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SOFTWARE-HARDWARE LABORATORY INTEGRATION AND DISSEMINATION

Abstract

A course has been developed under an NSF grant to demonstrate a pedagogical approach for integrating software solutions and physical measurements into the experimental curriculum, and to allow interactive access of shared resources between educational institutions.

The rapidly evolving nature of technology makes it impossible for most schools to keep current with correspondingly expensive laboratory equipment to offer evolving technology courses. Conversely, the development of sophisticated and versatile software with constant upgrades provides an attractive alternative in computer simulations. However, educators and students become so dominantly indoctrinated and highly skilled at executing this software approach so as to blur the appropriate relationship between simulated and physically real results. This can compromise the desirable educational experience of physical procedure and the validation of real data. In order to allow access to experimental capability shared faculty expertise and facilities between institutions are needed.

The solution is to create, demonstrate and share laboratory-based curriculum in which computer simulations are integrated with experimentation. The resultant educational outcome will provide students and educators with an approach for understanding the capabilities, advantages, limitations, and validation of simulations relative to physical experience. The product is a course in which integrated computer simulations and physical experiments can be conducted and shared via direct Internet access by other universities. The existing College of Engineering Photometric Lab (largely equipped by a recent NSF ILI grant) has been networked with the just completed Lighting Computer Simulation and Studio Mock-up/Measurement Laboratories. An inventory of experiments have been developed in which students will create software lighting design models and then perform measurements to validate parameters such as illumination intensity, functional effectivity, and energy efficiency. Lighting is a national priority as it consumes approximately one-third of all expended electrical energy. This has resulted in national and state regulatory legislation for both new and retrofit lighting. This project will also establish the Internet protocol whereby any remote computer location can be granted access to and interactively participate in the developed experiments and facilities.

This project involves collaboration with Dr. Richard Mystick, of the Architectural Engineering Department and Global University at Penn State University in the design of experiments, and three California State Community Colleges with Lighting programs that will participate to demonstrate and evaluate the transportability of the course. This network will provide a model for the 23 California CSU campuses, the 122 California Community College campus systems, and any other interested education institutions.

Introduction

An Illumination Engineering Minor at California State Polytechnic University has been on going since 1993 with the awarding of an $805,000 grant from the Department of Energy (PVEA funds) to expedite the development of a lighting education program in California. A grant of $87,319 along with University and Corporate matching funds and donations of more than $117,000 were used to improve the existing Photo-optical, Lighting, and Electrical photometric laboratory facilities. A partial view of this laboratory is shown in Figure 1. The laboratory is equipped with modern equipment capable of making most of the measurements for characterizing both lamps and ballasts performance. The five-foot black integrating sphere shown in the background is calibrated with lamps traceable to NIST. It is used to measure efficacy, lumen output, chromaticity, and output of a lamp versus wavelength. Data from this laboratory can be used as input to software programs such as AGI-32 when designing a lighting system. Although, most manufacturers supply the necessary data files with their commercial fixtures and lamps, the resulting lighting characteristics such as intensity gradients, color, and shading on combining fixtures to light a given space for a given application must be established.

The Approach

This paper presents the results of developing three laboratories and then combining their capabilities to give students to ability to start with the measuring the basic parameters of lights and luminaries and ending with a computer simulation of an actual lighting system and then verifying the results in a mock-up/measurement laboratory. The three laboratories are:

- Photo-optical, lighting, and electrical systems laboratory
- Modeling/simulation laboratory
- mock-up/measurements laboratory

Educators and students can become so dominantly indoctrinated and highly skilled at executing a software approach so as to blur the appropriate relationship between simulated and physically real results. This can compromise the desirable educational experience of physical procedure and the validation of real data. A grant of $180, 000 from the Department of Energy (DOE) and administered by the California Energy Commission was used to upgrade the modeling/simulation laboratory shown in Figure 2 and construct a mock-up/measurements laboratory shown in Figure 3.

Figure 1. A Partial View of the Photo-optical, Lighting, and Electrical Systems Laboratory.

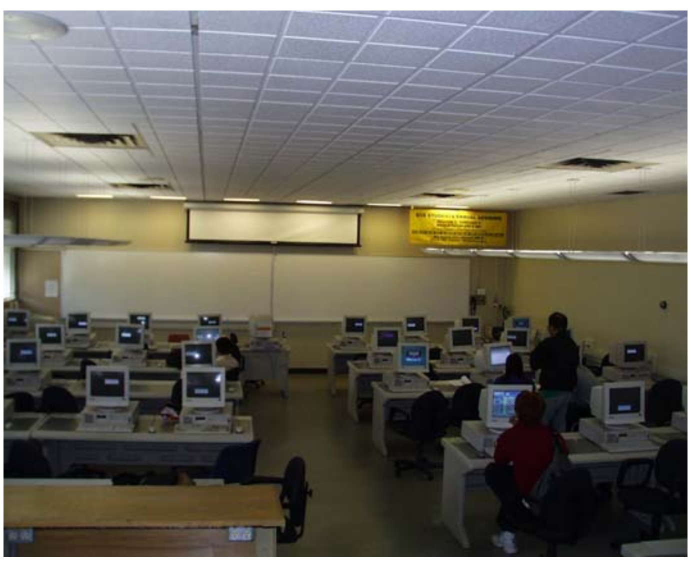

Figure 2. View of Modeling/simulation Laboratory

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The juxtaposition of these laboratories affords students the opportunity to simulate a lighting design then verify the results in the mock-up/measurement laboratory. Making these laboratories available over the internet to other universities that do not have the physical laboratories will enhance the educational experience of students at those institutions. Remote sites can request that the host university mock-up a particular lighting scenario. Data from the mock-up can be transferred to the requesting university over the internet, either in real time or as archived data that can be accessed at the leisure of a remote student. Security of the data is provided by passwords. An inventory of experiments have been developed in which students will create software lighting design models and then perform measurements to validate parameters such as illumination intensity, functional effectivity, and energy efficiency. Results of a typical computer simulation are shown in Figure 4. This simulation was performed using AGI-32. The simulation shown is a student simulation of the lighting system in the Modeling Laboratory shown in Figure 2.

Figure 3. View of Mock-up/measurement Laboratory.

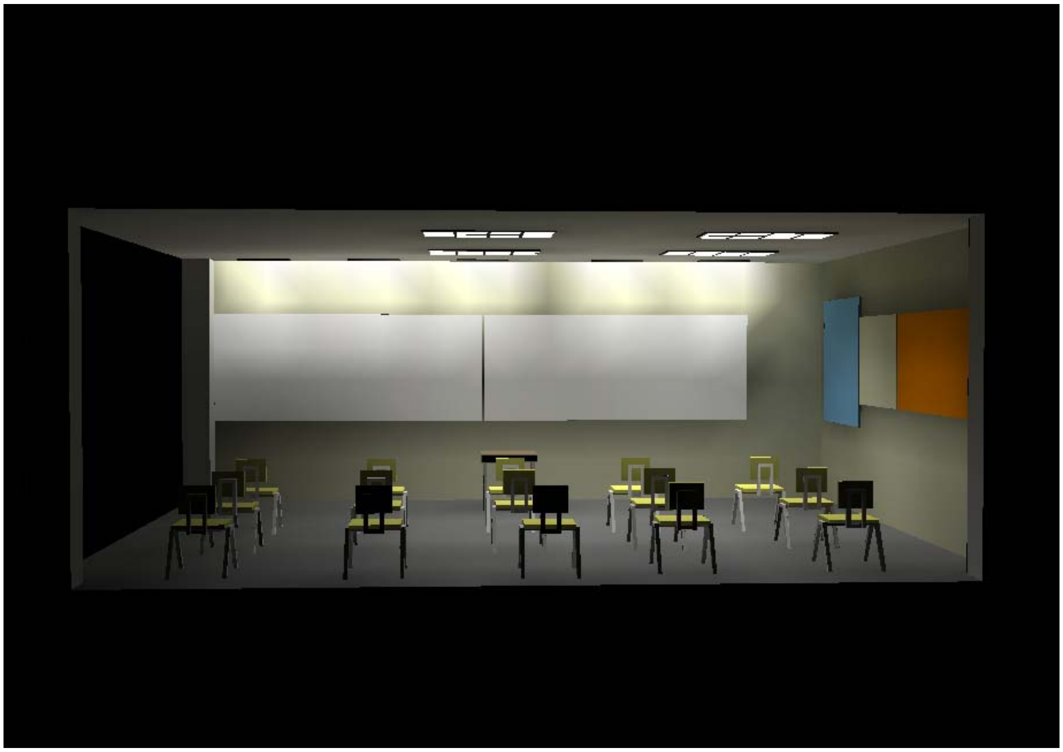

Figure 4. Computer Simulation of the Mock-up/measurement Laboratory Lighting System.

The first course to utilize the new facilities and capabilities was offered in the Fall Quarter of 2002. In the mock-up/measurement Laboratory a 16-channel photodiode array and amplifier shown in Figure 5 is used to measure the actual illumination levels at locations defined by the computer simulation software. A film of typical measurement has been made and can be viewed on the Internet. The use of a film rather than a real time video connection reduces the Internet bandwidth required to share an experiment. Students viewing the film will have an orientation of what can be accomplished in the mock-up/measurement Laboratory.

The photo diode array is connected to a desktop computer, which is connected to the University's Ethernet. The computer contains the software LabVIEW and a 16-channel analog-to-digital I/O card. A LabVIEW virtual instrument is used to make measurements using the 16-channel array. Control of the measurements is done though a LabVIEW virtual front panel shown in Figure 6. The front panel contains a chat room that allows the host university to directly converse with a remote university in real time. This allows the host university to configure the model according the specifications provided by the remote university. Some typical requests by the remote site experimenter are the placement locations of the photo sensors and the type of fixture to be placed in the moveable ceiling. Overall a Lutron Corp. dimming system using RF remote controllers controls lighting levels of each light in the modeling laboratory. The results of typical measurements are shown in Figure 7. The output can be displayed as a data array and as a 3-D plot shown in Figure 8. Successive data output can be displayed as spread sheet, graph or any desired form independently at the remote site and at the experimental site.

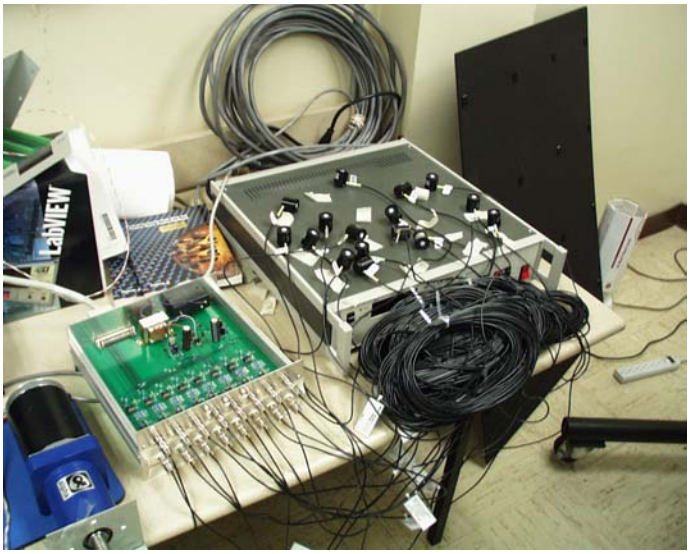

Figure 5. 16-Channel Photo Diode Array located in the Modeling Laboratory.

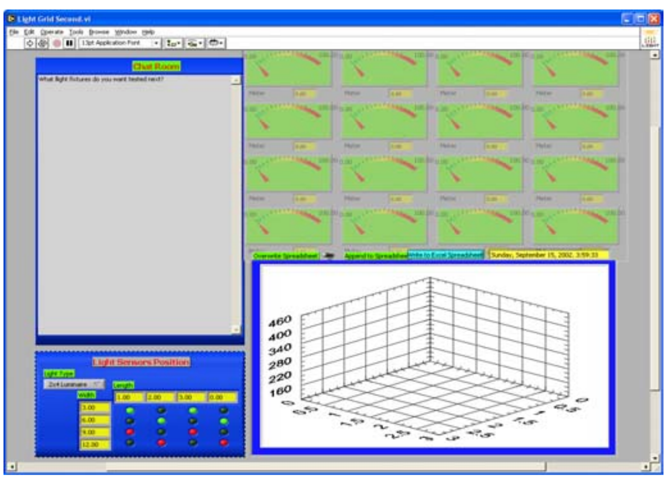

Figure 6. Front Panel Diagram of LabVIEW Virtual Instrument used to Control measurements

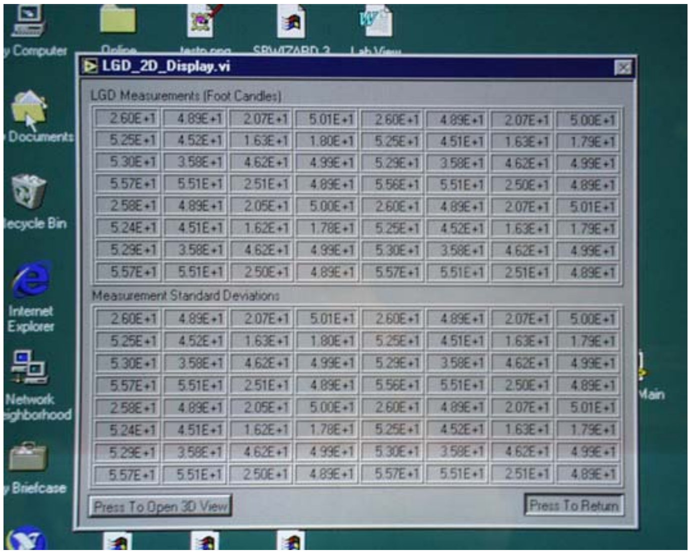

Figure 7. Typical Data Resulting from Measurements using a 16-Channel Photo Diode Amplifier connected to a computer using LabVIEW.

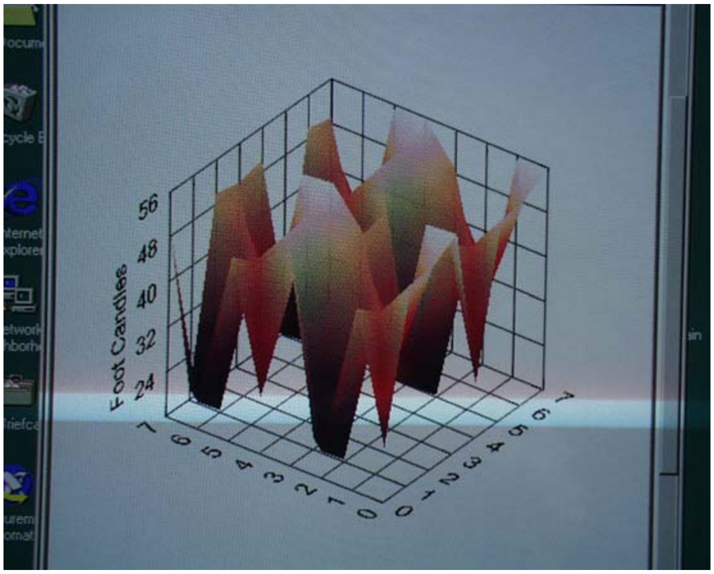

Figure 8. A Typical plot of the data shown in Figure 7.

Course Outline

I. COURSE DESCRIPTION

ARC 499/499L Advanced Architectural Lighting Design and Analysis (3/1)

Advanced architectural lighting design and analysis using computer simulation and laboratory experiment to understand parameters that affect lighting system performances, calculations, and design applications. Three hours of lecture and one hour of lab exercise per week.

II. Required Background or Experience

Prerequisite: *EGR 299, ARC332 and at least junior standing* with approval of instructor.

III. Detailed Description of the Course

A. Expanded Description of the Course

1. Introduction to architectural lighting and design parameters.
2. Lighting design criteria and procedure.
3. Preliminary design considerations.
    a. Energy considerations
    b. Cost considerations.
    c. Types of lighting systems.
    d. Functional objectives: artistic effect, computer workstation, or safety.
4. Luminaires types, sources, characteristics and efficiency.
5. Detailed design calculations and laboratory measurements.
    a. Lumen method.
    b. Illuminance and brightness.
    c. Coefficient of utilization.
    d. Zonal cavity method.
6. Daylighting and design considerations.
    a. Characteristics of Daylighting.
    b. Daylight analysis method.
    c. Physical modeling in Daylighting design.
    d. Computer assisted simulation.
7. Computer simulation methods.
8. Lighting design applications.
    a. Residential buildings.
    b. Educational facilities.
    c. Commercial Interiors.
    d. Industrial Lighting.
9. Outdoor/Landscape lighting applications and considerations.
10. Lighting control

11. Computer aided design analysis.

B. Methods of Instruction and Evaluation
Lecture/seminar, field trips, computer labs, lab experiments and examinations.

C. Expected Outcomes

The student will be able to:
1. Understand and describe various types of lighting systems
2. Propose appropriate types of lighting systems for specific applications.
3. Explain the energy related criteria of lighting design.
4. Calculate the performance of specific design proposal.
5. Explain and calculate the integration of daylight design.
6. Utilize computer analysis methods for various designs.
7. Explain the outcomes of lighting design.

D. Minimum Student Materials
Text and standard materials for design and computations

E. Minimum University Facilities
Standard studio laboratory

IV. Text and References

Schiler, M., Simplified Design of Building Lighting, Wiley & Sons, 1992.
Michel, L., Light: The Shape of Space – Designing with Space and Light, V. Nostrand Reinhold, 1996.
IES Lighting Handbook, Application Volume, 9th Edition, 2000 version

Lighting Design Competition of IES-LA web site: www.iesla.org under scholarship.

Summary
This project has developed and conducted a prototype course that demonstrates the integration of software simulation and physical measurements into the experimental curriculum. That is, verifying the correctness of simulation results is an important step in the problem solving procedure. The subject matter addressed in the course is software lighting design coupled with photometric measurements. This involved three computer networked laboratories at Cal Poly Pomona University. The capability was also developed to allow remote access and interactive participation by other universities via the Internet. A follow up activity is anticipated to demonstrate the remote conduct of experiments by one university in another university's laboratory.

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R. FRANK SMITH

R. Frank Smith received his BSEE from New Mexico State University in 1965, Master in Business Administration from Pepperdine University in 1974, and MSEE from California State Polytechnic University in 1993. He worked for McDonnell Douglas, General Dynamics, and General Motors. He worked for Kaiser Steel Corp. for 19 years and has taught at California State Polytechnic University for 16 years. He is the co-author of several books and has patents in the medical field. His current research interests are in the biomedical instrumentation and illumination engineering field. He is director of the Photo-optical, Lighting, and Electrical Systems Laboratory and technical director of the Lighting Education Program. He is a member of the IESNA and ISA and is also a registered engineer in both electrical and controls.

MARV C. ABRAMS

Marvin Abrams received his B.S. and M.S. in Chemistry from the University of Nevada and Ph.D. in Physical Chemistry from Washington State University. He has undergraduate minors in biology and mathematics, and a graduate minor in physics. For the past eight years he has been Coordinator of Technology Initiatives and Manager of Lighting Programs for the College of Engineering. He is also a teaching faculty member of the Colleges of Engineering and Science. He spent 33 years in the aerospace industry where he was Chief Scientist for Lockheed Aeronautical Systems Company and Manager of Materials, Processes and Manufacturing Technology for General Dynamics. His research interests have been in spectroscopy of high temperature gasses and combustion mechanisms. He has published over 20 papers in the classified and unclassified literature. He is a member of the American Chemical Society, Illumination Engineering Society and the Engineering Educators of America.

Hofu Wu, ArchD, FAIA

Over the last 20 years, Dr. Hofu Wu has taught the integration of energy efficient systems and architectural design in Michigan, Arizona State, and Cal Poly. His leadership roles on professional technical committees have generated several national standards for energy efficient systems and design. His researches in passive cooling strategies, daylighting and solar energy applications are highly recognized internationally. As a professor of Architecture and director of Cal Poly Environmental Design Technology Unit, Dr. Wu has developed many "learning by doing" course wares that challenge future architects on the integration of advanced technology with renewable energy resources and innovative architectural solutions. Dr. Wu holds a Bachelor of Architecture degree from Tamkang University in Taiwan, a Master of Architecture degree from University of Illinois, Urbana-Champaign and a Doctor of Architecture from University of Michigan.