Distance Design Collaboration Through an Advanced Interactive Discovery Environment

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Abstract

Syracuse and Cornell Universities are collaboratively working on the Advanced Interactive Discovery Environment (AIDE) for Engineering Education Project, which integrates and advances the best features of virtual, collaborative engineering environments, state-of-the-art simulation tools, and advanced learning management systems. An integral part of this project involves the development and teaching of a new, two-semester senior level design course that is offered synchronously at both institutions and which emphasizes teamwork, collaboration at a distance and multidisciplinary activities. One long-term goal of the project is that the course provides the context for feedback on the nature of virtual interactions, and therefore on how to improve the AIDE. In addition, we aim to study whether multifaceted instructional methods that leverage emerging information technologies can enhance student learning on fundamental technologies, systems-level engineering, and the multidisciplinary nature of, and approach to, present and future engineering problems.

The project is currently in its second year, during which emphasis has been placed primarily on getting the course, AIDE, and all the related hardware and software functioning effectively. The course is presently being taught in distance learning classrooms that use teleconferencing and screen-sharing technologies. Each distance learning classroom contains two screens in front, one that shows the image of the instructor at the remote site (when applicable) and the other that displays the image from a computer running a screen sharing application such as a slide presentation. In this manner, a virtual seminar environment has been created wherein students and faculty at the two locations can freely interact.

The focus of the first semester is small-team design of a thermo-structural system for a second-generation reusable launch vehicle. All teams consist of students from both Cornell and Syracuse Universities. Outside of classroom hours, student teams collaborate and interact using the AIDE. The project is being continually evaluated through the use of surveys, in-class observations, and tracking of web sites used by the students, and this information is used for improvements as well as to evaluate the effectiveness of this learning method in comparison to more conventional approaches.

Introduction

In industry and government laboratories, teams of scientists and engineers need to work together closely to achieve their goals. In large projects, the team members may live and work at geographically distant sites, and may work for different organizations, making communication and interaction between the team members difficult at best and disastrous at worst. An example of the worst-case scenario is the loss of the Mars Climate Orbiter in September 1999. "The peer review preliminary findings indicate that one team used English units [inches, feet and pounds] while the other used metric units for a key spacecraft operation" [1]. Such a breakdown in communication is much less likely if the team is well connected, either by physically being in the same place or by using effective collaboration tools.

Recognizing the need for teams at distributed geographic locations to work together, NASA formed the Intelligent Synthesis Environment (ISE) program. ISE's goals were to develop the capability for individuals at distributed geographic locations to interact effectively on the development of systems and/or missions, and to create the conditions for the acceptance of the required information technology (IT) tools by NASA employees and contractors. Although ISE is no longer an official NASA program, its goals remain in place and, in many respects, form the basis of the project described here.

In the Spring of 2001, with support from NASA, the State of New York, and the AT&T foundation, Syracuse and Cornell Universities began working on the Advanced Interactive Discovery Environment (AIDE) for Engineering Education Project, intended as a path-finder for NASA as it researches and works to gain the acceptance of the information technologies that will enable geographically distributed personnel to work closely on future vehicles and/or missions. The project consists of several key components, including: (1) development of the AIDE software to facilitate distance collaborations, (2) development of a two-semester, senior level, collaborative distance design course taught synchronously at Cornell and Syracuse Universities, (3) development of a reference space, which may be searched through powerful natural language processing techniques [2], contains links to appropriate knowledge bases and known experts on various topics, and can be integrated into the AIDE, (4) evaluation of the use of high performance computing and three dimensional virtual reality environments for the teaching of engineering design, (5) exploration of the potential of the AIDE tools for K-12 outreach, and (6) ongoing measurement and evaluation of all components of the project. We report here on items (1), (2) and (6) above; that is, the design course, development of supporting IT tools, and evaluation. At the time of this article, the second semester of the course is underway, and this work therefore focuses on our first semester experiences.

Course Description

One aspect of the project is to test the hypothesis that effective IT based collaboration tools can enhance engineering education, thereby better preparing students for professional practice. To this end, a two-semester design course was created that is being taught synchronously to seniors at Cornell and Syracuse Universities. The specific project undertaken by the students during the first semester was the design of a thermo-structural system for a specific location on a hypothetical second-generation reusable launch vehicle (RLV). This vehicle, shown in Figure 1, is based on a concept developed at NASA Langley Research Center (LaRC).

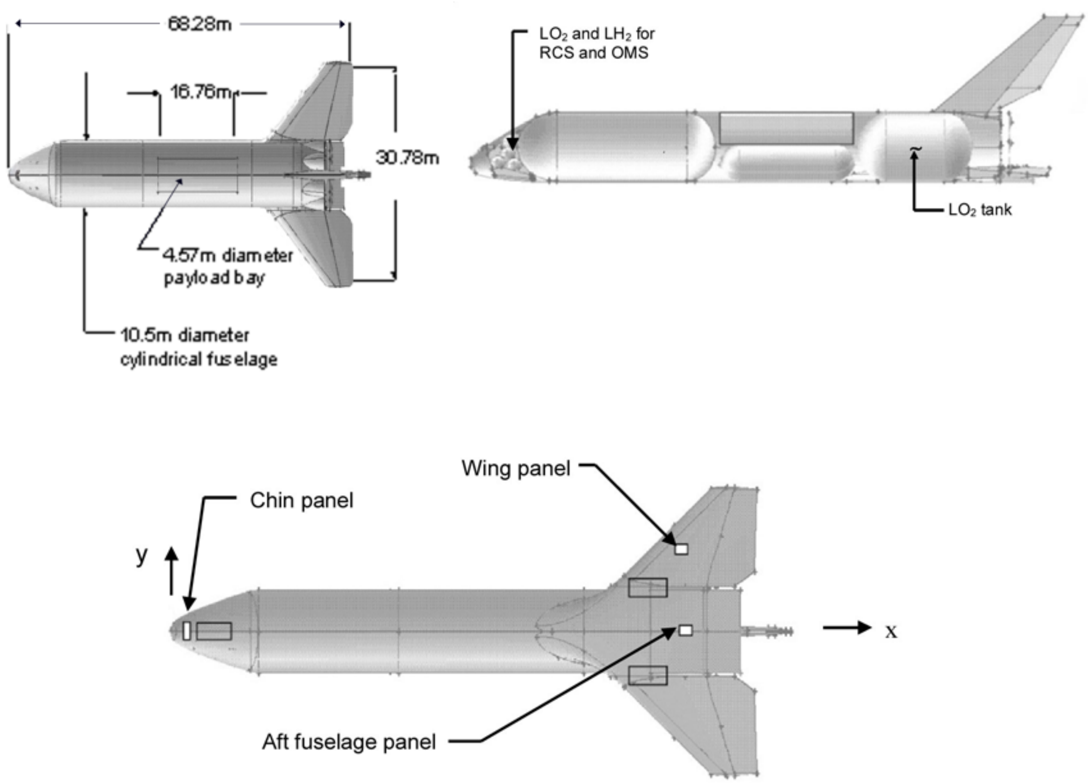

Figure 1, Top, side and bottom view of RLV concept that design project is based on.

Thirty-one students enrolled in the course, fourteen from Syracuse University (SU) and seventeen from Cornell University (CU). All of the SU students were Aerospace Engineering seniors and took this class in place of a previous requirement. One of the CU students was a Master's Degree candidate and the remainder were all seniors in Civil and Mechanical Engineering. This course was an elective for the Cornell students and, for all SU and many CU seniors, the course was used to satisfy their capstone design requirement. Early in the semester the students were split into six teams of five or six students. Each team had members from Syracuse and Cornell, thereby requiring each team to collaborate at a distance. Two "team-building events" were held early in the semester: an outdoor challenge course and an afternoon of project planning followed by bowling. These helped students get to know each other socially and significantly eased the distance collaboration processes.

Each team was given the task to perform the preliminary design of a thermo-structural system for a specific location on the vehicle shown in Figure 1. Three locations, the chin panel, an aft fuselage panel and a wing panel, and three thermal management concepts, hot structure, thermal protection system, and active cooling, were considered. That is, each team chose a different concept to design out of the 9 possible permutations. The resulting designs were required to withstand a given set of thermal and mechanical loadings for its location, which were provided by LaRC and were based upon thermo-fluids and structural finite element analysis results.

As the teams worked on their designs, the students were provided with lectures on aerospace structures, materials, design and analysis of composites, thermal analysis, risk assessment, cost assessment, project management, optimization and probabilistic approaches to design. Given the large number of topics, none were covered in great depth; rather the lectures and accompanying homework were designed to provide a base of information upon which students could ask questions and perform their own research to find the answers they needed to complete their designs. In parallel with the lectures, two case studies were performed, one of the current space transportation system (the Space Shuttle) and the other of the X-33 RLV demonstrator.

All lectures and case study presentations were given using PowerPoint; a typical sequence of slides is shown in Figure 2. Instructors prepared their slides and posted them to the AIDE (described in a subsequent section) the night before the lecture. Students could download the slides to their own computers for annotating or viewing during lecture. At SU, the computers were built into the desks, whereas at Cornell the students were each loaned wireless laptops. All lectures, presentations and discussions were recorded, and these audio and video recordings were synchronized with their associated PowerPoint presentations for subsequent on-line viewing.

Each team wrote two short progress reports that were accompanied by oral presentations. In addition, oral preliminary and critical design reviews were conducted, each of which was accompanied by a comprehensive written report. Oral presentations were in the distance learning classrooms (discussed in the following section) and, using three-way video conferencing, were attended by NASA LaRC structural and thermal experts. The faculty, students and NASA personnel all provided feedback during question and answer sessions.

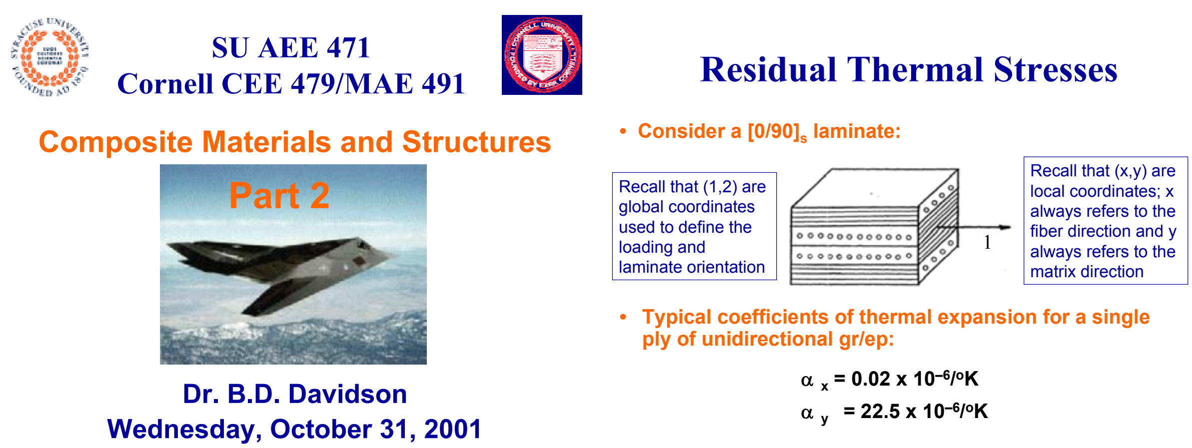

Figure 2, Sample PowerPoint slides from lecture on composite materials.

The faculty worked as a team on the determination of course grades. Final grades were assigned using both individual and team performance metrics on the written and oral reports, as well as peer evaluations to assist in the determination of each students' individual contributions. In these peer evaluations, students answered questions such as: "Did the team member seek out tasks and responsibilities?"; "Of all the team, how effective was this member?"; "How valuable was his/her contribution?"; or "If you were an employer, would you hire this individual for a design team?".

Physical Teaching and Learning Environments

All formal class interactions took place in distance learning classrooms (DLCs) equipped with video conferencing systems using an internet connection. Each classroom is equipped with two cameras, one focused on the instructor, the other on the students. Each classroom is also equipped with two screens in the front of the room; at SU, there are two screens in the back of the room, and at CU there is a single screen in back that uses picture-in-picture technology. The way that these screens and cameras are used is described below.

Figure 3 shows a photograph of the CU classroom taken from the back. As an illustrative example, when lectures were given by a Syracuse University instructor, SU would transmit its instructor camera signal to Cornell, and Cornell would transmit its student camera signal to Syracuse. The image of the SU instructor would be seen on one of the two screens in the front of the CU classroom, and the image of the Cornell students would be seen on one of the screens at the back of the Syracuse classroom. This allowed the SU instructor to engage all students (SU and CU) in essentially the same fashion. Regarding audio transmission, the Cornell classroom is equipped with push to talk microphones, while the Syracuse classroom is equipped with room microphones. The push to talk system provides less background noise; however, students often neglected to turn on their microphones prior to asking a question, in which case the SU classroom could not hear. In addition, these microphones required a longer "adjustment period" for the students to become accustomed to the DLC environment. With a room microphone, interactions occur in essentially the same fashion as in a traditional classroom; however, more background noise is transmitted. Thus, there appears to be no "best choice," and one can only consider these various trade-offs when designing a classroom.

As shown in Figure 3, the second screen at the front of each classroom was used to display the slides that were being presented. Again assuming the lecture originates at SU, screen-sharing technology was used to share the SU slides with a computer in the CU classroom that was attached to a second projector. Thus, the SU instructor controlled the information displayed at both sites. The second screen at the back of the room (picture-in-picture at CU) was used to display the outgoing signal, which allowed the instructor to ensure that the remote site was viewing the appropriate image.

At SU, one of the two front screens is a SmartBoard, a device that allows the instructor to draw or write on top of the presentations as well as to control applications from the board [3]. This system allows for a greater level of spontaneous interaction than conventional PowerPoint presentations. The SmartBoard was used quite successfully to sketch and to answer questions, but its full utility was not explored due to the lack of a similar piece of equipment at Cornell. Thus, a SmartBoard is currently being installed in the Cornell DLC, which will allow us to experiment with providing less information on the slides available to the students before class, and then adding information during the lecture as one might do with a chalkboard.

In addition to the above, a design studio was built at each school as a place for students to meet and work together on their projects. The studios are each equipped with high end, large screen computers running the AIDE software, the MS Office Suite, and a variety of simulation and project management packages. The PCs also are equipped with small cameras and headsets with microphones.

Figure 3, Cornell distance learning classroom. Left screen shows instructor from Syracuse giving a lecture. Right screen shows SU instructor's slides projected from a computer sharing the screen of the Syracuse classroom's computer. In foreground, CU students use wireless laptops to view and annotate presentations. A camera at the front of the Cornell classroom transmits a separate image – showing the CU students as viewed from the front - to Syracuse, which the SU instructor views at the back of the Syracuse University classroom.

The Advanced Interactive Discovery Environment

Collaborative IT tools have recently been recognized as key technologies in education and business. There are a number of large corporations now entering this market, such as Microsoft Windows Messenger in Windows XP or IBM's Lotus Sametime and Quickplace, as well as small firms such as Collabworx Virtual Classroom, NexPrise Program Manager [4] and others. These systems bring together audio and video conferencing, file and application sharing, message boards, chat, whiteboard sketching, document repositories and other features.

At the time that this project was initiated, an assessment was made that the commercially available software packages were insufficient to meet our needs for the classroom interactions and the associated research on collaboration and distributed learning. For this reason, we worked with Collabworx to develop the AIDE. A screen shot from an on-line meeting using the AIDE is shown in Figure 4. The left portion of the screen, or "control panel," provides on-line awareness features that also allow for instant or e-mail messages to be sent. Below this are buttons for access to user-controlled features; in our case, these include announcements, the course syllabus, and assignments that have recently been posted. There are also plans to include a button for accessing the reference space (cf. item (3) in the introduction). Below this are the collaboration tools. The white square will display active or scheduled meetings, and below this are buttons to activate chat, shared whiteboard, audio/video connections, and/or application, browser or screen sharing. The top right part of the screen contains the curriculum and applications "control tabs." The curriculum tab allows access to instructor presentations, assignments,

Figure 4, Screen shot of the AIDE. This system combines course information, access to lecture presentations, access to lecture recordings, instant messaging, chat, message boards, audio/video conferencing, screen sharing, application sharing, and whiteboard. The screen shows a video/audio conference in progress that is using browser sharing.

and lecture recordings; the applications tab allows access to all software which includes (among others) MS Office, MS Project, Matlab, CAD, FEA, and CFD codes. The remaining screen is the "working space" that may be filled with whatever an individual or a team is working on. All items that are accessible may be shared with other people in a meeting, and the environment has the capability for setting up team-specific spaces and multiple simultaneous separate interactions. All audio, video, screen and application sharing functions are fully scalable.

Evaluation

The course and AIDE were evaluated using a series of questionnaires completed by students throughout the semester, monitoring of web sites visited by the students while working on the design project, observations made of the students in the DLCs, and focus group interviews with students. We will report here only on the results of the questionnaires and interviews. We asked open-ended questions and asked students for ratings on specific questions. Examples of open-ended questions were: "Please comment on things you like/dislike about the course," or "Comment on any improvements that could be made." Students were asked how much they agreed or disagreed with statements such as: "I feel a part of this class," "I find that working as a member of my team increases my ability to perform effectively," or "The AIDE provides many useful functions." Students were also asked to describe they way that they interacted with each other and with the faculty, as well as which technologies they found most useful.

Results and Discussion

We might summarize the results to-date by one word, *communication*. Teaching and learning are communication. Teamwork and design are communication. Despite having access to excellent distance learning facilities and information technology tools, communication has proved to be the leading challenge faced by the project. To a large extent, this is an issue inherent in a course taught be a team of faculty that involves teams of students, and these inherent problems were somewhat exacerbated by the use of two sites and the associated need for collaboration using IT tools. However, the student evaluations also indicated that this is an endeavor worthy of continuation. Students commented positively on the "real-world, high-tech" nature of the course; learning about and experiencing first-hand team dynamics, project management, and a multidisciplinary, systems approach to engineering design; being forced to "think outside of the box"; the broad nature of the course; the wide range of expertise among the faculty and topics to which they were exposed; using the AIDE, the other software packages and the related hardware; interactions with external experts; and the overall exposure to new technologies. The primary challenges that we face for the immediate future are described below.

Instructor coordination and integration of material was one major challenge for this project. Integrating lecture material, developing homework and other assignments of appropriate scope, providing well defined grading metrics and delivering consistent grading were all complex undertakings. A second challenge for the project was to encourage a collaborative learning style within the DLCs. The use of prepared slides often reduces interactions with the students; perhaps since students have the material written down for them, they do not become as actively engaged during lecture. As described earlier, the use of a SmartBoard at both sites may alleviate this problem, in that one could prepare slides with only a few "bullets" and/or complex graphics and allow the students to fill in the details during lecture. However, students commented on other aspects of the classroom experience, for example, “there's something with this medium…the lecturer is stuck behind the podium.” This refers to the need for the instructor to be cognizant of the camera position, as well as lighting, physically blocking the projected images, and similar concerns. In addition, most camera auto-tracking features provide relatively unsatisfactory images, and as a result the instructors tend to restrict their movement. This results in a perception that the DLC environment is more stifled than traditional classrooms. The third primary challenge involves both introducing the technology and meeting student expectations. The issue here is that student expectations and their associated excitement are quite high, indicating that a system with many features will be of great benefit. However, today’s students commonly teach themselves to use software packages and their patience with training sessions is limited. This may lead to the introduction of a complex system with limited training, which results in early usage failures and dissatisfaction with the technology. Important lessons learned based on our experiences with this include (1) new technology should be introduced in stages of increasing complexity, e.g., by starting with simple yet robust tools, (2) it is critical to rapidly address and resolve problems - or even perceptions of problems – when new technologies are introduced, and (3) extensive training for the users is required to ensure early success. These lessons will be applied during the introduction of future environments.

Conclusions

Our experience to-date with advanced information technologies in the classroom is largely positive. Although there are problems to be overcome involving the technology, course design, and interactions with a large diverse faculty team, the benefits to the students appear to strongly justify continuing work in this area. Our current efforts are focusing on the next version of the AIDE and the associated course, which will utilize the best aspects of the current versions, our experiences and lessons-learned, and any new observations or lessons that result from an ongoing evaluation of external projects, hardware and/or software packages of a related nature.

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