Robotics: Integrated System Design Spring 2004

Final Project: Urban Search & Rescue

Updated: April 7, 2004

Goals

- To design & implement an autonomous search and rescue robot
- To design & implement a custom sensor for sound localization
- To explore methods of localization.
- To design & implement an algorithm for autonomous navigation

Introduction

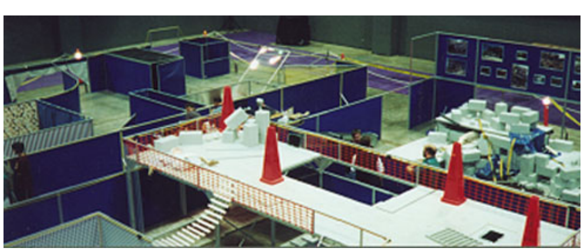
An earthquake registering 7.5 on the Richter scale along the New Madrid Fault has caused extensive damage across Missouri, Southern Illinois, and Tennessee. An emergency response team was sent out to search for potential victims in a warehouse near I-255, which has suffered severe damage in part of its storage facility. In the midst of their heroic efforts to find and save factory workers an aftershock measuring a 5.3 on the Richter scale hits and 7 emergency workers, scattered throughout the factory are too badly injured to escape. Rescue workers have asked that your Robotic Rescue Team dispatch a robot to help identify where the workers are trapped so that critical resources can be focused on the rescue of the emergency workers.

The local rescue workers have provided you information about the warehouse that you might find useful for your robot. They have provided a blueprint of the area needed to be searched as well as photos of the facility prior to the earthquake. Your team has been given 25 minutes to search the facility for the rescue workers.

Entries from the AAAI 2003 Rescue Robot Competition

Team Assignment: Build an Urban Search & Rescue Robot

1. Design & build a robot that can explore an earthquake-damaged building.
2. Your robot will search for victims in a damaged warehouse. All of the victims are wearing uniforms of a specific color, except for the supervisor. It is likely one victim will be screaming for help.
3. Once discovered, your robot should approach the victim as closely as possible and set off a series of beeps.
4. The robot will store a grid corresponding to 1 square foot/grid space for each floor. The robot should indicate where the victim is on the grid. At the end of the search mission, the Rescue Team will download and print the grid.
5. Because of the size limitations, your robot should fit in a 1-foot cubic area at the start. It may expand, but not above the walls (virtual ceiling).



NIST Reference Test Arenas for Autonomous Mobile Robots at the AAAI 2000 in Austin, Texas, USA.

Demonstration

- Demonstrations will be during class over the final two weeks of the course.
- The order of demonstrations will be assigned by lottery. Teams going the 1st day will receive a 5-point bonus.
- Each team will have 25 minutes to conduct the search mission.
- Robots must begin at the entrance to the building.
- A robot returning to the entrance may be restarted without penalty.
- A robot that is judged by the team and referee to be stuck or irrevocably lost may be "pulled" out of the building and restarted without penalty.
- Up to 3 human interventions will be allowed that involve re-orienting or nudging the robot.

The Building

- The building layout will remain fixed. The debris field may be changed.
- The Rescue Team may use the building layout and any other additional knowledge of the rooms to program a map for the robot to use.

Presentation

- Each team will give a 10 minute, in class presentation that describes their project.
- The presentation will consist of four power point slides, one for each of the following four aspects of your project: Overall Search Strategy, Mechanical Design, Electrical Design, Software Design
- Copies of the slides are to be handed in with the project report.

Hand-in

- A lab report describing your team's design including slides from presentation
- Team Meeting notes (as described in the General Lab Philosophy)
- A post-mortem write-up that discusses the robot's performance with regard to potential future enhancements. This report should emphasize what went right and what went wrong with the project development, including significant feedback on the effectiveness of the multidisciplinary teamwork, as well as suggestions for how this aspect of the project (and the course) might be improved.
- Due date: the first Monday after your team's demonstration. Soft copies should be mailed to Erin Harris.

Evaluation: 100 points

- Visited each room: 5 points per room (25 points possible)
    - A robot must be entirely in the room to consider it visited.
- Identifying a victim: 4 points per victim (28 points possible)
    - A robot's camera must be pointing in the direction of the victim (or sound sensor if appropriate) and be approximately one foot away from the victim when sounds the found signal.
- Indicating a victim on a map within 1 square feet of actual placement: 3 points (21 points possible)
- False identification of a victim could hamper the human rescue workers' effort or put them at unnecessary risk. For each false identification over 3: -3 points.
    - False identification includes pointing in the direction where no victim is or indicating a victim by being further than the one-foot radius.
- Lab Report & Post-mortem: 25 points
- Team Meeting Minutes: 10 points

Bonus

- Successfully implement feedback control to improve your robot's accuracy for going in a straight line: 5 points. This must be demonstrated by traversing a 3-foot line.
- Successfully implement feedback control to improve your robot's accuracy and reliability for making a 90 degree turn: 5 points.
- Successfully implementing the sound localization sensor. This must be demonstrated in the same way that the light sensor was demonstrated in Lab 3: 5 points.

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Post-Project Interview

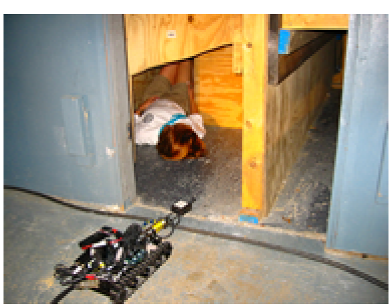
- Each team will sign-up for a post project interview with Dr. White.

Important Notes

- Adding materials beyond the Robot Kit
    - Your team may use additional LEGO components. Some are available in EB 2029 or you may supply your own. However, please be sure to list these in you design reports.
    - Your team may use non-LEGO mechanical parts and custom sensors not included in the robotics kits, but limit the total cost of additional parts to $50.
- Your robot kit has two CPU's: a HB and an RCX. You may use both in anyway your team sees fit (one robot two cpu's, two robots each with a single cpu, an active landmark beacon, …).
- Note that some of the areas may be dark, so your team might consider attaching a self-contained light source (flashlight).
- It will be very difficult to do accurate mapping or navigation if your robot does not travel in a straight line or execute accurate turns. Consider implementing PD feedback control to improve navigation (see Resources).
- Distributing the drive power evenly across the drive axle improves accuracy. There are a number of different gear trains set-ups using the LEGO differential that achieve this (see Resources).
- You can also improve straight line and turning movement by measuring error and accounting for it in the pose estimation. (see Resources)
- The photos supplied to you by the rescue workers reveal that each room as a unique and distinctive landmark.
- Another way to do localization not covered in class is called Occupancy Grids. A version of this called HMM (Histogrammic in Motion Mapping). It is a simple method of building a local map with sonar and comparing it to a global map (see Resources).

Resources

- Urban Search and Rescue Competition Website Run by NIST: http://www.isd.mel.nist.gov/projects/USAR/
- Center for Robot Assisted Search and Rescue: http://www.crasar.org/
- Lecture slides and paper for building differential drive trains to improve accuracy of dead reckoning:
  http://www.cs.siue.edu/robotics/integratedsystems/ProjectResources/Localization.ppt
  http://www.cs.siue.edu/robotics/integratedsystems/ProjectResources/ss104MayerG.pdf
- Mobile robot lab from CMU for implementing feedback control for robot motion:
  http://www.generalrobotics.org/labs/lab04/
- Using a PID-based Technique For Competitive Odometry and Dead-Reckoning:
  http://www.seattlerobotics.org/encoder/200108/using_a_pid.html
- CMU Lecture on navigation with additional methods for mapping:
  http://www.cs.siue.edu/robotics/integratedsystems/ProjectResources/motion-planning-final.ppt
- HMM method for localization: Introduction to AI Robotics by Robin Murphy, section 11.5 (a copy of this will be made available).
- CMU's Robotics Club Urban Search and Rescue Team: http://www.roboticsclub.org/projects/usar/



Robot with vital sign sensors being tested at the University of South Florida