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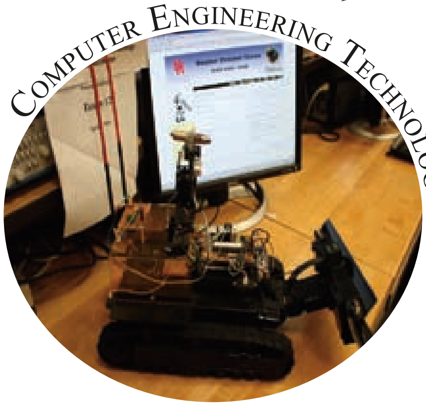

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Mark Rajai, IJME Editor and IAJC President

The Inauguration Hardcopy Special Issue

On behalf of IJME editorial board, I am pleased to present our spring/summer 2008 inauguration hardcopy special issue to celebrate the beginning of our ninth year in publication. When IJME was lunched at turn of new century as a purely electronic journal, the idea of an online journal was something of a novelty. However, with growing publication costs, and rapid changes in disseminating information, many new journals and a growing number of established print journals adopted IJME's mode of either creating new online journals or becoming electronic. Today, IJME, as a recognized leader among engineering and engineering technology journals, plans to offer its issues in both print and electronic formats. This issue contains nine (9) peer-reviewed articles, a book review, and software review.

Creation of IJME Parent Organization

Beginning in 2004, and continuing IJME's pioneering vision, we embarked on our groundbreaking—and on-going—efforts to establish strategic partnerships with other major rival journals and organizations to share ideas and resources. These efforts resulted in an innovative joint international conference including number of organizations and journals in 2006, and also the creation of a new organization called "International Association of Journals and Conferences" (IAJC). IJME and several other journals are now members of IAJC. IAJC is a first-of-its-kind organization and intends to become a prestigious and an exclusive global and multilayered umbrella consortium of academic journals, conferences, organizations, and individuals committed to advancing excellence in all aspects of technology-related education.

Editorial Changes and IJME Future Management

IJME's move to become a print journal and its rapid growth has created new editorial positions. Victor Gallardo of the University of Houston is the new copy editor. Jerry Waite and the University of Houston press are our new publisher. Mulchand Rathod of Wayne State University is our new financial editor. Robert Canter of Virginia Tech, our long-time associate production editor, has been promoted to production editor, and Jennifer Fickley-Baker of the University of Central Florida is now our new associate production editor.

Also, at special meeting of IJME board of directors, the board decided to dissolve itself and IJME advisory board and place the management of the journal under the new distinguished board of directors of its parent organization, IAJC. However, the board decided to maintain the IJME international review board. Meanwhile, IJME's current board continues to manage the journal until the new board of IAJC takes control of the journal in its first official meeting at the site of its sponsored conference in Nashville, Tennessee, on November 18-22, 2008.

Acknowledgment

Publishing a journal in hardcopy is not only expensive, but also time-consuming, requiring dedication from many individuals. On behalf of our board, I would like to thank Dean William E. Fitzgibbon, Farrokh Attarzadeh, Victor Gallardo, Jerry Waite, and his staff, Ella O'Neal and Harold Halliday at University of Houston, College of Technology, Graphics Technology for sponsoring and publishing this issue in print. Also many thanks to Monica Peon of Igloo Design, Mexico City for art, logo design and Saeed Namyar of Namyar IT solution for the Web site design.

We hope you enjoy this special print issue and continue to support the journal and its parent organization, IAJC. We also hope to see all of you at our upcoming international conference in Nashville, Tennessee.

APPLICATIONS OF MATHEMATICAL MORPHOLOGY IN EDGE ANTI-ALIASING ALGORITHMS

Matt Lazarowitz, American Megatrends Inc.; Aldo Morales, Penn State University

Abstract

Aliasing artifacts in images are present when high-resolution images are displayed on lower resolution screens. These artifacts are shown as stair step-like diagonal lines or edges and are commonly known as "jaggies." In this paper, four efficient anti-aliasing algorithms are presented. Instead of operating on the entire image, these algorithms find edge maps by using morphological edge detectors and then applying average filters only on the regions indicated by these edge maps. The algorithms show a significant reduction of these aliasing artifacts. The algorithms were developed as a part of the final project in an image processing class at Penn State Harrisburg, and implemented entirely in MATLAB.

Introduction

Aliasing is a very common problem in computer graphics, where mathematical models with infinite resolution are mapped onto screens that have inherently finite resolution [1,2]. Edge aliasing artifacts are typically called "jaggies." In order to improve image's quality, anti-aliasing algorithms are essential features in consumer electronic products where graphics are heavily used [3,4,5]. Anti-aliasing algorithms are traditionally rendering algorithms but they can be used wherever digital image data is utilized—for instance, in camera phones and digital cameras [5].

There are two major types of anti-aliasing algorithms: pre-processing and post-processing [4,5]. Of these two types, post-processing is the most common. In post-processing, there are two basic algorithms: the full scene anti-aliasing (FSAA) [5] and edge anti-aliasing [6]. FSAA typically uses a method known as super sampling. This is the process of converting a high-resolution image into a lower one without damaging the details but removing the artifacts. Edge anti-aliasing offers another alternative whereby aliased-edges ("jaggies') are overdrawn as anti-aliased lines. Recently, [6] developed an algorithm to blend edges to the silhouette of an image so that "jaggies" are minimized. Figure 1 shows a typical "jaggy" when zooming out an image.

In this paper, four efficient anti-aliasing algorithms are presented. Instead of operating in the entire image, these algorithms find edge maps by using morphological edge detectors and then applying average filters only on the regions indicated by these edge maps. The first method using an edge map has the advantage of being the simplest of the four methods introduced here. A side effect of this method is that bright areas are expanded. However, this could be a problem in small regions of high contrast where the loss of darker pixels is unacceptable. In order to use the same inputs, a second halo edge method is developed. This second method entails two extra steps and the extra memory needed to store an additional binary edge map. In images with long, fine horizontal and vertical $(G_e = d - f)$ lines, both of the above methods may cause an unacceptable loss of quality in these fine details. The next two methods are developed to address such cases while still working to eliminate the objectionable jagged edges. Only the endpoints of lines are detected for filtering in these two methods, with the understanding that a diagonal line is a set of horizontal and vertical line segments. The last two methods require more steps than either of the two previous methods as well as more memory. However, the efficiency of the algorithms introduced in this paper stems from the fact that morphological edge detection is a fast operation and that the averaging is performed only on limited areas (near or at the edges) of an input image. As demonstrated by our results, the algorithms show a significant reduction of the aliasing artifacts, commonly known as "jaggies."

This paper was developed in the context of an image-processing course at Penn State Harrisburg and entirely implemented in MATLAB. The paper's organization is as follows: first, basic concepts of mathematical morphology and its applications to edge detection are briefly reviewed; in the following section, edge anti-aliasing algorithms are proposed; then results of the applications of these algorithms are discussed; finally, conclusions are drawn.

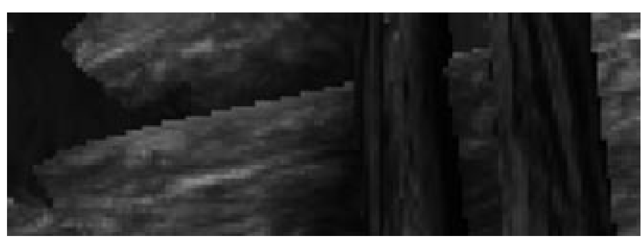

Figure 1 Jagged edges that result from no anti-aliasing when zooming out from an image

Background

In this section, basic definitions of morphological operation are reviewed (see also [7-8]). Binary discrete images are represented by 2-D sets. Given a set F and a set B, denoted as structuring element, two primitive operations are defined between F and B. The first operation is called dilation and is defined as:

$$D = \{x : B_x \cap F \neq \varnothing\} = \bigcup_{y \in B} F_y = \bigcup_{x \in F} B_x \qquad (1)$$

where B_x is the translation of set B by x, and $\varnothing$ is the empty set. Dilation is an operation that expands the original set F. The second operation is called erosion and is defined as:

$$E = \{x : B_x \subset F\} = \bigcap_{y \in B_0} F_{-y} = \bigcap_{-y \in B_0} F_y \qquad (2)$$

where B_0 denotes the structuring element associated with the origin. This operation can be viewed as an operation that shrinks the original image. Since the dilation operation expands the original image, a simple morphological edge detection algorithm can be defined as:

$$G = D - F \qquad (3)$$

where G is the edge image. For example, Figure 2a shows an original image; Figures 2b and 2c show the results of dilation and erosion with a disk-shaped structuring element of radius 5. As it can be observed from Figures 2b and 2c, the original images have been expanded and shrunk by using dilation or erosion, respectively. Figure 2d depicts the edge image, which is the result of taking the difference of Figure 2a from 2c (eq. 3). These operations were performed in MATLAB. Dilation and erosion were extended to gray scale imagery by several authors, among them [7-8]. Dilation of a gray scale image f by a structuring element b is denoted as:

$$d(r,c) = \max_{i,j}\left(f(r-i, c-j) + b(i,j)\right) \qquad (4)$$

where the maximum is taken over all (i,j) in the domain (window) defined by the structuring element b. The erosion of a gray scale image f by a structuring element b is defined as:

$$e(r,c) = \min_{i,j}\left(f(r+i, c+j) - b(i,j)\right) \qquad (5)$$

where the minimum is taken over all (i,j). For our experiments, the set b is defined as a flat structuring element; therefore eqs. 4 and 5 reduce to finding a maximum or minimum, respectively, in the window defined by the structuring element b. In [9], a dilation edge detector was defined as

$$G_e = d - f \qquad (6)$$

where d is the dilated image as in eq. 4 and f is the input image. There are several applications of morphological edge detection in the technical literature [9-10]. In this paper, morphological edge detection will be used in removing some artifacts introduced by aliasing.

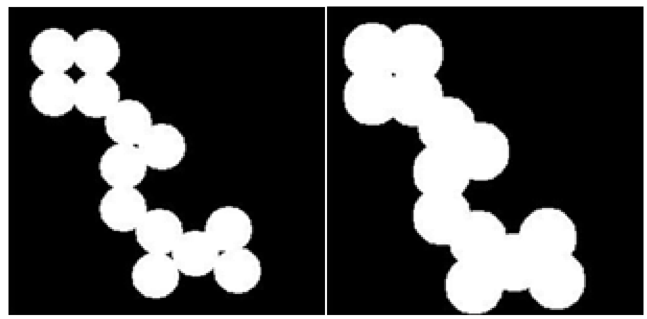

Figure 2a Original Image Figure 2b Dilated Image

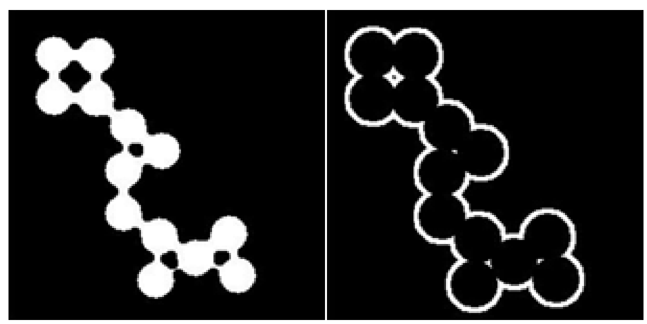

Figure 2c Eroded Image Figure 2d Difference Image

Proposed Edge Anti-Aliasing Algorithms

In this section, four efficient edge morphological anti-aliasing algorithms are described. Instead of operating on the entire image, we focus on the edges only, since these are the areas where artifacts are most noticeable. For edge detection, a simple morphological operation was used. First, the original image is dilated with a 3×3 square-shaped flat structuring element, and then the original image is subtracted from its dilated version. Thresholding is used in the difference image to convert it into a binary image. This image is referred to as an edge map. When applying the anti-aliasing algorithm to the image, the operation is checked against this edge map. If no edge is present at the current pixel, indicated by a zero, then the process moves onto the next pixel. If an edge is detected, then a function averages a neighborhood in the original using a user-supplied 3×3 kernel. For instance, Figures 3 and 4 show the original and its edge map image, respectively.

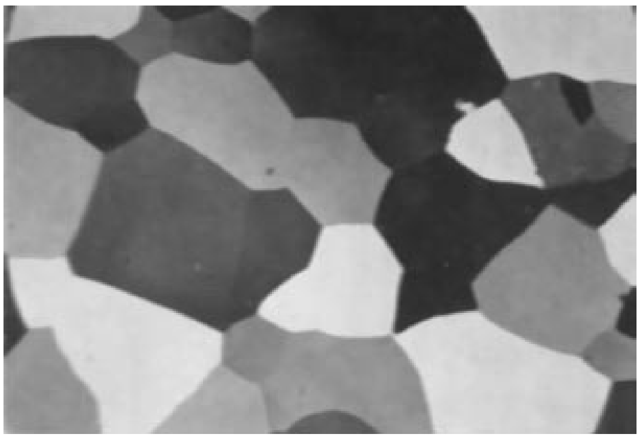

Figure 3 Original Image

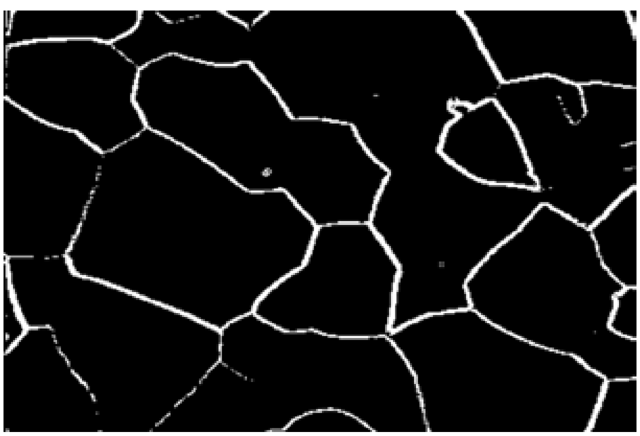

Figure 4 Edge map of 3

However, in images that have stepped lines that must remain continuous, this simple algorithm may erase lines. The second proposed algorithm gets around this problem by creating a halo or ring around the edge so that the points just beyond the edges get modified. Dilating the edge map image and subtracting the resulting image from the original edge map creates the "halo" images, one of which is shown in Figure 5.

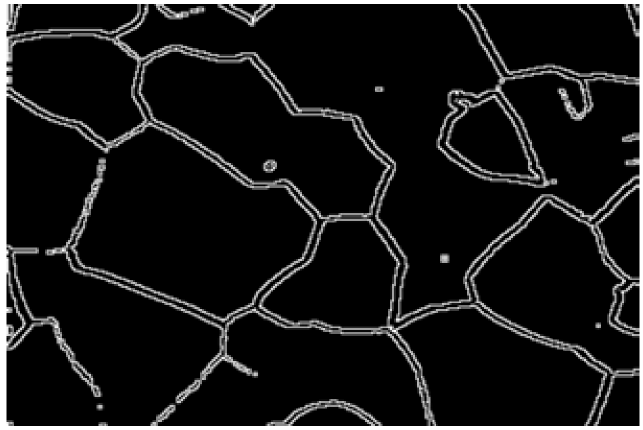

Figure 5 Halo Image

The final two methods deal explicitly with corners. The first algorithm detects the inside corners, which really are endpoints of line segments. The reason they are called "corners" is that they usually occur at the corner of a staircase artifact. By operating only on these points, jagged edges can be blended together without hurting the definition of the line. Figure 6, below, shows the inside corners of the sample images. To obtain the edge for these corners, two different structure elements were used. One was a row to obtain the horizontal edges, and the other was a column for the vertical edges. Once the two binary maps were obtained, a logical AND was performed to find the common points of both maps, which are the corners.

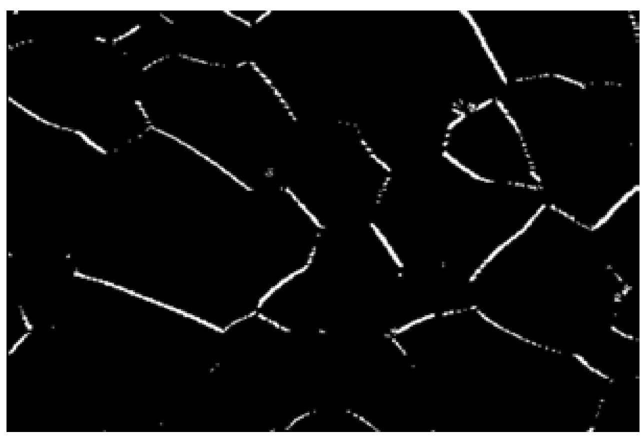

Figure 6 Inside corners

In addition, there are the "outside corners." Operating on the inside corners presents the same problem of apparent line erasing as the first method, so the corners were found just outside the edges. In Figure 7, the result of this operation on the sample images is shown.

Figure 7 Outside corners

Finally, there is the selective application of the anti-aliasing mask based on the various maps. A pure averaging filter was used to sample from the four corners and the center of a 3×3 neighborhood. The following matrix was used:

The next section presents the results of the algorithm's application to different images.

Results

Figure 8a shows the input image, which is a rotated version of the cameraman. The "jaggies" are quite noticeable. Figure 8b shows the results of the morphological edge detector, with a square structuring element of size 3×3. The dilation was implemented by partially modifying a code found in the MATLAB file exchange site [11]. The output image for the first algorithm is shown in Figure 9, where it is observed to foster a reduction of the "jaggies"; however, the tripod's brace is somewhat lighter, thinner, and not as clearly defined as in the original image. Figure 10a shows the halo edge image obtained for the cameraman, while Figure 10b shows the results of the application of the second algorithm described in the previous section. This picture depicts a better definition of the tripod's brace, at the price of somewhat lower definition of the image's jagged contours. The application of the third algorithm is depicted in Figures 11a and 11b. Figure 11a shows that fewer pixels were detected as inside corners; therefore, fewer adjustments were needed for the jagged contours. Figure 11b shows better results for the tripod's leg and the cameraman's face; these details are less blurred than Figure 10b. Finally, Figure 12a depicts the detected outside corners of cameraman. The edges appear smoother, and much less jagged.

It is noted that the CPU time for the algorithms was between 1 to 2 seconds. Although we did not optimize the code, the algorithms were fast.

Figure 8a Original jagged image

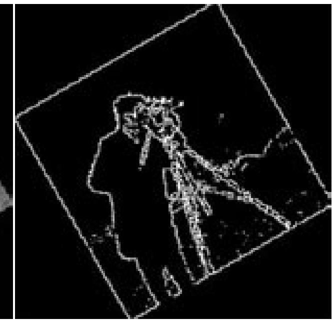

Figure 8b Edge map

Figure 9 Output for the first type of anti-aliasing

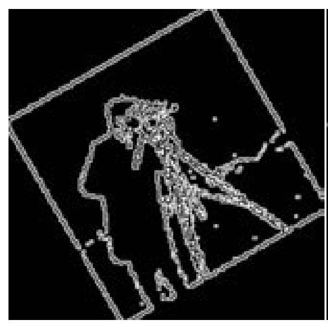

Figure 10a Halo edge for cameraman

Figure 10b Output image of the second type of anti-aliasing

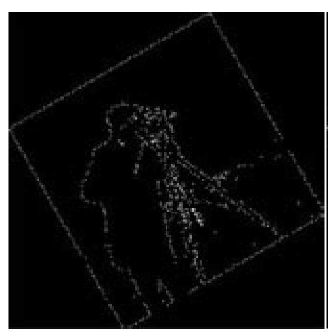

Figure 11a Inside corners for cameraman

Figure 11b Output image of the third type of anti-aliasing

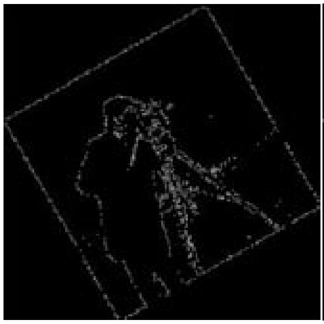

Figure 12a Outside corners for cameraman

Figure 12b Output image of the fourth type of anti-aliasing

Conclusions

In this paper, new and simple morphological-based anti-aliasing algorithms were proposed. These algorithms created edge maps to process only the regions where "jaggies" are most likely to occur. These basic morphological algorithms can be easily implemented in graphics hardware for consumer electronics products. The results show both that these algorithms were successful and that they have a very short CPU time. Further research will include developing automatic means of choosing either one of or a combination of these anti-aliasing algorithms when suppressing "jaggies." The algorithms were entirely implemented in MATLAB.

Notes

Preliminary version of this paper was presented at the International Conference on Consumer Electronics, January 8-12, Las Vegas, Nevada, 2005.

References

[1] http://www.siggraph.org/education/materials/HyperGraph/aliasing/alias0.htm

[2] J. Blinn, " Ten More Unsolved Problems in Computer Graphics," IEEE Computer Graphics and Applications, September/October 1996.

[3] N. Liu, H. Jin and A. Rockwood, " Anti-aliasing by Gaussian Integration," IEEE Computer Graphics and Applications, May 1996.

[4] Y.Yeh and C.Y. Lee, "A New Anti-Aliasing Algorithm for Computer Graphics Images," Proceedings of the International Conference on Image processing, 1999, Vol. 2, October 1999.

[5] R. Woo, S. Choi, J.H. Sohn, S.J. Song and H.J. Yoo, " A 210-mW Graphics LSI Implementing Full 3-D Pipeline With 264 Mtexel/s Texturing for Mobile Multimedia Applications," IEEE Journal of Solid-State Circuits, February 2004.

[6] P. Sander, H. Hoppe, J. Snyder and S. Gortler, "Discontinuity Edge Overdraw," Proceedings of the 2001 Symposium on Interactive 3D Graphics, March, 2001, Research Triangle Park, North Carolina.

[7] C. Giardina and E. Dougherty, Morphological Methods in Image and Signal Processing. Englewoods Cliffs, NJ: Prentice Hall, 1988.

[8] R. M. Haralick, S.R. Sternberg and X. Zhuang, "Image Analysis Using Mathematical Morphology," IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. PAMI-9, no 7, 1987.

[9] J. S. Lee, R.M. Haralick and L. Shapiro, "Morphologic Edge Detection," IEEE Journal of Robotics and Automation, Vol. RA-3, No. 2, April 1987.

[10] X. Song and Y. Neuvo, "Robust Edge Detector Based on Morphological Filters," China 1991, International Conference on Circuits and Systems, June 1991, Shenzhen, China.

[11] Yali Wei at http://www.mathworks.com/matlabcentral/fileexchange/

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E-Learning Laboratories for Optical Circuits: Separation of Imperfections in Technology and Teaching Methodologies

Richard Franzl, University of Houston; Deniz Gurkan, University of Houston;
Driss Benhaddou, University of Houston; Alan Mickelson, University of Colorado at Boulder

Abstract

One of the main challenges in teaching online laboratories is the separation of imperfections in technology and teaching strategies. In this paper, learning assessment of a set of remote laboratories that cover "optical circuits" material will be discussed. Optical circuits employ optical fiber or free space links to carry encoded information. These laboratories involve the evaluation of optical fiber, fiber compatible components, and links for transmission of encoded optical signals. Remote laboratories that have been developed at the University of Colorado Boulder (UCB) and the University of Houston (UH) have been assessed for the first time in the Spring 2006 semester in courses offered in the Engineering Technology Department of the University of Houston. One of the objectives of this project is to evaluate the teaching strategies given the imperfections in the technology of remote data acquisition. In order to fulfill this objective, the authors have conducted opinion surveys among the participating students and some experts in the field. The paper will present the findings from the collected data, student success evaluation through a hands-on testing of skills, and faculty observations. The data is collected from sixteen students who took the course and four experts who participated in the evaluation of the teaching methods.

Introduction

Online education is bringing new opportunities for faculty from different institutions to share resources and research on more cost effective methods to provide high quality learning environments [1], [2]. There seems to be a consensus that video streaming is preferable to simply static placement of material on a website. The efficacy of live streaming (large scale teleconferencing) versus asynchronously accessible streamed video on learning may be an open question. Technological advances in data compression and bandwidth increase in home connections allow students to view high quality video streaming of lectures from home. This broadband access to the Internet is beginning to have an effect on the content of such materials [3] and [4]. Combined with chat rooms, some being video equipped, there are techniques available for dynamic interaction. However, experimentation is a pervasive need within engineering education, and one that is hardest to address in a learning-effective as well as a cost-effective manner. Several other efforts on online laboratories have been reported [5-16]. The authors of this paper have presented results in [17] on a remote-controlled optical time domain reflectometer for optical circuits. See Figure 1.

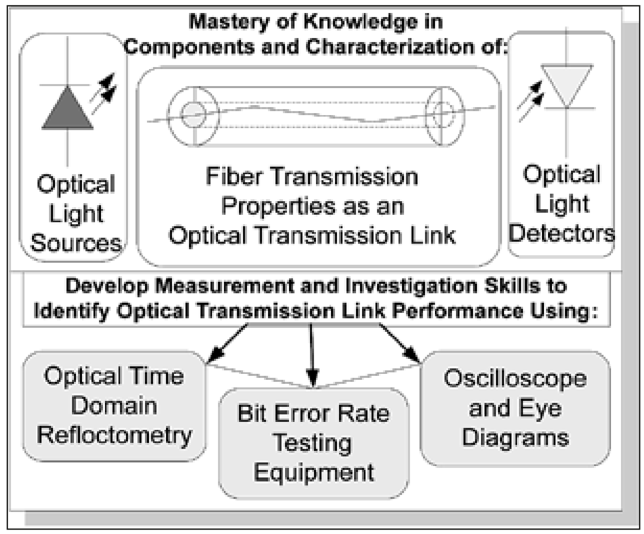

Figure 1 Depiction of an archetypical fiber optic link with source and detector

The Engineering Technology Department in the University of Houston and the Electrical and Computer Engineering Department in the University of Colorado at Boulder are offering online laboratories for optical circuits classes in their curricula. The content of the course includes tools necessary to understand and operate optical components and their test and measurement instruments. The need for this knowledge arises from the lack of knowledge base in the curricula on optics concepts such as fiber optic transmission systems, optical detection, and bit error rate through optical transmission. These concepts traditionally were offered in the theoretically upper level engineering curricula. However, the industrial push for more fiber-optic transmission and a more mature optical technology for various applications call for practical and interdisciplinary knowledge on this technology rather than the rigorous treatment of the theory behind all. In this respect, six laboratories have been developed in these two institutions. These include characterization of optical sources such as laser diode and light emitting diode, characterization fiber link properties that affects the performance of an optical circuits, bandwidth measurements using time domain and frequency domain measurements, characterization of optical detectors, characterization of optical link performance using bit error rate (BER), and eye diagram techniques. Figure 1 depicts a representation of all the components and concepts involved in a typical optical circuit. The diagram illustrates that the experimental themes may address specific hardware components as well as more general performance characteristics of a fiber system as a communication link.

The first two labs and a hands-on skill transfer version of the first two labs have been conducted in the Spring 2006 at University of Houston. The objective of this paper is to investigate the **separation on the effect of the imperfection of the technology employed in transmitting the information to the student from the imperfection of the teaching methodology.** This objective will help the education community understand the challenges that remote laboratories delivery across the disciplines. The technological advances have enabled self-practice virtual laboratory environments with a broadband connection. However, the data acquisition and integration of a laboratory setup into one interface with an instructor is still challenging for most institutions. In order to separate the technological imperfections from the shortcomings in the teaching methodology, the assessment methods have to be designed with careful considerations. Assessment results as well as observations will be presented in this paper.

The rest of the paper is organized as follows: section B presents the concept of separation of imperfections while teaching methods and technology is presented in section C.

Technology Imperfections

The imperfections in technology might include the connection speed to the equipment and data acquisition server; the data acquisition software limitations due to possibly inefficient instrument drivers and connections, and remote lab interface with less than optimal number of controls on the experiment. These imperfections are detailed below.

The connection speed to the equipment and data acquisition server: the connection has been performed through the College of Technology's LAN with 100 Mbps capacity. Students have connected to the setup through their home computers as well as the campus computers. From the demographic surveys, that data shows that none of the participants had a dial-up connection. However, connection issue has two sides. One relies on the network to transmit the acquired data from the measurement instrument. Since there were not any dial-up connections and the LAN line has been sufficiently fast, there is no anticipation that latency is related to this side of the transmission. The other relies on the response speed of the instrument to data acquisition setup. This speed not only depends on the data acquisition method, but it also depends on the instrument response time to refresh measurement data. Work has been closely done with the National Instruments in order to optimize the LabView data acquisition software for a real-life performance in a remote setting. The refresh rate for a spectrum display is almost 2 Hz. The switching from one setting to another (e.g. LED to laser transmission) happens almost in 2 sec. The server has been reported stalling at times with no response. The students would have to reset the whole connection by exiting from the LabView screen and reopening in another browser. The solution to this problem will be investigated to have a resolution by the next semester.

The data acquisition software limitations due to possibly inefficient instrument drivers and connections: the data acquisition software has been advanced to a level that it can perform similar to a network device with an asymmetrical transmission characteristic. Namely, it would read data from a test instrument to transmit back to the main display station (large data transmissions). In return, the display station would send requests to better visualize the measurement outputs such as resolution, wavelength/time range, etc (relatively small data transmissions). The Optical Spectrum Analyzer and the Optical Switch have a connection through a GPIB cable to the control server station. The oscilloscope/network analyzer, which is a more current instrument, has an Ethernet connection to the server station.

Remote lab interface with less than optimal number of controls on the experiment: the more controls there are on the server station, the greater the complexity of the LabView program. On the other hand, it will become a close-to-hands-on experience if there can be more controls on the server. It is our goal to have the students gain the skills necessary to operate and investigate the optical components and instruments as if they have been exposed to them in a traditional hands-on laboratory.

Given the outlined issues, the technology is mature enough to conduct experiments at almost the hands-on level of experience using the remote access and data acquisition methods. In addition, the technological advances push the remote data acquisition even further towards an automated system with a decision and control station managing various system parameters. In this case, systems have become plug-and-play with a user-friendly access mechanism and control. The setup of the system almost never needs to be tweaked.

Teaching Imperfections

Laboratory manuals are prepared using a model adopted by a group of faculty at the University of Houston, Engineering Technology. The salient feature of this method is that students carry out the lab in two steps. Firstly, the pre-lab is conducted where students watch a video orientation and then perform a simulation. The simulation will give student a first hand interaction with the concept dealt with in the lab portion. Secondly, the lab is conducted where students perform the actual remote control of equipment and take real measurements.

The simulation and the orientation video are the pre-lab activities. The learning outcomes depend highly on both the hands-on experience to be gained through the remote laboratories as well as the understanding of fundamental concepts in each experiment. Whenever the remote lab has a shortcoming of relaying the big picture of an experimental setup, the orientation video should fill in the gaps in equipment familiarization and setup details. Similarly, simulation should be able to provide a larger scale experimentation venue for comparison of parameters that have a high degree of importance in the concepts.

The simulations are designed by the instruction using the VPI Software for optical systems. The actual modeling software is being used to create system scenarios. These simulations are then saved as an executable file to be played later by students using VPI's free run-time engine: VPI Player [18]. The simulations include a variable parameter that can be set to various cases. This parameter gives the students a tool to change the conditions of their observations. Although the students cannot design a system using the VPI Player, they can observe the setup on the screen and play with the variables governing the experiment.

Figure 2 displays fiber link attenuation simulation implemented using the VPI player. The simulations were for multi-mode and single-mode fibers with varying propagation distances. The results of the simulation execution are displayed to the side of the simulation display. The input power to the links is displayed by the powermeter pop up windows as well as their corresponding output power levels. Link budget calculations can be done using these results. These results are in power measurements at the input and output ports of various distances of propagation through multi-mode or single-mode fiber.

The orientation video has the recordings of the instructions to the simulation software and the remote access mechanism outlined by the instructor. The available technologies vary from institution to institution for the video and instructions delivery. Polycom iPower has been used to prepare this first orientation. In future implementation the orientation will include a demo of the instructor setting up the real experiment for students to have a feel of what an experiment takes to set up. See Figure 2.

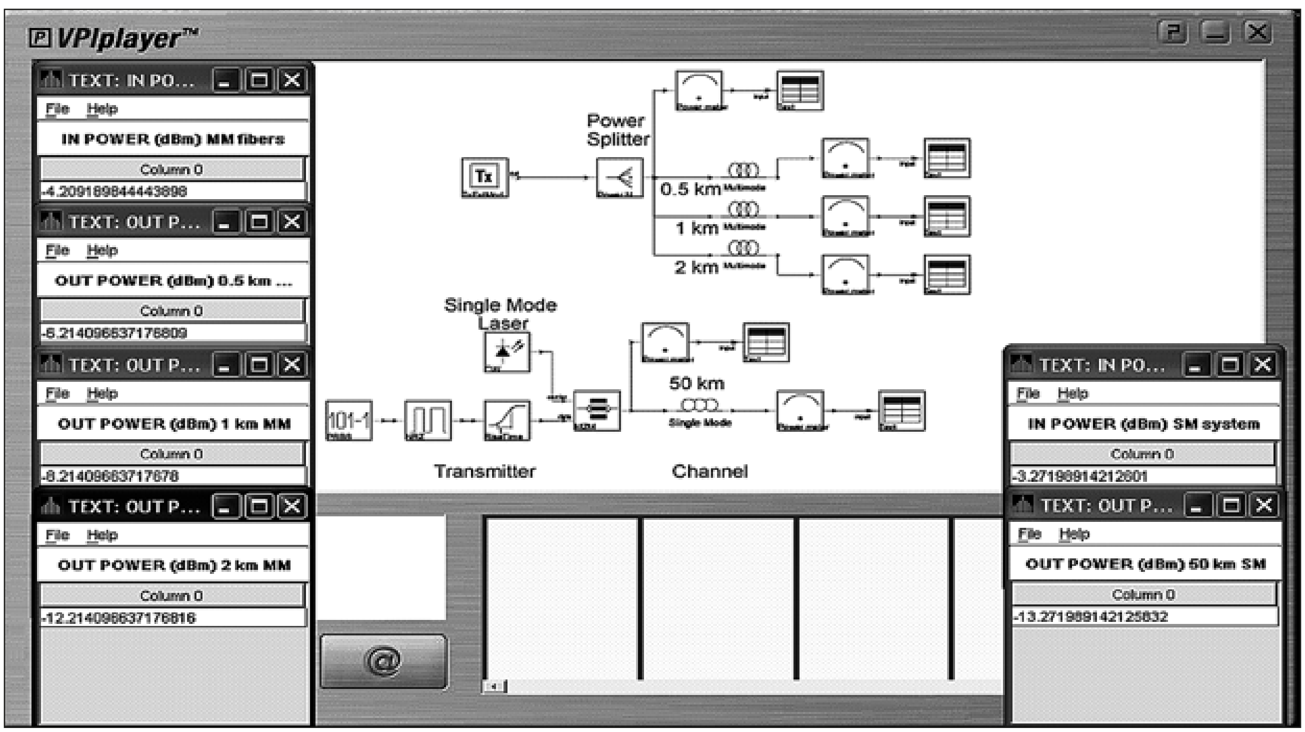

Figure 2 Simulation window for fiber link loss analysis

Implementation Of Experiments

Multiple parts of the experiments are remotely controllable or connected to an instrument that is controllable. For instance, in the source characterization experiment, the laser and LED sources are connected to a switch that is remotely controllable. The output of the switch is connected to the Optical Signal Analyzer (OSA). The OSA screen and switch controls are displayed on the remote control window through the LabView web server. Students can access the remote laboratories using an ActiveX plug-in on their web browser. The setup in figure 3 gives an overview of how the access mechanism works for the students through the remote data acquisition. An optical switch enables the selection of the concept to be monitored. It is remotely controlled by the same Virtual Instrument program that controls the OSA. The spectrum is monitored when the selection is changed between a laser and an LED source. Possible teaching method imperfections may include orientation video, concept to experiment mapping, and parsing of experiment to simulation and remote data acquisition.

Concept to experiment mapping: the concepts will need to be mapped to an experiment in such a way that they will teach students in an effective way while being sufficient without troubleshooting skill development over the system demonstration. The remote laboratories will lack the troubleshooting practices unless there is a mechanism to physically control the setup by moving components around and connecting them via a robot hand.

Parsing of experiment to simulation and remote data acquisition: the parsing has a great impact in the understanding of educational delivery methods in remote laboratories: e.g. perfect results of a fundamental concept through a simulation model might create confusion when the student is presented with the real-life experience from the actual laboratory results (including noise, system imperfections, etc.). The simulation should be able to address the imperfections in real-life cases to keep these confusions at a minimum. See Figure 3 above..

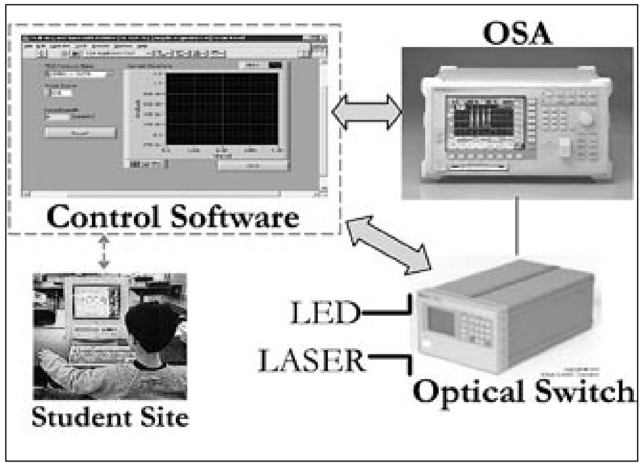

Figure 3 Remote access mechanism for experiments

Orientation video: Orientation video further enhances the pictorial understanding of the setup.

Assessment Results Of Pilot Implementation

The assessment plan encompasses both formative and summative assessment methods. The experiments are being developed at the University of Houston (UH) while the other institutions and experts from industry are providing feedback on the teaching methodologies and the performance of the remote access laboratories. In order to assess the learning outcomes with the learning objectives in mind, the assessment methods are developed. These methods with their action items are listed in table 1.

Summative assessment methods involve a project demonstration as well as the final application of the skills by the

Table 1 Formative and Summative Assessment Activities

Outcomes	Assessment Method
Formative Assessment	Tests & pre-lab activity reports
	Faculty evaluation rubrics
Develop Investigation Skills in Link Error Characterization	Student perception surveys
	Interview & visits by industry
Summative Assessment	
Mastery in hands-on skills by developing innovative e-learning mthods in laboratory instruction	End-of-semester project demonstration at the physical lab (every semester)
Develop transferable skills in optical systems applicable to biotechnology, communications, networking, etc.	

Table 2 Student Opinion Summary

	Strongly Disagree	Disagree	Agree	Strongly Agree
Optical Sources				
The laboratory improved my understanding of laser	17%	8%	75%	0%
Wavelength ranges were easy to set and observe	8%	33%	50%	8%
Fiber Links				
My understanding of fiber link loss is improved	0%	11%	61%	28%
Power level after each fiber link was easy to measure	0%	6%	72%	22%
6Remote Assess				
The remote control speed was enough to do the lab	3%	10%	59%	28%
The remote control panel software was easy to use	3%	31%	45%	21%
The instrument control was clear	7%	10%	63%	20%
The remote laboratory provided a similar experience to a hands-on lab	6%	26%	65%	3%
The lab manual was easy to understsand	10%	19%	61%	10%
The web interface was easy to follow and understand	6%	10%	74%	10%
The pre-lab was helpful in understanding and performing this lab	3%	16%	65%	16%

graduates of the class. This assessment method will help the project shape the portability and flexibility of its methods.

Faculty evaluation reports as well as student perception surveys are being initially used to steer the project evaluations. The expert opinion surveys are useful to keep the project up-to-date with its technological advancement. The formative assessment methods are being conducted as the experiments are pilot tested in classes. The initial results from the Spring 2006 semester are presented here.

Student Opinion Surveys encompass questions related to the teaching methods in a remote setting. There are two questions that directly address the student knowledge acquisition. In addition, the demographics of access methods are also collected. The results of these opinion surveys are listed in table 2. So far, students have been very successful in their performance of the experiments. All of the sections of the experiment are completed, and the average grades in these experiments have been very high. The end-of-semester laboratory has been a hands-on implementation of the knowledge and investigation skills presented in the remote laboratories. Another survey that directly compares the skills of remote and hands-on labs is conducted in this experiment. Most of the students felt comfortable with their interface to the real instruments. See Table 2 above.

In order to identify the teaching shortcomings and to separate these from the technological shortfalls, a hands-on test experiment in the lab has been conducted. The results of the survey over this pilot implementation are listed in the table 3. The resulting opinion survey from the hands-on experience represents a good understanding of fundamental differences between the remote and hands-on labs. Although the success rate was high in transferring the skills gained in the remote labs, student opinions on the comparison of remote vs. hands-on experience has a variance. See Table 3 below.

Some expert opinion on the experiments has been requested. Table 4 summarized the results of the opinion

Table 3 Opinion survey from the hands-on experience

Question	Yes	No
Were you able to conduct the experiment?	100	0
Can you identify different connectors used?	100	0
Did you check if the bias current of the LED is set correctly?	94	6
The hands-on laboratory helped me undertand the concepts better.	100	0
I as able to set up the OSA correctly to get the spectrum characteristics.	100	0
I was able to set up different wavelength ranges in the OSA.	100	0
The remote laboratory gae a similar experience to a hands-on experiment.	56	44
I was able to measure the output peak power after various fiber link lengths.	100	0

survey. Suggestions have been received to improve both technological setup as well as our teaching methods. See Table 4 below.

Table 4 Expert opinion survey results

Question	Yes	No
The remote control speed was enough to do the lab	100%	0%
The remote control panel software was easy to use.	100%	0%
The instrument control was clear.	75%	25%
Instrument visualization was clear.	100%	0%
The laboratory helps in teaching the fiber link loss concepts.	100%	0%
The laboratory helps in teaching connector loss in fiber links.	25%	75%
Power readings for each of the link were easy to observe.	100%	0%
The remote laboratory provided a similar experience to a "hands-on" lab.	75%	25%
The lab manual was easy to understand.	100%	0%
The laboratory instructions were clear.	50%	50%
The Webcam was necessary to help me control the experiment.	0%	100%
The web interface was easy to follow and understand.	75%	25%
The pre-lab was helpful in understanding and performing this lab.	100%	0%

Conclusions

Laboratory distance education opens new challenges such as separation of imperfections in technology and teaching methodologies and development of assessment strategies that provide reliable feedback about student learning capabilities. Feedback from students and experts provided a lot of constructive comments and suggestions. Consequently, the teaching strategy has been updated to include a setup instructions video. This updated version of the orientation video would include the instructions on how to connect the optical circuit, showcases of the equipment used in the labs, and instructions on the measurements to be taken during each lab. This is an ongoing effort; and further work must be done to provide more experiments with student assessment feedback and analysis.

Acknowledgement

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References

[1] P. Hernandez--Ramos, D. Alexander, A. Belous and J. Behrens, Changing the way we learn: How Cisco Systems is doing it, International Workshop on Advanced Learning Technologies, pp. 177--179, 2000.

[2] D. Gillet, A. V. Ngoe, and Y. Rekik, Collaborative web-based experimentation in flexible engineering education, IEEE Transactions on Education, vol. 48, no. 4, pp. 696-704, Nov. 2005.

[3] S. Kariya, Online education expands and evolves, IEEE Spectrum, pp. 49--51, May 2003.

[4] E. Magana, and D. Morat'o, Internet Technologies course with combined professor and on-line contents methodology, Tenth International Conference on Telecommunications, pp. 1756--1761, 2003.

[5] E. D. Lindsay and M. C. Good, Effects of laboratory access modes upon learning outcomes, IEEE Transactions on Education, vol. 48, no. 4, pp. 619-631, Nov. 2005.

[6] National Instruments, Distance-learning remote laboratories using LabVIEW, web document of National Instruments, 2002.

[7] L. Hesselink, D. Rizal and E. Bjornson, CyberLab: Remote access to laboratories throughout the world wide web, Stanford University document (1999).

[8] L. Hesselink et al., CyberLab, ETOP '99, Sixth International Meeting on Education and Training in Optics and Photonics Workshop, Cancun, Mexico, July 28--31, 1999.

[9] L. Hesselink, E. Bjornson, and D. Rizal, CyberLab: A new paradigm for internet learning, SSGRR—2000 Conference, L'Aquila, Italy, July 31--August 6, 2000.

[10] L. Hesselink et al., CyberLab: A new paradigm in distant learning, WMC 2000, Society for Computer Simulation International, San Diego, CA, January 26, 2000.

[11] L. Hesselink et al., CyberLab: A new paradigm for distance learning, NSF Workshop: Learning from the Net: The Leading Edge in Internet--Based, Stanford University, February 11, 2000.

[12] L. Hesselink, D. Rizal, E. Bjornson, S. Paik, R. Batra, P. Catrysse, D. Savage, and A. Wong, Stanford CyberLab: Internet assisted laboratories, Journal of Distance Education Technologies, vol. 1, pp. 22--29, Jan.—Mar 2003.

[13] P. Pratap, A. Hunter, A. West, Remote Instrumentation, Invention and Impact: Building Excellence in Undergraduate Science, Technology, Engineering and Mathematics (STEM) Education Symposium, [Online document], April 2004, Crystal City, Va., [cited 05/08/2005], available HTTP: http://www.aaas.org/publications/books_reports/CCLI/

[14] D. Yaron, J. Cuardos, M. Karabinos, Virtual Laboratories and Scenes to Support Chemistry Instruction: Lessons Learned, Invention and Impact: Building Excellence in Undergraduate Science, Technology, Engineering and Mathematics (STEM) Education Symposium, [Online document], April 2004, Crystal City, Va., [cited 05/08/2005], available HTTP: http://www.aaas.org/publications/books_reports/CCLI/

[15] W. K. Ziemer, WeBWork: An Open-Source Online Homework System, Invention and Impact: Building Excellence in Undergraduate Science, Technology, Engineering and Mathematics (STEM) Education Symposium, [Online document], April 2004, Crystal City, Va., [cited 05/08/2005], available HTTP: http://www.aaas.org/publications/books_reports/CCLI/

[16] G-W. Chang, Z-M. Yeh, H-M. Chang, and S-Y. Pan, Teaching photonics laboratory using remote-control web technologies, IEEE Transactions on Education, vol. 48, no. 4, pp. 642-651, Nov. 2005.

[17] E. McKenna, R. Direen, F. Barnes, D. Gurkan, A. Mickelson, and D. Benhaddou, E--learning Environmental Design of a Distributed Online Laboratory for Optical Circuits Courses, Proceedings of the American Society for Engineering Education Annual Conference and Exposition, Portland, Oregon, June 2005.

[18] VPIPlayer™ Product Page, [Online document], May 2006, available HTTP: http://www.vpiphotonics.com/VPIplayer.php

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Assessing Industrial Technology Programs: A Comprehensive Approach Yielding Beneficial Results

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Abstract

Assessing industrial and engineering technology programs and student outcomes is at the very heart of improving what educators do best: preparing students for entry into the world of business and industry. This paper presents a comprehensive assessment model in use by the Department of Industrial Technology at the University of Nebraska at Kearney. The department assesses its National Association of Industrial Technology accredited programs to assure effective student learning through a comprehensive assessment process tied directly to student outcome statements. The model is based on five assessment measures: Final Evaluation of Intern by Work Site Supervisor, Comprehensive Exam, Employer Survey, Graduate Survey, and Student Confidence Scale. Quantitative and qualitative data collected from each assessment instrument are evaluated by department faculty and staff, industry representatives, and industry program advisory committees to determine changes that may be required in the department's programs.

This paper describes the assessment measures and presents and evaluates the results of the 2006-2007 academic year assessment of the Industrial Distribution program. The assessment model is evaluated annually and has a positive effect on improving the quality of the department's programs.

Introduction

The Department of Industrial Technology (ITEC) at the University of Nebraska at Kearney (UNK) annually conducts direct and indirect assessment measures to verify the continued viability of its programs and its success in preparing graduates for professional positions in Industrial Technology. Program assessment is an essential element in the assessment process [1] and departmental faculty are committed to program improvement via assessment measures. This article presents the 2006-2007 assessment data received from the Industrial Distribution program, one of the four ITEC department programs accredited by the National Association of Industrial Technology.

The ITEC department constantly assesses itself and its programs to remain up-to-date and competitive. Since the department's programs are not part of the required general studies curriculum, one of the department's most important assessments is the extent to which industrial partners recruit and hire its graduates. Amos [2] discusses the application of assessment techniques to measure industry-derived competencies. The department considers its industrial partners an essential element of the department's programs. Advisory committees help prescribe the competencies that students should develop while in school, and the committee members' opinions are taken seriously by the ITEC faculty and staff.

Assessment or accountability of educational programs has gained ever-increasing importance in higher education during the last two decades [3]. However, assessment can be tracked at least as far back as the Morrill Act of 1862 [4], when assessment was mandated to demonstrate that the stakeholders' funds utilized for higher education were being used judiciously and efficiently. Section 5 paragraph 4 of the Morrill Act of 1862 (12 Stat. 503) states:

An annual report shall be made regarding the progress of each college, recording any improvements and experiments made, with their cost and results, and such other matters, including State industrial and economical statistics, as may be supposed useful.

Since this is the very act that established the Land Grant Universities to include "such branches of learning as are related to agriculture and the mechanic arts" [4], assessment of engineering and technology programs should not be foreign to those engaged in the teaching of these subjects. While the concept of assessment is not new, the formal processes employed certainly have been refined over time. A review of relevant accrediting associations reveals strong support for assessment. The Accreditation Board for Engineering and Technology (ABET) Criterion 3 of the 2006–2007 Criteria for Accrediting Engineering Technology Programs [5] states:

Each program must utilize multiple assessment measures in a process that provides documented results to demonstrate that the program objectives and outcomes are being met (p. 6).

The National Association of Industrial Technology (NAIT) provides assessment criteria to improve the quality of industrial technology programs through an ongoing evaluation process. Section 6.16 of the 2006 NAIT accrediting standards [6] includes language that requires an assessment plan.

An assessment plan shall be comprised of, but not limited to, the following for each program: (1) program mission statement, (2) the desired program outcomes/student competen-

Table 1 Assessment Instruments – Advantages and Disadvantages

Method	Advantages	Disadvantages
Final Evaluation of Intern by Work Site Supervisor	Direct measure. Measures soft skills. Measures long term personal development. Easy to administer.	Can be subjective – depends on supervisor's definition of survey terms. Lack of uniformity from supervisor to supervisor.
Comprehensive Exam	Direct measure. Easy to administer. Subjectivity or bias is less likely. Validity and reliability can be established over time.	May not measure employer's requirements. Time lag between course work and administration of exam may skew results.
Employer Survey	Indirect measure. Correlates with Intern Evaluation. Large data base over time.	Lack of uniformity from employer to employer. Does not measure cognitive capabilities.
Graduate Survey	Indirect measure. Measures attitudes toward university, college, department, and major.	Difficult to maintain contact over time.
Student Confidence Scale	Captive population makes it easy to administer.	Without work experience judgments may be unreliable.

cies, (3) evidence that the program incorporates these outcomes/student competencies, (4) the assessment measures used to evaluate student mastery of the student competencies stated, (5) compilation of the results of the assessment measures, and (6) evidence that these results are used to improve the program (p. 31).

The North Central Association Commission on Accreditation and School Improvement [7] also calls for "an assessment system that is broad in scope and appropriate to document student development" (p. 7). Universal threads which intertwine through these different accreditation models are: (1) an emphasis on student achievement; (2) a set of general guiding principles, which include various procedures or approaches to data gathering that allow for both quantitative and qualitative data; and (3) the use of data to refine and advance the educational programs. This third aspect is analogous to concepts contained within the ISO 9000 Quality Systems Handbook [8] and the Baldrige-style organizational evaluation. [9]

The ITEC department made its initial decision to seek NAIT accreditation in 2000. In 2002, three of the four programs received their initial accreditation with 15 standards in partial compliance, one standard in non-compliance, and the assessment plan cited as deficient. The fourth program was not part of the department at that time. Through a series of faculty meetings and collaboration with the campus Coordinator of Assessment, it became obvious that it was not necessary to "reinvent the wheel." To bring the programs into full compliance, the department employed aspects of assessment plans that were, for the most part, already in place within the university. Today, all four ITEC programs at UNK are accredited by NAIT through 2012.

Overview Of Assessment Instruments And Assessment Process

An analysis of the literature indicates a seemingly infinite range of methods to assess student learning outcomes and program success. Among the approaches described in the literature to assess students and programs are certification exams; student, alumni, and employer surveys; and capstone experiences [10]. Each of these approaches, in addition to others, has been used within the ITEC department over the years with varying degrees of success.

Each of the department's programs developed a broad set of student outcome statements (competencies) that are evaluated to assure the programs meet the department's mission and objectives. For the Industrial Distribution program, these competencies were initially identified in the Delphi study Essential Competencies and Traits for Industrial Distribution Careers [11]. Competencies for the other programs have been identified via other means, but in all instances, industrial advisory committee input was drawn upon and employed on a continuing basis to maintain the programs' alignment with contemporary industrial practices

Through the process of evolution five assessment instruments, two direct and three indirect, are currently being utilized. Direct measures include the Final Evaluation of Intern by Work Site Supervisor and the Comprehensive Exam. Indirect measures include the Employer Survey, the Graduate Survey, and the Student Confidence Scale. The assessment instruments, other than the Comprehensive Exam, can be viewed at http://www.unk.edu/academicaffairs/assessment/index.php?id=5041 and are directly tied to the student outcome statements.

The Final Evaluation of Intern by Work Site Supervisor, Employer Survey, and Graduate Survey were originally developed over 15 years ago, and validity has been established by program advisory committee review on a regular basis. While some changes have been made in the questions throughout the years, tying them to student competency statements, the core of the instrument has remained virtually unchanged. The data generated over the years have also been consistent, which indicates these instruments' strong reliability. The Comprehensive Exam and the Student Confidence Scale were developed within the last 5 years and continue to be refined.

To determine if changes are required in the curriculum, quantitative and qualitative data collected from direct and indirect assessment instruments are evaluated once a year by department faculty and staff, industry representatives, and program advisory committees. Advantages and disadvantages of each instrument are shown in Table 1. Table 2 lists 12 selected examples of the 70 student competencies contained in the Industrial Distribution Student Outcome Matrix. See Table 1 on previous page. See Table 2 below.

The most important part of the assessment process is the analysis and evaluation of the assessment data. It is pointless to implement an assessment process, collect detailed data,

Table 2 Student Outcome Matrix – Selected Competencies

Competency by Course	Intro to Technology	Engineering Design	Technology Today	Electricity / Electronics	Machine Tool Products	Industrial Products I	Industrial Products II	Instructional Systems	Applied Electronics	Automated Devices	Manufacturing Distribution	Branch Operations	Safety & Health	Industrial Management	Leadership in Business	Ind. Distribution Seminar	Beginning Accounting I	Business Communication	Principles of Marketing	Principles of Selling	Internship	Economics	Telecom Literacy
I. Professional																							
Marketing and selling activities							✖	✖			✖								✖	✖			
The sales management function											✖	✖								✖			
Industrial distributor operations						✖	✖					✖		✖		✖							
II. Applied Science and Technology																							
Mathematical and scientific information.			✖						✖	✖													
Demonstrate technical expertise		✖		✖					✖	✖													
Apply trouble shooting skills.				✖	✖				✖	✖													
III. Business																							
Understand principles of selling.						✖	✖				✖									✖			
Comprehend industrial marketing.						✖	✖												✖				
Understand human motivation.											✖	✖		✖					✖	✖			
IV. Oral and Written Communication																							
Use appropriate vocabulary.	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖
Speak the language of industry.					✖	✖	✖			✖	✖				✖			✖	✖				
Convey organized thoughts.						✖	✖	✖		✖	✖						✖			✖	✖		

and then do nothing with the data. To assure a continuous cycle of curriculum improvement faculty, staff, industry partners, and advisory committees meet annually to review the assessment data. It is important to stress that the program advisory committees play an integral role in reviewing and analyzing the assessment data and making recommendations to faculty for curriculum improvement. The authors believe that industry involvement is what contributes to successful engineering and industrial technology programs.

Final Evaluation Of Intern By Work Site Supervisor

An internship is mandatory for all the department's Construction Management, Industrial Distribution, and Telecommunications Management students. The Final Evaluation of Intern by Work Site Supervisor, a direct measure, is an obligatory element of the internship. The evaluation is completed by the intern's work site supervisor at the end of the 12 credit-hour (480 work hours) internship, typically completed between the student's junior and senior years. The Final Evaluation of Intern by Work Site Supervisor is a synopsis of individual comments and appraisal of work performance signed by both the student and the employer.

The rationale behind this measure is to document the interns' work performance progress since their midterm evaluation and to evaluate the training plan objectives set at the beginning of the internship. Each internship training plan is unique. However, there is a standard group of questions in the Final Evaluation of Intern by Work Site Supervisor instrument covering the areas of Productivity, Business Techniques, and Personal Behaviors (Table 3). The questions address the "soft" skills necessary for success in the profession. These skills are arguably the most difficult to teach and yet are those which highly impact the success or failure of the individual. Given the consequence of these skills, or lack thereof, it was determined by Envick and Envick [11] that assessment was necessary. See Table 3 below.

Many of the soft-skill topics are also addressed in departmental student-led organizations, making these organizations a fundamental part of the curriculum. The information gathered through the Final Evaluation of Intern by Work Site Supervisor instrument is summarized and distributed to faculty and staff, industry representatives, and program advisory committee personnel for review.

Comprehensive Exam

The four ITEC programs developed and administered a Comprehensive Exam, a direct measure, for the first time during the spring semester 2005. Graduating seniors participated in the exams to determine the knowledge level mastered in both technical and non-technical areas. Prior to the development of the comprehensive exams, the department considered using a nationally-normed exam. The four programs that make up the ITEC department are distinct from each other, and although a core group of courses is required for all majors, departmental faculty determined that purchasing or producing a "one-size-fits-all" exam was not possible. The decision was made to develop instead a comprehensive exam consisting of questions from the core courses within the department's programs to be given in conjunction with program specific technical questions.

Graduate Survey

Alumni are asked to complete the Graduate Survey, an indirect measure, one and five years after graduation. The survey is administered through Opinio, a Web-based survey software package. In addition to its ease of use, one of the principal reasons for using Opinio software for the Graduate

Table 3 Internship work performance evaluation

Business Techniques	Personal Behaviors	
Meeting People	Appearance/Dress	Cooperation
Working Harmoniously with others	Initiative	Flexibility
Telephone Techniques	Tact	Dependability
Following instructions, Accepting Criticism	Accuracy	Leadership
Oral & Written Communication	Judgement	Motivation
Listening	Patience	Tolerace for Stress
Relationship to Supervisor	Creativity	Independence
Relationship to Co-workers	Self-Confidence	Willingness to work

Productivity		Comments
Volume of work	Quality of work	Allows for employer and student comments
Knowledge of work	Steadiness	
Interest in work	Attention to detail	
Organizing efficiently		

Survey is its ability to compile the data as it is collected and to import the data into a spreadsheet while facilitating the analysis of the data.

The analysis of the data generated by the Graduate Survey assists the department and its advisory committees in gauging the success and advancement of graduates in business and industry and in appraising the program's strengths and weaknesses from the graduates' viewpoint. Information is sought on graduate employment status, salary, advancement information, and graduates' satisfaction with the quality of instruction, facilities, equipment, and academic services within the department and the university as a whole.

Employer Survey

The Graduate Survey, an indirect measure, provides the option for the graduate to identify and permit the department to contact his or her current employer. If this option is selected, an Employer Survey is sent to the graduate's employer, also using Opinio. As with the Graduate Survey, the Employer Survey is conducted at the one and five year anniversaries of the student's graduation, in part to meet NAIT accreditation requirements.

Employers are requested to provide information concerning the graduates in terms of (1) their initial hire position, current position, and the degree of increased responsibility; (2) Work Performance, Productivity, Business Techniques and Personal Characteristics; and (3) an employer's overall satisfaction with the graduate. The questions are virtually identical to those in the Final Evaluation of Intern by Work Site Supervisor instrument. The rationale for this is to be able to compare and contrast a student's performance as an intern versus his or her performance as an employee over a five-year period.

Student Confidence Scale

The Student Confidence Scale, an indirect measure, is administered to all graduating seniors immediately preceding graduation. The measure helps curriculum planners within the department to develop an understanding of the students' confidence level regarding their preparation in terms of knowledge, skills, and abilities to successfully enter the workplace. The Student Confidence Scale is also correlated with the Student Outcome Matrix (Table 2) for each program.

Final Evaluation Of Intern By Work Site Supervisor – Analysis

The work-site supervisors for 50 Industrial Distribution interns during 2006-2007 were required to complete the evaluation instrument: Final Evaluation of Intern by Work Site Supervisor. A total of 49 "complete" responses were received, giving a return rate of 98%.

In the Productivity category, interns were rated highest (outstanding) in Interest in Work and Quality of Work Performed. While still rated average to good, interns were ranked lowest in Organizing Efficiently. In the Business Techniques category, interns ranked highest in their Ability to Work Harmoniously with others, Following Instructions, and in Having Good Relationships with co-workers. While most scores were good to outstanding, they were lowest (average) in Written and Oral Communications and Listening skills. In the Personal Behaviors category, the interns were ranked highest (outstanding) in Dependability, Flexibility, Cooperation, Willingness to Work, Motivation, and Appearance and Dress. Lesser rated attributes (good to average) were Leadership, followed by Judgment and Self-confidence.

These findings mirror the findings from previous years. Given the consistency of data from year to year, the faculty continues to make incremental changes to the program to address "apparent" weaknesses as reported in this measure.

Comprehensive Exam – Analysis

The Comprehensive Exam continues to be the department's most problematic assessment instrument. The exam for the Industrial Distribution program was developed by using (1) the skills identified in Essential Competencies and Traits for Industrial Distribution Careers [11] as the template, with (2) conceptual and technical questions developed from the core courses within the department's programs. The department first administered the Comprehensive Exam during the spring semester 2005 in its respective capstone classes for the different programs. For the Industrial Distribution program, this exam is administered in the Industrial Distribution Seminar capstone course.

The results of the spring 2007 Comprehensive Exam, as was the case in 2005 and 2006, continue to indicate that the exam lacks validity and/or reliability. Forty-eight percent of the students failed to correctly answer 38 of the 80 questions. More disturbing was the fact that of those 38 questions most often missed, they were missed by almost 87% of the students. Only 37 of the 80 questions were answered correctly at the 80%-or-greater level. Believing that the instruction presented in coursework is sound, the faculty has determined that significant changes to the exam are required. Feedback provided from discussions with the program's advisory committee lead the faculty to believe the exam needs to be made more conceptual in nature, thereby eliminating questions that require students to simply recall discrete facts and formulas. The Industrial Distribution program faculty will make these changes to the Comprehensive Exam before it is administered in the spring of 2008.

Graduate Survey – Analysis

The Graduate Survey represents one of the most important assessment measures, and during the 2006-2007 academic year 58 alumni were asked to complete the survey. A total of 37 responses were received for a return rate of 63%, representing a slight increase in respondents from the previous year. Eighty-one percent of the Industrial Distribution alumni responding to the survey indicated that their primary objective for attending UNK was to prepare for immediate entry into a career, and all respondents claimed that this objective was achieved. A full 97% rated overall satisfaction with the quality of their learning experience as good to excellent, the same as reported in 2006, and would recommend UNK to others. Also noteworthy is that 39% of alumni plan to seek a Masters degree at some point in their career

Within the Student Services category, students were again most satisfied with Career Planning and Job Resources, followed by Admissions, Registration, and Student Organizations. As reported in the previous three years, alumni were least satisfied with Financial Aid Services. It is believed that the dissatisfaction reported with the Financial Aid Services is directed at the Financial Aid Office and not the scholarship opportunities available within the ITEC department or the Industrial Distribution program. Scholarships specifically issued from the Industrial Distribution program now account for 58.3% of all scholarships given out by the Department of Industrial Technology, and 18.5% of all scholarships awarded by the College of Business and Technology.

From the Academic Service category, students were very satisfied with both Courses in the Major and Faculty Availability, followed by Faculty Concern for Students. This data represents the same findings reported in previous years. The General Studies program continues to be a source of dissatisfaction among alumni, and the faculty continues to address this issue with the General Studies committee. It is, however, the faculty's belief that the problem is not with the General Studies program itself as much as with students' understanding the value of the program, and how the program contributes to students' overall educational experience while in college and in later life.

From the Facilities and Equipment category, the majority of alumni were especially satisfied with the availability of computer resources (hardware and software) for general and major coursework. Yet there was some dissatisfaction with facilities and equipment. However, an effort is underway to eliminate machine tools and equipment dating back to the 1950s, replacing them with a multi-purpose Technical Products Application Laboratory more in keeping with today's Industrial Distribution program and focus

When it comes to employment, 100% of Industrial Distribution graduates started work within six months of graduation, with the majority (90%) being employed immediately following graduation. Seventy-four percent indicated that they were employed in a position directly related to their major course of study, with 26% reporting a position somewhat related to their course of study. A full 100% of respondents were employed full time

The value to companies offering an internship is also clearly apparent, with 58% of graduates having taken full time employment with the company where they completed their internship. Ninety-seven percent also indicated they have received increased responsibility since starting work, with 35% now supervising others and 58% working with minimal supervision

Industrial Distribution graduates continue to be flexible when it comes to relocation. Eighty-one percent responding have taken employment in the Midwestern states of Nebraska, Illinois, Iowa, Missouri, Minnesota, and South Dakota. (This data is for the 2007 reporting period only.) Over the years, Industrial Distribution graduates are known to have relocated to almost every state in the country

With respect to salary, the majority of alumni started their first position between $30,000 and $45,000. For the 2007 reporting period, starting salaries range from less than $30,000 (10%) to over $60,000 (6%). Current salaries for alumni (one to 5 years after graduation) range from below $25,000 (3%) to over $100,000 (3%) with the majority of alumni currently earning between $45,000 and $65,000 (42%), with weekly work-hours averaging 40-60 (87%).

Employer Survey – Analysis

When the alumni are surveyed, authorization is requested to allow the department to send the Employer Survey to their current employer. Seventeen employers were invited to respond to the Employer Survey, with 11 complete responses being returned for a return rate of 64%, an 8% increase from the previous year

In the Productivity category, employers replied that most Industrial Distribution graduates were doing an outstanding job in terms of Volume, Quality, and Consistency of Work. Attention to Detail and Organizing Efficiently, rated the lowest in 2006, increased to a rating of outstanding in 2007, while Knowledge of Work moved from outstanding to average to good. The reason for this remains unknown and will be a focus for the next assessment cycle

In the Business Techniques category, employers rated alumni high in all categories (Meeting People, Working Harmoniously with others, Telephone Techniques, Following Instructions and Accepting Criticism). If there was an area to be sensitive to, Oral Communication may be onr requiring additional emphasis in coursework.

In the Work Performance Characteristics category, Industrial Distribution alumni were ranked highest by employers in Initiative, Cooperation, and Dependability. Having Self Confidence was ranked the lowest with a rating of average. Overall, almost all categories were ranked good to outstanding except for Creativity and Leadership, which were rated good to average

Overall, employers continue to be pleased with the caliber of Industrial Distribution graduates, with 100% indicating they were pleased, by an average of 4.55 on a 5 point scale, representing a slight increase from the previous year.

Student Confidence Scale – Analysis

The 17 students enrolled in the capstone course were asked to reply to the Student Confidence Scale survey. A total of 16 complete responses were received for a return rate of 94%. The students were asked to evaluate how confident they felt in their ability to carry out the 70 tasks (Table 2), which will be expected of them once they take full time employment upon graduation. A seven-point Likert scale was used, with 1 indicating insufficient ability and 7 signifying excellent ability. Scores ranged from a low of 4.59 to a high of 6.29

The department is pleased with the outcome and is addressing the causes of the lower scores. For example, the respondents rated their ability to "describe finance and accounting as related to other organizational activities" as 4.65. After consulting advisory committee members, the Industrial Distribution Branch Operations course was supplemented with a new curricular unit in Distributor Economics.

Recommendations For Program Changes

While much can be done to further enhance the Industrial Distribution program, limited resources constrain what can be accomplished in the short term. The following steps were deemed to be the most urgent, and available resources will be directed to accomplish them during the next academic year.

- More hands-on, product knowledge. The existing machining lab will be converted to a multi-purpose Technical Products Applications Laboratory with hardware from the electrical, hydraulic, mechanical, controls, and sensors areas.
- Much more emphasis on blueprint reading – currently being implemented in the Design Engineering Graphics course.
- Further development of the "soft" skills—communication, time management, critical thinking, etc.—to be further emphasized within the existing curriculum.
- The addition of business statistics in place of trigonometry and/or calculus.
- Greater opportunities for elective courses during the program sequence, e.g., electrical rather than electronics, mechanical power rather than electrical, etc.

Conclusion – Assessment Of The Assessment Process

In keeping with W. Edward Deming's philosophy of continuous improvement [12], the assessment model undergoes annual review. Therefore, each spring semester, the departmental faculty reflects on the following points:

- Are our graduates' desired outcomes relevant and defensible?
- Do the current means of assessment actually assess the department's desired outcomes for graduates and provide information that allows for continuous improvement of departmental programs?
- Are the scope and focus of the assessment process reasonable?
- Do we need to discontinue or add any assessment activities?

The department has been collecting data for many years and the assessment instruments have been refined as the assessment process has evolved. While the process time is consuming, it is increasingly more reliable. After the spring 2007 review of the student outcomes and the measures used to assess the outcomes, the department's faculty and staff, in collaboration with the program advisory committees, concluded that the outcomes for graduates are relevant and defensible.

The assessment activities have resulted in a positive and measurable impact in improving the Industrial Distribution program, as well as the other three programs within the department not specifically addressed in this article. These actions have also been instrumental in the department obtaining initial and subsequent NAIT accreditation. The assessment model presented in this paper may be useful to other industrial and engineering technology departments with similar missions and programs.

Bibliography

[1] Boser, R., Stier, K.W., Implementation of Program Assessment in a Technical ITEC Department. Journal of Industrial Technology, Volume 21, Number 2, April 2005 through June 2005.

[2] Amos, S.J. Assessment Techniques for Industry Desired Competencies in Construction Education, ASEE Annual Conference Proceedings, 1998.

[3] Frye, R., Assessment, Accountability, and Student Learning Outcomes, June 2002, http://www.ac.wwu.edu/~dialogue/issue2.html Last Accessed January 18, 2008.

[4] Morrill Act of 1862: Donating Lands for Colleges of Agriculture and Mechanic Arts: An ACT Donating public lands to the several States and Territories which may provide colleges for the benefit of agriculture and the mechanic arts, July 2, 1862 (12 Stat. 503).

[5] ABET Technology Accreditation Commission, Criteria for Accrediting Engineering Technology Programs, 2006-2007 Accreditation Criteria. http://www.abet.org Last Accessed October 19, 2007.

[6] National Association of Industrial Technology, Accreditation Handbook 2006, http://www.nait.org/accred/2006accreditationhandbookcomp.pdf Last Accessed November 2, 2007.

[7] North Central Association Commission on Accreditation and School Improvement, Standard and Criteria For Accreditation of Schools Approved for Postsecondary Education. http://www.ncacasi.org/postsecondary/resource/doc/PS_Criteria_April2006.doc Last Accessed November 2, 2007.

[8] Hoyle, D., ISO 9000 Quality Systems Handbook, Oxford: Butterworth-Heinemann Ltd., 5th. Edition, 2006.

[9] Latham J., Vinyard, J., Baldrige User's Guide: Organizational Diagnosis, Design, and Transformation, New Jersey: Wiley, 2nd. Edition, 2006.

[10] Nichols, J.O., Nicholas, K.W., A Road Map for Improvement of Student Learning and Support Services through Assessment., New York: Agathon Press. 2005.

[11] Envick, D.D., Envick, B.R. Essential Competencies and Traits for Industrial Distribution Careers, Don Envick and Associates, Inc., 1996.

[12] Deming, W. E., What Every U.S. Business Person Should Know About Successful Management and Bringing Quality Back Home., New York: Simon Schuster. 1990.

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Molecular Beam Epitaxy Growth and Instrumentation

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Abstract

Molecular-beam epitaxy is a versatile technique for growing epitaxial thin films for semiconductors and metals by impinging molecular beams of atoms onto a heated substrate under ultrahigh vacuum conditions. Growth conditions can be monitored in real time with the help of the reflection high-energy electron diffraction (RHEED) technique. The period of one RHEED oscillation corresponds exactly to the growth of one monolayer of atoms of the semiconductor material. Therefore, it is crucial to dynamically monitor the oscillation rate in order to precisely control the epitaxial growth of thin films to the monolayer accuracy. This paper proposes a LabVIEW program that forms the basis of a real-time control system to transform MBE into a true-production technology. The PCI-1409 frame grabber card supplied by National Instruments is used with the LabVIEW software to capture the RHEED images and capture the intensity of RHEED oscillations. The intensity values are written to a text file and plotted in the form of a graph. A fast Fourier transform of these oscillations gives the growth rate of the epiwafer being grown. All the data being captured by the LabVIEW program can be saved to file, thus forming a growth pedigree for future use.

Introduction

The ever-growing demand of high-performance semiconductor devices calls for controlled and precise growth of the semiconductor compounds to achieve the targeted device properties. Epitaxy is the process of depositing, or growing, atomically thin crystal layers of typically dissimilar elemental materials onto a substrate to produce a compound semiconductor. A novel, and the most popular, means to achieve these requirements is to use the molecular-beam epitaxy (MBE) [1] growth process. MBE allows the growth of crystalline layer combinations with accurate dimensional control down to the atomic level. This precision would not be possible without adequate accurate characterization techniques. One of the most useful tools for in-situ monitoring of crystal growth is the reflection high-energy electron diffraction (RHEED) system. RHEED provides resolution on the atomic scale and at the same time is fully compatible with the crystal growth process. It has been well established that the period of these oscillations corresponds exactly to the growth of one monolayer of atoms of the semiconductor material [2].

The development and refinement of MBE over the last two decades has transformed this ultrahigh vacuum crystal growth technique into a near-production-ready technology. Commercial MBE vendors have made great progress in producing clean wafers and source cells with accurate dimensions. For advanced epitaxial-based structures such as high-electron mobility transistors [3] and heterojunction bipolar transistors (HBTs) [4], MBE is capable of preparing these extremely complex structures with atomic-layer precision. However, important concerns in mass production of these materials are reproducibility from run to run, over periods of times, and from system to system. Frequent system calibration runs and test runs still have to be prepared routinely. These nonproductive runs increase average cost and reduce growth yield. Moreover, processing specifications of many devices are tightened because stricter tolerance of certain critical parameters can significantly affect the production of high-performance, low-cost modules and circuits. The MBE growth process must be automated to improve wafer-to-wafer processing repeatability and reduce run time by eliminating the error-prone process to produce devices on a large scale without compromising the quality of the device structures grown. In this paper, we propose a LabVIEW [5] program that overcomes limitations of the existing RHEED software that prevents MBE growth from automation. The work forms the basis of in-situ monitoring of MBE growth for the development of production-ready MBE.

Methodology

Unattended automation can be achieved by designing a control system that monitors growth in real time and compares it with the data available from previous growth. The difference between real-time data and ideal data can be calculated; furthermore, feedback to the control system and the growth parameters can be adjusted in real time, thereby achieving accurate device structures. The variables that strongly affect layer growth are the substrate temperature and the flux emitted from the individual source materials. In the MBE reactor, it is not possible to change the diffusion rapidly (by controlling surface temperature) over the time period of typical growth of 5 to 10 monolayers because of the slow thermal dynamics of the substrate. Hence, substrate temperature is useful as a "run-to-run" control variable. Alternatively, flux can be rapidly changed by adjusting the effusion cell shutters, and more slowly changed by controlling the cell temperature. Hence, flux is the effective control variable. A change in flux will affect the deposition time to achieve a desired coverage—i.e., decreasing flux increases the deposition time to reach a coverage goal, and vice versa.

Because the period of one RHEED oscillation corresponds exactly to the growth of one monolayer of atoms of the semiconductor material, growth conditions can be monitored in real time with the help of RHEED data. These RHEED oscillation patterns can be observed from time to time and compared to historical data of the material being grown. A schematic depiction of such a system is shown in Figure 1. The wafers are grown in the MBE chamber, and the RHEED images are observed on the computer; the real-time data is compared against the already available data. If any changes are to be made in the growth conditions, the computer calculates the values and sends the signals to change the temperature of the source cells or to control the movement of the shutters in front of the source cells. In addition, the current data being captured can also be saved for future reference. Figure 1.

With the existing Video RHEED Intensity Measurement Program for the MBE system in the laboratory of the University of North Texas, the data was recorded only in the form of a graph; it could not be written to a spreadsheet so that it could be analyzed further for more accurate results. If the recording of oscillations was stopped at a particular point (e.g., to alter the temperature of the sample being grown or the temperature of the source cell), new oscillations could not be appended to the existing file. Thus, it was difficult to observe the change in oscillations accurately when the temperature was varied. The user did not have a choice to change or specify the rate at which the oscillations were recorded. In addition, the RHEED program and the video card did not have the necessary software and hardware interface associated with it so that it could form the basis of a real-time shutter control unit as shown in Figure 1. Moreover, the program did not offer the option to record the images before, during, and after the growth of the semiconductor material.

It is important to save the RHEED images so that they can be used when similar materials are grown. For example, if a sample material is grown in ideal conditions and gives accurate results, the RHEED images obtained during this growth cycle can be compared with the RHEED images obtained during mass production. If it is seen during mass production that the RHEED images differ from the ideal images already available, then the necessary corrections can be made to the growth conditions. To overcome the limitations in the Video RHEED Intensity Measurement Program, a LabVIEW program was developed. The PCI-1409 frame grabber card supplied by National Instruments was used with the LabVIEW software to capture the RHEED images and calculate the intensity of the oscillations. The LabVIEW program developed performs the following functions:

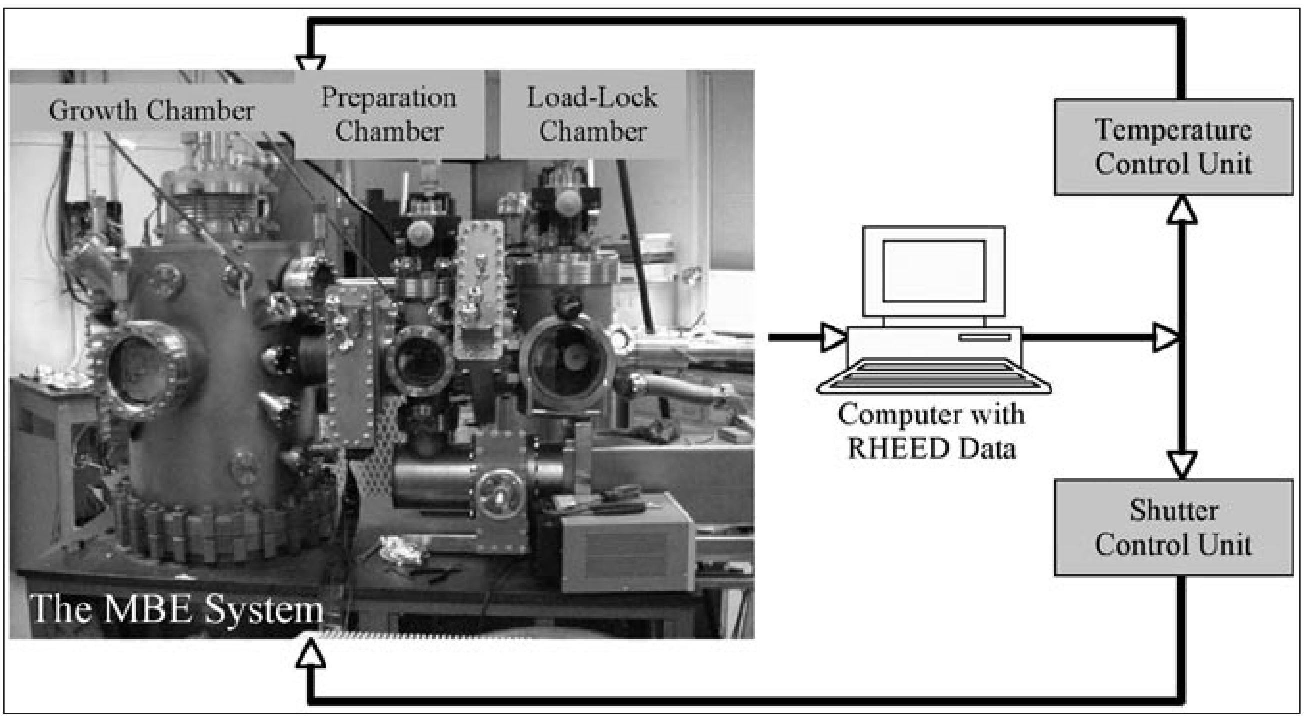


Figure 1 Block diagram of the shutter control unit that can be designed depending on the RHEED oscillations

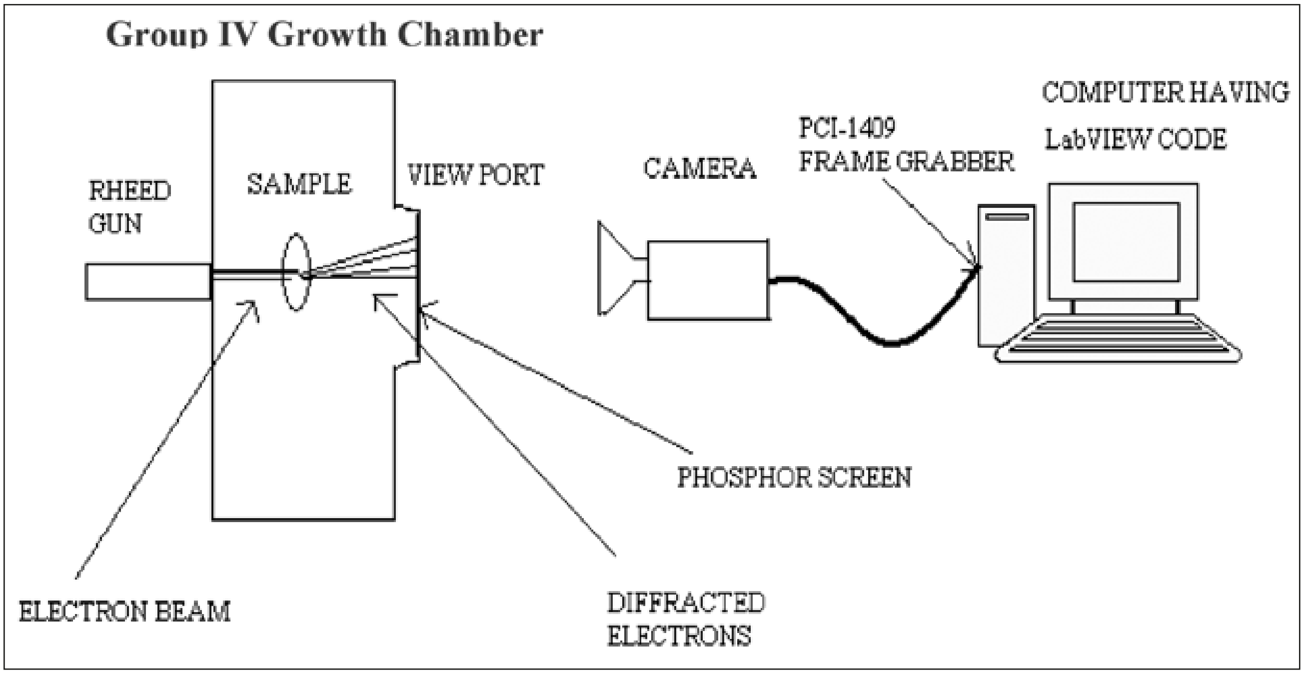


Figure 2 Experimental setup to capture RHEED images and intensities of the Group IV MBE chamber

Measures the intensity at a particular point on the image through a Panasonic charge-coupled device (CCD) camera and uses the frame grabber card to read the intensity values. Plots the intensity values as time versus amplitude.

Observes the RHEED images continuously on the same computer monitor that has the LabVIEW code in it. Records the RHEED images before, during, and at the end of the sample growth. The program has the flexibility to change the point of measurement on the image during the growth.

Writes the recorded intensity and the time values to a spreadsheet. While growing different samples, the user is given the choice to append the data to an existing file or write it to a new file. The program has flexibility to record the intensity values at different time intervals as specified by the user.

This program is portable. It does not depend on the MBE system being used to take the measurements but rather on any MBE system that uses RHEED.

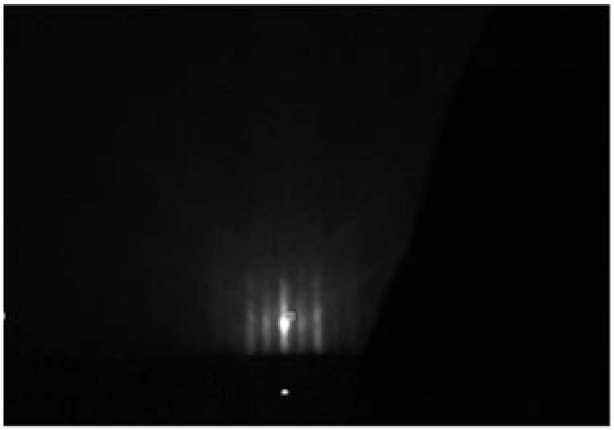
Experiments

The Group IV MBE system is used to grow samples to demonstrate the functioning of the LabVIEW program. The RHEED system present on the MBE chamber is used to monitor the growth of the samples. The experimental setup used to capture the RHEED images is shown in Figure 2. The camera, connected to the PCI-1409 frame grabber card installed in a peripheral component interconnect (PCI) slot of a computer, is placed in front of the phosphor screen of the Group IV MBE system. During the growth process, the camera controlled by LabVIEW program continuously records the RHEED images and intensities through the PCI-1409 frame grabber card. A detailed description of the LabVIEW code has been reported elsewhere [6]. Figure 2.

A layer of silicon (Si) is grown on an Si wafer for 10 minutes at 500°C. Then a layer of iron (Fe) is grown for 19 minutes at 550°C. Next, a layer of germanium (Ge) is grown for 4.5 minutes at 475°C. Two RHEED images recorded during the growth are shown in Figure 3. Figure 3(a) is the image taken right after the Fe source is opened, whereas Figure 3(b) is captured when the Ge source is opened.

Figure 3. Captured images when the Fe source is deposited at 550°C (a) and after Ge is deposited at 475°C (b)

Figure 4(a) represents a typical oscillation pattern captured during the Fe growth. The fast Fourier transform (FFT) calculations, using ORIGIN software [7], at various stages of growth are shown in Figure 4 (b) through Figure 4(d). Figure 4(b) shows the growth pattern when Fe is being deposited. The FFT has a predominant peak at approximately 1.6Hz. Figure 4(c) shows the growth pattern when Si is being deposited. The FFT has a predominant peak at approximately 1.8Hz. Figure 4(d) shows the growth pattern



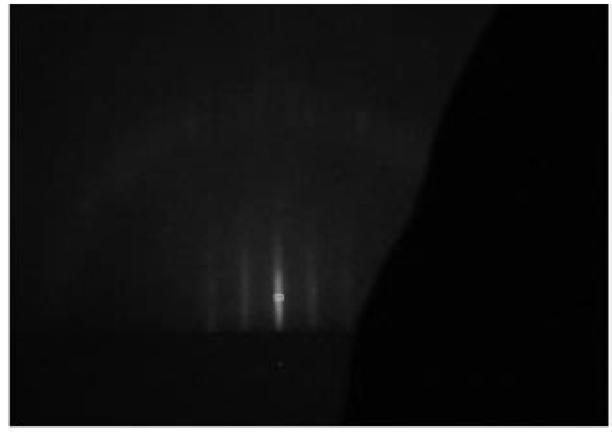


Figure 3 Captured images when the Fe source is deposited at 550°C (a) and after Ge is deposited at 475°C (b)

when Ge is being deposited. The FFT has a peak at approximately 1.9 Hz. From the FFT calculations, it can be observed that different materials exhibit different RHEED patterns. The time to grow one monolayer is the reciprocal of the oscillation frequency. Therefore, the accurate device structure can be precisely controlled by the growth time. These RHEED oscillations and images can be saved and can be compared with the data obtained from the similar samples that are being grown. These samples are then sent out for further analysis to test whether they exhibit required characteristics. Once the good samples are identified, the related RHEED data can be pulled out and be used to grow similar wafers on a large-scale production basis. Figure 4.

Limitations

The LabVIEW program can be used only with the PCI-1409 frame grabber card. The data acquisition rate of the frame grabber card is limited to 30 frames per second with the National Television System(s) Committee (NTSC) camera that is used for this study. The accuracy of the intensity of oscillations being captured depends highly on the resolution of the camera. In this program, the intensity is recorded every 50 milliseconds.

Conclusions and Future Work

An MBE system coupled with a feedback control system can refine the MBE system into a turnkey manufacturing process. A real-time MBE control system has to be designed in such a way that it works with the already existing MBE growth systems. It must be able to provide real-time information of the wafer growth states, must be simple to install and maintain, and must allow fast processing of data at a low cost. We have demonstrated the first step toward converting MBE to a true mass-production technology. The LabVIEW program developed during this study can record the RHEED intensity oscillations and RHEED images and save the data to a Microsoft Excel sheet for future analysis. Combined with the ORIGIN software, FFT calculations can be made successfully on the data obtained from the LabVIEW program. The RHEED images can be recorded at any particular point of time during the growth and the FFT calculations can be stored effectively. In addition, if more than one sample of same kind is being grown, the oscillations can be appended to the same file if needed. This capability is particularly useful for comparison purposes to observe the growth pattern of a single sample under different growth conditions such as temperature and pressure.

To establish a truly production MBE system, a control system has to be designed that accepts the signals from the computer having the RHEED program and accordingly sends signals to the temperature-control unit and the shutter control units on the MBE system, thereby increasing yield and decreasing the cost of production.

References

[1] J. A.Y. Cho and J.R. Arthur, "Molecular beam epitaxy," Progress in Solid State Chemistry, v 10, pt.3, pp. 157-91, 1975.

[2] J. S. Resh, K. D.Jamison, J. Stozier, and A. Ignatiev, Multiple reflection high-energy electron diffraction beam intensity measurement system. Space Vacuum Epitaxy Center, University of Houston, Houston, Texas.

[3] A. Y.Cho and K. Y.Cheng, Growth of extremely uniform layers by rotating substrate holder with MBE for applications to electro-optic and microwave devices, Appl. Phys. Lett. 38, pp. 360–362, 1981.

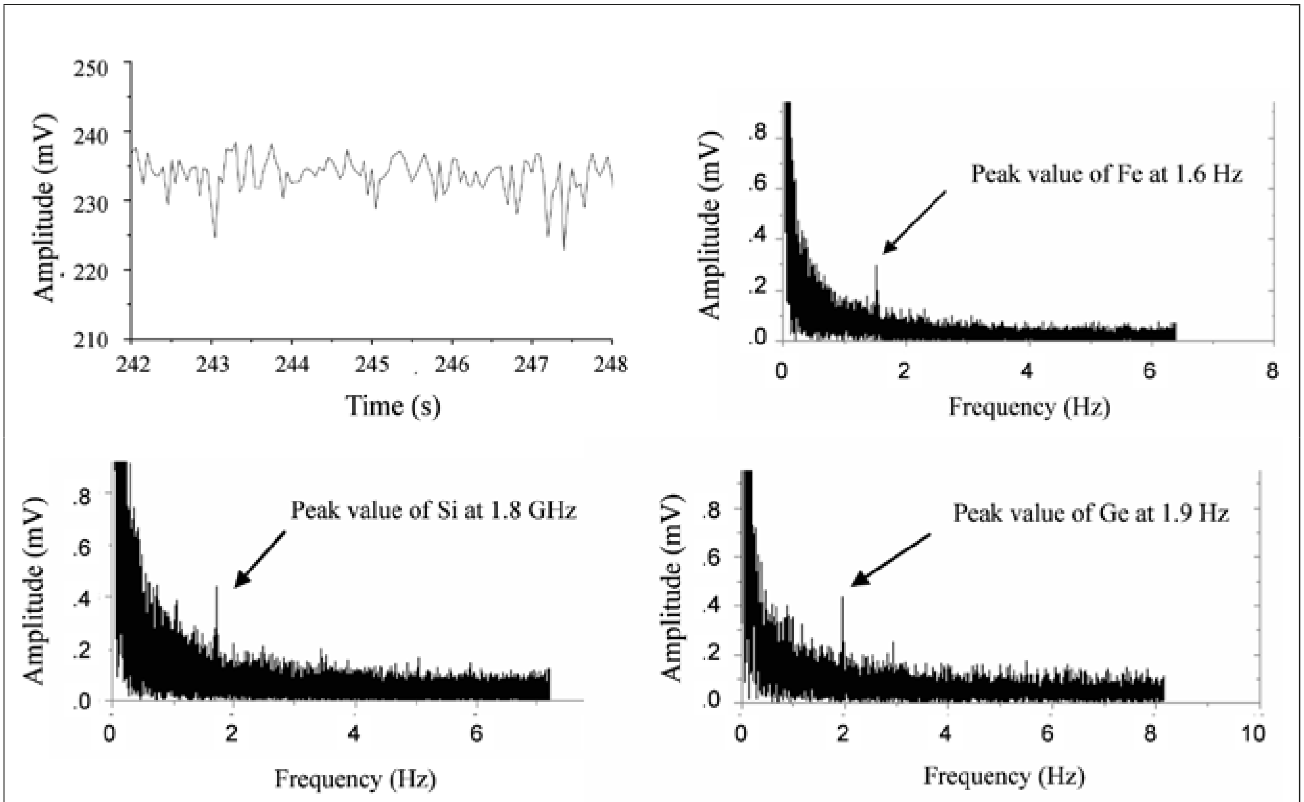


Figure 4 RHEED intensity recording for Fe (a) and FFT oscillations for Fe (b), Si (c), and Ge (d) Growth

[4] A. Gruble, H. Kibbel, U. Erben and E. Kasper, "MBE grown HBT's with High β fTo and fmax," IEEE Electron Device Lett., 13, pp. 206–208, 1992.

[5] National Instruments Co., http://www.ni.com.

[6] Sriteja Tarigopula, "MBE Growth and Instrumentation," M.S. thesis, University of North Texas, 2006.

[7] RockWare Inc., http://www.rockware.com/.

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Using Rapid Prototyping Tools for Automatic Control System Laboratory

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Abstract

In this paper, the development and implementation of laboratory tools for a control system laboratory is presented. Typical control system laboratory experiments are excessively time-consuming, require complex student instructions, and are inflexible and expensive. These drawbacks are addressed with the proposed system, which incorporates rapid prototyping software development tools, a user-friendly graphical user interface (GUI), a DC motor with feedback, a motor drive, and a low-cost digital signal processor (DSP) to carry out the control algorithm. This workstation provides a flexible, low-cost control system trainer that is capable of supporting a variety of demonstrations and experimental activities while encouraging student experimentation and emphasizing practical aspects of control systems design, simulation, and real-time implementation. An example of a laboratory exercise is included to illustrate the suitability of the system for student use and the effectiveness of the overall implementation. The prototype control system trainer is presently being integrated into the Engineering Technology curriculum at Penn State Altoona.

Introduction

Recent developments in the area of rapid prototyping tools for software have brought about a new paradigm in the development of control systems. In the industrial sector, these tools have enabled developers to quickly and easily design, simulate, and deploy complex real-time control systems [1], [2], [3]. This technology can be exploited to realize improvements in control system education as well. Typical control system courses focus on theory with little emphasis on implementation and practice [4]. By contrast, rapid prototyping tools provide a seamless transition from system design to implementation, and therefore can be employed to bridge the gap between theory and practice in our control system courses [5], [6].

In this paper, the apparatus and software for an automatic control system trainer that employs rapid prototyping tools is presented. This workís main goal is to replace existing control system trainers, which have excessive response times, are difficult for students to operate, are inflexible and costly, and do not encourage student experimentation.

The proposed control system trainer consists of a permanent magnet DC motor and quadrature encoder, a mechanical load, a low-cost Digital Signal Processing (DSP) board with power electronics, and the MATLAB® Simulink rapid prototyping tools for software development. With this equipment, the current, velocity, and position of the electric motor are controlled by the DSP board, and the complete control system is programmed graphically. A GUI is used to provide real-time student interaction with the system, including gain selection, command input control, and data logging and display. The trainer is thoroughly tested to verify its suitability for laboratory use. With further development, the proposed control system trainer is expected to provide an excellent educational experience for students of automatic control systems.

Control Systems Laboratory Equipment Development

In this section, the use of rapid prototyping tools in the development of an educational workstation for automatic control systems is described. Software, hardware and the integration of those components to establish the control system workstation are discussed.

Software

Software tools such as Matlab® have long been used in the design, analysis, and simulation of control systems. Recently, Matlab has introduced real-time code generation tools that target common microcontrollers and DSPs. These tools translate a graphical control system description into executable code, therefore enabling real-time control systems to be quickly developed and tested. When integrated with appropriate hardware, these tools form a visual modeling and simulation environment that is effective and easy-to-use for the entire control system development cycle.

To perform control system design and simulation, a graphical description of the system is entered into Matlab Simulink®. A high-level graphical control system description for DC Motor position control, for instance, is shown in Figure 1. Each block in Figure 1 can be examined by double-clicking on that block. In Figure 2, the contents of the A-to-D Block of Figure 1 are shown. This hierarchical design isolates students from implementation details embedded within low-level blocks, yet promotes student experimentation since modifications to the control system are performed in the graphical environment. Furthermore,

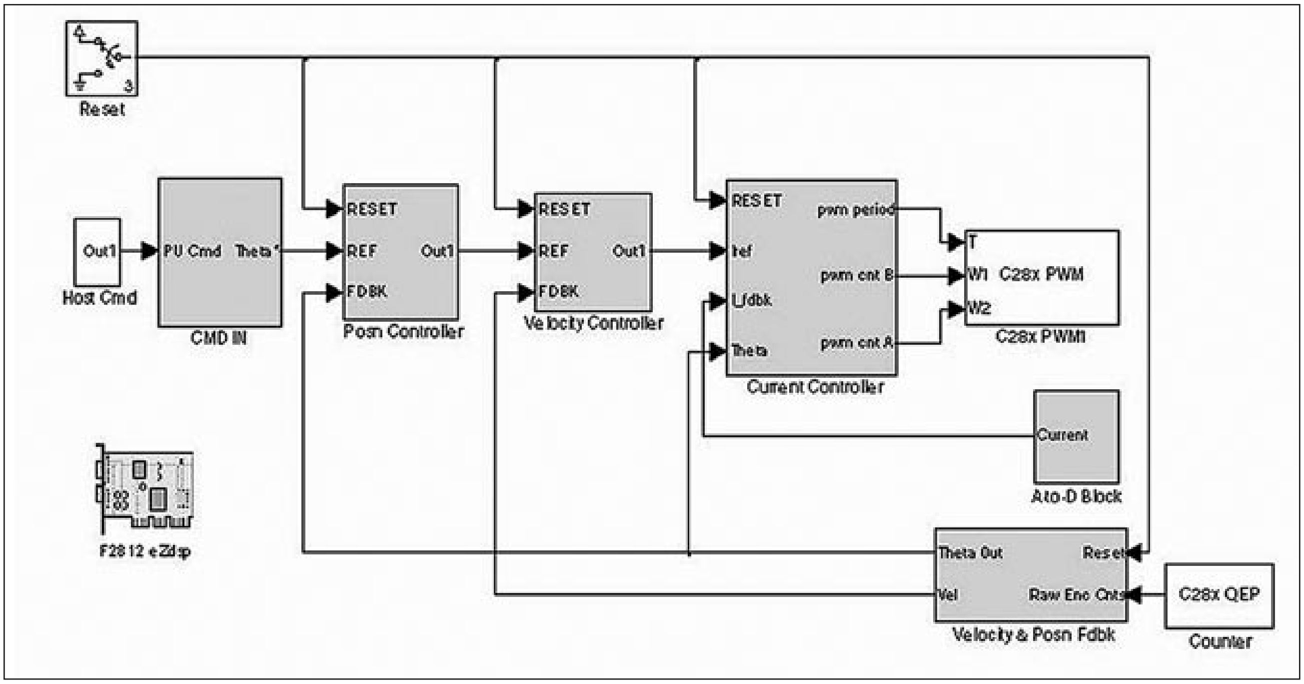

Figure 1 Graphical depiction of permanent magnet DC motor position controller

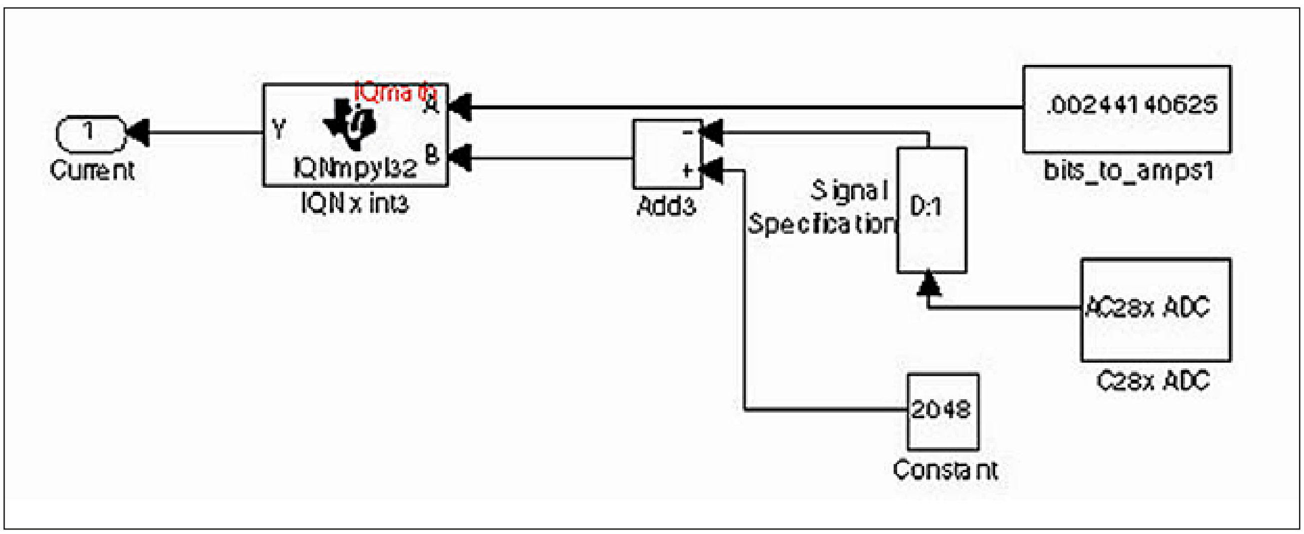

Figure 2 Contents of the A-to-D Block of Figure 1

since the graphical description shown in Figure 1 looks much like the block diagram format commonly used in the study of control systems, students are comfortable working with the graphical control system description and can quickly configure and simulate a system.

When simulations yield satisfactory performance, the graphical description of the controller is converted by the Matlab® Real-Time Workshop into C code, cross-compiled, and downloaded to the DSP board. No programming is required. The DSP executes the auto-generated code and communicates information with the host computer via Real Time Data Exchange (RTDX). The GUI, which is shown in Figure 3, provides the opportunity to optimize control system gain settings in real-time, and provides access to operating conditions associated with the system.

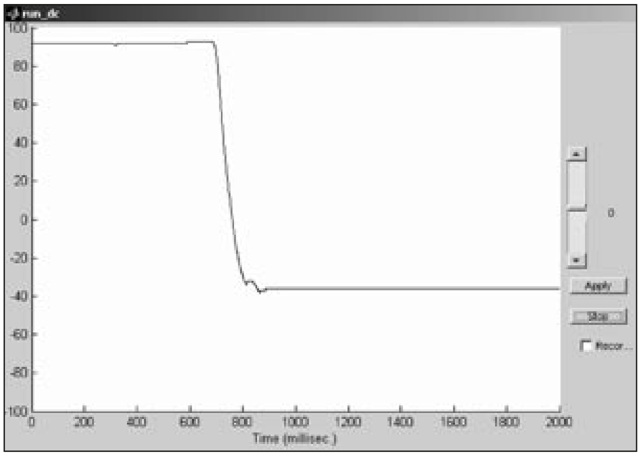

Figure 3 Graphical User Interface for the DC motor control workstation

Hardware

Following satisfactory simulation of the graphical description of the DC motor control system, the design is ready to be deployed using actual hardware. For the workstation described in this paper, the hardware consists of a permanent magnet DC motor with encoder, a DSP development board, and a power electronics interface to drive the motor. The rapid prototyping tool is a key element in implementing the control system, since it quickly translates the graphical description of the system into executable code capable of operating the hardware in a real-time experiment.

The automatically generated code is downloaded and executed by a TI 2812 development board (Spectrum Digital Inc. ezDSP2812). This board contains a 32-bit fixed-point DSP operating at 150 MHz and with 128 kwords of on-chip memory. This DSP is optimized for motor and motion control applications, and carries 16 channels of 12-bit analog-to-digital converters, integrated encoder interface, and 6 programmable pulse width modulation (PWM) output channels. The 32-bit fixed point mathematics are easily managed with the fixed-point blockset that is integrated with Matlab Simulink.

The permanent magnet DC motor is equipped with an encoder and analog tachometer for rotary position and angular velocity feedback. As shown in Figure 4, the motor hardware arrangement provides a small and light test stand that is easily stored. A prony brake was included to provide a variable in the control system, with prony brake tension easily adjusted by using the screw on the top of the test stand. This arrangement is such that a variable inertia disk could also be included in the system to provide another variable in the control system.

The power electronics provide the required interface between the DSP and the DC motor test stand. The selected power electronics interface is a commercially available solution (Spectrum Digital DMC 1500) that provides a 10 amp three-phase inverter with PWM signal conditioning, onboard power supplies, encoder interface circuitry, and signal conditioning for the analog-to-digital interface. The DSP board, shown mounted on the power electronics in Figure 5, connects directly to the compatible power electronics board.

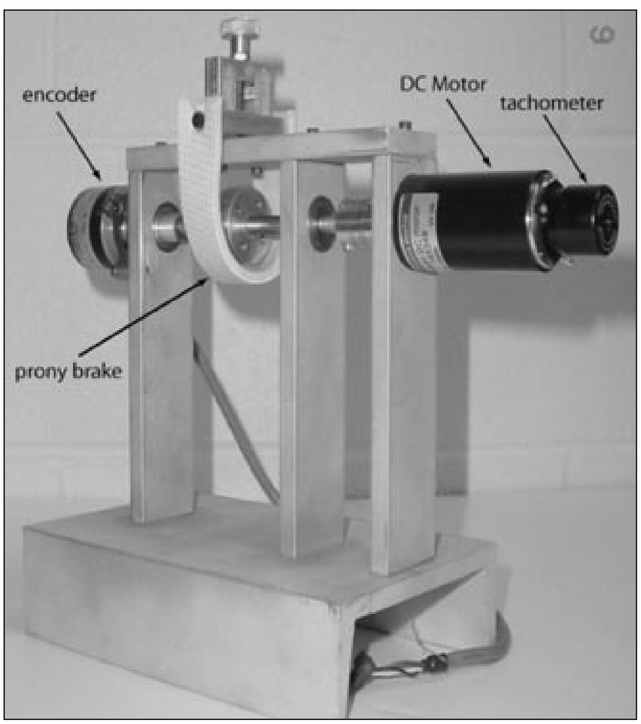

Figure 4 Test stand with DC motor, encoder and prony brake

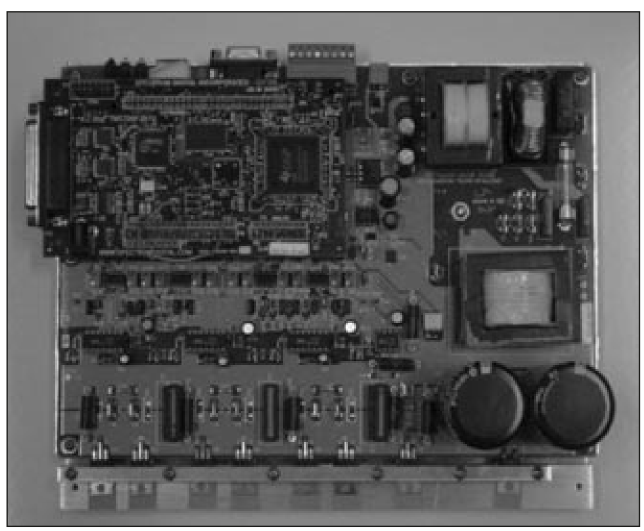

Figure 5 Power electronics and DSP board

System Integration

The control system design process is generally considered to consist of three iterative procedures: design, simulation, and implementation. Although many automatic control system courses do not emphasize the implementation aspect of the design cycle, the ideal workstation would support each step of the design cycle. That is, the system must support learning of control system theory, design, and implementation through hands-on laboratory experiences that do not present a steep learning curve to students. The proposed workstationís integrated components are shown in block diagram form in Figure 6.

The typical design cycle using the proposed workstation includes determination of the plant model, controller design and simulation, implementation, and final gain selection. The components of this design cycle are normally iterated until design goals are met.

The workstation can be used to perform hands-on experiments to determine the modeling parameters of the plant (DC motor), such as tachometer gain, armature resistance and inductance (R_a, L_a), the motor back-emf and torque constants (K_w, K_t), and the mechanical time constant (τ_m). For example, to determine armature resistance and inductance, the DSP may be programmed (graphically) to excite the armature with a step voltage waveform, while the resulting current waveform is displayed and analyzed via the graphical user interface.

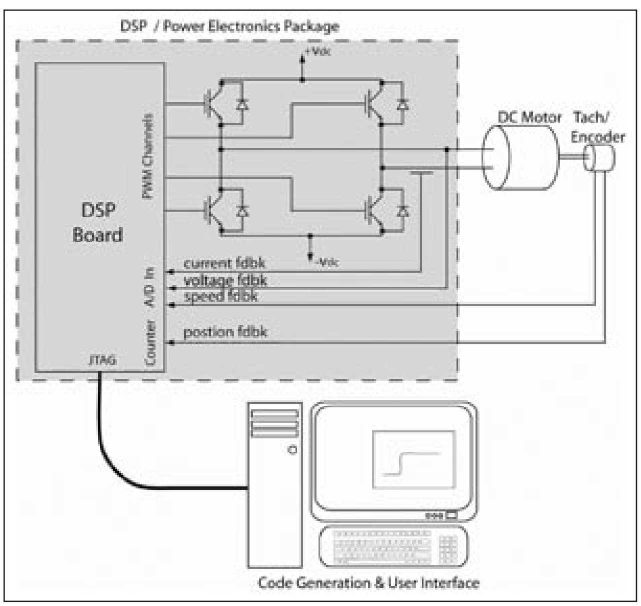

Figure 6 Block diagram of control system workstation

After the plant model is determined, the appropriate controller may be designed and simulated on the host computer. When the designer is satisfied, the resulting control system is downloaded to the DSP for real-time analysis. In the real-time experiments, the DSP performs the controller algorithm and sends selected data to the host computer for display and analysis. Parameters associated with the control system may be adjusted in real-time through the host computer interface. This interactive experimentation provides an excellent experiential learning opportunity for control system parameter tuning.

The host PC shown in Figure 6 is dual-purpose. In the design cycle, it is used to analyze and simulate the system. During the implementation phase, the PC host provides the user interface that communicates data through the JTAG interface of the DSP to the PC parallel (or USB) port. This communicated data is displayed on the host, and can also be recorded to a file on the host computer for further analysis with Matlab or Excel.

Control System Experiments Using Rapid Prototyping Tools

In this section, samples of the control system experiments that were developed using the rapid prototyping tools are presented. Results are included to demonstrate the developed learning moduleís effectiveness.

Experiment Descriptions

Although the workstation is capable of supporting a variety of plants, the focus will be on the DC motor plant described in Section 2. A typical series of experiments using this plant include the model determination, torque control, velocity control, and position control.

Model Determination: In an initial laboratory session, experiments may be conducted to determine the modeling parameters of the DC motor plant. The model determination experiments can be dual-purpose; they act to acquaint students with the DSP and host computer GUI operation, as well as with the obvious objective of plant modeling.

Torque, Speed, and Position Control: After the motor model is determined, a current, velocity, and position control may be developed sequentially by students to meet given specifications. Single loop current, speed, and position control design laboratories may be employed to demonstrate control systems design for first order and higher order plants. In later laboratory experiments, the advantage of the cascaded control loop structure can be demonstrated.

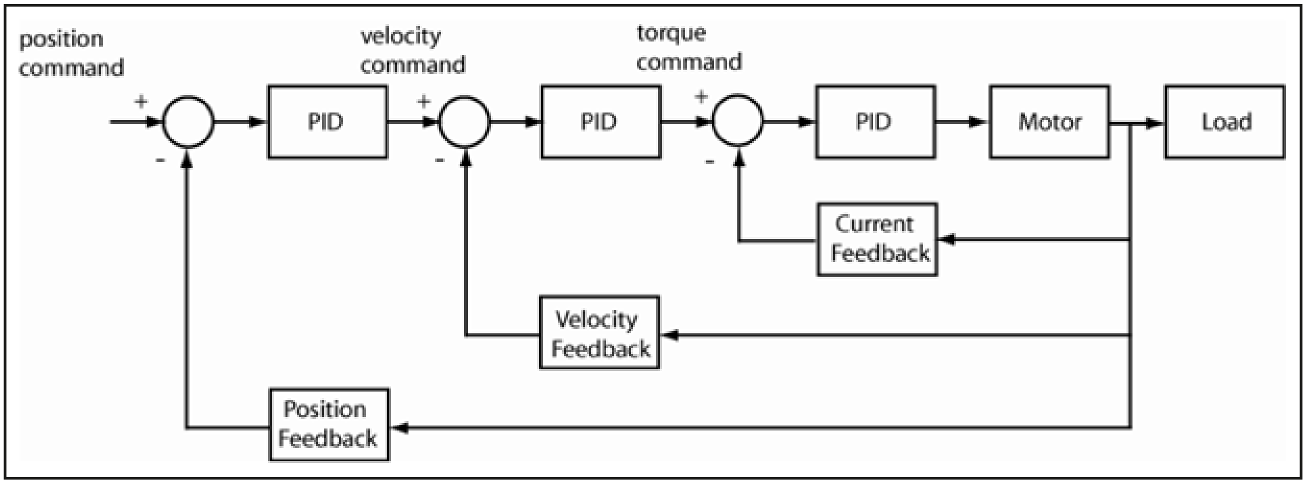

Figure 7 Block diagram of the cascaded DC motor feedback system

Many motion control systems employ cascaded position, velocity, and current control loops [7], as shown in Figure 7. The advantage of the cascaded structure is that the design and tuning of the loops are conducted step-by-step, beginning with the innermost current loop. The tuning of the loops is performed independently, with the assumption that the bandwidth increases toward the inner loop.

As a first laboratory experience with control system design for a first-order system, students may design a current (torque) controller for the DC motor. The primary goal for the current control design is for high bandwidth. This is necessary so that in later experiments, the current controller may be regarded as a current source to the slower outer loops. In the cascaded system, the current controller also plays a major role in stabilizing the position control [8]. This can be demonstrated in subsequent laboratory experiments.

Rotor velocity and position control loop designs follow logically, since the innermost current controller has already been designed. The velocity controller is first designed and implemented, followed by position control. Both of these controllers may be designed using a single loop and the cascaded structure. Comparison of these implementations will allow students to determine which strategy is both more stable and easier to tune.

Experimental Results

In this section, the experimental results of a DC motor position control system using the cascaded loop structure shown are shown. The goal of the experiment is to obtain fast and accurate response to changes in the commanded rotor position with low steady-state error. The input from the user in this experiment is the tension of the brake, the rotor position command, and the PID variables for each cascaded loop of the feedback control system. The motor response can be viewed in real time through the GUI, which will display the current, velocity, and position of the motor. This data also can be saved and then later analyzed in Matlab.

The results of this experiment are shown in Figures 8 and 9. Figure 8 shows the motor position and controller output with well-tuned PID variables for each controller (current, velocity, and position loops). As seen in Figure 8, the motor responds immediately, has no overshoot, and has an excellent settling time. This is an example of what the students will want to achieve at the end of their lab experiments.

By contrast, Figure 9 shows a DC motor response that exhibits overshoot and slow settling time. Comparison with Figure 8 shows the increased control effort required of the poorly-tuned system. The workstation allows students to manipulate PID gains until a response similar to Figure 8 is achieved ñ thus demonstrating the effect of each PID variable. This exercise provides students an excellent educational experience related to the tuning of automatic control systems.

Conclusion

A control system workstation that employs rapid prototyping tools has been developed and evaluated for use in an automatic control system laboratory. The system has been found to be flexible and low-cost, and encourages student experimentation. The workstationís rapid-prototyping aspect allows students to implement the control system quickly, permitting a hands-on learning experience that bridges the gap between control systems design and implementation.

Although a DC motor is used as the plant in this experiment, it should be mentioned that the DSP is capable of supporting a

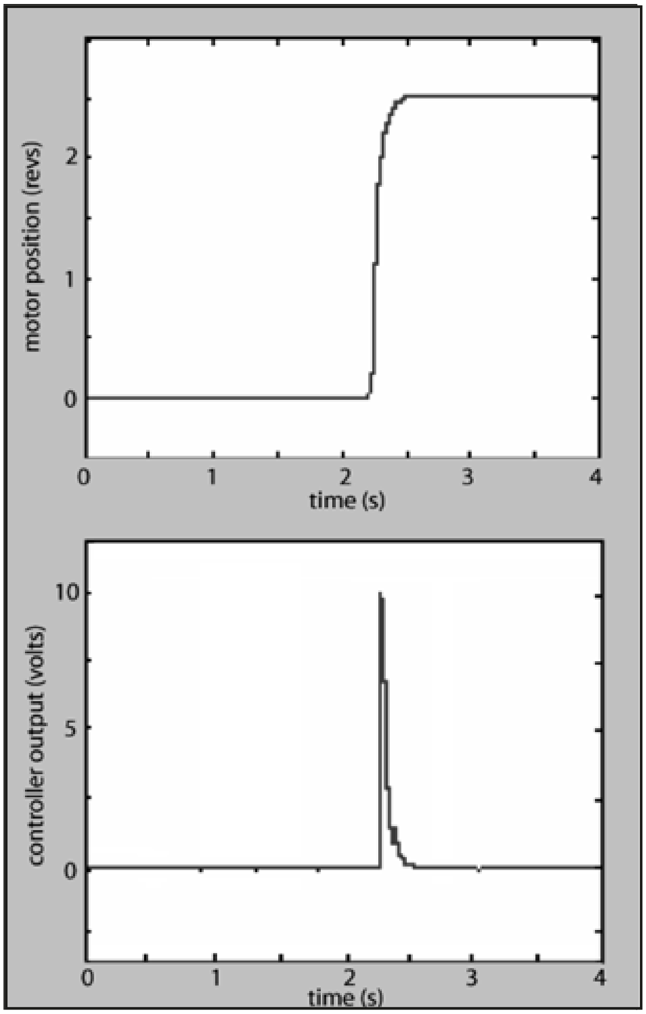

Figure 8 Motor position (top) and controller output (bottom) for a tuned system

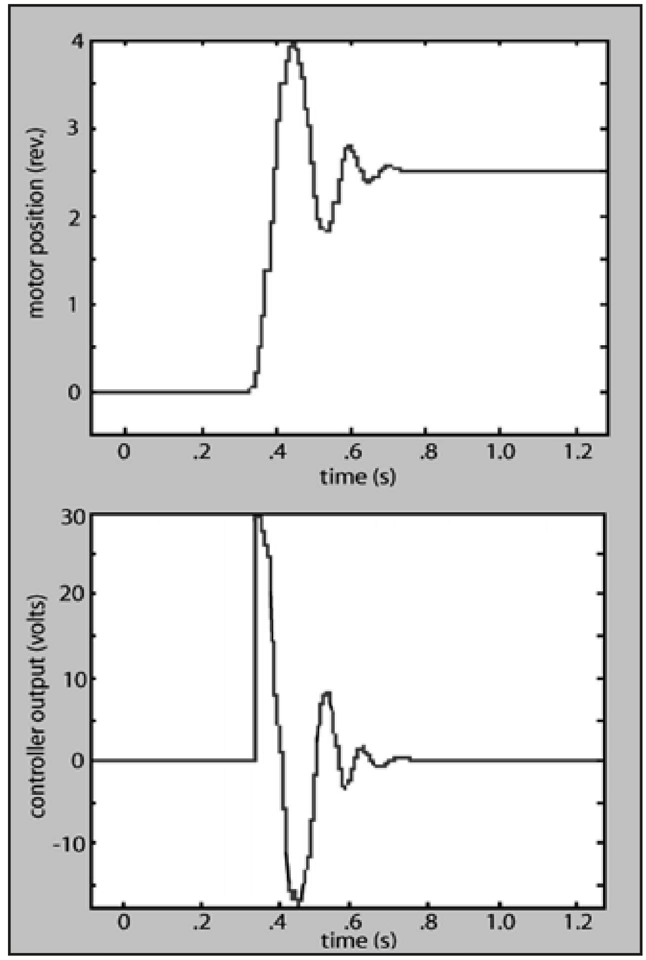

Figure 9 Motor position (top) and controller output (bottom) for an untuned system

variety of control plants, such as a simple RC circuit, buck converter, or other student-developed plants. In the future, more plants will be developed for laboratory experimentation

Bibliography

[1] Anakwa, W.K.N., E. Cohen, A. Naik, D. Carlton, D. Glen, and J. Lopez (2001). Tools for rapid prototyping of embedded control systems. The 27th Annual Conference of the IEEE Industrial Electronics Society, vol. 1, pp. 90-94.

[2] Yan, Y. and R. Zane (2004). Digital controller design for electronic ballasts with phase control. IEEE 35th Annual Power Electronics Specialists Conference, vol. 3, pp. 1855-1860.

[3] Hawkins, C.E., and I.J. Berry (1997). Rapid prototyping in the Automotive Industry. IEEE Colloquium on System Control Integration and Rapid Prototyping in the Automotive Industry. Vol. 1, pp. 1-3.

[4] Shiakolas, P.S., and D. Pitabongkarn (2003). Development of real-time digital control system with HIL magnetic levitation device. IEEE Transactions on Education, vol. 46, no. 1, pp. 79-87.

[5] Uran, S., D. Hercog, and K. Jezernik (2004). Experimental control learning based on DSP2 learning module. 2004 IEEE International Conference on Industrial Technology, vol. 1, pp. 310-315.

6] Van deMolengraft, R., M. Steinbuch, and B. DeKraker (2005). Integrating experimentation into control courses. IEEE Control Systems Magazine, vol. 25, no. 1, pp. 40-44.

[7] Leonhard, W. (1985). Control of Electrical Drives. Chapter 7. Springer-Verlag, Berlin.

[8] Ohm, D.Y., and R.J. Oleksuk (1998). On practical digital current regulator design for PM synchronous motor drives. Thirteenth Annual Conference Proceedings of the Applied Power Electronics Conference and Exposition. vol. 1, pp. 56-63.

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A Reliable User Tracking Framework for Locating Mobile Objects

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Abstract

The continued advances in positioning technologies and wireless communication technologies provide the ability to track and record the position of objects capable of continuous movement. One of the important positioning technologies is Global Positioning System (GPS). GPS provides continuous, real-time, three-dimensional positioning and navigation worldwide. It can also be used for any application that requires location coordination, since a user with a GPS receiver is able to access the system satellites. In this paper, we propose to design and develop a system that employs positioning technologies to allow the prevention of many deadly and violent accidents and crimes using any type of vehicles. Our proposed system provides the required safety for security personnel including police force and the ordinary, innocent people through eliminating unpredictable behaviors of drivers.

Introduction

Positioning technologies provide location or position information and services about resources for the general public by using new location finding systems and techniques. The main positioning technology is the Global Positioning System (GPS), which is a satellite-based radio navigation system. It is equipped with atomic clocks and provides highly accurate position/time information at low cost by transmitting two specially coded carrier signals, one for civilian use and another for government and military use [1]. Most civilian uses of GPS fall into one of the following four categories: navigation, surveying, mapping and timing.

The first GPS satellite was launched by the U.S. Air Force in late 1970. There are now at least 24 satellites orbiting the earth at an altitude of about 11,000 nautical miles. The high altitude ensures that the satellite orbits are stable, precise and predictable, and the motion of the satellites through space is not affected by atmospheric drag. These 24 satellites make up the full GPS constellation. Also, there are other positioning systems such as GLONASS and GALILEO. The first one was developed by Russia, and the latter is a European contribution to the next generation of Global Navigation Satellite System (GNSS).

The remainder of this paper is organized as follows: In section 1, we provide a brief overview of GPS technology. In section 2, the application of GPS technology for vehicle tracking is explained. Section 3 presents our proposed system for creating safety through controlling the driver's behavior. And finally, section 4 presents the conclusion and offers suggestions for future research to provide the required safety for all drivers.

Global Positioning System Technology

GPS consists of three segments: the space segment (the GPS satellites themselves), the control system segment and the user segment. The space segment (GPS satellites) continuously broadcasts its information using radio signals. The radio signals travel at the speed of light. It has been shown that GPS signals down to -155 dBW can be acquired without any assistance data or the need for a complex FFT (Fast Fourier Transform) post-processing [10]. Any device with a GPS receiver is able to access the GPS satellites, and it can be used for any application that requires location coordination [2]. However, the performance of a receiver is very much dependent on the ability to receive signals from the satellites. GPS satellites transmit navigational messages for the receivers. The receivers can determine the target positions by using the three dimensional coordinates (i.e., latitude, longitude and altitude) of the target [3].

The positioning methods can be implemented in two ways: self-positioning and remote positioning [4]. In the self-positioning method, the mobile user (i.e., terminal, phone) calculates his or her position by using signals that are transmitted by gateways/antennas (which can be either terrestrial or satellite). More specifically, the positioning receiver makes the appropriate signal measurements from geographically distributed transmitters and uses these measurements to determine its position. Therefore, a self-positioning receiver knows where it is. Also, the applications that are co-located with the receiver can use this information to make positioned-based decisions, such as those required for vehicle navigation. The second method is called remote positioning. In this method, the mobile user can be located by measuring the signals that are traveling to and from a set of receivers. More specifically, the receivers, which can be installed at one or more locations, measure a signal originating from or reflecting off the object to be positioned. These signal measurements are used to determine the length and/or direction of the individual radio paths, and then the mobile terminal position is computed from the geometric relationships.

GPS receivers process the signals to compute positions in three dimensions (i.e., latitude, longitude and altitude) with high accuracy (i.e., ten meters or less) [5]. However, these receivers require a clear view of the sky to operate properly, and they need to receive signals from at least three or four (depending on the type of information needed) satellites [6, 5]. These requirements prevent these receivers from operating in indoor environments. Also, research shows that attenuation of the GPS signal through buildings is not typically more than 1 dB per meter of structure [10]. Therefore, in these environments, the Assisted-GPS method needs to be used to track the GPS signals inside high buildings and elevators because the receiver needs to acquire signals with the power level raging from -155dBW to -200dBW. In the Assisted-GPS method, the mobile network or a third-party service provider can assist the navigator or self-locator, either by directing it to look for specific satellites or by collecting data from the navigator to perform location identification calculations. This is because the navigator may be unable to perform the calculation of the location identification due to the limited processing power. The Assisted-GPS method can be extremely accurate, ranging from one to ten meters [5].

GPS Receivers and Position Calculation

GPS receivers are sophisticated receivers with digital demodulation systems, which are controlled by powerful microprocessors. The principle components of a GPS receiver are receiver, antenna, processor and I/O devices. The basic operations of a GPS receiver consist of satellite selection, signal acquisition, tracking, measurement, data recovery and corrections. GPS receivers come in many shapes and forms. The most common receivers in the consumer market are handheld devices. These receivers provide the information about the location of any objects to around 100m, depending on the receiver's design. These receivers can be used for marine, aviation or terrestrial navigation use. Currently, they are readily available from a number of manufacturers, and they are not as costly as their sophisticated counterparts. Furthermore, the demand for these devices is set to rise with the U.S. Federal Communications Commission (FCC) mandate for inclusion of these devices in mobile phones [11]. Also, more advanced receivers are available for use in more demanding applications such as accurate navigation, surveying, tracking and the like [7].

A GPS receiver calculates its position by a technique called satellite ranging. It involves measuring the distance between the GPS receiver and the GPS satellites, which it tracks. The range or distance is measured as an elapsed transit time (the range that a receiver calculates is actually an estimate of range rather than a true range). Also, the position of each satellite is known since satellites transmit their positions as part of the "messages" that they send via radio waves. However, the GPS receiver on the ground is the unknown point, and it must compute its position based on the information it receives from the satellites.

Measuring Distance to Satellites and Using the Distance Measurements to Calculate a Position

The first step in measuring the distance between a GPS receiver and a satellite is to measure the time it takes for the signal to travel from the satellite to the receiver. To compute a three-dimensional (i.e., latitude, longitude and altitude) position, it is required to measure the distances from four satellites. Once the receiver knows how much time has elapsed, it multiplies the travel time of the signal by the speed of light (as the satellite signals travel at the speed of light, approximately 186,000 miles per second) for computing the distance.

To measure the travel time of the satellite signal, the receiver needs to know when the signal left the satellite and when the signal reached the receiver. The latter is easy to compute because the GPS receiver just needs to check its internal clock whenever the signal arrives. However, how does it know when the signal left the satellite? This can be easily answered because all GPS receivers are synchronized with the satellites to generate the same digital code at the same time. Therefore, when a GPS receiver receives a code from a satellite, it can look back in its memory bank and find out when it emitted the same code. This allows the GPS receiver to determine when the signal left the satellite. Once the receiver has done the distance measurements, the rest is solving a simple geometry problem. That is, if it knows where the four satellites are and how far its distance is from each satellite, then it can easily compute its location.

GPS Applications

There are many possible uses for GPS; in fact, in any application where location information (e.g., land, sea, air) is needed, that application is a possible candidate for GPS. There are also many additional applications such as agriculture, mapping and surveying, property evaluation and tax assessment, air quality studies, environmental protection, demographic analysis (including marketing studies), atmospheric studies, oil and gas exploration, scientific exploration, vehicle tracking and more.

GPS-based Automatic Vehicle Tracking System

Of all the GPS applications, vehicle tracking and navigational systems have brought this technology into people's day-to-day lives. Today, GPS-enabled cars, such as ambulances, fleets and police vehicles, are a common sight on the roads of developed countries. These vehicles are known by many names such as Automatic Vehicle Locating System (AVLS), Vehicle Tracking System (VTS) and Mobile Asset Management System (MAMS). These systems offer an effective tool for improving the operational efficiency and use of vehicles [8].

In these vehicles, GPS is used for both tracking and navigation. Tracking systems enable a base station to keep track of the vehicles without the intervention of their drivers, while navigation systems help drivers reach their destinations. The architecture is more or less similar, whether GPS is used as a navigation system or as a tracking system. The navigation system will have a convenient presentation, which is usually a graphical display for those drivers which do not need to use the tracking system. The VTS combines a number of well-developed technologies. It consists of three subsystems irrespective of the technologies being used: In-Vehicle Unit (IVU), Base Stations and Communication Channels.

The IVU includes a suitable position sensor and an intelligent controller together with an appropriate interface to the Communication Channels. The controller interacts with the GPS receiver, collects and co-ordinates at predefined intervals, processes it and sends it out to the Communication Channels. Optionally in certain cases, it uses a man-machine-interface, similar to a display, which can be combined with a keyboard for message communication between the driver and the base station. The network overlay systems use a mobile (cellular) phone infrastructure for locating vehicles. The cell centers, with additional hardware and software, assess the time of arrival (TOA) and the angle of arrival (AOA) of radio signals from vehicles to compute the position of the vehicles. This information is sent to the tracking center through the cell channels or conventional channels. Another technique used to locate vehicles is to compute the time difference for signals to reach the vehicle from two different cell centers. This computation is made in the IVU, and the position information is sent to the tracking center through the mobile (cellular) phone link. A more common technique used is direct radio link (DRL). In this system, dedicated radio infrastructure is used with a special IVU to compute vehicle location. Alternatively, embedded GPS receivers provide absolute position coordinates at any point, without any area restrictions, as opposed to the above techniques that impose some limitations on the operational area.

The second subsystem, namely Base Stations, consist of a high-speed system that receives the position data from the vehicles and displays them on a digital map. The Base Station has the interface to the Communication Channels as well as some enhanced features such as video features, trace mode, history track, vehicle database and network support. The most costly part of a VTS is the data channels. The data channels, together with a suitable communication protocol, have to be selected after a thorough study of various parameters such as the bandwidth requirement, number of vehicles to be tracked, expandability, terrain, area of coverage, etc. A sophisticated VTS can be linked to different databases, which can support information about vehicles such as the cargo, the temperature of storage of perishable goods, fuel consumption rate, etc. Naturally, such systems demand data link with a higher bandwidth. The UHF links are suitable for short range without shadow region because they require a line of sight. The mobile phone-based systems demand a minimum infrastructure investment, but they are limited in coverage. On the contrary, Low Earth Orbit (LEO) satellite systems are expensive and offer the largest coverage [11]. The recently introduced Wireless Application Protocol (WAP) and General Packet Radio Service (GPRS) technologies hold great promises for VTS.

When multiple vehicles are being tracked, a suitable communication protocol needs to be established to avoid the collision of radio signals. The simple technique is Time Division Multiple Access (TDMA), where each IVU communicates during predefined time slots. This synchronization is easy in a GPS-based IVU because the GPS receiver provides very precise time reference signals. However, TDMA-based systems have limited expandability and flexibility and are known for underutilization of bandwidth [9].

Proposed System

We propose a Distributed User Tracking (DUT) system that uses GPS technology and has remote access facilities, which enables the security forces (especially the police force) to combat violent crimes. The proposed system consists of two components, the Enforcer and Tracker. Each of these components basically consists of an intelligent coordinator (processor, memory), a monitor and an appropriate interface to the Communication Channels. The Enforcer component is installed in each vehicle and has a unique ID (e.g., the vehicle plate number) to identify the vehicle. It is also able to perform a number of functions such as interpreting the signals (commands) received from the Tracker and applying them to the engine of the specified vehicle. The Tracker, however, is used by authority or security forces only. It communicates with each Enforcer remotely to track and control the violating vehicles by issuing the appropriate signals. These signals will put the violating vehicles under the control of the authorities. As a result, these two components together allow security forces to track the suspected/criminal drivers who are endangering the life of other innocent people and, secondly, to reduce or shut down the flow of gasoline to the engine of the violating vehicles by using the remote control capability of the Tracker component. In this situation, suspected drivers are not able to speed up while security personnel are approaching them, and they will be put out of action instantly without requiring the use of many security vehicles and creating a number of tragic incidents.

Currently, there are many devices ready in the market that have the remote access control capability to access vehicles. These include devices that can remotely lock or open the doors of the vehicles, start the engines of vehicles, etc. Also, some newer vehicles have other functions such as a path finding system, vehicle tracking capability, etc., as explained in section 2.1. As a result of these improvements, many initial issues, such as how to track a specific vehicle or how to remotely access a vehicle, have been resolved. Therefore, in our proposed system, the basic idea works as follows: upon the remote request from the Tracker component, the Enforcer component, which is installed in each vehicle, provides the related information about the pursued vehicle to the Tracker component. It facilitates the Tracker to get control of the pursued vehicle. This can be achieved by employing GPS and mobile wireless technologies. Each Enforcer component is unique in each vehicle and must not be tampered with. Therefore, this allows the Tracker to communicate and issue specific signals to a particular Enforcer. These signals can range from reducing the flow of the gasoline to the engine or locking the functionalities of an appropriate vehicle. The Enforcer also can be used for other purposes such as tracking the stolen vehicles or finding the stolen vehicles in car yards.

Therefore, our proposed DUT system can prevent and reduce many deadly and violent crimes including stopping violent criminals when they are fleeing from the scene of crimes using high speed cars, juvenile car races, criminals that are escaping from police chase, vehicle theft, etc. In any of these incidents, security forces have to pursue these vehicles intensely to arrest or stop the drivers. Unfortunately, these pursuits usually turn into dangerous, high-speed car chases that endanger the life of innocent bystanders and security forces and may cause costly damages to common and private properties.

Conclusion

In this paper, we propose to design and develop a DUT system, which allows authorities, such as security or police forces, to have the universal access and control to all vehicles to stop or slow down suspected vehicles before approaching them. The DUT system allows authorities to control the speed of the suspected vehicle by reducing or stopping the flow of gasoline to the engine of suspected vehicles. This compels suspected vehicles to travel within a limited speed, or if it is required, the offending vehicles can be completely stopped. Fuel reduction not only prevents drivers from speeding when they realized that they have been pursued, but it also allows the offending vehicles to be directed to a safer environment for further investigation. Further extension to our system enables authorities to inform or automatically control the speed of drivers in parts of roads that have been changed due to an earthquake or other natural disasters. This allows drivers to drive with a safer speed on those parts of the roads or highways. As a result, our proposed system not only protects the security forces from the violent criminals but also provides a safer driving environment for everybody on the roads or highways.

References

[1] Djuknic, G. M. and Richton, R.E., Geolocation and Assisted GPS, IEEE Computer, 34, 2, pp. 123–125, 2001.

[2] Pateli, A., Giaglis, G.M, Fouskas, K., Kourouthanassis P. and Tsamakos A., On the Potential Use of Mobile Positioning Technologies in Indoor Environments, In the Proceedings of 15th Bled Electronic Commerce Conference -e-Reality: Constructing the e-Economy, Bled, Slovenia, 2002.

[3] Tseng, Y., Wu, S., Liao, W. and Chao, C., Location Awareness in Ad Hoc Wireless Mobile Networks, IEEE Computer, 34, 6, pp. 46–52, 2001.

[4] Gudrun Klinker, Thomas Reicher, and Bernd Bruegge, Distributed User Tracking Concepts for Augmented Reality Applications, In Proceedings of the International Symposium on Augmented Reality, Munich, Germany, 2000.

[5] Giaglis G., Kourouthanasis P., Tsamakos A., Towards a classification network for mobile location services, In Mennecke, B.E. and Strader, T.J. (Eds.), Mobile Commerce: Technology, Theory, and Applications, Idea Group Publishing, 2002.

[6] A. Boukerche and S. Rogers GPS query optimization in mobile and wireless ad hoc networking. In Proceedings of the 6th IEEE Symposium on Computers and Communications, pages 198–203, 2001.

[7] Zeimpekis, V., Alvarez, R., Tafazzoli, R., and Evans, B. G., Impact of constellation design on Doppler rate based MT positioning for S-UMTS, AIAA 2002-2010, In 20th AIAA International Communication Satellite Systems Conference, Montreal, Quebec, Canada, 2002.

[8] Hargrave, S., Mobile Location Services: A Report into the State of the Market, White Paper, Cambridge Positioning Systems, 2000.

[9] Sakagami, S., Vehicle Position Estimates by Multi-beam Antennas in Multi-path Environments, IEEE Transactions on Vehicular Technologies, 43, 4, pp. 902–908, 1994.

[10] B. B. Peterson, D. Bruckner, and S. Heye, Measuring GPS Signals Indoors, Proceedings of the Institute of Navigation's ION GPS-2001, September, 2001.

[11] Makki S., Pissinou N., and Daroux P., LEO Satellite Communication Networks – A Routing Approach, Journal of Wireless Communications and Mobile Computing, Vol. 3, No. 3, 385–395, May 2003.

Biography

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Enhancing Network Availability and Security via Multi-homed Virtual Private Networks

Baijian Yang, Ball State University; Tianguang Gao, Humana Inc

Abstract

This study explores one solution to enhance the network availability and security by supporting Virtual Private Networks (VPNs) over the multi-homed networks. While the conventional VPN technology offers a cost-effective way to communicate securely through unsecured public networks, it still suffers from single point failures. Another interesting technology, termed multi-homed network, can increase the network availability by having more than one external links to the Internet. Multi-homed networks are more reliable especially if the external links are offered by different Internet Service Providers (ISPs). This article discusses and analyzes potential problems and solutions associated with incorporating VPN technology within multi-homed networks, such as the inability of IP Security (IPSec) packets to travel through Network Address Translation (NAT) devices. The work simulates the proposed multiple VPN tunnels solution and the primary results demonstrate the correctness and the feasibility of the proposal.

Introduction

In this digital era, having secure and reliable computer networks is vital to many enterprises that offer business transactions online. However, employees sometimes connect to their company's servers through public, unreliable networks. While Virtual Private Networks (VPNs) technology has been widely adopted to make data transmission secure, it still suffers from network failures and congestion. The purpose of this study is to examine a solution to that problem by implementing VPNs over multi-homed networks, i.e. networks have multiple external links so that VPNs can transparently switch from a congested or a downed public network to other public networks to improve reliability and load balancing.

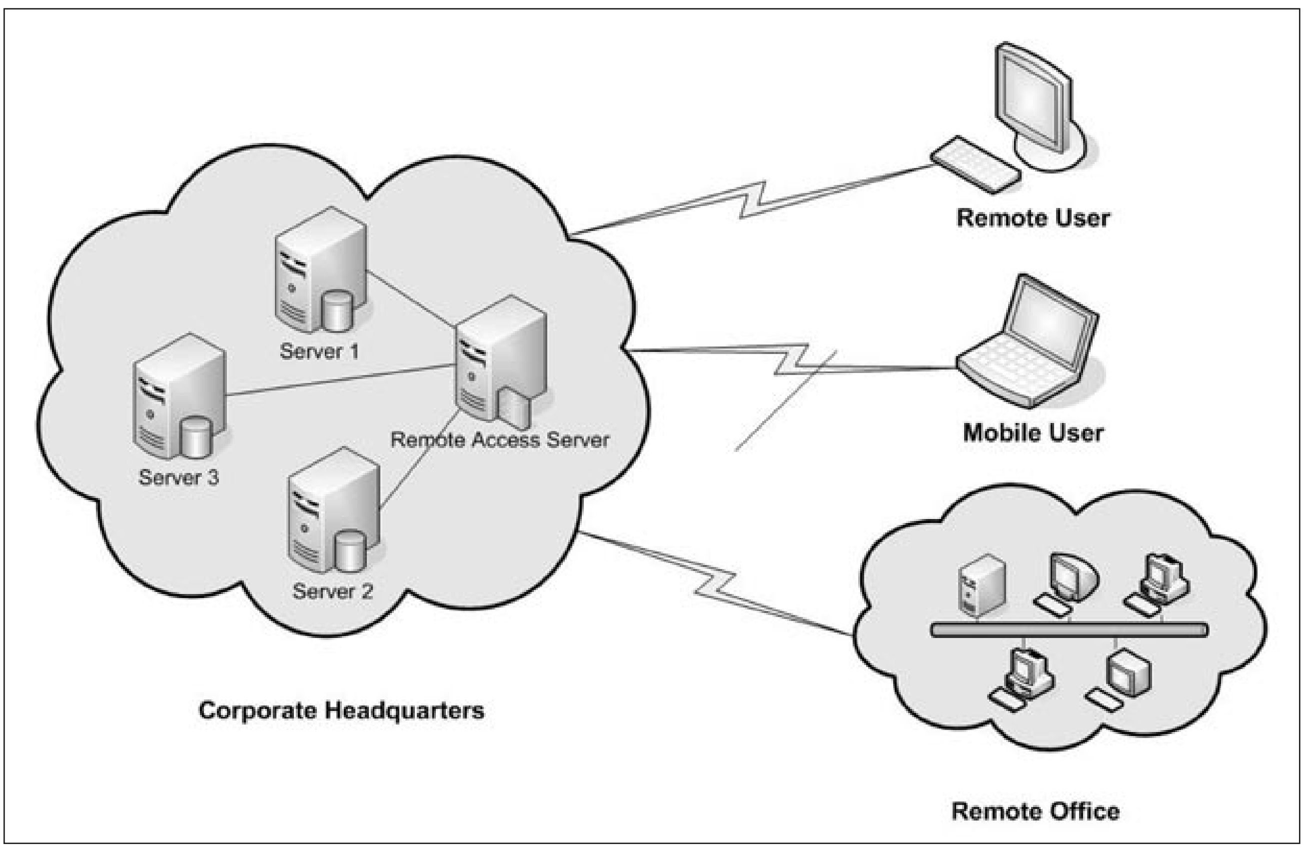

Figure 1 A network without the support of VPN

Several proposals have been presented to make current Internet connections more reliable. One of the techniques is using an overlay network in an attempt to build multiple links from the source to the destination instead of a single end-to-end link [5]. Therefore, when some of the nodes or links on the routing path are either congested or down, the overlay network can simply deliver data using other paths. The advantage is obvious: the end users do not have to wait for the slow convergence of network, which is of benefit to both consumers and the Internet service providers [4]. A typical way to implement an overlay network is to modify the current design of Border Gate Protocol (BGP) such that the edge routers of each domain can keep the status of multiple links. However, the routing entries of overlay networks are very difficult to integrate into an existing classless inter-domain routing scheme, and therefore could impede the rapid growth of the Internet [7].

Another popular idea is to have more than one external links connected to a customer, which is termed as multi-homing. To implement a multi-homing network, one does not have to change the underlying network routing scheme. Common solutions include multiple-entry Domain Naming Services (DNS) and Network Address Translation (NAT) so that each machine will have multiple IP addresses in the DNS lookup table. As a result, a multi-homed machine can be reached through one of its network addresses [6].

Studies [1, 2, 3, 8] have demonstrated that multi-homing approach is more cost effective and is easier to implement than overlay networks. Performance gains from multi-homing networks are comparable to overlay networks. Regarding network security, the conventional Virtual Private Network (VPN) is limited to a point-to-point structure [9], which makes it very slow to switch over to another network in case of single node or single link failure.

While recent studies are focused only either on reliability or on security, none of them have put both schemes together. The purpose of this report is to investigate the integration of VPNs with multi-homing networks. See Figure 1 on previous page.

VPN Technology

A Virtual Private Network is a common network mechanism to provide a secure end-to-end network connection. The idea is to first negotiate and setup a network tunnel between the two communication nodes. Usually a VPN server also connects to a Remote Authentication Dial In User Service (RADIUS) server to allow only authorized users have the privilege to establish such tunnels. The data is then encrypted before it is transmitted over the network and decrypted on the receiver side. Compare to dedicated private leased lines, VPNs are less costly and are ideal to many companies.

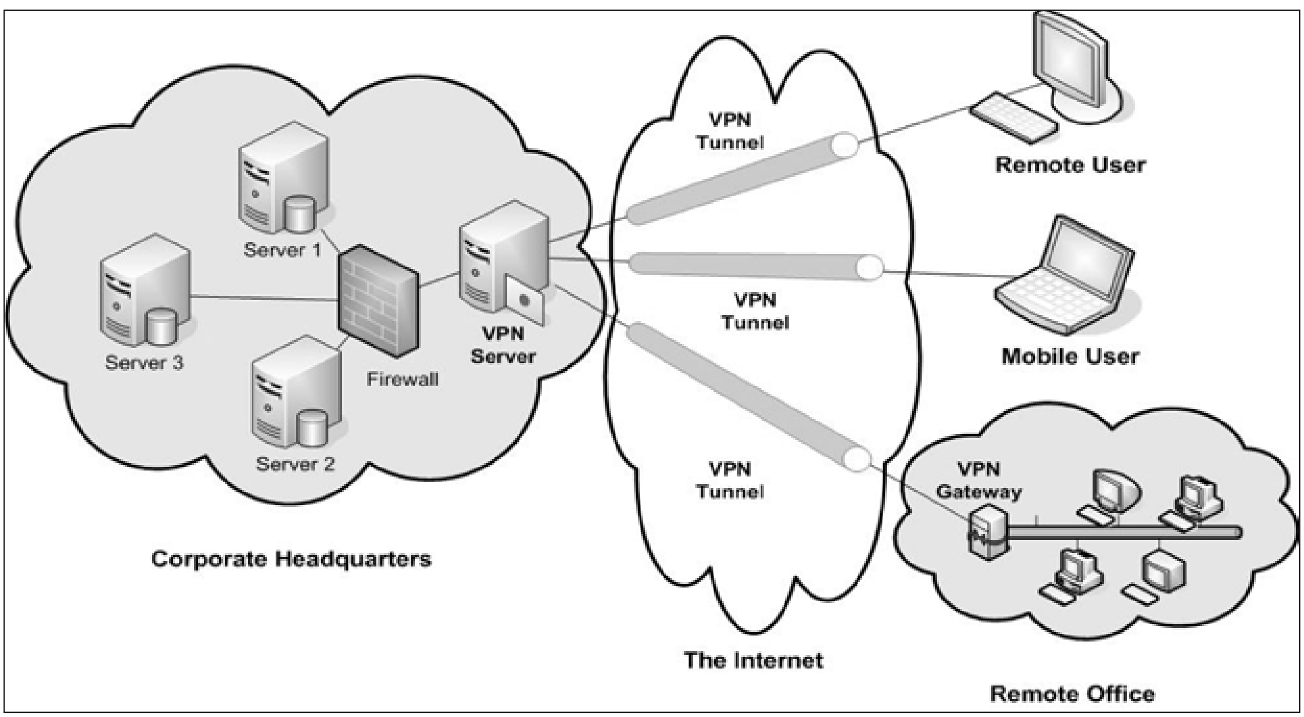

Figure 2 A Network with Virtual Private Networks

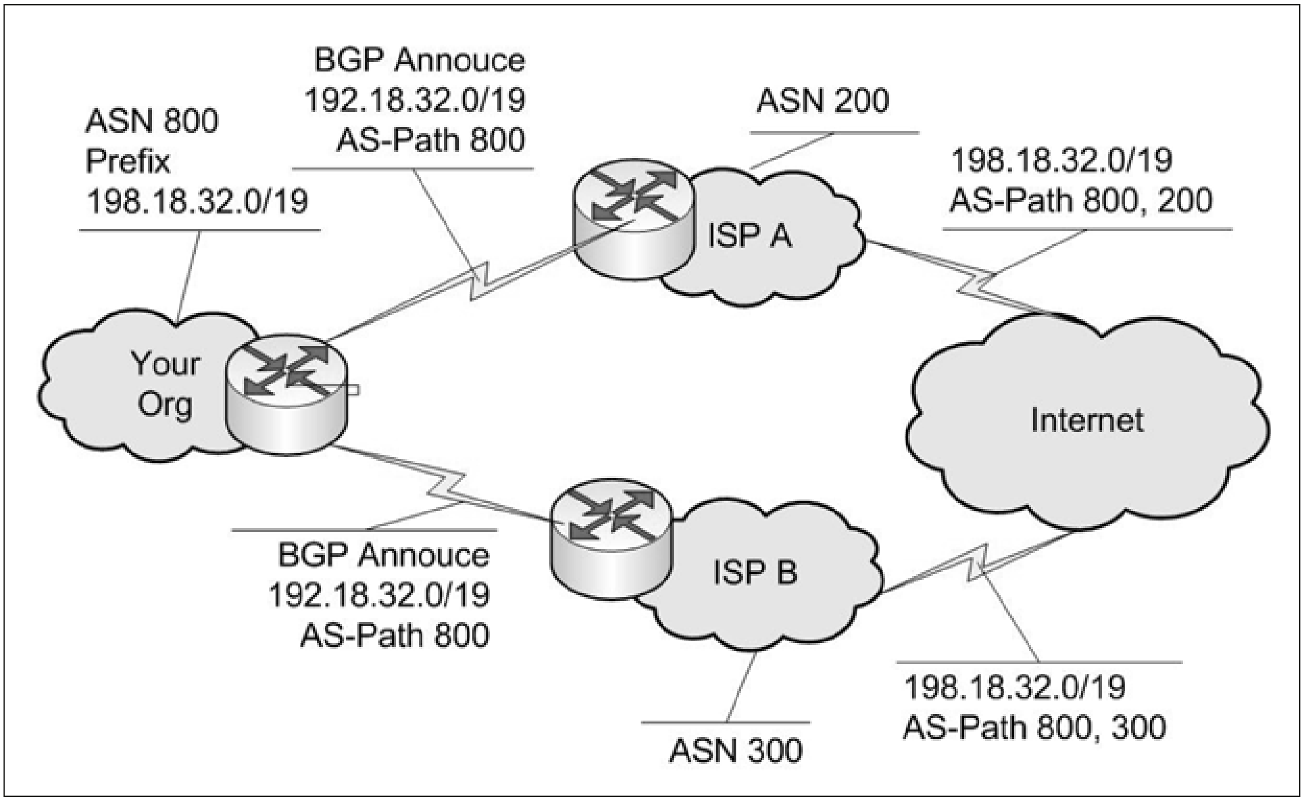

Figure 3 Multi-homing solution with Border Gateway Protocol offers same IP

Consider a corporate network without the VPN support. Shown in Figure 1, a remote user needs to dial up to the corporate Remote Access Server (RAS) to get access to the servers. This could be costly if users are trying to make a data connection through long distance calls. Similar problems also exist for mobile users and users at remote offices. See Figure 2 on previous page.

With VPN, however, users do not need to dial up directly to the corporate headquarter. As shown in Figure 2, a remote user can simply dial into the local access server, relying on their ISP to package the data and route it through a secure 'tunnel' to the remote servers. There is typically a cost associated with the tunnel services offered by ISPs. However this is normally less than half of the cost of leased lines or long distance phone calls. Three major tunneling protocols are supported in the Internet, as described below:

- IP Security (IPSec). It operates at network layer and can be implemented independent of application layer.
- Point-to-point Tunneling Protocol (PPTP). It works at Data Link layer and is preferred for Microsoft Windows based network traffic.
- Layer 2 Tunneling Protocol (L2TP). It combines Layer 2 Forwarding with PPTP. It offers more flexibility than PPTP, but need supports from the underlying network devices.

The advantages of VPN include reduced cost, effective use of bandwidth, enhanced scalability, and enhanced connectivity. It also has better security than conventional Internet connections because it often encrypts the data during data transmission. Among the drawbacks of VPN are its dependency on the Internet and a low degree of interoperability of devices and protocols.

Multi-Homed Networks

Multi-homed networks are those with more than one link external to local network. For example, there can be two or more links to the same ISP to get link redundancy. In case one link fails, there would still be another link operating. For increased reliability, a user can sign contracts from See Figure 3 on above.

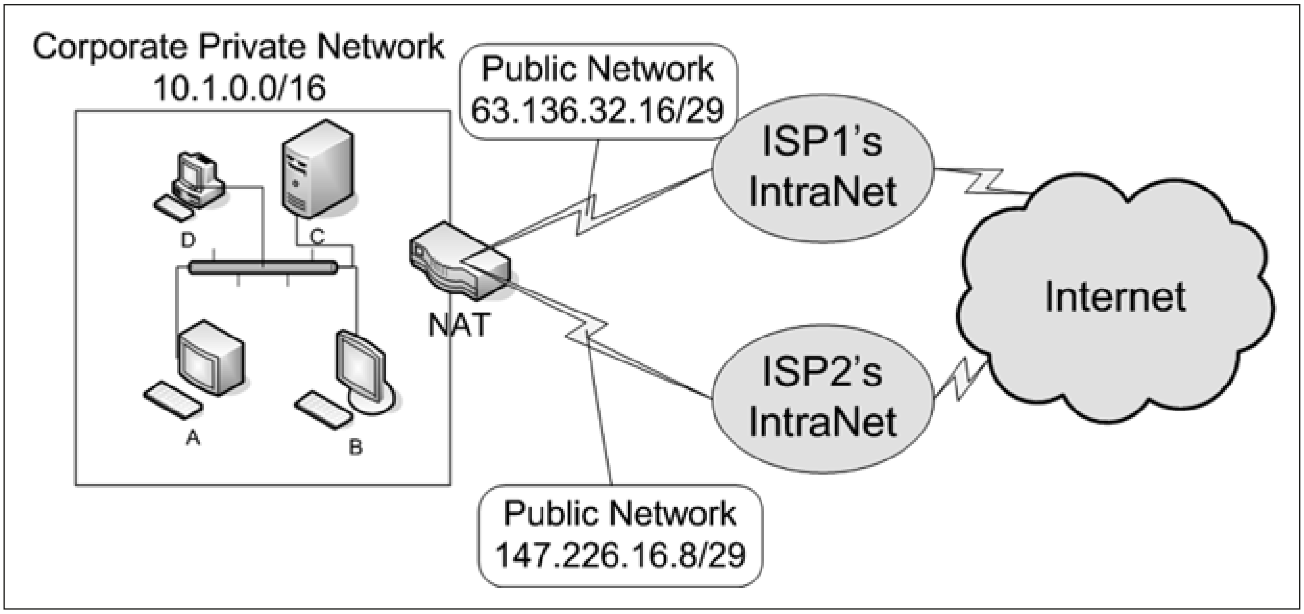

Figure 4 Multi-homing with NAT support

different ISPs for the external links. In addition to greater reliability, benefits of multi-homing include more bandwidth, high availability, and cost effectiveness.

Several solutions have been proposed to support multi-homing technique. From an end user's perspective, they can be categorized as single IP solutions and multiple-IP solutions. The former is more user-friendly: a client machine does not need to worry about which path to take because the same IP addresses are registered at both paths of the egress router.

As illustrated in Figure 3, an organization registered a network 198.18.32.0/19 at both ISP A and ISP B. Assuming Border Gateway Protocol (BGP) is supported on the routers of the organization and the access routers of ISP A and ISP B, the network announcement can be passed to the access routers of both ISPs. Then both access routers advertise the path to the Internet. When the Internet users try to reach the web servers of the organization, their network requests can be relayed to the destinations via the path offered by either ISP A or ISP B. Therefore, if one ISP has service difficulty, the network can still be externally accessed through another ISP.

Another category of solutions offers different IPs with each from one unique ISP. For example, a company registered a domain name www.mywebserver.com and leased an IP of 143.120.18.25 from ISP A and an IP of 63.68.123.17 from ISP B. Both IPs are then assigned to this web server. Outside users can access the server through either 143.120.18.25 or 63.68.123.17. However, one drawback to this solution is that the outside user must know both IPs. Fortunately, this can be solved by multiple DNS entries.

In order to map different IPs to the same network, Network Address Translation (NAT) is usually required. This is illustrated in Figure 4 where a corporate network has two public networks address, 63.136.32.16/29 and 147.226.16.8/29. Internally, the private network uses 10.1.0.0/16 network. A NAT device is situated between the public and private interface to translate and map the internal IPs to external IPs, and vice versa. See Figure 4 above.

Supporting VPNs Over Multi-Homed Networks

As mentioned, VPN offers cost-effective and secure communications, while multi-homing networks are cost effective and provide for enhanced network availability. Naturally, if there is a scheme that can incorporate both techniques, the resulting network infrastructure may be attractive in light of the following features:

- Cost effective: Both VPN and multi-homing are cost effective techniques.
- More secure: A variety of security features are available with VPN.
- More reliable: The use of redundant ISPs improves reliability.

- Better performance: More bandwidth is available, load-balancing is possible and Quality of Service (QoS) is possible.

Unfortunately, multi-homing and VPN will not go together automatically. We identified three possible problems. The first problem is that NAT devices do not understand IPSec packets duo to the fact that both IP addresses and port numbers are encrypted in IPSec. The second issue is auto fail-over. In current VPN technology, users need to manually reinitialize a VPN connection to switch to a live network path. The third problem concerns the challenge of load balancing VPN traffic over Multi-homed network. In this report, the focus of the study is to present a solution that offers auto fail-over in case of network path failure.

Multiple VPN Tunnels Solution

To address the auto fail-over issue, one solution would be to educate the end users about the multi-homing. When VPN fails, users know they need to create another VPN by using another IP address. But this approach results in losing on-going transactions. A more elegant solution might be to create an "any-cast" type of VPN tunnel, which could send data through a tree-like tunnel to any one of the public IP addresses of the VPN server. The difficulty is that any-cast is not even well supported on native IP networks and the behavior of tree-like tunnel is not well understood.

The solution we propose is to create multiple VPN tunnels simultaneously. The role of those tunnels can be classified as either primary/back up or a means for load balancing. As illustrated in Figure 5, below, the home agent has two different public IP addresses, HA1 and HA2. When the end user tries to access the corporate private network from FA, two separate tunnels are created. Both tunnels insert a tunnel packet header into the original IP packets, add the tunnel number and encrypt the payload.

By default, multiple VPN tunnels do not provide auto fail-over because home agents (HAs) have different IPs. This can be solved by modifying the foreign agent's (FA's) routing table when one path is congested or down. In our simulations, we modified the 'cost' entry of the routing table at the client side. The FA periodically evaluated the average of Round Trip Time (RTT) and changed the 'cost' of each path to reflect the network conditions. Therefore, a faster link would have precedence over the slow link, and a live link would always be chosen over a dead link. This solution not only solves the auto fail-over issue, but also helps to perform load balancing and to provide QoS to the network application.

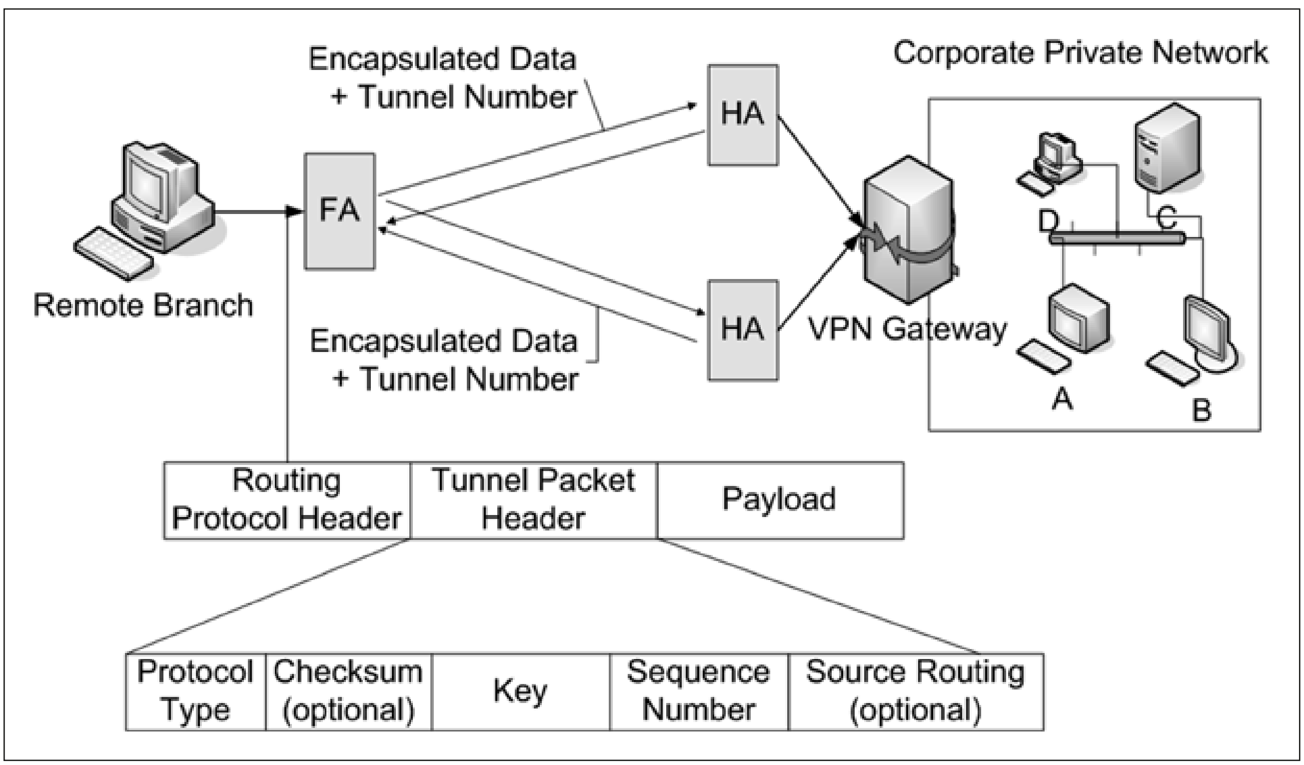

Figure 5 Multiple VPN tunnels

In terms of cost and performance, the proposed approach wastes no bandwidth. The only resource consumed is a reduction by 50% of the maximum number of VPN connections a corporate network can support, assuming dual addresses. But this cost seems justified if network availability or fault tolerance is a concern. Furthermore, the devices required to implement a multi-homed VPN are typically off-the-shelf hardware and no special computing power is needed. Of course, the cost of managing multiple VPN tunnels is slightly higher than maintaining a single VPN tunnel.

Conclusions And Future Work

In this paper, we proposed a scheme to integrate VPNs and multi-homed networks. The combination of these two techniques is challenging and beneficial. A multiple-tunnel solution was proposed to support VPN on a multi-homed network. The proposed solution can be implemented at either the networking layer or at the application layer by changing the cost of the routing table as needed. The resulting routing paths can provide auto fail-over features and are helpful to balance network traffic.

Future investigations could further explore this solution by testing the performance on different platforms and a variety of networks to gain deeper understanding as how the scheme impacts the network and the end users. Further study is also needed to find a load balancing scheme that is more appropriate for VPN connections. In addition, a practical solution could be proposed and examined to support NAT over IPSec. Lastly, another area of study is to discover if a point-to-multipoint VPN tunnel can further reduce the cost than the proposed multiple point-to-point VPN tunnels.

References

[1] A. Akella, J.P., A. Shaikh, S. Seshan, and B. Maggs. A comparison of overlay routing and multihoming route control, Proceedings of ACM SIGCOMM. 2004. Portland, Oregon.

[2] Armando L. Caro, J., Janardan R. Lyengar, Paul D. Amer, Gerard J. heinz, and Randall R. Stewart, Using SCTP Multihoming for Fault Tolerance and Load Balancing, ACM SIGCOMM Computer Communication Review, 2002. 32(3): p. 23-32.

[3] David K. Goldenberg, L.Q., Haiyong Xie, Yang Richard Yang, Yin Zhang, Optimizing Cost and Performance for Multihoming, Proceedings of the 2004 Conference on Applications, technologies, architectures, and protocols for computer communications.

[4] Jahanian, J.H.a.F. Impact of Path Diversity on Multihomed and Overlay Networks, International Conference on Dependable Systems and Netoworks. 2004. Florence, Itly: IEEE Computer Society.

[5] Ningning Hu, L.L., Zhuoqing Morley Mao, Peter Steenkiste, and Ja Wang, Locating Internet Bottlenecks: Algorithms, Measurements, and Implications, ACM Conference on Applications, technologies, architectures and protocols for computer communications. 2004. Portland, Oregen, USA: ACM Press.

[6] Ramakrishna Gummadi, R.G. Practical Routing-Layer Support for Scalable Multihoming, IEEE Infocom on Computer Communications. 2005.

[7] Ratual Mahajan, D.W., and Tom Anderson. Understanding BGP Misconfiguration, in ACM SIGCOMM. 2002.

[8] Shu Tao, K.X., Ying Xu, Teng Fei, Lixin Gao, Roch Guerin, Jim Kurose, Don Towsley, and Zhi-Li Zhang, Exploring the Performance Benefits of End-to-End Path Switching, ACM SIGMETRICS Performance Evaluation Review, 2004. 32(1): p. 418-419.

[9] Z. Morley Mao, D.J., Oliver Spatsheck, Jacobus E. Van Der Merwe, and Jia Wang, Efficient and Robust Streaming Provisioning in VPNs, in International World Wide Web Conference. 2003. Budapest, Hungary: ACM Press.

Biographies

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Fixed Mobile Convergence Based on Internet Multimedia Subsystems

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Abstract

Consumers are growing to expect ubiquitous, constant connectivity and access to all manners of information applications. Service providers, large and small, must simultaneously find ways to offset the declines in traditional sources of revenues while driving top-line growth. This article addresses the future transformation of telecommunication networks to an FMC (fixed mobile convergence) IMS (Internet multimedia subsystem) environment that meets the requirements of both consumers and providers. Additionally, this article describes potential multifunctional, multimedia, consumer subscriber devices that will have to be developed by consumer equipment vendors and future seamless multimedia applications for consumers and Homeland Security across wired and wireless platforms. The article will address the business, competitive, and technological issues involved in the telecommunication transformation and summarize the progress being made toward this transformation. Finally, the article presents a brief description of our ongoing research and development of affordable, mobile, FMC IMS-like capabilities for emergency response and management.

Introduction

The challenges facing modern telecommunication system operators differ by region, by company and marketplace size, and by their area of focus and differentiation. But there are certain themes such as revenue preservation, revenue expansion, brancy, and speed-to-market cycles that impact all of them. Service Providers require a true next-generation network, built on an open-standards architecture and able to support "always on," access-agnostic and device-independent services.

Ongoing telecommunication transformation will provide "anywhere, anytime [1] interactive" access for consumers by converging "independent" multimedia communication technologies [2] such as voice switched calls, VoIP (Voice Over Internet Protocol), high speed broadband Internet service using DSL (Digital Subscriber Line) or cable modem technology, and IPTV (Internet Protocol TV) video seamlessly and simultaneously by using FMC IMS technology over an "all" IP NGN (Next Generation Network). FMC IMS open standard IP SIP (Session Initiation Protocol) and RTP (Real-time Transport Protocol) are critical keys in the future telecommunications transformation [3].

Several industry executives expect to see IMS technology emerge strongly within the next 12 to 18 months [4]. Achieving this FMC IMS "all" IP NGN transformation will require new telecommunication infrastructures and associated software applications capable of transporting and controlling the bandwidth demands these new seamless converged technology applications will need, as well as new "compatible" multi-functional consumer equipment [5]. This will require unheralded co-opetition (the blending of cooperation and competition that improves a company's competitive position through the use of common standards and the free-flow of data among competing networks) between service providers, telecommunication equipment vendors, and consumer product vendors that will no doubt provide an economic stimulus both nationally and internationally that has not been seen for many years to meet pent-up consumer demands.

Additionally, FMC IMS greatly reduces the cost of market entry and technical complexity for service providers to deliver a host of multimedia applications [6]. The potential customer base that can be reached in both wired and wireless markets due to FMC IMS technology has put cable mobile operators and Baby Bell service providers literally in a competitive fight for their survival.

State and federal government regulatory agencies will need to create regulation that encourages industry growth while at the same time maintains competitive fairness and consumer protections [7]. The government, with regulations, can either stagnate or encourage the delivery of new multimedia technologies, some of which could be used for Homeland Security applications due to the multi-platform and security features in FMC IMS "all" IP NGN.

FMC IMS Overview

FMC is essentially an integration of already existing solutions especially targeted at integrating mobile and fixed networks. The new capability introduced by FMC is the seamless handoff between the converged services and service delivery to a single device/platform. IMS is based on the SIP and is responsible for registration, session setup and teardown, routing, etc.

The 3rd Generation Partnership Project (3GPP) has been dedicated to IMS, which is free of access technologies after the launch of its Release 5 (R5) specification. Presently, the 3GPP is also studying IMS-based FMC, which starts with WLAN (R6) and xDSL (R7) access. Likewise, the Focus Group on NGN (FGNGN) of ITU-T and ETSI TISPAN R1 selected the IP Multimedia Sub-system (IMS) as specified by the 3GPP R5/6/7 as the heart of its network. The IETF is also engaged in research aimed at IP mobility protocols that will support FMC.

The FMC IMS architecture shares centralized database components that provide user authentication, user location, user security, network security, billing, QoS (quality of service) via session control, and data management that ensure proper prioritization and end-to-end allocation of infrastructure resources for new IP packet switched applications and non-IMS applications, such as CS (circuit switched) voice, that enter onto the IMS architecture via gateways. All incoming and outgoing multimedia calls are processed through the IMS core to meet the above criteria [8], [9], [12], [17].

The IMS architecture core consists of three layers all sharing software and hardware component resources. Those three layers are the Service Application layer, IMS layer, and the Transport layer. See Figure 1 [17] to view how a multimedia application enters onto the IMS architecture at the Service Application layer, processes through the IMS layer, and is connected to the wired and wireless consumer via the Transport layer. Additionally, IMS enables much more than just real-time, user-to-user services. Operators, using the IMS platform as the heart of FMC, are also able to offer near real-time applications such as chat, IM, server-to-user services, and click to dial.

There are currently several primary approaches in the industry for delivering converged seamless services, such as Unlicensed Mobile Access (UMA), VoIP Extension, and IMS Voice Call Continuity (VCC) [10], [11]. UMA is facilitated by the Fixed-Mobility Convergence Alliance (FMCA), which is comprised of operators and manufacturers. While UMA may be appealing to GSM operators as well as wireless local area networks such as WiFi, there are a few drawbacks with this approach—it applies only to GSM operators, it does not provide any new end-user services, its only connectivity is to legacy services, and it does not leverage SIP-compliance. The advantages with VOIP Extension are a very low cost to the end user, an easy-to-install overlay solution, and the ability to add multimedia services. A large and problematic drawback is that there is no opportunity to

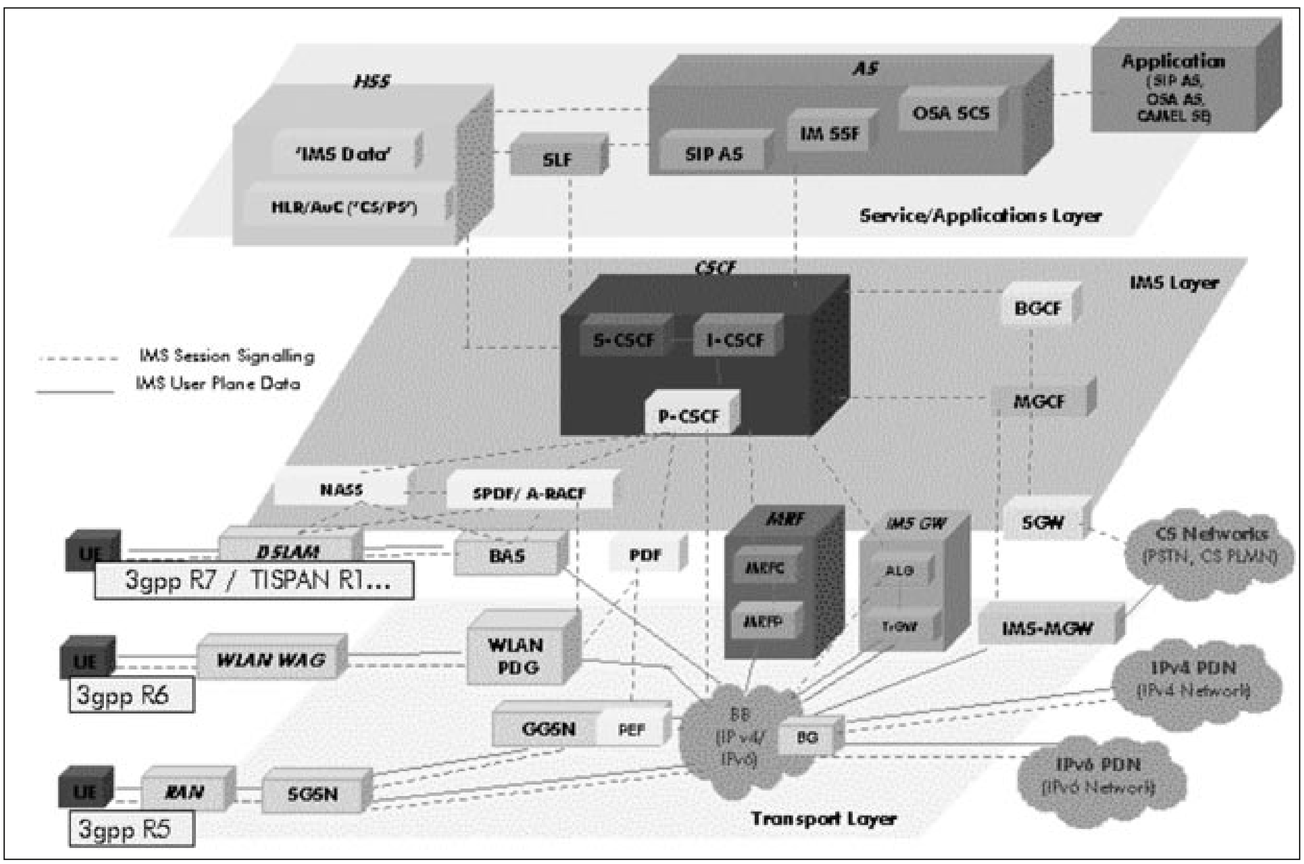

Figure 1 Multimedia Application and IMS

provide roaming for cellular service, so you have a converged device but not a converged service as part of an enhanced service portfolio. Thus, it is a step toward convergence but not true convergence. IMS-VCC currently extends an IMS network to cellular coverage and addresses handover. See Figure 1 on previous page.

It provides seamless voice call continuity between the cellular domain and any IP-connectivity access networks that support VoIP. It is the most comprehensive of available converged service approaches because it can work between any cellular technology (GSM, UMTS, CDMA) and any VoIP-capable wireless access. IMS-VCC provides for the use of a single phone number (or SIP identity) as well as handover between WLAN and cellular. It also provides other key advantages:

- A single solution to target multiple markets and segments
- Enhanced IMS multimedia services, such as greater personalization and control
- Seamless handover of voice calls between a circuit-switched domain and IMS
- Seamless integration with other VoIP networks
- Access to service from any IP device

Business and Economic Aspects

Service providers see this new FMC IMS all IP NGN technology as a way of lowering their network infrastructure cost as it provides a shared, common, flexible architecture capable of offering new service applications over both wired and wireless networks, which will enable them to compete more cost effectively and generate more profits [13]. The driving factor will be what is in it financially and competitively for service providers and the ROI (Return on Investment) they would like to achieve per customer household by creating service bundles, which in turn create a higher ARPU (Average Return Per Unit) and a reduction in consumer churn. It is obvious to service providers that the provider offering the best variety of bundles and delivering the best quality service at a reasonable market price will win the consumer market. The once desired "triple play" concept, delivering voice, data, and video to only the consumer's fixed land-based services, is now an outdated concept for leading service providers. Service providers now seek to achieve at a minimum "quadruple play" or more by delivering voice, data, and video applications to both the consumer's wired and wireless services, all on one convenient bill [6]. Figure 2 [14] indicates the projected monthly ARPU for "triple play," and Figure 3 [8] indicates the projected monthly ARPU for "quadruple play." See Figure 2 at the top of next column.

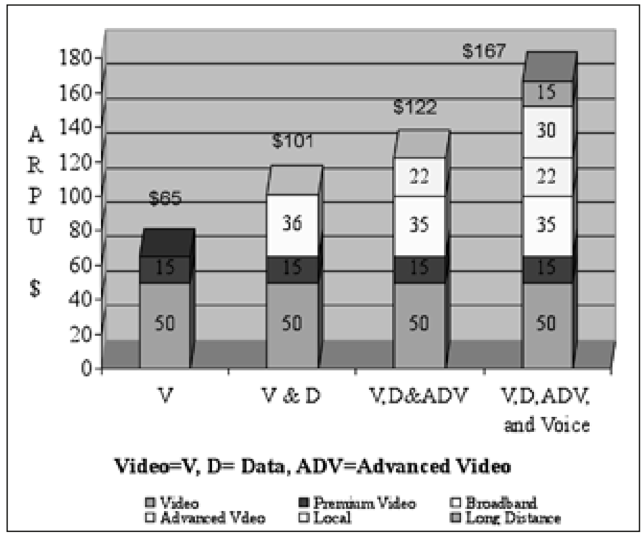

Figure 2 Triple Play as Driver of ARP

However, quadruple play technology can be achieved with the present day "vertical silo" model, but it is FMC IMS technology that provides the enhanced capability to seamlessly switch between the customer's wired and wireless services for an "anytime, anywhere" consumer experience. Additionally, the capex (capital expenditure) and opex (operational expenditure) savings, not to mention the flexibility and scalability to grow new multimedia applications and increase ROI, will undoubtedly drive service providers toward FMC IMS technology. See Figure 3 below.

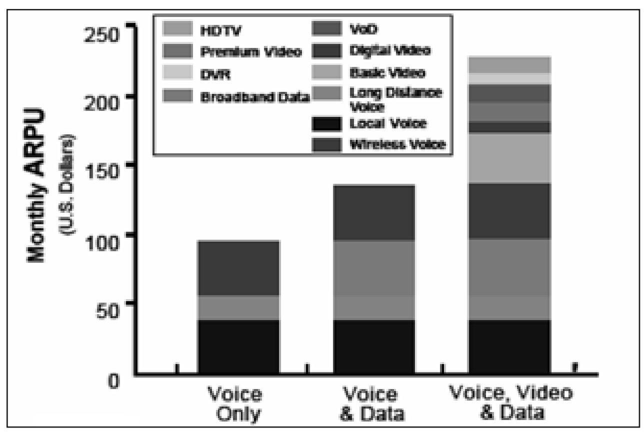

Figure 3 Monthly ARPU achievable in North America for quadruple play service

Service Provider Local Loop Bandwidth

In addition to deploying FMC IMS technology, service providers will also have to ensure their local loops are capable of transporting the bandwidth required to support these new quadruple play multimedia services, especially the bandwidth hungry IPTV video application. To do this, service providers plan to use two methods for delivering the new IPTV multimedia services. They are the "broadcast" method and the "select channels" method [15]. The "broadcast method" delivers all channels simultaneously all the time to the consumer and requires great amounts of bandwidth. The "selected channels" method only sends out the channels specifically requested from the consumer's TVs, requiring far less bandwidth, which is much more cost effective.

Delivering the "broadcast method" will require all FTTP/H (fiber to the premise/home), which is usually a telco infrastructure, or HFC (hybrid fiber/coax) mix, which is usually deployed by Mobile Switching Operators [15]. Delivering the "selected channel" method is mostly being considered by telcos that deploy a hybrid fiber and copper infrastructure to the consumer, known as FTTC (fiber to the curb) or FTTN (fiber to the node).

The service providers deploying FTTC and FTTN are initially planning to deliver 20–25 mbps (megabits per second) over a single copper pair or up to 50 mbps on a bonded (double) copper pair [18] to the consumer with DSL technologies and therefore will have to use codec (coding/decoding) technologies to deliver IPTV. Service providers using codec technologies such as MPEG-2 (moving picture expert group 2), MPEG-4/H264, and WMV-9 (Windows Media Video 9) can provide higher quality applications with less bandwidth.

It should be noted that delivery of this bandwidth and multimedia quadruple play services can be achieved over the local loop with the "vertical silo" model. However, the FMC IMS technology provides great advantages for delivery of these multimedia quadruple play services over the local loop by providing an "end-to-end" solution. FMC IMS recognizes the bandwidth required for delivery of each application, recognizes the bandwidth available regardless of the infrastructure and method of delivery, and can prioritize the delivery of packets accordingly for each application as needed for a smooth, seamless, end-user experience.

Multiplatform Multimedia End User Equipment

The new FMC IMS "all" IP NGN multimedia architecture is capable of seamlessly supporting all wired and wireless technology platforms including WiFi, WiMax, cellular, satellite [16], and wired landline services. The scope of platform technologies and the scalability for multimedia application growth FMC IMS unleashes both the consumer's and the service provider's dependency on one technology platform or the other.

To maximize the potential FMC IMS offers, consumer equipment vendors will need to develop multiplatform, multimedia, interactive consumer devices. These devices will need to have the capability to selectively pick up the best signal strength and seamlessly move accordingly across the wired and wireless technologies without consumers recognizing the transition. For example, if a consumer's best quality wired IPTV landline service goes out, the TV set would automatically switch and pick up the next best signal source, whether that is cellular, WiFi, WiMax, or satellite. The same seamless technology and switching capabilities should be applied to all consumer communication devices such as laptops, handsets, etc.

Land-based infrastructure often left service providers unable to justify the expense of expanding their network with enhanced multimedia broadband application services. Due to the networked, secure, multiplatform, multimedia capability FMC IMS offers and multiplatform end user devices, service providers will be able to deliver their multimedia application services much more economically and rapidly by being able to use wireless infrastructures alternatively.

Homeland/Emergency Disaster Preparedness

As compelling as the economic and consumer satisfaction motivations toward FMC IMS capabilities are, there are other more important opportunities that can be achieved by eliminating the consumer's and service provider's dependency on one technology platform or another with FMC IMS multiplatform multimedia technology. These opportunities are in Homeland Security and emergency response and management. It is well documented that inadequate communication system interoperability was a major contributor to loss of life in the September 11, 2001, terrorist attacks. Further, loss of communications contributed significantly to loss of life during the August 2005 Katrina hurricane aftermath when much of the land-based and cellular infrastructure was destroyed, leaving residential consumers, business consumers, and more importantly, emergency response personnel struggling to communicate.

FMC IMS uses standardized open SIP protocol technology that is seamlessly interoperable across all wired and wireless platforms. Emergency personnel equipped with FMC IMS multiplatform communication devices would have been able to overcome much of the interoperability problems they experienced during the September 2001 terrorist attacks. In the wake of Hurricane Katrina, FMC IMS would have also helped emergency personnel and potential victims communicate by allowing their handheld devices to detect and switch to whatever signal was working and available, possibly starting with local cellular or WiFi networks that survived the hurricane and were at least temporarily powered by backup batteries or generators, eventually switching to mobile wireless networks brought in by emergency personnel and telecommunications service restoration teams. As a last resort, the FMC IMS capable devices could have reverted to the use of satellite signals.

Another technical issue during emergencies and disasters is that consumers and emergency personnel overwhelm present day separate wired and wireless networks. The same problem could occur even with FMC IMS technology. Therefore, another key consideration that needs to be implemented in the FMC IMS architecture and compatible FMC IMS communication devices for emergency personnel is to allow prioritization for emergency calls. This could be done a number of ways, which might include prioritized trunk groups set aside for emergency personnel telephone numbers or signaling out emergency personnel communication devices.

Worst Case Disaster Scenarios

There are two "worst case" scenarios for emergency response personnel where they must bring their own, complete communications capability with them. The first is the natural or manmade disaster scenario where all land-based, cellular, WiFi, and WiMax infrastructure is destroyed or disabled. The second is the remote disaster site that has no terrestrial communications infrastructure. This second case is a much more common situation than many people would expect as there are still vast stretches of rural and remote areas in the United States that are not supported by terrestrial commercial communications, and satellite communication technology has not been widely adopted by non-government users.

To address these worst case scenarios, a research consortium consisting of the University of Louisville, Murray State University, and the Kentucky Technical Community College System has designed, built, and field tested a mobile, self-contained communications system for first responders (fire departments, law enforcement, medical/evacuation, Hazmat, etc.) based on commercially available communications components. Working in cooperation with commercial partners and numerous federal, state, and local emergency management, law enforcement, fire safety, and emergency medical organizations, the system has been engineered to be mobile, affordable, robust, and reliable and particularly well suited for field operation in rural or devastated communities.

Funded by the U.S. Department of Homeland Security, this research has resulted in the development of the Man-portable and Interoperable Tactical Operations Center (MITOC). The MITOC prototype is essentially a large sport utility vehicle (SUV) that is jammed to the roof with state-of-the-art, mobile shelf communications gear, computers, and software. Within 30 minutes of arrival at the site of an emergency, MITOC can transfigure into a modern, robust command post equipped with satellite-based voice and data communications, a wireless LAN, portable VoIP phones, rugged laptop computers, FM radio integration hardware, and other systems essential for organizing and executing emergency management and crisis response.

Today, there are still few communities in the United States that have achieved more than one or two of these capabilities, especially at the Mobile Incident Command level. Except for major cities like New York or Los Angeles, there are few coordinated plans, strategies, or capabilities to integrate and deploy such technology tools in support of Homeland Security and Emergency Management. At best, you may see one or two of these critical technology capabilities available at a fixed Emergency Operations Center (EOC) in a major urban setting, or in very large (tractor-trailer or RV sized) expensive mobile command posts, which may offer little more than a conference room, environmental support (light, heat, A/C), and a coffee pot. The overall concept of MITOC is to deliver a self-contained, upgradeable, affordable, quick response, mobile emergency communications system with key information technology that can support emergency personnel in any situation.

The MITOC COTS capabilities include the following:

- Satellite communications terminal
- Radio base stations compatible with a user's jurisdiction (up to four)
- A Radio Interoperability system to support the radio frequencies used in the user's jurisdiction and surrounding mutual aid agencies
- An Internet router
- An Internet server
- A wireless local area network (Network Access Point)
- A VoIP telephone switch
- A controller PC with a daylight viewable monitor screen
- Panels for phone jacks, antenna patch panel, and power

A central feature of MITOC is its secure wireless Internet access "bubble" shown in Figure 4. This wireless network provides authorized users access to all MITOC applications from wireless capable computers, laptops, or PDAs and supports on-scene collaboration with instant messaging. A low-cost, reliable, easy to set up, commercial broadband wireless router supports wireless Internet access via the network. The MITOC satellite communications WAN module gives emergency personnel high-speed Internet access and a worldwide voice communications capability. See Figure 4 in the next column.

MITOC is not currently FMC IMS capable system, but the lessons learned from more than two years of using evolving versions of MITOC in experiments, demonstrations, and real-world operations at major public events such as the 2006 Kentucky Derby clearly point out the potential value of FMC IMS-like seamless communication device interoperability. Real-world MITOC users seem to naturally gravitate toward the use of the systems-integrated VoIP phones. These phones allow them to communicate locally in a seamless manner across departments and to the command post and globally via the satellite link. An important goal of the MITOC project is developing and evaluating standardized tactics, techniques, and procedures (TTPs) for the effective use of advanced information technology to enhance the performance of incident commanders, support agencies, and first response personnel, and an emerging lesson learned is the importance of "converged" communications. As a result, FMC IMS capabilities are a high priority for future integration in the MITOC project.

Most recently, on October 20, 2006, the MITOC research team conducted a regional exercise and system demonstration titled "Quake at the Lake." Representatives from the U.S. Department of Homeland Security and more than 60 regional first responders came together to use and evaluate MITOC and a variety of emergency management software tools developed by research team members. Feedback was generally very positive, and all comments will be taken into account for future iterations of the system.

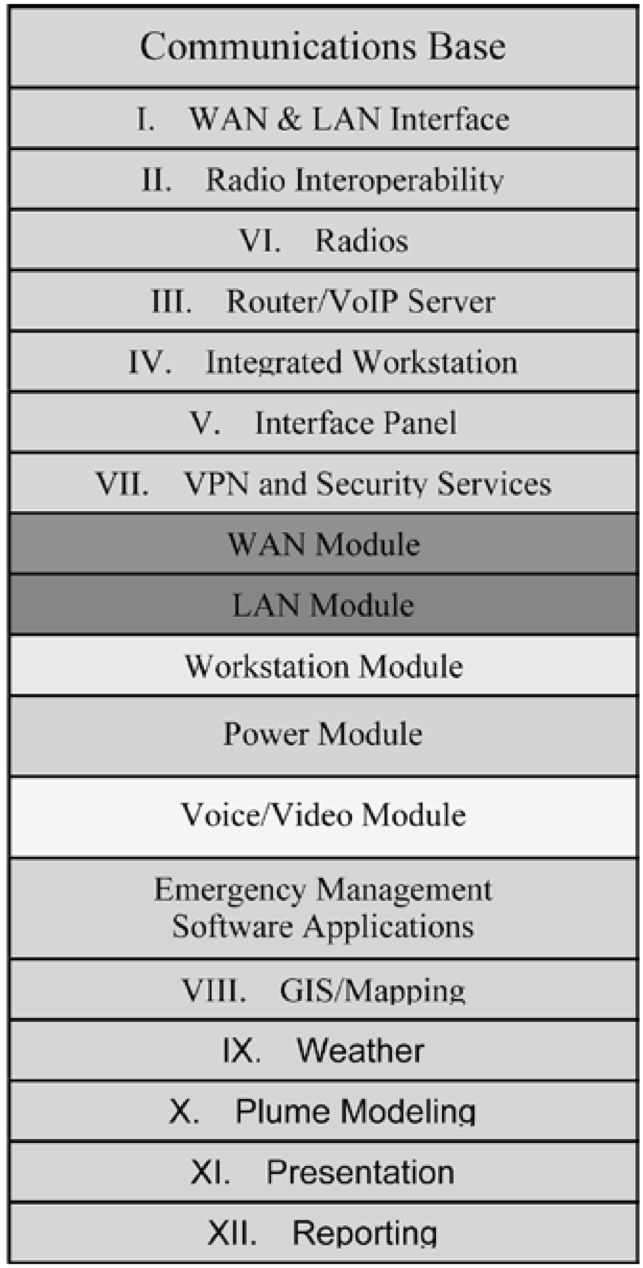

Figure 4 MITOC Architecture

Conclusion

Although FMC IMS may not be necessary for telcos or Moss to deliver voice, video, and data, it certainly provides a much more cost effective, less technically complex, standardized secure architecture capable of expanding and delivering these multiplatform, multimedia applications to either a wired or wireless infrastructure customer more expeditiously. FMC promises exciting opportunities for end users to consume services anytime, anywhere, and on any device while maintaining the same personalized rich user experience. It also allows operators to reduce their cost and generate revenue from existing and new services. As the networks, devices, and services continue to evolve, FMC is rapidly realizing the significant benefits of the ubiquitous wireless lifestyle.

More importantly, this technology stimulates the growth of new applications by simplifying the method of delivery to consumers and opens a wide range of new possibilities that can be used by Homeland Security to protect citizens. It is imperative that the government work with service providers and consumer equipment providers to research and assess the possibilities this FMC IMS technology could provide during times of emergency and disasters. The opportunity FMC IMS technology could provide for national security should provide adequate reason for Homeland Security to fund research for this new technology and offer incentives for service providers and consumer equipment vendors willing to lead this transformation.

The successful transformation to a standardized FMC IMS network will need co-opetition and "buy in" across the entire telecom industry. Both IMS and non-IMS applications will need to deliver QoS that is equal to anything on the market today, be seamless, and be secure for the user, network, and government needs.

References

[1] Lucent, "SBC Communications Selects Lucent Technologies Multimedia Platform to Enable Anytime, Anywhere Access to Consumer IP Services," (2005).

[2] Your Television is Ringing, The Economist, Oct. 2006.

[3] S. Wilcox and Dan Stein gas, "An IMS Evolution Strategy," Telecommunications Magi. supplement, Ultimate Guide to IMS, pp. 12–14, Sep. 2006

[4] D. Ho, "Tech to Merge Wired, Wireless and More Coming Closer" Cox News service, July 23, 2006.

[5] Intel, "Delivering on the Promise of Triple Play Digital Media," 2005.

[6] Bundles of Services, Double, Triple, Quadruple Play. Research and Markets, Dec. 2005.

[7] C.B. Goldfarb, "CRS Report for Congress: Access to Broadband Networks," June 2004.

[8] Lucent, "IMS and RACF Overview," 2006.

[9] "FMC: What-Is, and What-Is-To-Be", Huawei, April 2006, issue 21.

[10] Bernhards and V. Livingston, "The Power of IMS," Telecommunications Mag supplement, Ultimate Guide to IMS, pp. 8–14, Sep. 2006.

[11] IP Multimedia Subsystem, Wikipedia.

[12] "Why Fixed Mobile Convergence?" Nortel, 2006.

[13] "Fixed Mobile Convergence based on IMS for Mobile network Operators," Siemens, June 2006.

[14] J. Marinho, "IMS Benefits – The Land of Opportunity," June 2006.

[15] Davis, "Telcos Take on Cable with Video Delivery," Yankee Group, May 2004.

[16] C.B. Goldfarb, "CRS Report for Congress: Access to Broadband Networks," June 2004, Available (Online).

[17] V. Y. H. Kueh, "Call Setup Signaling Performance in Satellite UMTS Based on Session Initiation Protocol," 22nd AIAA International Communications Satellite Systems Conference & Exhibit 2004 9–12 May 2004, Monterey, California.

[18] F. Dawson, "AT&T Progresses in San Antonio but Date for Rollout Remains Uncertain," June 2006.

Biographies

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An Innovative Approach to a Cross-Disciplinary Senior Design Project

Saeed Moaveni, Minnesota State University; Karen C. Chou, Minnesota State University

Abstract

In this paper, we discuss a collaborative effort among civil and mechanical engineering faculty, students, and industry in a capstone design project. It is well known that funding for educational laboratory equipment is limited. It is also known that when industry upgrades their equipment, they donate some of their replaced equipment to universities. This type of activity renders an attractive opportunity for upgrading educational laboratory equipment, providing realistic design projects for students, and fostering collaboration among various programs within a university. In this type of collaboration, the students in the design team would work closely with faculty and students from another program to modify the donated equipment to meet their needs. The design objectives are defined by the faculty and students who will use the modified apparatus. This type of project meets the goals of a major design experience to emulate the practice of planning and designing of an engineering project. It also provides product-development experience and technical communication activities such as writing experimental procedures and a user's manual. Another unique feature of this type of collaboration is that the design team has direct interaction with the end-users (the students). This type of interaction may not exist in other projects, including the ones sponsored by industry. In this paper, we will share in detail our experience in managing and dealing with this type of collaborative project.

Introduction

It is well known that university funding for educational laboratory equipment is usually scarce, often complicating the educational objectives of engineering or a technology program. It is also well known that hands-on laboratory experience enhances students' learning and better prepares them for practice. This common lack of sufficient financial support for laboratory equipment in our civil engineering program compelled us to look for alternatives. As is the case in many other universities, the need for educational equipment is first conveyed to the department chair. After receiving the equipment request and considering the budget, the department chair then decides to purchase the equipment, or considers other alternatives, namely, design and fabricate the entire test apparatus in-house, or seek slightly old equipment from industry through donation and modify it to meet the need. In this paper, we present an example of a project that deals with modifying donated equipment— a direct shear apparatus to measure shear strength of sand—to meet the educational objective of our civil engineering program. After receiving the donated equipment from the Minnesota Department of Transportation (MnDOT), the challenge became how to modify the donated equipment to meet the need of our geotechnical engineering lab. To solve this problem, we turned to our mechanical engineering colleagues and seniors for a solution. We created a capstone design project that not only provided a realistic design experience for the mechanical engineering students, but also addressed the need of the geotechnical engineering lab in our civil engineering program.

The Capstone Design Project

The capstone design project in our mechanical engineering program at Minnesota State University is a two-semester course sequence. With the goal that mechanical engineering graduates should have prior experience with how a mechanical engineering project is planned and executed in industry, the two-course design sequence focuses on both a project's overall design process and on design calculations. It also meets ABET criterion 4, which states that "students must be prepared for engineering practice through the curriculum culminating in a major design experience based on the knowledge and skills acquired in earlier course work and incorporating appropriate engineering standards and multiple realistic constraints."

The design team is required to consider numerous technical/non-technical factors associated with the project and to seek feedback on their preliminary design from their peers, faculty advisor, and the engineers from the company donating the equipment. During the first semester, students are assigned the project, faculty advisors, and advisors from the sponsoring company. During the second semester, students are expected to complete the project by a target date even if the project is behind schedule by the end of the first semester. Communication and interpersonal skills are stressed extensively during the design project. The team gives formal and informal presentations throughout the year. All of our mechanical engineering design projects include the following tasks:

- define the project objectives
- investigate alternate concepts to achieve objectives
- prepare a schedule for project completion using a Gantt chart

- conduct engineering analyses and create engineering drawings
- develop proof of concept model
- present preliminary design to students, faculty, engineers, and anyone interested in the project
- test and evaluate
- submit fall semester and final reports
- present the final project to students, faculty, engineers, and anyone interested in the project
- The design team is also required to meet with

faculty advisor(s) weekly and document progress. Figure 1 shows the organization and execution of a typical mechanical engineering design project. In order to reflect the participation of the company donating the equipment, the faculty from the other program (civil engineering), and the end-users (civil engineering students), we have modified Figure 1, on the following page. This modification in organization and execution of the project is shown in Figure 2. Boxes with double-line borders represent the steps unique to this type of cross-disciplinary design project.

The donated equipment

When Minnesota Department of Transportation (MnDOT) received their new fully automated-digital direct shear testing equipment, they donated their manual-analog apparatus to our civil engineering program. This donation created an attractive opportunity to enhance our geotechnical engineering laboratory while adding a much needed undergraduate soil mechanics experiment. At the same time, the donated equipment provided a realistic capstone design project for our mechanical engineering students. The design project also provided a means for collaboration between our mechanical and civil engineering programs. The design team's mechanical engineering students worked closely with faculty and students from the civil engineering program to modify the donated analog direct shear testing apparatus to meet their soil mechanics experiment needs. Another unique feature of this collaboration was that the design team had direct interactions with the end-users—the civil engineering students. This type of interactions does not commonly exist in traditional capstone projects. The modified apparatus, shown in Figure 3, on page 61, was evaluated by the end-users by measuring the shear strength of sand, while following the operational procedure written by the mechanical engineering design team. This type of project not only meets the goals of a major design experience to emulate the practice of planning and designing of an engineering project, but also provides product-development experience and technical communication activities such as writing experimental procedures and a user's manual.

The Design Process

In this section, we explain in detail the tasks associated with the design process.

Meeting with faculty advisor(s)

As a first step, the design team is assigned a mechanical engineering faculty advisor. Students from the design team then meet with their faculty advisor to learn about the project and its expectations. They schedule times for their weekly meetings and discuss other routine design activities such as maintaining a design logbook.

Meeting with Engineers and Technicians from the donating company

In a typical mechanical engineering design project, after meeting with their faculty advisor, the design team would meet with representatives from the sponsoring company. However, in this project, the design team met with representatives from the state organization, MnDOT's geotechnical engineering lab, which had donated the equipment. Meeting with engineers and technicians who had used the equipment, the design team gathered as much information as possible about the apparatus. With the permission of MnDOT, they also took pictures of the lab space and the apparatus setup, and learned about the new equipment's features.

Meeting with the client

Next, to establish the project's specific design objectives and overall goals, the team met with the client, the civil engineering faculty who had requested the equipment for testing the shear strength of sand. The primary objective of this cross-disciplinary design project was to fully automate the donated direct shear testing equipment to meet the specifications prescribed by the faculty, whose students would eventually use the equipment to conduct soil mechanics experiments.

Creating a Gantt chart (task chart)

To ensure that the project is completed on time and within the allocated budget, the design team had to prepare a Gantt chart (task chart). The task chart assigns adequate amount of time for various project activities, such as establishing specifications, presentations, background research on the apparatus, concept development, selection

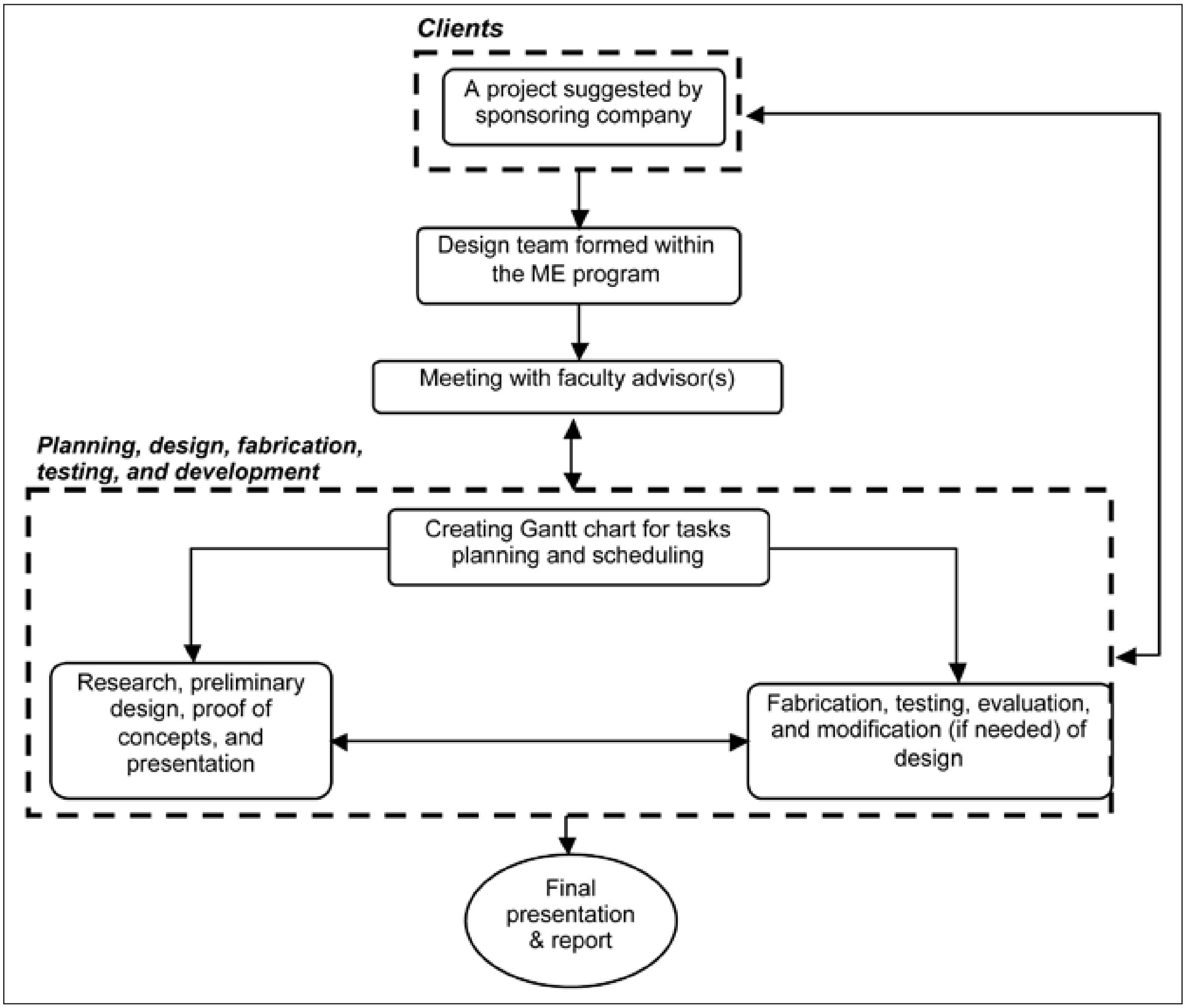

Figure 1 Organization and execution of a typical mechanical engineering design project at MSU

of a concept, analysis, producing detailed drawings, ordering parts, fabrication, instrumentation of the test apparatus, producing lab manual, testing, modifications, and an end-of-the-year oral presentation and final written report.

The remaining steps in the design process are similar to those of a traditional design. Although, at first glance, the direct shear testing apparatus project may appear to be simple and small in scope, the project was as challenging as a typical capstone design project. The design included modifications to the apparatus to accept a linear variable differential transformer (LVDT), a new force transducer, and a control system to measure the relative lateral movement of the sand shear planes under a load. In addition, the design team developed a software using LabView [1] to perform fully-automated data acquisition. The original mechanically driven system with gears and belts was also modified to accommodate the automation.

Student Evaluation

The term grade for each student in the design team was determined based on performance in weekly meetings and progress reports, interim and final presentations, the final written report, the peer evaluation, and design documentation maintained in a notebook.

Weekly meeting and progress reports

The team was required to meet with the faculty advisor weekly and submit a progress report addressing three items: what was done during last week, what is to be done next

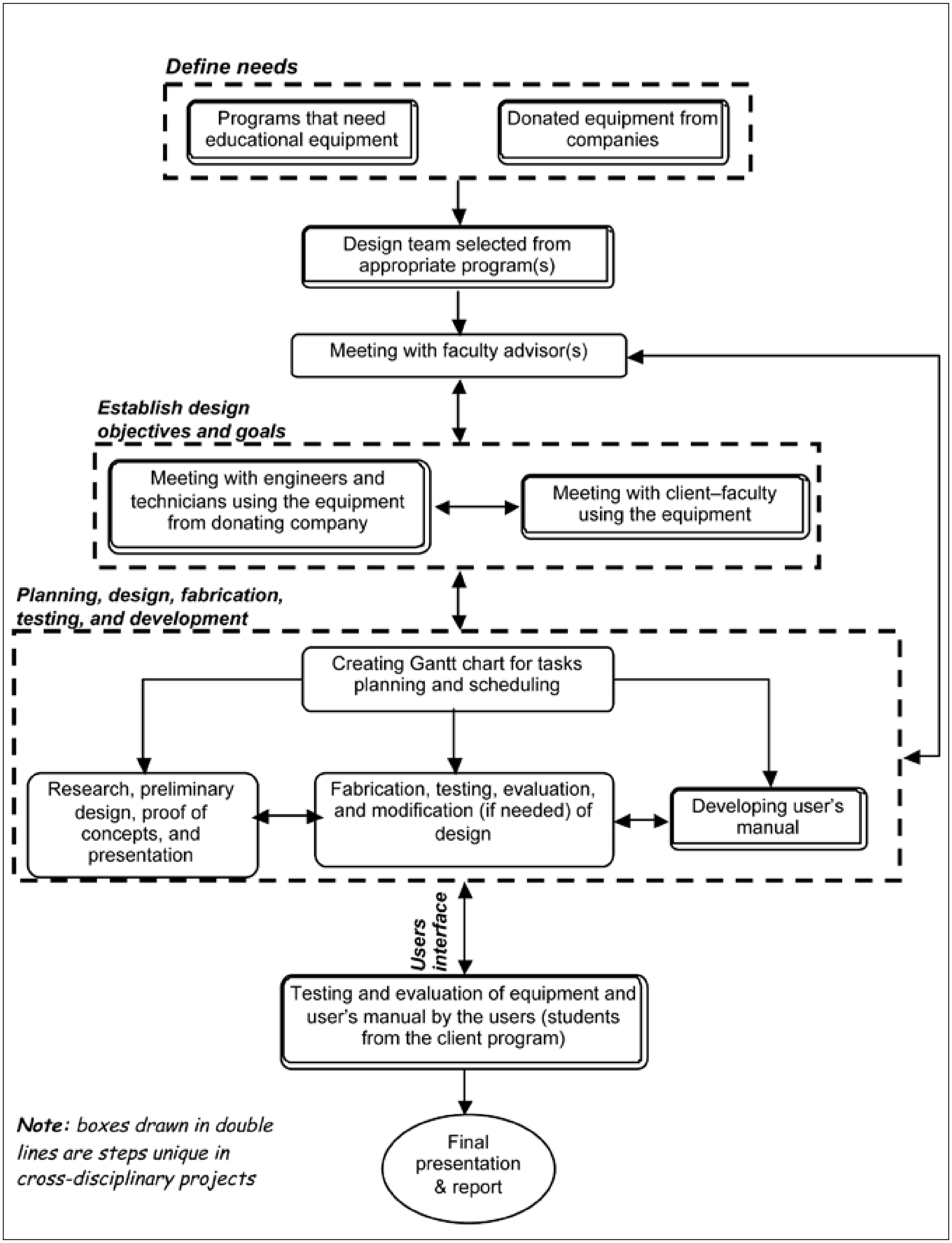

Figure 2 Organization and execution of a cross-disciplinary design project at MSU

Figure 3 A picture of the modified and automated direct shear apparatus

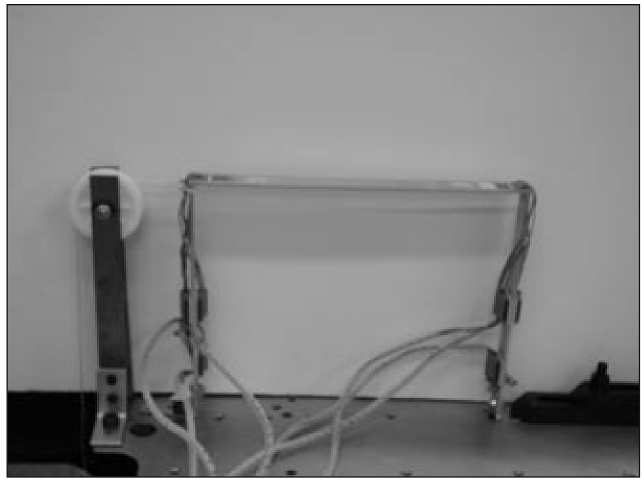

Figure 4 A picture of the portal frame test apparatuses

week, and what will be done about any unexpected major design issues that may have arisen during the previous week.

Interim and final presentations

The team was required to give a number of presentations to their design class discussing progress made in their project. For the final presentation, the public, representatives from the agency donating the equipment, the client, and the civil engineering faculty were invited to attend.

Final written report

The design team was required to provide a final written report with the following items: project overview, project scheduling and planning, design specifications and requested modifications, engineering drawings of all modifications, detailed analyses, lab manual, and other pertinent materials.

Peer evaluation

Students were asked to evaluate the performance of the other members of their design team. They were asked to use a numerical scale of 0 (no contribution) to 5 (the most contribution) to evaluate their team members' performance in: (a) teamwork, (b) helpfulness, (c) contribution to the project, (d) research effort, (e) knowledge of the project, (f) participation, and (g) overall performance. In addition, each student was required to include a self-assessment of his/her specific contribution to the project.

Design documentation maintained in a notebook

Students had to maintain a design logbook with the records of all meetings, calculations, drawings, and so on.

Producing a user's manual

In addition to the final written report, the team working on the direct shear project was required to produce a lab manual that would be used by the civil engineering students. The user's manual included information about the apparatus, operating procedure, experimental objectives, and theoretical background related to the experiments, experimental procedures, blank data sheets, results sought, and the required discussion.

Testing by client and providing feedback

Most design projects are tested and evaluated by the design team, and the final design is not usually assessed by the actual end-users before the product is released. In this project, however, the end-users (the civil engineering students) tested the product. They followed the instructions and information given in the user's manual and conducted the direct shear test. Any ambiguity in experimental procedures, theoretical background, sample data sheet, or expected results was reported to the design team for clarification and revision.

Other cross-disciplinary projects

During the last three years, because of the success of the direct shear project, other similar cross-disciplinary projects were carried out. A team of mechanical engineering students designed and fabricated a tri-axial consolidation testing apparatus—for our geotechnical engineering lab to test the strength of clay. Another team designed and fabricated a portal frame test apparatus to demonstrate the fundamental concepts related to mechanics of structures. A picture of the frame is shown in Figure 4 above.

Concluding Remarks

In this paper, we discussed an innovative approach to a cross-disciplinary senior design project that meets the ABET criterion 4 (major design experience) and at the same time creates additional laboratory equipment for an undergraduate curriculum in another engineering program. The modified direct shear testing apparatus has been used successfully for the past four years by the civil engineering students.

Upon completing the project, informal surveys—with a focus on the cross-disciplinary nature of the project—were conducted to evaluate the positive and negative aspects of this type of projects. The design team (mechanical engineering students), the end-users (civil engineering students), and the faculty all found the project to be beneficial and largely had positive comments. The survey revealed the following positive aspects:

1. this cross-disciplinary project offered many benefits, including low cost and strong interaction among students and faculty from different programs;

2. the traditional approach in providing realistic design experience for mechanical engineering students is to seek a project from a sponsoring company. While the end product may be used in other fields including civil engineering, the students (the design team) rarely have an opportunity to have direct interaction with the end-users;

3. although the civil engineering students were not involved directly with the design of the product, they participated as end-users and contributed to the learning experience of their peers. Our civil engineering students learned first hand the contribution that other disciplines make to their field of study. It is important for students to recognize how one engineering discipline contributes to another; and

4. the project not only provided the mechanical engineering students with product-development process experience, but also provided them with technical communication activities such as preparing a user's manual and writing experimental procedures.

The survey also showed that this type of project possesses some challenges. When faculty and students from multiple programs are involved in a project, careful planning and scheduling of the project, for example, is a must.

References

[1] LabView Manual, National Instruments.

Biographies

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Software Review

LightTools® for Illumination Design and Simulation

Reviewed by Shuping Wang, College of Engineering, University of North Texas

Introduction

LightTools® is a commercially available windows-based illumination system design and analysis software. It features multiple modules, with the Core Module being the prerequisite for the Illumination Module, the Data Exchange Module, and the Image Path Module. LightTools® allows optical modeling and simulation of optical systems and creation of virtual prototypes of optical system for a variety of applications. The Image Path module is mainly used with the CODE V® software [1] to exchange data; e.g., importing or exporting lenses from/to the CODE V®. The Data Exchange module is used to import and export computer-aided design models in different formats. In this article, only the key features included in the Core and Illumination modules, which are used primarily for design, simulation, and illumination analysis, are reviewed through a design example. The full descriptions of the software modular can be found at the manufacturer's Web site [2].

Basic Capabilities

With the Core and Illumination modules, LightTools® allows optical modeling, design, and illumination analysis. Users can create and modify the sources, receivers, and geometries in an optical system. Users can modify the geometry and surface qualities by using predefined optical properties in the built-in library or by defining the surface properties directly. A number of optical sources, including point source, surface source, and volume source with different characteristics such as the shape, power, spectral region, emitting direction, etc. may be defined by users. The types of receivers that may be created include surface, infinite far field, and finite far field. Illumination on the defined receiver can be analyzed by different methods in order to obtain information such as the light distribution on a receiver or the spatial distribution of the energy on a receiver. Some of the features are reviewed in the following sections.

Source And Receiver Creation

LightTools® supports a variety of sources; namely, point, surface, and volume emitters in different shapes. Fig. 1 shows an example of a point source that is located at the focal point of a faceted reflector that is available in the utility library. A surface receiver is created at some distance from the source.

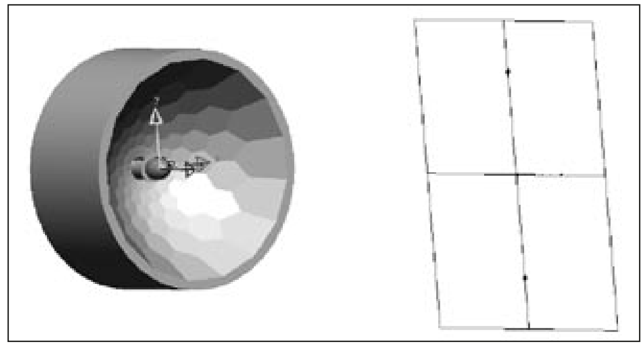

Figure 1 A point source located at the focal point of a faceted reflector.

Ray Tracing

After the source is defined with specific characteristics; the receiver is created and placed; and the geometry and the surface property of the reflector are defined, illumination simulation is performed. Fig. 2 depicts the ray preview of a simulation that traces a small number of rays to make sure that rays behave as expected. More rays are then defined and simulated for illumination analysis.

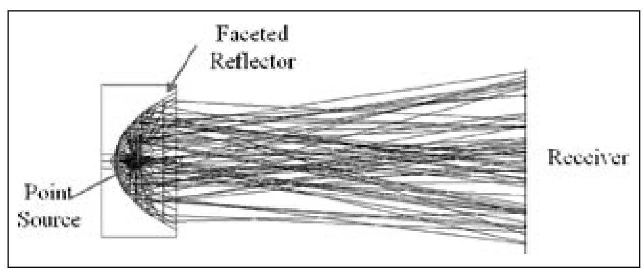

Figure 2 Ray preview of a simulation that traces a small number of rays.

Illumination Analysis

Illumination outputs on a specified surface (e.g., a receiver) can be analyzed by displaying simulation results, which are stored in memory, with user-specified illumination charts. The type of chart to be used depends on the objectives of the simulation. For example, the scatter chart shown in Fig. 3 allows seeing light distribution on the receiver, but not the information about the energy or statistics. A raster chart, on the other hand, provides information on the spatial distribution of irradiance on the receiver. As shown in Figure 4, a histogram is used to show the energy level.

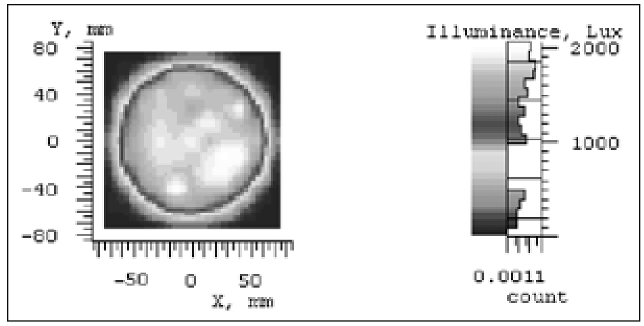

Figure 3 Scatter chart to show light distribution on the receiver.

Summary

Some of the features of the Core and Illumination Modules of the LightTools® are briefly reviewed. LightTools® is capable of creating virtual prototypes for a variety of applications although, as an example, only a simple optical system with one point source and one surface receiver is demonstrated in this article.

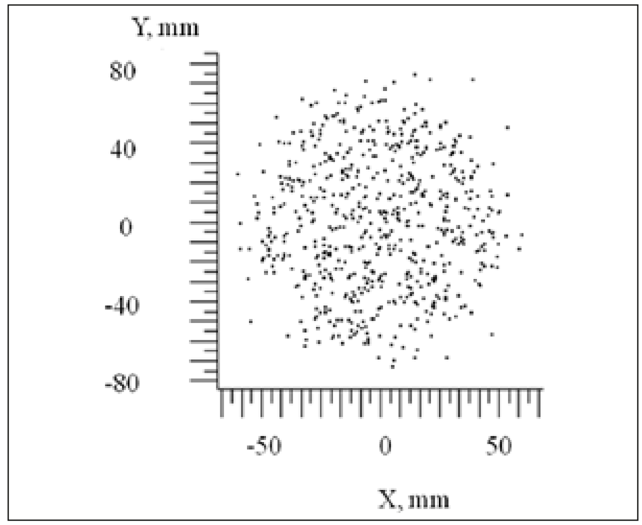

Figure 4 Raster chart to show the spatial distribution of irradiance on the receiver.

References

[1] http://www.opticalres.com/cv/cvprodds_f.html
[2] http://www.opticalres.com/

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Book Review

Digital Signal Processing: Fundamentals and Applications

Authored by Li Tan; Elsevier Science and Technology Books; ©2007

Reviewed by Dr. Vijay Vaidyanathan, Dept. of Engineering Technology, University of North Texas

Book Description

This textbook presents digital signal processing (DSP) principles, applications, and hardware implementation issues, through the presentation of numerous worked examples, while reducing the use of mathematics. Features include: * Real-time implementation of DSP algorithms using DSP processors * MATLAB programs for simulations and C programs for real-time DSP * Coverage of adaptive filtering with applications to noise reduction and echo cancellation * Applications of DSP to multimedia applications - such as u-law and adaptive differential pulse code modulation, sampling rate conversions, transform coding, image and video processing - show the relevance of DSP to a key area in industry * MATLAB programs, student exercises and Real-time C programs available at http://books.elsevier.com/companions/9780123740908 This text gives students in electronics, computer engineering and bioengineering an understanding of essential DSP principles and implementation.

Features

This book is targeted to meet the needs of electrical engineers and technicians who design and build hardware and software for DSP systems as well as senior-level students in Engineering Technology programs (electronic, biomedical, and computer engineering technologies) at technical colleges and junior-level students in traditional university engineering programs. Also appropriate for courses on instruction in government and industry.

Review

The clarity and flow of the material is fine and commensurate with the intended audience. Among other topics, the book covers definition of z-transforms, applications and examples. New material is explained clearly and key terms are defined clearly when introduced. The introduction to FIRs is very apt. The section on phase distortion effects is presented in a very cogent manner. Also, solved problems followed by MATLAB code examples, greatly enhances the learning experience for students. Application example at the end of the chapter is welcome and provides a practical perspective to students.

The level of the book is suitable for its intended audience. The depth of coverage is lacking in the chapter on z-transforms. The level of math in this chapter is on the lighter side taking into view the intended audience. The math level would increase once more topics such as region of convergence, stability of digital systems, convolution in the z-domain; bilinear transformation, etc. are added.

The content presented in the book is correct and also current. However, currency of topics would be better with addition of more topics, as stated below:

1. Region of convergence
2. Unit circle and stability condition, relating it to stability in the s- domain
3. Bilinear transforms – going from s to z domain and vice versa.
4. Application of z-transform in convolution
5. Typical characteristics of non-idea low-pass filter
6. Mention of the concept of recursive and non-recursive difference equations and the classification of the FIR filter.
7. Mention of moving average filters
8. Definition and properties of sinc function when approximating the behavior of the ideal Low Pass FIR filter.
9. Windowing – Kaiser window is not mentioned

Assertions in the book are backed up with further information and clear examples. Addition of MATLAB codes after solved examples is an excellent idea. Also, solving application examples introduces students to the practical world of DSP.

The figures in the book are illustrative of the material presented. The number of figures is just right. Topics on region of convergence and stability would benefit from figures pertaining to them.

All tables presented in this book are effective.

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