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Approaches to Multi-robot Exploration and Localization

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Abstract

We present approaches to several fundamental tasks in multi-robot team-based exploration and localization, based on student projects developed in the past year.

Introduction

We have constructed a framework that is designed to support a team of robots working with a human operator in a dynamic, real-time environment. Our work is motivated by an interest in practical deployment of heterogeneous human/robot teams to settings where robots explore regions that are unsafe or undesirable for humans to visit. For example, *rescue robots* search collapsed buildings for victims whose positions they transmit to human first-responders (Murphy, Casper, and Micire 2001; Yanco et al. 2006), or *demining robots* search post-conflict areas for anti-personnel landmines and transmit their positions to human deminers (Habib 2007; USDoD 2011). Typically, one or two expensive, multi-function robots are deployed for exploration. They are often tethered for continuous power and uninterrupted communication, and they receive instructions from a human operator remotely located on safe ground. A lost robot can suspend operations and may impose heavy costs, in terms of equipment and human life.

We investigate a *multi-agent* strategy that deploys a team of simple, inexpensive, heterogeneous robots whose combined abilities provide diverse functionality and flexibility. If a robot gets lost, the team can reconfigure automatically and dynamically. The team must address several fundamental tasks. First, robots must be able to *explore* a region collaboratively (traverse and maneuver in the physical space) and *localize* (determine and track their positions). Second, robots must be able to *recognize* objects of interest, using on-board sensors and possibly augmented intelligence to interpret sensor input. Third, a human operator must be able to communicate with the robots remotely and *strategize* so that the team can accomplish its overall task effectively. The work presented here demonstrates approaches to the first set of tasks: **exploration** and **localization**.

Projects

Approaches to four problems in multi-robot team-based exploration and localization are described in this section: *real-time mapping*, *pseudo GPS*, *obstacle avoidance*, and *team formation*. Students have implemented approaches to these problems, using our *HRTeam* framework (Sklar et al. 2010), which is built on *Player/Stage* (Vaughan and Gerkey 2007). Three robot platforms (see Figure 1) are used for the approaches detailed here. Testing and experimentation are conducted in the test arena pictured in Figure 2a.

(a) Create (b) Fribbler (c) Surveyor

platform	*sensing*	*locomotion*	*communication*
Create	laser	wheeled	wireless
Fribbler	camera	wheeled	bluetooth
Surveyor	camera	tracked	radio/wireless

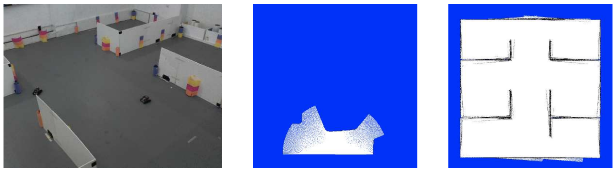
Figure 1: Robot team

Real-time mapping

Mapping of the robots' environment is performed in real time using an occupancy grid approach. This has been implemented and tested using a Roomba Create robot with an Hokoyu URG laser and laptop mounted on top. Figures 2b and 2c show the initial and final representations, respectively, collected by the Create mapping our test arena. The robot starts at the bottom of the image, in a central location (measured horizontally). The robot wanders through the arena while the laser scans, and the map is acquired.

Pseudo GPS

While the real-time mapping process described above suffices for plotting out an overall binary representation of the robots' environment, it does not solve the *localization* problem, i.e., for each robot to be able to determine its own position and orientation within the arena. Some of our related work entails developing a learning algorithm for vision-based localization (Sklar et al. 2011). To complement



(a) test arena (b) initial map (c) final map

Figure 2: Mapping the arena

this work (and to help with debugging and error modeling), we have implemented a simple "global positioning system" which combines multiple overhead cameras in a coordinated tracking system that follows the robots. Each camera finds the 2-dimensional (x, y) coordinates and orientation (θ) of any robot (wearing a unique colored marker) in its field of vision (Baltes 2002). Multiple camera images are combined to form a single composite image that represents the arena. Several issues are being addressed, including devising colored markers for the robots that are not confused with the colored *landmarks* (markers that are placed in the arena to help with vision-based localization), and transforming and merging camera coordinates into a unified global coordinate system.

Obstacle avoidance

In order for robots to be able to explore the arena, they need to know how to avoid obstacles. These are classified as anything blocking a robot's path, such as a wall or another robot or a landmark or debris. Experiments have been conducted in simulation (using Stage) with a *Vector Field Histogram (VFH)* algorithm (Ulrich and Borenstein 1998). VFH builds a polar histogram of range information (like an occupancy grid) that shows the robot which directions are cluttered and which directions are free of obstacles. Current work involves implementing vision-based VFH (Viet and Marshall 2007) on a Surveyor robot. OpenCV (2011) is used to retrieve camera images, which are processed for estimated range information by measuring the amount of "ground" color from the robot's horizon to an obstacle, and are then stored in the histogram for VFH to use.

Team formation

A variety of methods for robot team formation, to be used in combination with wave front exploration methods, are being investigated (Yamauchi 1998; Balch and Arkin 1999; Fierro et al. 2002). The aim is for the system to divide the map (created above) into sectors and distribute regions amongst the robots automatically, adjusting dynamically as exploration proceeds and adapting if team configuration changes during run-time. Current work involves automatically deriving natural partitions within the area, such as rooms and corridors, and identifying points in each partition from which to perform a sensor sweep, customized to the sensing capabilities of each type of robot and the shape and size of the partition.

Summary

The projects described here demonstrate approaches to exploration and localization, as adapted and implemented by (primarily undergraduate) student researchers in the MetroBotics group at the CUNY Agents Lab[1]. The proposed exhibition will include live robot demonstrations and video presentations.

Acknowledgments

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