Experimental Validation of Computer Simulations Increases the Synergy Between Simulation and Physical Reality

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Abstract

This paper discusses the development of course materials at California State Polytechnic University, Pomona, CA. that will demonstrate a pedagogical approach that allows the synergism of computer simulations and laboratory experimentation. The model being developed will include shared resources with other schools through computer access of physical laboratory facilities between academic institutions. The goals of this project are directly responsive to significant areas of educational and national concerns. The primary goal is in response to the dynamic and diverse expansion of new high technology subjects that make it very difficult for many academic institutions to keep pace. The rapidly evolving nature of technology makes it impossible for most schools to keep current with correspondingly expensive laboratory equipment and to offer newly evolving courses. Conversely, the development of sophisticated and versatile software with constant upgrades provides an attractive alternative in computer simulations. Educators and students can become dominantly indoctrinated and highly skilled at executing this software approach to the extent of blurring the appropriate relationship between simulated and physically real results, thus compromising the educational experience of physical procedures and the validation of real data with simulated data. Shared expertise/facilities are needed to be responsive to educational programs that typically require new expensive physical laboratories and faculty with appropriate expertise.

Introduction

Development of 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. This grant resulted in the development of a six course curricula for community colleges and an Illumination Engineering minor for the College of Engineering at Cal Poly Pomona. In addition, curricula for a Design-Architecture lighting minor was also developed. Approval of this minor is still in progress. To revitalize its Photo-optical, Lighting, and Electrical Systems Laboratory the Electrical and Computer Engineering (ECE) Department received a National Science Foundation Instrumentation Laboratory award. This grant of $87,319 along with University and Corporate matching funds and donations of more than $117,000 were used to improve the existing facilities. A partial view of this laboratory is shown in Figure 1.
This laboratory supports the two laboratories that were developed under a $180,000 grant from the Department of Energy (DOE) and administered by the California Energy Commission. These two laboratories are the Lighting Modeling/Simulation Laboratory, Figure 2 and the Mockup/Measurement Laboratory, Figure 3. The laboratories located in the College of Engineering are available to lighting students and faculty in the Agriculture Department (Landscape Lighting), Interior Design Department, Theatre Department, and the Architecture Department. These laboratories give the students the opportunity to do research and thus encourage them to publish technical papers.
A KECK grant in the amount of $500,000 was awarded for the development and demonstration of real time remotely operated experiments and data collection. Several laboratories across the
campus were selected for this project. The Photo-optical, Lighting, and Electrical Systems Laboratory is one of the laboratories that participated in this project. The networking methods learned in this project are being applied to the Lighting Mockup/Measurement Laboratory. The computers in this laboratory are connected to the campus LAN and some are connected to the new high speed optical fiber network. The campus wide network allows students and faculty in one location to observe an experiment being performed at another location and have the experimental data loaded into their computer for analysis. Presently, an experiment can be performed in the Photo-optical, Lighting, and Electrical Systems Laboratory and the results can be observed by anyone on the internet. At this time only one experiment is available to the internet. Faculty from other universities or industrial participants can request that a particular luminaire be tested and the photometric data posted to the internet. The process can be observed in real time on the internet.

A new grant from the National Science Foundation under the CCLI-Educational Materials Development program in the amount of $74,650 will endeavor to solve the problem of the rapidly evolving nature of technology and how it makes it impossible for most schools to keep current with correspondingly expensive laboratory equipment to offer conventional courses. Conversely, the development of sophisticated and versatile software with constant upgrades provides an attractive alternative in computer simulations. Educators and students can also become dominantly indoctrinated and highly skilled at executing this software approach to the extent of blurring the appropriate relationship between simulated and physically real results, thus compromising the educational experience of physical procedure and the validation of real data with simulated data. Shared expertise and facilities are a necessary part of the pedagogical approach.

The Approach

The objective 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 correlation/validation of simulations relative to physical experience. Courses developed using this technique will feature integrated computer simulations and physical experiments with direct Internet access by other universities to participate and share resources. The methodologies being developed under a National Science Foundation CCLI-Educational Materials Development grant will assist other educators in expanding and improving their curriculum by juxtaposing physical measurement with computer modeling/simulation labs.

Three physically separate laboratories will be used to accomplish the goal of providing resources so that students can model and simulate a lighting design on a computer work station. These laboratories are:

- The photo-optical, lighting, and electrical systems laboratory
- The modeling/simulation laboratory
- The mock-up/measurement laboratory

Students have the option of using standard Illumination Engineering Society of North America (IESNA) photometric files supplied by fixture manufacturers or they can take a fixture to the photo-optical, lighting, and electrical systems laboratory. There they can generate their own IESNA compatible photometric files for use in the Modeling/Simulation Laboratory. All of the software must have IESNA formatted models of the lighting fixture to be simulated otherwise a
simulation cannot be performed. This procedure is similar to building models in a netlist for PSpice before a circuit simulation is performed. Software has been purchased for converting data from a goniophotometer into an IESNA file format. A goniophotometer is presently under construction in the photo-optical, lighting, and electrical systems laboratory. Following a design simulation, students can construct a real physical lighting system in the mock-up/measurement laboratory that has a moveable ceiling that allows different lighting fixtures to be installed. First the ceiling (12’ X 12’) is lowered and the appropriate fixtures are installed and connected to the proper electrical circuits. After the ceiling is raised, the students can then use a LabVIEW based data acquisition system to collect photometric data for comparison with the simulation data. With the assistance of several students a 16-channel photodiode amplifier was designed, constructed, and calibrated. This multichannel amplifier interfaces a photodiode array with National Instruments MIO-16 A/D card in the computer designated for making illumination level measurements in the mock-up/measurement laboratory, see Figure 5. In the photo-optical, lighting, and electrical systems laboratory students can determine many other characteristics of their selected lighting fixtures such as chromaticity, spectral distribution, EMC conducted and radiated emissions, power harmonics, in-rush current, efficacy, and sputtering time.

Figure 5. 16-Channel Photodiode Amplifier and Photodiodes

Software is also available to simulate the response of different reflector/lamp combinations. If a student constructs a fixture based on a ray-tracing simulation, then the fixture can be taken to the photo-optical, lighting, and electrical systems laboratory where its actual optical characteristics can be measured on a goniophotometer (under construction,) and then it can be placed in an integrating sphere where its luminous efficacy, chromaticity, and spectral distribution can be measured.

Lighting Modeling/Simulation Laboratory

The Lighting Modeling/Simulation Laboratory is equipped with 32 Hewlett Packard computer workstations, 16 of which were donated by Hewlett Packard and the rest were purchased under the DOE grant. As part of this project, various lighting simulation software was installed on these computers. In addition software for performing energy calculations in accordance with California Energy Commission Title 24 Energy Code is installed on the computers as well as software for making electrical systems drawings such as one-line diagrams and panel schedules. Some of the software requires AutoCAD based plan and elevation drawings. Keeping all of this software up to date will be a major task for the laboratory staff.
Sample Experiment
The following experiment presents an exercise that is used to provide students with an experimental validation of a computer simulation so as to increase the synergy between a simulation and physical reality.

ADD experiment Here

The computers are operated under a Windows NT operating system through a central server. A variety of Lighting simulation software and other supporting software are installed on the computers. The major software used by the Illumination Engineering Students is:

- Lumen Micro
- PSpice
- AutoCAD
- MathCAD
- Light Scape
- Title 24 Compliance
- Reflector Design
- Microsoft Office

The design of the lighting in this laboratory was used as a class project by an architectural student. This design was reviewed and modified by various manufacturers. The final design was reviewed by members of the Industry Advisory Committee, which meet regularly with Cal Poly Pomona faculty to review the lighting program. The laboratory is equipped with a state-of-the-art infrared lighting control system designed by students in the ECE 492 course. It is also equipped with the latest projector system that can project from four different sources including a digital camera for projecting high quality images directly from texts and magazines.

Figure 4. Sample of Lighting Modeling/Simulation using the software Lumen Micro

Lighting Mockup/Measurement Laboratory
The Lighting mockup/measurement laboratory is a 30 by 40-foot laboratory that has a 12 by 12 foot section of ceiling that can be lowered from its highest position of 10 feet down to 3 feet. In its lowered position, students can install different fixtures into the 2 by 2 foot grid and connect each fixture to a circuit which can control the lights once the moveable ceiling is raised. Once the ceiling is raised a matrix of light sensors can be placed on the floor below the grid and on the surrounding walls to measure the light distribution. The matrix of LI-COR light sensors is connected to a National Instruments data collection system. Students will be able to enclose the simulation area with different office type partitions so that the effects of different materials and colors on a student-constructed mock-up can be measured and studied. Furniture can also be placed in the work area. This laboratory is being modeled after similar labs that are being used by utility companies. Data taken in the mockup laboratory is compared with data from the simulation runs in the simulation laboratory. Students obtain immediate feedback on correlation/validity of their computer simulation.

Photo-optical, Lighting and Electrical Systems Laboratory

The NSF-supported photo-optical, lighting, and electrical systems laboratory consists of nine workstations that can perform various measurements. This laboratory was completed in December 1998 under a National Science Foundation ILI grant and matching funds totaling approximately $270,000. It contains advanced data acquisition equipment consisting of 16-channel MIO-16 data acquisition boards operating under LabVIEW and 20-channel NetDAQs donated by John Fluke Co. The laboratory is divided into different functional areas. For example, one area is dedicated to an integrating sphere while another area is dedicated to an environmental test chamber.

Conclusions

The authors are the principals responsible for establishing and advancing academic education programs for the State of California and for the profession. This experience along with advisement from their industry partners has expanded the facilities available to faculty and disciplines across the Cal Poly Pomona University campus. The latest additions to the facilities consist of two new laboratories, the modeling/simulation laboratory and the mock-up/measurement laboratory. These laboratories contain the necessary software and hardware to mathematically model lighting system components, simulate a lighting design, and then validate the design by constructing the lighting system with real hardware. The design is validated by the taking of data from the real hardware system and comparing it to data obtained by computer simulation. Students obtain immediate feedback on the capabilities, advantages, limitatons, and correlation/validation of simulations relative to physical experience. The operation of the modeling/simulation laboratory and the photo-optical, lighting, and electrical systems laboratory will have the capability of being operated and viewed remotely across the campus.

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Bibliography


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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.