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Development of a Summer High School Research Program

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Development of a High School Summer Robotics Research Program

Introduction

This paper focuses on secondary school outreach efforts of this School of Engineering, Mathematics, and Science. The school recently divided its research center into a two-fold entity, a research and outreach center. Direction of research was also altered from extension-based industrially-driven applied projects to basic research activities. At the same time, the previously independent K-12 outreach arm of the school was added to outreach segment of the center. In the last decade, the K-12 outreach arm has been operating by offering teacher and student workshops, organizing conferences and competitions as well as summer camps. Events organized by the school have included Expanding Your Horizons (EYH) Conference, MathCounts and First Tech Challenge (FTC) Competitions, and summer camps in Animatronics, CSI/Forensics, Alternative Energy/Sustainability, and Ecology. In addition, the outreach arm has been actively engaged in the local exhibitions and fairs including Carnegie Science Center events.

A new initiative has been developed to present research opportunities to high school students. The theme selected for the research activities is alternative actuation methods for robotics. These new actuation methods do not utilize conventional electric motors. Recent developments of flexible gumby robots[1], interesting memory alloy behaviors[2] as well as other alternative means such as magnetic and pneumatic actuation are employed in attracting students into this field. A 3-day pilot study was developed and conducted with participation of 8 interested high school students. Students designed and built robots that were actuated by pneumatic propulsion or magnetism. This paper will present objectives and structure of the initiative, lessons learned from the pilot study, and will conclude with the future plans. As a part of the objectives of the effort, one of the participants is involved as a co-author of this paper giving her perspective as she contributes to the further development of the research program.

Developing a Research Summer Camp

The lead author has been designing and conducting summer camps for a decade. The camps varied in subjects from Robotics and Animatronics to Computer-Aided Design, Computer-Aided Engineering, and Computer-Aided Manufacturing (CAD/CAE/CAM). These camps were in residential and non-residential nature. Duration of these high school-level camps varied from three to seven days in length. Work spanning a decade allowed the lead author to develop extensive materials for short-lessons based on Power Point slides and hands-on fixed goal laboratories as well as open-ended capstone projects. His longest lasting camp, Animatronics, drew close to 200 students within the decade. At times, these camps gained recognition of the local media[3]. While initial efforts relied on scrap materials and components, more recent efforts were funded by the Ohio Department of Education Summer Honors Institute Program or the Benedum Foundation.

Due to strong demand from prospective participant families, the lead author decided to hold middle school Animatronics camps for the first time in the summer of 2012. Camp materials were adapted to the middle school level. Resulting products of the middle school camp are shown in Figure 1 and 2. While Figure 1 depicts an ALF (TV character) and Star Wars hybrid type of robot, Figure 2 is a monster designed and built by a middle school student. The hybrid was radio-controlled and the monster was autonomously driven by using ROBOT C programming language. In the meantime, a new concept was

Figure 1. Product of a 2012 Summer Animatronics Camp[3]

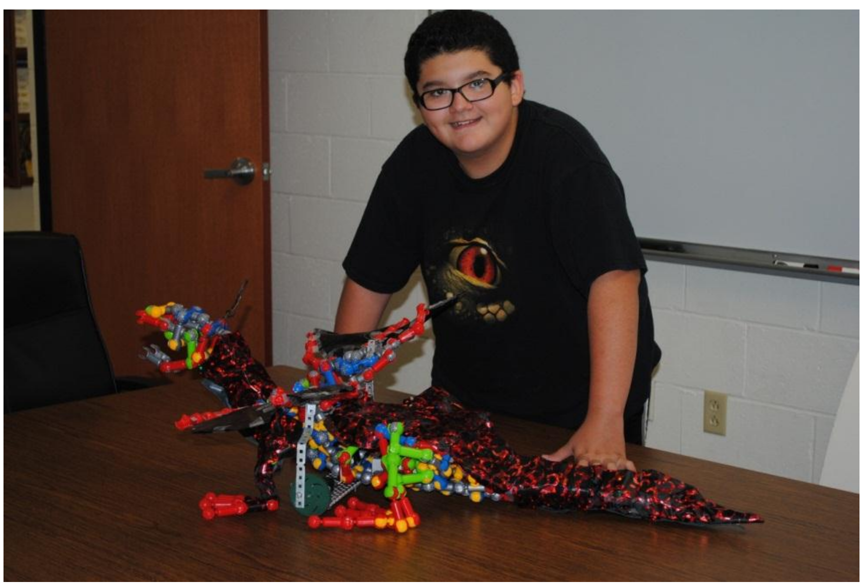

Figure 2. An autonomous monster built in summer 2012

also being developed to shift summer experiences from open-ended cross-disciplinary animatronics projects to more research-based direction. New developments within the robotics actuation field were chosen as the theme. The open-ended design based approach in animatronics camps was not so far-fetched from conducting research since both approaches were based on similar methodology.

The Development Process and Structure of the New Camp

The camp development team included the lead author and his outreach manager. The group, with the help of their Institutional Advancement (IA) Office, developed the concept for the camp as well as a funding proposal to be submitted to a local foundation. The proposal was not funded, but the team decided to offer the camp on a smaller scale anyway. A limited number of students were recruited since this was the pilot for the future camps. Most participants have previously participated in animatronics camps. They registered by responding a listserv-wide announcement. Unlike the animatronics camps which drew almost 40 middle and high school students, this camp drew 8 only students and was held in the summer of 2012.

The schedule of the camp was compressed into 3 days and included the following steps:

- Introduction of the camp team and participants
- Presentation of problem statement (camp objective)
- Literature review and presentation of various background information
- Brainstorming
- Project work
- Presentations of completed projects

After the introduction of the camp leader and the helpers, the outreach manager and laboratory engineer, the students were given a problem statement. Students were

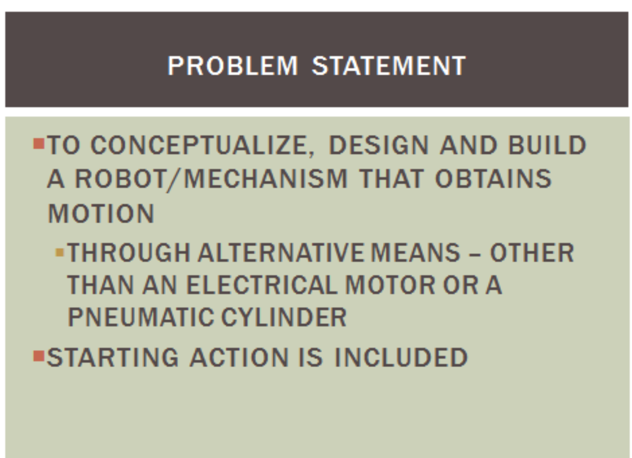

Figure 3. Problem Statement

expected to conceptualize, design and build a robot or mechanism that obtained motion through alternative means other than an electrical motor or a pneumatic cylinder. Students were allowed to initiate the action with traditional means before their method can take over the action.

Prior to working on concept development, students were exposed to means of electronic research databases including Google Scholar with keyword and abstract search, Google Patent search, hard copy and electronic book resources, and trade and scientific journals. Students from the previous Animatronics camps actually took advantage of some of these tools very well.

After the introduction of information search tools, the lead author made some presentations on shape memory alloys (currently used in flexible gumby robots), magnetic propulsion and some mechanical designs driven by spring motors, and a slinky to give additional background to the students.

Presentations were followed by a formal brainstorming session based on idea triggering. The form students used are given in Figure 4. Multiple iterations were made until they came with ideas which were feasible and agreed on by the team members.

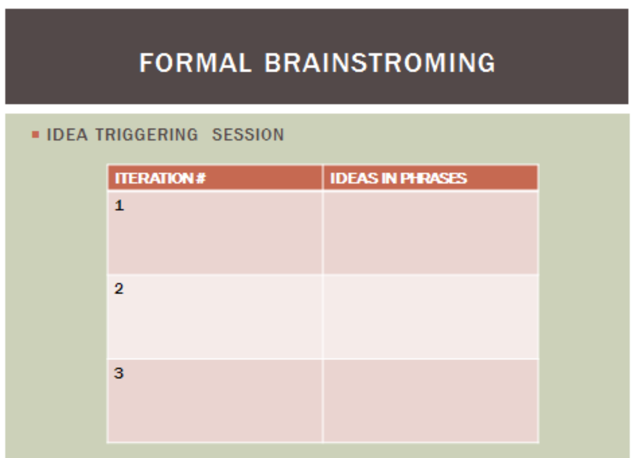

Figure 4. Formal brainstorming form

Students were broken into two 4 person teams. They were told that they can use shape memory (Nitinol) wires and springs, VEX Robotics Development components including its PIC microcontroller, spring motors, and any other available parts within the laboratories.

Camp participants utilized Nitinol wires and springs in simple experiments. These experiments were taken from Roger G. Gilberston's Muscle Wires Project Book[4]. The main author also purchased and utilized 050 – 250 LT Flexinol wires as well as 3-642 NiTi tension springs.

- Students were asked to stretch a spring, and then they applied a small current (in mA) to it at 3 VDC. After the current was applied, the spring returned its original shape.
- Students then learned the mechanics behind the Shape Memory Effect (SME). Students were amazed that the effect was caused by heating due to the small current. Heating the alloy to above its transition temperature forced the crystalline structure to undergo a phase change and allowed the spring to return its original shape.
- Several students built a basic muscle wire device where a Nitinol spring was used to lift a small object. The simple mechanism included two links similar to lower and upper arms of a human. The lower link held the part and was driven by the Nitinol spring.
- In addition, students were shown Stiquito robots that generated locomotion based on SME.

In addition to SME actuation, students were given multiple resources on new flexible gumby robots[1,5,6]. The resources included articles and videos (Figure 5). Students were explained the inner workings and potential applications of these robots. Besides being made from flexible structural materials some of these robots also used SME to actuate or to reshape the robot.

Figure 5. Gumby robot developed at Harvard University[5]

Once deciding on using pneumatic propulsion (using air from a pressurized air reservoir) and permanent magnets, they started working on their projects. Since only the initial action can involve use of an electrical motor or a pneumatic cylinder, students in the second group were allowed to use an electrical motor driven by the VEX controller to start the magnetically controlled arm. Figure 6 is illustrating the lead author and students installing the required firmware into the VEX PIC microcontroller before a ROBOT C program can be downloaded. The section of the arm was moved by an electrical motor, and the permanent magnets took over to complete the action. The other group chose to utilized air propulsion to move their floating device shown in Figure 7. Group members were given both a solenoid and manual valve. Most of their design work consisted of improving pneumatic propulsion controlled by the manual valve. They experimented with different air reservoir pressures and valve openings since they had a solenoid not a servo valve.

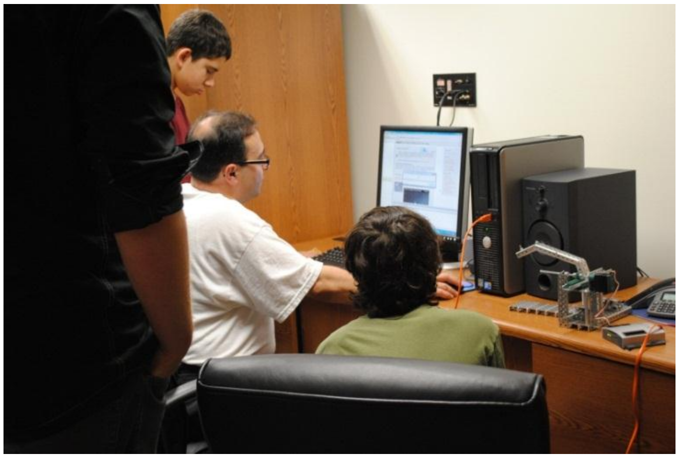

Figure 6. Preparing the VEX controller

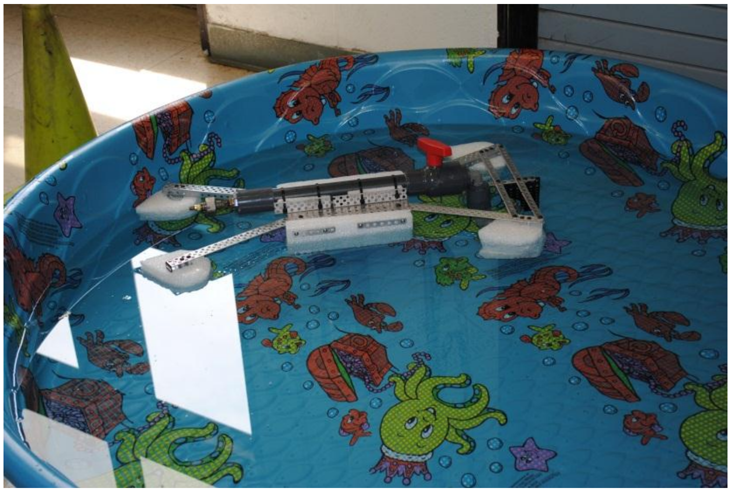

Figure 7. Air propulsion in a floating device

Comments from Camp Participants

This section presents detailed feedback from two of the participants. Both have been involved in the Animatronics and other camps offered by the main author. The first participant is also the co-author of this paper.

- As a participant in the Alternative Robotics Camp, I had the opportunity to learn about alternative means to actuate various types of robotic mechanisms. First, we studied alternative means through which robots can move, such as the utilization of shape-memory alloys (muscle wires), pneumatics, and magnetism. I particularly experimented with shape-memory alloy-based springs as an attempt to move a small load by applying a small electric current to the spring. Other camp attendees experimented with permanent magnets and pneumatic controls.

Two different mechanisms were built: a VEX robot arm driven by permanent magnets and a pneumatically driven robotic water floatation device. Both groups were permitted to use an external impact to initiate motion. The first group utilized only the interaction of the poles on their permanent magnets to actuate the robot, while the second group used an air jet coming out of a pneumatic system to generate trust to move the robotic floater on water.

Through my experimentation with shape-memory alloys, I was able to understand the impact of crystalline structure changes of the material on the shape or length of the alloy. This practical experience allowed me to not only visualize, but to further justify the theoretical information about shape-memory alloys. However, we did not utilize the shape memory alloys in our design. On the contrary, it was fascinating to observe the results of both groups as they constructed and tested their creations.

- This was one of the more challenging camps offered through the STEM program at the university, as well as one of my favorites! It was a weeklong day camp designed to make you think outside of the box. It was not just a robotics camp. It pushed you to really think how alternative energy works, and how to relate it to robotics. In previous robotics camps, we would add a battery powered electric motor to make a robot function. But, in this camp you had to design a functioning robot that could complete a task using some form of alternative energy.

  As a group, we had access to a variety of building materials provided at the university. We worked together to design a robot. Then, we had to brainstorm to figure out which type of alternative energy would work best to make the robot function.

  Overall, it was an educational experience that was very enjoyable and fun. The only problem with the camp was that it was short. More time would have enabled our group to not only build a robot using alternative energy, but also to work out the problems to make it more functional.

Conclusions

In conclusion, the three day pilot built on the lead author's previous summer camp experiences presented a good insight on the possible content, project scale and duration of the new research camps[7,8,9,10]. It also strengthened the idea of combining high performers with (hands-on) practically oriented students in groups to help improve each others' weaknesses. Next year's camp duration will be extended to 5 days, since 3 days did not allow enough time for elaborate design and problem solving. Students in the pilot study were told to prove concepts and work hard to come up with a working-prototype.

Even though both groups delivered good results, they could have improved their designs if given two additional days.

Feedback from camp participants and parents was very positive. Besides working on the projects, students conducted literature reviews using different sources and experimented with shape-memory alloys, permanent magnets, pneumatics, or spring motors. Students were able to gain additional insight into some concepts they had not previously been exposed to. Students did not continue their projects at their respective high schools as planned, but this will be attempted next year. All of the high school senior students from the research camp are applying or have applied to mechanical engineering programs, and some have already been admitted.

Future efforts will also include submission of research work to trade or scientific journals as well as specific conferences. For this reason, one of the participants was invited to contribute to this paper.

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