# CPE 481 - Autonomous Mobile Robots

# Mid Term Assignment (Due March 1st)

**Overview**
This assignment is based on a new robot I am designing called Herman (see Figure 1 below). Herman is a mobile robot designed to conduct security in the halls of Cal Poly campus buildings. It has two independently driven wheels, and 2 omni-directional castors, one at the front and one at the back of the robot. It is equipped with three sharp infra-red range sensors and a compass. Each wheel has an encoder to measure distance traveled.

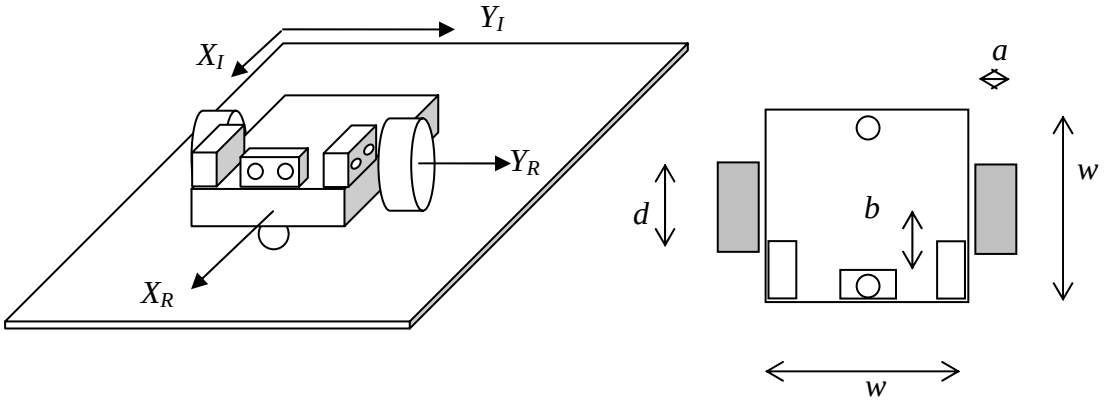



**Figure 1: Herman the robot**

Herman will be deployed with an on board processor and wireless communication capabilities. If it detects large differences between its sensor readings and a map of the building, then it will contact the police with its current location and wait for further instructions.

**Multiple-Choice – 2 marks awarded for each correct answer, 1 mark deducted for each incorrect answer, 0 marks if no answer. Circle the answer that BEST completes the sentence.**

1. Herman has:
   a) Full autonomous control
   b) Semi autonomous control
   c) Tele-operated control
   d) None of the above

2. Herman should use Behavior based navigation instead of Planning based navigation because:
   a) It uses a world model
   b) Behaviors cannot be fused through competitive coordination schemes
   c) It navigates by constructing a collision-free path and then following the path.
   d) None of the above

3. Herman should use Planning based navigation instead of Behavior based navigation because:
   a) Robot localization is easy with IR range sensors.
   b) Robot localization is difficult with IR range sensors.
   c) It needs to know its location within the building to report intruders.
   d) None of the above

4. Herman will have difficulty navigating because
   a) Orientation within a global coordinate frame will be difficult to measure.
   b) It requires particle filter navigation that is based on vision processing
   c) Sharp range sensors only work well when for ranges of 1-80cm
   d) None of the above

5. If Herman uses Kalman Filter localization instead of Particle Filter localization, it will
   a) Not require proprioceptive sensors
   b) Be easy to implement in real time
   c) Use encoder measurements within the prediction step.
   d) None of the above

6. Herman will have better localization capabilities if it uses control inputs instead of encoder measurements because:
   a) The control inputs represent the desired motion of the robot.
   b) The control inputs are always better representations of the robot motion
   c) Encoders do not model slipping.
   d) None of the above

7. If Herman's workspace was an empty square room, its differential drive configuration will allow it to

a) Follow any path through the workspace provided the path does not lead to collision with the walls.
b) Follow any trajectory through the workspace provided the trajectory does not lead to collision with the walls.
c) Follow any path and any trajectory through the workspace provided they don't lead to collision with the walls.
d) All of the above

8. If Herman localized itself using a particle filter with three particles,

a) The localization algorithm could run in real-time because it only uses 3 particles.
b) The localization algorithm would perform better than a Kalman Filter because it has three particles and therefore 3 estimates of the state instead of one.
c) All three particles will always converge to the same estimate.
d) None of the above.

9. Herman is equipped with:

a) Exteroceptive sensors
b) Proprioceptive sensors
c) Active sensors
d) All of the above.

10. If Herman had an extra wheel

a) It would be more maneuverable.
b) It would be less maneuverable.
c) It would be just as maneuverable.
d) None of the above

**Question 11:** 10 marks

We are considering mounting a laser range finder (e.g. SICK) on Herman.

a) What advantages and disadvantages would the laser range finder provide over the existing sensor suite? (Provide minimum 4 total)

b) Describe how laser range finding sensor works when phase shift measurements are used to obtain the distance to an object. Be sure to use a diagram.

c) What would be the drawback of rotating a sonar 180 degrees back and forth instead of a laser? Explain.

**Question 12:** 10 marks
In the figure below, a sample workspace is provided for Herman. In this workspace, there are two platforms connected together by a ramp. To stay within the workspace, the robots should never drive off the platforms.

There are six robot configurations labeled 1 through 6 whose location and orientation are described by arrows. Show the reachability relations between the six robot configurations. Specifically, provide a 6x6 table where each row represents one of the 6 start configurations, and each column represents one of the 6 end configurations. In each entry of the table, place an R, N, or I for *reachable*, *not reachable* or *ill-posed question* respectively. If assumptions are made about dimensions not given, please state them to clarify your decisions on the table. Assumptions should be given in point form, and only be one sentence long. Use diagrams to explain any difficult maneuvers.

| | | End Configuration | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 |
| Start Configuration | 1 | | | | | | |
| | 2 | | | | | | |
| | 3 | | | | | | |
| | 4 | | | | | | |
| | 5 | | | | | | |
| | 6 | | | | | | |

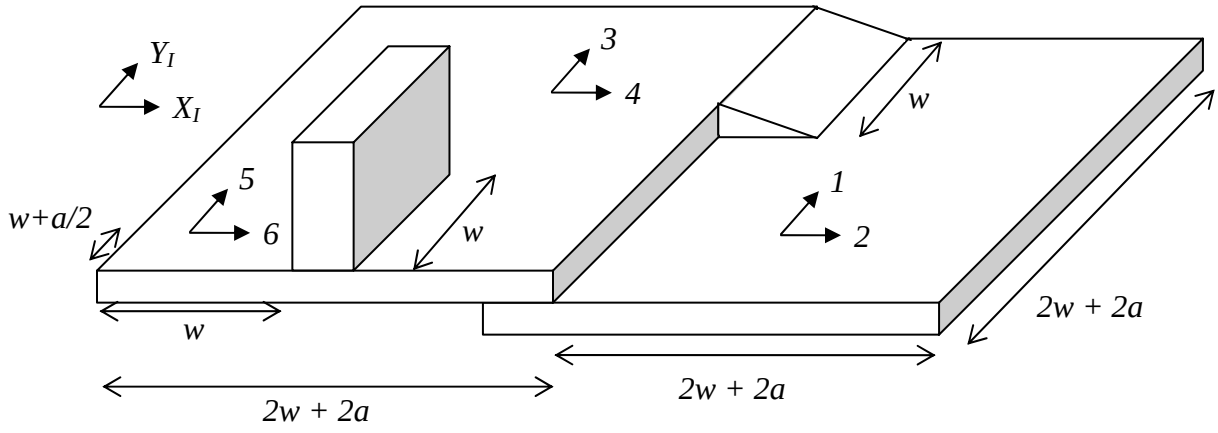
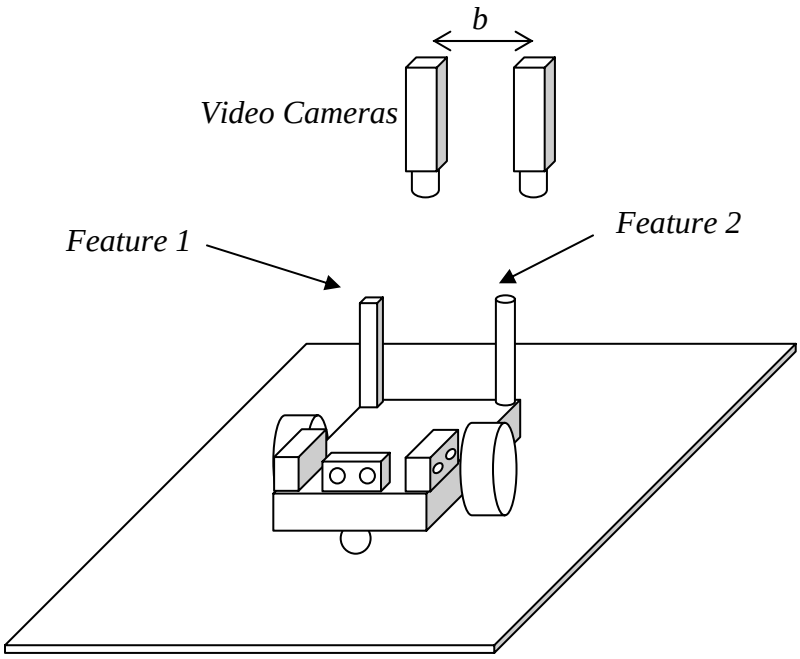



**Figure 2: One of Herman's workspaces.**

**Question 13:** 10 marks
Stereo Vision will be used to track the location of Herman in the workspace provided in Figure 2. Herman will have two distinct features that the camera's can distinguish and identify.




Develop equations that will determine the full configuration of the robot, given that $(x_{li}, y_{li})$ and $(x_{ri}, y_{ri})$ are measurements of the $i^{th}$ feature in the focal plane from the left and right cameras respectively. Assume the focal length of each camera is $f$.

**Question 14:** 20 marks
Using 2-10 pages, design an autonomous lawnmower. Include a general description with sections:

*Introduction*
Give a brief overview of the robot,

*Hardware*
Using a figure, explain the chassis, actuators and sensors used. Assume that the blade/motor system used to cut the grass is set for you. Determine how to power your system.

*Software*
Provide a block diagram of the major software components. Indicate the type of algorithm you would use in each block. Indicate the information/variables/signals being sent between blocks.

*Operation*
Explain how the system works. Give a typical situation where it is designed to work, and describe its operation. Describe the level of autonomy (e.g. will it fill itself with gas?). Reference the components from the hardware and software section where necessary.

*Summary*
Make conclusions about your design, where it is lacking, where it will do well and where it will do poorly.

This is not a formal design project, but something to check how much you have learned about robot systems so far. Be inventive!