Abstract

With the creation of the Internet, the world has standardized a way to share information over computer networks. Such a standard will have no less an impact on communication than standardizing a verbal or written language. The Project Automation and Collaboration Environment (PACE) provides a case study that illustrates these "network effects" as implemented for the University of Illinois Electrical Engineering Senior Projects course. The course has been set up to emulate a professional engineering environment and typically has 100 students working on 50 projects each semester. The course rarely meets as a group, yet demands communication between students, staff, and outside parties. PACE addresses these needs through many subsystems and distributes information to students on methods and procedures. The electronic form of paper submission eliminates paper delays, simplifies collection of late papers, and simultaneously builds the searchable Project Pages without burdening students. The Event Sign-up system allows instructors to easily schedule as many as 130 meetings in one week with specific people attending each meeting, and the Parts Request system allows students to quickly and easily obtain the parts that they need. PACE also improves the quality of projects since the added exposure makes it more worth a student’s effort to do well. During its first semester of operation, PACE archived 242 student documents and logged over 90,000 page views.

1 Introduction

In just a few short years, the Internet has moved from an unknown technology to the driving force behind an industry that impacts all other industries. Beginning in 1998, more data traffic traverses worldwide networks than voice traffic\(^1\). According to some statistics, Internet traffic doubles every 100 days. This growth comes from the increase in popularity of the Internet, the demand for higher bandwidth applications, and the fact that the absolute number of computers is growing at 20% - 30% per year\(^2\).

With the creation of the Internet, the world has standardized a way to share information over computer networks. Such a standard will have no less an impact on communication than standardizing a verbal or written language. With verbal communication we were able to share thoughts with others that were present and better coordinate immediate efforts. With written communication, we were able to share thoughts across time and space. People were able to build on the knowledge of others and share what they learned over a large area. As Sir Isaac Newton
wrote in 1675: “If I have seen further it is by standing on the shoulders of Giants.” With the advent of electronic communication over the Internet, anyone can now share information, from anywhere, with anyone, in real time. The next revolution in communication may require ESP. With electronic communication there is no longer a delay to distribute information, and a specified source can immediately distribute the latest version of a document. A single document can be updated and viewed in real time by all interested parties even if those parties are spread across the entire world. With such capabilities, it is not difficult to see that the Internet can transform the way that collaborative efforts are conducted. Organizations that make proper use of the new medium can experience orders-of-magnitude improvements in efficiency and capabilities just like a baby that learns to speak or an elementary school student that learns to read and write.

This project involves creating the Project Automation and Collaboration Environment (PACE) for the Senior Design course of the University of Illinois at Urbana-Champaign (UIUC) Department of Electrical and Computer Engineering (ECE). While PACE was created for a university course, it is applicable to many other environments. The Senior Design course emulates the day-to-day life of a real professional engineering environment. The course lasts four months with 100 students developing 50 projects, and it sometimes grows to as many as 200 students. With a new group of engineers every four months working on a wide variety of projects, the course is a more dynamic environment than most corporations and research organizations. The home page of the new course Web site can be seen in Figure 1.1.

The challenges for this Electrical Engineering Senior Design class are likely similar to many design classes in engineering departments. This class is organized around the following design process: 1) brainstorm to identify a project and team, 2) write a proposal including a design specification, 3) prepare a design schematic, schedule, and parts list, 4) order and assemble parts 5) perform functional and specification tests, 6) demonstrate functionality to the customer, 7) formally present the project, and 8) prepare a final report suitable for publication. The projects are built in a dedicated Senior Design Laboratory, which has 14 dedicated computer workstations, parts lockers, and state-of-the-art testing tools. We are also fortunate to have a dedicated parts shop, which stocks electrical components for most needs. Additionally, parts that are not available can be purchased. A mechanism was needed to provide communication between students and staff, as well as to distribute information to faculty and parties external to
the university. Also, an important need existed to manage the meetings and reviews associated with the course. For example, Instructors, the assigned Teaching Assistant (TA), and a peer student group attend each of the reviews. Anyone that has ever tried to arrange as many as 120 meetings for a single week with six to eight specific people in each meeting understands the value of an automated scheduling system.

Thanks to its setup, the course has needs that are very similar to those in industry. The information technology developed for this course is very applicable to industrial or research environments. The course only meets as a group three times at the beginning of the semester, making the Web site an invaluable tool. With the distributed nature of the course, PACE has become its communications hub. All important course information is available on the Web site, including course resources, course guidelines, details about each of the projects, and a parts request system. PACE received over 90,000 page views in the Spring 1999 semester, and over 200 project ideas, questions, and announcements were posted to the class discussion board. A sample search result can be seen in Figure 1.2.

In summary, the class is large, and every group is working on a different project with unique challenges. The Web tools help to meet many of these challenges. It is important to distribute information such as project ideas, guidelines, and calendar quickly. Also, a searchable database of past projects makes it easier for students to gauge the complexity level of their project and acts as a library of practical engineering knowledge. Finally, with potential exposure to the entire world, it becomes more worth the student’s effort to do well.

1.1 System Benefits

The centerpiece of PACE is the database of Project Pages. The Project Pages were created in an effort to help promote student projects. They provide a worldwide showcase where employers, other students, and friends can see what UIUC students are capable of. PACE also has the potential to turn into a valuable recruiting tool for the ECE department and employers. Employers, in particular, will be able to search projects for skills that they need. Finally, the site will grow over time into a valuable and practical resource that future students can tap when it is time for them to do a project. Some of the best projects will be identified each semester and placed in the Senior Design “Hall of Fame,” while the rest will be accessible by semester and

---

**Search Results**

This Search Engine currently searches the "projects" database (i.e. titles, parts, descriptions) and ASCII uploaded documents (i.e. HTML, DOC, TXT). It is not capable of searching PDF files.

Search results for magnet.

Project 4 [Integrated Wireless Connection For A Microprocessor-Controlled LAN With Individually Addressable Nodes] - found in project4_proposal.html

This project is comprised of the design, construction and testing of a self-contained, microprocessor controlled local area network system with a moveable wireless link. Each network node is fully addressable. The system is designed to offer a great deal of flexibility and modularity. The concept...

Project 5 [Magnetic Levitation System] - found in 'keywords'

We will design and construct a magnetic levitation system. This system will be used to control the motion of a permanent magnet within an enclosed chamber. The levitation device will consist of a rectangular array of electromagnets. A PC will generate the appropriate current intensities needed to control...

Project 13 [Dream Machine (An Enhanced Alarm Clock)] - found in project13_final_paper.doc

We want to design a super alarm clock. The device will make sure you can sleep well and wake up easily. For example, if you want to wake up at 9:00 AM the next morning, then the alarm clock will filter out any phone calls from 8:56-9:00 AM. It will even relay messages to your answering machine. The...

---

Figure 1.2: Sample Search Engine Result - This page shows the search results for the word “magnet.” The search engine lists hits by project instead of by document.
PACE automates many tasks, including the posting of projects onto the Web. Students that build Senior Design projects build a Web page that describes their project without placing any extra burden on them. In fact, the system streamlines tasks and creates a digital library of information, making student’s lives much easier. The building of the Project Pages is completely integrated with the course. Students actually submit papers by posting them to the Web site, eliminating the need for hard copies and ensuring high quality content on the Web site. The additional exposure that the students receive makes it more worth their while to do well on their projects since they know that they are beginning to build a reputation. Posting the projects on the Web also gives the course a way to interact with the outside world. Exposure beyond the course boundaries enables new capabilities such as a Partners Program where companies can sponsor projects and see the results.

Because PACE was actually going to be used, many extra hurdles had to be dealt with. These hurdles were met by striving towards the following goals:

1. Ease of use
2. Thorough debugging
3. Completely automated administration (no programming knowledge required)
4. Selective access to different features by different people
5. Scalability to meet internal traffic and significant third-party traffic
6. Ability to address concerns of many groups

Most of the points do not require explanation, but the last should be explored in more detail. The project is going to have an impact on the day-to-day lives of many individuals, so these individuals all deserve to have some input into its creation. Most of the ideas came directly from suggestions by students, professors, TAs, and the Parts Shop. In order to address the remaining goals, PACE should be taken through test runs with the people who are actually going to use it.

2 System Tour

The best way to explain how PACE is used is to walk through it. This section of the paper will walk through a typical semester going from one phase of the class to the next. At each phase, relevant subsystems will be presented and discussed (Figure 2.1). Since many subsystems are used in several phases of the course, each subsystem will be

<table>
<thead>
<tr>
<th>Week</th>
<th>1-2</th>
<th>3</th>
<th>4</th>
<th>6</th>
<th>7-14</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information Distribution</td>
<td>★</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discussion Board</td>
<td>★</td>
<td>★</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Search Engine</td>
<td>★</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upload File</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>★</td>
<td></td>
</tr>
<tr>
<td>Project Page</td>
<td>★</td>
<td>★</td>
<td>★</td>
<td></td>
<td>★</td>
<td></td>
</tr>
<tr>
<td>Sign-up System</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>★</td>
<td></td>
</tr>
<tr>
<td>Submit Schedule</td>
<td></td>
<td></td>
<td></td>
<td>★</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grades</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>★</td>
</tr>
</tbody>
</table>

**Figure 2.1: System Usage Timeline** - This timeline outlines when different systems are used. The stars indicate that parts of that subsystem will be explained in that section of the paper.
Figure 2.2: List of Projects - This page contains the list of projects for a particular semester. Award winning projects are marked to give those students well-earned recognition.

The database of past projects (Figure 2.2) archives projects and marks the award winners (Figure 2.3). It gives new students a library of practical knowledge that will help them to figure out how to build presented when its benefits are most easily comprehended. Screenshots of many of the interfaces are included to help describe each subsystem. Across the top of Figure 2.1 are the different milestones of a typical semester, and down the left side are the subsystems created on PACE. The shading indicates that the subsystem is used during that particular phase of the course, while the stars indicate that parts of the subsystem will be explained in that section of the paper.

2.1 Weeks 1 and 2 – Getting Started

PACE is first used as a way of distributing course information such as the course guidelines and calendar. The site also informs students of many of the resources available to them including equipment and parts. Most of these static informational pages were adapted from the old course Web site. Currently, project ideas from faculty and TAs are posted onto the discussion board to help students quickly identify a project that interests them. In the future, the discussion board will also have project ideas that come directly from companies and have financial support.

2.1.1 Past projects

The database of past projects (Figure 2.2) archives projects and marks the award winners (Figure 2.3). It gives new students a library of practical knowledge that will help them to figure out how to build

Figure 2.3: Award Winning Project Page - The links on the “Hall of Fame” page go directly to the Project Page of the award winners.
projects that they may not have already known how to build. It also gives them a way to gauge
the scale of projects that are acceptable and the success rates of different types of projects. High
quality content is encouraged in PACE by making the final papers a large portion of the grade,
and by reminding students that their projects will live past the end of the semester through their
resume, the Project Database, and course awards. The award winners from past semesters are
marked in the Project Database (Figure 2.3) and showcased in the Senior Design “Hall of Fame”
to give students that have done outstanding work recognition among their peers, potential
employers, and Instructors. The awards also help browsers identify the best work. The database
contains the contact information of the students that worked on each project. Many of these
students have been attending classes together for years, and advice from past students can prove
invaluable. The database is searchable so that students can easily find projects in topics that
interest them, such as “wireless” projects, or “DSP” projects.

2.2 Week 3 - Initial Ideas

PACE next has an impact in the second week of the semester when students email the
professor with initial ideas. Instead of email, a discussion board (Figure 2.4) will save the
trouble of compiling 50 initial project ideas and re-emailing them out to everybody as they
change. The discussion board implemented is a free piece of software created by Matt Wright
called “WWWBoard”. A discussion board will allow everybody to see in real time what
projects ideas are being proposed. Everyone will then know the scale of the other projects, and
can begin identifying people that are working on similar projects, or even find partners. Once a
project idea has matured enough, a team will officially be formed, a
project Web page will be created,
and an email will automatically be
sent out to the students with
instructions on how to use the
system. This Web page becomes
the home of the project. It will
contain general contact and project
information, allow uploading of
documents such as the project
proposal, and have some space for
free-form HTML. Publicly sharing
goals reinforces students’
commitment to their projects.
Students do not think strictly in
terms of minimizing their workload
since they know that an exciting
project will draw more attention
and help from everyone and is more
likely to be approved.

Figure 2.4: Discussion Board - Instructors, TAs,
students, and visitors can all post messages to the
discussion board. About 250 messages were posted in
the Spring 1999 semester.
2.2.1 Submit schedule subsystem

At this point, students are also asked to submit their schedule to PACE. This makes it much easier for TAs to schedule meetings in a timely fashion. In the past TAs would have to email students asking when they were available. The responses would come in a wide variety of formats and often would not come in time. With PACE’s scheduling subsystem, each student checks off the boxes indicating when they are not available and this information is stored in a database. The TA can then select several schedules, view the combined schedule in matrix format (Figure 2.5), and then select from the times that have not been blocked out. Some good enhancements to this system can be seen at autoschedule.com. They include allowing different levels of availability and displaying these as different colors. For example, a student would make the time slot white if that space is free, green if that space is preferable, red if that space is inconvenient, and black if it is impossible.

2.3 Fourth Week - Formal Proposals

In week 4 of the course, the formal project proposals are due. Detailed guidelines and model documents from past semesters are available on the Web, and in the future a template could also be made available. In the past students turned in hard copies of these reports, but with PACE students will publish directly onto their project page. This electronic submission follows a trend that is converting over to electronic submission of proposals. NSCA (National Center for Supercomputing Applications), for example, no longer accepts hard copies. All proposals must be uploaded through the Web. The electronic submission also has the advantage that the proposal is automatically posted onto the student’s project page, and it can be done from home or any computer lab. There is no need to make a special trip to the lab to turn in the paper, and the Project Pages are built without placing any extra burden on the students. One drawback of electronic submission is that it prevents students from printing out separate documents from different programs and stapling them later. The entire paper must be included in the Word document and a disk space limit must be imposed. Creating unified electronic documents is a skill that does not take much effort to develop and one that students will need to learn eventually. The space limitations are currently set to 2 MB for Proposals and 4 MB for Final Papers. In the future, when Web page creation is a common skill and is simplified, students will publish directly onto the Web in HTML format using programs such as Microsoft FrontPage Express. The simple fact that someone other than the instructors may read the proposal makes it more worth the effort spent.
2.3.1 Update project page

At this time, the students update their Project Pages. Course instructors and students commonly look up project summaries to remind themselves which projects are being pursued by which students. The Project Pages allow students to easily create a basic Web page that can then be turned into a full-fledged Web site. Students enter information such as name and project description through a form. PACE then displays this information in a standard format, saving students the trouble of learning HTML and being artistic. For those students that do know HTML, there is a field that will allow them to include some free-form HTML. This HTML will be displayed at the bottom of that group’s Project Page (Figure 2.6).

2.3.2 File Manager

The proposal is posted through the use of the File Manager (Figure 2.7). Students select the “Proposal” slot from the drop-down box, select the file that they want to upload using the “Browse” button, and then click on the “Upload Now” button. They will next receive a confirmation that explains that the file was uploaded and automatically linked to their Project Page. Each file slot is given a separate limit so that groups do not use too much space too early in the semester. In addition to slots for special documents such as the proposal, PACE also has some general file slots (File1 – File10) that can be used for additional images or information. In the past students have used these slots to post diagrams, code, or sponsor logos. PACE does not link these automatically, but they can be linked through the use of the HTML field on the “Update Project” form. The confirmation for general file slots will display the image if the file was an image. It will also give the code that can be used to link or display the file. This code can then easily be cut and pasted into the HTML field of the Update Project form.
2.4 Sixth Week - Design Review

In week 6 of the course, students use PACE to sign up for a time slot for their Design Review and sign up to review another team. In the past they signed up onto a schedule that was posted onto the lab door. An interactive sign-up system on the Web offers many advantages over the older system.

2.4.1 Sign-up system benefits

The Sign-up system has many benefits. First, the sign-up sheet is much more accessible. It is easier for students to get together with their teammates, check the schedule, and sign up since they can do it from any Web browser. They do not have to make a special trip to the lab. The page makes it much easier for the professor and TAs to check and print out hard copies of their schedules as well. An electronic system will additionally allow instructors to better enforce certain guidelines. For example, the electronic system can be locked so that students do not move their times around without instructor approval. A changing schedule makes it difficult for instructors to plan their days and also might leave a review team without a project to review. In addition, students are supposed to only sign up for slots when their TA is available. One semester, out of a sample of twelve teams, five signed up for times when their TA was not available. They thought that TA blockout times were availability times. A Web-based system will only allow teams to sign up for appropriate slots. Finally, the electronic system can automatically look up project titles and descriptions and post those onto the sign-up calendar. This creates a convenient single document with all pertinent information that can be distributed to interested third parties.

2.4.2 Sign-up system interface

The Sign-up system has a very intuitive user interface (Figure 2.8). One student from each team simply logs in and signs up for the time slot by clicking on the button in that slot. Once a time slot has a team in it, then a review team may sign up in a similar manner. TAs may block out times when they cannot attend reviews by using the form in Figure 2.9. These slots will be blocked out, preventing groups from signing up for slots that their TA cannot attend. Instructors may also edit the sign-up sheet using the form in Figure 2.9. While an instructor is editing the sign-up sheet, it is checked out so that others cannot make changes at the same time. Instructors are prevented from editing and students are prevented from signing up during these times in order to prevent inconsistencies from occurring. Once the instructor is done editing, he will submit the form, and the checkout will be released. If someone tries to edit while the sheet is checked out, then an error message will be displayed. The instructor who is editing the sheet has a link to his email address displayed just in case he left his computer and forgot to check the sheet back in. If an excessive amount of time passes before the sign-up sheet is checked backed in, then the instructor can be notified by email so that he can correct the situation. This sign-up system will also be used later in the semester for demonstration and presentation sign-ups.
Figure 2.8: Sign-up Schedule - Here is an example of the sign-up sheet for demonstrations. Students sign up for a time slot to demonstrate their project and also for a slot to review another project. The blacked out boxes indicate that TA is not available, the white boxes indicate that the TA is available, and the green boxes indicate that one of the TA’s groups has signed up for the slot.

Figure 2.9: Sign-up Schedule Edit - All instructors may edit the sign-up sheet with this page. They can select which times reviews are to be held, change which teams are signed up for the slot, and block out times when they cannot attend reviews.
2.5 Engineering Phase - Parts System

By this time in the course, students have begun to identify the parts that they need. PACE implements a much enhanced parts request system that eliminates an expensive step from the process. Because parts are given out for free, a check must be put into place. In the past this check required students to get the signature of a course instructor. This prior approval will be removed from the system while increasing student accountability thanks to technology.

2.5.1 Parts system benefits

In the past a student who burned out a part had to go to the lab, fill out a form, leave the form in a tray, wait for their TA to sign the form and deliver it to the Parts Shop, wait for the Parts Shop to fill the order, and finally pick up the parts when enough time passed. The delay for getting parts ranged from minutes, if a TA was around to fetch the parts, to a week. Students request parts numerous times in a semester, often spontaneously, making a wait of a week a serious hurdle. In one semester there were 1227 distinct requests of different quantities, or an average of 18 per team. The most irregular delay, TA approval, will be removed with the Web-based system. The average team would have to get a TA signature five times during a semester.

2.5.2 Electronic parts request system

With PACE, a student who needs parts will fill out a Web-based request form. This form will post the request to an automatically refreshing "Pending Requests" Web page (Figure 2.10), and email a copy of the request to their TA. Once the order has been filled, the order will move to a "Parts Log" Web page (Figure 2.11) that will contain a history of all requests that each team makes during the semester.

![Figure 2.10: Edit Pending Requests - In order to take action on a pending request, Parts Shop personnel are presented with this page.](image)

The students will be held more accountable with this system for two reasons. First, their assigned TA will find out about all of their requests, including the ones that other TAs would have approved. Second, students will be informed that all requests are logged by team. Parts Shop personnel have the ability to fill minor requests themselves and request TA approval for larger requests. For each request, the Parts Shop is presented with the following options:
• **Take No Action:** This option simply leaves the request on this list for later.
• **Fill Request:** This option removes this request from the list and posts it to the parts log.
• **Fill and Comment:** This option removes the request from the list, posts it to the parts log, and emails the comments to the students and their TA.
• **Seek TA approval:** This option emails comments to the Teaching Assistant responsible for the project and changes the default option to “Wait for TA.”
• **Wait for TA:** This option takes no action. It simply informs the parts shop personnel that a TA has been contacted to approve this request.
• **Approved by TA:** This option allows a TA to approve a request. It changes the default option for this request to “Approved by TA.”
• **Deny Request:** This option allows Parts Shop personnel and TAs to deny a request. The students and their TA receive an email with the comments.

The Parts Shop personnel are also able to make better-educated decisions since they have access to information such as the project title and description. In the semester that the system was used, no abuses were noted. Ultimately this system could be integrated with the Parts Shop catalog and could automatically track inventory levels. This would provide the added benefit that all catalog information will be available to the Parts Shop personnel, such as drawer number, exact part number, and official description.

2.6 Finishing Up – Final Reports

As the semester nears a close, students sign up for demos and presentations using the same system as for Design Reviews. Presentation slides and demonstration videos may also be posted to the Project Pages. Final papers are submitted in a method similar to the proposals. This is the most valuable document posted to a Project Page since it summarizes all the important information about the project.

2.6.1 Electronic final papers

Grading and returning of the electronic documents are enhanced with PACE since copies are instantly available to both the Publications Office, which assigns grades for English and format, and TAs, who grade for technical content. Since it is required that papers are submitted in Word format, the grading is simplified since the Word grammar checker, spell checker, and search-and-replace features can be used. The quality of the paper’s grammar also improves since students know in advance that the grammar check will be run. The electronic papers can be returned in a timely fashion, making it easier to go through a second revision, if necessary, since
the graded copy can be similarly uploaded directly to the Project Page. The delays associated with passing around stacks of hard copies are eliminated. The electronic submission also greatly eases the difficulty of collecting late submissions since a special trip does not have to be made to collect the late copy. One important drawback to electronic grading of final reports is that the excessive reading on computer monitors is a strain on the eyes.

2.6.2 Campus Gradebook

Students want to be able to monitor their grades. The university’s Computing and Communications Services Office (CCSO) has created the “Campus Gradebook” to allow TAs to directly enter scores into a single grade book rather than requiring the professor to copy the grades into a unified spreadsheet. Having all six of the course instructors edit the same on-line spreadsheet helps to prevent errors from copying grades. Each instructor can be given permission to edit only the grades of their students in order to prevent accidental grade changes. Also, the Publications Office grades the final reports for English and format. They can be given permission to directly enter these grades, further preventing mistakes. Allowing everyone to edit the same on-line spreadsheet also speeds up distribution of grades to students. Not only is there no need to compile separate spreadsheets, but the Campus Gradebook allows students to look up their scores in a secure fashion with existing university passwords. They can see their scores and distributions of class scores at the course director’s discretion. This makes for a very convenient way of distributing grades.

3 Site Administration

Administration of PACE is designed to be entirely automated, so that the course director may administer the site without the help of a programmer. All of the instructor’s tools are available from the Instructor’s Login page.

3.1 Beginning of Semester

This page will display a different set of tools depending on who has logged in. The course director will have all of the options shown in Figure 3.1, while TAs and Parts Shop personnel will have access to a subset of these options. In order to begin a new semester, the course director will use a form. This form will archive the previous semester, and set up the system to start a new semester. After beginning a new semester, the next step is to begin adding TAs to the system using another form. Currently PACE will not allow a single to person to have multiple levels of access. For example, the course director cannot also be a TA, and a TA cannot also be listed as a project partner. After TAs have been added to the system, the next step is to approve projects and add them to the system by using a third form. When this form is submitted, a Project Page will be created, and the students will automatically receive an email describing how they can edit their Project Page.
3.2 Additional Tools

The Instructors Only page provides links to several resources that have been described earlier. Instructors and Parts Shop personnel may access the Pending Requests page to fill requests, and may view the Parts Log to view request trends. Instructors may access student schedules and a list of all student email addresses from this page. Additional information unrelated to PACE may also be posted to this page. For example, locker combinations are encrypted using Word’s password feature, and are linked from this page. Finally, the Sign-up system may be administered from this page. The sign-up schedule may be cleared and edited each semester. Also, the schedule may be disabled when it is not needed or visibly frozen to keep it from changing during an event.

3.2.1 Bluestem: password system

Editing information in PACE is password protected using the university’s existing network identifications (called Net IDs) and passwords. The university has set up a system called Bluestem which allows the student to be authenticated on a university server using the same password that they use to register for classes. The authentication server then tells the course server who logged in. This setup eliminates the administrative burden of maintaining passwords just for the course and also eliminates the need for students to remember another password.

4 Measurable Results

Most of the results are not easily measurable, but two elements of PACE may be numerically evaluated. Disk space usage gives a good picture of how the system is being used by students and how large the system can grow. Traffic measurements show who is visiting the Web site and what pages are being used most. These traffic measurements may be made on a per-request basis or on a transferred-bytes basis.
4.1 Disk Space Usage

There are three questions that arise when assessing disk space usage: (1) How many project teams are uploading each type of document? (2) How large are the documents that the students are uploading? (3) Are the space limitations appropriate?

4.1.1 Overview of disk usage

Table 4.1 shows the files that can be uploaded onto a Project Page and the size limitations that were imposed during the Spring 1999 semester. Table 4.2 shows file usage, while Figure 4.1 illustrates the relative disk space usage. All students that completed their Spring 1999 project posted a final report. The proposal and presentation were both strongly encouraged, but not required. The general file slots were optionally used for special needs.

4.1.2 Disk usage analysis

The final paper clearly used the most disk space since it was required and was also the most detailed document of the semester. Only one project used more than 2 MB of space for the final paper, indicating that the 4-MB limit was appropriate. Verbal feedback from the semester gives a more complete picture of the limit’s appropriateness. A handful of teams had to change the format of their images because of the size limitation, and other teams posted sections of their report in general “File” slots. With these observations, the limit for the final paper will certainly cause some groups difficulty every semester. This issue can be addressed in three ways. The first is to educate students on how to use space efficiently. For example, photographs are generally saved most efficiently in JPEG format, while drawings are generally saved most efficiently in GIF format. The next way to address the question is to have students post documents in the compressed PDF format instead of DOC format. Currently this cannot be done because the search engine cannot search PDF files. Of course the third alternative is simply to increase the size limit of the final report.

Table 4.1: Spring 1999 File Slots – These file slots were available during the Spring 1999 test semester.

<table>
<thead>
<tr>
<th>Document</th>
<th>Max Size</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proposal</td>
<td>2 MB</td>
<td>2 MB</td>
</tr>
<tr>
<td>Design Review</td>
<td>2 MB</td>
<td>2 MB</td>
</tr>
<tr>
<td>Presentation</td>
<td>4 MB</td>
<td>4 MB</td>
</tr>
<tr>
<td>Final Paper</td>
<td>4 MB</td>
<td>4 MB</td>
</tr>
<tr>
<td>3 x Resume</td>
<td>128 kB</td>
<td>384 kB</td>
</tr>
<tr>
<td>File 1</td>
<td>512 kB</td>
<td>512 kB</td>
</tr>
<tr>
<td>2 x File 2-3</td>
<td>256 kB</td>
<td>512 kB</td>
</tr>
<tr>
<td>7 x File 4-10</td>
<td>64 kB</td>
<td>448 kB</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>13.8 MB</td>
</tr>
</tbody>
</table>

Table 4.2: Disk Space Usage – This table illustrates disk usage for Spring 1999

<table>
<thead>
<tr>
<th></th>
<th>All</th>
<th>Final Paper</th>
<th>Proposal</th>
<th>Presentation</th>
<th>File</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>52 MB</td>
<td>36 MB</td>
<td>3 MB</td>
<td>9 MB</td>
<td>3 MB</td>
</tr>
<tr>
<td>Average</td>
<td>220 kB</td>
<td>604 kB</td>
<td>69 kB</td>
<td>335 kB</td>
<td>26 kB</td>
</tr>
<tr>
<td>Median</td>
<td>46 kB</td>
<td>360 kB</td>
<td>41 kB</td>
<td>214 kB</td>
<td>20 kB</td>
</tr>
<tr>
<td>St Dev</td>
<td>448 kB</td>
<td>693 kB</td>
<td>114 kB</td>
<td>396 kB</td>
<td>46 kB</td>
</tr>
<tr>
<td>Max</td>
<td>3.9 MB</td>
<td>3.9 MB</td>
<td>0.6 MB</td>
<td>1.9 MB</td>
<td>0.4 MB</td>
</tr>
<tr>
<td>Min</td>
<td>46 B</td>
<td>2,543 B</td>
<td>4,539 B</td>
<td>2,827 B</td>
<td>46 B</td>
</tr>
<tr>
<td>Count</td>
<td>242</td>
<td>61</td>
<td>43</td>
<td>29</td>
<td>100</td>
</tr>
</tbody>
</table>
4.1.3 Disk usage projections

PACE currently limits the size of each type of file individually to ensure that students do not use too much space too quickly. For example, the final paper is given 4 MB, while the proposal is limited to 2 MB of disk space. Out of a possible 14 MB per project, an average of less than 1 MB was actually used. Even if it had been required to upload proposals and presentations, little more than 1 MB would have been used by each project on average. The Fall and Summer semesters combine to match the size of a single Spring semester, so at the current rate about 110 MB of disk space will be used each year. That leaves space for 45 years worth of projects on a 5-GB hard disk. This assumes, of course, that the server is capable of serving the traffic that this information would generate. At most, five years worth of projects need to be archived, so extra space can easily be allocated to each project. The file limits for the final paper and presentation may be increased to help the few students that reach those limits, and several additional slots may be created. Slots could be created that would automatically post a project picture and photos of the project partners. An Appendix slot may be created for projects that wish to include extra information that was not in their report such as code and PC board layouts. By far the most interesting addition would be videos of each project. A brief clip showing the project in action might not require much more than 2 MB of space. Table 4.3 and Figure 4.2 show how project disk usage changes with the following adjustments:

1. Extend final paper limit from 4 MB to 6 MB
2. Extend presentation limit from 2 MB to 4 MB
3. Require proposals and presentations
4. One 64-kB photo of each project
5. Two 20-kB student photos per project
6. One 2-GB video of each project

Table 4.3: Projected Disk Usage

<table>
<thead>
<tr>
<th>Document</th>
<th>Total Size</th>
<th>Document</th>
<th>Total Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Final Paper</td>
<td>50 MB</td>
<td>Files</td>
<td>2.7 MB</td>
</tr>
<tr>
<td>Proposal</td>
<td>4 MB</td>
<td>Pictures</td>
<td>7 MB</td>
</tr>
<tr>
<td>Presentation</td>
<td>30 MB</td>
<td>Video</td>
<td>122 MB</td>
</tr>
</tbody>
</table>

4.2 Traffic

There are three primary questions to answer about the traffic that PACE generates: (1) What is the impact on the server? (2) Who is visiting the Web site? (3) How often are certain pages visited?

4.2.1 Site-wide traffic analysis

Figure 4.3 shows when PACE was visited during the Spring 1999 semester, and who visited. These graphs may measure a single page hit as multiple server hits since each image on the page is loaded separately. This gives the absolute number of hits displayed in Figure 4.3 less meaning, but still allows a good comparison of how accesses change throughout the semester.
The first graph in Figure 4.3 shows more traffic at the 1/3 mark of the semester and the end of the semester since these are the times when proposals and final papers were being uploaded and graded. It took a while for students to learn of the value of PACE early in the semester, and then midway through the semester they were primarily concerned with debugging their circuits.

The pie chart in Figure 4.3 shows where visitors are coming from. The graph is slightly misleading since half of the commercial (.com) visitors were actually students visiting from their apartments in Urbana-Champaign. These graphs will become more meaningful in later semesters once a semester’s worth of reports have been archived. No real efforts have yet been made to attract outside traffic. For the time being these figures simply demonstrate that not all visitors are from within the UIUC domain. In particular there were some corporate visitors from Motorola, Lucent, Microsoft, General Electric, Bell Atlantic, and others. There were also university visitors from the University of Virginia, University of California at Berkeley, Ohio State University, Massachusetts Institute of Technology, University of Nebraska at Omaha, Boston University, Northwestern University, and Stanford University.

There were also a variety of visitors from within the UIUC domain. Table 4.4 shows what some of this UIUC traffic looks like. One-third of all requests came from within the Senior Design Lab, and half came from within the ECE department. It is impossible to determine how many of the UIUC visitors were enrolled Senior Design students, but given the global traffic patterns, it is a safe bet that there were a large number of third party visitors from within UIUC.

**Figure 4.3: Hits / Hour** – These figures characterize Spring 1999 traffic. A single page view may count as several hits if several images are also loaded.

**Table 4.4: UIUC Visitors** – This table characterizes visitors within the UIUC domain

<table>
<thead>
<tr>
<th>UIUC Subgroup</th>
<th>Requests</th>
<th>Bytes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Senior Design Lab (246 Everitt Lab)</td>
<td>189,029</td>
<td>577,912,972</td>
</tr>
<tr>
<td>All ECE Teaching Labs</td>
<td>197,001</td>
<td>607,057,993</td>
</tr>
<tr>
<td>Entire ECE department</td>
<td>293,332</td>
<td>960,085,558</td>
</tr>
<tr>
<td>Engineering Workstations (UNIX)</td>
<td>93,815</td>
<td>370,740,875</td>
</tr>
<tr>
<td>CCSO Labs (PC/Mac)</td>
<td>13,244</td>
<td>71,045,748</td>
</tr>
<tr>
<td>CSL</td>
<td>10,297</td>
<td>43,272,874</td>
</tr>
<tr>
<td>All of UIUC</td>
<td>494,140</td>
<td>1,906,627,167</td>
</tr>
</tbody>
</table>
4.2.2 Page view analysis

The next question is, Where are the visitors going? There were a total of 550,000 hits on the server transferring over 2.3 terabytes of information. This can be refined into about 90,000 separate page views since a single page view may also require that several menu and counter images be requested. It should be noted that many of the hits occurred while testing the system. About 10% of the hits came from the computer that was used to implement the site. Most of these hits came from testing, but a significant portion were also true page views. There are a number of notable observations that can be made from Table 4.5. For example, the discussion board accounted for 18,000 page views, including 10,000 views of the main Discussion Board page. This indicates that students were checking the Discussion Board on a regular basis for announcements, but were not necessarily reading every message. Between the Projects List, Project Pages, and Search Engine, the Projects Database was visited about 13,000 times. Nearly all of these hits were internal routine business hits demonstrating how useful the system is for encouraging internal interaction within an organization. Each Project Page was visited an average of 120 times primarily by instructors and fellow students. In the short time since the final reports were posted, each final report was viewed an average of 11 times. The Project Page and final report accesses should increase dramatically when a new batch of students begins searching them and word of PACE begins to get out.

4.2.3 Third party traffic

There are numerous sources of potential traffic. Of course, new students will use PACE heavily to find project ideas and technical information. Also, graduating students will likely provide links from their homepages and mention PACE to their friends and new employers. The addition of a Partners Program will also generate traffic from employers. Various offices in the ECE department and the rest of the campus attract corporate visitors and would gladly provide a link to a resource such as this. PACE can also be listed with the major search engines. With 250 seniors working on 125 projects every year, knowledge of PACE will likely spread fast just by word of mouth. In the near future the primary source of traffic will continue to be students enrolled in the course, but this could quickly be overtaken by outside visitors from other courses, other universities, and industry. Since this Web site is the only one on its server, the server has plenty of room to handle more traffic. Unfortunately there is no historical data available characterizing the processing load, but a similar server handles far more traffic without any trouble. If the outside traffic grows too quickly, it may become necessary to create a new version of PACE that can better scale with traffic better.
### Table 4.5: Page Hit Analysis

- This table illustrates where visitors were going, and analyzes the traffic. Calculations are based on 130 students, 61 projects, 151 days, and 6 Instructors (5 TAs, 1 director).

<table>
<thead>
<tr>
<th>Portion of Web Site</th>
<th>Requests</th>
<th>Bytes</th>
<th>Notes / Calculations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entire Site</td>
<td>548,247</td>
<td>2,348,091,834</td>
<td>3,600 hits / day, 16 MB / day</td>
</tr>
<tr>
<td>Page views (without counter and menu hits)</td>
<td>90,617</td>
<td>1,325,802,199</td>
<td>600 hits / day, 9 MB / day</td>
</tr>
<tr>
<td>Home Page</td>
<td>19,027</td>
<td>105,908,018</td>
<td>126 hits / day</td>
</tr>
<tr>
<td>Hall of Fame</td>
<td>263</td>
<td>3,592,402</td>
<td>No projects listed until semester’s end</td>
</tr>
<tr>
<td><strong>Projects Database</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Projects List</td>
<td>5,052</td>
<td>115,283,731</td>
<td>33 hits / day</td>
</tr>
<tr>
<td>View Project</td>
<td>7,324</td>
<td>35,536,376</td>
<td>120 hits / Project Page, 56 hits / student</td>
</tr>
<tr>
<td><strong>Documents</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Final Paper</td>
<td>697</td>
<td>395,561,139</td>
<td>11 hits / project, 567 kB / request (very short period of time)</td>
</tr>
<tr>
<td>Proposal</td>
<td>1,051</td>
<td>67,068,544</td>
<td>24 hits / project, 64 kB / request (43 proposals)</td>
</tr>
<tr>
<td>Presentation</td>
<td>182</td>
<td>81,445,231</td>
<td>7 hits / project, 450 kB / request (28 presentations, very short period of time)</td>
</tr>
<tr>
<td><strong>Parts System</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Request Form (several distinct requests of various quantities)</td>
<td>-</td>
<td>-</td>
<td>430 submissions, 7 forms / team, 3 forms / day, 86 forms / TA</td>
</tr>
<tr>
<td>Distinct Requests (various quantities)</td>
<td>-</td>
<td>-</td>
<td>1227, 20 requests / project, 8 requests / day, 245 requests / TA</td>
</tr>
<tr>
<td><strong>Discussion Board</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discussion Board – Main Page</td>
<td>10,561</td>
<td>49,194,542</td>
<td>70 hits / day, 81 hits / student</td>
</tr>
<tr>
<td>Discussion Board – Messages</td>
<td>7,588</td>
<td>27,090,327</td>
<td>50 hits / day, 58 hits / student, 50 hits / message (only general discussion and Initial Idea messages)</td>
</tr>
<tr>
<td>Entire Discussion Board</td>
<td>-</td>
<td>-</td>
<td>213 messages total</td>
</tr>
<tr>
<td><strong>Sign-up System</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student Sign-up / View</td>
<td>6,901</td>
<td>144,319,439</td>
<td>54 hits / student</td>
</tr>
<tr>
<td>Sign-up Edit</td>
<td>428</td>
<td>16,390,682</td>
<td>7 hits / project</td>
</tr>
<tr>
<td><strong>Other Subsystems</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Submit Schedule System</td>
<td>908</td>
<td>7,164,293</td>
<td>130 hits / TA (assuming 2 hits / student)</td>
</tr>
<tr>
<td>Instructors Only Page</td>
<td>1,989</td>
<td>6,317,066</td>
<td>13 hits / day, 331 hits / instructor</td>
</tr>
</tbody>
</table>
5 \hspace{2em} \textbf{FUTURE WORK}

There are many possible enhancements for PACE. Some of these are very simple but helpful and others would provide tremendous benefits but would require more effort.

5.1 \hspace{2em} \textbf{New File Slots}

The simple enhancements would include adding Upload File slots for video and pictures. The video would automatically get linked into the “Documents” section of the Project Page, and the pictures could automatically be displayed on the Project Page. If pictures are truly worth a thousand words, then photos of the project and video would provide a much better understanding of the projects. In addition to pictures of the project, it would be very helpful to have pictures of the students available on the Project Pages. The ECE department already has pictures of all of the faculty and graduate students in the halls of Everitt Lab. The faculty pictures are also available on the Web. If the undergraduate pictures were available on a department Web server, then they could automatically be displayed on the Project Page. Otherwise, a separate File Upload slot could be created for students to post pictures of themselves manually. PACE already connects projects to names, but does not connect those names with faces. Students often will be hesitant to contact a stranger by email, but if they know what the person looks like then they will probably see them in the lab sometime. Faces on the Project Page would also help the professor, TAs, and other students learn names at the beginning of the semester. With more people on a first-name basis there will be more informal interaction in the lab among students, TAs, and the course director.

5.2 \hspace{2em} \textbf{Status Reports}

Another possible enhancement to PACE involves adding status reports to the Project Pages. All entries would be automatically stamped with a date and time, and email reminders could automatically be sent out if a report does not come in. Text could easily be appended to existing entries and with the addition of figures this could potentially turn into an electronic laboratory notebook. The additional benefit of an electronic notebook would be that everyone, particularly people affected by the project, would have access to it in real time. The project leaders would know the status of the project without having to speak with the project partners, and others could anticipate interfacing problems. Who knows if such a notebook would stand up in court, but for a course it would serve the purpose of teaching students to document their work as they go.

5.3 \hspace{2em} \textbf{Security for Proprietary Information}

PACE was created for a university course, but the ideas are applicable to many other environments. PACE archives projects easily and helps with project management. One of its most important benefits is the internal interaction that it promotes. It provides a real-time view of what is going on with all of the projects for others inside and outside the organization. With as many as 200 students working on 100 projects, the course director and TAs cannot possibly keep up with each project. They regularly look up the Project Page of teams to remind themselves of what the project is all about. This is especially true when they receive questions via email with missing information. PACE would prove to be especially useful for large-scale
projects or projects that had geographically distributed members. If everyone could find well-written information about what everyone else is up to without actually contacting them, it would eliminate misunderstandings and interfacing obstacles. People would be better able to plan for making their part of the project work with the other parts. One system enhancement that would be helpful in an environment like this is tighter security. PACE was designed for the very purpose of publishing information to the entire world. In a business or research environment, there may be a strong desire to keep certain information proprietary. A more secure version of the software might allow the director to select the access level of his subprojects, and then would allow each project team to further limit access. For example, a student in this course might allow only project members and instructors to view the project, limit access to the class, limit access to the UIUC domain, or allow the entire world to view the project. PACE is already running on a secure server created by Netscape, so all information is encrypted as it traverses the Internet, and the server itself is resistant to hackers. PACE also already provides selective access to different parts of the site through the use of passwords. This could potentially be extended to provide selective access to the content in addition to the content editors.

5.4 System Scaling

A big step that could be taken would involve replicating PACE to work with many different courses or departments. Department Pages could be created similar to the Project Pages, but with the intention of giving a description of a group of projects. All of the projects would then be displayed under their Department Page in a hierarchical fashion. As the disk space demands and bandwidth demands increase, the site might need to span several servers.

Once several courses are using PACE, a portfolio of each student’s work could be created automatically since all of the content is already available. This Student Portfolio would summarize what the student had accomplished in college, and might include other automatically linked information such as the student’s GPA. The Student Portfolio would begin by recasting the information in the Project Pages into a student view instead of a course view. Then additional information would be added automatically, with even more information maintained by the student. The system might look up the projects that a student worked on and create links to all of the corresponding Project Pages, or even display some of the information directly in the Student Portfolio. Next, the system might look up and display additional information such as pictures of the student, courses that student has taken, and the student’s GPA. Each student would then maintain additional information on their own. Examples might include contact information, resume, extracurricular activities, and interests. Such a system would be entirely searchable making it the ultimate recruiter’s tool. The recruiter would not only be able to search resumes, but would also have access to all of the details of what the student had done in college. With several universities involved, the database would become an even more valuable tool.

Once all of the projects are available on the Web, many other unforeseen possibilities open up. As the content builds, there likely will be more and more outside visitors. Behind every hit on the Web site is a person who may be interested in sponsoring a project in the future. The exposure of the projects makes the idea of a Partners Program more realistic. Companies that propose project ideas will then likely visit other projects, creating a feedback that gives those students even more exposure.
The parts request system could be enhanced in an important way by integrating it with the Parts Shop catalog. This would eliminate the need for a student to retype information. More importantly, it would provide useful information to the Parts Shop. Inventory levels could be automatically tracked, and other request statistics could be automatically generated. Also, the Parts Shop would receive all important request information such as exact part number, description, and drawer number.

6 CONCLUSION

In a small, stable organization it may be possible for a manager to keep track of all of the projects without information technology. This course emulates a 100-person business working on 50 highly varied projects with a new group of people every four months. Organizations in a dynamic environment such as this benefit tremendously if information is distributed throughout the organization quickly, and if that information is also archived for others in the future. As the pace of innovations continues to accelerate, information technology will become more important for doing business.

6.1 System Pros and Cons

PACE has many benefits. It creates a digital library of practical engineering knowledge for future students. It also gives them a source of ideas and a way to gauge the appropriateness of their project’s scale. PACE can prove to be a good recruiting tool since it is entirely searchable and contains both student resumes and the details of the project that they worked on. It also improves the quality of the projects since the added exposure makes it more worth a student’s time to do well. PACE improves internal interaction since all students can see what the others are up to. This not only helps students working on similar projects to find each other, it also helps course instructors to keep track of projects. PACE also automates several functions, freeing course instructors to focus on their teaching role. The sign-up sheet for design reviews, demos, and parts requests is much more accessible, and it is possible to ensure that teams only sign up for times that their TA is available. The electronic form of parts requests eliminates the need for prior approval by logging requests by team. TAs also receive an email copy of each request, allowing them to monitor requests. This prevents abuse of the free source of parts and simultaneously allows the TA to gauge the status of the project. The electronic form of submission eliminates paper delays, simplifies collection of late papers, and simultaneously builds the Project Pages without burdening students. It may even reduce the number of grammar mistakes, since students can be informed that Word’s built-in grammar checker will be used on reports.

To summarize, PACE provides a long list of communication and management benefits for the Senior Projects class for Electrical Engineers at the University of Illinois including the following:
1) Added motivation for students through greater exposure
2) Communication between students, staff, and partners through the Discussion Board
3) Efficient communication of updated procedures
4) Convenient parts ordering and usage tracking
5) Archiving of project reports, pictures, and video without burdening students
6) Convenient scheduling of large groups of meetings with multiple participants
7) Ability communicate with Industry and Alumni through “Partners Program”

One of drawbacks of PACE is that documents that are turned in must be a single file in Word format. This means that images must be scanned and pasted into the document. They cannot simply be stapled into place. Also, other word processors such as Latex and WordPerfect cannot be used. Another drawback is disk space limitations. Efficient use of disk storage is important not only to save on disk space, but also to minimize download and search times.

6.2 Endless Possibilities

While the specific ideas above demonstrate the Web’s ability enhance an organization’s day-to-day life, the rate at which the project grew demonstrates the magnitude of the potential impact. PACE began with only one part, the easy-to-create Web pages for each team. Ideas were then shared and discussed with the involved parties including students, professors, TAs, Parts Shop, and the Publications Office. Through this interaction, ideas were refined and new ideas emerged almost effortlessly. Only a fraction of this free-flowing creativity was targeted for implementation, and even those ideas have plenty of room for improvement. This project shows, by case study, how the tools of the “Virtual World” can enhance the “Real World.”

Bibliography

PURVESH B. THAKKER
Purvesh B. Thakker is pursuing a joint Masters degree in Electrical Engineering and Business Administration at the University of Illinois at Urbana-Champaign. He received his B.S. in Electrical Engineering from the University of Florida in Gainesville, Florida. In addition to research, Purvesh has been involved with the Senior Design Project Laboratory (ECE 345) as the Instructor for one semester and as a Teaching Assistant for three additional semesters.

GARY R. SWENSON
Gary R. Swenson earned his MS (1968) and PhD (1975) in Aeronomy at the University of Michigan. He worked at the NASA/Marshall Space Center in Space Science (1968-1984) and Lockheed Palo Alto Research Laboratory in Atmospheric Remote Sensing (1984-1996). He currently is a Professor in the Department of Electrical and Computer Engineering at the University of Illinois at Urbana-Champaign and is the Instructor for Senior Design.