Solar Bug Bot Olympiad: A STEM Educational Outreach Workshop

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Abstract
The ongoing development of a Solar Bug Bot Olympiad is discussed as an educational outreach workshop that implements electrical components and devices with photovoltaics-powered motors, modeled after Beam robotics. The development of this workshop includes educational demonstrations to middle school students and hands-on educational activities for high school students, with mentoring from students at the collegiate level. The STEM educational effort will implement project-based learning and employ a student feedback mechanism to enable continuous improvement as the workshop continues to evolve. A virtual learning environment will be included in the workshop design to allow for remote participation. Virtual integration will also allow for participation in parallel competitions across various sets of obstacles tied to learning objectives which are related to basic circuits, energy, power, voltage, current, along with the applications of motors and sensors in this context. The expected outcome is a more inclusive, sustainable and available STEM outreach, as well as acclimation to introductory engineering concepts under the guidance of college student mentors.

Keywords
STEM Education, project-based learning, educational outreach, beam robotics, engineering education, virtual learning, sustainability

Introduction
The proposed workshop involves building a robotic "bug" using basic electrical components that are easily accessible and available. This workshop is designed as an outreach program for middle and high school students, with varying degrees of difficulty for students, as appropriate. The workshop is designed to combine different methods to interact with energy, such as generation via solar power, storage via a capacitor and consumption of energy in a motor or an actuator. It also provides a competitive, collaborative and game-focused atmosphere in a generation where technology and video games are a big part of everyday life and are commonly implemented as part of academic curriculum in a primary and secondary school setting. Unique categories, based on individual or team efforts, will also be utilized as part of the competition in the proposed workshop, such as categories for originality and creativity. The functionality of the robot would remain consistent for all student entries, but there would be a creative aspect in the design of the bug itself, that would be included as part of competitive rankings.

This educational outreach workshop employs BEAM (biology, electronics, aesthetics and mechanics) robotics [11-16], which includes biologically inspired robotics designs that utilize basic circuits concepts, motors, resistors, transistors, actuators and capacitors. BEAM robotics do not involve computing or microcontrollers, rather the function resides in the bio-inspired design. This workshop can help introduce or reinforce the basic concepts of circuit analysis and operation. It improves critical thinking skills when designing a robot that is the fastest, strongest, etc. There is also the added benefit for high-school students of learning/improving how to solder and becoming aware of component assembly. Having a team of different disciplines could help combine talents and produce an effective and efficient bug that accomplishes a given task. Alternatively, there can be challenges that can be tackled individually. For middle school (primary and secondary) students, this presents an opportunity to introduce them to the basic concepts of electrical and computer engineering, touching on topics such as circuit operation, analysis and energy consumption with the support of a mentor. The process of assembly and use involves fundamental topics ranging from voltage, current, and power with components like resistors, capacitors and wires to more advanced concepts such as transistors, actuators and solar cells highlighting energy generation, storage and electrical-mechanical energy conversion, which are topics that may serve older students, such as high school students. Topics Introduced: Circuit analysis techniques, resistance, capacitance, energy consumption, transistor, actuation and capacitor operation, solar cell operation. The work on progress aims to expand the topics covered by the workshop, workshop learning materials and methods to sustainably source the components and resources.

Background

Significant work has already been done in the field of project-based learning (PBL) related material. Many similar variations of PBL educational robotics and competitions have been created and provide examples ranging in complexity, such as marble sorting machines, hydrogen and solar cell powered cars to autonomous robotic systems. Another important feature of this trend is Robo Cup soccer, an idea developed in 1997 [4]. The project includes a soccer game played by fully autonomous robots. There are multiple versions; one that is software based with robots would play soccer on a server, and the other with robots competing in different areas of competition other than soccer. Two decades later, significant enhancements have occurred to the robots that are designed, [4] as we see commoditization of robotic components, enhanced availability of consumer robotic systems and growth of robotics STEM initiatives for a trend in more inclusive access to educational opportunity and expanding the game based approach to robotics education.[3,5,6] A recent example of these efforts involves students at the University of California San Diego creating robots to compete in a robot Olympics[1] and the trend in the maker community making these concepts more available to the public[2]. The goal is to design a robot that can pick up Olympic “medals” and place them in their appropriate pedestals. Points are awarded based on correctly placing a first, second, or third place medal. The higher the place medal, the more points awarded and the heavier the medal. The outreach potential and engagement of students for these types of efforts can allow for broadening participation of females in STEM, diversity and inclusion, reaching a larger community of students [8,9,10,17].

Discussion

The development of a process to engage middle and high school students from multiple disciplines by creating a robotics outreach activity began with an undergraduate electrical engineering student serving as a mentor to undergraduate mechanical engineering students as they worked together to develop the solar bug bot Olympiad. The process for development of the bug robot and its components, where the students would consider the idea of a “bug” based bio-inspired robot and then the physical form is left to interpretation by the student and built in any way that maintains the appropriate electrical connectivity. The workshop activities are expected to require approximately one half-days’ time. Activities for middle and high school students would include: 1) creating student teams and assign remote mentors, 2) identifying components provided in the kit, 3) reviewing instructions for kit under the guidance of assigned mentors, 4) assembly of components under the guidance of assigned mentors, test the bot functionality and practice the games, 5) student teams will compete in a set of games, with scores recorded, and, finally, 6) winning teams will be announced and awarded. Students at the high school level will also participate in evaluating the connectivity of components, as well as testing the final product with a sunlight source. Middle school students most likely will not be ready to solder the bug robot from scratch. Therefore, they will receive a robot that is premade, and possibly create the legs for the bug using a hot-glue gun, or they could create the robot using a breadboard to connect the components and then hot glue the breadboard to the robot. For high school students, they should have the ability to build the robot from scratch using a project-based learning method in order to accomplish a specific task or a series of tasks. Mentors for this project will include students at the collegiate level, to guiding high school and middle school students through the process of the workshop and provide interactive demonstrations as part of the solar bug bot Olympiad.

Guidance for participants would include an assembly guide, safety guide and game participation instructions, along with assignment of a mentor. The plan for building the robot would be given in sequential steps. They would follow the steps to solder the components together correctly. As for the appearance of the bug, it would be left up to their imagination. Equipment required will include soldering iron, fan, wire cutters, heat gun, hot glue gun, wire strippers and hand held multimeter along with a ventilated or open-air space. Consumables required will include solder, hot glue, wire, solder wick and shrink plastic. Other consumables that may be included are conductive threading and fabrics. Bug bot components include; 4.7V small solar cells, PNP transistors, NPN transistors, 2.2kOhm resistors, voltage trigger with 1 input and voltage threshold of 2.7V, 1.5-4.5V vibration motor at 0.195A, and 4700uf capacitors. Other components that may be included are LEDs, piezoelectric sensors, and upcycled components. Solar bug bot with solar panels, transistors, a motor, and a capacitor with related parts is shown in figure 1. The capacitor charges and discharges through a voltage trigger to momentarily power a motor that has a counterweight attached that makes the unit vibrate. The solar cells apply 5 volts each to the capacitor to begin charging. Once the voltage of the capacitor exceeds the trigger voltage of the voltage trigger, the voltage trigger will allow the voltage to the base of transistor A. Transistor A then becomes forward biased and enables current to flow across it to the base of the transistor B. Transistor B then acts as a switch to enable the stored voltage in the capacitor to discharge across the motor causing it to vibrate. The capacitor discharges until the capacitor voltage drops below the threshold voltage of the voltage trigger and the transistors turn off. This now enables the capacitor to build up its charge again and the process repeats itself. As long as there is sunlight applied to the solar panels, there is nothing to prevent the function of the circuit from repeating. The bot will continue to vibrate at intervals until either the solar power is removed or a failure of a component.

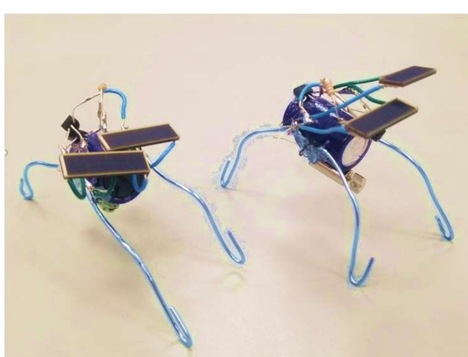

Figure 1: Functional Solar bug robot constructed for evaluation

The limitations of this device are that it only works during daytime hours or with a sufficient light source. Some in-progress efforts involve modifying the current form of the solar bug bot, to enhance its ability to follow the path of the sun or a light source. The circuit could be assembled to allow fo minor position changes to a unit for maximum sunlight exposure. Additionally, the entire workshop along with the games are designed to make use of low cost and highly available components, utilizing basic circuit components that will be readily available for the near future. In general the time required to assemble a solar bug bot can range between 3-5 hours given correct preparation and being new at soldering. Soldering is not an easy activity for a first time user, so mentoring is expected. Soldering is also a safety issue. High school students would be briefed on the importance of safety when soldering and handling electrical components, along with direct mentor support. Middle school students and those that are younger will not be soldering. The time to participate in the Olympiad portion of the workshop may range from 1-3 hours. Currently, the effort is to reduce the overall time required to 3 hours for assembly and the games. Another, important aspect of the design is to allow for sustainability, as it needs no external power source or batteries to power the unit. Additionally, some of the components are harvested from e-waste, and the concepts of sustainability and environmental protection from e-waste are embedded into the outreach activity. The sustainability features of the activity are expected to grow and influence the theme of the entire workshop as it evolves.

Multiple games have been developed that incorporate educational robotics and associated sports. The goal for this workshop is to create games that can be implemented to the robot being designed with a game in mind. Tug of war is the first example. Two robots can be facing away from each other with a string attached between them. Based on their effective design and efficiency, one bug would move better more frequently to pull the flag towards them. Another example of a game could simply be a race to the finish line. They begin at the same place and let their bugs do the work to see who crosses the finish line first. Rules would be established and altered after a few tests runs to overcome any potential obstacles such as possibly repositioning your robot to face the correct direction. Other potential games being considered are robot wrestling in the style of sumo wrestling, where one bug bot attempts to push a second robot out of a circle to score points, with consideration of timing and function. Multi-robot games are also being explored to consider teams of robots that may involve a more interactive playing field. All the games have the purpose of bringing experiential learning into the workshop, provide social interaction and expand demonstrable features of the robot circuit to ideas of applications in a gaming context.

Collecting Data for the games: Game data collection is accomplished though collaboration of mentors and judges for the games. Data is recorded related to scoring for each event based on a rubric into spreadsheets or a similar user interface. Data will be captured via a stopwatch for the tug of war, wrestling and sprint races.

Collecting Data for the project: Surveys would be administered to the teachers of students, student mentors and the students performing the workshop to determine the overall effectiveness of the workshop and any recommendations for improvement along with providing opportunities for unstructured feedback as an end of project activity. Some of the types of feedback requests are on the process of building the robot, the mentoring experience and the structure of the games they played.

Analysis

The analysis for this outreach activity would be based measures of the student participation, and student success in assembling, operating, and deploying a game context. We may also incorporate a measure of sustainability by number of upcycled components used. This data will provide information for analysis of the number of students engaged, progression through the activities and various states of levels of success as part of the game portion of the outreach activity. Another primary resource is the implementation of surveys and the review unstructured feedback results. Review results from surveys and address any issues with the program as necessary for improvement. Determine if the system was effective in accomplishing some of the goals. Questions could be considered by the developers of the outreach activity as part of this future analysis such as: Did the program work the same for all the groups or were there faults in the design process or components given? If there were differences between groups, did it hinder the process of achieving the desired goals? Were the activities inclusive and accessible? In general, the opportunity to analyze the survey feedback in relation to the student success in the activities will allow for specific improvements to be identified. The unstructured feedback may allow for more qualitative details both from students participating and undergraduate student mentors supporting the outreach activity.

Conclusions

The proposed workshop promotes engagement of undergraduates through service learning and project based learning, and serves as an STEM outreach activity for primary and secondary students. The mentorship of high school students by undergraduate volunteers provides guided participation to build robots and then compete in a series of games. For younger students, demonstrations are expected to get them interested in the idea of electrical engineering and circuits, but the games remain a hands-on component at every level. Methods to measure participation, success of students and feedback for continuous improvement are described, but the surveys and activities are an in-progress. We expect these resources to support the ability to analyze the ongoing development of the workshop and potential to make it available to students beyond this initial work. Some challenges expected are the logistics of making similar components available, supporting training in remote learning cases and making mentors available in all locations where the solar bug bot Olympiad occurs. Early builds of the solar bug bot were unsuccessful and needed some analysis. The bot worked after some troubleshooting and testing of the voltage trigger so some adjustments had to be made. Similar issues may occur, so some remote technical support for teachers testing this may be needed. The participation at the undergraduate level for an initial trial for assembly and operation showed the value of a potential service learning activity engaging sophomores and juniors, while providing leadership opportunities to coordinate the activity at the senior level.

Future work for this workshop may involve expanding the functionality of the robot. Perhaps to incorporate additional sensors, switches and LEDs into the project. Using different materials for different parts of the robot to make it more effective or accomplish tasks easier could be considered. Expanding the selection of games to be played and more creative ways to utilize these robots may also result in a more engaging activity. Some specific changes to the robot could include conductive fabric to enhance interactive features in multi-robot games to form multi-robot circuits. Additionally, some expansion of the functionality of the solar bug bot could include sensors, and a contact switch to allow them to de-activate each other based on contact, like playing a game of tag. The content delivery options for guides, instructions and training of teachers along with assigning mentors could be enhanced in the planning stage to be done online to allow for virtual participation, sharing of ideas, sharing designs, purchasing components at larger scale and potentially crowdsourcing the sourcing upcycled components for a future Green Olympiad for the solar bug bots.

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