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MAKER: A Study of Multi-Robot Systems Recreated for High School Students

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Abstract

This paper describes the engineering design approach to be applied in an instructional module for 11th and 12th grade GT Engineering students on Swarm / Multi Robot Systems. The module consists of a combination of research analysis, discussion and activities, is STEM extensive and also supports county wide reading initiative policy. The research analysis component focuses on work by C. Ronald Kube and Eric Bonabeau, titled ‘Cooperative Transport of Ants and Robots’. The discussion component analyzes the Biomimic inspiration of ants and bees, robot mechanics, and programing. After completing research paper analysis, the Activity Component will begin with determining a method of reproducing the project using materials available to students. Students will then apply the engineering design process in designing, building, programming, testing evaluating and modifying prototype. Students will be evaluated on the following outcomes: understanding of biomimicry, design approach, programming, robot construction / modification, and ability to complete task. The project itself will be evaluated on its ability to engage students in upper level programing challenge, and students ability to achieve learning outcomes. The module consisted of one GT Engineering Tech class.

Motivation

As tasks being completed by robotics become more sophisticated the trend has been to design and build bigger more complex systems. An approach, under current research, is ‘swarm / multi robot systems’, biomimicry inspired by ants and bees. Swarm or Multi-Robot systems incorporates teams of less sophisticated smaller robots ‘working together’ to accomplish a task. During this project students will analyze how ants and bees are able to apply ‘goal oriented’ behavior to work to complete a task then recreate a research experiment demonstrating swarm robotics. During this lesson students will analyze a Swarm / Multi Robot research described in paper to determine the mechanics, programming logic of robots and how this model can be recreated using educational robotics systems.

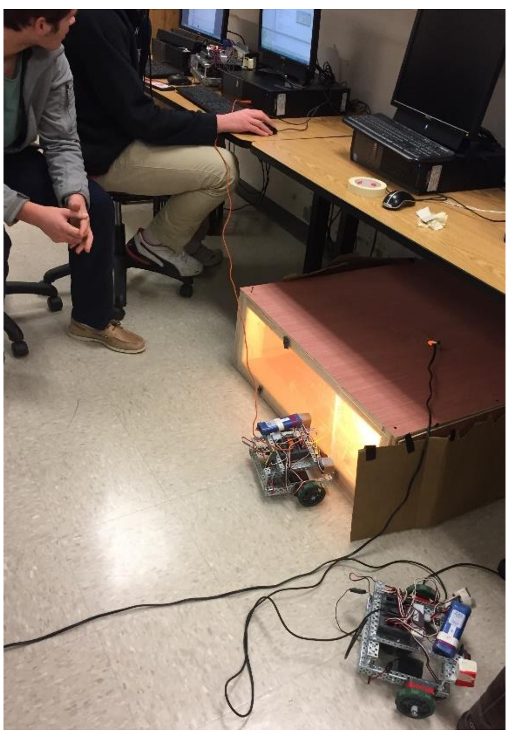
Biomimicry is an engineering approach that uses natures’ solutions as inspiration in the design of a problem. The biomimicry inspiration in this design approach is that of ants.’ In several species of ants, workers cooperate to retrieve large prey’. After an ant finds its prey it will try to move it, when unsuccessful, due to size of prey, it will recruit other ants. The group of ants will continually change positions to move prey. The robotic implementation that the class will attempt to recreate may not seem very efficient, but it is an interesting example of decentralized problem-solving by a group of robots, and will allow students to study input sensors on robots, and interdisciplinary problem solving.

GT Engineering Technology The author teaches four courses of Engineering and Technology Education at a high school in the U.S. The course that the sensor push bot groups unit was taught is GT Engineering Technology. The course covers the following topics: (1) Drafting and Computer Aided Design, (2)) Rapid Prototyping, (3) robotics & sensor technology (4) Mechanical engineering, and (5) Structures. These areas are designed to introduce the student to the engineering process. The course utilizes Blended Learning and Project Based Learning to engage students and create culminating activities designed to have students to apply what they have learned. Students are encouraged to apply concepts studied in drafting, CAD, and Rapid Prototyping in future units.

Swarm / Multi Robot Systems unit introduces students to ROBOTC programming using a set of 9 pre-made motorized robot chassis. Each chassis measures 17" x 17", has four 393 motors, four 3.25" omni wheels, with a cortex controller. Teams of three students learn basic ROBOTC programming and how to use sensors following teacher instructions and completing online tutorials (http://www.education.rec.ri.cmu.edu/products/cortex_video_trainer/).

Upon completion of introductory programming students were introduced to the concept of biomimicry inspired design in engineering. This was followed by three day analysis of C. Ronald Kube and Eric Bonabeau, titled 'Cooperative Transport of Ants and Robots'. During this time students were permitted revisit programming techniques in which they were weak. After initial article analysis student design teams (3 student design teams) were combined with three other design teams to form four robot 'sensor push bot groups, and provided time to design and build their sensor push bots.

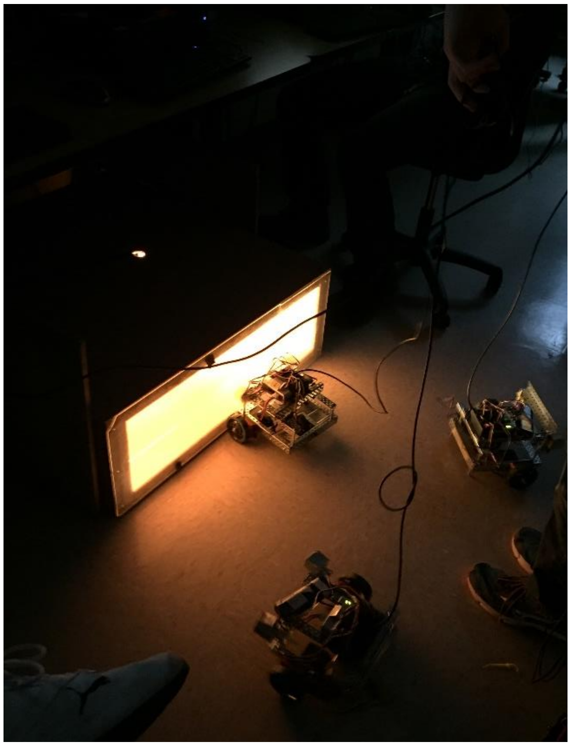
Each Design team was given task of programming their robot to complete the locate 'target ' (locate light box)', travel to 'target', sense 'target' with push button and attempt to push the box.

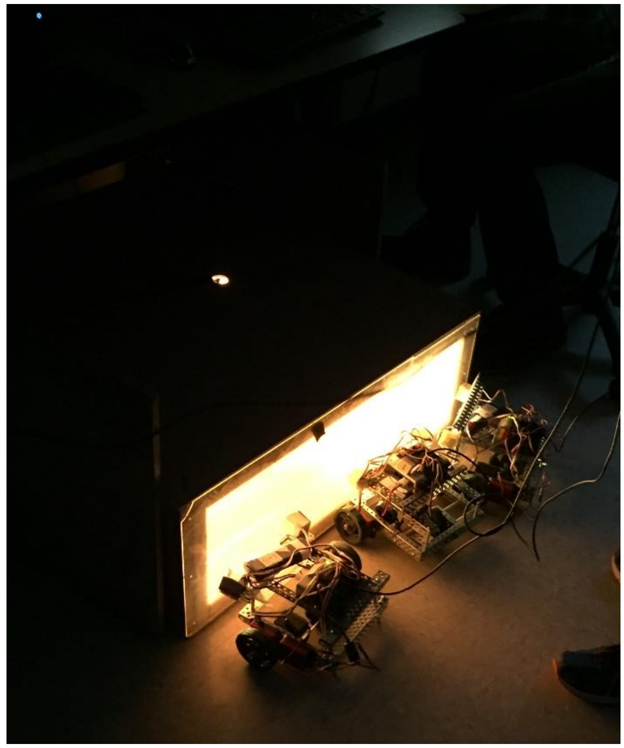


After completing above as individual robots, design teams were allowed to group with 'sensor push bot groups' to compare solutions and work together to complete multi robots.

Sensor push bot groups demonstrated their solutions to class at conclusion of unit.

I believe the simulation would have benefited if some of preliminary investigations were moved to the Cooperative Transport simulation. This change is to make some of the content more meaningful as students will need information at time to complete scenario. It will also allow more time during scenario simulation. I will also provide more time to modify push bots.





Project System Platform

A robot system typically consists of controller, sensors, motors, and system structure. I wanted students to have a building platform that would permit open ended solutions. Since this class enrolls about 24 students, and teams consist of three members (8 teams total), a low initial cost system was needed. In addition, we wanted system components that could be reconfigured for different purposes, allow several systems to be integrated into a larger system (i.e., scalable), and be used by other students when not in use by GT Engineering Tech. Since a strong VEX Robotics Program already exists in our school VEX Robotics was chosen.

Project System Platform. The robot platform used VEX robots, as we have invested heavily into this system and have enough materials for nine robots. We have used Boe Bots by parallel but I did not feel that provided a flexible enough platform.

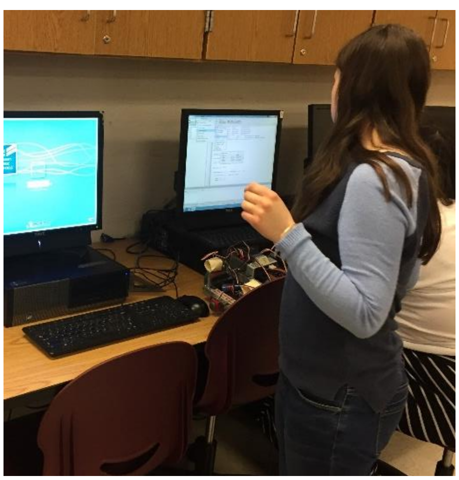
Programming Platform The unit used RobotC programming language. The high school has a 30 seat license for this program. This language is well developed and there are corresponding tutorials, developed at University, that explain programming the sensors in a clear concise manner.

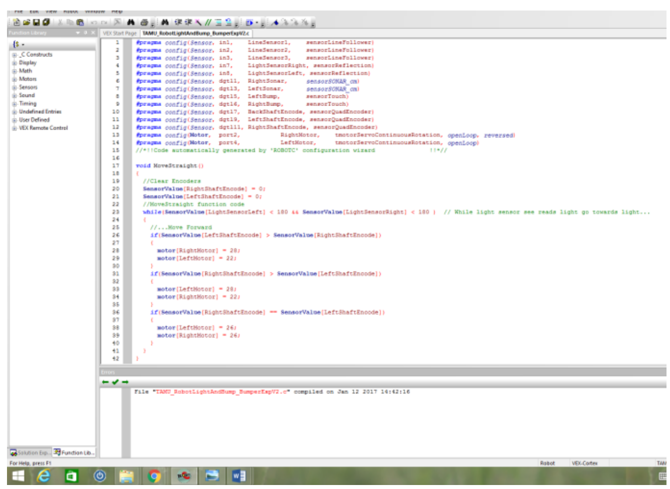
Following information is from http://www.vexrobotics.com/robotc-vexedr-vexiq.html

ROBOTC has a similar look and feel as the programming environments used in the computer science industries, but also includes many useful tools that help beginner programmers to get up and running as quickly as possible:

- All new Graphical Natural Language editor to easily program VEX IQ and VEX EDR robots.
- Graphical Natural Language mode allows beginners to use simplified commands such as “Forward”, “LineTrack”, and “Repeat” loops.
- The easy to use ROBOTC editor includes smart code indenting, automatic code completion, code formatting, and other tools to make programming even easier
- Program robots using industry standard C-programming
- ROBOTC’s real-time debugger allows users to run code line-by-line and monitor values on sensors, motors, and encoders in real time..
- Over 200 included documented Sample Programs with extensive documentation, enabling students to immediately begin programming.
- Free web-based curriculum available for VEX EDR and VEX IQ provided by Robomatter.
- ROBOTC for VEX Robotics 4.x (VEX EDR & VEX IQ) **P/N:** robotc-vexedr-vexiq

The VEX online Video Tutorials http://www.education.rec.ri.cmu.edu/products/cortex_video_trainer/ were completed in the following order. The programs were introduced at beginning of each class. Students were asked to preview each tutorial as homework to make programming time in class more efficient. It was evident which students followed preview advice and those that did not. Lab time was also made available during lunch and two days after school (Tuesdays and Thursdays 2:30 – 5:30)





Fundamentals

1. Programmer and Machine
2. Planning and Behaviors
3. ROBOTC Rules Part 1
4. ROBOTC Rules Part 2

Setup

5. Updating the VEX EDR Firmware(Wired)

Movement

6. Program Dissection
7. Reversing Motor Polarity
8. Renaming Motors
9. Timing
10. Motor Power Levels
11. Turn and Reverse
12. Manual Straightening
13. Shaft Encoders
14. Forward for Distance Part 1
15. Forward for Distance Part 2
16. The Sensor Debug Window
17. Forward and Turning
18. Automated Straightening Part 1
19. Automated Straightening Part 2

The site also provides printed information which students used for introduction to light sensors, optical shat encoders, and touch sensor, while the ultrasonic sensor was a online video tutorial.

Sensor Push Bot configuration Each robot consisted of three optical shaft encoders (We later determined only one is needed), four light sensors (two light sensors to find box, two sensors to search goal), one ultrasonic sensor, one push button sensor (sense box find), two 393 motors, a vex cortex, two 3.25" traction wheels (drive wheels) and one 3.25 inch omniwheel (back wheel – attached to optical shaft encoder, and structural material. A robot 'footprint size of 8" x 8" was established to encourage students to design robots in layers.

Optical Shaft Encoder **P/N:** 276-2156 - 2-pack $19.99

Light Sensor **P/N:** 276-2158 - $19.99

Ultrasonic Range Finder **P/N:** 276-2155 $29.99

Bumper Switch **P/N:** 276-2159 2-pack - $12.99

2- Wire Motor 393 **P/N** 276-2177 $14.99

Motor Controller 29 **P/N:** 276-2193 $9.99

3.25" Omni-Directional Wheel P/N 276-3526 - 4-Pack $39.99

3.25" Traction Wheel - Plastic Insert P/N 276-3525 4-pack $19.99

VEX ARM® Cortex®-based Microcontroller **P/N:** 276-2194 $249.99

Outreach Activities The Swarm / Multi Robot Systems unit introduces students to the concept of biomimicry design and fundamental robotics design, construction and programming. The use of online tutorials allows individuals to learn to use resources to work at their best pace, and allows teacher to become more of a facilitator in the classroom. The robots are built to be modular, can be easily modified for future learning, such as adding arms, manipulators, or geared transmissions to teach mechanics. The Swarm / Multi Robot Systems unit was very popular among participating students and during a recent 'Community Night event' sponsored by school National Technical Honor Society.

Conclusion and Future Directions In this paper, we described the motive, design, and results related to a blended learning and project-based activity to enhance high school students' learning about biomimicry and Swarm/ multi robot systems. The activity provides an excellent opportunity for students to integrate their knowledge of biomimicry design and robotic (such as sensor, actuator, relays, switches, push buttons, PLC and interfacing) in real-life problem solving. The experience is challenging, but seems positive and has been well received by students (some have even brought their parents to see their projects). Future plans include combining sensor push bot robot with a robotic arm to study mechanics, and making the systems available to be controlled remotely via controllers.

It is hoped the unit will also add interest into other automated systems including flying UAVs and participation in robotic competitions.

Learning Outcomes - The project addresses the following ITEEA Learning Standards as the learning outcomes:

- Standard 1- Students will develop an understanding of the characteristics and scope of technology.
- Standard 3 – Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.
- Standard 5 – Students will develop and understanding of the effects of technology on the environment.
- Standard 8 – Students will develop an understanding of the attributes of design.
- Standard 9 – Students will develop an understanding of engineering design.
- Standard 10 – Students will develop an understanding of the role of troubleshooting, research and development …in problem solving
- Standard 11 – Students will develop the abilities to apply the design process.

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[5] A Cooperative Architecture Based on Social Insects Iain Brookshaw, Dr. Tobias Low http://www.araa.asn.au/acra/acra2013/papers/pap117s1-file1.pdf