Reinvigorating Microcontroller Laboratories with Experiences and Applications of Common Devices

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Abstract

Many non-engineering Cadets at the United States Military Academy take a sequence of courses in Electrical Engineering as part of their requirement to earn a Bachelor's of Science. The final course in the sequence incorporates the programming of a microcontroller, including the utilization of analog and digital circuits, and implementation of robotics as part of military electronic systems. Because of the limited programming experience of these students, the course uses the BOE-Bot containing a BASIC Stamp 2 microcontroller that is programmed in PBASIC. Despite the amount of resources in programming and circuits provided by the vendor, the activities need augmentation, or reinvigoration. The incorporation of common devices such as TV remotes, flashlights, gaming controllers and RC controllers provide students the opportunity to analyze and apply simple circuits with programming. These implementations and associated activities allow the operation of a robot and actuators in a semi-autonomous or tele-operated mode, through the use of various sensors, communication systems and programming techniques. At the end of the course with a capstone project, students demonstrate the application of various aspects of electrical engineering through a small-scale robotic system.

Introduction

The use of the BOE-Bot is a simple and capable system for beginners and allows for the integration of digital circuits, analog circuits and programming. The previous knowledge gained from courses in digital logic and basic electronics are incorporated together with microcontrollers and the environment. The small robotic platform easily incorporates many different sensors, user input, communication systems and easy programming. By the end of the course, students are capable of configuring a robot with various sensors for semi-autonomous operation to complete a series of tasks. Each individual task or sensor may be simple, but the final integration of multiple subsystems and programming subroutines is not.

The modification and improvement of the course, EE450 Military Electronic Systems, over several semesters, allows the opportunity to enhance and augment lectures with activities and in-class circuit exercises. These enhancements then allow for more complex laboratory exercises which include common devices such as TV remotes and RC controllers. The addition of hands-on activities or exercises minimizes "the lecture's relative ineffectiveness at transmitting information"[1] and can increase retainability.

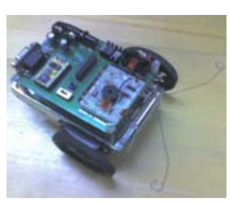

Figure 1: BOE-Bot

Selecting a Robot System

The BOE-Bot has many online and free resources available to program and incorporate various circuits and sensors. The vendors provide texts with a myriad of activities to explain and teach various components. However, many of these tasks are limited in their scope of operation, provided with colored diagrams and circuits and attached with the corresponding code that it easily incorporated. It also has a single USB interface and a simple programming and debugging interface. Overall, these tasks are great for the junior high or high school level, but not for those at the college level with background in electronics. Another important aspect with non-engineers is not the difficulty in teaching engineering aspects, but showing everything does not always work on the first try and that they provide another aspect of creative thinking to the course.[2] Additionally, since the free resources include many activities, these are great to incorporate into the lectures. They explain and integrate the circuit and code together, which is electronically provided, include a working demonstration, and then allow the students an opportunity to perform the activity themselves. These "observational and hands-on activities will have more educational value if they are planned so as to be integrated with overall course objectives and actively connected to what is happening in class."[3]

Incorporating the Robot System

In many engineering, math and science courses, teachers take a very active approach to assist the students in learning. Mainly, in-class exercises or daily work problems help achieve this goal. With computer science, practice in writing code with various structures are demonstrated and executed. With robotics, especially a small and simple BOE-Bot, the simple activities that the vendor provides are easily incorporated into daily lectures as in-class exercises. This approach provides the students with demonstrations, incorporates self-implementation of the activities, reinforces concurrent and active learning and allows reflection by the students to build on the topics of the course over a longer period of time. This approach to tinkering is a great and fundamental approach to an active, hands-on approach to learning. Older generations had tinkered to understand theory and to provide motivation, while the current generation wants instant gratification and the internet.[4] In order to supplement this need by current students, technology and the internet are integrated. The projector and screen provide an electronic blackboard of circuit schematics, colored circuit implementations, and code excerpts from the texts. The course webpage and Wi-Fi access in the classroom for student laptops fulfill that immediate need to complete and test the circuit and program because "equipping its classrooms for high-quality multimedia…spend a little time learning how to use the equipment…the educational benefits can be enormous."[5]

Improving and Modifying Laboratory Exercises

Originally, the course utilized small-scale laboratory exercises in lieu of class lectures. There were 10 small labs of 50 minutes each. The scope of activities and experiments had to be limited due to time and classroom configuration. Therefore, the labs were focused on using the provided activities from vendor-supplied references. These simple activities had to be practiced in the beginning of the lab period, and then expanded upon during the lab. The labs had to supplement lectures with hands-on exercises during the labs. Even though this was an active learning model, the labs provided little time for students to reflect on the new activities they were completing for a grade. Also, when the students began the labs with simple activities, they had reduced time available to complete complex activities. These initial activities were essentially copy and paste demonstrations from the text; the lectures and demonstrations of the circuits and code were now out of context from previous lessons. Despite achieving an 85.9% average on these laboratories, the students learning appeared diminished through retention based on a final course average of 84.0% which reflected reduced performance on written exams. Additionally, this class had an improvement of 0.16 course GPA over their incoming GPA which demonstrates the student's academic capability.

Changes to the curriculum structure allowed for the shift of these smaller labs to be focused to five double-period lab sessions which were previously used only as class drops. This provided an opportunity to augment lesson material beyond the scope of the vendor-supplied activities. Some lessons now reviewed digital logic and electrical circuits from previous courses, but enhanced with the BOE-Bot architecture in terms of programming and interfacing. Additionally, the lab periods were no longer confined to a classroom setting, but to a laboratory setting with increased space which is beneficial with even small robot systems.

The labs were not necessarily doubled up where two small labs created one larger lab. The labs became more efficient with half the time used to start and finish a lab, reduced some of the redundancy of activities from different labs and added enhanced activities. These more difficult tasks incorporated previously smaller tasks that were not provided by the vendor. Therefore, each lab was only 1.5 times the work, not doubled, yet more difficult. However, by improving lectures and increasing the number of lectures, only explanations and examples were increases with demonstrations and still out of context with the later lab periods. The students were encouraged to practice the activities on their own as part of their lesson readings and preparation since they had access to the labs and their robots. Very few students would utilize this availability. This semester the students achieved a slight improvement to the lab averages with an 87.4% which can be attributed to less work and a better lab environment. The students learning continued to appear diminished with a final course average of 83.9%. However, the class had a reduction of 0.06 course GPA over their incoming GPA which demonstrates this lab approach provided a negative result according to their academic capability.

Previous labs utilizing in-class exercises have demonstrated the need and this aspect of learning for this course; reintroduction of hands-on practice without sacrificing the lecture enhancements appears crucial. In the most recent iteration of this course, the demonstrations of activities were further enhanced with student demonstrations of these copy and paste activities from the text. The students were now required to bring their robots, encompassed within a tool box kit, to lectures in order to practice some of these simple programming and circuit activities. The tool box kit and programming excerpts available via course webpage were more readily accessible than using the vendor-supplied texts of over 500 pages. This focused the learning on completing the activities and not preparing for them. Additionally, this minimized the amount of time detracted from the lecture and discussion portion.

Now, the labs no longer included the activities practiced during lectures, and augmented with more complex and exciting activities. The time savings recovered from the simple activities provided opportunities to use communications with FM radios, IR remotes and RC controllers. The labs were more challenging, but more exciting and applicable. Furthermore, utilizing previous activities and coding from autonomous navigation during lectures, the students now had the time to incorporate semi-autonomous operations incorporating various sensors and tele-operated navigation using the different control devices.

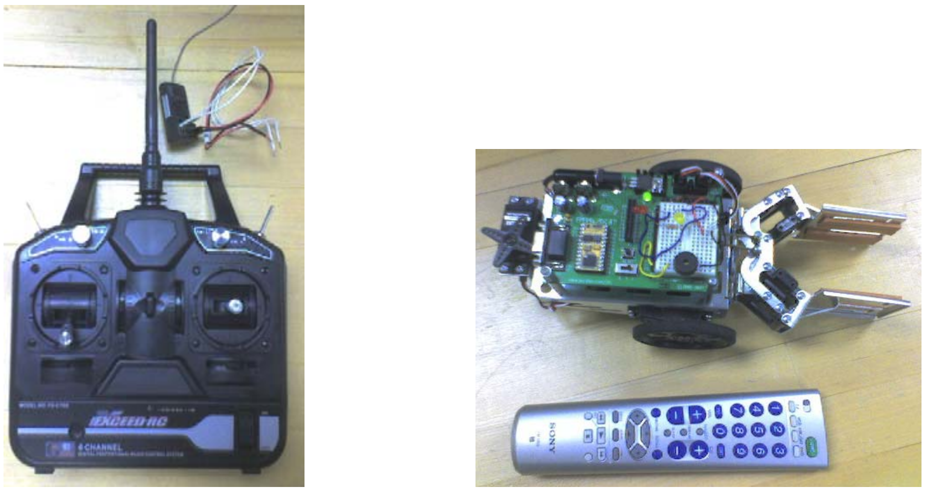

Figure 2: RC controller and BOE-Bot with TV Remote control

Another previous activity controlling a single servo with a potentiometer and a button were enhanced in a lab exercise by controlling a 2-DOF servo arm with gripper using a 2-axis joystick and a button.

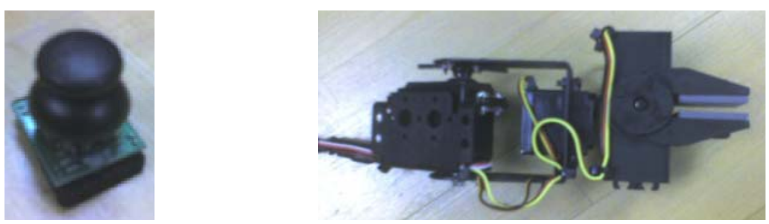

Figure 3: 2-axis joystick and servo arm used in lab exercise

These enhancements of the classes and learning led to the completion of more difficult and rewarding laboratory exercises utilizing the same amount of time. One of the reasons to enhance activities is not to just to do more, but to make the labs more interesting, fun, challenging and rewarding for the level of the students in the course. The lab averages further increased to an 89.5% with a corresponding increase in the final course average of 86.2 %. The class again had a 0.17 course GPA increase over the incoming GPA which demonstrates academic capability despite the increase in difficulty and complexity of the course.

Capstone Project

The course has a design project that incorporates activities practiced during lectures and laboratories, but also implements new equipment in a limited aspect. The latter aspect verified the capabilities and continuance of learning for the student to implement new activities not previously implemented in the course. In the first iteration, because of the lack of scope and use of enhanced activities, the project did not require any new equipment and was very limited in scope difficulty and requirements. The class received an 88.5% average. In the second iteration, the scope of the project was increased with a written report and utilization of a sensor not previously discussed. Their average was 88.7%. Again, for this class, even though this was a slight improvement, they should have been better based on academic capability but were limited by their hands-on experience. In the last iteration, the project was significantly increased in difficulty for the tasks to be performed and equipment to use. They not only had one, new piece of common equipment to implement, but had a second, new sensor to incorporate. This class averaged 92.7%; a significant improvement despite the increased difficulty. This demonstrated the benefits associated with hands-on practice and the ability to increase the complexity of a requirement.

Figure 4: Project Maze

The incorporation of several different sensors was the not the only tasks need in the above maze. Other tasks included light tracking for non-discrete input, music and tone integration, line detection and programming to provide situational awareness within the project area after exiting the maze. The first iteration required students only to use discrete and autonomous navigation. Only one group completed the maze successfully and most of the activities after the maze. The second iteration of students required the use of sensors and semi-autonomous navigation to complete the maze. A majority of the students completed the maze and follow-on activities. In the final iteration, the students had to utilize multiple sensors to complete the maze and the activities after the maze. Most of the students completed the maze and the more difficult activities.

Conclusion

Over the course of several semesters, the instruction and learning of a class has been improved through an active, hands-on approach. Utilizing robots requires the integration of not just different components and sensors or subsystems, but also previous knowledge and experience to build upon. Throughout this course, the practice phase was an instrumental beginning to the learning and retention process. The laboratory excises further expanded the basic and simple tasks to more complex and challenging tasks. The final project finally demonstrated the amount that the students had learned and their ability to keep on learning. The incorporation of common devices such as RC controllers was not an issue of complexity, but demonstrated that the integration of such devices was neither too complex nor unachievable. Remember, these students were not engineering majors; they were liberal arts majors.

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