King Fahd University of Petroleum and Minerals
Department of Computer Engineering

INTRODUCTION TO ROBOTICS COE 484

Homework No 3 (Due on April 19, 2008)

Questions	**Grading**
1	
2	
3	
4	
5	
TOTAL	

QUESTION 1: GT 2005 modules to implement the sense-think-Act paradigm for Soccer

GT 2005 describes their humanoid system as composed of three major modules: (1) Low-Level Vision, (2) Self-Localization, and (3) Behavior Programming. The above scheme describes one iteration of Sensing, Processing, Thinking, and Acting. The above iteration repeats (soccer playing) until the program is aborted.

Describe each of the above three modules by presenting:

(1) The module inputs and outputs,
(2) The meaning of the input and output parameters by referring to the robot, player, ball, and field,
(3) The processing which is done by each module in connection with Sensing, Processing, Thinking, and Acting.

At the end, link the above three modules to present the "Soccer Playing" approach in GT 2005.

Solution:

GT 2005 describes their humanoid system as composed of three major modules:

- The low-level vision system which takes as inputs pictures grabbed from a Camera with resolution of 208×160 pixels. The output of the vision module computes (fills) the data structure PerceptCollection. A percept collection contains information about the relative position of the ball, the field lines, the goals, the flags, the other players, and the obstacles. The processing consists of below-horizon grid of horizontal and vertical scan lines. Color detection of a scanned pixel allows invoking an object procedure (beacon, ball, etc) that computes some the coordinate of some points that fill the corresponding percept.

- The Self-Localization module takes as inputs the PerceptCollection and generates as output a number of poses such as the RobotPose, BallPosition, PlayerPoseCollection, ObstacleModel, and RobotState, e.g. parameters of the robot, player, ball, and field features. The above data structure contains all the parameters that characterize the robot and all seen objects like ball, the field lines, the goals, the flags, the other players, and the obstacles. It also describe the time aspect and frequency in observing the field features such as how often and how long a specific feature has been seen or not seen. A probabilistic processing (Monte Carlo) is used. It consists of placing particles (hypotheses robot locations) in many field places, applies a motion and observation models, and evaluate a particle probability based on percepts seen at the particle location and its similarity to the percept seen from current (unknown) robot location. The process converges to an accurate hypothesized position.

- The Behavior programming takes as input the above robot, player, ball, and field parameters. It uses an Agent like "Soccer" described as an "Option Graph" which is directed acyclic graph, where each node is an option. Each option carries out checking on the some parameters which lead to select a path through the Option Graph. The selected path is called the activation path which represents one possible state in the Soccer Game. The roots of the Option Graph are special nodes called "Basic Behaviors" which represent robot motion functions. This means that a specific activation path, which represents one possible state, terminates by one Basic Behavior. This is how the robot moves based on current state or current set of parameters.

The above scheme describes one iteration of Sensing, Processing, Thinking, and Acting. The above iteration repeat (soccer playing) in time until the program is aborted. Note that GT 2005 uses the XABSL which is a software tool to describe the above Option Graph.

QUESTION 2: GT 2005 Low-Level Vision System for the GT 2005

The low-level vision processing (image processor) takes as input an image grabbed using a low-resolution camera, e.g. 208 ×160 pixels. Although GT 2005 uses a low-resolution camera of 208×160 pixels the image processing is still time consuming in computing the percepts of the ball, the field lines, the goals, the flags, the other players, and the obstacles. Answer with details each of the following questions:

(1) Describe the approach used in used GT 2005 to reduce the amount of processed pixels and the scanning strategy.

(2) What approach is used to ensure that each pixel is visited once.

(3) GT 2005 used a set of Procedures for the detection of ball, field lines, goals, flags (beacons), other players, and obstacles. How these procedures are invoked in view of the fact that each pixel is visited once.

Solution:

(1) The horizon is a horizontal plan going the robot camera forward. Since all the objects of interest lies below the horizontal plan, then by identifying the horizon the robot may prune a large amount of pixels (above horizon) that need not the be processed which reduces the processing time of this vision module. The horizon can be identified based on both the rotation matrices of the camera and robot with respect to filed.

(2) A grid of horizontal and vertical lines is drawn below the horizon so that regions close to horizon are given higher resolution (finer grid) and regions that are far away from horizon are given coarse grid. The strategy is to scan the image only on the vertical and horizontal grid lines. This ensures that each grid pixel is visited once.

(3) GT 2005 used a set of Procedures for the detection of ball, field lines, goals, flags (beacons), other players, and obstacles. These procedures are invoked based on specific color detection because each of the ball, field lines, goals, flags (beacons), other players, and obstacles has specific color in YUV pixel space. Thus determining the YUV of a pixel allows invoking the corresponding procedure for the detection of a specific object like the ball, field lines, goals, flags (beacons), other players, and obstacles. For example when a pixel falls in the orange color, the ball detection procedure is called.

QUESTION 3: Object Detection by the Low-Level Vision System

Answer with details each of the following questions:

1. For what reason the Gradient operator is used for the detection of the field lines! Refer to the nature of the elements of the LandMarksPercept in your description.

2. Which module uses the LandMarksPercept and why! What happens when some elements of the LandMarksPercept are not seen in the current picture.

3. Describe how the centre circle is detected. Suggest a check that improves the reliability of the computed centre.

4. Describe how the ball and the centre of the Ball are detected. How to eliminate false-positive for the ball detection.

5. Describe how the Beacons are detected. How to eliminate false-positive for the ball detection. Is it possible that the detection is confused on where is located a specific beacon with respect to the field.

6. For what reason the field detection procedure uses an extended color classification based on a generalized distance function (Chi-Square).

Solution:

1. The Field-Line-Detector is invoked when the color switches from Green to White or the inverse. It uses the Gradient of the field line is used to identify the line direction on the boundary between two colors like the Green and White. The line cannot be used as a fixed object in the percept which requires only points with known coordinates be identified. Therefore, the need for the detection of the line direction is derived from the need to identify the intersection points (line crossing) between intersecting lines which represent field edge points that are the elements of the LandMarksPercept.
2. The SelfLocator module aims at finding the location of the robot based on knowledge of last position, some motion from that point (odometry), and the use of the points that are observed using the vision which include the LandMarksPercept. The SelfLocator can function in a normal way using an arbitrary subset of percepts. The SelfLocator uses any observable subset of percepts. Thus, the SelfLocator continues working when some elements of the LandMarksPercept are not seen in the current picture.
3. The centre circle is detected by detecting some of its curved peripherals. Two distant arcs can be selected. The two lines which are perpendicular to each arc are set up. Thus these lines must intersect at the circle centre. This is similar to finding two tangent lines to the circle centre intersecting at the centre. A check that improves the reliability of the computed centre may consist of taking the middle of the filed line which intersects the circle if it is fully observed.

4. The ball has orange color which is used to call the ball detection procedure. This procedure invokes the Ball Specialist which scans the ball along horizontal and vertical lines until their intersection with ball circle. The scan algorithm uses counters

that counts the number of non-orange pixels to tolerate variation in ball color and for ball boundary detection. To eliminate false-positive for the ball detection one may measure the ball diameter which must be within some bounds given the minimum and maximum distance between the robot and the ball on the field.

5. The beacon is expected to be seen close to the horizon line. For this a set of scanlines parallel and perpendicular to the horizon are checked for finding the frame of each color region. Overall, a rectangular frame is identified for the beacon. Each beacon has a unique combination of colors such as PinkYellow, YellowPink, PinkSkyBlue, SkyBluePink. For this it is not possible that the detection is confused on where is located a specific beacon with respect to the field because each combination of colors is associated a unique location on the filed.

6. The Goal detection and goal edges represent a set of critical resources for soccer gaming. The goal is formed by large plans at the Goalie Post and the top corossbar. The large plans may have quite different pixel colors than than the expected Skyblue. For this the distance D(X,R) = (X-R) C^-1 (X-R) is computed for each pixel, where X is pixel color in YUV, R is the reference for Skyblue, C is the 3*3 variance matrix. Depending on the value of D(X,R), three classes are identified which are the inner, intermediate and outer pixels. The detection algorithm uses an Edge Counter (EC) and a Deviation Counter (DV). EC is used to tolerate a specific number of accumulated outer pixels in a scan. DV to help in the detection of the goal edges. DV is used to avoid confusing deviating pixel colors within the plans as edge pixels.

QUESTION 4: The Monte-Carlo Self-Localization (MCSL)Module

1. State the problem that the MCSL SelfLocator tries to solve by referring to the initial robot Pose, robot motion given by Delta_Pose(Odometry), and the vision percepts.

2. Describe the details of MCSL SelfLocator algorithm using (1) motion model, (2) observation model, (3) evaluation model, (4) evaluation, (5) selection, and (6) re-sampling.

Solution:

The SelfLocator module aims at finding the location of the robot based on knowledge of (1) last robot position (Pose), (2) some motion (odometry) from the previous point (Delta_Pose), and (3) the use of the edge points that are observed using the vision such as the LinePercept and the LandMarksPercept. Thus the problem is to find out the best possible estimate of Pose+ = Pose + Delta_Pose + Some_random_errors. Thus Pose+ is identified based on the knowledge of Pose, Delta_Pose (Odometry) and more importantly the edges which are seen by the vision system. The robot is currelty located at Pose+ but we do not know the real values of the coordinate of Pose+ which is the object of the self-localization.

The MCSL SelfLocator operates as follows:

1. Whenever the robot is placed in an unknown location, the MCSL selflocator generates a set of randomly positioned particles (positions) on the field to determine the position of a subset of particles from where the vision detects some edge points having the same angles as those measured from the robot pose.
2. It applies the Motion model to each particle using Delta_Pose (Odometry) which also allows setting up the camera orientation matrix on a hypothetical robot placed at each particle.
3. It applies the observation Model to each particle by using the camera to detect some field edges based on the knowledge of the camera and its orientation at the particle position. Since the set of relevant percept points or edge points are fixed on the field, the Pin Hole Camera model is used to identify a horizontal and a vertical angles characterizing the seen edges from the camera.
4. The evaluation step consists of associating a probability to each particle. Each edge point is associated a probalility q= Exp{- sigma * (angle_seen- angle_ measured)}. Thus q is 1 when angle_seen = angle_ measured and smoothly decreases to zero when the above deviate from each other. The probability of each particle is being the product of the individual probabilities associated to its edge points. Parameter "sigma" is determined to reduce dependence on images taken while robot is moving at relatively high speed.

5. The selection process consists of pruning most of the particles for which the probability is lower some threshold and retaining a small set of particles having high probability.

6. Re-sampling consists of generating random particles close to those which received high probability in the selection process and repeat the process all over again to refine the particle location and possibly find some particle with a very high probability.