UNIVERSITY OF SOUTH CAROLINA

2018

Possible Final Examination Questions

Robotics

CSCE 574

1) Describe the three main robot architectures providing for each of them an example.

2) Define what middleware is.

3) Show how two nodes (one publisher and one subscriber) interact with each other in ROS.

4) Describe the core elements in ROS.

5) Define ROS topics, services, and actions, and when is more appropriate to use each of them.

6) Define the terms exteroceptive and proprioceptive sensors. Provide two examples for each.

7) List and compare three different range sensors in terms of ease of use, accuracy, computational cost, and energy cost.

8) What are the differences between Hydraulic drive and Shape Memory Alloy drive? Name one application in which each one of them is appropriate.

9) What are the differences between Hydraulic drive and Pneumatic drive? Name one application in which each one of them is appropriate.

10) What are the differences between Hydraulic drive and Electrical drive? Name one application in which each one of them is appropriate.

11) What are the differences between Pneumatic drive and Shape Memory Alloy drive? Name one application in which each one of them is appropriate.

12) What are the differences between Electrical drive and Shape Memory Alloy drive? Name one application in which each one of them is appropriate.

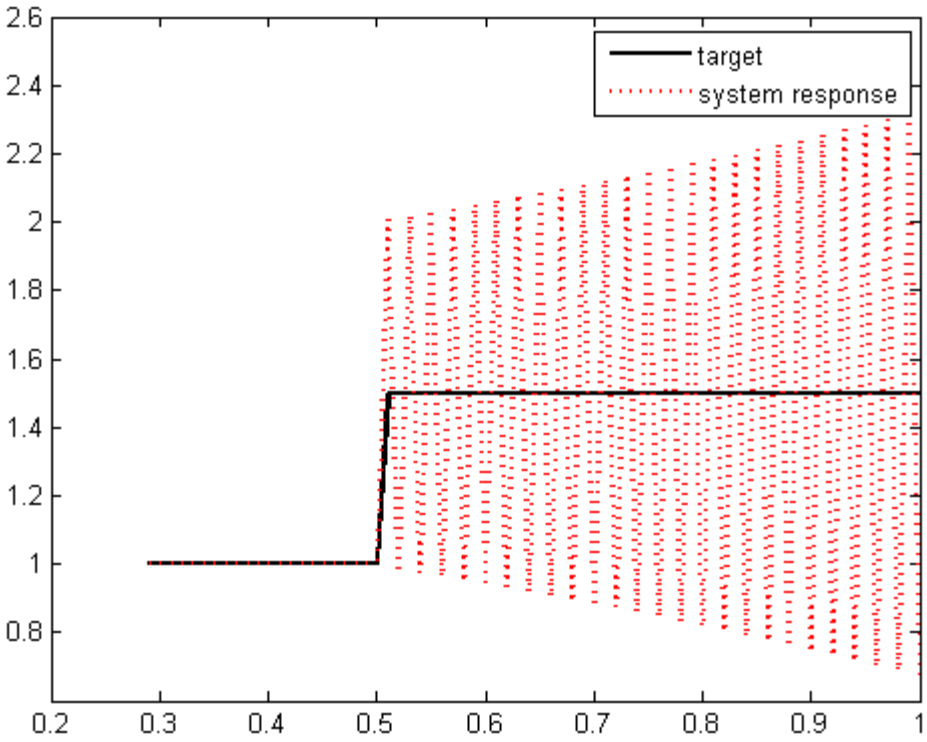
13) What are the differences between Pneumatic drive and Electrical drive? Name one application in which each one of them is appropriate.

14) Define forward kinematics and inverse kinematics.

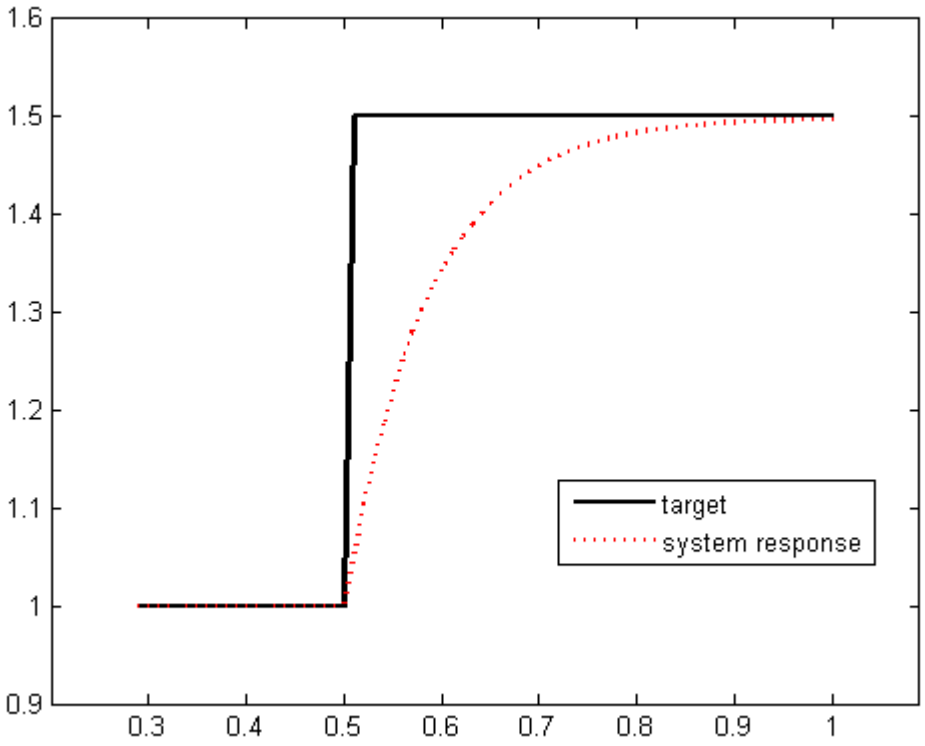
15) For a differential drive robot, where the wheels are distance d apart and the wheel velocities are V_l and V_r. Estimate the linear velocity $\boldsymbol{V}$ and the angular velocity $\boldsymbol{\omega}$.

16) In a PID controller with gains K_p, K_i and K_d: describe which quantity each one of them is controlling. Describe also the effects of changing each gain.

17) When a proportional controller tries to follow the step function (y=1: x<0.5; y=1.5: x>0.5) describe the possible causes for the response shown here:



18) When a proportional controller tries to follow the step function (y=1: x<0.5; y=1.5: x>0.5) describe the possible causes for the response shown here:



19) Describe two problems with Euler angles for representing rotations in 3D:

20) Please perform the following matrix multiplication:

$$AB = \begin{bmatrix} a & b & c \\ d & e & f \end{bmatrix} \begin{bmatrix} k & l \\ m & n \\ o & p \end{bmatrix} =$$

21) Define Simultaneous Localization and Mapping (SLAM) and explain what are the main challenges:

22) What are the differences between topological and grid based maps? Name an application for each one.

23) What are the differences between topological and feature based maps? Name an application for each one.

24) What are the differences between feature and grid based maps? Name an application for each one.

25) Describe two different types of inaccuracy that can result from using the sonar sensor.

26) Define and compare "Global Localization" and "Tracking".

27) Define and compare "Global Localization" and "Kidnapped Robot Problem".

28) Define and compare "Kidnapped Robot Problem" and "Tracking".

29) For a Bayesian Filter:

$Bel(x_t) = p(x_t \mid o_t, a_{t-1}, o_{t-1}, a_{t-2}, \ldots, o_0)$

where o_i are observations at time i and a_i are actions at time i

Simplify the equation using the Markov property, the theorem of total probability and Bayes rule to get to:

$$Bel(x_t) = \eta p(o_t \mid x_t) \int p(x_t \mid x_{t-1}, a_{t-1}) Bel(x_{t-1}) dx_{t-1}$$

where:

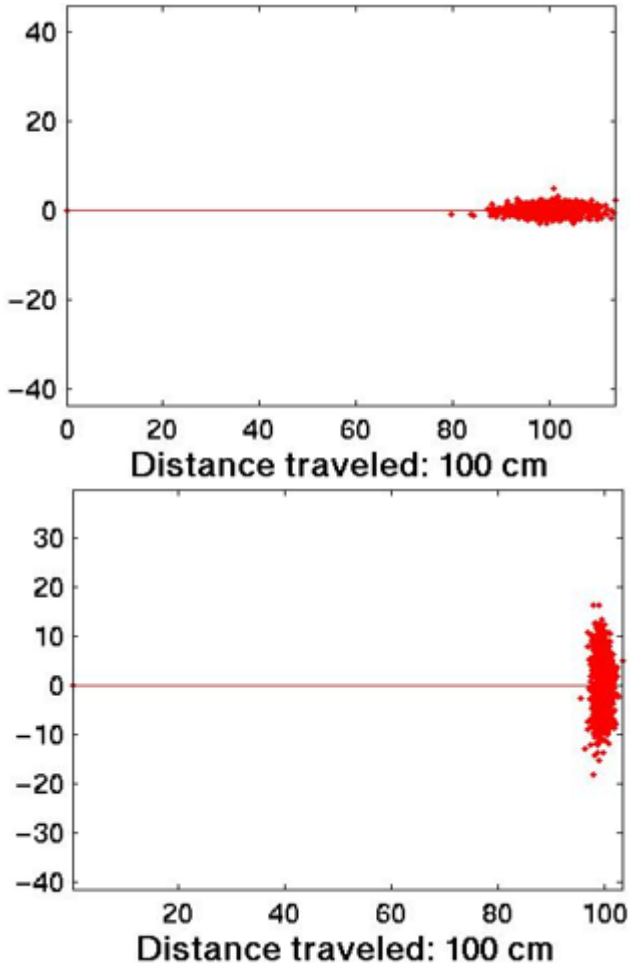
$$\text{Bayes Rule} : p(a \mid b) = \frac{p(b \mid a) p(a)}{p(b)}$$

$$\text{you can assume} : \eta = 1 / p(o_i \mid a_{t-1}, \ldots, o_0)$$

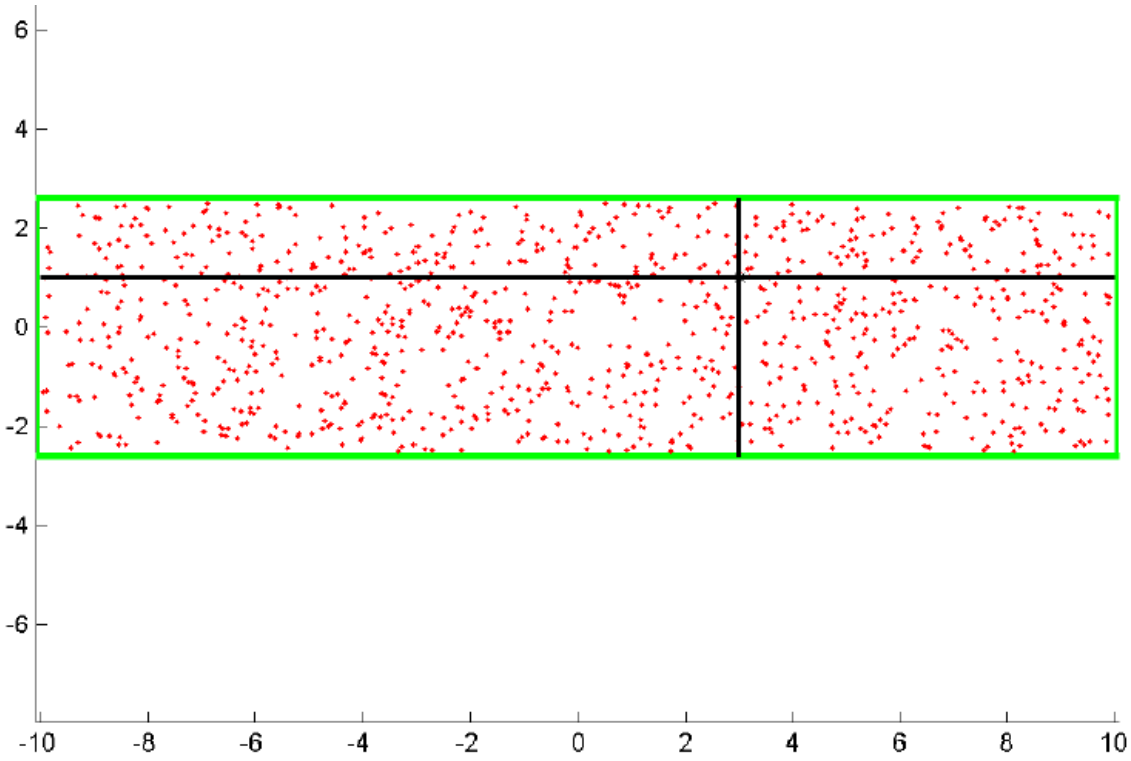
30) One major component of the "Particle Filter" algorithm is resampling. Provide a brief description. What is the main goal of the resampling step?

31) Provide a brief description of the Particle Filter state estimation algorithm. Explain how the: Propagate, Update, and Resampling steps work.

32) In the following a particle filter is used to track the position of the robot in a two dimensional environment, with noise in translation (x axis) and in lateral drift (y axis). The two pictures identify two different instances of using such a particle filter for a robot that goes forward of 100 cm along the x axis. Why is there a difference between the two instances?



33) Assume that the state of the robot is the position x and y. In the following picture, depicting a particle filter on an environment for localizing a robot denoted with an asterisk, please draw the areas where after the update particles will have the weight increased. The robot can sense the distance from the walls as shown in the picture.



34) What is Cooperative Localization?

35) For a Kalman filter estimator provide a small explanation about the following equations:

$S=H*P*H^T+R$

Where H is the measurement function matrix P the covariance matrix before the update and R is the sensors error covariance matrix.

36)For a mobile robot whose estimated motion is described by:

$$\hat{x}_{t+1} = \hat{x}_t + (V_t + w_{V_t})\delta t \cos\hat{\phi}_t$$
$$\hat{y}_{t+1} = \hat{y}_t + (V_t + w_{V_t})\delta t \sin\hat{\phi}_t$$
$$\hat{\phi}_{t+1} = \hat{\phi}_t + (\omega_t + w_{\omega_t})\delta t$$

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and its real motion is defined as:

$$x_{t+1} = x_t + V_t\delta t \cos\phi_t$$
$$y_{t+1} = y_t + V_t\delta t \sin\phi_t$$
$$\phi_{t+1} = \phi_t + \omega_t\delta t$$

Derive the error: $\tilde{x}_{t+1} = x_{t+1} - \hat{x}_{t+1}$

using small angle approximation.

37) When using an indirect EKF the error in the state of a mobile robot is described by the following equation:

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. $\tilde{X}_{t+1} = F_t\tilde{X}_t + G_tW_t$

where W is zero mean Gaussian noise, and the covariance P is defined as:

$$P_{t+1/t} = E[\tilde{X}_{t+1}\tilde{X}_{t+1}^T]$$

Derive the equation of the covariance as a function of $\mathbf{F_t}$ and $\mathbf{G_t}$

38)Consider a vehicle travelling with linear velocity *v* and angular velocity ω affected by noise w_v and w_ω respectively. Therefore, the measured velocities are:

$$\begin{bmatrix}\hat{v}_t \\ \hat{\omega}_t\end{bmatrix} = \begin{bmatrix}v_t + w_v \\ \omega_t + w_\omega\end{bmatrix}$$

The real pose of the vehicle is $\boldsymbol{x_t}=[x_t, y_t, \theta_t]^T$; and the estimated pose is $\hat{\boldsymbol{x}}_{\boldsymbol{t}} = [\hat{x}_t \quad \hat{y}_t \quad \hat{\theta}_t]^T$

Provide the equations for time t+1 for the real pose:

$$\boldsymbol{x}_{t+1} = \begin{bmatrix} x_{t+1} \\ y_{t+1} \\ \theta_{t+1} \end{bmatrix} =$$

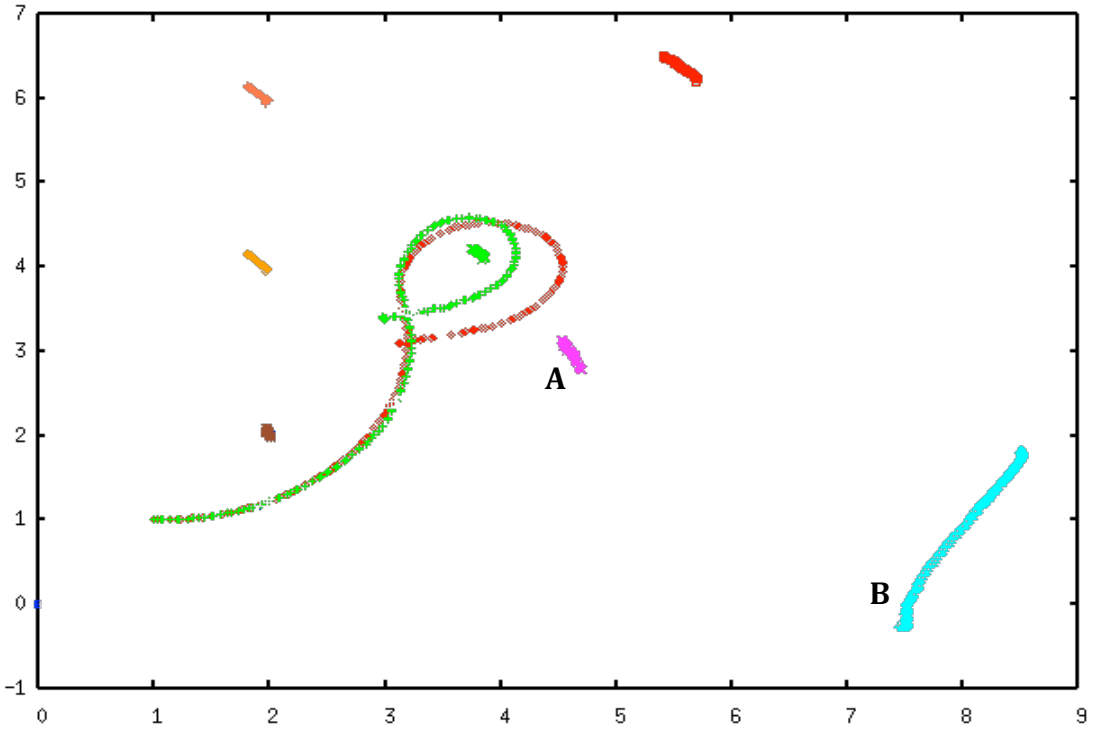
and the estimated pose:

$$\hat{\boldsymbol{x}}_{t+1} = \begin{bmatrix} \hat{x}_{t+1} \\ \hat{y}_{t+1} \\ \hat{\theta}_{t+1} \end{bmatrix} =$$

as a function of the previous pose, the real velocities, and the noise.

39)What is the iterative Kalman Filter?

40)In the SLAM experiment shown in the following image describe the reason for the difference in the location uncertainty between the **A** and **B** landmark



41) Define Optical Flow

42) Define the aperture problem

43) What is the baseline in a stereo camera?

44) What is the difference between “Optical Flow” and “Scene Motion”?

45) Describe the Generalized Voronoi Graph (GVG) exploration algorithm. Outline the major steps:

46) For an outdoor robot, describe at least 3 cost parameters affecting path planning.

47) For an indoor robot, describe at least 3 cost parameters affecting path planning.

48) Define the terms C-Space (configuration), Free Space, Semi-Free Space, and C-Obstacle space. When are two paths homotopic?

49) Describe the differences between the “Probabilistic Roadmap” (PRM) and the “Rapidly Exploring Random Tree” (RRT) path planners:

50) What is the guiding principles behind: a) visibility graph and b) generalized Voronoi graph path planning algorithms? What is the major difference between the two algorithms?

51) For the Bug2 algorithm what is the minimum set of sensors needed.

52) Define the main idea behind potential field path planning. What is its main disadvantage? Describe the most common technique to overcome it:

53) For a two-link manipulator, with two revolute joints, each rotating [0,360] degrees, what is the configuration space. Draw a representation.

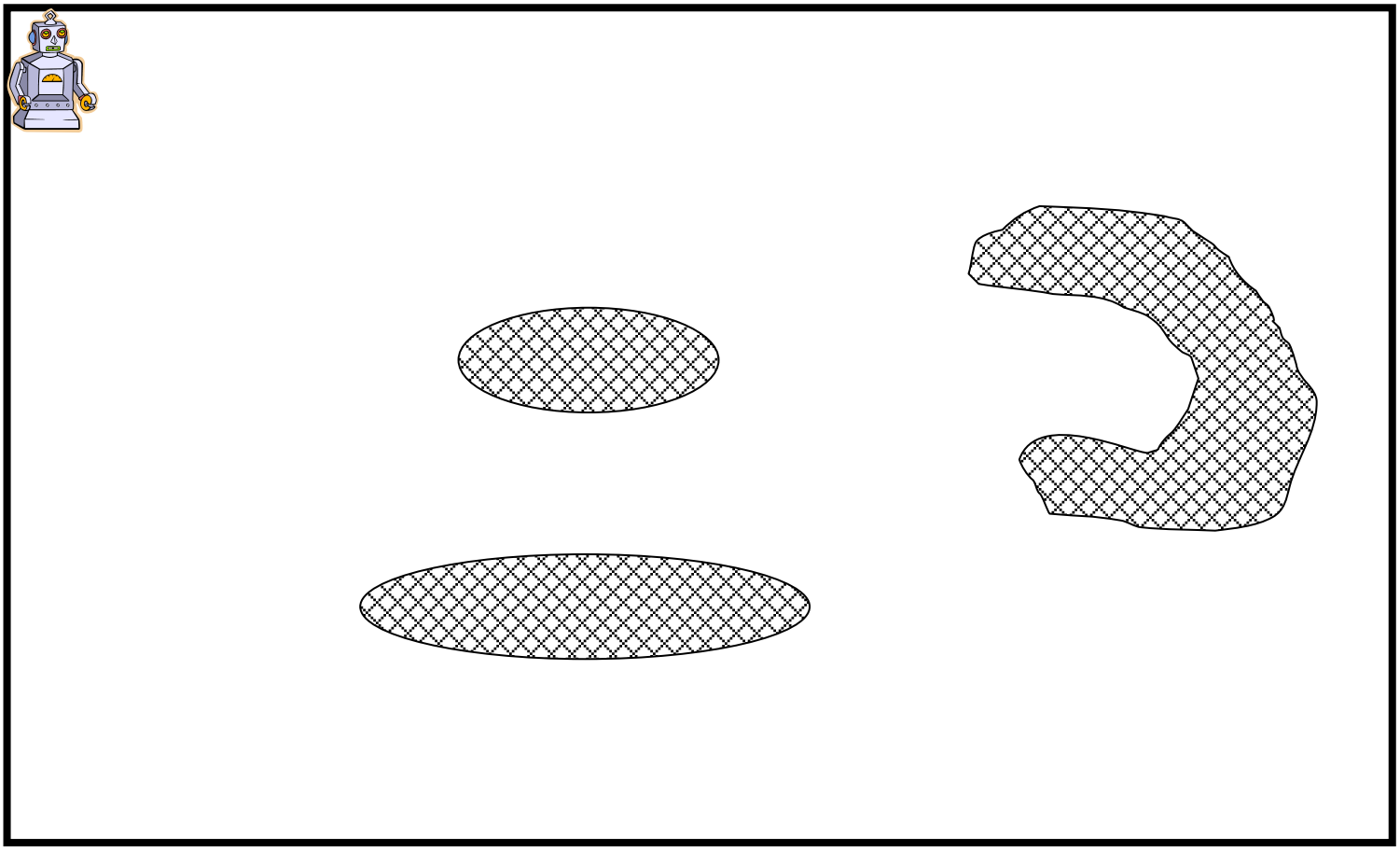
54) What are the advantages/disadvantages of multi-robot systems?

55) Describe two different strategies for multi-robot formation.

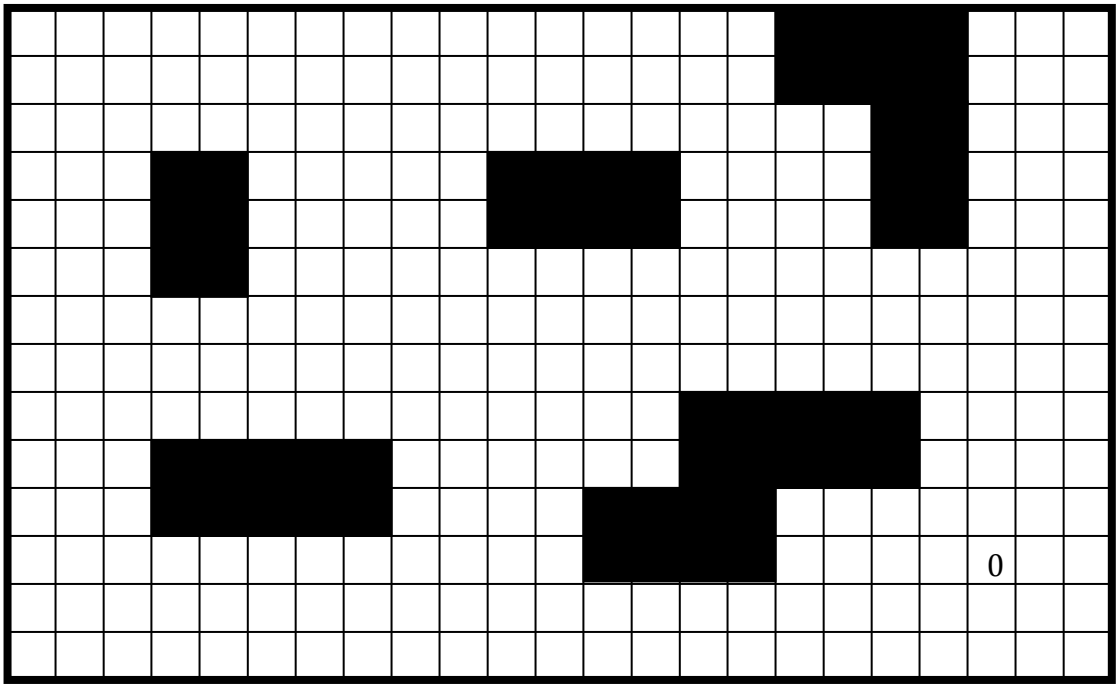
56) Define Marsupial Robots.

57) Describe the Auction mechanism for task distribution in multi-robot systems.

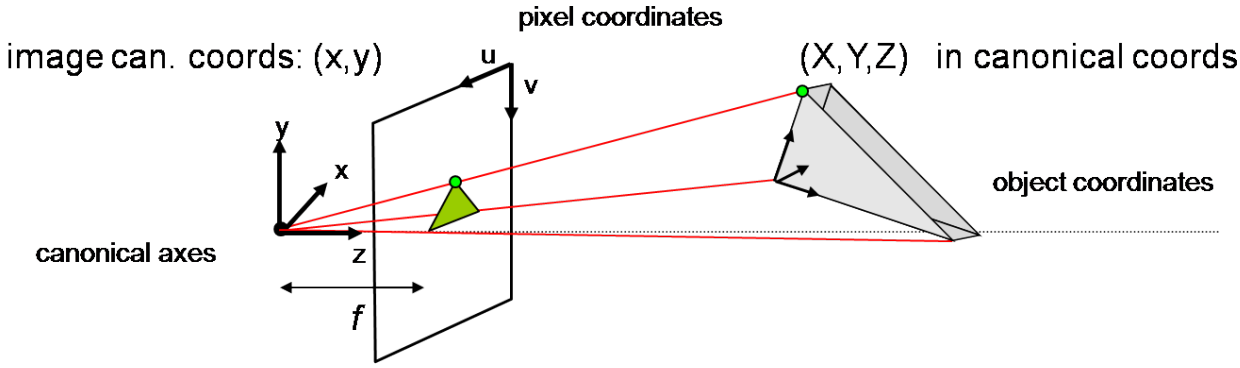
58) Draw the Reeb graph and a plausible optimal order of cell coverage for the following environment. Hint: Remember to double certain edges. Start position: top left corner.



59)Use the Wavefront planner on the following world, starting at “0”:



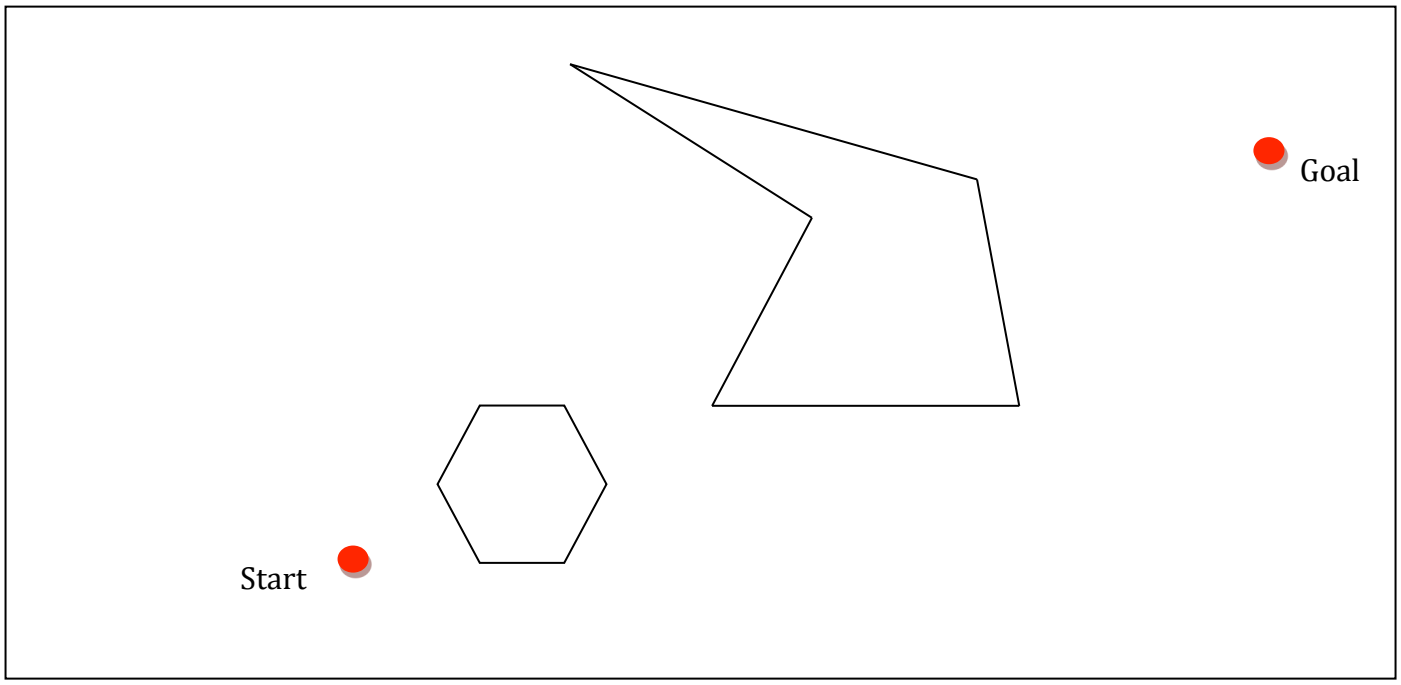
60) Using the pinhole camera model derive the relationship between (x,y) and (X,Y,Z).



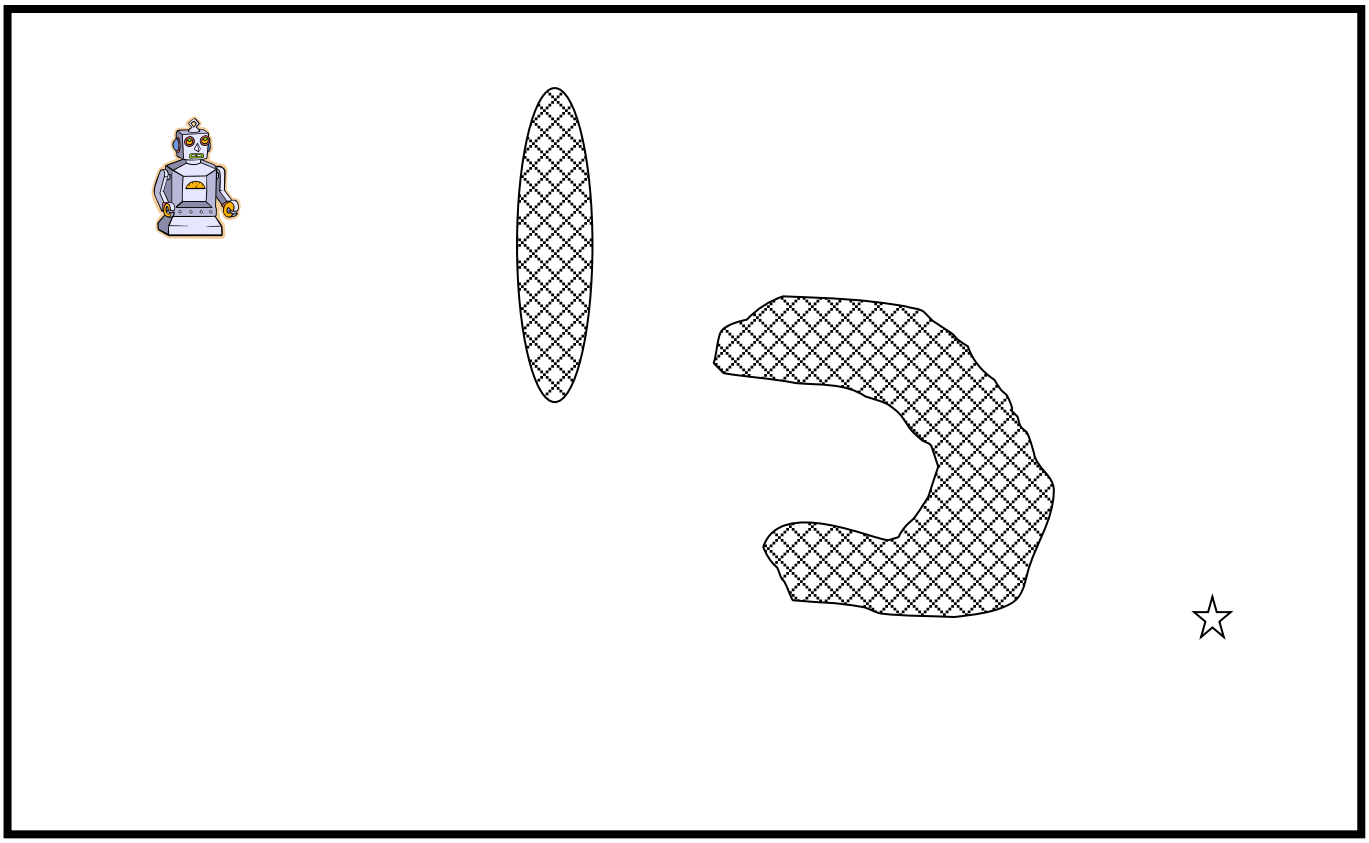
x=

y=

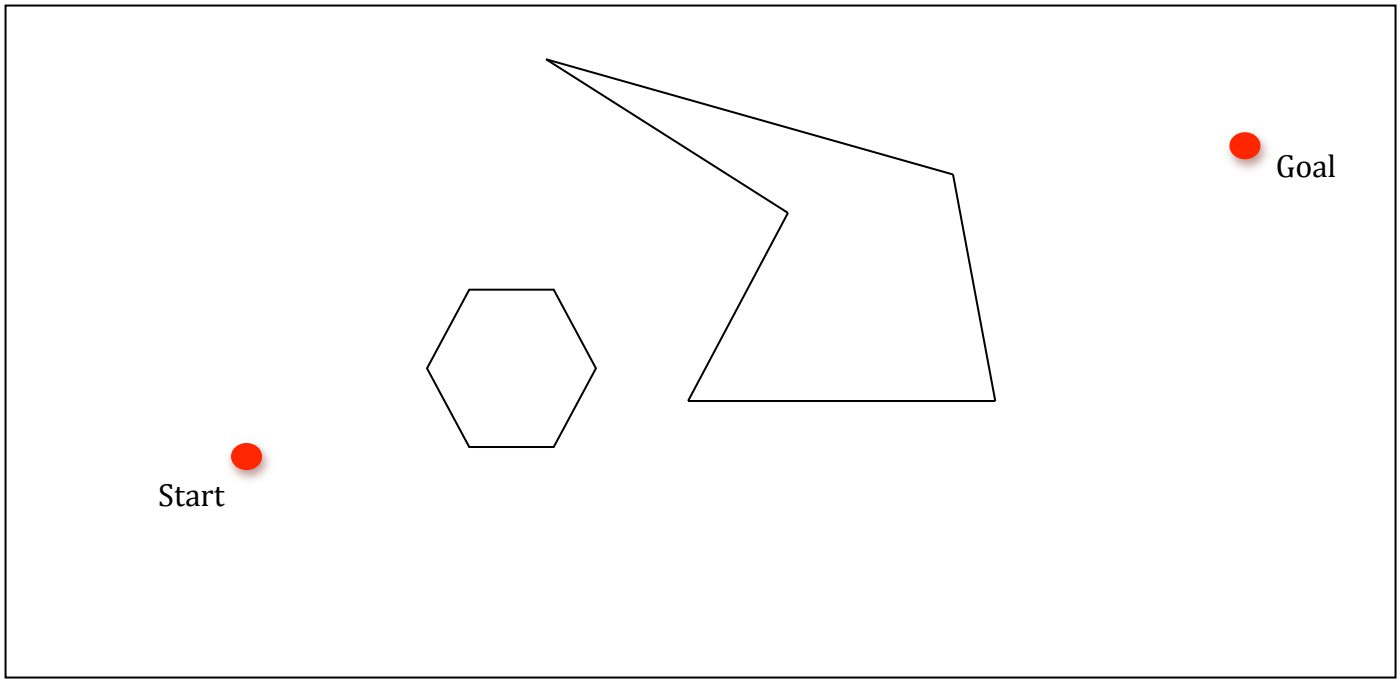
61) Draw the path used by the Bug1 algorithm from Start to Goal.



62) Draw the trajectory for the Bug2 path planning algorithm, starting position the robot goal the star. Consider a left turning robot.



63) Draw the visibility graph in the following environment. Draw also the shortest path through the visibility graph from Start to Goal.



64) Describe the Frontier based exploration algorithm.

65) Discuss the dilemma between exploitation (localization) and exploration of new territory in any exploration and mapping algorithm. In particular, consider accuracy and efficiency.

66) What is the difference between deterministic and random coverage algorithms? Give an example of an application which each type is more suited for and justify your selection.

67) Use the grassfire transform to create the configuration space on the following world, dilating the obstacles by 2 pixel. Is the resulting space connected?