# Using Robotics to Teach Computer Programming & AI Concepts to Engineering Students

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**Abstract**

Many ABET approved engineering programs contain but a single credit hour of "programming" classes. In many situations, that programming class does not even include a general purpose programming language but instead concentrates on MathCAD or even Excel. In the opinions expressed by many of these engineering students, programming is considered hard and unnatural. Over the past few years we have introduced robotic projects into the introductory engineering classes and into several of the engineering lab classes (measurements, controls, etc.). The robots being designed and built are centered around KISS Institute for Practical Robotics' Botball robot kit. The robots are programmed in IC4 (KIPR 2002) an interactive environment that uses a subset of the C programming language. This paper will present some of the curriculum material and projects that are used in these classes as well as an informal analysis of the impact this methodology has had on the students. In addition, we will discuss how the Collegiate Botball contest is being used to keep these students programming once they are done with their required hour of programming class.

## Robotics for Intro to Engineering

For the past three years at the University of Oklahoma, we have merged the Engineering Computing and Introduction to Engineering courses in some sections. These merged courses have used a version of the Botball robot kit as the major tool for teaching computer skills, the design process, project organization, and general engineering techniques. The class meets in two 2-hour sessions per week allowing adequate time for both lecture and in-class hands-on work.

This course is aimed at freshman engineering students and is supposed to cover several objectives:

- Overview of the major engineering disciplines
- Introduction to the engineering design process
- Engineering ethics
- Basic engineering productivity and analysis tools
- Introduction to computer programming



We have successfully used design projects around robots, using the Botball kit, to meet all of these educational objectives.

### Structure of the Course

Two basic course outlines have been used for this class over the past four years. The first was based on the Managing Creativity curriculum (Shirley 2002).

**The Managing Creativity Approach** In this version of the class the students are broken into groups of about a dozen to form companies. They are then tasked to develop a product idea, form engineering groups to develop various portions of the product and then prototype the system.

Throughout this process the instructor presents tutorials on a variety of topics including:

- Programming in C using IC4
- Personality categorization (e.g., KeirseyBates personality types (Keirsey & Bates 1984))
- Engineering topics and specializations

This version of the course spent a lot of the time on the management and conflict resolution issues. Using large groups, and the relatively small amount of pieces, processors, etc available in a single Botball kit forced the group to spend a lot of time on organizational issues. They had to decide on a product idea that could be prototyped with the kit. The more difficult task was to come to agreement on what that product idea would be.

A typical project that would arise from the class was an automated party photographer. This was a robot that would wander around a room, and when it got near a person, it would back off a bit and tape a snapshot. The prototyped version from the Intro to Engineering class was somewhat limited in that the robot constructed simply wandered what it hoped wan an unobstructed plain with the occasional person in other words, it would photograph anything it noticed sticking out of the floor. Students in the class did feel vindicated in their basic product idea when the next semester it was discovered that professors at Washington University had come up with the same concept and (mistakenly) claimed that they had produced the first robot photographer (Washington University at St. Louis 2003).

**The Multi-Project Approach** In the second version of the course the students were broken into groups of three for all of their projects. The memberships of the groups changed throughout the semester. On the first project the teams were selected based on the instructors choice to try and spread people around so that every group had someone with programming experience and that students who had expressed interest in the different fields of engineering were mixed up, rather than putting all of one type together in a single group.

In the second project each student made a list of the top five people they wished to work with. The groups were formed to try and match as many of those requests as possible. For the final project, there were four different projects to choose from, and different roles for each of the projects. The students used an online bidding and registration system to apply for the project and position they wanted. They could also view else had received assignments, and then relinquish their position and apply for another if they wished. After a day, all the positions were locked into place.

Throughout the term, three major projects are given where complete robot systems must be designed, built and programmed. The first project is a relay race where a series of two robots races between two stacks of soda cans and around a central obstacle, trying to make the best time without knocking over any cans. A marked parabola between the stacks allows some robots to navigate by line following and a tutorial on line following is given in the course. However other robots manage to follow a straight path by going over the obstacle, and in a few cases picking up and moving the obstacle out of the way (allowing the second robot to go much faster).

The second project requires traversing rough terrain as the robot must go over a simulated Moonscape trying to find the leaky habitat (marked with a beacon) and plug the hole, literally, with a cork. The terrain used for this project is reconfigurable in three different ways making it (the instructors thought) very difficult to have the robots simple execute a preprogrammed path to get to the habitat. However, it turns out that many of the groups were able to program in all of the paths, and then have the robot early in its traverse scan for a specific patter of rocks to determine which configuration was in play.

The third project, attempted to be substantially different that the previous two. Towards that end the students were given a choice of four possible projects, working in larger groups, to prototype a project (much in the spirit of the Managing Creativity approach). The four options for this past year were: MySDI the personal security robot; Chembot an automated system for measuring out and mixing liquid chemicals; Y-prize long distance robot racer; and Servbot the personal caterer. The exact definition of each of these was largely left up to the team, and in this project significant augmentation of the kit was allowed.

In addition to the projects, additional assignments are given throughout the term that tie programming to other computer tools needed by engineers. For example, programs are written to store sensor values in an array. The arrays are then uploaded from the robot to the PC and placed into spreadsheet programs for analysis and graphing. This exercise teaches rudimentary data structures as well as spreadsheet techniques.

The third project was most educational for the instructors. One of the important things we learned was that doing a project with a large group in a short time really shows whether or not you have adequately taught the team management and conflict resolution strategies to the students (we had not). But despite some of the personnel difficulties, the majority of the projects resulted in creative, and for the most part successful robots, and enthusiastic students.

## Aerospace Engineering Robotics Lab

In the Spring of 2004, the OU added a new robotics lab to its aerospace curriculum. The goal of this course is to familiarize aerospace students with the electronics and programming now common in various aspects of avionics and space robotics. This senior level course may be the first course involving programming that many of the students have had since their freshman year.

This course is using the Botball kits in a manner somewhat different to that outlined above. The course first concentrates on sensors including the CMUcam color tracker. In this module all of the sensors are examined and their output over a range of inputs is plotted against one another (in particular against the sonar which is already calibrated to metric units). Even the camera is calibrated to find out the size of objects at different distances, and then back calculate the focal length of the lens.

The second module in the course concentrates on motors and servos. The students implement encoders and then use the gear motors under bang-bang control and compare their positional accuracy to that of the servos provided in the kit.

The third unit introduces more complex control systems: p-loops, and pd-loops and compares their performance to the positional servo motors . The students create a mobile robot that then performs some positional and speed servoing using the encoders to close the loop. Again the results are analyzed and written up in a report.

The fourth module combines the results of the first three to produce a mobile robot capable of controlled movement. The students create robots that can perform line following and analyze the change in speed verses maneuverability as the rate of turn and sampling rate are changed. Similar exercises are done with light tracking and following a colored object.

The fifth module covers kinematics and manipulation. A simple 2-DoF arm is built out of the kit materials and inverse are calculated. Experiments with positional control of the arm are performed and the results written up.

The last portion of the class then tries to combine all of the pieces that have been created so far, into a single unified challenge. The task involves object tracking, dead reckoning, position estimation, manipulation and a large design element. For this final portion we are using the 2004 Collegiate Botball Challenge (KIPR 2004).

## The Collegiate Botball Challenge as a Way to Keep Students Programming

College Botball was originally created to answer the request of Botball alumni students who had participated in the robotics contest as high school students. The annual challenge which now takes place as part of the National Conference on Educational Robotics (co-located in 2004 with the National Conference on Artificial Intelligence) is similar but distinctly different from the high school contest.

The motivation for having a different challenge is twofold: first, these are college students with potentially more time and access to more expertise than your typical high school student, there fore then should be able to handle a more difficult challenge; second, by having a different contest, it makes it easier to avoid spontaneous challenges from the middle and high school teams who also attend the event. In the past, those challenges had often had embarrassing outcomes.

The high school Botball challenge usually has a part of the scoring that can be achieved by having the robot simply run into certain things. In the college version, the game is designed so that all scoring should be the result of intentional manipulation. The college game also relies more heavily on elements of the Botball kit that are often under utilized by the high school teams (e.g., the color camera).

At OU we are offering some travel grants college students who demonstrate a robot team that can perform in the college challenge. Students wanting to apply for the grants have to assemble, program and demonstrate an entry that can score what is estimated to be a competitive score in the seeding/performance rounds of the college challenge. The top teams from that then do a head to head double elimination tournament to find the winners of the travel grants.

Our hope is that the skills used for designing and programming the robots will take on a new level of importance, and be less likely to fade away as soon as the semester ends.

## Conclusions

End of course student surveys for all of these courses have shown an overwhelming positive response to the robot kits and robot projects. Of the complaints that were recorded, almost all referred to the team interactions and these problems were much more prevalent with the larger teams (4 to 6 people) than in the two and three person teams. Students describe the courses as time intensive, with conceptual content on par with other courses in the curriculum. They also report that this course uses and teaches engineering tools better than most engineering courses. In the course surveys, the students also have endorsed the competition format employed for several of the projects.

In providing a comprehensive kit and in serving as a single source of supply, KIPR has provided a sole-source, reasonably priced means for utilizing a Handy Board component-based approach for the support lab for AI robotics. The incorporation of LEGO RCX elements into the kit also permits an instructor to draw on resources already developed for use with the LEGO Mindstorm kit. Though it should be noted that after an initial experience with the RCX it was seldom used in projects where the students had a choice to use the Handy-board instead.

Because of the motivation that the robots provide the students, we are able to teach computing techniques far beyond that which would normally be covered by an engineering computing course. These include issues such as: multi-threading, structures, and semaphores. Topics that are more typical of an intermediate computer science curriculum. Computer science students also get advantages from robotics classes. They get to learn aspects of control, mechanics and electronics not addressed in the normal CS curriculum.

In many of the engineering disciplines, students may never have to program during their undergraduate career with the exception of their intro programming course. However, the inclusion of a Botball collegiate game at the National Conference on Educational Robotics, now encourages the students to keep their computer skills active as they prepare for the Summer tournament. We believe that the use of robots as a teaching tool early in the engineering curriculum will both improve computer skills for non-CS engineers, and will also increase the number of students interested in pursuing computer science.

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