Using Robotics in the Engineering Technology Classroom

by

Harry W. Fox
h.fox@csuohio.edu
Department of Engineering Technology
Cleveland State University

Abstract: This paper describes how robotics technology is used in Electronic Engineering Technology (EET) and Mechanical Engineering Technology (MET) curriculums to enhance students education along with outreach programs offered to local high school students. Details are presented on how robots and robotic technology are being used in three areas: in a senior-level capstone design course for the EET program, in three technical elective courses in a robotics option / concentration for both the EET and MET programs, and in hands-on activities geared towards introducing high-school students to engineering and technology through robotic presentations and summer-camp programs.

I. Introduction

Robotic technology and robots are finding wide spread use in grammar school, middle school and high school curriculums.[1] For the younger students, robotics can generate an interest in science and increase self-esteem, while teaching skills in problem solving, decision making, goal setting and logical thinking.[2] For the older students, robotics can introduce basic engineering and computer programming concepts. At the college level, robots and robotic technology can be used to demonstrate and reinforce engineering and computer science concepts.

Robots have been used in the classroom since the late 1970's when MIT educator Seymour Papert introduced his Logo Robots, along with the Logo programming language designed for children.[2] By the 1980's, LEGO robots were being controlled by Logo programs and about a decade later the LEGO DACTA™ *Control Lab*™ was introduced, which currently is being used by about 20,000 schools in the United States involving more than one million children.[3] In 1998, the LEGO *Mindstorms*™ was introduced, with its Robotics Invention System and RCX Programmable LEGO brick, as a commitment to bringing entertainment and education to children. Today, LEGO robots are used in classrooms ranging from kindergarten to college courses.

The advancement of robotic technology has made it easier to develop introductory courses or lecture series in robotics for students at any academic level. Students can now look at basic ideas without having to be overly concerned about the robot hardware. The instructor guides the student through any complexities and uncertainties about the hardware and encourages the student to explore more deeply into what a robot can do. This makes it possible to hold classes in robotics using easy-to-use, inexpensive robots, such as the LEGO Mindstorms or the Parallax Boe-Bot.[2]

This paper describes how robots and robotic technology are being used in engineering technology curriculums at Cleveland State University to enhance education and to serve as promotional material for high school outreach programs. Related educational issues, such as design, hardware, software, teamwork, and documentation, are discussed.

II. Background

Over the past ten years the faculty of the Department of Engineering Technology at Cleveland State University have incorporated robots and robotic technology into the curriculums of the Electronic Engineering Technology (EET) and Mechanical Engineering Technology (MET) programs. These are 2 + 2 programs in which students must first complete the Associate of Applied Science Degree in Electronic or Mechanical Engineering Technology from a regionally accredited community college, technical institute, or university branch before transferring to CSU to complete the upper-division courses in years three and four of a bachelor's degree program. Graduates from ET Department programs, as well as those from other CSU programs, generally find employment in the local community.

Robotics-based training was first introduced at CSU in 1998, by engineering technology professor Robert Mikel, in a capstone design course for EET seniors featuring mobile autonomous robots. A few years later, a robotics option or concentration was created consisting of three technical elective courses which can be taken by EET and MET juniors and seniors..

In addition, this training material is being used in outreach programs aimed at exposing local high school students to various facets of engineering. Throughout the year, the Fenn College of Engineering at CSU sponsors a series of hands-on, minds-on engineering themed robotic activities which are available during scheduled high school visits and specialized summer camps. Here robotics are used for both their promotional value and their educational value.

In what follows, details will be presented on how robots and robotic technology are being use in the following areas:

- Capstone Design Course
- Robotics Option (technical electives)
    - Robotics I (mobile robots)
    - Robotics II (robotic arms)
    - Robotic Systems Design (CIM work cell design)
- Outreach programs to local high school students
    - High School Visitation Days
    - Faculty Lecture Series (go to local high schools)
    - Engineering Challenge Summer Camps

Further information on the robotics-based capstone senior design course and the outreach programs for local high school students are described in other articles.[4,5]

III. Capstone Design Course

All fourth-year students in their final term at CSU are required to take a senior capstone design course in order to be graduated. The course is structured to satisfy the ABET TAC criteria[6] and to involve the technical skills and expertise used in industry. In their projects students are required to design, build, and program robot vehicles to perform basic tasks or behaviors, while keeping a weekly log of their progress and status. The course enables seniors to apply knowledge and skills from various classes they have completed; work independently and in small groups; accomplish assigned tasks; design, test, and troubleshoot problems; and meet deadlines.

The choice of mobile robots for design projects was made because robotics involves a multidisciplinary approach using knowledge in the fields of mechanics, electronics, control, computer science, and communications. A robotics project therefore provides the integrating experience, called for in the ABET evaluation criteria, that draws together the various elements of the electronics engineering technology curriculum, and it provides for a practical engineering design effort, much like those in industry. In addition, the design and building of a small-scale mobile robot can be exciting and invigorating to students, who can feel empowered when they elicit complex behaviors from the machine.[7]

In the fall semester of their final year students take the lecture course Senior Design A, during which the planning and preparation of the robotics project take place. In the following spring semester students take the lecture-laboratory course Senior Design B, during which the robotics project is completed. The two-semester course sequence is organized to emphasize the *engineering design process*. The fundamental elements (steps) of the design process are listed in Figure 1.

The Engineering Design Process

- Identify the need or problem
- Research the need or problem
- Develop solutions
- Select the best solution
- Construct a prototype
- Test and evaluate
- Redesign (as needed)
- Communicate solution

Figure 1. Fundamental steps of the engineering design process

Students are to design and build an autonomous (no human intervention) "smart" robot that will navigate a 12-foot by 12-foot flat surface (floor) play area, avoiding objects in its path, with the intent of getting to a light in the far corner of the play area. In the center of the play area is a 3-foot by 3-foot forbidden zone, that should the robot wander into, a sound buzzer will be engaged and the robot must respond to the sound by removing itself from the forbidden area. The robot design must be an original student creation. No robot kits are allowed.

Students have not managed enough projects, however, to know all the steps necessary to successfully carry out an engineering design of this size. The instructor therefore takes the task of setting up the design project definition, organizing the individual design teams, and establishing the reporting requirements.

To help the students breakdown the design project into a set of smaller, more manageable tasks, a project handout is distributed which lists required project milestones or checkpoints with due dates.

- Build, pick, get, choose a chassis or body (2 weeks)
- Mount motors on chassis and get it to move (2 weeks)
- Get controller to make an output and to move robot forward and in reverse (3 weeks)
- Get proximity or touch sensor and get robot to maneuver around objects (2 weeks)
- Get light sensor and get robot to move towards a light (2 weeks)
- Get sound sensor and get robot to respond; e.g., stop or back up and turn (2 weeks)
- Combine all three behaviors into a single controller program (2 weeks)
- Perform on Robot Day (Week 16) the required tasks and submit final report.

The robotics-based design course enables seniors to apply knowledge and skills from various classes they have completed; work independently and in small groups; accomplish assigned tasks; design, test, and troubleshoot problems; meet deadlines; and to communicate both orally and in written form. The designs developed and the reports given indicate high-quality student work and the ability to use the engineering design process. A robot built in senior design class is shown in Figure 2.

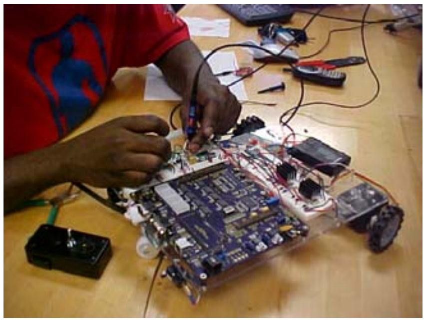

Figure 2: Robot built in senior design class

Student reaction to the capstone course is measured each semester with the college standard course evaluation form, on which the students have consistently rated the course positively (e.g., 4.0 to 4.5 rating out of 5.0). Samples of student comments from the final project reports are summarized below:

- *This robot project was a great experience in applying many different circuits together to create an entire system. The project involved applying our programming and electronic skills.*
- *Overall, this project was challenging, expensive, and very time consuming, but well worth the effort placed into it.*

- *This project utilized many of the engineering concepts learned throughout the engineering technology program…it also taught new concepts and strengthened the foundation of learned concepts by applying them to practical situations.*

IV. Robotics Option Courses

In response to the student interest in robotics, the faculty have developed and implemented (starting in the 2002-2003 academic year) a three-course Robotics Option in its electronics technology and mechanical technology bachelor's degree programs (BSET and BSMT). The Robotics Option is a way mechanical and electrical technology students can develop interdisciplinary skills and knowledge to work on designs and products requiring the integration of mechanical, electrical, and microprocessor-control systems. The Robotics Option is a three-course sequence: Robotics I, Robotics II, Robotics System Design.

The first course in the sequence (i.e., Robotics I) is a junior-level course featuring the following commercially available, programmable mobile robots: LEGO Mindstorms and Parallax Boe-Bot. The catalog description reads: An overview of the technology, methods, and practices of robotics and mechatronics (the integration of mechanical, electrical, and computing elements), with basic details on key topics such as kinematics, mechanisms, actuators, sensors, motors, electronic hardware, and controllers.

This course is designed to:

- Provide an introduction to robotic and mechatronic systems using interactive learning method featuring student-based hands-on projects using the LEGO Mindstorms robot and the Parallax BOE-BOT.
- Identify the popular sensors, actuators, and control systems used in robotic and mechatronic systems.
- Develop basic techniques for the design, synthesis, and programming of simple mobile and stationary robots.

The LEGO Mindstorms robot, shown in Figure 3, is used in the first one-half of the course. Students practice their skills in constructing the robot (from LEGO bricks) and in programming the RCX controller using two languages, the LEGO icon-based programming language and the Not-Quite-C (NQC) programming language. Touch sensors, light sensors, and speed (rotation) sensors are used to perform various assigned tasks, involving navigation around obstacles, collision avoidance, position (follow-the-line) control, and speed control.

Figure 3: Lego Mindstorms robot

The Parallax Boe-Bot robot, shown in Figure 4, is used in the second one-half of the course. Students practice their skills in electronic wiring of sensors (on solderless breadboard) and programming the BASIC Stamp2 controller using the PBASIC language. Touch sensors, photo-resistor light sensors, infrared light sensors, and ultrasonic detector sensors are used to perform assigned tasks similar to those performed with the LEGO robot. This robot requires students to work more closely with the physical hardware, without the need for constructing the chassis.

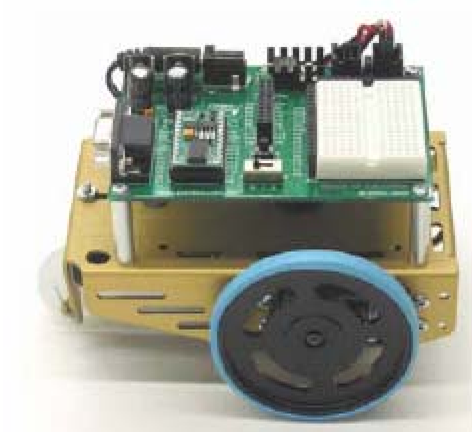

Figure 4: Parallax Boe-Bot robot

The second course in the sequence (i.e., Robotics II) is a senior-level course featuring the following commercially available, programmable manipulator-arm robot: Rhino XR-3. The catalog description reads: Continued study of the technology, methods, and practices of robotics and mechatronics. Foundations and principles of robotic manipulation. Topics include computational models of objects and motion, the mechanics of robotic manipulators, coordinate transformations, direct (forward) kinematics, inverse kinematics, trajectory planning, and vision. These topics will be exemplified with Matlab/Simulink simulation studies.

This course is designed to:

- Provide senior-level students with second course in robotic and mechatronic systems, involving the analysis, design, synthesis, and selection of systems which combine electronic and mechanical components with modern controls and microprocessors.
- Focus on selection of sensing, actuating, and control devices and methods (rather than overview all industrial solutions).
- Use Matlab and Simulink to model and simulate various sensors and actuators used in robotic and mechatronic systems.
- Introduce state-of-the-art approaches in robotic and mechatronic systems design and integration.
- Provide hands-on experiments with interfacing of electromechanical components, data acquisition, and computer control (PC-based and microcontroller-based).

The Rhino XR-3 robot, shown in Figure 5, is used in the course. Students practice their skills in programming the robot controller using the BASIC programming language. Hands-on activities performed with the robot arm include multiple-axis moves, gripper control, simulated automated production system, and accuracy and repeatability measurements.

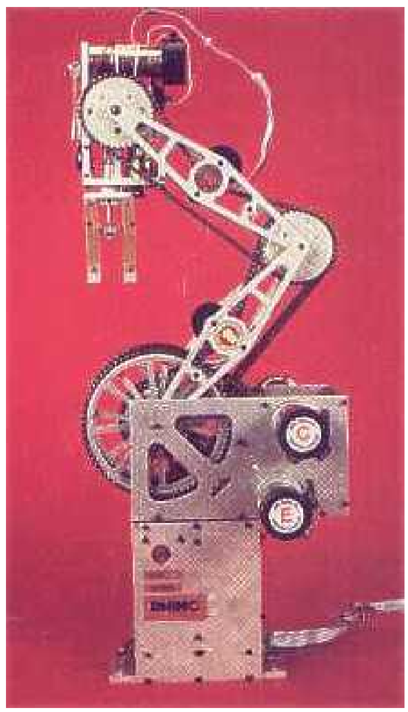

Figure 5. Rhino XR-3 robot arm

The third course in the sequence (Robotic System Design) is a senior-level course featuring robot work cell design for computer-integrated-manufacturing (CIM) systems. The catalog description reads: Design of robotics systems, including concept development; modeling and simulation; selection and optimization of equipment, sensors, and controllers; economic considerations; reliability and safety; and documentation of final designs. Examples of robotic system designs will be chosen from industrial and non-industrial applications.

This lecture course (with no hands-on laboratory activities) may be taken out of sequence and serve as a first course for students interested in the applications of robots and robotics technology. It covers all the necessary topics concerning the development of a robot work cell; a summary of the topics is as follows:

- Introduction to Industrial Robots
- Robot Classifications
- Case Study: Plastic Bowls Production Work Cell Development
- Design of gripper
- Select sensors; sensor checklist
- Work cell support systems
- Work cell and robot system integration
- Cost justification
- Robotics systems design project
- Work-Cell Design Case Study: Automate (robotize) upset forging process in turbine fin production

V. High School Outreach Programs

At Cleveland State University (CSU), the Fenn College of Engineering currently offers a variety of outreach programs for high-school students. These programs are aimed at raising the overall awareness of engineering and how CSU can introduce students to a potentially-meaningful career. The three outreach programs specifically related to this paper are:

- Faculty Lecture Program
- Engineering Activity Days
- Engineering Challenges

For the Faculty Lecture Program, engineering faculty from each discipline are available for travel to local high school classrooms to give a brief one-hour presentation on their area of expertise. For the Engineering Activity Days program, groups of high school students visit the college facilities for a half-day session including tours, presentations and activities. For the Engineering Challenges program, the engineering faculty have developed and offer different week-long summer camps opportunities.

Robotics is unique in that it is used in all three of our outreach program areas. Centering activities around robotics is an excellent way to reach these young people. In this format, these programs can range from short one-hour activities in the Faculty Lecture Program and High School Visitation Days, involving slide and video presentations and brief hands-on activities with Lego robots, to a week-long summer camp experience, where participants design and construct scale-model robots using Lego and Parallax BoeBot technologies.

The current format for our short one-hour presentation on robotics is a follows:

- Introduction: Greetings and a brief description of the who we are at CSU
- Slide presentation: Basic Tasks and Behaviors

  An interesting survey of where we find robotics at work, in space and the military, in hobbies, around the house, in hospitals performing surgery, in service roles, and performing hazardous duties. It includes a look at walking robots, flying robots, underwater robots, crawling robots, and stationary robots. And it concludes with a quick look at educational robots, including the LEGO Mindstorms robot, the Boe-Bot mobile robot, and the Rhino manipulator robot.

- Video: Introduction to Successful Robotic Solutions

  A fast-paced, informative look at industrial robot applications, produced by the Robotic Industries Association, Ann Arbor, MI.
- Slide presentation: LEGO Mindstorms features

  A very short look (10 slides) at how to handle, operate, and program the LEGO Mindstorms robots (that they are about to work with).
- Hands-on table-top activities with the LEGO Mindstorms robot

  5 preprogrammed activities
  1. forward, back, turn maneuvers
  2. touch sensor activates motion
  3. light sensor calibration and tone generator
  4. light sensor activates motion
  5. light seeking maneuvering

Although the LEGO robot is quite simple in geometry, the students go through several steps, including installing touch and light sensors and running a number of built-in robot programs which demonstrate basic tasks and behaviors of autonomous mobile robots. A number of these high school students with no robotics experience at all appear to easily adjust to handling and working with the robots even though they have had no LEGO building history. The result has provided positive reinforcement. There is genuine excitement in the room. Some schools now bring second and third classes to Engineering Activity Day and request the robotics presentation. There have even been requests for follow up visits by schools visited during the Faculty Lecture Series.

The summer, week-long outreach program presented by the Department of Engineering Technology is centered around robotics. The summer program introduces students to the electronics, mechanics and computer science of robotics, through a series of daily autonomous robot challenges. Students build, program and operate autonomous mobile robots capable of sophisticated sensing and intelligent decision-making.

The students spend four and one-half days from 9:00 a.m. to 3:00 p.m. working on their robotics activities. They get hands-on experience by learning how to build and program their own miniature robots. This is an opportunity to increase student awareness of engineering technology. It allows students to build robots and learn about how robots see and work.

Hands-on activities involve designing and building robots, learning programming and presentation software, working in teams, mastering tasks, and sharing in themed robotic adventures with other students. The students learn how to program robots to navigate using touch, light, and ultrasonic sensors and motor controllers. Three different robots are used: the Lego Mindstorms, the Boe-Bot, and the Robosapien robot.

By introducing progressively more challenging daily contests and providing important information in brief lectures, the summer camp Engineering Challenge builds incrementally on the students' knowledge and the robot systems until, at the completion of the camp, the students can perform a variety of activities with their robot.

VI. Conclusion

This paper describes three ways of how robots and robotic technology are being used in the engineering technology curriculums at CSU to enhance education and to serve as promotional material for high school outreach programs.

The highest level of robot and robotics technology is presented in the senior capstone design course, in which the use of robotics involves a multidisciplinary combination of knowledge in the fields of mechanics, electronics, control, computer science, and communications. This robotics project therefore provides the integrating experience, called for in the ABET evaluation criteria, that draws together the various elements of the electronics engineering technology curriculum, and it provides for a practical engineering design effort, much like those in industry.

The robotics option courses present various levels of robots and robotic technology, from junior-level hands-on activities in mechatronics to senior-level labs with a robot manipulator arm and practical training on robot workcell development for CIM applications.

Finally, the use of robots in outreach programs for high school students has proven to be effective in getting the attention of young people, particularly when hands-on activities are incorporated into the presentations. The programs can range from short one-hour activities in the Faculty Lecture Program and High School Visitation Days, involving slide and video presentations and brief hands-on activities with Lego robots, to a week-long summer camp experience, where participants design and construct scale-model robots using Lego and Parallax BoeBot technologies.

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