Relative Localization in Colony Robots

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Abstract
Using relative inter-robot communication signal strength and basic proximity sensing, we propose a method for a colony of robots to become aware of its basic surroundings and the pose (orientation and location) of each of its members. While this problem is generally solved through the use of expensive vision and ranging sensors, we hope to find an affordable solution by culling extra information from sensors already necessary for operation of the colony and adding some inexpensive co-processing.

Research Question and Significance
This project is a continuation of Emergence in Behavior-Based Group Robotics, funded over the summer in full by a Small Undergraduate Research Grant. Following the summer's successes, we wish to explore relative localization using the same inexpensive colony robots. Localization is arguably the most difficult problem facing robotics researchers today. Much as humans struggle with their place in the world, robots struggle with their place *relative* to the world. The quintessential approach to this problem has been to invest ever-increasing amounts of money in the robots, outfitting them with more complex sensors, requiring complex drive systems, increasing power requirements, in a never-ending feedback loop. We propose to develop a solution with a $300 sensor package per robot in a form factor small enough to fit on our smaller-than-a-breadbox microBots designed by Botrics, LLC. Relative localization between colony robots would allow, at the basic level, to create formations, like a marching band. This is difficult due to the lack of centralized computation and similar lack of world landmarks. The robots only have each other to decide where they should place themselves. With this relative localization hurdle cleared, the robots' capacity can be expanded to a hunting scenario, in which the robots must work together to "capture" the hunted, perhaps an excommunicated member of the colony. The colony should also be able to maintain its structure even with unexpected obstacles in its path. By following rules developed by studying the behaviors of flocks of geese, ant colonies, and other groups of animals, we propose a simple (and computationally cheap) solution to be explored in this grant cycle.

Project Design and Feasibility

The Robotics Club owns twelve microBots produced by Botrics, LLC which were appropriated for this colony project during the summer. Over the summer, a token-ring network was developed, along with simple "beacon" sensing capability to allow robots to find one another using modulated infrared light. Although the ability to synchronize robot movement and to communicate about another robot's existence was developed, a single robot is not yet aware of any other colony robot's relative pose. That is, while the robots are a colony, they are only in a loose sense – they work only minimally with one another. Since we have this shell to work from, we believe that it is feasible for us to have a working demo of relative localization in time for the National Conference of Undergraduate Research (NCUR) in the spring of 2005.

The following are our expected monthly objectives:

October 2004 – To specifically define the "problem" or challenges of the colony project, to illustrate the exact arena the colony robots will operate in, to test all of the sensors for the robots, to choose an appropriate antenna for the robots, and to have placed the bump sensors on all of the robots.

November 2004 – To fully research algorithms of other colony group behaviors and begin implementing them, to characterize error in sensors and develop a solution, to mount all sensors, to begin construction of arena, and to submit abstract to NCUR.

December 2004 – To finish implementing the communication protocol for the robots and to complete the construction of the arena.

January 2005 – To have the robots self-organize themselves into a predefined arrangement and to debug any remaining mechanical problems.

February 2005 – To maintain a predefined arrangement going around an obstacle, and to begin mechanically developing the next generation of colony robots.

March 2005 – To expand organization of robots to track and trap a target, and to debug any existing problems.

April 2005 – Prepare for and attend NCUR.

Applicants

Nathaniel Filardo is a junior hoping to double major in computational physics and mathematics. He has self-taught experience in microcontroller programming from his high school robotics club and an enthusiasm for network-related problems. **Aaron Johnson** is a freshman Electrical and Computer Engineering major. He was president of his high school robotics team, which won the 2004 US FIRST Chesapeake regional competition. **Richard Juchniewicz** is a Junior Mechanical engineer with several years of robot building experience. He has built and entered a walking robot in the Mobot competition that won the Judge's choice award. **Jessica Kang** is a freshman in Computer Science, considering a minor in business. She is a new to robotics but is eager to learn and hopes to contribute to the group. **Ryan Kellogg** is a sophomore Electrical & Computer Engineering and Biomedical Engineering double major. His past robotics projects include MOBOT, Rubik's Cube manipulation, and the original colony project. **Kate Killfoile** is a sophomore double major in Electrical and Computer Engineering and Public Policy and Management. She has previously worked for Howie Choset on snake robots. **Suresh Nidhiry** is a freshman Computer Science major and a new member in the Colony II project. He is currently involved in working with sensors, analyzing how they will be used and how they will impact the project. **Iain Proctor** is a freshman majoring in Cognitive Science. His areas of interest include connectionist and embodied artificial intelligence. **Justine Rembisz** is a freshman mechanical engineering major. She is a first time member of the robotics club, but hopes to get involved in many of the projects. **Steven Shamlian** is a junior in Electrical and Computer Engineering and the Co-President of the Robotics Club. He has worked for Sebastian Thrun on robots to assist mobility of disabled people and with Illah Nourbakhsh on Urban Search and Rescue in his five semesters at CMU. He has worked at iRobot Corp. on the Roomba autonomous vacuum cleaner for the last three summers. His QA embedded test beds are currently in use in China on the Roomba production line. **Prasanna Velagapudi** is a senior double major in Computer Science and Electrical and Computer Engineering, and webmaster of the Robotics Club. He worked on the Red Team in preparation for the 2004 and 2005 DARPA Grand Challenge, and won the Judges' Choice Award in the 2003 Mobot competition for creative design of a hexapod line following robot. **Sungjoon Won** is a freshman major in Computer Science and a possible minor in Robotics. He is currently involved in the Colony II project in the Robotics club, and in the CALO (Cognitive Assistant that Learns and Organizes) research project in Carnegie Mellon University.

Dissemination of Knowledge

We plan to hold a demonstration of our robotic colony at the 2005 National Conference on Undergraduate Research as well as the 2005 Meeting of the Minds. We also hope to publish findings in Momentum, as well as at the 2005 National Conference on Undergraduate Research.

Presentation and Evaluation

We will present our final results at the Undergraduate Research Symposium in 2005. We will continue to exchange weekly emails with our advisor Brett Browning as well as our secondary advisor Brian Kirby to make certain we stay on track. In addition, we will also have monthly meetings with Brett Browning and weekly meetings with Brian Kirby to monitor our progress and ensure we keep to our schedule. Once the project is completed, the robots will be available at the Robotics Club for additional programming and experimentation.

Proposed Budget

Components						Cost
Math Co-Processor Boards (x12)						$720
Bump Sensors (4x12)						$80
Pyroelectric Sensors (x4)						$240
					Total	$1,040

The math co-processor boards will allow the robots to compute trigonometric functions for triangulating other robots' locations. Bump sensors will enable detection of obstacles impeding the robots' movement. Pyroelectric sensors facilitate in the detection of a heat source, or the "hunted," as discussed earlier.