MIT MASLAB Robot Contest

Student-designed, vision-based bots integrate technologies

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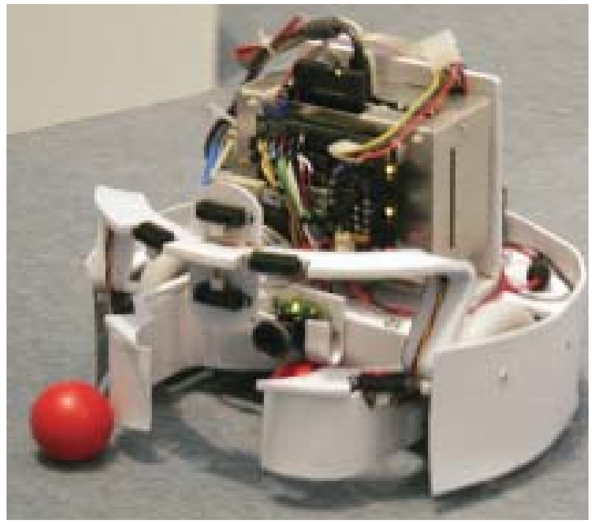
Independent Activities Period (IAP) is a special month-long term at MIT during January. IAP offers students a well-deserved break from conventional coursework and an opportunity to participate in hands-on subjects. One of these subjects is the Mobile Autonomous Systems Laboratory (MASLAB). Over a dozen teams participate in MASLAB every year by building autonomous, vision-based robots. The class culminates in a competition to see which of these robots is the best at collecting balls and putting them in goals.



For MASLAB's 2005 competition, Valerie Morash and Roger Hanna built a simple robot that did something no MASLAB robot had done before: it used its vision to detect if it was stuck. Photo by Jonathan T. Wang.

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BUILDING BOTS AND TACKLING THE COMPETITION

Each MASLAB robot starts as a "pegbot," consisting of a square piece of pegboard, two rubber wheels with drive motors, a caster, a 733MHz x86 computer running Linux, a circuit board for the computer to interface with motors and sensors, and a color webcam. Receiving the pegbot, already equipped with some of the necessary tools for the project, really gets the students motivated to start programming their robots' behavior and image processing as soon as possible. All of the robots are written in Java, although some students choose to write some of their code in Jython or C in order to optimize performance.

PLAYING FIELD

So that programming an entire vision system within one month can be a feasible undertaking, objects in the playing field are kept to a basic set of colors: white, blue, yellow, green, black, red, and light blue. The playing field is surrounded by twelve-inch white walls topped with a thick blue line so that the robots can pay attention to the playing field and not the crowd at the competition. The goals consist of rectangular holes cut into the wall surrounded by a thick yellow line. There are periodic strips with unique sequences of green and black boxes on the playing field walls. These simple barcodes help robots create a map of the playing field to aid in their strategy.

Image processing is only a fraction of what MASLAB students must accomplish. They must also program in artificial intelligence (AI) to use the webcam and any other sensors (IR, ultrasound, gyroscopes, optical encoders, moment buttons, etc.) on the robot. All teams need to come up with their own unique designs, and must construct their chassis from raw materials. MASLAB robots can be grouped into three broad categories: simple, complex and extravagant robots.

SIMPLE ROBOTS

Simple robots are behavior-based or are programmed to remember only a handful of things about past actions and their surroundings. Their chassis have a central cavity for collecting balls and a gaping mouth for ball capture. These robots are generally successful in competition because their simplicity makes them fast and reliable. With an innovative strategy, a simple robot can give even a very sophisticated robot a run for its money.

"STUCKNESS" AVOIDANCE

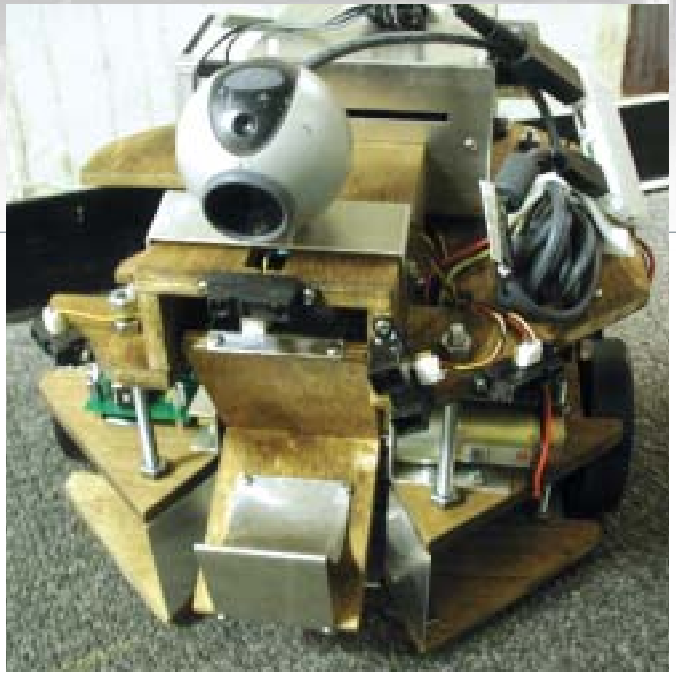
MASLAB robots typically detect if they are stuck by measuring the amount of current the drive motors draw. If a robot is stuck, the current will be unusually high, and if a robot is lifted off the ground, the current will be unusually low. Unfortunately, other factors such as battery voltage can affect this current and mislead the robot. For MASLAB's 2005 competition Valerie Morash (a Neuroscience and Electrical Engineering major and the writer of this article) and Roger Hanna (Math and Computer Science) built a simple robot that did something no MASLAB robot had done before: it used its vision to detect if it was stuck.

The team decided to avoid current sensing problems by simply not getting stuck. They covered their robot in IR sensors: four short-range sensors angled obliquely from the front of the robot, and two long-range sensors pointing directly in front of the robot. Unfortunately, the team discovered that the use of long-range IR sensors caused the robot to have a blind spot directly in front of it.

Morash and Hanna chose to keep the IR sensors on their robot as a matter of pride, rather than settle for the faulty current-sensing approach. They decided to use the robot's camera to detect changes in the visual scene simultaneously with their existing IR sensors.

In 2006, Gautham Arumilli, Andrew Muth, Justin Rigling and Matthew Spencer built a robot that stored balls in a column so that it could sense how many balls it had.

Mike Anderson, Ben Bloom, Iris Cheung and Dennis Miaw used a paddle-wheel roller that, when reversed, could expel balls one at a time. The robot could remember the order in which it had collected balls.



> "MASLAB provides a framework other institutions can use to introduce their undergraduate students to robotics."

COMPARING PIXEL VALUES

To use their robot's camera in this way, Morash and Hanna directed their robot to save a picture of its visual scene every twenty milliseconds and compare each picture to its previous picture. The differences in pixel values between the pictures were squared and then added. If this variance was below a particular threshold, the robot was stuck looking at the same scene, and it would correct the situation by thrashing violently in random directions.

This behavior kept the robot from getting stuck, and kept it moving about and exploring the playing field constantly. This simple solution to keeping a robot from becoming stuck has been adopted by many teams since its first appearance.

BALL DISCRIMINATION STRATEGY

In the 2006 competition, robots could earn extra points by putting a special ball in a certain goal. This challenge was difficult for many simple robots to accomplish because it required the ability to discriminate between collected balls. For example, if a robot had collected two normal balls and one special ball and came across a normal goal, to be successful in the competition, it would need to deposit the two normal balls but not the special ball.

To give their simple robot the ability to discriminate between balls, Mike Anderson (Math), Ben Bloom (Physics), Iris Cheung (Electrical Engineering & Computer Science), and Dennis Miaw (Electrical Engineering & Computer Science and Music) came up with a simple but effective mechanical design.

The team followed the example of many other simple robots' designs and put a roller in front of the robot's mouth to suck balls into the robot's central cavity. This team was unique, however, in its choice to use a paddle-wheel roller that, when reversed, could expel balls one at a time. This feature was useful because it could be used with the robot's ability to remember the order in which it had collected balls.

This paddle-wheel was composed of four wooden paddles arranged in a cross. To keep the paddles from jamming on balls that were clustered together, the team attached aluminum scoops to the paddles, and the scoops served as wedges between individual balls. This simple design proved to be extremely reliable.

COMPLEX ROBOTS

Simple robots are very effective in competition, but can be unsatisfying for ambitious students. Some students opt for building robots that implement strategies based on information from a variety of sensors. They also build complicated mechanical designs to complement their robots' AI. They form chassis into nonstandard shapes in order to better house these gadgets and motors.

BALL COUNTING

Many MASLAB robots keep track of how many balls they have picked up and use this information to direct their behavior. However, if a robot remembers picking up a ball but actually failed to do so, the robot can act in non-useful ways. In 2006, Gautham Arumilli (Computer Science & Electrical Engineering), Andrew Muth (Computer Science & Electrical Engineering), Justin Rigling (Computer Science & Electrical Engineering), and Matthew Spencer (Electrical Engineering), built a robot that stored balls in a column so that it could sense how many balls it had instead of remembering how many it had collected. It did this by detecting balls at discrete heights in the column with phototransistors.

Storing balls in a column also gave this robot an unusual ball release mechanism. Initially, the balls were to be released with a solenoid and the help of gravity. This setup would have allowed the robot to control how many balls it would release at a time. The team had to abandon this system days before the contest because the solenoid proved unreliable. It was replaced with a dowel attached to a motor that was already being used to push balls up the column.

This team also had to deal with another problem with their ball storage system. Several red LEDs were used to help sense balls in the column. The light from these LEDs reflected in the walls of the playing field, causing the robot to see non-existent red balls. The quick and effective fix for this problem was wrapping a UNIX source code manual around the column.

EXTRAVAGANT ROBOTS

Every year, one or two MASLAB teams decide to build the most complicated robots they can dream up. These students spend day and night working on their robots, sometimes never quite reaching their lofty goals.

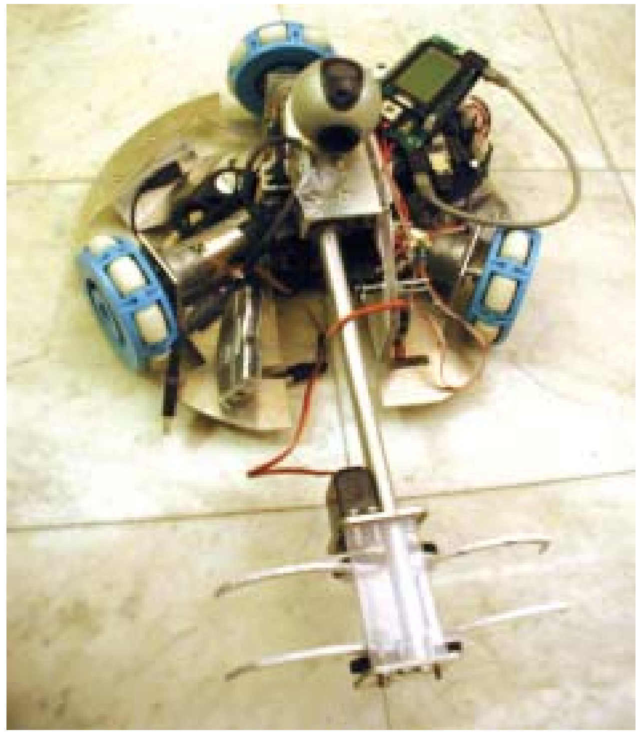
UNFINISHED ROBOTS

In 2006, Jonathan Grimm (Computer Science), Jayant Krishnamurthy (Computer Science), and Sean Torrez (Aerospace Engineering) set out to build one of the most complicated robots that MASLAB has ever seen. Their robot had three omniwheels spaced equally around the perimeter of a circular base that allowed it to move in any direction. The camera was mounted on a servo in the middle of the robot. This helped the robot to change its visual scene quickly despite its slow turning speed caused by the high-torque motors it needed to drive its omniwheels. A horizontal arm with an articulated claw could extend out from between the omniwheels and the camera with a rack-and-pinion system.

This daunting mechanical design was accompanied by AI that had sophisticated image processing and the ability to map the playing field. Not surprisingly, this robot was never fully completed in the one month given to MASLAB students. In particular, the arm was never able to reliably grab a ball off the ground.

In 2005, Jason Furtado, Nestor Hernandez, Josiah Rosmarin, and Derik Thomann were able to successfully integrate into their robot's design an articulated arm that lifted balls into an overhead bin.

At the competition, this robot exhibited some of the most unusual and interesting, though ineffective, behavior. Because of its omniwheels and servo-mounted camera, it appeared to have no preferred orientation. It could change directions and view any angle without turning. The construction of this robot in a single month was an incredible feat, and a testament to the enthusiasm and energy that robotics can bring out of an engineer.



In 2006, Jonathan Grimm, Jayant Krishnamurthy, and Sean Torrez built a robot that had three omniwheels spaced equally around the perimeter of a circular base that allowed it to move in any direction. This extravagant and very interesting design was not completed in the month allowed and never reliably picked up balls. Photo by Jonathan T. Wang.

ARTICULATED ARMS

Several MASLAB teams try to build an articulated arm every year. Because of the challenges involved in fabricating an arm, most of them abandon this dream early on. However, in 2005, Jason Furtado (Electrical Engineering & Computer Science), Nestor Hernandez (Computer Science), Josiah Rosmarin (Mech anical Eng -ineering), and Derik Thomann (Mechanical Engineering) were able to successfully integrate an articulated arm into their robot's design.

This team was driven to build the arm because in the rules of that year's competition, robots could earn extra points by dropping balls over a goal wall of the playing field. Their strategy was simple: collect balls in a bin on top of the robot, and then drive up to a goal and release the balls over the wall. Their robot needed the arm to get balls off the ground and into the bin.

The design and execution of their arm was effective and well thought out. The claw had a span of eight inches so that it did not have to center itself perfectly on a ball to capture it. Its two halves were angled in such a way that they could securely cradle a ball, even as the arm moved. Once it grabbed a ball, the arm would lift itself as though it were throwing salt over the robot's shoulder (if the robot had a shoulder) and drop the ball into the collection bin. Actuation was achieved with cables and pulleys, a system that kept the arm from being too heavy. The attention that this team gave to designing every detail of their arm is what made this arm reliable, and, therefore, a resounding success.

MASLAB'S FUTURE

MASLAB does not benefit its participating students only. Researchers, educators, hobbyists, and industries can learn and benefit from the engineering design solutions that MASLAB participants have implemented. They can also learn from the robotics teaching methods that the program has developed. MASLAB provides a framework other institutions can use to introduce their undergraduate students to robotics.

MASLAB was started by and has always been operated by MIT undergraduates. Therefore, it encourages a peer-based community, with the ultimate goal of making awesome robots. Other institutions, groups, and individuals could benefit from creating a community like this, and MASLAB is eager to develop new relationships with programs that have a similar focus in robotics. If you would like to learn more about MASLAB and see some of these robots in action, visit www.botmag. com/issue3, and feel free to email me at valm@botmag.com. ◎

Will Peters (Aerospace Engineering), and Nick Allard (Mechanical Engineering) join efforts in assembly. Behind them, Tom Hsu (Electrical Engineering & Computer Science) and Matt Hofmann (Computer Science) are busy on the computers.

Links

MIT Robotics, http://web.mit.edu/newsoffice/topic/robotics-archive.html

MASLAB, http://maslab.csail.mit.edu/

For more information, please see our source guide on pg. ___.