Assignment 1 – Cooperative Multi-Robot Observation of Moving Targets

Scenario

$m = 3$ holonomic point robots with 360-degree field of view sensors of range $do_3 = 30$ m must observe $n = 6$ holonomic targets moving randomly within a circular environment of radius $R = 100$ m. The speed of each target is fixed and randomly chosen to be between 0 m/s and 1.5 m/s. The maximum speed of each robot is 2 m/s. You may assume that the sensing of each robot is perfect and that each robot may communicate with other robots throughout the environment. The goal of the robots is to maximize the average number of targets that are being observed by at least one robot at each time step $dt = 1$ throughout the mission of length $T = 120$ s.

Hint

Consider implementing the algorithm from class on Tuesday, September 12th, as described in Parker, "Distributed Algorithms for Multi-Robot Observation of Multiple Moving Targets," Autonomous Robots 12:231-255, 2002. Suggested settings for the parameters to the potential fields in figures 2 and 3 of Parker, 2002 are $do_1 = 4$ m, $do_2 = 8$ m, $do_3 = 30$ m, $dr_1 = 12.5$ m, and $dr_2 = 20$ m, however, you are encouraged to experiment.

Experimentation

Observe the changes of behavior as you vary the number of robots m from 1 through 10, the number of targets n from 1 through 20, and the radius of the environment R from 100 m to 500 m. Plot graphs of environment radius R vs. average number of targets observed (metric A in Parker, 2002) for ratios of targets to robots n/m of 1/5, 1/2, 1, 4, and 10 (see figure 9 of Parker, 2002).

Extra Credit

Reduce the range of the sensors on each robot to $do_3 = 25$ m and implement a predictive tracking range from 25 m to 30 m from each robot where it is assumed that the motion of previously observed targets will continue linearly from their last observed state. Repeat the experiments above and observe any changes in behavior.

What to Submit

Upload to Sakai your documented source code, graphs, and plots, screenshots, or video showing the locations of the robots and targets as your code runs for the original scenario of $m = 3$ robots and $n = 6$ targets in an environment of radius $R = 100$ m (see figure 5 of Parker, 2002). Include detailed instructions for building and running your code, as appropriate.

Deadline

Before class (4:40 pm) on Thursday, October 12th. For one of the assignments, you may choose to take a seven-day extension without penalty, otherwise you will be deducted one point for each day that the assignment is late.

Homework 1

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1 Instructions

Instructions for installing and running the simulation can be found in the `README.md` file.

2 Experimental Method

This section gives a brief overview of the implementation's assumptions and parameters, as well as shares results from a variety of runs with differing target-robot ratios.

2.1 Assumptions

Given the complexity of the problem, there are many design decisions to consider. Thus, the implementation makes the following simplifying assumptions:

1. The robot and target dynamics are a linear function of position, orientation, velocity, and steering angle only. Acceleration is not considered.

2.2 Parameters

The simulation implemented the following:

1. Suggested potential field parameters.
2. Each target moves linearly with a 5% chance at each time step to alter direction randomly between $\pm 90°$.
3. A robot or target heading out of bounds is reflected off the boundary.
4. The weighting factor w was chosen to be either 0.25, if the given target was being observed by another robot, or 1.

3 Results

3.1 Example Scenario

The simulation was run with $m = 3$, $n = 6$, and $R = 100$. In this case, the average, normalized number of observed targets was $A = 0.849$. A plot of this scenario is included below and a video can also be found in `data/ex_sim.mp4`.

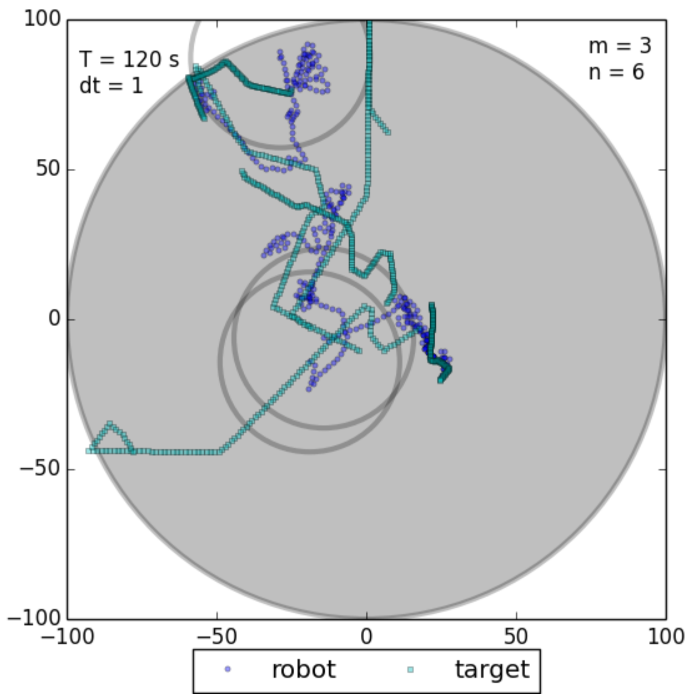

Figure 1: Simulation result from example scenario.

3.2 Target-Robot Ratios

The simulation was additionally tested on the specified target-robot ratios. For each ratio, 9 equally spaced samples were taken for the radii range. For each sample radius, the average simulation results across 5 instances was used to fit a third degree polynomial to the data. This was chosen due to the slow and stochastic nature of the simulation.

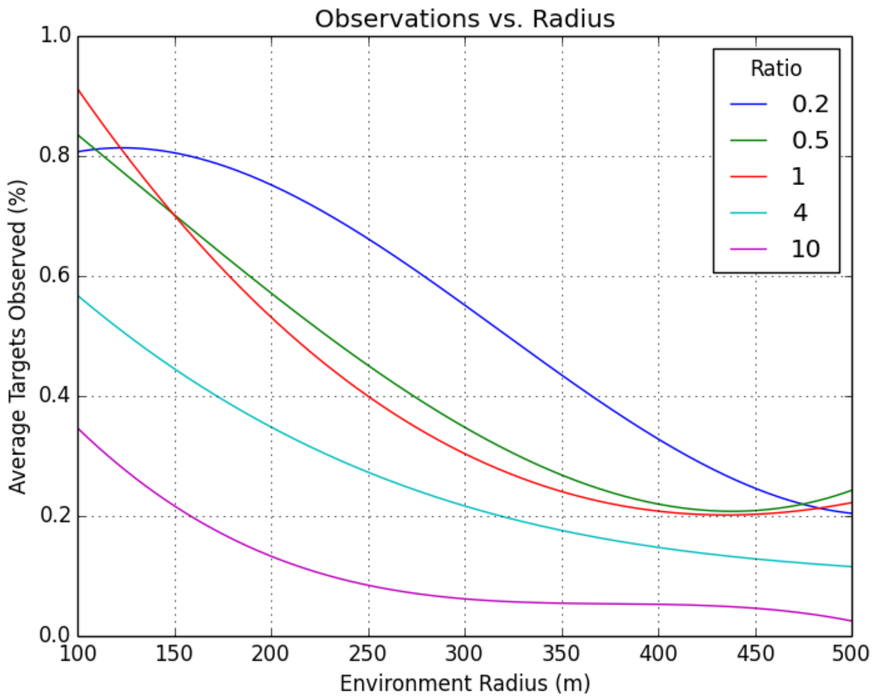

Figure 2: Simulation results for various target-robot ratios.

3.3 Predictive Tracking (Extra Credit)

The same example scenario was run again after decreasing the sensing range and implementing predictive tracking. This time, the average, normalized number of observed targets was $A = 0.78$. This decrease results from each robot now having less information than before, with only an imperfect state estimation of targets between 25 and 30 m. A plot of this scenario is included below and a video can also be found in `data/ex_sim_track.mp4`.

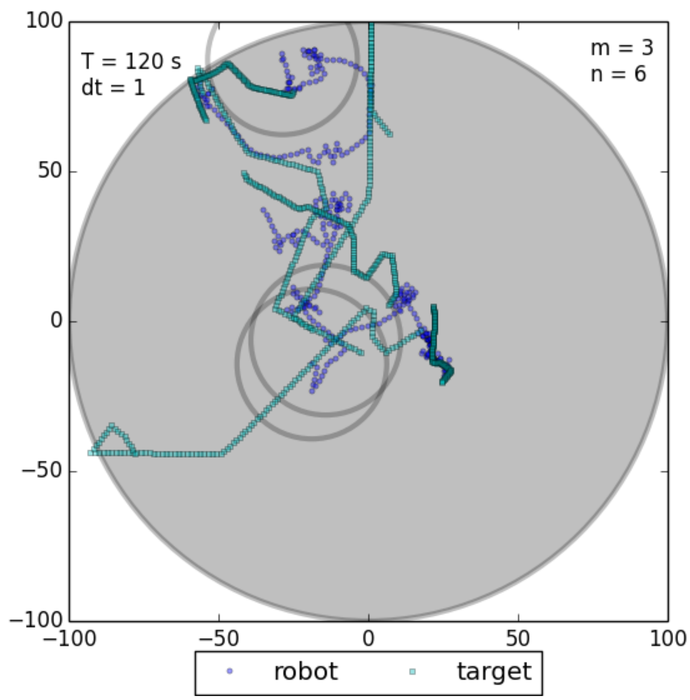

Figure 3: Simulation results from example scenario with predictive tracking.

The same ratios were also tested again. Note the slight decrease in performance.

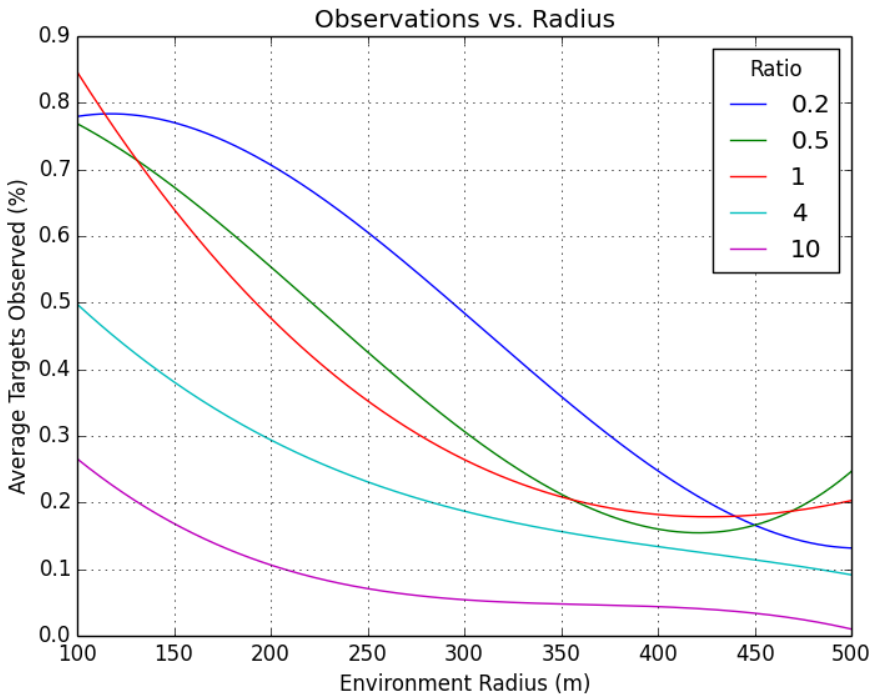

Figure 4: Simulation results for various target-robot ratios with predictive tracking.

4 Discussion

The average number of observed targets varied inversely with the ratio of targets to robots. In other words, more targets were observed when they were more robots. In addition, the average number of observed targets varied inversely with the environment radius. In other words, more targets were observed in a smaller environment.

With predictive tracking, the results show a slight decrease in performance. Again, this arises from the decreased sensing range of each robot.

Note that these results do not seem to show the same level of performance as the paper. A possible explanation is that the ratio alone does give enough information about the simulation. Here, m and n were found from a maximum value. But as the environment radius increased, the chance that at least one robot could find any given target decreased. Perhaps a better way to choose m and n is to calculate the minimum m needed to achieve a combined sensing area that covers a given fraction of the total environment area.