CS Bits & Bytes
Highlighting Innovative Computer Science Research

CS Bits & Bytes is a bi-weekly newsletter highlighting innovative computer science research. It is our hope that you will use CS Bits & Bytes to engage in the multi-faceted world of computer science to become not just a user, but a creator of technology. Please visit our website at: http://www.nsf.gov/cise/csbytes.

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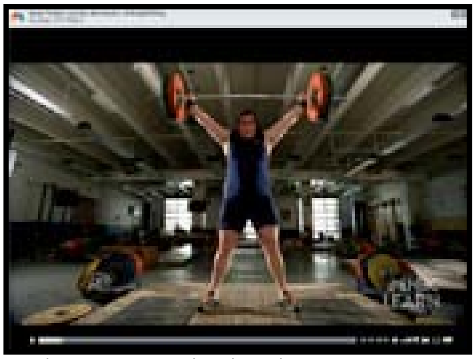
Biomimetic Robots

Did you watch the summer Olympics? Embracing the Olympic motto, *Citius, Altius, Fortius*, or Faster, Higher, Stronger, athletes try to find the optimal way to perform in their sport. Like Olympians, computer scientists use optimization to learn the best ways to control systems.

MUST SEE!



Watch an NBCLearn Video about the science of weightlifting at: http://www.nbclearn.com/summerolympics/cuecard/59575.

This is especially important for **biomimetic robot systems** - robots that mimic the structure and function of biological systems. Consider Sarah Robles, a three-time national champion and Olympic weightlifter. After careful observation and analysis of Robles, roboticists determined that she uses the movement and momentum of her whole body to lift weights larger than she could if she was just trying to lift the weights straight up with her arm muscles. Roboticists have been able to replicate or mimic that same approach to enable a robotic arm to lift a heavier weight than it could otherwise.

When computer scientists develop such biomimetic robots, they start by creating **algorithms**, step-by-step sets of instructions for accomplishing a goal. Computer software uses the algorithms to specify the actions that a robot performs. Sounds easy, right? But getting a robot to reach for an object without over- or under-reaching it, or without gripping it too hard or too loosely is very difficult. It requires sensors and precise algorithms that take into account feedback from the environment to ensure that the ultimate goal is reached.

In the Movement Control Laboratory at the University of Washington (UW), researchers focus on **optimal control**, using mathematical concepts to find the best, or optimal result given a specific measurement of performance. Over time, the human body has become very good at figuring out how to best complete tasks, and roboticists try to replicate that knowledge for optimal performance. The UW research team has built an artificial finger for use in robotic hands that mimics the strength and dexterity of a human finger. The "bones" are modeled after the bones in a human finger. The joints allow for the same degrees of freedom as a finger joint and are constrained by "ligaments" of crocheted fiber chosen to match the stiffness and flexibility of human ligaments that constrain our joints. Motion control is guided by strings that mimic the role of human tendons. When the strings are pulled or released, the movement of the artificial finger is similar to that of a human finger. This research spans many areas including computer science, robotics, control engineering, neuroscience, psychology, biomechanics, and applied mathematics.

An anthropomorphic robotic finger with biomimetic finger joints. Courtesy of Professor Emanuel Todorov

Prof. Emanuel Todorov

Who Thinks of this Stuff?! Professor Emanuel "Emo" Todorov heads the Movement Control Laboratory at the University of Washington. He is from Bulgaria and has Bachelor's degrees in math, computer science and psychology from West Virginia Wesleyan College, and a Ph.D. in cognitive neuroscience from the Massachusetts Institute of Technology. He, like Sarah Robles, is an Olympian of a sort. While in high school, he competed in both the International Olympiad in Informatics (computer science is called informatics in Europe) and the International Mathematics Olympiad, winning a silver medal and two gold medals.

Links:

Learn more about UW's robotic finger at: http://www.cs.washington.edu/homes/todorov/papers/JosephFinger.pdf.

What about a robotic arm? Learn more about Whole Arm Manipulators at: http://www.nsf.gov/news/special_reports/science_nation/roboticarms.jsp.

Biomimetics is not just about humans! Watch what we can learn from fish: http://www.sciencefriday.com/video/04/27/2012/pied-piper-of-fish.html.

Classroom Activity:

Olympians perform a task, and if they perform optimally, they win a medal. Optimal performance is determined by a metric, and that metric is different for each sport. For example, the 100m dash has a very simple performance metric. Everyone starts at the same time and the first one to cross the finish line receives the gold medal. Because the metric for that race is the fastest to cross the finish line, it does not matter whether or not the runner finishes the race in the least amount of time ever recorded. Being the fastest ever recorded is the metric used to determine the world record for that activity.

In small groups, have students pick a sport and define the performance metric, indicating what would result in the optimal performance. Remind students of the Olympic motto when thinking about the metrics: Citius, Altius, Fortius, or Faster, Higher, Stronger.

Then, discuss the different metrics as a class. Further discussion topics could include which sports might have performance metrics that are difficult to assess. If performance was assessed automatically, what information would sensors need to gather? For example, in the 100m race, referees often decide on the winner using the outputs of high-speed cameras. Could diving be assessed automatically? What would that device need to capture?

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