Special Session - Real World Engineering Projects: Discovery-Based Curriculum Modules for First-Year Students

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Abstract – **This special session is organized to provide an interactive forum for the introduction of a set of curriculum modules developed under IEEE's Real World Engineering Projects (RWEP) program. The modules, available to the public via a RWEP web portal, are designed for use in the first-year engineering and computer science classroom, and are hands-on, team-based projects that emphasize the societal impact of the work that engineers do. After a brief introduction to the RWEP program and the curriculum modules, the authors of the modules will present their ideas and demonstrate the laboratory activities associated with their modules in interactive, informal simultaneous sessions.**

Index Terms – laboratory instruction, first-year students, curriculum development, and engineering education.

SESSION GOALS AND EXPECTED OUTCOMES

The goal of this session is to showcase new curriculum materials that have been developed for first-year students in the IEEE fields of interest (electrical engineering, computer engineering, computer science, and electrical engineering technology) under IEEE's Real World Engineering Projects (RWEP) program. Each module showcases how the work of engineers directly benefits society. The modules are designed as stand-alone units, so that they can easily be adopted by faculty for use in the first-year classroom. The modules are expected to make the related fields of interest more relevant to first-year students. Their use will improve retention of students by allowing them to discover the importance of a contemporary problem, and excite their interest in creative solutions. The modules make use of activities that allow students to discover key concepts about engineering science and design in a hands-on way; they demonstrate how and why technical methods work, rather than simply providing a recipe for a solution. The societal impact focus of the modules is expected to help particularly with the retention of women students.

The expected outcomes of this special session are that attendees:

- Will be encouraged to use or adopt curriculum material for use in their own classrooms.
- Will engage in discussion about the importance of relaying to their students the benefit to society of what engineers do.
- Will exchange information on learning methods that successfully engage first-year students and support recruitment and retention of those students.
- Will be made aware of future opportunities to contribute to IEEE Educational Activities Programs curriculum development efforts, particularly through grants from future rounds of the RWEP program. This awareness will help the RWEP "gain momentum" in building and strengthening its library.

SESSION AGENDA

The session will begin with a 10 minute overview of the Real World Engineering Projects program, followed by a brief (10-minute) introduction to the six projects and a short question and answer session. The bulk of the session (60 minutes) will be used for live project demonstrations by the authors of the curriculum modules. Six authors will simultaneously provide informal presentations, akin to a "poster session". Each project will have its own demonstration table, with posters of information and hands-on demonstrations and/or videos. This will allow for audience members to interact directly with the authors, and to try out the same sorts of activities that are proposed for the students. This will give audience members a strong sense of how the activities might work at their own institutions, and an opportunity to talk interactively with the authors about their own experiences with the project in the classroom.

HIGHLIGHTED RWEP PROJECTS

Manipulating Everyday Objects with Prosthetic Hands

Chris J.B. Macnab, James A. Smith, Laurence E. Turner, and Karl Kalveram

The-elbow prosthetic arms and hands have assisted people for hundreds of years, but traditional designs rely on stiff components with limited functionality. Engineers and scientists are revolutionizing prosthetic design by incorporating sensors, actuators, elasticity, and microelectronics. Devices that operate precisely, flexibly, and intuitively allow amputees to lead fuller lives, achieving a more just society. As the nature of the disability varies from one person to the next, the range of problems and solutions is equally varied. Providing affordable custom engineering of such devices requires a new way of thinking about product design and development.

In this project students create an artificial hand (gripper) that passes a coffee cup to a person. The students build a prosthetic input suitable for an amputee. This project relies on Lego Mindstorms NXT robotics rapid prototyping kits. These kits, featuring programmable microcontrollers, sensors, actuators and key mechanical components, provide an intuitive, time-efficient, and cost-effective platform for developing ideas. Adding springs or elastics provides more natural motions and forces. Sensors attached to arms or body allow the user to provide commands, analogous to the neuromuscular inputs in modern prosthetic devices.

In order to meet project requirements, the resulting prosthetic gripper hand must:

1) grip and then lift an empty disposable foam coffee cup 5cm off the table,
2) grip and then lift a weighted (full) coffee cup 5cm off the table,
3) allow a person to take the coffee cup out of the gripper, without releasing the gripper
4) receive commands from a sensor located on the user's body (not on legs or hands)

The first three requirements encourage gripper designs that incorporate an elastic element (spring or elastic band). The project consists of four main lab activities. The engineering design philosophies familiarization-functionality-test (FFT) and express-test-cycle (ETC) guide the structure of the labs, providing the students with an introduction to engineering methods. During the familiarization phase, students learn not only about the Lego NXT hardware and software but also discover the basic mechanical and electrical principles involved by conducting experiments (including Hooke's law, electric motor constants, sensor accuracy and repeatability).

In a two week period the students discover some basic mechanical, electrical, and software principles. They experience the fun of designing, building, and programming a robotic device. The formal engineering design structure of the labs introduces students to the engineering paradigm. The scope and purpose of the project inspire students to envision technology solutions for achieving a more just and equal society.

Digital Communications: Error Correction Codes for Wireless Communication Systems
Sami Khorbotly

In the high technology era, wireless communication systems have become an integral part of everyone's daily life. Emerging wireless communication systems are expected to transmit high data rates to provide a wide range of services including high quality voice, data, images, video, and multimedia. In a wireless communication channel, the transmitted signal propagate from the transmitter to the receiver via multiple paths where the signal encounters obstacles and mixes up with interfering signals. The multi-path propagation and the interfering signals weaken the transmitted signal resulting in errors at the receiver end.

In order to eliminate/reduce the errors in the received signal, error correction codes (ECC) are used. The simplest ECC is the n-redundancy coding. In this type of coding, every data bit is encoded in an n bit codeword. For example in a 3-redundancy coding, a '0' data bit is encoded as '000' and a '1' data bit is encoded as '111'. This scheme can correct one bit per codeword at the expense of having a data transmission rate of 1/3 of the overall transmission rate. Similarly, a 5-redundancy coding, corrects up to two bits per codeword at the expense of further reduction in the data transmission rate. More sophisticated coding schemes, like block coding and convolutional coding, if well designed, can achieve higher error correction at a relatively lower cost.

The project is based on a Matlab simulation of a wireless communication system. A data signal (ASCII text or JPG image) is converted to a binary vector, encoded, modulated, and transmitted through a simulated wireless communication channel. At the receiver end, the received signal is decoded and converted to its original format (text or image). Also, the received data vector is compared to the transmitted vector to measure the bit error rate (BER) of the system.

Students, supplied with the Matlab simulation codes for the data conversion, modulation, and channel simulation, will be asked to develop the error correction coding/decoding blocks. Students will then run their simulations to create plots of the BER of the n-redundancy systems against the values of n to understand the performance-cost trade-off.

Block and convolutional coding will then be explained and student teams will develop their own codes. The performance of the various codes will be investigated using the simulation block to identify the systems with the best performances for various data transmission budgets.

The project helps students understand the importance of computer simulations as well as teaching them how to model a real-life phenomenon/system and develop simulation blocks. The project also demonstrates the performance-cost trade-off in the context of a real-life problem.

The author of this paper will explain the different blocks in the system and demonstrate the simulation for both images and text data. The audience will be able to observe the efficiency of the ECC, not only by looking at the BER figure, but also by seeing the quality of the received text/image.

Solid State Lighting for the Developing World a Real-World Engineering Project

Loren Wyard-Scott and James A. Smith

About two billion people in the world's under-developed nations do not have access to modern forms of energy. Hand-in-hand with this is a lack of access to modern forms of lighting, forcing these people to resort to using kerosene wick lamps or candles. These devices are relatively expensive, inefficient, and the gases they produce (such as Carbon Monoxide and Sulphur Dioxide) are dangerous. While taken for granted in the world's developed nations, the lack of safe and reliable sources of light after dark has a profound negative effect on the socio-economic condition of people in under-developed nations. Without adequate lighting, education and economic development programs suffer: it is difficult to improve literacy when there is insufficient light to read a book or a blackboard. Recently, non-governmental organizations have suggested that solid-state devices, in conjunction with small-scale energy sources, could be used as an alternative to devices such as kerosene wick lamps or candles. The technical challenge is to develop an inexpensive, reliable, clean and safe source of light for those who currently do not possess it.

In this project, students learn about the properties of light, the basic concepts governing operation of devices such as LEDs, photoresistors, and batteries, and about the engineering design process in general. The design process is constrained by realities particular to the creation of useful technology in the developing world. The students work in teams to design, fabricate and package portable light sources that meet predefined specifications for cost, weight, time-between-recharging and conditions of the operating environment. A variety of solutions are encouraged to tap into the resourcefulness of today's engineering students. Students test the solutions under realistic conditions to evaluate reliability and ruggedness. Cost, environmental impact, usability, and simplicity of maintenance of solutions are examined.

Power Electronics/System: A Look at Renewable Energy

Taryn Bayles and Jonathan Rice

Introduction and Impact: As the world moves further into the 21st century, the need for development in the field of renewable energy is becoming more apparent. The amount of fossil fuels available continues to decline and statistics show that only one barrel of oil is discovered for every six that are utilized. In fact, if the current rate of consumption is maintained, worldwide oil reserves are slated to last only for the next forty years. Even the reserves for natural gas may become depleted in approximately eighty years. While there has been an increase in developments for hydro, wind, and solar powered systems over the past few decades, it is essential that the technology continue to grow, specifically in the generation of students who represent potential engineers to solve the energy issues over the ensuing century.

Hands-On Project: Students are asked to design, construct, test, and evaluate a device that simulates a system for collecting, storing, transporting, converting, and utilizing renewable energy from a water, wind, or solar source. The overall goal of the project is to light a 1 cell AAA Maglite® light bulb after being allowed to collect energy for up to two hours. The students are offered the following possibilities for sources: water at an approximate flow rate of 0.5 liters per second; solar energy provided by a 90-watt flood light; and wind energy provided by a box fan with settings of 166 watts, 117 watts, or 87 watts. The system must be constructed on a maximum budget of $100.00, which includes any parts outside of those providing the "source," and operate with the utmost regard to safety. Performance is judged based on power generated, system efficiency and device cost index.

This project was developed as the overarching design project to be used with a series of precursor hands-on activities to provide insight into the individual processes prior to the generation of the final system. It is designed in a fashion which allows its implementation as a stand-alone activity, which has already been tested in two college-level introductory engineering courses and a high-school outreach engineering program. For either method of implementation, students will learn about the challenges surrounding renewable energy, specifically realizing the low efficiency associated with these processes. Five hands-on activities will be demonstrated along with videos of successful energy system design solutions

Feedback Controlled Brushless DC Motor

Stephen Williams

Introduction to the Technical Problem Solved and to Societal Impact: Brushless dc motors use solid state power electronic switching to provide reliable and efficient rotating torque sources in systems with a DC power supply. Applications range from high precision position controlled computer disk drives to hybrid electric vehicle drives. Advanced personal transportation applications that may experience growth in the near term are electric bicycles and devices such as the Segway. The societal impact of brushless dc motors is presently significant and could become ubiquitous as electric drives are implemented in transportation systems. I have found that showing a short video of the Segway or Honda Civic Hybrid serves as an excellent motivational project tie-in and encourages student discussion of societal impacts of this technology.

Project Description: The brushless dc motor project has been used for the past two years in a first semester introduction to electrical engineering (EE) course. Over 100 first year EE students have successfully built the project during that time. The simple-to-construct motor kits provide exposure to elementary circuits, magnetics, power electronics, and feedback systems. Feedback signals are generated using magnetic and optical sensors. The feedback signal causes an electromechanical reed switch or a power transistor to actuate an electromagnetic coil. Project benefits are a personally-built class memento; an animated, physical manifestation of electrical engineering; and a recruiting tool for future students. Assessment results indicate a high degree of student satisfaction with the project.

Educational objectives of the project are to gain an understanding of the application of brushless dc motors, particularly in transportation systems; to comprehend the electrical, magnetic, and mechanical principles of operation of the brushless dc motor; to correlate the physical system components and layout with their abstract schematic representation; to use physical sensors as feedback elements; and to compare the use of a operationally visible mechanical reed switch as a coil commutator with the use of a solid state power transistor.

As an EE professor, it is rewarding when first year EE students comprehend the functional operation of the transistor as a switch. The motor is built in stages. The first operational stage uses a mechanical reed switch to commutate the electromagnetic coil. Students can see the reed switch actuate as they move the rotor permanent magnets. In a later operational stage, the reed switch is replaced with a bipolar junction transistor (BJT). Their physical understanding of switch operation provides a basis for understanding transistor operation as a switch. Students perform a simple calculation of reed switch life and compare it to transistor life given the motor speed, construction geometry, and manufacturer mean-time-between-failure (MTBF) data for the reed switch and for the BJT. Upon completing this calculation students discover why the transistor has replaced mechanical switches in devices from computers to electric power transmission systems.

Smarter Vehicles
Leyla Nazhandali

Introduction and Impact: With over 40,000 deaths a year in the U.S. from traffic accidents, there is a huge need for increased safety in vehicles. With computers assisting and eventually driving the vehicles, the number of deaths and traffic accidents can decrease dramatically.
Autonomous vehicles can also carry cargo through dangerous territories without risking human lives. Currently most vehicles use a number of embedded processors to read sensor data and assist the driver in certain situations. Anti-lock brakes take control of the braking system and more efficiently apply the brakes when skidding is detected. Electronic stability control detects when the car is not responding to the steering wheel (skidding or fishtailing) and controls the brakes and throttle to regain control. Recently, more complicated techniques have started to emerge. Adaptive cruise control can detect the speed of cars in front of the driver and change the speed of the cruise control to match it. Lane departure warning systems can detect if the car is drifting out of the lane. These systems are all eventually leading to a vehicle that can carry cargo and passengers without any human control at all. DARPA held a yearly challenge to design a vehicle that can navigate a 132 mile course without a human driver and in 2005 a car designed by Stanford navigated it in 6 hours without incident. In the future, it is not out of the realm of possibility that computers will drive all of our cars and prevent the deaths of thousands of drivers.

Hands-on Project: The students will program a small "smart" car that will follow a black line drawn on a white piece of paper. The students will be given a shoebox sized car with two independently controlled motors. By turning one motor slower than another the car can steer
left or right. The car also has two infra-red sensors mounted on it that can detect if they are over the black line. Students will write microcontroller code in C that uses the sensor data to steer the car. Students will try to achieve five objectives one at a time. The first objective is to simply control the motors and have the car drive in a circle. The second objective is to control two LEDs and have them turn on when the corresponding image sensor is over a black line. The third objective will be to drive the car in a straight line on a white piece of paper and have it stop when it reaches a solid black line. The fourth objective will be to have the car follow a straight line. The final objective will be to have the car follow a curvy path. Most of the framework of the code will be already implemented and students only need to solve the problem and write simple logic. Minimal programming experience is required. The students need to improve their solution as they try to increase the speed of the car and steer the car over sharper turns.

In addition to learning about how embedded microprocessors can better our lives, the students will discover the actual physical constraints when designing such systems including the trade-off between the speed of the car and accuracy of steering.

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