and muss finish the project within a matter of a few months. Because of this, the students do not yet have a firm grasp of what VR is and the technical challenges, when the students must define their projects. Therefore, they have difficulty defining a project, either because they are unable to imagine what they can do or because they imagine too much. A related secondary problem is that with the complete open nature of the task, the students often have difficulty defining a project.

Individual projects are commonly done with the student defining their own project. In a large group project, if the group is left to select the project, the instructor will likely have to intervene in order to get the group to decide on a single idea. Even then, many students may be disgruntled because their ideas weren't chosen. If the students define the project themselves, they may be

more motivated to complete the project. Conversely, a predefined project may be uninteresting to the students, creating motivation issues.

2.3 Support

As instructors, one of our concerns in planning a project is how the students are going to get the support they need to complete the project. Traditional project definitions often lead to support problems. Central to this issue is the question of whether the students can help support each other, or if the instructor is the sole support mechanism available.

Generally students, particularly when the course is taken by multiple disciplines, will define individual projects of diverse theme and scope. This results in varied and interesting projects, if they can be completed. It also results in frustration for both the students and instructors. As the projects are all unique, the students are not easily able to support each other. Either the instructors have to leave the students to battle through on their own or they have to become the support mechanism for each student. Supporting all the students is a heavy burden for the instructors.

In a large group project the students are, by the typical division of work, all working on different problems. This leaves little opportunity for the students to learn from each other, requiring support from the instructors. This is compounded when the exchange between the students on issues they are facing is limited. A project manager can help by knowing what students are working on and forging the connections between students working on similar problems and with similar issues.

2.4 Educational Impacts

In the individual project approach the educational impact of the project is usually only dependant on the project selection details. As long as the project is defined to cover the concepts required, the student should get educational benefits from completing the project. Another point of consideration is that the students are exposed to various applications and aspects of VR through the project. In one large group project, the students may receive a narrower view of VR, as they experience only one application of VR, instead of the various applications present in the individual projects.

The educational outcomes of the project for each student is another point to consider. The students all do only some small piece of the whole and all differing pieces. In this way the educational outcomes students all get different educational values out the project, as their project experience differs. The project has reinforced something different for each student, eg. modeling vs. programming, making the overall learning basis of the project questionable. If a specific student is assigned the task of project management this question is more profound. While the educational value of learning project management skills is undeniable for the student's future in industry, their understanding of the course materials may suffer. Conversely, it could be argued that they will have a broader understanding, as they should be involved in all aspects of the project.

Figure 1: Virtual Reality Course Task Design

3 Our Multi-Layered Project Design

In the past we have been part of and taught using both individual and group projects in various courses. We have also taught using both student and instructor defined projects. In this section we present an approach to defining a project, which we feel successfully combines individual and large group project designs into a better form. This combination retains the many of positive aspects of the two designs, while minimizing the negative aspects. We discuss our new multi-layered project approach and how this differs from the project designs presented in Section 2. Throughout this discussion, we present arguments on why we believe the new project design is a beneficial approach, particularly for Virtual Reality courses.

The basic idea is to have the students build a single large project that is equally divisible. In contrast to the typical large project, the division of tasks is performed by having the students working on creating a toolkit of equal building blocks, e.g. implementing different techniques that perform the same function. Students implement one technique, either individually or in small groups. The project is the composition of individual building blocks and the surrounding portions, which form a larger whole. Figure 1 shows the course design of our navigation technique based VR project. Section 4 explores this approach on hand a concrete example of implementing it.

Having students working on a toolkit of techniques, which all address one issue, has a number of advantages. Having all sub-projects address the same basic task results in the students all facing similar issues. The issues that one has are likely be affecting others. Hence, they are more easily able to support each other, simplifying the instructor's support role. Additionally, as the students are not all working on completely different tasks, the instructors need only to be prepared for questions surrounding a single topic area instead of the multitude of possible questions abounding in Virtual Reality's diverse topics. This division into toolkit tasks also reduces the possibility of inter-project dependencies.

This multi-layered approach has many factors built in that are designed to bolster student motivation. The students still have feeling of being part of a larger project. If the collection of building blocks is designed to be further used, for instance in research projects as a testbed application

for comparative evaluation, students may be more motivated. This format also more directly exploits competitive nature found in many students, as the building blocks are solutions to the same problem, so it is easier for students to directly compare their results.

A number of potential methods for selecting topics in such a project exist, one seeming particularly advantageous. We expect that the topic for the building block portion of the project will be defined by the instructor of the course. Defining the project around a toolkit for a particular task, provides constraints to the broad space of possibilities. With this constraint, the students can easier select a topic of interest to them. It is possible to have them either develop their own design to implement. In the worse case, the techniques can be defined by the instructor, leaving the selection of which to implement to the individual students.

Regardless of what the theme of the project is, there are two supporting requirements, which generally dependant on the university environment. The first is the choice of which VR framework the students' projects should created with. The second is the virtual environment in which they should work. For the virtual environment either an existing environment can be used or the students can develop something as a group. Developing the environment as a group provides yet another opportunity for the group to incorporate their own ideas, increasing their feeling of it being their own project. Naturally, it also places more requirements on the students, such as learning to model.

Within VR, this multi-layer approach will often be naturally research related. As the building blocks are typically a working set of techniques, the students exposure to research and research methods is high. They will likely have to work from research papers for the implementation of the ideas and have to read papers for selecting ideas that interest them. A further useful aspect is that integrating an evaluation process into the course can provide a functional capstone to the project. For instance, a comparative evaluation of the different methods implemented, as is often performed in VR papers, is possible.

4   Virtual Reality Course Design

This section describes a course we held on Virtual Reality, using our described approach. The course goals precede a description of the course structure. After presenting how the course preceded, we highlight portions of the project the students complete in the course.

4.1   Course Goals

In planning a course on Virtual Reality, we contemplated what we wanted to achieve with the course. We decided to place a focus on a particular theme within VR, particularly for the project portion of the course. We chose navigating virtual worlds to be the focus topic in that year. With

the term navigating we intended a broader sense, including such topics as: wayfinding, travel, locomotion, maneuvering, and exploration. [BKJP05]

Our *goals for the outcome* of the course were: development of a testbed application for navigation, a toolkit of navigation methods for research purposes, potentially have new navigation methods developed, and lay the foundations for further student projects and diploma theses. The *student learning objectives* we identified in planning for the course were: real-time graphics (enough understanding to confront common VR problems), Scene Graph principles, the Avango VR system [Fra, Tra99], interaction with VEs, in-depth understanding of navigation in VEs, and that the students obtain basic modeling knowledge and experience.

In order to meet these goals, we needed an appropriate format for the course, within the university course structure. At the University of Hamburg, the diploma courses range from dedicated projects to seminars and lectures. The VR course was a six hour per week course, divided over two semesters, called a "Project." Project courses are applied courses in an otherwise largely theoretical curriculum. We chose this form, as it is focused on application of materials, which we believe a very successful way of teaching and learning and rewarding for students. Project courses are six hours per week presence time plus working hours outside class, leaving sufficient time to both teach and explore a subject and apply the knowledge learned.

4.2 Course Flow

The students in our VR course were third to fifth years students, pursuing a five year German Diploma in Computer Science (comparable with MSc level). By their third year, they already possess a solid theoretical base in mathematics, programming principles, and theory. A prerequisite for our course is fundamental computer graphics knowledge, as, for example, taught in a dedicated course CGB (Computergrafik und Bildsynthese, Computer Graphics and Image Synthesis), plus working knowledge of C++. The CGB course focuses primarily on ray-tracing fundamentals, with only rudimentary real-time CG coverage.

The course was divided into two semesters. In the first semester, 4 semester hours of class time, instruction was given on the necessary materials, both directly for the project and over general VR topic. Although this is slightly unconventional in a "Project" course, it was required, as many of the students only marginally fit the prerequisite criterion and VR was a new topic in itself.

In the first semester, the group was to define and develop a virtual world in which they could test out the techniques they would later implement. This idea followed roughly Bowman's testbed application [BJH01]. The students were free to chose a world of their own design, but it had to fulfill criterion, specifically that all of the different navigation related tasks could be tested within the environment. They were also required to be able to divide the modeling task into components for each individually complete. During the time allotted for defining the world's content, they were taught rudimentary modeling skills for building their Virtual Environment.

Instructor defined	Student suggested
Walk in Place	PogoStick (ChairIO based input)
Redirected Walking	SwopperFly (ChairIO based input)
Worlds In Miniature (WIM)	First Person Shooter (desktop)
Bird's Eye View	JetPack (desktop)
Hand's Eye View	
Wand based (traditional *wand* based methods)	
Path Planning (A*)	

Table 1: Navigation techniques implemented, both those defined by the instructors and those suggested and developed by the students.

The students chose to create a "middle ages" setting, centered around a castle on an island in the middle of a river in a valley. The castle was populated with a few buildings, a marketplace, and a hidden, extensive, maze-like dungeon. In the process of conceptualizing the world they would build, the instructors had to help steer them to make sure they did cover all aspects of navigation, mostly by asking questions on how they would test different aspects, e.g. "How will searching for an unknown target be supported?" To ensure that the model was created and meet the guidelines they had set forth, the group elected a team of students to perform the project management. Portions of the model they created can be seen in Figures 2 and 3.

With the model in place, the second phase of the project, could begin, implementing navigation methods. This transition took place at the end of the first semester. This allowed the students to use their summer break to get a jump start on their projects if they desired. We presented them with a list of methods we wanted to see implemented, but also allowed the students to develop their own projects. Projects of their own design had to be presented to the instructors and required instructor approval. Those who did not elect to create their own method selected from the given list of methods. The techniques implemented in the course can be found in Table 1.

The students had the second semester to complete their projects, with instructor support during the course times. The final presentation of the completed projects was done in form of an evaluation of the individual navigation methods. In the evaluation the different navigation tasks had to be performed with another student operating the device. Intuitivity was tested by requiring the unfamiliar operator to attempt to use the system, without explanation. Finally, the students had to write a written report over the project, including evaluation results, in order pass the course.

Figure 2: A: the modeled Virtual World as testbed for the navigation tests. B,C: JetPack navigation method (B - free focal point, movement through cellar, C - fixed focal point on top of tower, mover circulating tower from distance)

4.3 Project Results

Here, we present the results of the project. The project was successful on both of the project levels. The students developed a fairly complete world, which contained all required components for testing navigation techniques. The world extents are approximately 3 km x 3 km and the buildings of the castle provide ample places to perform fine maneuvering. An encompassing view of the world can be seen in Figure 2 A. Several close-up views are shown in Figure 2 B and C, and Figure 3. The students collectively completed a toolkit of navigation methods, with each student implementing one navigation method. The toolkit enables any of the different methods to be dynamically switched into. We present three of the sub-projects here. The first two are of the students' design, the JetPack and the SwopperFly. The third demonstrates what the students accomplished with the instructor selected approaches and is a combination of two methods, walk-in-place and redirected walking. In this course we used the Avango VR system [Fra, Tra99].

4.3.1 JetPack

The JetPack method is a desktop based technique, designed to be a replacement for the movers present in the Avango system. The basic concept of the mover was that it worked in a manner similar to a jetpack. Translation in the cardinal directions is controlled through keypress. A control mode was integrated on top of this jetpack metaphor, which makes the developed technique quite interesting. This modus allows the user to set a focal point (see Figure 2 B and C) and constrain the movement, rotation, around the focal point. The mover then functions similar to the "Trackball" movement found in many systems. For complex environments this combination seems quite practical. The user evaluation, unsurprisingly, showed that the user did need some instruction to use all capabilities of the JetPack. However, within a short period of time the user was performing well. Performing the defined tasks, the user did not exploit the full capabilities of the JetPack. It may be most useful in other task settings, such as the design and implementation of a Virtual Environment.
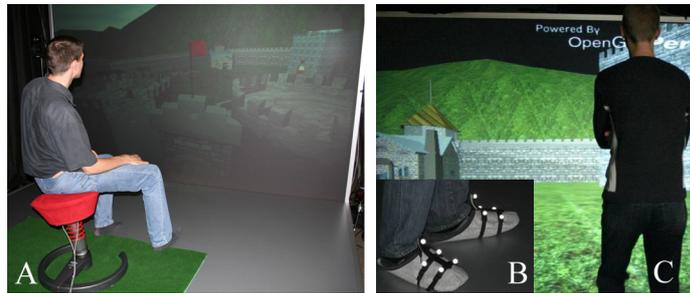
Figure 3: Navigation Methods - A: SwopperFly, B,C: Walk-In-Place

4.3.2 SwopperFly

The SwopperFly mover, shown in Figure 3 A, is a new technique, using a input device developed within our research group, the ChairIO [BBH05b]. The SwopperFly mover's goal was to develop a method of flying through the virtual world in addition to the ground following based technique previously developed. The ground following functionality of this mover is as is presented in the ChairIO literature [BBH05a, BBH05b]. The student's contribution is an addition flying modus.

Rather than the traditional modus change through digital input buttons, the student reflected on the freedoms of the stool itself. The seat is on top of a shock and spring system allowing it to move up and down. As the user moves along the ground, they activate the flying modus by a bounce on the seat to separate themselves from the ground. The flying mode itself is based on an airplane metaphor. Leaning back on the ChairIO to move up and conversely forward for down, i.e. pitch. Rotation of the seat maps to heading. Instead of roll, the student elected to deviate from the metaphor to make the side to side motion of the ChairIO map into "sidestep," as is popular from First Person Shooters. The forward velocity of the flying mode is controlled through use of the bouncing possibility of ChairIO. Bouncing up and down increases the velocity. After a period of bouncing inactivity the velocity tapers off. Moving from the flying modus back to ground following modus is accomplished by simply "landing."

The evaluation showed some room for improvement on the SwopperFly method. In the areas where the original ChairIO was shown to be highly intuitive, the SwopperFly also excelled. However, no user activated the flying portion without instruction. In flying modus the velocity input method was found to be cumbersome, as it required the user to be bouncing on the seat frequently, making it undesirable for lengthy usage.

4.3.3 Walk-In-Place and Redirected Walking

Two students worked as a small group on implementing walk-in-place along with redirected walking. As the sole device available to them at the time was our L-shaped immersive project system,

their development was mostly constrained to it. In total, they implemented three differing rotational methods into their mover, making them selectable at runtime, through Avango's scheme scripting. The students on this project struggled through numerous hardware issues, yet managed to complete their project on time and learned a great deal. Tracking issues in our laboratory due to a strong metal field affecting our magnetic tracker lead the students to struggle with getting recognition of the steps. They had to try various methods. Unfortunately, after setting up a optical tracker, they again had to recode, but were rewarded with a stable system (see Figure 3 B and C). Users in the evaluation were able to operate the method immediately. Naturally, the students pointed out the usability of the method was not particularly good for large distances, but well suited for maneuvering.

5   Conclusion

In this paper we have presented a new method for defining projects in Virtual Reality courses. This project definition is a two layer project, consisting of an overall group project and individual portions. It differs, however, from both traditional group projects and individual projects, attempting to draw from their best aspects. The individual portions of the project are building blocks, where each is a different solution to the same problem, e.g. navigation methods. These individual portions are then fit together into a framework, a task for the group as a whole. The group is also responsible for the portions necessary to support the individual sub-projects.

We also presented our realization of this multi-layer building block design in our 2005-2006 Virtual Reality course. In this course, we structured the project around a core issue in VR, navigating Virtual Environments. The students designed and built a testbed application in which to test all aspects of navigation. The students then built a toolkit of methods to be tested, with each method implemented by one student.

In the course evaluation the eleven students reported that they were motivated by both layers of the project, that is having their well defined individual sub-project and also the complete group project. The median rating for both were a 4 on a 5 point Linkert scale (1: not at all/very bad, 5: very much/very good), with 0.74 and 1.2 deviation respectively. When asked if the students would rather like an individual project of their own proposal, the response trended to the negative side, 2 (1.14). When asked what had motivated them to complete the project and in such a good fashion, the number one factor was the theme, Following this was needing the credits, the group itself, and the instructors, rounding out the most responses. The students evaluation of the course as a whole was good, 4 (0.36) and that they had had fun 4 (0.72).

The results of using this project method were encouraging. In our experience the resultant VR project was fairly complex and good outcome for a VR course. The students created something

they are proud of and which we will be able to further use. Some of the students continue to improve what they have done outside of the course, and several have elected to continue with our current course, purely for the enjoyment. We have continued to use this project design principle in our VR course this year.

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