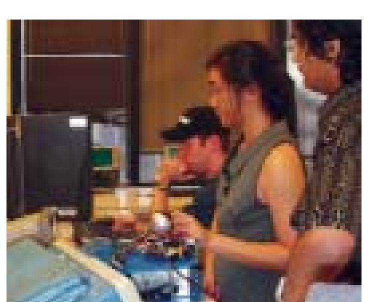
MASLAB'S Autonomous Vision-Based Robot Competition

Story and photos by Valerie Morash, Christopher Celio, and Kimberlee Collins

Student-designed robots embody radically different strategies

Sixty MIT students spent January building autonomous vision-based robots as part of the Mobile Autonomous Systems Laboratory (Maslab). The object was to build robots that could navigate an unknown playing field to find balls and put them in goals. Each team of two to five students started with basic materials: a square piece of pegboard, two rubber wheels with drive motors, a caster, a small computer programmable in Java, a Road Narrows Robotics ORC controller board, and a color web camera. The students expanded on these building blocks with their choice of materials to create custom robots. They were given an opportunity to test their designs at the end of January in a final competition in which robots scored points by taking possession of balls, putting them into goals, and putting them in front of goals. Students were not told the configuration of the final competition playing field beforehand, but they did know some basics. They knew that the playing field was surrounded by white walls topped with a thick blue line and periodic blue tick marks. Goals consisted of rectangular holes cut into the wall surrounded by a thick yellow line. Strips of green and black squares, called barcodes, were put on the walls so they were connected by line of sight. These were intended to help robots navigate the field. Finally, the floor was made of black carpet, and balls were painted bright red.

Each team produced a unique robot with its own strengths and weaknesses. The following descriptions highlight just a handful of the teams and their creations for the 2007 Maslab competition.

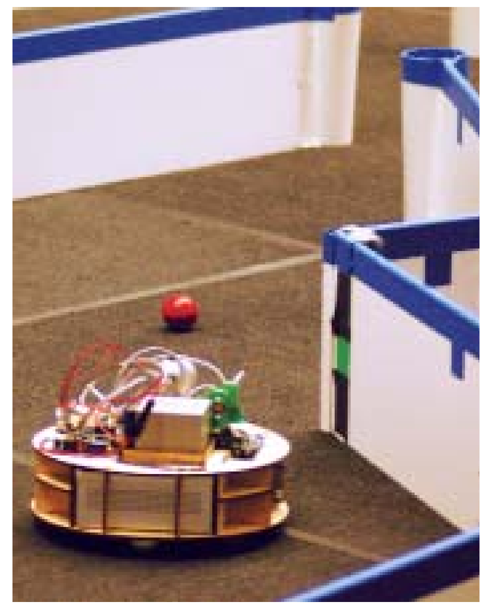


Andrew, Stephanie and Sarang working on their simple round robot's code.

SIMPLE SOLUTIONS LEAD TO A 2ND-PLACE STANDING

As an all-freshman team, Stephanie Chin (Ocean Engineering), Sarang Kulkarni, and Andrew Lewine (Electrical Engineering and Computer Science) felt they to make a simple robot. Their approach was to make a circular robot with a front gate that would open as the robot drove forward to collect balls. Once in front of a goal, the robot would open its gate, drive backward to release its balls, close its gate, and drive forward to push the balls into the goal. When not collecting balls or scoring goals, the robot explored the field using short-range IR sensors to follow the wall.

The team opted for simple solutions to problems that other teams spent a great deal of time overcoming. For example, instead of writing software to filter out camera data above the top of the playing field walls, they angled their camera so that it could not see above the walls. With the time they saved building a simple robot, the team was able to rigorously test their design. They brainstormed potentially problematic situations for their robot, made appropriate changes to the software, and tested the robot on mock playing fields to expose further vulnerabilities. In the rush to create a robot, very few teams found the time to improve their design by testing their robot and uncovering its weaknesses. By keeping things simple, this team created a robot capable of a second-place ranking in the final competition.



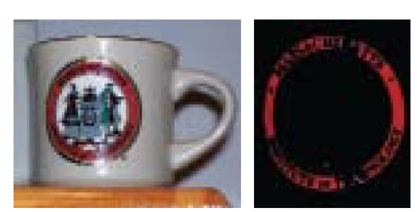
A robot navigating the final playing field toward a red ball.

NEURAL NETWORK SEES

Omobayonle Olatunji (EECS), Huan Liu (EECS), Maciej Pacula (EECS), Matthew Gordon (Math), and Alexandre Oliveira created a robot that used a strategy similar to that of the freshman team's robot, but relied on no sensors except its camera.

To do this, they needed to differentiate colors very reliably. Data from the robot's camera was accessible to its computer in the form of numbers representing the color and brightness of each camera pixel. To decide which numbers represented which colors, other students set thresholds determined by trial and error. Although this worked, the team worried that it would not allow for differences in lighting conditions. Therefore, the team set their thresholds by training an artificial neural network on 20,000 examples of pixel numbers and their associated colors.

The team also used their camera for wall following and avoidance. They found the distance between their robot and a nearby wall by comparing the wall height through the camera to its known height. Combined with knowledge of its own shape, this enabled the robot to navigate without any unexpected wall collisions. Even though their camera-based navigation system worked, the team added IR sensors for extra security during the final competition.



Left: A picture used by the team relying only on vision to test their neural network for red color identification. Right: The result of this identification

Maciej and Huan watch their robot navigate using only its camera (classmates Hans Anderson and Ayman Abu Shirbi in the background)

GIANT WHEELS

When Ben Switala (EECS), Jason Bryslawskyj (Physics), Ted Blackman (EECS and Physics), and Melodie Kao (Architecture) saw a pair of 9-inch-diameter wheels, they were inspired to add them to their robot. These wheels became the most defining aspect of their robot, as they made it both incredibly large and unusually fast.

The giant-wheeled robot with team member Melodie.

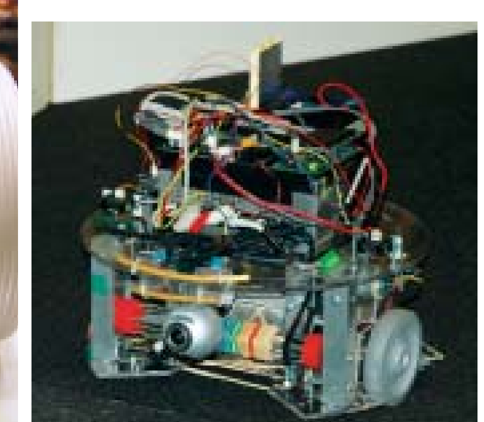
Besides the giant wheels, the team made their robot, nicknamed Arnold, distinct with an unusual ball collection and delivery mechanism. Balls were stored in two parallel tubes, accessible in the front of the robot via a two-door gate controlled by a servo. To deposit balls into a goal, two aluminum push plates moved forward from the back of the holding tubes, shooting the balls out at high velocity. The push plates were controlled by a belt and guided by rods that the team harvested from a used inkjet printer. To prevent this mechanism from binding, they relied on a heavy coat of WD-40.

The giant wheels and complicated scoring mechanism made designing and programming this robot difficult. In the end, this caused the robot to not be entirely debugged. Neverthe-less, it was a favorite among those watching the final competition, Maslab students, and the Maslab staff for its brazen design.

Daniel talking to staff member Timothy Abbott about starting up his team's robot during the final competition.

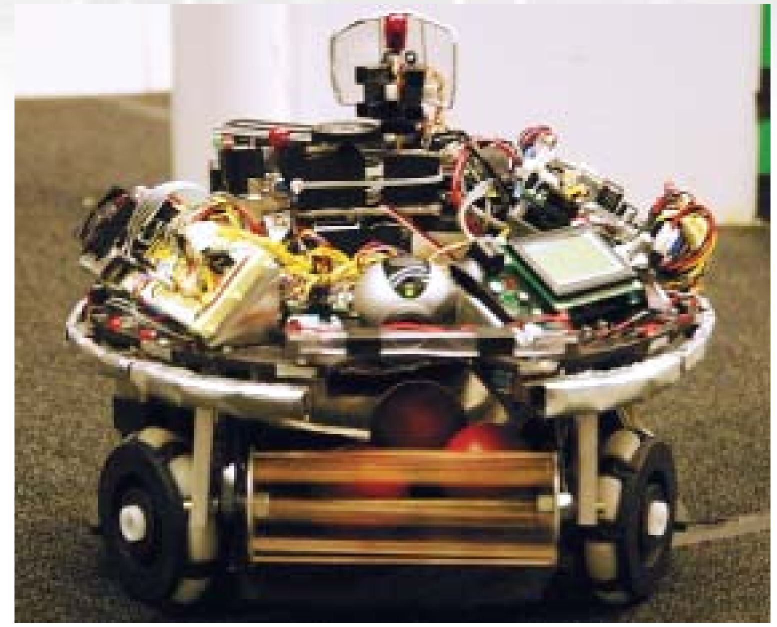
THREE STRATEGIES OF WANDERING

Mark Stevens (EECS), Jeremy Smith (EECS), Alex St. Claire (Mechanical Engineering), and Jenny Liu (EECS) built a robot with effective software and a solid mechanical design. Their strategy was to design their robot's hardware to simplify its code. For example, the robot's ball-capture mechanism consisted of a rotating drum that would push balls up a ramp and into an internal storage bin. The mouth of this mechanism was wide, reducing alignment requirements for the software. The team also made it a priority to construct their robot's physical mechanisms rapidly. This allowed software to be tested on a working robot early, and provided more opportunities for discussion between software and mechanical team members.



Mark, Jeremy, Alex and Jenny designed this “wandering” robot.

The team developed a number of wandering strategies for exploring the playing field. Unfortunately, no single strategy worked perfectly. To deal with this, the team decided to use three different wandering algorithms and alternate between them randomly. These approaches were to travel along the nearest wall, drive toward the farthest open distance detected with an IR sensor, and



Christopher, Yi and Kimberlee's robot collecting balls during the final competition.

follow a path from one barcode to the next.

Another unique feature of this robot was its use of a hacked roller ball mouse as an encoder. Despite being a demonstration of clever ingenuity, the team admitted that the effort to create this encoder outweighed the functional benefits. The device, however, served as an example of the team's good understanding of engineering principles and practices.

MOVING, COLLECTING, AND SEEING IN EVERY DIRECTION

Matthew Farrell (Physics), Matthew Robertson (Mechanical Engineering), Alexander Sanchez (EECS), and Daniel Torres (EECS) pushed themselves to create an ambitious robot that could move, pick up balls, and see in any direction.

This was done with three omnidirectional wheels, which enabled the robot to travel in any direction without rotating. Rollers on each of the robot's three sides were controlled with a single motor, and were used to raise balls up and into the chassis. Finally, the camera sat on top of the robot, where it was mounted on a servo to give the robot a 360-degree view of the playing field.

The team took advantage of the robot's extended field of view by having it continuously create detailed local maps with its camera. These local maps were initially intended to be used to create a large global map, but integrating past and new maps turned out to be difficult. The problem was that the robot could not accurately keep track of its position while moving, a problem compounded by its use of omnidirectional wheels. Therefore, each map was created to get the direction to the nearest unexplored territory and then discarded as the robot moved toward this direction.

Ultimately, the team's plans to have a directionless robot that created maps for navigation were too ambitious. During the competition, the robot successfully picked up balls, but had difficulty reaching unexplored areas or nearby goals. The team felt that, although they tested individual pieces of their robot, it was problematic that they did not have time to test the design in its entirety until the very end. In hindsight, they suggested it might have been better to throw everything together early on, and fine-tune the robot as a whole. Nevertheless, the robot awed the crowds. It was a learning experience for the team and a marked accomplishment.

MULTI-FEATURED BOT

Christopher Celio (EECS), Yi Chen (Mechanical Engineering), and Kimberlee Collins (Mechanical Engineering and Physics) had a broad skill set that allowed them to implement a wide range of features for their Maslab robot. One example was their robot's drive system, which used three omnidirectional wheels. Among other things, this allowed their robot to reach balls it could see, but not directly approach due to walls partially blocking its path. To deal with this problem, the robot would back up or move sideways to avoid the walls, without losing sight of the ball.

To explore the playing field, the robot would move toward open directions that it found using two rotating IR sensors. If it hit a wall, one of fourteen bump sensors around its perimeter would alert the robot to pick a new direction to continue exploring. Balls were collected in an internal cavity using a wide rubber-band roller. Entering this cavity triggered a break beam, telling the robot to stop at the next goal it saw to deposit its balls.

To implement all of their robot's features, the team emphasized keeping a schedule with strict deadlines. They designed their robot to be built in stages, with modules that added incremental capabilities. This tactic let the team move forward while always maintaining a working robot to test and debug. It proved to be a successful strategy, since the team tied for first place in the final competition.

Anand Deopurkar and Yaim Cooper planning their robot's construction.

CONCLUSION

Maslab allowed its students to direct themselves according to their own ambitions, and learn firsthand the pluses and minuses of engineering techniques. Each student experienced Maslab differently, and therefore learned different things. However, all of the students left Maslab with a better understanding of the engineering process: design, implementation, troubleshooting, and teamwork.

For more information on Maslab students and robots, please see the Robot Magazine Summer 2006 issue, or visit http://maslab. mit.edu.

—the editors