1 Dates

- Assignment 4 waypoint milestone due: Wednesday, November 4, 2009
- Assignment 4 project demonstrations in class: Friday, November 13, 2009
- Assignment 4 handin due: Friday, November 13, 2009 (10 pm)

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 (or ROS nodes) 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: Subsumption).

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, as well the fixed locations and dimensions of the goals, to facilitate the 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 probability of the robot being in a certain pose $X = (x, y, \theta)$ given the 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]:

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

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, although we will only cover the particle filter in depth during lecture:

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

- Filtering with grid-based discretization
- Kalman filtering: Markovian linear dynamics with parametric Gaussian-distributed unimodal noise
- Particle filtering: probabilistic 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, filter dynamics will use odometric information about the robot's pose given by Player's position2d proxy to **predict** a new belief forward in time. Your likelihood function will **update** the belief by evaluating the plausibility of perceiving information from the blobfinder and bumper proxies given a hypothesis of a particular robot 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 actions taken by the robot can help resolve ambiguity for your localization system. That is, you can decide to move your robot towards locations that would make its location more clear.

4 Desired Pose Determination

In addition to estimating the current pose of the robot, your client will need to make decisions for determine desired poses and generating actions to reach these desireds. This decision making can be performed by the path planner you implemented for Assignment 3, assuming the location of the ball can be determined. You are not restricted to using only your path planner for decision making, but it is highly recommended. At the very least, some combination of path planner and other control heuristics is likely warranted. Sharing of path planning code between groups is allowed, only through checkout of code of Assignments 1-3 from course svn repositories.

Your calculation of desired pose can (and probably should) use estimates of the ball location of your robot's pose along. While it is not necessary to perform localization on the ball's location, estimating some information about the state of the ball is typically necessary. One recommended approach is to estimate the range and bearing of the ball from the robot's pose. 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 Milestone: Landmark Range and Bearing Estimation

An intermediate demonstration of your progress is required before the final due date of the Localization project. For this milestone, you will need to demonstrate a working estimation of range and bearing from the robot to fiducial objects (yellow ball, pink landmark, green/orange landmark, orange/green landmark, green goal and orange goal) when seen through the robot's blobfinder. For the milestone, you will be required to estimate range and bearing for all the landmarks, in centimeters and radians respectively. The TAs will set the robot at a random location in the field and place varying landmarks in your field of view. For each landmark, in the robot's current visual stream, you must print out a distance and relative angle to the landmark. No visualization is required for this milestone, but would be appreciated.

It is recommended that a **data-driven** procedure is used to learning a function that outputs the predicted range of landmark objects, each which have known dimensions and appearance, from perceived blob features. To estimate the range from your robot to a landmark, place the landmark at varying distances from the robot[2] and record features (e.g., height, width, area) of the perceived blob(s) corresponding to the object.

[2] preferably from 0 cm (or the closest the robot can see an object) to at least the entire length of the FC148 field

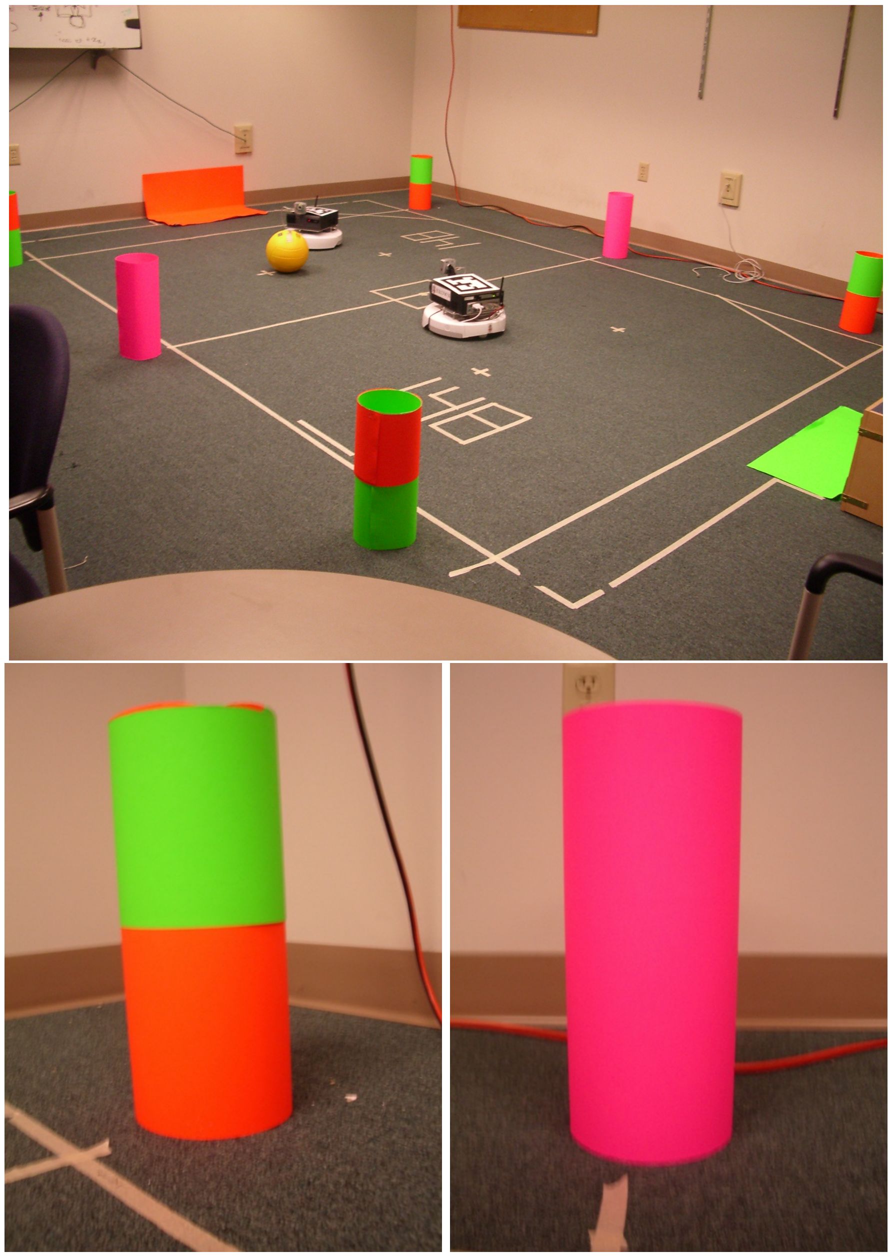

Figure 2: Snapshot of the "FC 148" robot soccer field with fiducial landmarks at the corners (such as "green" over "orange") and midfield line (as "pink").

The result is a set of example input-output pairs that relate blob features to distance[3]. Once you have recorded blob measurements for each landmark, you should approximate the function that predicts distance from blob features. It is up to you to determine the appropriate features of blobs to use for estimating range.

This blob-feature function can be approximated through a variety of regression techniques[4], including a nearest neighbors lookup table, linear interpolation, radial-basis interpolation, spline interpolation, and nonparametric regression. You should import your approximated function into your client. For example, a nearest neighbor regressor would import a lookup table data structure into a client. Upon seeing a blob, your client will first identify the type of object (ball, goal, landmark) for the blob, and then use the dimensions of the blob(s) to predict/lookup the distance to the landmark.

To estimate bearing, it is suggested to use the relative proportions of the robot camera field of view, assuming the (default) camera view center is 160 pixels and the view angle is 60 degrees.

6 Soccer Skills Challenges and Competition

The goal scoring challenges and inter-group soccer competition from Assignment 3 (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.

6.1 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> <radius>
...
<color_top> <color_bottom> <x_location> <y_location> <radius>

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

Avoid
<x_location> <y_location> <radius>
...
<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 befor your run. However, example and competition files will be provided in /course/cs148/pub.

[3]Note, that measurements at far distances will vary only slightly and may become difficult to distinguish an accurate distance based on blob size

[4]Regression is the analysis of the relationship between a dependent variable(s) and an independent variable(s)

7 Grading

Please make appointments to run the demonstrations of your challenges with the TA staff on or before the project due date.

Note: The soccer competitions will be held during class and the preceding hour (12-2pm). Though performance in this competition is ungraded, failure to participate in the competition will result in a 10% deduction in the grade for this assignment, at a minimum.

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 player 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%