King Fahd University of Petroleum and Minerals
Department of Computer Engineering

INTRODUCTION TO ROBOTICS COE 484

EXAM II

April 30, 2008

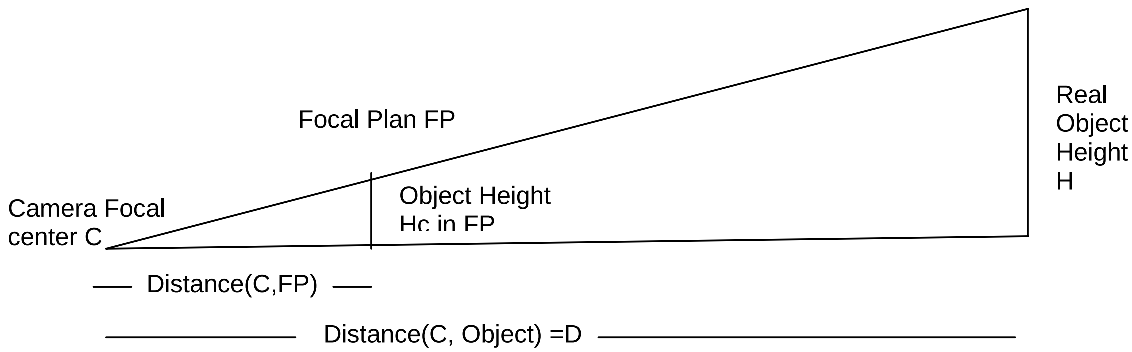
Questions	Grading
1	
2	
3	
4	
5	
TOTAL	

QUESTION 1: THE PIN-HOLE CAMERA MODEL

In the Pin-Hole camera model is defined as follows:

- An object A of height (H) is placed at a distance (D) from the camera focal center.
- The distance from the camera focal center to the focal plan is (F), e.g. focal distance.
- In the camera focal plan the object is seen with a height Hc.

The pin-hole camera model allows writing Hc / H = F / D.



Suppose an object A of height H = 1m and distant to camera focal center by D = 2m. This camera is installed on a robot R. An object A is seen with height Hc=27 pixels in the camera focal plan.

Answer following questions:

1. Following some motion of object A, now the height Hc of A is seen by the camera as Hc= 20 pixels. Determine the distance from Camera to A.

   Answer: Since F= (Hc / H) * D = 27p*2/1= 54 pixels. Therefore, the new D = (H / Hc) F = (1/20p)*54p=2.7 meters.

2. In a soccer game the used ball has a diameter (height) of H=0.05 m. When the ball is located on the soccer field, the robot minimum and maximum distances are Dmin = 0.5m and Dmax = 7.5 m. Determine the minimum Hcmin and maximum heights Hcmxn of the above ball.

   Answer: Since for Dmin we have Hc = H * (F / D) = 0.05 * (54 pixels / 0.5)=5.4 pixels. And for Dmax we have Hc = H * (F / D) = 0.05 * (54 pixels / 7.5)=0.36 pixels.

QUESTION 2: The LOW-LEVEL VISION SYSTEM (GT 2005)

Describe the image scanning motivation and strategy which is used in GT 2005. How the procedures for computing the percepts of the ball, the field lines, the goals, the flags, the other players, and the obstacles are invoked.

Answer: The robot horizon is a horizontal plan going from the robot camera forward at the camera height. Since all the objects of interest lies **below** the horizontal plan, thus by identifying the horizon the system may prune a large amount of pixels (above horizon) that need not the be processed which reduces the processing time. The horizon can be identified based on both the rotation matrices of the camera and robot with respect to filed. 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. 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 using a hashing scheme on pixel color classification because each of the ball, field lines, goals, flags (beacons), other players, and obstacles have distinct color in YUV pixel space. For example when a pixel falls in the orange color, the ball detection procedure is called.

QUESTION 3: MONTE CARLO SELF-LOCALIZATION (MCSL)

1. Shortly answer each of the below listed questions:

    a) How particles are generated according to MCSL when robot is placed in an unknown location.
    b) How MCSL applies the motion model,

Solution:

a) 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.
b) MCSL 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.

2. Consider the Re-Sampling process of MCSL and answer each of the below listed questions:
    a) What is main criterion behind that guide the process of copying particles from previous distribution to new distribution.
    b) Why do we need to generate particles which are drawing from observations! How particles or robot pose are generated in this case.
    c) Under what condition random particles have to be generated!
    d) What is the motivation for process which leads the particles to be moved locally according to their probability! Discuss this issue. How this process may improve the accuracy.
    e) Finally, describe the steps for the calculation of the robot pose based on the retained particles.

Solution:

a) Copying a particle from previous distribution to new distribution is based on particle probability p', so more probable particles are copied more often than less probable ones, and improbable particles are removed. The particle set is reduced by some percentage making room for new generated particles.

b) New particles are introduced based on drawing from observations by using candidate postures (stored in the Template Buffer) that are directly determined from sensor measurements (percepts) such as
   i. the last 3 reliable beacons seen over some specified time with their estimated robot distances and corresponding odometry parameters,
   ii. the combination of beacon and goal-post from the current percept with their reliable distance information are used to generate 1 or 2 candidate posture, and
   iii. finding a posture from a single observation is based on using a lookup table for each edge type. The table contains a large number of poses (postures) indexed by the distance to the edge.

   All combinations of three bearings are used to determine robot postures by triangulation. Calculated postures are given some probabilities (below average) and are only hypotheses, but they have the potential to speed up the localization of the robot.

c) If the number of particles that have to be added is larger than the number of postures in the Template Buffer (found based on sensor measurements), a template posture can be used multiple times, while adding random noise to the template postures. If no templates were calculated, random particles are employed.

d) In a third step that is in fact part of the next motion update, the particles are moved locally according to their probability. The more probable a particle is, the less it is moved, e.g. pose_new = pose_old + (1-p) * rand(-1,+1). This can be seen as a Probabilistic Search for the most accurate position, because the particles that are randomly moved closer to the real position of the robot will be rewarded by better probabilities during the next observation update steps, and they will therefore be more frequent in future distributions.

e) The pose of the robot is calculated in two steps: (1) the particles are assigned to a digitized grid (x-y-z), (2) the sub-cube that contains the maximum number of particles is identified, (and (3) then the current pose is calculated as the average of all particles belonging to that cluster.