Student Name:

Introduction to Aerial Robotics

Final exam, May 11, 2016

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Student Information

First Name: ____

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Student ID: ____

Department: ____

Undergraduate: ☐ **Graduate:** ☐

Prob. 1 (10%/10%): _________

Prob. 2 (10%/10%): _________

Prob. 3 (20%/20%): _________

Prob. 4 (25%/25%): _________

Prob. 5.a (35%/25%): _________

Prob. 5.b (0%/10%): _________ **(only for grad)**

Total: __________

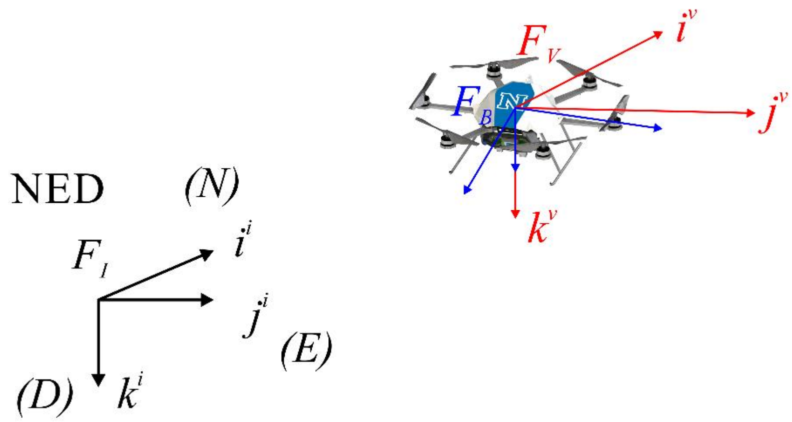
Problem 1: Provide very brief answers to the following questions:

- The inverse of a rotation matrix describing the body-to-vehicle frame transformation of a robot orientation is also its ___________
- The minimum amount of satellites to acquire GPS-based position information on Earth is __________
- In a Kalman Filter, one has to run equal amount of prediction and correction steps: **True / False**
- Unconstrained Linear Model Predictive Control is a nonconvex optimization problem **True/False**
- RRT is a probabilistically complete algorithm for collision-free waypoint navigation **True/False**
- Frontier-based exploration methods always guarantee complete coverage **True/False**

Problem 2: Consider a hexacopter Micro Aerial Vehicle executing a set of maneuvers, namely:

- A roll turn of π/4
- A pitch turn of –π/3
- A yaw turn of π/4

Describe the relation between the body frame *(F_B)* velocities u, v, w and the inertial frame *(F_I)* velocities $\dot{p_n}, \dot{p_e}, \dot{p_d}$ *after the combination of all these maneuvers*.



Solution:

Problem 2: Consider the following sensor-based test data and scenario:

- Scenario: we are using a sensor which detects a specific color (i.e. yellow) and checks the clothes of people entering a mall. It raises a positive – True flag when the person is estimated to wear yellow clothes, and zero – False flag otherwise.
- Scenario data: We know that only 5% of the population wears this color.
- Sensor data 1: Given that a person entering the mall wears yellow clothes, then the probability of the sensor reading being positive is 90%.
- Sensor data 2: Given that a person entering the mall is not wearing any yellow clothes, then the probability of the sensor reading being positive is 20%.

What is the probability of a person actually wearing yellow clothes when the sensor outputs a positive result?

Solution:

Problem 4: Considering the problem of Collision-free navigation from an initial configuration x_0 to a final configurations set X_f, taking place in an environment with X_{Obs} representing the obstacle space and X_{free} the collision-free world, answer the following:

- Describe the Rapidly-exploring Random Tree algorithm (RRT) providing a pseudocode overview as well as a drawing example based on the following diagram.

Solution:

Description of the pseudocode

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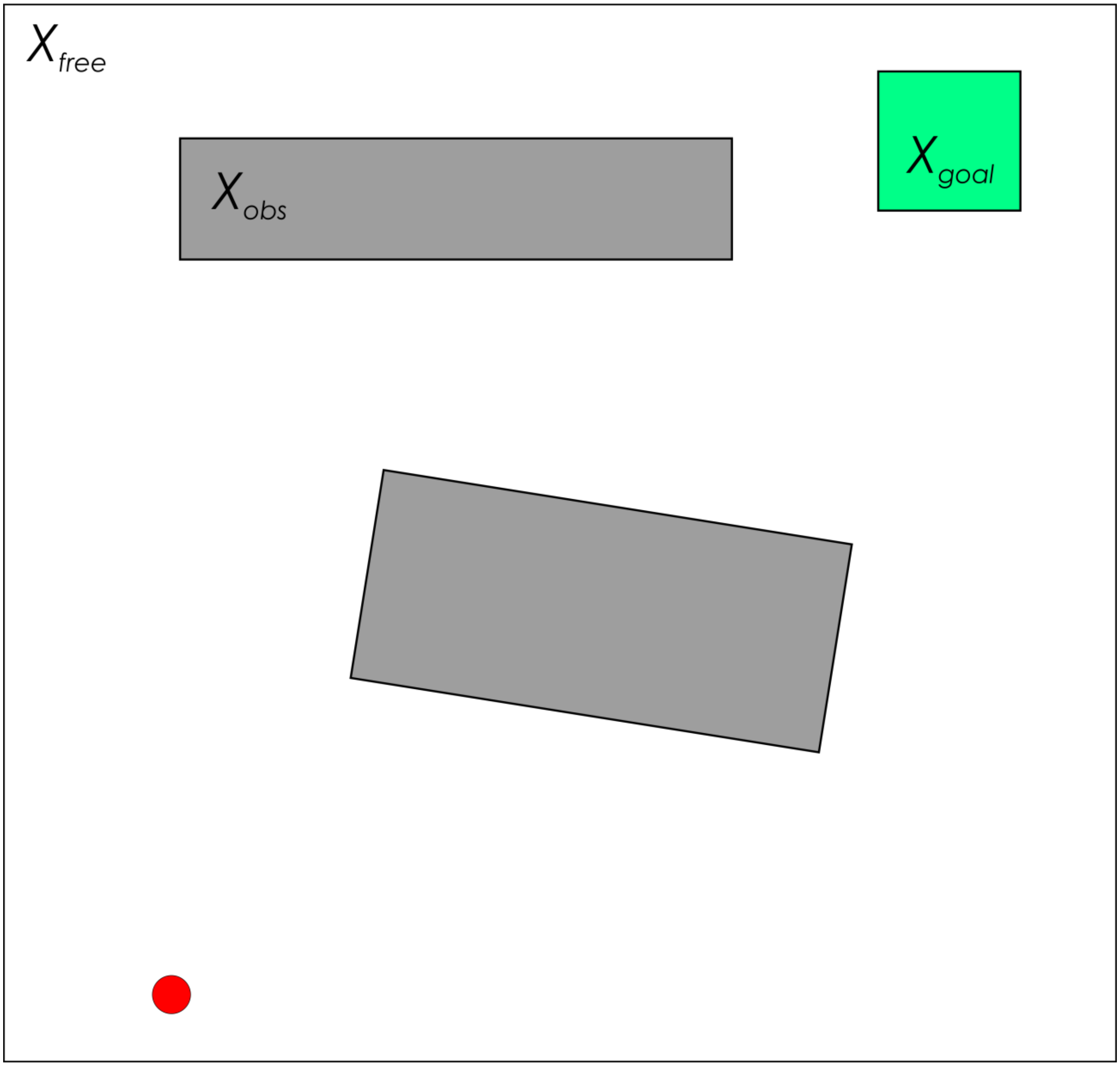
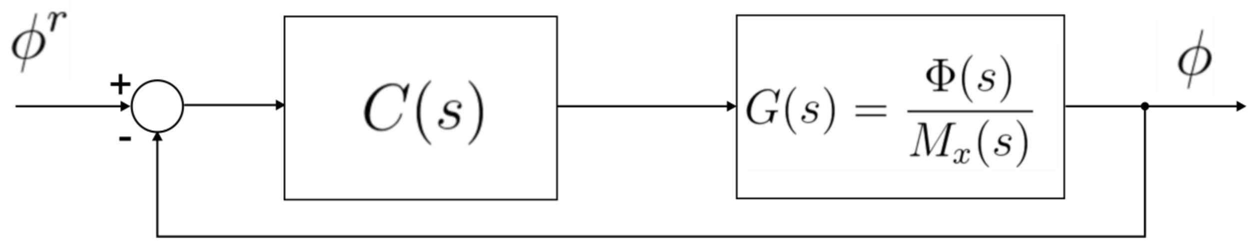
Explain RRT with a drawing



Problem 5.a: Let the following decoupled and linearized representation of a rotorcraft MAV roll dynamics:

$$\begin{bmatrix} \dot{\phi} \\ \ddot{\phi} \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ 0 & 0 \end{bmatrix} \begin{bmatrix} \phi \\ \dot{\phi} \end{bmatrix} + \begin{bmatrix} 0 \\ 1/J_x \end{bmatrix} M_x$$

Design a simple control structure C(s) capable of ensuring stability for the aforementioned system. The control structure should be placed in the following way:

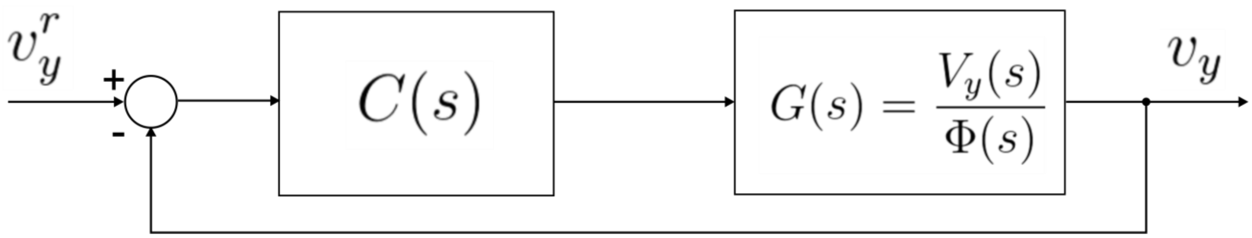


Solution:

Problem 5.b (Graduate level only): For the following representation of the linear acceleration around the y axis –and given that all rotations are negligible– design the simplest possible control structure that provides stability for the velocity dynamics of the vehicle $v_y = \dot{y}$.

$$\ddot{y} = g\phi$$

Again the control loop takes the form:



Solution:

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