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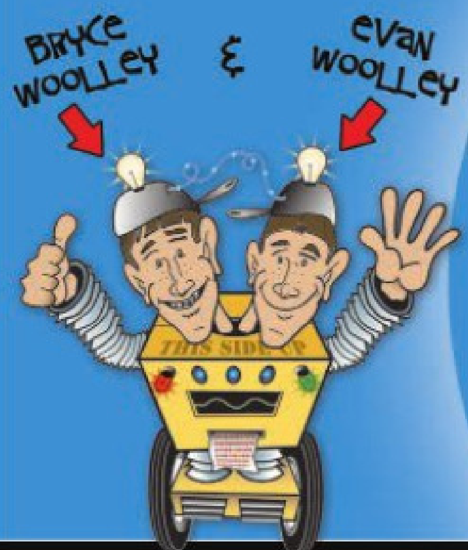
Twin Tweaks



THIS MONTH:
The Education of Budding Roboticists

COSMOS CLUSTER 2.

In previous installments of Twin Tweaks, Evan has had the privilege of chronicling his education as a mechanical engineering major at UCSD, because it just so happens that robotics are an excellent way to prepare engineering students for real world problems that demand interdisciplinary knowledge, teamwork, and technical communication skills. Robotics projects have been a critical part of Evan's studies as a mechanical engineer, from the ring stacking robot contest of MAE 3, the lower division design course (August '06 Issue), to the sophisticated safe cracker of MAE 156B, a senior design course (January '09 Issue). But while *SERVO* readers may now be convinced that engineering students are given a generous dose of robotics during the course of their education, there is yet another important issue where a careful application of robotics can be the solution. The adequate preparation of engineering students in American schools is not really at issue, but the numbers of students pursuing those degrees are. Numerous organizations — perhaps most notably FIRST — have recognized that robotics are an effective and inspirational way to both prepare high school students for the rigors of an engineering program and to inspire them to pursue it in the first place. During the summer of 2009, I was given an inside look at how the COSMOS program seeks to achieve those same results.

A COSMOS That Carl Sagan Would Be Proud Of

COSMOS is the California State Summer School for Mathematics and Science — a program that offers a variety of four week residential programs hosted at several campuses of the University of California system. The concentrations

THE CLUSTER 2 TEAM, (FROM TOP): DR. NATE DELSON, DR. RAYMOND DE CALLAFON, BRINN BELYEA, EVAN WOOLLEY, AND ZAC DOOLEY.

of the programs (or "clusters" in COSMOS lingo) range from biomedical engineering to oceanography to robotics. The participants are high school students entering the ninth through the 12th grades. The tuition for the summer 2009 program was $2,550 for California residents and $6,500 for non-residents. That may sound steep, but the program offers a lot. The tuition pays for on-campus residence (a great introduction to college living for the students, who even have resident advisors) and food at the dining halls for the four weeks (another essential introduction to college life). But tuition pays for much more than the bare necessities. Transportation for field trips is also provided, but the best part of all of this is the attention that the students get from real university faculty members. The cluster that I was involved with was staffed by two full time professors (the incomparable Dr. Nathan Delson and Dr. Raymond de Callafon), a high school physics teacher (the fantastic Mr. Brinn Belyea of Torrey Pines High School), and two recent graduates from UCSD, myself and fellow mechanical engineer Zac Dooley. All of this brain-power was brought together to inspire a group of 23 high school students in Cluster 2 about the joys, trials, and tribulations of building a mechanical clock and a kinetic sculpture.

The folks at COSMOS are dedicated to keeping this as an accessible program, because students can apply for financial aid to pursue this great opportunity. Approximately 40% of the students for the 2009 COSMOS program received full or partial financial aid.

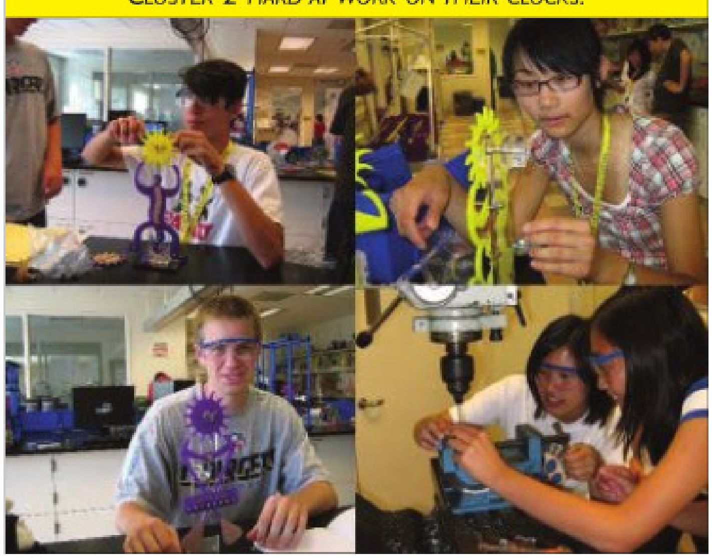
COSMOS-politan

Evan wanted to be involved with the COSMOS program because he remembered how inspirational the engineering programs we went through in high school were. During three weeks at the Palo Alto Research Center, we had the opportunity to see the types of real world projects that engineers worked on, and the FIRST program gave us a dose of intense interdisciplinary teamwork where we experienced the sense of accomplishment that comes from completing an intimidating project. These were the experiences that inspired Evan to go into engineering — an admittedly daunting field — because completing these programs comes with the realization that with the right team and the right drive, anything is possible.

The other Cluster assistant, Zac Dooley, was similarly dedicated to inspiring students about engineering, and he had served as an MAE 3 undergraduate tutor like Evan had. That means they both already had the opportunity to work for Dr. Delson. *SERVO* readers may remember Dr. Delson as the mastermind behind both the MAE 3 (ring-stacking robot) and MAE 156A (safe-cracking robot) projects. Joining Dr. Delson was Dr. de Callafon, an expert on controls that would be teaching the COSMOS students the ins and outs of programming in Basic. To complete the team was Mr. Belyea who would teach the students physics fundamentals that would be essential in building their kinetic sculptures. Kinetic sculptures and programming, you ask? That's not even the half of it!

If You Want To Start From Scratch, Start With The Creation Of The Universe

The COSMOS program is a seemingly short four weeks, but in Cluster 2 we hit the ground running. After some quick introductions, the



CLUSTER 2 HARD AT WORK ON THEIR CLOCKS.

EVAN HELPS OUT AARON AND AMARAJ WITH THE LASERCAMM.

Zac helps out Andrew and Danee with some programming.

Visiting the Stingray.

The COSMOS Control Box.

students were thrown head first into their first project: a mechanical clock project eerily similar to the one presented to mechanical engineering students in MAE 3 at UCSD. The COSMOS students were expected to design a pendulum and escapement wheel on AutoCAD, and perform a timing analysis using the simulation program Working Model. A tutorial on AutoCAD was on the menu for the very first day. By the end of our first session, the students had already designed fierce looking escapement wheels.

The mechanical clock project is a great introduction to many fundamentals that are critical for any engineering project. The swinging pendulum is wonderfully illustrative of conversion from kinetic energy to potential energy, center of mass, and moments. Fabricating the clock is also a great introduction to basic shop tools and the super cool Lasercamm for rapid prototyping. The clock project is a fabulous way to practice the most essential skill in any engineer's toolbox: creativity. Students were able to exercise their creativity by designing their own pendulums. Pendulum designs ranged from Atlas holding the world, to microphones to dragons and everything in between.

You Must Be Kessler

The first week was spent wrapping up the mechanical clocks, so that in the second week we could get started on the main event: kinetic sculptures. Kinetic sculptures, you ask? This is a robotics magazine, not an art magazine! But these kinetic sculptures are automated, with a Basic ATOM as a brain and servo motors for locomotion.

The kinetic sculpture project is a group activity where teams of 3-4 students can quite literally let their imaginations run wild. The sculpture is where the Cluster curriculum diverges from the MAE 3 syllabus, with the sculpture replacing the robot contest. Taken as a whole, however, the kinetic sculpture project is quite similar to the robot contest. The requirements of the sculpture are that it must have several mechanisms that respond to both sensor input and manual control — much like a robot. The competitive aspect comes in when each team tries to make their sculpture bigger, better, and cooler than the next team's.

Casino de Geisel by The Justice League.

The main brain of the kinetic sculpture is the COSMOS controller box. The controller box uses a Basic ATOM microcontroller, an LCD screen, and inputs and outputs for the sensors and actuators. The sensors used with the sculptures are optical speed sensors containing two sets of phototransistors. The phototransistors can count the number of passing balls (the bright yellow passengers of the kinetic sculpture thrill ride) or calculate their speed based on the distance between the phototransistors and the time of each reading. Traditional limited rotation servomotors were used for the actuators.

The skeleton of the kinetic sculpture is an intriguing set called the Chaos Tower, which is meant to be a fun and interactive introduction to physics. The Chaos Tower includes a basic structure of blue cylindrical beams, plastic connectors, and a track for some intrepid yellow balls. The kit includes a multitude of ways to see physics in action, including trampolines, to illustrate the coefficient of restitution and vertical loops to demonstrate centripetal force. The Chaos Tower forms the foundation for the COSMOS kinetic sculptures, and the students are given the task of automating the sculptures.

Two examples that we provided to kick-start their imaginations were a moving trampoline and moving basket. The trampoline used a random number generator to change positions to bounce a ball into one of three baskets. The moving basket used data from a speed sensor to change its position to catch balls approaching at different speeds.

To supplement the basic kit, we provided the students with the speed sensors, servo motors, potentiometers, switches, and generous amounts of acrylic for use with the Lasercamm.

These Pretzels Are Making Me Thirsty

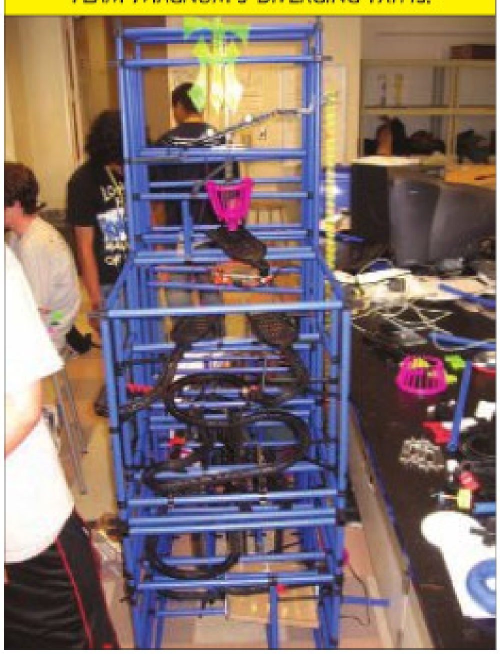
For the purposes of the kinetic sculpture project, the students of Cluster 2 were divided into five teams of four and one team of three. For Week 2, students were tasked with building a mini-sculpture that used at least one sensor and one actuator. To aid in the designing and building of the mini-sculptures, students were given instruction in physics by Brinn and programming by Dr. de Callafon. But as any good project manager knows, the brainstorming process can be a tumultuous and unruly tempest, so Dr. Delson sought to provide some guidance with teamwork and prototyping exercises. Teamwork was solidified with the classic Oreo cookie tower exercise (building the highest tower possible out of Oreo cookies); brainstorming required drawing ideas out on paper and risk reduction activities.

Risk reduction exercises were essential for the COSMOS program because the compressed schedule forced students to make quick design decisions. To test the feasibility of their designs, the teams were equipped with foam core boards and a working knowledge of the Lasercamm. Many ideas for basket mounts and servo arms proved fruitful, but perhaps the best discoveries were of

Cirque du Geisel by the Boyz In Da Hood.

Blue Steel's learning sculpture.

Team Magnum's diverging paths.



A steep slalom and gradual slide by We The Queens.

the designs that needed some work. How could jamming be avoided on the linear slide? What would be a more optimal gear ratio? Finding what doesn't work or what could be done better is truly what motivates good design.

In Cluster 2, we aimed to give the students a comprehensive exposure to the world of engineering and robotics, and many other activities provided respites from kinetic sculpting. At a set of outdoor physics activities, we shot bottle rockets, fired water guns, sling shot water balloons, and dropped bouncing balls off of the engineering building. While this might all seem like fun and games, the inclusion of inclinometers, coefficients of restitution, and cosines revealed these activities to be essential reinforcements of engineering fundamentals. Because no matter how advanced the project or how independent the robot, the fundamentals are always there.

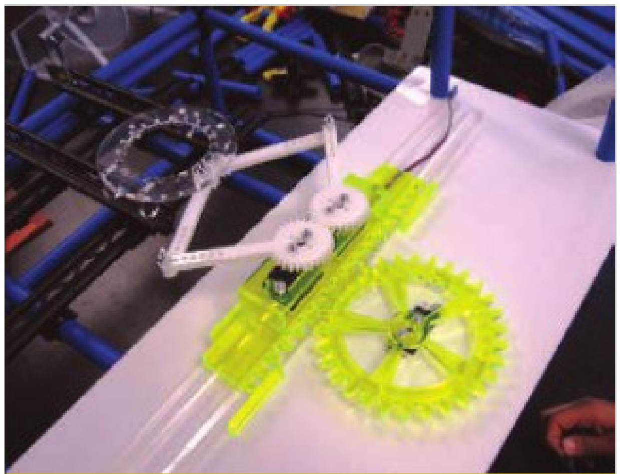
Speaking of advanced robots, one of our vicissitudes was a visit to see the Stingray — UCSD's entry for the AUVSI competition. We covered the AUVSI event in the August '06 issue of *SERVO*. It challenges teams to build an autonomous underwater robot capable of completing tasks like pipe inspection and buoy release. The great thing about visiting the Stingray was that it showed the COSMOS students the power of engineering; they got to see how tough and usually dry subjects like programming can come to life in an exciting way. It was just the kick-start they needed to wrap up their kinetic sculptures.

Made Of Star Stuff

At the end of our furious four weeks, all of the COSMOS students had put together some amazing sculptures; all with unique themes but united in the fact that they all presented a commitment to and excitement about the world of robotics and engineering.

Team 1 was the Justice League, comprised of Danee, Amara, Robert, and Andrew. They took a gamble when they created the Casino de Geisel, complete with a roulette wheel, pachinko machine, and moving basketball hoop. One of their biggest challenges was perfecting the basketball hoop which moved vertically up and down to catch the balls. It was a perfect linear slide problem, and the Justice League saved the day by customizing some long bearings and by rigging up their lift to apply the upward force as evenly as possible.

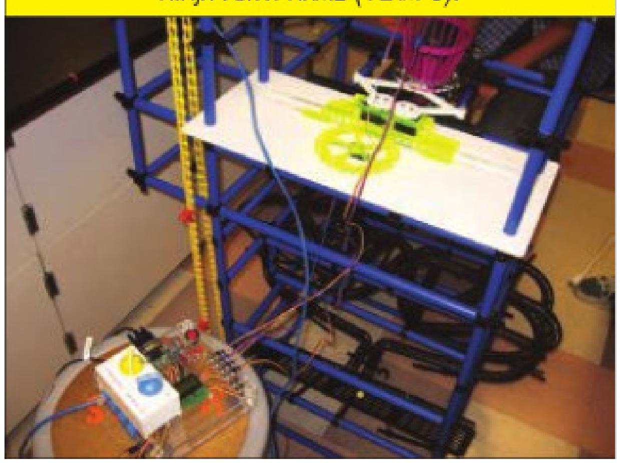
Team 2 was the Boyz In Da Hood and included Trevor, Jonah, Amaraj, and Jonathan. They invited us to the death-defying Cirque Du Geisel (Dr. Seuss would be proud). This circus included heart-stopping jumps powered by two non-geared motors. The Boyz had tested out the non-geared motors in their mini-sculpture, and to do so they used the MotoMaster Motor Controller normally reserved for the MAE 156A students. They were even able to work out a program that allowed them to randomize the speed of the motors, just in case the jumps were not yet death-defying enough.



The custom mechanism for Team 6's catching basket.

Team 3 was Blue Steel, made up of Amaris, Christine, Aaron, and Rafael. They took on the incredibly ambitious task of building a sculpture that could "learn." Blue Steel's build was truly a compelling case study on optimization, which is certainly an important concept in any field of engineering and the focus of the MAE 156A safe-cracking robot. The basic structure of their sculpture was deceptively simple – a nice slope comprised of flexible track pieces. The slope took a hairpin turn at the end, which then funneled balls back to the carrier. A servomotor was situated at the bottom of the slope with an arm that could pull back and forth so that it could increase or decrease the tension in the track and change its

The sculpture from the team too ninja for a name (Team 6).



slope accordingly. The track was designed so that when pushed to its steepest, the ball would fly off the hairpin turn and never make it back to the ball carrier. If the track was pulled to its most gradual slope, the ball would complete its journey, but at a slow pace. Blue Steel's self-imposed challenge was to use feedback from speed sensors and ball counters to optimize the track – make it so the ball could complete its journey as quickly as possible without falling off. In four weeks, they were able to complete this gargantuan task, and they had a sculpture with programming so sophisticated it might even give the Stingray a run for its money.

Team 4 was Magnum, consisting of Eric, Javier, Daniel, and Cesa. Their sculpture included diverging paths and a harrowing labyrinth. The paths diverged by a ball tray that could change position using a servomotor controlled by a button. The guys on Team Magnum also put their newly-found AutoCAD skills to work by cutting out a team logo on the Lasercamm.

Team 5 was We The Queens, with Rocio, Carla, and Joana. Their sculpture featured a steep slalom with a catching basket. Their sculpture also included diverging paths; one was designed to achieve high speed and the other took a more languid pace. The two paths converged before a catching basket; the Queens aimed to create as big a difference in ball speeds as possible to really test the reaction of the catching basket. Despite some trying times with the speed sensors and the programming, the Queens completed their sculpture, and they successfully showcased a catching basket with a huge range of motion.

Team 6 — comprised of Stephanie, Jennifer, Su, and John — was simply Team 6, because they were too ninja for a name. Their sculpture showcased a super cool catching basket that was manually controllable using a custom control box. The ninjas of Team 6 wanted to create a catching basket that could move in both the x and y directions. They cut out a mechanism that was a combination of a rack and pinion and a scissor arm using fluorescent green acrylic that matched the coolness factor of the mechanism. To control the mechanism, the ninjas created their own control box using two potentiometers with knobs as controls. Moving trampolines created the uncertainty that would test the ninja reflexes of anyone at the controls, but the responsive mechanism allowed even the non-ninjas among us to save the yellow ball from off-track oblivion.

All That Is Or Ever Was Or Ever Will Be

The robotic sculptures were all a success, but a real engineering project involves so much more than the project itself – science is not performed in a vacuum! In addition to building the sculptures themselves, the COSMOS students also had to construct a website and prepare an oral presentation. The designs of the sculptures themselves needed to be supported by a plethora of analysis, including physics calculations and mathematical simulations. We were even able to have some fun with a high speed camera, which was ostensibly an analytical tool that allowed us to verify the results of the simulations (even though it really made us feel like we were on Mythbusters).

The websites and presentations challenged the students to hone their communication skills, because the greatest engineering solution in the world isn't great at all if you can't explain it. One of the best parts of the presentations was to see the genuine sense of pride that everyone radiated. Building a robotic sculpture with servos and sensors and programming may have seemed like an insurmountable task at the beginning, but in four weeks they built one. Plus they built a clock and designed a website!

It was undeniably a challenging and fulfilling time for everyone involved. After a barrage of lectures and lab time, all of the students had created something to be proud of. Perhaps the best thing that everyone gleaned from COSMOS was confidence. Robotics, science, and engineering are all daunting fields which many students may avoid in college because they can't imagine themselves being an engineer and solving the tough problems day in and day out. Cluster 2 posed a tough problem, and every single student came up with a creative solution that showed they really can be engineers.

If this sounds like a great opportunity for you or someone you know, check out more about COSMOS online and consider submitting an application. The application period for the 2010 program is February 1st through March 15th. Who knows ... it might just change your life. SV

Recommended Websites

http://maelabs.ucsd.edu/cosmos/
www.jacobsschool.ucsd.edu/cosmos/

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