CSCE 274
Robotics Design and Applications
Fall 2022

Textbook Readings

Textbook: Maja J. Mataric, The Robotics Primer. MIT Press, 2007

Midterm Exam Chapters: 1 - 5

Question samples

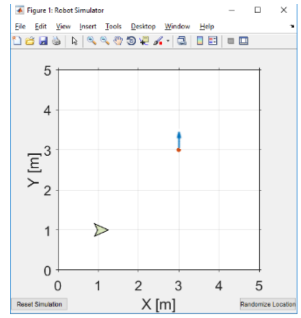
This sample of questions is intended as a help to understand the type of questions that can be in the final, **not as a binding agreement** about its contents. Please read all the Review Sheet. You should be also familiar also with your project assignments.

** Note: these questions cover the material that will be covered during the entire semester, so not all the questions listed have been covered in class or will show up on the midterm exam.

1. **Define** what a robot is, and provide one example of *robot* and one example of *non robot*.
2. Show a very high-level overview of the progress over the years of the robots, briefly describing one example for each of the milestone.
3. **List** *three* types of mobile robots.
4. **List** *three* types of aquatic robots.
5. What are the **main differences** of *pneumatic* actuation and *electric* actuation? Describe the main **pros and cons** for each of the actuators and **one example** for each where they could be appropriate to be used.
6. What are the **main differences** of *hydraulic* actuation and *pneumatic* actuation? Describe the main **pros and cons** for each of the actuators and **one example** for each where they could be appropriate to be used.
7. What are the **main differences** of *hydraulic* actuation and *electric* actuation? Describe the main **pros and cons** for each of the actuators and **one example** for each where they could be appropriate to be used.
8. What are the **main differences** of *pneumatic* actuation and *electric* actuation? Describe the main **pros and cons** for each of the actuators and **one example** for each where they could be appropriate to be used.
9. **Describe** the difference between *passive* and *active* actuation.
10. What are the total and controllable degrees of freedom of a differential drive robot such as the duckiebot?
11. Define holonomic, nonholonomic, and redundant robots.
12. **Define** forward and inverse kinematics and **write the forward and inverse kinematics** for a single wheel of a radius *r* able to move over a line.

13. Given a differential drive robot starting in (1m, 1m, 0°) depicted with a triangle in the figure with the following characteristics
    - *l=30cm*
    - $v_l \in$ *[-50cm/s, 50cm/s]*
    - $v_r \in$ *[-50cm/s, 50cm/s]*

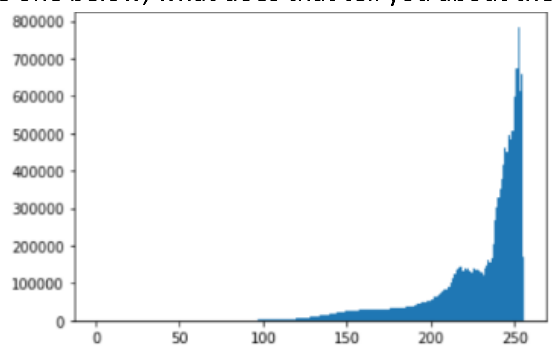
    provide a *sequence of motions* to get to the goal in (3m, 3m, 90°), For each motion, specify the velocity of left and right wheels v_l and v_r in m/s, the amount of time Δt, and the resulting state (x, y, θ). Please **show** your work.



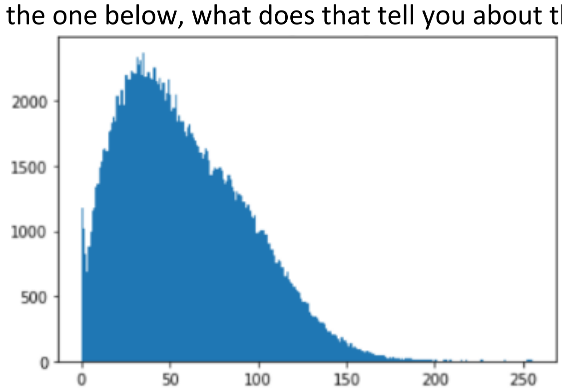
14. What is a stereo camera?
15. Please perform the following matrix multiplication

$AB = [a\ b\ c\ d\ e\ f\ ][k\ l\ m\ n\ o\ p\ ] =$

16. Define Thresholding:
17. If the histogram is like the one below, what does that tell you about the image?



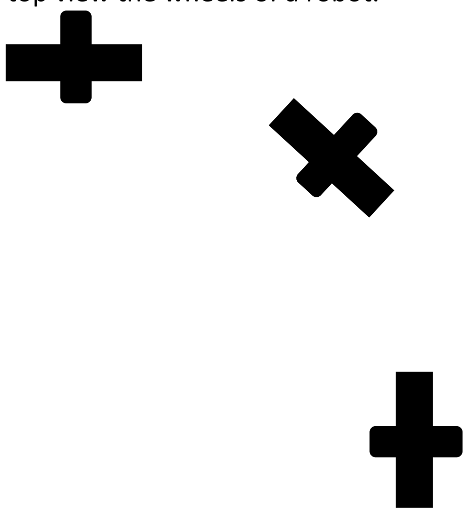
18. If the histogram is like the one below, what does that tell you about the image?



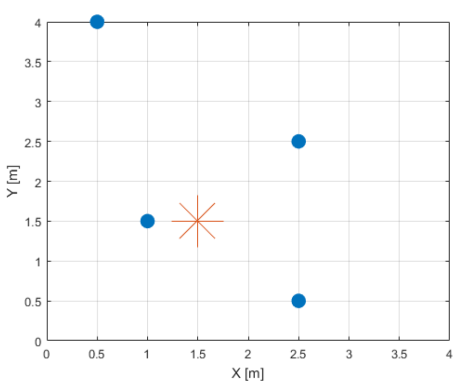
19. If the transfer function (gamma correction) is $s=c*r^{1.3}$ where s is the new intensity value and r the old intensity value. What would be the code for creating a look-up table?

20. A differential drive robot applied the same velocity to both wheels of 3 m/s for 3 s.
    - What is the *distance* that it traveled? **Show** your work.
    - Measuring the actual distance traveled shows that the robot traveled for 8.7 m. Is it different from the calculation in the subpoint a)? If it is, why could be so?

21. **Define** what the ICC is for a wheeled robot. Also **draw** the ICC on the following drawing, depicting top view the wheels of a robot.

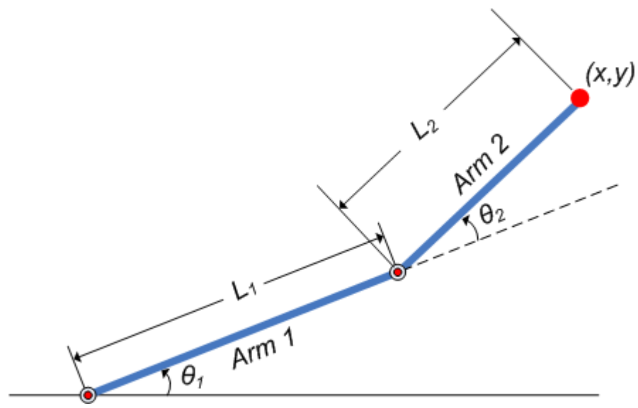


22. A 4-legged robot stands with all of its legs in contact with a flat, horizontal surface. The positions of the legs are indicated by blue circles; the star indicates the projection of its center of mass onto the ground.



- **Draw** the *support polygon* of the leg positions and the *margin of stability* on the figure. Is the robot statically stable in this position? In a sentence or two, **explain** why or why not.
- If you answered "YES" in part a): Suppose the robot wants to lift one of its legs to walk. Which legs can be lifted without immediately destroying the robot's static stability?
- If you answered "NO" in part a): Describe or draw a new statically stable configuration by changing the position of the minimum number of legs within a range of 1 meter each along the x and/or the y.

23. Given the following manipulator with two revolute joints



where

$L_1 = 50cm$
$L_2 = 30cm$

and the following actions are applied

$\theta_1 = \pi/4$

$\theta_2 = \pi/2$

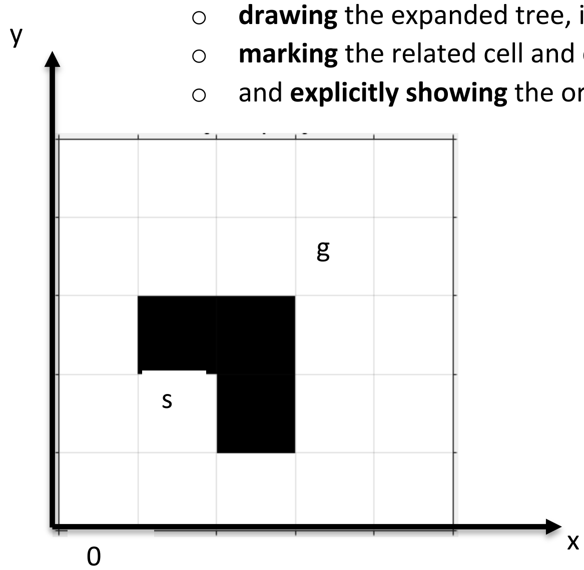
find the position of the end effector *(x,y)*. Show your work.

24. What are the **main differences** of deliberative architecture and reactive architecture? Describe the main **pros and cons** for each architecture and **one example** where they could be appropriate to be used.
25. What are the **main differences** of deliberative architecture and hybrid architecture? Describe the main **pros and cons** for each architecture and **one example** where they could be appropriate to be used.
26. Define the terms **exteroceptive** and **proprioceptive** sensors. Provide **two examples for each**.
27. **Describe** the difference between *passive* and *active* sensors, **showing and describing** an example for each.
28. Describe **two challenges** of using sonar sensors.
29. Describe **two challenges** of contact sensors
30. Describe **two challenges** of using camera sensors.
31. Provide one reason that makes vision a good sensor and one reason that makes vision a challenging sensor.
32. What is the baseline in a stereo camera?
33. What is an open-loop controller?
34. A discrete PI controller is used to control a robot. The set point is 30, the proportional and integral gains are 1 and 3, respectively. The sensor, able to measure the state, is sampling every 1 second. When the controller is executed, the first four states are 35, 25, 28, and 31. **Compute** the output of the controller after the fourth sensor reading. **Show** your work.
35. A discrete PID controller is used to control a robot. The set point is 29, the proportional, integral, and derivative gains are 2, 1, and 3, respectively. The sensor, able to measure the state, is sampling every 1 second. When the controller is executed, the first four states are 25, 35, 31, and 28. **Compute** the output of the controller after the fourth sensor reading. **Show** your work.

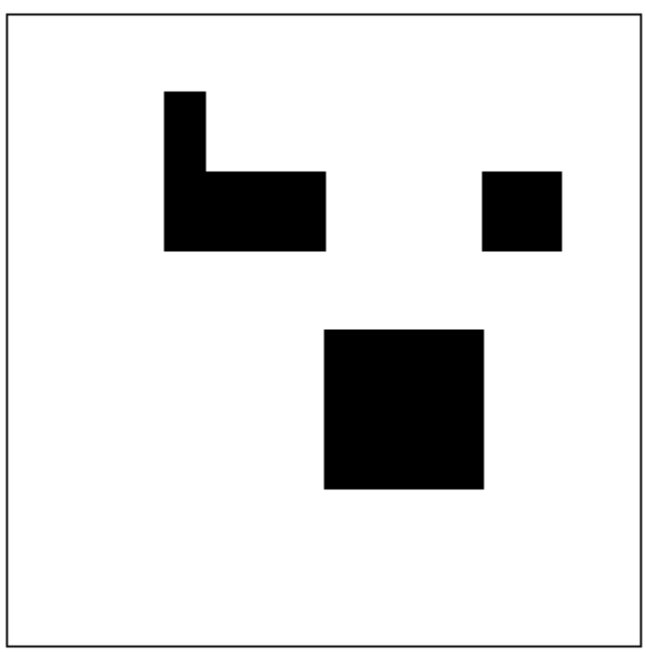
36. Given the following environment represented as a grid (black cells: obstacles, white cells: free space), where a robot, able to move up/down/left/right with cost 1, starting from the 1,1 (marked with s) wants to reach 3,3 (marked with g)

    Apply the *Depth-First Search* algorithm (*graph-search variant*)

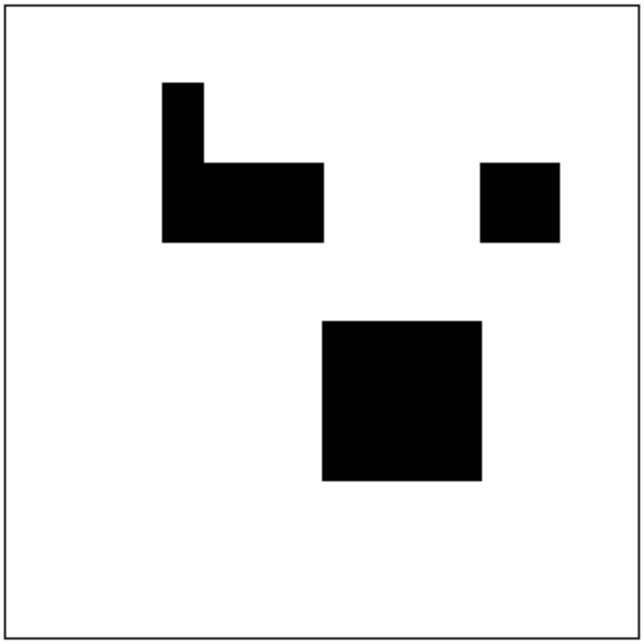
    - **drawing** the expanded tree, in the first five iterations,
    - **marking** the related cell and cost for each node,
    - and **explicitly showing** the order in which nodes are expanded in the first *six iterations*.



37. **Draw** on top of each environment (which size is 10 m x 10 m) the *occupancy grid map (where the size of each cell is 1 m)*

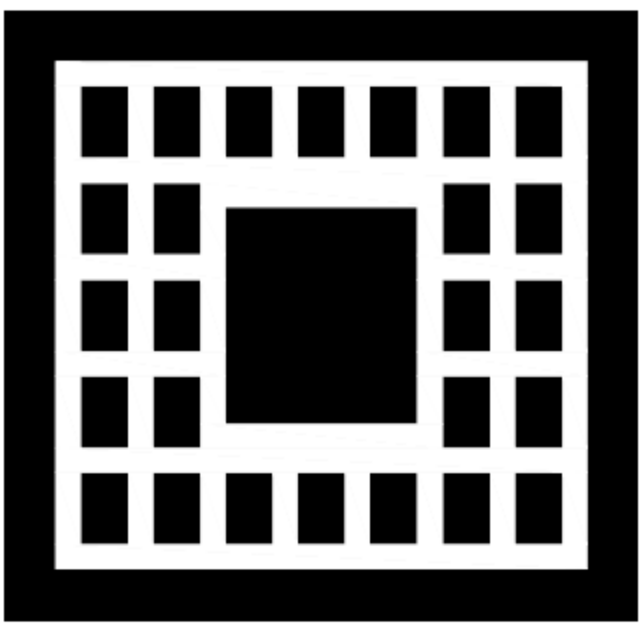


and the *quadtree*.

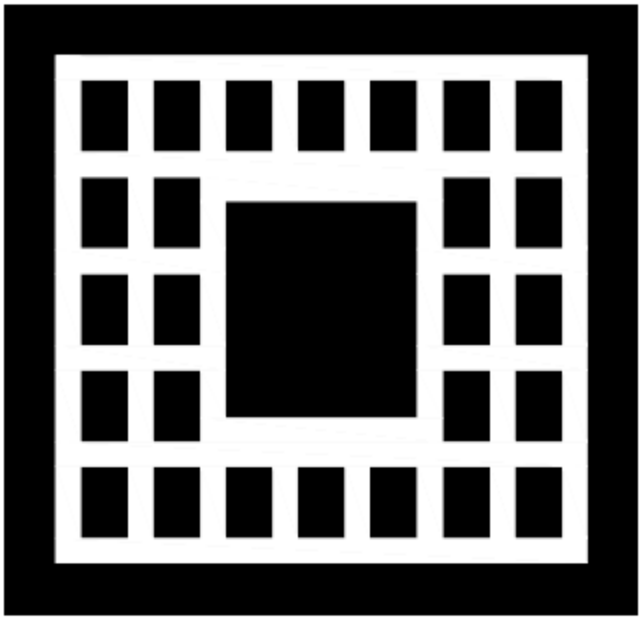


- Discuss the main differences between the two representations.

38. **Draw** on top of each environment (which size is 10 m x 10 m) the *occupancy grid map (where the size of each cell edge is 1 m),* Discuss the main differences between the two representations.



and the *quadtree*.



39. Draw the state machine in a graph form for random walk.
40. Define the localization problem termed global localization.
41. Describe data association problem.
42. Describe registration problem.
43. Describe loop closure detection.
44. **Describe** what the problem of using just odometry to localize the robot is and how it can be mitigated.
45. **Explain** the difference between *behavior fusion* and *behavior arbitration*.
46. **Describe** the two main categories of approaches that can be used to solve a *coverage* problem.
47. **Describe** how *frontier-based exploration* works
48. **Describe** the main *ROS* core elements.
49. **Describe** what a *middleware* is.
50. **Represent** the process to make two nodes interact with each other in ROS through *topics and messages*.
51. **Describe** one benefit and one drawback of using simulators.
52. Suppose you want to control a very small differential drive robot whose wheels are 5cm apart. The robot starts at (x, y, θ) = (4cm, 8cm, π/2) and wants to navigate to (x′, y′, θ ′) = (0, 0, 0). Each wheel velocity must remain between −2 cm/s and 2 cm/s. **Provide** a *sequence of motions* to get to the goal, specifying for each of them, the velocity of left and right wheels v_l and v_r in cm/s, the amount of time Δt, and the resulting state. **Show** your work.