Education Paper

Teaching Computer Graphics in the Context of Theatre

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ABSTRACT

Since the spring of 2004 the authors have coordinated efforts in teaching computer graphics within courses in their disciplines of computer science and computer graphics design, while collaborating on virtual theatre productions. On the computer science side one course is devoted exclusively to building the infrastructure necessary to produce participatory virtual theatre over the Internet. Some projects in CS extend beyond that single course into projects in other courses and some aspects have developed into thesis projects. On the design side, students in several different courses design and construct elements and assets for the production. In a modeling course, students design and build the sets. In a character design course, students design and build the characters. The design professor serves as artistic director and the CS professor as the technical director. This paper describes the advantages of this approach and tells of our experiences in teaching graphics in this theatrical context for both computer science and design.

Categories and Subject Descriptors: I 3.7 [Computer Graphics]: Three Dimensional Graphics and Realism – *Virtual reality*.; J 5 [Arts and Humanities]: Performing Arts

1. Introduction

Theatre is by nature a collaborative art: the perfect melding of the artistic and technical; an art that requires intricate synchronicity and coordination between teams of professionals, all working together towards a common goal. Much the same can be said about most projects in the field of computer graphics. From its infancy, computer graphics has always been a unique juxtaposition of art and technology.

Theatre has been a part of human existence in one form or another for centuries. However, the use of computer graphics in theatre is a relatively new idea. With backgrounds in theater and a shared interest in computer graphics, two faculty members, one in Computer Science and the other in Computer Graphics Design, found ways to utilize their common interests to create opportunities for students in the two departments to collaborate and for both groups to learn computer graphics via projects in theatre.

Many industry partners have encouraged the inclusion of interdisciplinary teamwork in the curriculum. Since theatre is, by nature, intensely collaborative with writers, designers, directors, actors and technicians all bringing different skills together to create a production, it seemed the perfect vehicle for creating an interdisciplinary context for learning computer graphics.

In this paper, we explore the question of how theatre can, and has, been used as a motivating application to educate those in the discipline of Computer Graphics and describe our experiences over the past four years with teaching graphics in the context of theatre.

2. The Virtual Theatre Project

The Virtual Theatre project was started in 2004 with the goal of combining computer graphics, animation, and virtual reality to realize a live, interactive theatrical performance [GS04]. The initial stages of this work began with research to see what others had done in the way of virtual theatre. We were particularly interested in theatre rather than dance, television [BGC*00], movies, or musical performance. Work combining virtual reality with theatre has been performed with sophisticated motion capture equipment, controlling characters projected on screens in a live theatrical production [BP98]; AI directed avatars [PG96]; and video images over the internet [MM08]. For this collaboration, we envisioned a different theatrical scenario.

Our vision involved a performance on a virtual stage (Figure 1), with human actors controlling performing avatars, stagehands controlling lighting and set changes, and a stage manager coordinating all of the cues. In addition, audience participation and the ability of the performers and crew to respond to audience reactions were essential. All this was to be achieved with the requirement that each of the participants need not occupy the same physical space.

Some consideration was given to building performances in existing virtual worlds like Second Life and since then, theatrical performances have indeed been produced there

[SLShakespeare08] [Schrum08]. However, at the time, these worlds did not yet offer the flexibility and the degree of control that we sought to achieve in our vision.

Figure 1: *A Virtual Stage Model*

We chose instead to adapt a game engine, defining a means for users to interact with objects in a 3D world during the course of a performance (Figure 2) . A game engine is a natural choice for the project, as it provides layered access to 3D graphics, sound, and networking libraries using an intuitive interface. As part of this adaptation, we define and implement an additional layer of abstraction to allow *theatrical* control of the 3D world defined using the processes and langauge of theatre.
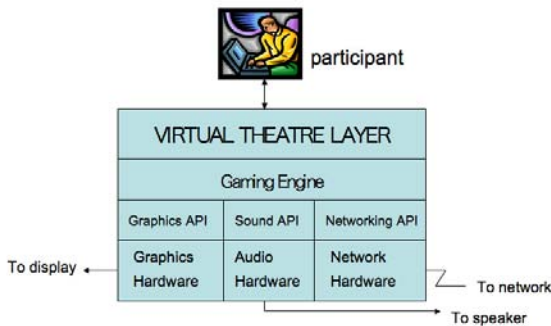

Figure 2: *Adapting a gaming engine for theatrical purposes*

This challenging project would require many levels of input from faculty and students; particularly in the early years, when tools, hardware, and devices at our disposal were limited. For our first exploration, we use a single node motion capture system in combination with a data glove and a behavioral model [Law04], to control a swarm of bees in search of nectar from some uncooperative flowers (Figure 3). The plot was simple. The bees attempted to get nectar from a sequence of flowers, with the order selected by the audience. Each time they were thwarted, until their final demise.

With an educational goal, student participation in all levels was mandatory. A special topics course in Virtual Theatre was developed in the Computer Science Department. Modeling of the virtual actors and backgrounds was incorporated into two separate courses in Computer Graphics Design. In the end approximately 30 students contributed to the production of a virtual theatre performance called "*What's the Buzz?*" in the spring of 2004 [GS05].
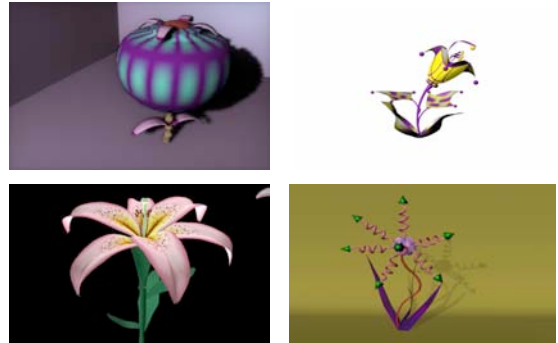

Figure 3: *Uncooperative Flowers*

Since that time, these courses have been offered annually, resulting in two additional theatrical productions. Our suite of available virtual reality devices has grown (Table 1) and several new versions of the software framework have been implemented based on several different commercial gaming engines (Table 2).

When Offered	Production	Interface devices
Spring 2004	*What's the Buzz?*	Single node FOB motion capture device, 5DT dataglove keyboard / mouse
Spring 2005	*Getting By*	Full body motion capture keyboard / mouse
Spring 2006-2008	*Critters*	Full body motion capture 5DT Dataglove P5 Dataglove keyboard / mouse

Table 1: *Virtual Theatre Productions*

	Engine	Language	When used
V1.0	MUPPETS [PBP03]	Java	2004/2005
V2.0	RenderWare (graphics) RakNet (networking)	C++	2006

| V3.0 | Torque Gaming Engine | C++ | 2007/2008 |

Table 2: *Gaming Engines*

3. Impact on Learning

The impact on the curriculum has been significant in both the computer science and design programs. Structuring each course around a large project spanning multiple programs led to increased student motivation. The fact that the work was to be presented to a large audience and the fact, that others were depending on students to successfully complete their work, influenced their attitude towards the work. Students felt an added importance to completing the work to the best of their ability. Most significantly, students learned hard lessons about the nature of collaboration and working together, and students in each discipline gained an appreciation for the knowledge and skills in the other. Below we consider each program separately.

3.1 Design

In the design courses, students met challenges that they rarely encounter in more traditional courses. By collaborating closely with computer science students they gain a deeper understanding of the technology that underlies the tools they use on a daily basis. They learn some computer science principles indirectly.

Due to the practical restrictions imposed by the gaming engine, the design students had to stick to strict limits on polygon counts. If the sets or characters became to complex, the performance would fail to work. These specific limits and trade-offs between the complexity of the set and the characters provided a more tangible goal than just 'keeping the models light'.
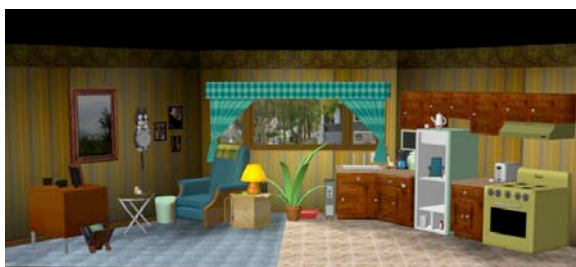
Figure 4: *Set design for "Critters"*

In addition to limits on the polygon counts, students had work within other constraints imposed by the technology employed by the virtual theatre system, as not all features provided by a modeling tool may be supported in a real time environment. For example, in one case, a model was created using transparency maps and the particular game engine in use for that production was not able to handle them. Thus, the model and maps had to be revised. This example emphasizes the need for clear communication and coordination between the artistic and technical teams.

The design students were required to work in a consistent style with other design students. When different components were not working well together, they had to discuss and debate how to revise the design to solve the visual problems.

Recently, one of the design students talked about how much he enjoyed designing scenery. A big part of that reaction is due to the very specific requirements for set design. The spaces have to be designed appropriately for the action of the script and the elements within the space have to be designed so that they are in keeping with the character(s) who live in the space during the time period of the play. For example, our latest production, *Critters*, centers on Ester, an elderly woman, and her interactions with imaginary friends in her dated studio apartment (Figure 4). In designing the set for this performance, questions such as: "do you really think that's what she would choose", or "don't you think her living room would be a little more cluttered?" or "everything in the room is 1970's, do you think that's realistic, or "has she accumulated items over the years from different periods?" were especially helpful in motivating students in the creation of the models for Ester's apartment.

The creation of a performance on a virtual rather than physical stage, also allowed for some creative liberty with respect to design of the set and stage pieces. For example, in *Getting By*, we were attempting to place a live performance in the world of a silent black and white movie. Unlike a physical stage play, individual sets for each scene were not constructed. Instead, a large continuous world, more resembling a movie set was built (Figure 5). Scene changes in the production were achieved by moving the viewpoint of each audience member in the virtual spaces as to focus on the area of the set where the action is taking place.

Figure 5: *Set design for "Getting By"*

The characters in *Getting By* were designed as stylized humanoid figures (Figure 6), fitting the theme and feel of the silent movie style of the story and production.

The impact on the design students, with regard to the computer science discipline, was significant. First, they gained respect and understanding for the skills and knowledge that is a part of computer science. Second, some of them started with a question "how did you do that?" and ended up with an interest in computer science. Granted

their interest may not be in pure computer science, but rather in the ability to use computer science to further their design goals. All the same they learn about computer science.
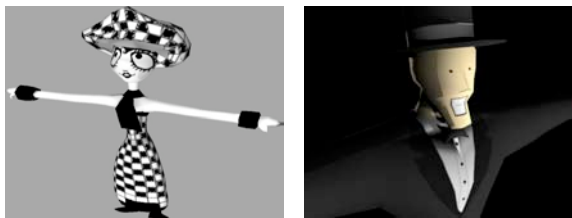

Figure 6: *Characters from "Getting By"*

3.2 Computer Science

On the Computer Science side, students were tasked with the challenge of designing and implementing the technical framework that allows real-time interaction within the virtual space. The majority of this work is done in a specialized Virtual Theatre course offered by the Computer Science department. (This course is described in more detail in [GS07]). Students taking this specialized course are given the opportunity to apply the theory and algorithms learned from other graphics classes; such as those focusing on rendering, procedural shading, and algorithms of animation; to a complex and real world graphics system in a team environment. On the flip side, often times, solutions to issues that arise in the Virtual Theatre class are explored as final projects in these other classes.

In the virtual theatre course, students are divided into teams based on interests and expertise with each team tasked to design and implement one or more components of the overall system. The course is totally driven by the technical challenges of building the complete Virtual Theatre system. The classes became production meetings. The teams report on their progress and the problems they were encountering; adjustments and compromises are made; innovating solutions are explored. This give and take produces a very different learning experience from the traditional situation where each student is working independently.

As a result, commitment to the overall project was strong. Students seemed to understand that if they didn't understand something or were having trouble solving a problem, they could work with someone else to find a resolution.

Often in these meetings, students would brainstorm on a given problem or issue. It is during these interactive sessions that the richest collaborative experience is observed. This is especially true when the discussion involves both artists and technologists. Just as the design students gained an appreciation for computer science, CS students become aware of the thinking process of the artists and learn how to specify and implement tools to meet the needs of these users.

At the end of the CS course, when asked, "What did you learn in Virtual Theatre, some of the more common replies included:

- Technical Content
- Integration on a Large Scale project
- The importance of deadlines and backups
- How to work with artists
- How to work independently and within teams
- Problem solving and the importance of communication
- That class can be fun

On several occasions, graduate students have extended the work done for Virtual Theatre to form the foundation for their graduate capstone project or thesis. Such projects include those in the areas of motion capture, behavioural models, and photographic simulation. Some of these projects, in turn, have been utilized in future offerings of Virtual Theatre and incorporated into later implementations of the virtual theatre framework.

3.3 Collaboration and Communication

One of the biggest learning opportunities for students lies in the areas of communication and collaboration. In traditional theatrical interactions, communication is critical and there is a kind of unspoken rule that if there is a problem, you make it known right away. Not doing so might jeopardize the production. Sometimes the problem is voiced and dismissed, but not voicing it is not an option.

Since students in these courses may not have any experience working in a theatrical setting, they are not accustomed to these rules. There was often hesitation to bring up problems directly with the parties concerned. In some cases, students felt that they had to go through the 'chain of command' to get the information that they needed, rather than just asking directly, causing delays in the completion of key elements of the production.

Another collaboration challenge is in recognizing boundaries and defining roles. In theatre, responsibilities and tasks are clearly defined with the success of production relying on respect of these boundaries. It is important to make clear to the students in both departments, who is responsible for what. For example, if a changed in needed in a model, it is OK to go directly to the modeler. If the change is in the look of the model, then the designer must be consulted.

Although effort is made by the professors to discuss these issues in class, the lessons learned don't have nearly the same impact as when a student realizes the effect communication, collaboration, or lack thereof, has on the production.

Finally, with all elements, it is important that the students complete their task under the guidance of the instructors who serve as technical and artistic directors. At the

same time, the instructors must resist the temptation to take too active a role in the development of code or models. The primary goal of the project is education and often, more learning takes place when something doesn't work than when everything goes smoothly.

4. Learning from the Theatre

Theatre provides a rich platform for learning computer graphics; as many of the challenges faced in the virtual theatrical context, both technical and artistic, involve solutions relating to graphics. In 2006, the SIGGRAPH Education Committee published a Curriculum Knowledge Base for the emerging discipline of Computer Graphics [OAL*07]. This knowledge base is presented as a palette of subject areas and skills that form the necessary educational framework for creation of undergraduate curricula that specialize in computer graphics. Of the areas listed as topics of study in this knowledge base, a majority are represented and required for the virtual theatre project. This includes:

- Programming and scripting
- Animation
- Rendering
- Human Computer Interaction
- Modeling
- Art and Design
- Graphics Hardware
- Digital Images
- Communication
- Real Time Graphics

The theatrical experience, and the process of producing a theatrical production in a virtual space, provide students the opportunity to apply their knowledge and expertise in these graphic related area to a large scale, real word problem.

Over the past four years, the virtual theatre project has been a source of endless opportunities for advanced studies in graphics. As the productions become more involved and the interaction techniques more sophisticated; the expectations for the final performance gets raised to a higher level. With each new production, come new technical and artistic challenges that must be faced and overcome. As a result, each of annual offerings of the courses is unique and quite different from the offerings that preceded it.

In addition, due to the collaborative nature of theatre, students also gain experience in some of the softer skills (e.g. communication, responsibility, collaboration between artists and technologists) required for a successful career in graphics. [Catron08] lists a set of attributes that theatre majors gain from completing a four-year degree. Some of these attributes, which are beneficial to any job, are listed below:

1. Broad vision
2. Learn by doing
3. Oral communication skills
4. Creative problem solving ability
5. Take pride in the quality of their work

6. Motivation and commitment
7. Willingness to work cooperatively
8. Ability to work independently
9. Time management
10. Taking initiative
11. Promptness, respect for deadlines
12. Acceptance of rules
13. Learn quickly AND correctly
14. Respect for colleagues
15. Respect for authority
16. Adaptability and flexibility
17. Work under pressure
18. Healthy self-image
19. Deal with disappointment
20. Self-discipline
21. Goal oriented
22. Ability to concentrate
23. Dedication
24. Accept responsibility
25. Leadership skills
26. Self-confidence
27. Enjoyment

Over the years that we have taught the courses in virtual theatre, we have observed clear examples of these same skills in many of the students who have taken these courses. We believe that the collaborative nature of the theatrical process explored in the courses greatly contribute to this learning.

5. Conclusions

We found that teaching computer graphics in the context of theatre to be a most effective means to motivate students and provide them an opportunity to learn and apply graphics knowledge. The implementation of a theatrical production in a virtual space requires knowledge in a broad spectrum of areas related to computer graphics and provides students with the opportunity to apply their graphics expertise in these areas. This is equally true with computer science students as well as those studying computer graphics design.

In addition to teaching graphics related content, theatre exposes students to many skills that are useful in most any position. The students learn to work with others, to communicate well, to respect others, to demand high standards, to meet a deadline, to accept responsibility, and to problem solve. Theatre proves to be a good context for learning the 'soft' skills, so useful to computer scientists. In addition, the designers who work with these computer science students learn about computer science, in ways that will benefit them on the job as well. Overall computer graphics and theatre are a winning combination.

6. Acknowledgements

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