UNIVERSITY OF
SOUTH CAROLINA

2015

Possible Examination Questions

Robotics

CSCE 574

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

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

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

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

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

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

7) 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 $\boldsymbol{\omega}$.

8) What are the differences between topological and grid based maps? Name one application in which each one of them is appropriate.

9) What are the differences between topological and feature based maps? Name one application in which each one of them is appropriate.

10) What are the differences between feature and grid based maps? Name one application in which each one of them is appropriate.

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

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

13) Describe the Frontier based exploration algorithm.

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

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

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

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

18) What is the difference between "Optical Flow" and "Scene Motion"?

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

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

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

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

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

24) 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:

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

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

25) 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.

26) 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.

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

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$$\tilde{X}_{t+1} = F_t \tilde{X}_t + G_t W_t$$

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

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

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

28) 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.

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

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

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

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

33) Describe the differences between the "Probabilistic Roadmap" (PRM) and the "Rapidly Exploring Random Tree" (RRT) path planners:

34) 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?

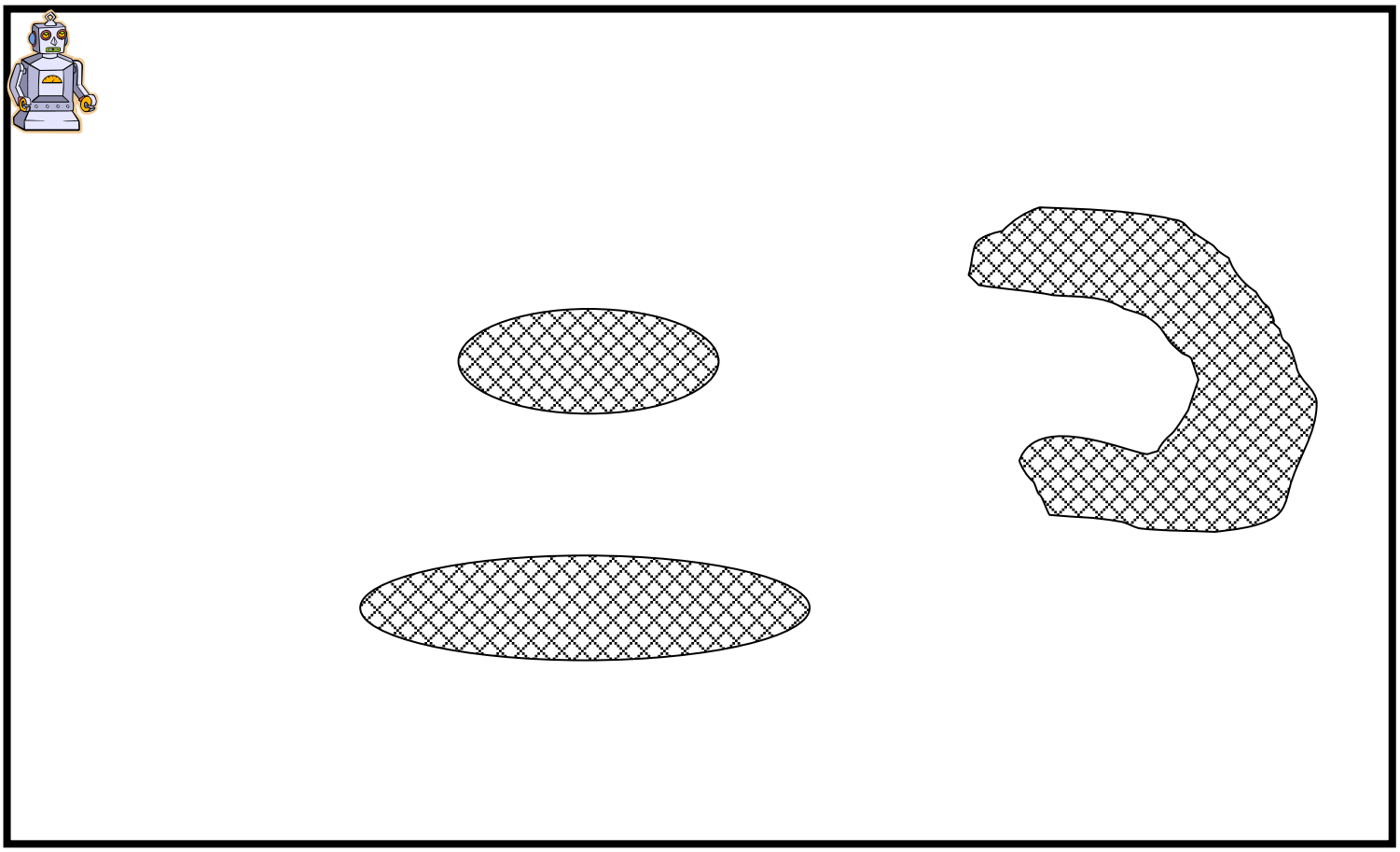
35) What is the difference between deterministic and random coverage algorithms? Give an example of an application which each type is more suited for and justify your selection.

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

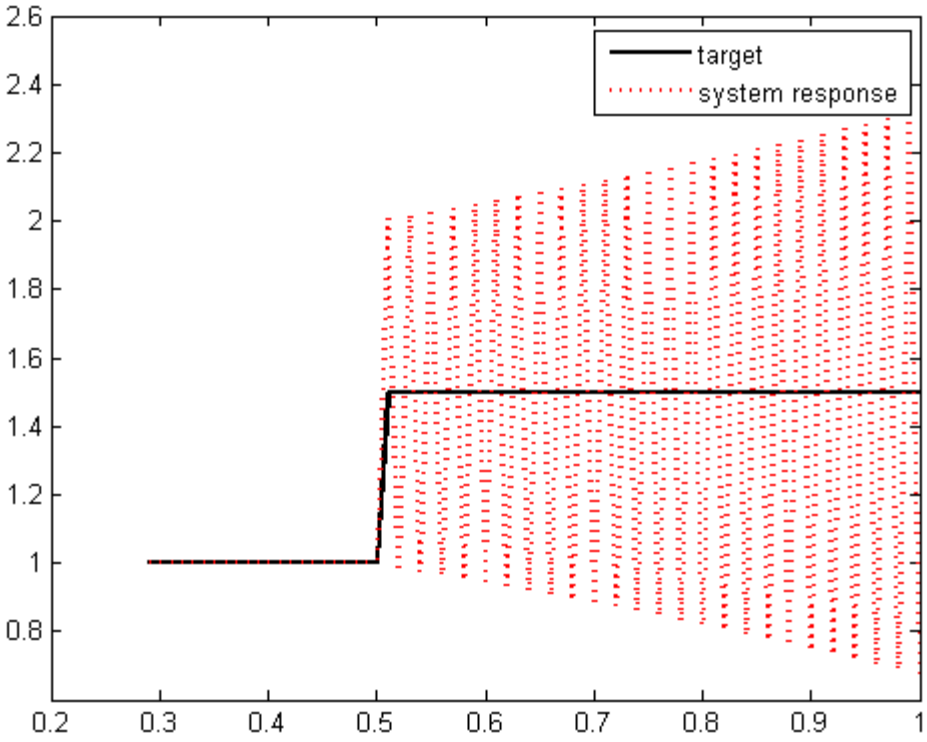
37) In a PID controller with gains K_p, K_i and K_d: describe which quantity each one of them is controlling. Describe also the effects of changing each gain.

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

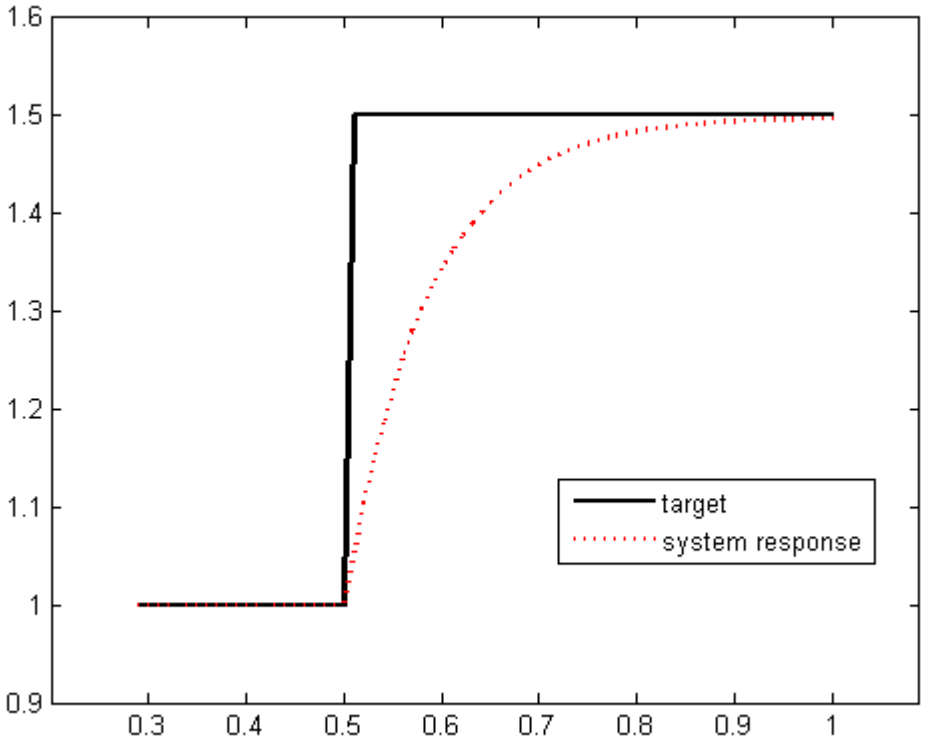
39) Draw the Reeb graph and a plausible optimal order of cell coverage for the following environment. Hint: Remember to double certain edges. Start position: top left corner.



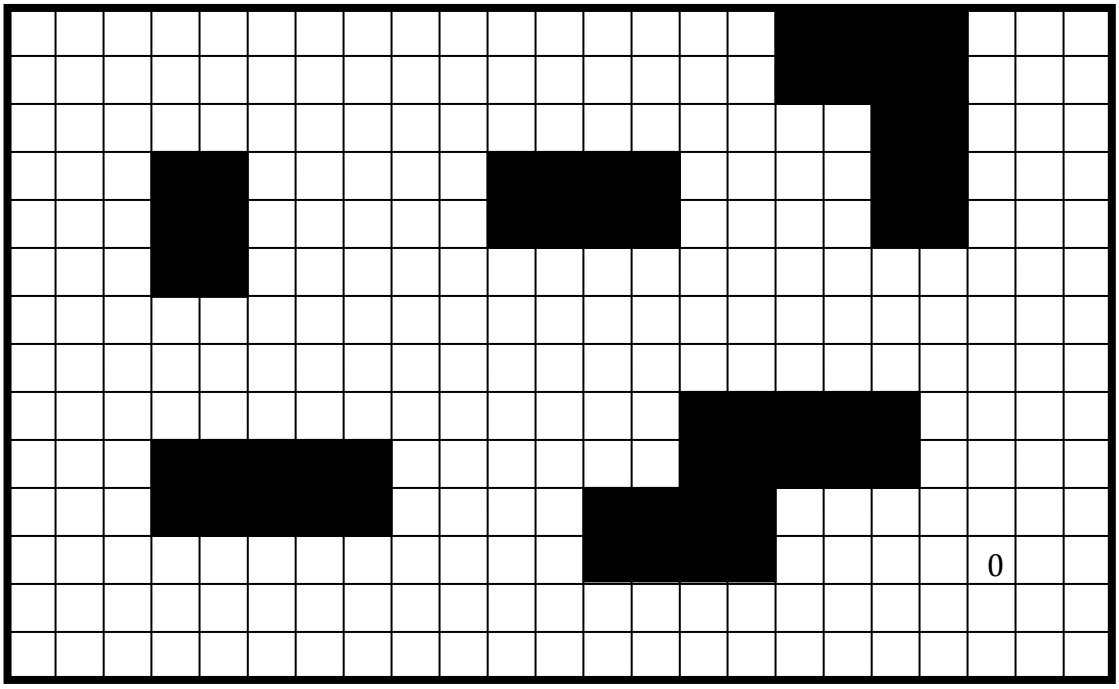
40)When a proportional controller tries to follow the step function (y=1: x<0.5; y=1.5: x>0.5) describe the possible causes for the response shown here:



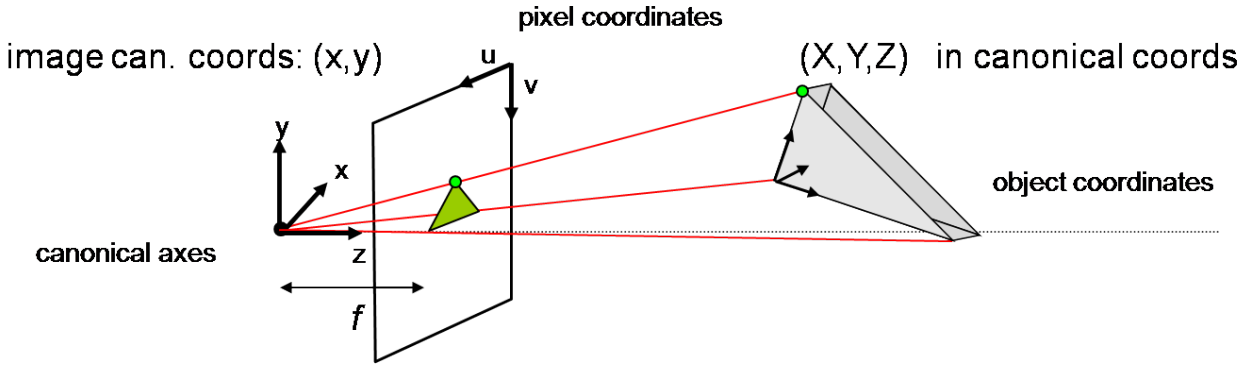
41)When a proportional controller tries to follow the step function (y=1: x<0.5; y=1.5: x>0.5) describe the possible causes for the response shown here:



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



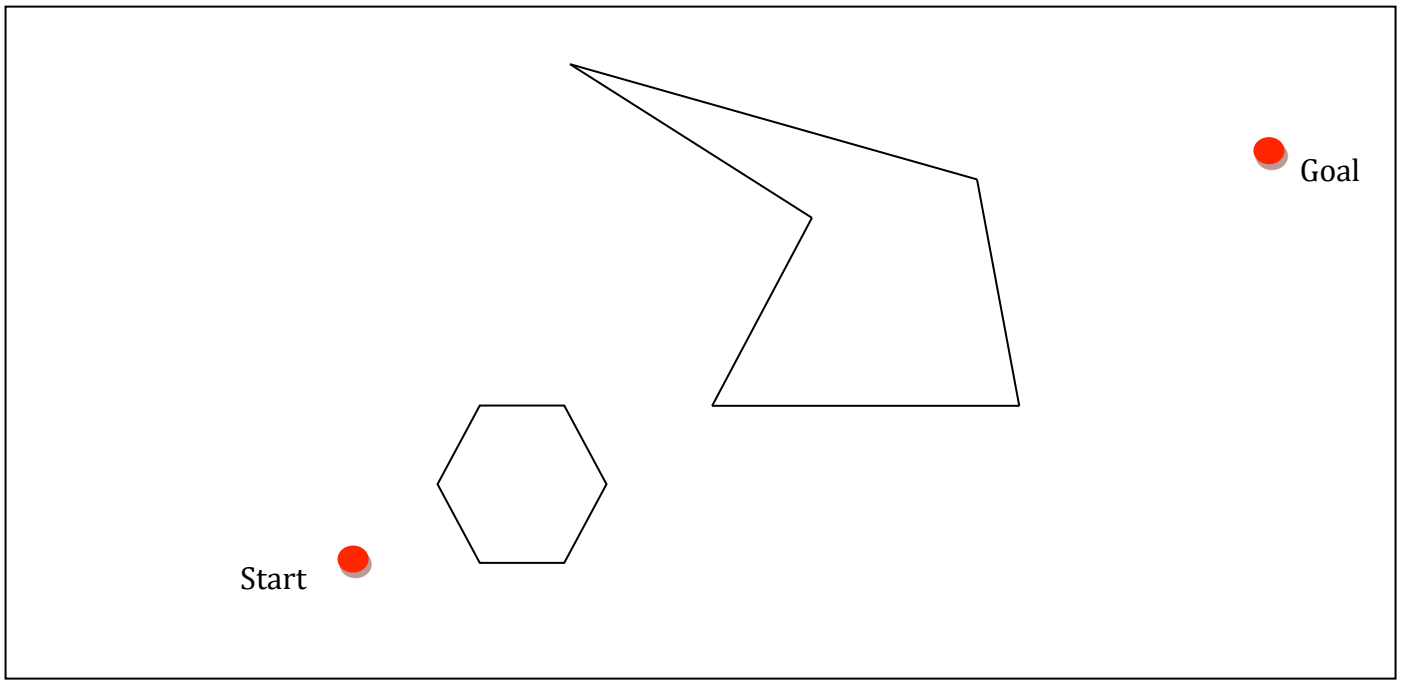
43) Using the pinhole camera model derive the relationship between (x,y) and (X,Y,Z).



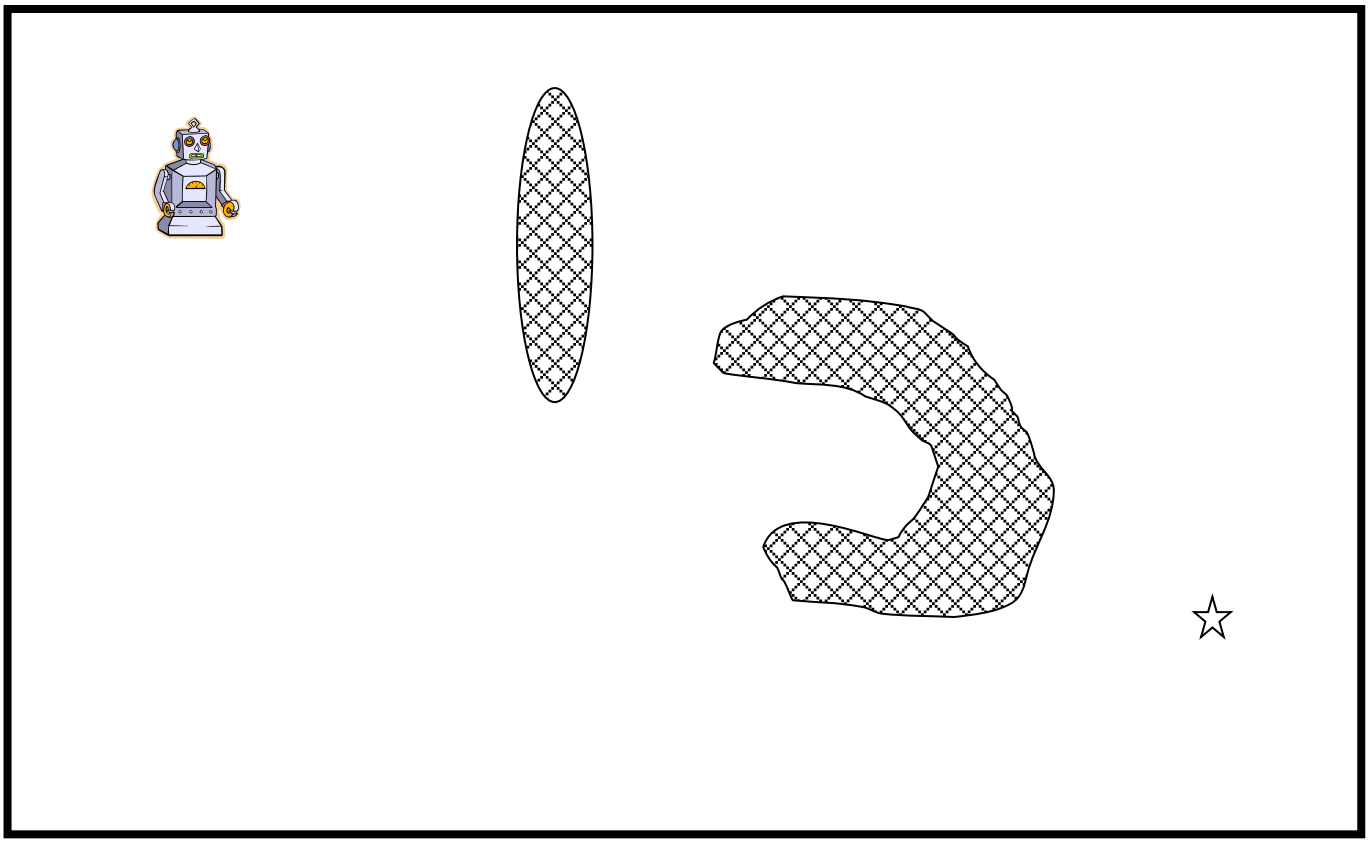
x=

y=

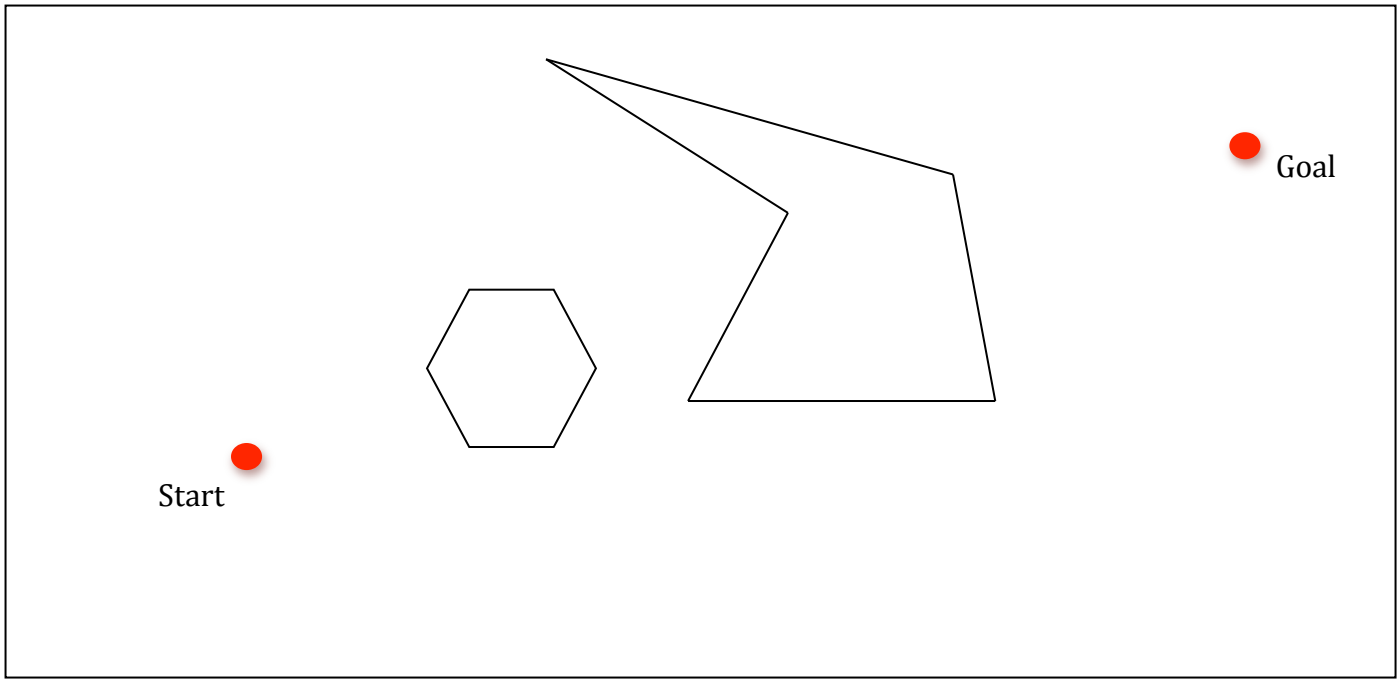
44) Draw the path used by the Bug1 algorithm from Start to Goal.



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



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



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