A MULTI-EXPERTISE APPLICATION-DRIVEN CLASS

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ABSTRACT

In this paper we report on our experience of teaching a multi-expertise application-driven course in which upper-level undergraduate and entry-level graduate students from computer science, computer graphics technology, and educational science worked together to design, develop and evaluate a distance learning system. We describe the activities pursued in the class, the interactions between the various groups of students, as well as the challenges and advantages ensuing from the great variety of student backgrounds. The success of the class is measured in two ways. First, the class achieved the goal of building a distance learning system that surpasses the state of the art by improving the integration of the remote students into regular on-campus learning. Second, a survey conducted at the end of the course indicates that the application-driven, collaborative, and multi-expertise structure of the class provided a uniquely effective learning experience.

1 INTRODUCTION

The ever increasing complexity of software and computing applications requires more and more large multi-expertise teams able to take advantage of the expertise of different team members. Many companies in the technology sector recognize the benefits of using participants with diverse backgrounds reaching beyond the computer science and engineering fields. For example, one relatively recent trend is the use of anthropologists [1, 2] to examine how users interact with technology and find ways of translating ethnographic insights into meaningful design and technology interventions and innovations.

Although current real-life projects require large teams and very often transition mechanisms accommodating frequent team changes due to the length of the projects, most of the courses on the computer science syllabus use small-scale projects that are completed in a few weeks by teams of 2-3 students. Within such small teams it is typical that one student assumes a dominant role in terms of overall understanding of the project, of effort, and consequently of benefiting from the learning experience.

One notable exception are software engineering classes organized around larger projects, sometimes having an industry partner, and which require several members to collaborate and significantly contribute to the project. Another exception is the well-known EPICS program [3] implemented at several universities, in which teams of engineering and computer science undergraduate students design, build, and deploy real systems to solve engineering-based problems for local community service and education organizations. Although these opportunities for working on larger teams are important for computer science education, they lack the multi-expertise and the research components, since all students are close to the computer science field and since the solutions to the problems solved by the projects are usually well known.

In this paper we report on our experience in teaching a course in which a large team of upper-level undergraduate and entry-level graduate students with a diverse background and enrolled in several departments worked together forming a multi-expertise team. The class was driven by the development of a novel distance learning system that surpasses the state of the art.

Our class was specifically structured to be run among several departments and accommodate students with non-technical backgrounds. Specifically, the students enrolled in the class were attending three different departments: computer science, computer graphics technology and educational technology, with expertise in networking, distributed systems, graphics, and educational science. To accommodate the needs of students from these diverse backgrounds, the class had several instructors acting as facilitators for the interactions between the students. Our instructor team consisted of experts covering the expertise required in taking the project the focus of the class: computer graphics, computer graphics technology, distributed systems, network security and educational science. The structure of the class provided opportunities to take advantage of the diverse background of the students. For example educational science students use their expertise to continuously provide feedback to the design team and design methods to evaluate to what degree the distance learning system achieved its educational goals.

We evaluate the success of the class in two ways. First, the class achieved the goal of building a distance learning system that overcomes important disadvantages of existing systems by improving the integration of remote students into regular on-campus learning. Second, a survey conducted at the end of the course indicated that the project-based, collaborative, and interdisciplinary structure

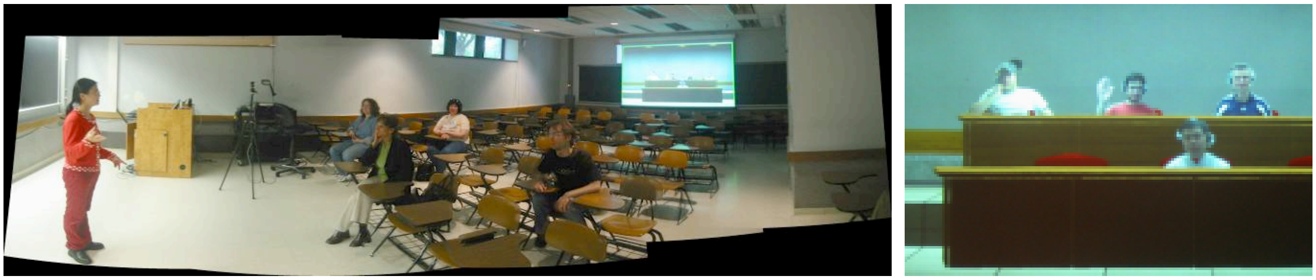

Figure 1 Distance learning system developed by the class. The remote students are integrated into a virtual extension of the classroom, projected onto the back wall (*left*—panoramic image, and *right*—magnified fragment of back wall projection).

of the class provided a uniquely effective learning experience.

2 CLASS STRUCTURE

The class was designed with two interdependent sets of goals. One set consisted of educational goals while the other focused on application development goals.

The educational goals of the project focused on providing a framework facilitating personal growth through interactions with others, use and increase of own expertise, and a glimpse of real-life project experience. Specifically, the educational goals were:

1. Give each student conversant knowledge in all the areas covered by the project, including computer science, graphics, networking, computer graphics technology, and educational science.
2. Let each student enhance the depth and breadth of knowledge possessed in the major field of study as well as in specialization subfields.
3. Let each student learn how to work in a large multi-expertise team; concretely a student had to identify problems within the student's area of expertise that had to be solved to reach the overall goal, to understand problems formulated by members of the team with different expertise, to formulate problems addressed to members of the team with different expertise, and to provide solutions that can be easily integrated in the overall system.
4. Let each student learn how to work such that a concrete goal can be attained with best results by a deadline.

The second set of goals provided a focused environment to achieve the educational goals. The project-based and application development goals were:

1. Study of existing distance learning systems and identification of shortcomings.
2. Design of novel distance learning system that overcomes these shortcomings.
3. Implementation and testing of first prototype of novel distance learning system.
4. Educational science validation of the novel distance learning system.

The class was offered for the first time in the spring semester of 2005, and continued in the summer and fall of 2005 and in the spring and summer of 2006. For maximum flexibility, each student could enroll in an independent study course in one of the three departments involved. Each student was required to participate in at least two modules (e.g. spring and summer). Some students have taken all modules, some have graduated and were replaced by new students.

The class was organized to accommodate team meetings, sub-team meetings and one-to-one meetings. The class met once a week with all the students. The students were further split in three groups: graphics, networking, and educational science. The groups met individually once a week.

3 STUDENT GROUP CLASS ACTIVITES

We describe the activities of each group below. To facilitate the presentation of the activities conducted in the class we first give an overview of the distance learning system designed and developed in the class.

3.1 Distance Learning System

The distance learning system developed within the class consists of three applications: the remote student application, the classroom application and the shared whiteboard application. A remote student is captured individually with a web camera, and is modeled as with video sprite inserted into a 3D model of a virtual classroom. The virtual classroom is rendered and projected onto the back wall of the real classroom (Figure 1). The remote students are provided with a panoramic view of the real classroom. A shared white board application was also developed. The local distance learning system users (instructor and students) had access to the electronic whiteboard while the remote users (students) interacted with a synchronized simulated whiteboard.

Each of the applications described above offered the students of our class the opportunity to work in teams, to learn from each other and to use their own expertise.

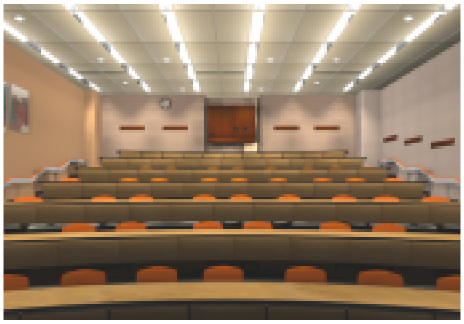

Figure 2 Maximal configuration of virtual extension.

Feedback from educational science was used in the design process of each of these components.

3.2 Graphics Group

Photorealistic classroom modeling

This activity focused on producing a 3D model of a classroom that can be rendered at interactive rates (>15 frames per second) to produce a believable extension of the real classroom, similar to an adjacent room seen through a window in the back wall. Many approaches to 3D modeling were investigated, including CAD [4, 5], laser rangefinding [6, 7, 8], stereo reconstruction [9, 10], and animation software [11, 12].

The animation software and the laser rangefinding approaches were actually pursued by two subgroups of students. The animation software approach proved to be the best suited for the regular man-made geometry of classrooms.

The resulting 3D model was optimized for the application at hand, namely it was designed such that it is reconfigurable to optimally accommodate between 7 (Figure 2) and more than 50 students (Figure 3).

The task allowed the students to learn about the capabilities and limitations of current graphics modeling techniques. In addition, it required computer graphics technology and computer science students to collaborate and make best use of their skills: programming, artistic talent, familiarity with state-of-the-art commercial modeling tools.

The photorealism classroom modeling group interacted with the remote student modeling group (described below) to clearly specify the interface between modules such as the placement of the remote student sprites.

Real-time remote student modeling

This activity focused on developing a filter that first learns the background then subtracts the background from each frame of a video feed (Figure). No special background is needed (i.e. blue or green screen), nor does the lighting have to be controlled in any way. The filter first blurs, subtracts the background, and then fills in holes and eliminates “flies”. This task required students to learn how

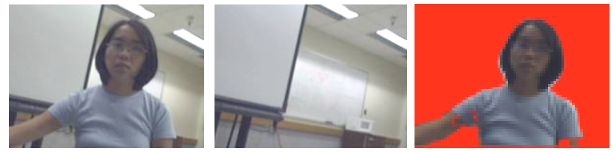

Figure 3 Frame, background, and foreground.

to work with virtually any camera. They successfully used a web camera that costs less than $100, which suggests that the system will work with minimal hardware at the remote student end.

The background subtraction module splits the foreground image in packets suitable for network transmission and sends it to the real classroom. The classroom application receives the sprite of each student and places each sprite onto a quadrilateral that matches a chair in the virtual classroom. The remote student application receives a panoramic video stream of the local real classroom including the instructor. The two way communication required close collaboration with the networking group (described below).

Hardware implementation

One of the unique features of this course is providing students with a realistic environment in which they could actually deploy and test their application. For the developing part of the project we took advantage of existing state-of-the-art computing and graphics infrastructure available in the several departments. In addition, we modified the projector support in one of the classrooms to provide the needed testing infrastructure. Figure 4 presents the main setup of the testing environment: a real classroom equipped with 2 projectors, a fisheye camera, microphones and projection screens.

Designing the testing environment provided the students with the experience of searching for suitable hardware and of interacting with vendors, marketers, business office, and hardware and software support offices. The students had the opportunity to deploy the application they had developed and they were its first users. This not only provided the opportunity to thoroughly test the system, but also to get a sense of the great impact their work could potentially have at societal scale.

3.3 Networking Group

The networking module is a crucial component of the system as it has the task to ensure effective communication among the different participants. The networking group performed a survey to identify the most appropriate technology to use for the given communication pattern, then once a technology was selected and the group become familiar with it, the networking module was implemented and interfaced with the rest of the system. The first step

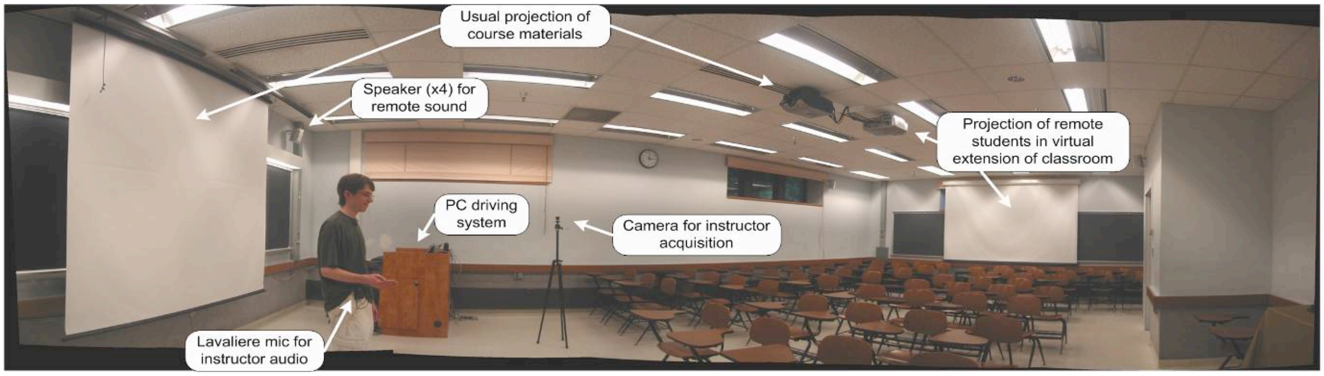

Figure 0 Hardware components of distance learning system.

was integration with the electronic whiteboard, then integration with the classroom application.

The application offered the networking students the opportunity to apply their knowledge that is sometimes acquired through dry projects to a very specific application with concrete problems: network bandwidth limitations vs. the amount of graphic information that must be sent. This required the networking group to interact closely with the graphics group, not only to define the protocol and interface specification, but also to modify some of the graphic representations and algorithms to minimize the amount of information sent. The approach allowed them to improve system scalability. One of the challenges encountered was finding a common language and understanding the existent limitations in each of the two areas. Another challenge was designing meaningful tools to quantify the performance of the system.

3.4 Educational Science Group

The educational science group had the task of guiding the design of and evaluating the distance learning system. In anticipation of the first prototype of the system, the educational science team conducted activities aimed at developing a rigorous evaluation model suitable for the system being developed. The group first conducted a literature review on *interactivity* in teaching and learning, on *presence* in virtual environments, and on *photorealistic graphics*. They synthesized the literature view into a paper that addresses how interactivity, photorealistic graphics, and a sense of presence enhance learning, support multiple modalities, and enhance motivation. The education science team articulated a set of design requirements accordingly. Finally, the team designed a system evaluation model.

One of the main benefits of the project was allowing educational science students who in some sense are beneficiaries of the distance learning system to understand the complexities involved in building such a system while being able to provide input at each phase of the project. In addition, students learnt about the issues involved in testing and setting up pilot studies involving human subjects.

4 COLLABORATIVE AND MULTI-EXPERTISE LEARNING

A thorough evaluation was performed to quantify the degree to which the course taken by students from different disciplines enhanced their learning experience. The evaluation focused on the degree to which the course utilized the following pertinent instructional strategies: discovery learning, project-based learning, collaborative/cooperative learning, and interdisciplinary learning. More specifically, the evaluation addressed the following four questions:

- To what degree did this course utilize discovery learning?
- To what degree did this course utilize project-based learning?
- To what degree did this course utilize collaborative/cooperative learning?
- To what degree did this course utilize interdisciplinary learning?

Evaluation of the degree of implementation of each of the four identified instructional strategies was done in multiple stages. First, indicators were developed; indicators are observable and/or reportable behaviors that suggest that discovery learning, project-based learning, collaborative learning and interdisciplinary learning occurred. The criteria were then ranked according to importance. Survey and interview questions were then created to elicit responses from instructors, students, and an observer; the responses were then analyzed and interpreted to answer the four questions above.

We looked at responses according to the four categories and found the following:

- 66% of discovery learning indicators were present in the course.
- 77% of the project-based learning indicators were present in the course.
- 67% of the collaborative/cooperative learning indicators were present in the course.

- 84% of the interdisciplinary learning indicators were present in the course.

The evaluation found that overall the four instructional strategies were determined by the majority of the participants involved in the course to have been incorporated successfully into the course structure.

5 CONCLUSION

In this paper we reported on our experience with teaching a multi-expertise, application-driven class in which a team of students with a very diverse background worked together to build a distance learning system. Probably the biggest achievement of the class was to produce a first prototype of the distance learning system. There is no substitute to actually implementing a complete, high-impact application when it comes to building student knowledge and self-confidence. The nature of the application made it fun as students assumed different roles in the testing process. The system built improved distance learning state-of-the-art in terms of interactivity and photo-realism.

A survey conducted at the end of the class, indicated that the class achieved successfully its goals of creating a multi-disciplinary environment that advanced learning, while being inclusive. The project-based, multi-disciplinary and collaborative nature of the class improved the learning process.

Teaching a class with students having such a diverse background was not without challenges. One of the major challenges was familiarizing students with the language from other areas or disciplines. Even in the context of computer science for example, graphics students and networking students had problems relating to each other when quantifying data in the design process. The instructors' role was critical in facilitating communication and helping students finding a common language. Another major challenge was managing such a large project, under specific deadlines to achieve quantifiable goals, while creating a framework to ensure project continuity from one semester to other. Unfortunately, computer science curriculum provides very little support in this aspect. The instructors contributed significantly at keeping the project focused and helping students setting up achievable goals.

We plan to continue offering the class. Current projects focus on enhancing the distance learning system to provide support for office hours, study groups in virtual environments like coffee shops and libraries, and to take exams in real time.

6 ACKNOWLEDGEMENTS

We would like to thank our students who made this experience fun and whose enthusiasm helped overcome the inherent challenges. This activity was supported by NSF grant 0417458-CNS.

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