CSE-483 Mobile Robotics

End Semester-Monsoon 2018

Open Book, Laptops Allowed, NO INTERNET

Max Marks 40

Non-Holonomic Motion Model

1) Write down the expressions for X(t) and Y(t) , for a differential drive robot in terms of 'the centre velocity v and angular velocity w' and , and also explain the situation where the integralscannot be evaluated in closed form. **(4 marks)**

2) **Trajectory Optimization: (5 marks)**

Derive the equations for a Holonomic motion model, based on the scheme discussed in the class:

Background Theory:

A holonomic model has decoupled equations for X and Y. So equations for

X(t)= , where are the basis functions (Bernstein polynomials), and .

Y(t)= , where are the basis functions (Bernstein polynomials), and .

Now derive the expression for these weights, based on the boundary conditions specified in the class. Specifically, get the weights into the format:, (W: is the array of weights) It is very important to clearly state the elements in 'A' and b.

Static Obstacle Avoidance:

3) Derive the Static Obstacle Avoidance scheme for the Holonomic Motion model. **(5 marks)**

You can assume the obstacle to be placed somewhere in the middle of the path, now write down the scheme for obstacle avoidance.

4. **Motion Model Uncertainty:** Consider a differential drive robot whose center is assumed to be at the mean of the distribution at $\mu_t = (\mu_{xt}, \mu_{yt}, 0)$ at time t with initial covariance Σ_t.

a) Write or expand the Σ_t matrix in terms of its elements. **[2 points]**

b) If the robot's center moves with a velocity <v,?> with a radius of curvature R, derive $\hat{\mu}_{t+1}$ = f(?$_t$, u_t), where u_t = <v,??> **[2 points]**

c) If the control noise $\sum_{ut}$ is,

$$\sum_{ut} = \begin{bmatrix} \sigma_{v^2} & 0 \\ 0 & \sigma_{\omega^2} \end{bmatrix}$$

Write down state covariance $\hat{\Sigma}_{t+1}$ expression clearly deriving the expression for all the Jacobian matrices involved **[4 points]**

5) EKF (Measurement Equation Stuff): Consider a robot R with state

$$X_R = [x_r, y_r, \theta_r]^T$$

. Instead of point landmarks we have line segments as landmarks. Do not characterize a line segment in terms of its endpoints and end up using a point landmark model:

a. Write down the appropriate measurement equation $z = h(X_R)$. **(3 points).**

b. What is the measurement Jacobian, H of the above measurement equation? **(3 points)**

c. How would you characterize/express the measurement noise for above ? **(2 points)**

6. **[Bundle Adjustment]** With regards to our discussion of the Bundle Adjustment (BA) technique in class, answer the following questions. **[1 + 1 + 1 + 4 + 3 = 10 marks]**

a. What are the inputs to the BA algorithm, and what does it optimize for?

b. Write down the BA cost function for three 3D points X_1, X_2, X_3 and four cameras with projection matrices P_1, P_2, P_3, P_4. Assume that all points are visible in all cameras.

c. What is the size of the Jacobian matrix and the number of residual terms?

d. Show the structure of the Jacobian matrix and mention what each populated term in the Jacobian matrix indicates (over here, a coarse, block structure of the Jacobian suffices. You needn't expand all the terms to their fullest).

e. Expand the Jacobian terms in the first two rows of the matrix.