Problem Set 4: Project Proposal
Multiple Agent SLAM

Ethan Howe and Jennifer Novosad

April 11, 2005

1. INTRODUCTION

Our project involves the extension of SLAM algorithms to multiple, communicating agents. We wish to explore the best ways of utilizing robots that are cooperating to achieve specific goals, while existing in an uncertain environment and having communication limitations. For example, in planetary exploration we would like to have numerous agents both for robustness and increased utility. Those robots should be independent enough to work in the environment on their own but also should be able to share information important for achieving shared goals like a complete map or shared operations like moving a rock. Even in more mundane systems, as soon as we create more than one robot, we would like to have a strategy for both robots to benefit from the information gathered by the other. In this project, we will focus on collaborative robotic efforts utilizing SLAM rather than other avenues that have been intensely studied such as adversarial games with established maps.

2. PROBLEM STATEMENT AND OBJECTIVES

The problem that our project addresses is how independent agents manage pursuit of a shared goal in an unknown environment. Our plan is to implement SLAM for a single robot and an environmental testbed to interact with the robot. We will try to make our model as close to the real world as possible, having the testbed control the true positions of robots and objects, and giving noisy values back to the robot. We will not be implementing the full vision system for determining landmarks but rather will have our environment hand these objects to the robot. We will then extend this framework to multiple robots allowing communication and map reconciliation. We will implement and compare different strategies for planning and group dynamics.

3. PREVIOUS WORK

We will draw on the work and methods presented in lecture on SLAM and the papers detailing the implementation of SLAM algorithms. In particular, our model of integrating maps from multiple robots will be an extension of the distributed particle mapping (DP) described in paper[2]. We will also look at the work done by last year's students in their presentation "SLAM for Dummies".

3.1. Papers

1: "Consistent, Convergent, and Constant-Time SLAM." J. Leonard and P. Newman, 18th International Joint Conference on Artificial Intelligence (Acapulco, August 2003).

2: "DP-SLAM: Fast, Robust Simultaneous Localization and Mapping Without Predetermined Landmarks." Austin Eliazar and Ronald Parr, 18th International Joint Conference on Artificial Intelligence (Acapulco, August 2003).

4. SPIRALS OF WORK

For our project, we have three spirals of work. Each spiral represents a different producible in our descope plan. The lowest level spiral is our bare minimum plan, while the last spiral is our enhanced plan.

- Spiral One – reimplement SLAM and a test bed for a single agent. This spiral includes the objects TestBed and Robot.
- Spiral Two – extend SLAM to include multiple agents which communicate with each other. This spiral modified the TestBed and Robot classes to incorporate moving agents into SLAM. It also adds functionality for Robots to decide if they should share maps, and to share maps.
- Spiral Three – extend the current system to let the Robots accomplish a simple goal, such as finding a particular object, or getting a certain number of robots to that object.

Our bare minimum plan does not add much scientific value to the community if it is easy to implement; however, unexpected difficulties result in the inability to complete any other spirals, we will learn enough about why it failed to describe possible pitfalls in a valuable way.

The second spiral, the baseline plan, adds scientific value by developing a way for robots to simultaneously map a space using SLAM. Because detailed communications may be time costly, we will create a fast method of communicating which allows robots to see if they will gain value by communicating large maps to each other. Additionally, we will modify DP-SLAM to be used by a robot incorporating another robot's map.

The third spiral is our enhanced plan, and would explore the use of our system. There are several goals we have in mind, and will choose one based on time allowances. A possible goal includes asking the robots to find an object (such as a scientifically interesting sample, or a particular mineral), and then requiring that a certain number of robots go to that site to carry it back. Another possible goal includes looking for an exit or safe zone, and then attempting to communicate that zone to as many other robots as possible before Godzilla hits (at which point, robots would need to rush to the safe zone while avoiding Godzilla).

5. PROPOSED TECHNICAL APPROACH

Our technical approach is designed to preserve the modularity of the spirals, so that we can completely finish a spiral and reconvene to modify the remainder of the approach and timeline before beginning the next spiral. We will implement our project in Java; hence our technical approach is organized by objects and their methods.

To complete the first spiral, of a single SLAM using agent and a test bed, we will create two objects (a TestBed and a Robot). Their specifications will be as follows:

The TestBed will provide a two dimensional environment, reminiscent of flat land. It will keep track of the positions of fixed objects (circles and line segments), and robots. It will need internal methods to detect collisions, and detect if an object is in the line of sight of the robot. It will have external methods that allow a robot to request to turn, see objects, and move forward. The see method will return a noisy distance to an object along the current line of sight of the robot, while the turn and forward methods will update the TestBed position of the robot (incorporating noise). We choose to have the TestBed incorporate the noise of movement and measurement to avoid programming mistakes in which the robot knows the exact amount of noise, and therefore the true value. If we find progress is made quickly, we may incorporate a graphic display.

The Robot will have an internal matrix which represents the noisy map of the universe, and a Kalman filter to update this map over time. During phase 1, the Robot will have a wander routine as a stub for actual planned movements. In order to move, see, or turn, it will request the board to perform the action. If we find that progress is made quickly on spiral 1, we may incorporate loop closing into the robot.

In completing the second spiral, we will modify the two above objects as follows:

The TestBed will need some changes to mediate robot communication, and prevent robots from existing in the same place. Communication will require that the two robots are within a certain distance (larger than the requirement for sight), and that there are no objects between the two. The TestBed would need to tell each robot that it hears another robot at a particular distance and direction. We are uncertain if we will add noise to this measurement, make it only an order of magnitude estimate, or let it be a perfect measurement. Since sound will only result in giving information about a moving target and not the static map, we do not feel this is an important detail at this time.

The Robot class will need three additions. First, it will need to recognize moving robots as not static, and as such, not put them into the map. Secondly, when it recognizes a robot in the general vicinity, it should check if it has communicated recently with that robot, and if not, open a line of communication. This initial communication would determine if the two robots have adequately large portions of unshared map. This can be completed by communicating a set of ordered points to describe a polygon, and then calculating if the two polygons have different regions. Thirdly, it should create a route to approach the robot and visually see it, and then to determine their relative origins and transfer their maps. The map transfer would need to take into account the uncertainty of the robots positions, and their uncertainty in visually measuring each other.

To implement Spiral 3, we will need to decide upon an adequately small plan for the robots (given the remaining time constraints). We are leaving this plan open ended at this time, because we do not necessarily expect to get this far in the project. However, the likely qualities of this plan include distributively searching for a goal object, and attempting to get a certain number of agents near the goal. To make this plan, we will likely need to edit the robots so that they have some basic path planning mechanism, and can recognize a goal object. We will also need to incorporate an idea of where other robots are located (up until this point, we have left them off the map for simplicity). Lastly, the specific reasoning about the goal will need to be added (such as, attempt to remain close to the goal while finding other robots).

6. TIME LINE

- Sunday, April 17, have objects with method stubs for Spiral one, so that testing can begin. Have CVS set up.
- Sunday, April 24, have completed and tested Spiral 1. Modify Spiral 2 plan to account for unexpected errors. Create stubs for Spiral 2
- Sunday, May 1, have completed and tested Spiral 2. Decide specifics of Spiral 3, and create stubs
- Sunday, May 8, have completed all progress that will be made on Spiral 3.
- Monday, May 9, have slides ready, give presentation
- Wednesday, May 11, turn in final paper

7. DIVISION OF LABOR

In the first spiral, Ethan will create the TestBed object and associated methods, while Jennifer will make the Robot object and associated methods. In the second spiral, Ethan will make the updates to the board, and create the ability for Robots to incorporate other robot maps, while Jennifer will create the other robot updates. The third spiral is not fleshed out in detail yet, and labor will be divided when more specific plans are made. Both team members will work on the paper and presentation.