1 Dates

- Assignment 4 project demonstrations in class: Friday, April 3, 2009
- Assignment 4 handin due: Friday, April 3, 2009

2 Introduction

CS 148 giveth, and CS148 taketh away.

Figure 1: Evil maposaurus, prepare to meet your doom.

In the previous assignments, we have built up to a working robot soccer player. You have developed an autonomous robot controller for 1-on-1 soccer using Player proxies for position control, bumper, and color blobfinding as well as our in-house overhead localization system. Now it is time to remove the training wheels, specifically external top-down localization (this assignment) and internal state variables (next assignment).

In the current assignment, you will implement a robot soccer controller that uses only the robot's on-board sensing and perception. Specifically, you are only allowed to use Player's position2d, bumper, and blobfinding proxies. With this perceptual information, you are tasked with implementing a localization system to determine your robot's pose on the pitch. The pitch has been augmented with six color fiducials at the corners and midfield lines to facilitate your localization process. These fiducials should be detectable using your object recognition code from Assignment 2. Pose estimates from your localization, along with desired pose generation, will given to your **working** path planning system from Assignment 3.

3 Robot Localization

For this project, your client will continually estimate the current pose of your robot to enable path planning. Your localization system must be able to estimate the probablity of the robot being in a certain pose $X = (x, y, \theta)$ given your current perception values Z given by odometry, object recognition, and bumper and a known map. The map will contain the locations of relevant objects, namely goals and fiducials. Your existing path planner will use this pose estimate to generate a path on the field to traverse.

In class, we have covered several different localization algorithms based on the Bayes filter[1]:

$$p(X_t|Z_t) \propto p(Z_t|X_t) \sum_{X_t} p(X_t|X_{t-1}) p(X_{t-1}|Z_{t-1}) \tag{1}$$

which, roughly stated, generates the robot's new location belief at time t, or *posterior* $p(X_t|Z_t)$, by using its old belief at time $t-1$, or *prior* $p(X_{t-1}|Z_{t-1})$ to predict a new belief, or *dynamics* $p(X_t|X_{t-1})$, that is matched against reality, or *likelihood* $p(Z_t|X_t)$. Several algorithms can be used to perform filtering for localization:

- Filtering with grid-based discretization

[1] refer to Wikipedia entry on "Recursive Bayesian estimation"

- Kalman filtering: Markovian linear dynamics with parametric Gaussian-distributed unimodal noise
- Particle filtering: probablistic Markovian dynamics with nonparametric noise distributions and importance sampling

However, you will find that defining proper likelihood and dynamics terms are not explicitly covered by the algorithms. Specifically, your dynamics should use odometric information about the robot's pose given by Player's position2d proxy. Your likelihood function should evaluate the plausibility of perceiving information from the blobfinder and bumper proxies given a hypothesis that you are in a particular pose. You will spend some time and careful consideration in defining these terms.

Additionally, you will need to consider how to extract a single localization decision if you have a multimodal posterior distribution. As discussed in class, *maximum a posteriori* (maximum), expectation (mean), and robust mean are options for extracting such pose estimates.

Active localization: It should be noted that your decision making can help resolve ambiguity for your localiztion system. That is, you can decide to move your robot towards locations that would make its location more clear.

4 Desired Pose Determination

Also, you are not restricted to using only your path planner for decision making, but it is highly recommended. At the very least, you should consider using some combination of your planner and other control heuristics.

In addition to estimating the current pose of your robot, you will also need to determine desired poses for your path planning system. Your calculation of desired pose can (and probably should) use estimates of your robot's pose along with recognition of the ball. It is not necessary to perform localization on the ball's location, but this is not necessarily a bad idea. You may want to try to estimate the depth of the ball from blob dimensions, which is (again) not necessary. Note: the ball will not be occluded during the skills challenges, but may be occluded during gameplay due to the other player.

Given our current soccer setup, localization of the other player will be difficult and is discouraged.

5 Soccer Skills Challenges and Competition

The goal scoring challenges and inter-group soccer competition from Assignment 4 (Path Planning) will be used for this competition in addition to a modified navigation challenge. In this navigation challenge, you will be given a set of locations on the field to visit in sequence along with regions on the field to avoid.

5.1 Map File Format

The pitch map will be given to you as file in the following space-delimited format:

```
Landmarks
<color_top> <color_bottom> <x_location> <y_location>
...
<color_top> <color_bottom> <x_location> <y_location>

Visit
<x_location> <y_location>
...
<x_location> <y_location>

Avoid
<x_location> <y_location> <radius>
```

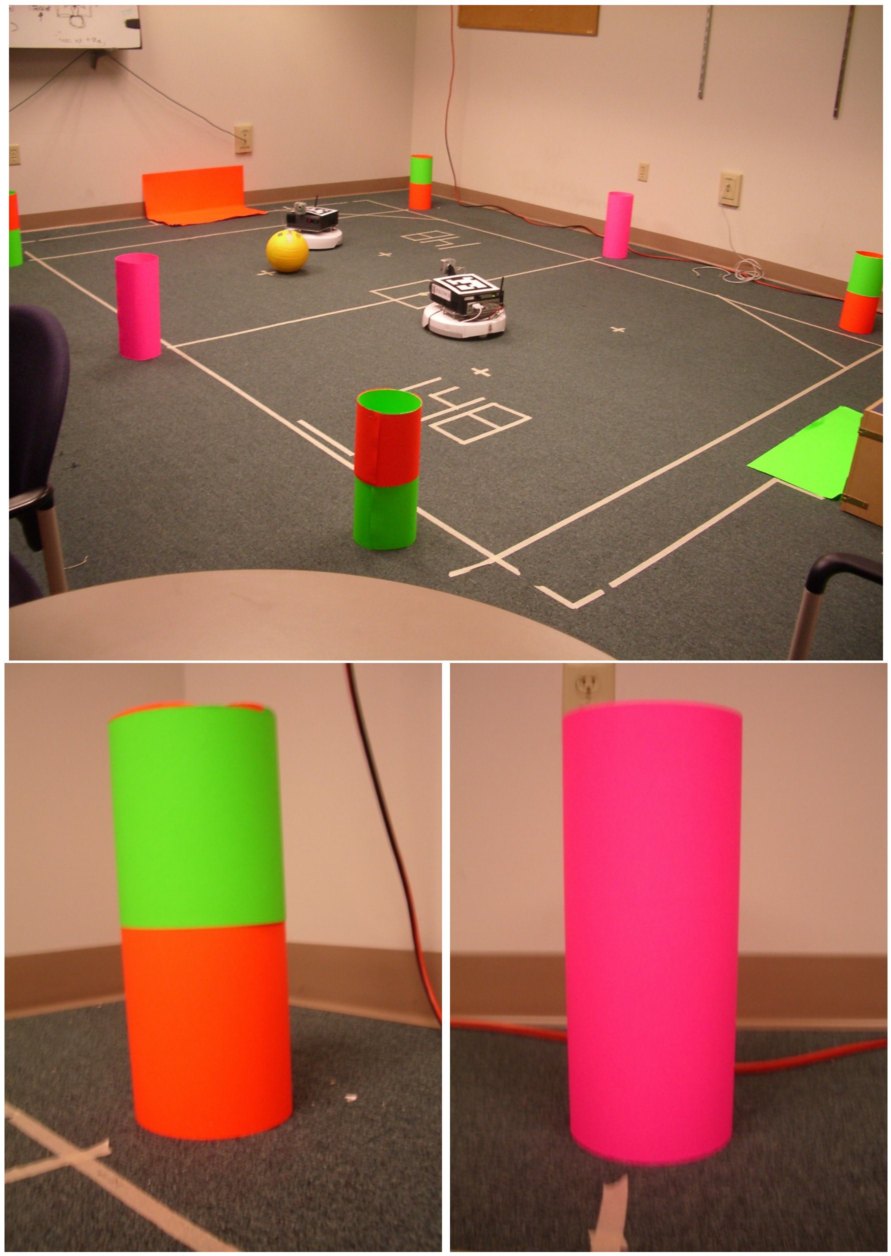

Figure 2: Snapshot of the "FC 148" robot soccer field with fiducial landmarks at the corners (such as "green" over "orange") and midfield line (as "pink").

```
...
<x_location> <y_location> <radius>
```

The “Landmarks” section lists the colors and locations of non-goal landmarks, the “Visit” section lists the locations to visit (in sequence), and the “Avoid” section lists circular regions on the field to avoid. The location and radius values will be given in the field coordinate system, as given in the last assignment by the overhead localization system. Colors for the landmarks will be specified as one of the following strings: “Green”, “Pink”, “Orange”, or “Yellow”. Top and bottom landmark colors can be the same to indicate a single colored fiducial.

Be careful to not make overly limiting assumptions about the map! Make sure you can parse and read the file format. Map files will not be given to you for the skills challenges until just before your run. However, example and competition files will be provided in /course/cs148/pub.

6 Grading

Note: The soccer competition will take place during class and the following hour (11-1), please make appointments to run your challenges a week before the due date.

Your grade for Assignment 4 will be determined by equal weighting of your group’s implementation (50%) and your individual written report (50%). The weighted breakdown of grading factors for this assignment are as follows:

Project Implementation	
- Localization → Does your robot properly estimate its location? → Does this estimate account for uncertainty and ambiguity in perception?	30%
- Goal Attainment → Can your robot drive to a given sequence of locations on the field? → Can the robot avoid given unseen regions on the pitch?	10%
- Soccer Proficiency → How well does your robot play soccer in the given environment?	5%
- Controller Robustness → Does your controller run without interruption?	5%
Written Report	
- Introduction and Problem Statement → What is your problem? → Why is it interesting?	7%
- Approach and Methods → What is your approach to the problem? → How did you implement your approach and algorithms? → Could someone reproduce your algorithms?	15%
- Experiments and Results → How did you validate your methods? → Describe your variables, controls, specific tests, and results from these test. → Could someone reproduce your results?	20%
- Conclusion and Discussion → What conclusions can be reached about your problem and approach? → What are the strengths of your approach? → What are the shortcomings of your approach?	8%