THE UNIVERSITY OF AUCKLAND

FIRST SEMESTER, 2002
Campus: Tamaki

COMPUTER SCIENCE

Intelligent Active Vision

(Time allowed: TWO hours)

NOTE: Attempt questions A, B, C, D, E, and F.
This is an *open* book examination.
Use of calculators is *permitted*.
Show your working to receive full marks.

SURNAME:

FORENAME(S):

STUDENT ID:

A	B	C	D	E	F	Total
5	20	15	20	20	20	100

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Section A: Kinematic Model of Mobile Robots

The following equation is the kinematic model of a differential drive mobile robot. The velocities v_r and v_l are for the right and left wheel respectively. The width of the robot is given as w.

$$\dot{\theta} = \frac{v_r - v_l}{w}, v = \frac{v_r + v_l}{2}$$

1. The state of the robot at time $t_0 = 0s$ is $x = 10.00$ cm, $y = 15.00$ cm, $\theta = 20^o$. The robot has a width w of 10 cm.

   Approximate the position of the robot at time $t_1 = 0.01s$, assuming that the velocities of the wheels were $v_r = 10$ cm/s and $v_l = 14$ cm/s.

   [5 marks]

```
-->vr=10;vl=14;w=10;dt=0.01;x=10;y=15;t0=20/180*%pi;
-->td = (vr - vl)/w
 td  =
  - 0.4
-->t1 = t0 + td * dt
 t1  =
    0.3450659
-->v = (vr + vl)/2
 v  =
    12.
-->xd = cos(t0) * v
 xd  =
    11.276311
-->yd = sin(t0) * v
 yd  =
    4.1042417
-->x1 = x + xd * dt
 x1  =
    10.112763
-->y1 = y + yd * dt
 y1  =
    15.041042
-->t1 = t1/%pi * 180
 t1  =
    19.770817
```

Section B: Fuzzy Logic and Fuzzy Inference

2. Given are three fuzzy sets Left, Straight, and Right as defined below:

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$$\text{Left}(x) = \begin{cases} 1.0 \text{ if } 0 \leq x < 2 \\ 1.0 - \frac{x-2}{6} \text{ if } 2 \leq x < 8 \\ 0.0 \text{ else} \end{cases}$$

$$\text{Straight}(x) = \begin{cases} 0.0 \text{ if } 0 \leq x < 3 \\ \frac{x-3}{2} \text{ if } 3 \leq x < 5 \\ 1.0 - \frac{x-5}{2} \text{ if } 5 \leq x < 7 \\ 0.0 \text{ else} \end{cases}$$

$$\text{Right}(x) = \begin{cases} 0.0 \text{ if } 0 \leq x < 2 \\ \frac{x-2}{6} \text{ if } 2 \leq x < 8 \\ 1.0 \text{ else} \end{cases}$$

Calculate the degree of membership of all three sets for $x = 3$.

[3 marks]

mLeft(3) = 0.83 mStraight(3) = 0 mRight(3) = 0.16

3. Given the fuzzy sets as defined in questions 2 and the rules shown below, complete the table to calculate the α-values for all rules, using Min inferencing.

Rule 1: if x is left and y is left then z is straight
Rule 2: if x is right and y is left then z is left
Rule 3: if x is left and y is straight then z is straight

[5 marks]

x	y	mLft(x)	mRgt(x)	mLft(y)	mStr(y)	$\alpha1$	$\alpha2$	$\alpha3$
4	5	0.66	0.33	0.50	0.00	0.50	0.33	0.00
5	4	0.50	0.50	0.66	0.50	0.50	0.33	0.50

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4. Show the fuzzy subset that is assigned to z for each of the three rules for $x = 4, y = 5$.

[4 marks]

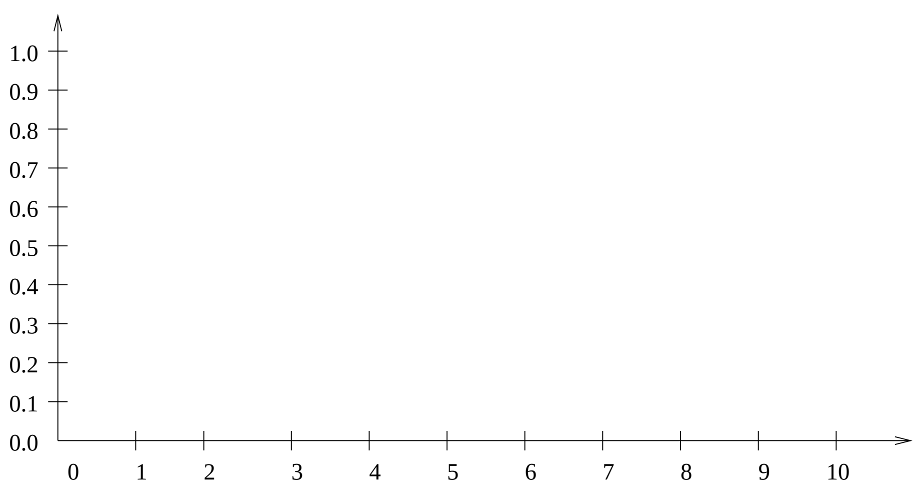
$$\text{Rule 1:} z = \begin{cases} 0.0 \text{ if } 0 \leq x < 2 \\ \frac{x-3}{2} \text{ if } 2 \leq x < 3.66 \\ 0.33 \text{if } 3.66 \leq x < 6.33 \\ 1.0 - \frac{x-5}{2} \text{ if } 6.33 \leq x < 7 \\ 0.0 \text{ else} \end{cases}$$

$$\text{Rule 2:} z = \begin{cases} \frac{x}{10} \text{ if } 0 \leq x < 5 \\ 0.5 \text{ else} \end{cases}$$

$$\text{Rule 3:} z = 0.0$$

5. Using Max composition, show the fuzzy subset that is assigned to z by composing the results of **all** three rules.

[3 marks]



6. Using centroid defuzzification, what is the crisp output value of z?

[5 marks]

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$$
\begin{aligned}
c &= \frac{***}{0.4 + 0.4 + 0.5 + 0.5 + 0.5 + 0.25+} \\
&= \frac{6.15}{2.55} = ***
\end{aligned}
$$

Section C: Subsumption Architecture

7. You want to design an intelligent search and rescue robot. The robot has a number of sensors (vision, infrared, and a microphone) which are able to detect the following features.

   - Your robot can recognize motion in the image,
   - Your robot can detect human body heat, and
   - Your robot can recognize sounds from a victim, and
   - Your robot can detect an obstacle in front of it, and
   - Your robot can detect when it is stuck (i.e., the motors are turned on, but the robot is not moving).

   The environment is unstructured, but you can assume that the environment is mostly two dimensional and that the robot can traverse the ground plane.

   A number of primitive behaviors are available:

   (a) Move into a given direction
   (b) Turn to face the motion in the image, and
   (c) Turn to face a heat source.

   Design a subsumption architecture using the behaviors mentioned above for an `intelligent search and rescue robot`. To coordinate your behaviors, you can use *inihibition* or *suppression* links.

   Add any additional behaviors, you may require (e.g., turn into a random direction).

   [15 marks]

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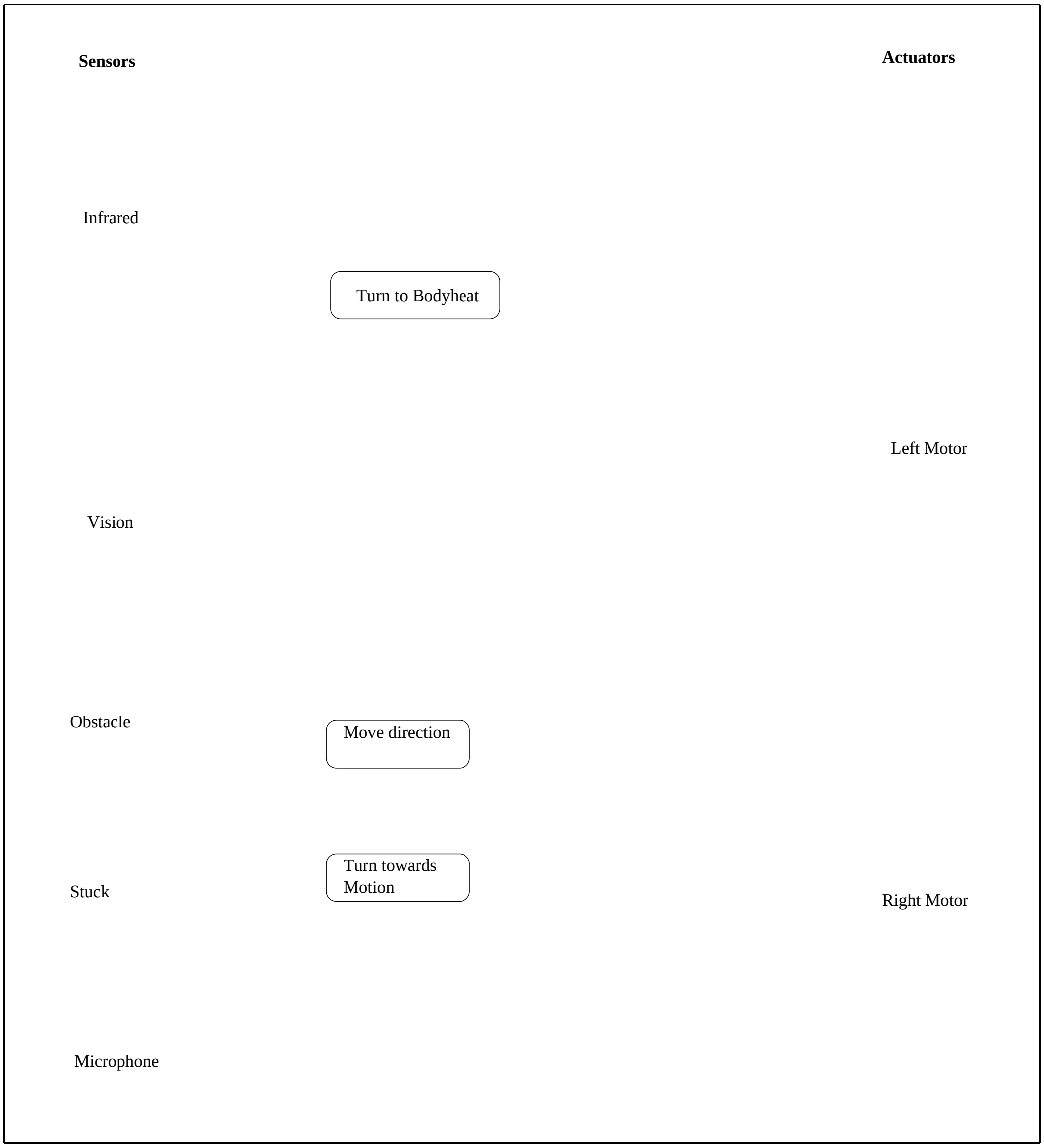

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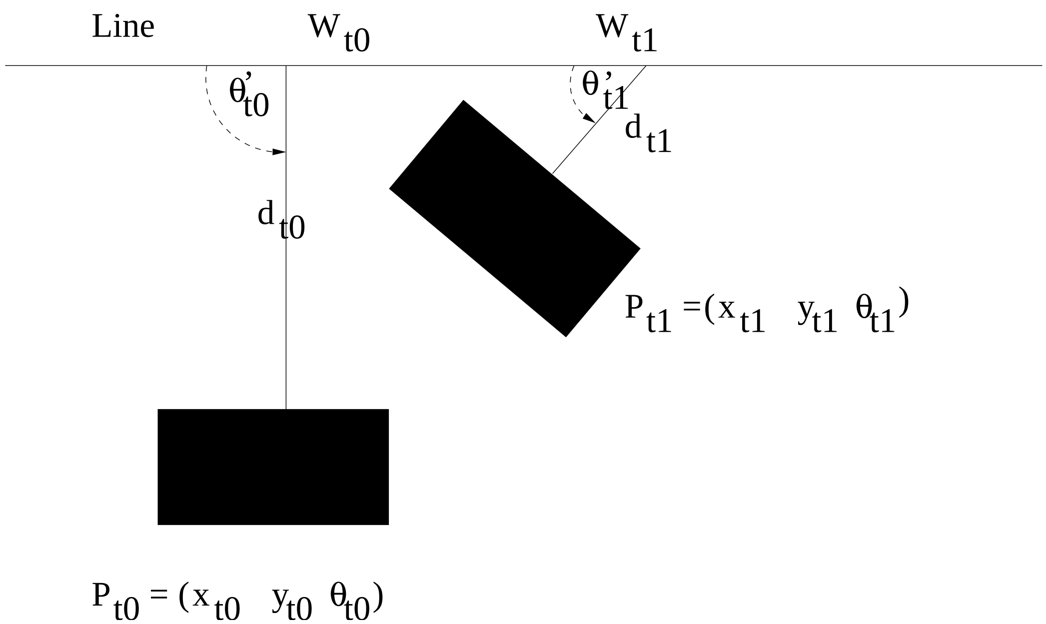
Section D: Localization

8. The following question assumes a robot that uses lines to estimate its own motion to support dead reckoning (Ego-motion estimation).

   At time $t_0 = 1.0s$, the robot detects a wall 50cm in front of the robot ($d_{t0} = 50$cm. The angle between the wall and the longitudinal axis of the robot is ($\theta'_{t0} = 90^o$).



   At time $t_1 = 1.3s$, the robot detects the same wall. The distance to the wall has changed to $d_{t1} = 40$cm and the angle between the wall and the longitudinal axis of the robot has changed to $\theta'_{t1} = 70^o$.

   Compute the shortest distance d between the robot and the wall at time $t1$. [3 marks]

   $d_{t1} = 37.59cm.$

9. Compute the turn rate $\dot{\theta}$ of the robot. [2 marks]

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$\dot{\theta} = -66^o/\text{sec}$

10. Given the information above, compute the left v_l and right v_r wheel velocities of a differential drive robot with a width of 10cm.

[15 marks]

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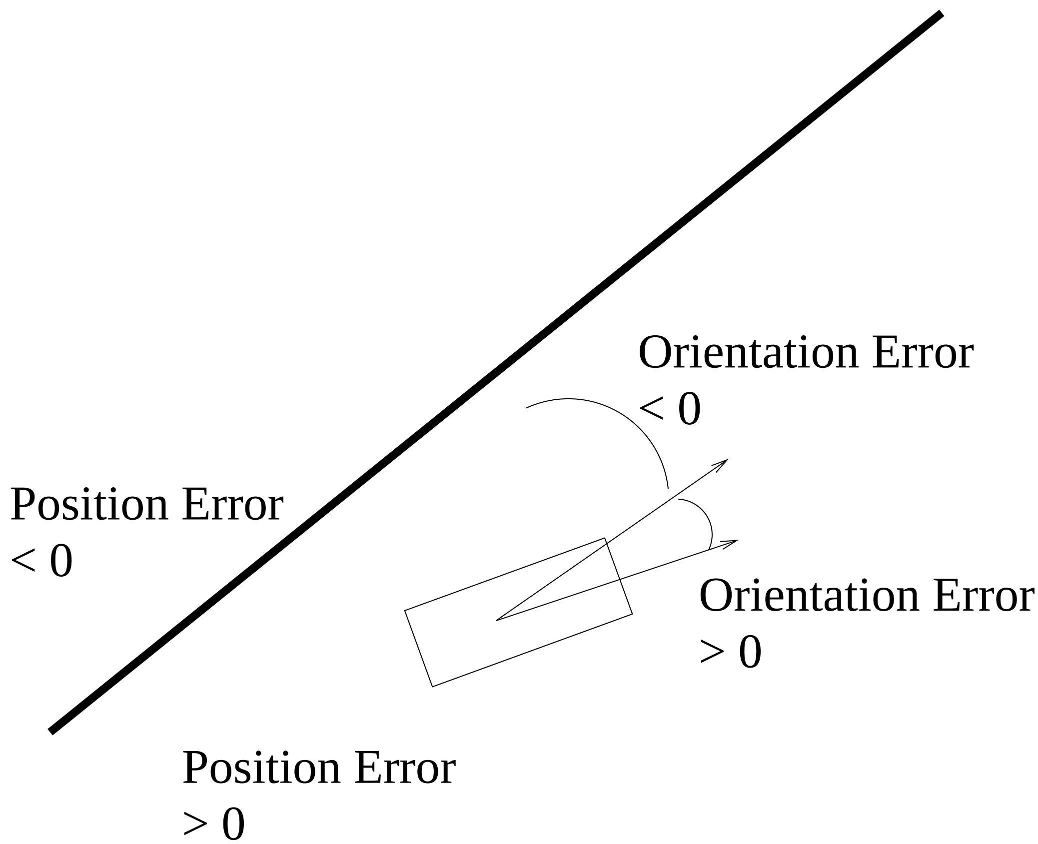
Section E: Cerebellar Model Articulation Controller (CMAC)

11. In this problem, you are trying to develop a CMAC controller for a differential drive robot to follow a straight line. The model of the control problem is shown below.

    The two inputs used by your controller are the position error and the orientation error of the robot with respect to the line.



There are five classifiers (a,b, c, d, and e) for the position error, which ranges from -4m to 4m.

There are four classifiers (A,B, C, and D) for the orientation error, which ranges from -180^o to 180^o.

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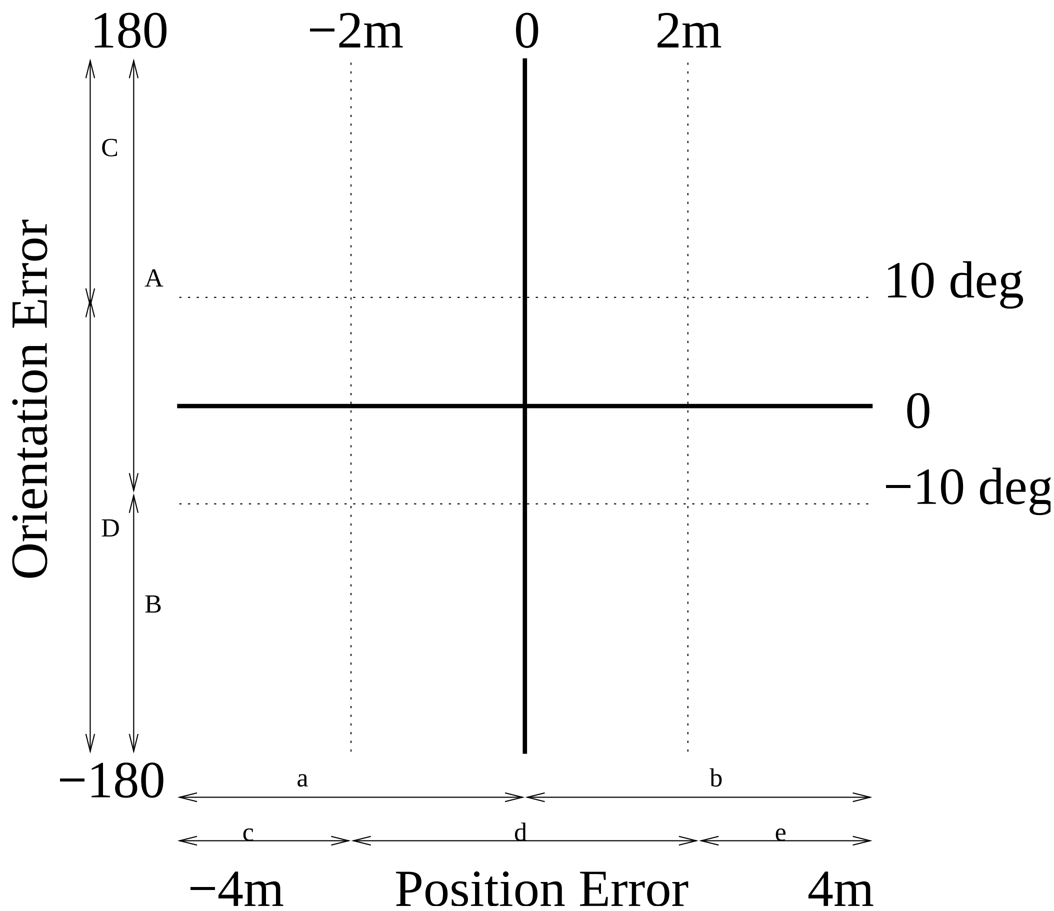

Show the different sets of orientation errors that can be distinguished using the classifiers shown above? For example, one set is an orientation error of 180^o to 10^o, which corresponds to A and C.

[2 marks]

3 Sets: 180 .. 10, 10 .. -10, and -10 .. -180.

12. Show the different sets of position errors that can be distinguished using the classifiers shown above? For example, one set is a position error of $-4m$ to $-2m$, which corresponds to a and c.

[3 marks]

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4 Sets: -4..-2,-2..0, 0..2, 2..4

13. Given the following table, what is the output of the CMAC controller for the input $(1m, 45^o)$?

Label	Value
Aa	0.1
Ab	0.2
Ac	0.8
Ad	0.7
Ae	1.2
Ba	0.3
Bb	-0.4
Bc	-1.0
Bd	0.3
Be	0.4
Ca	0.7
Cb	0.2
Cc	0.0
Cd	0.5
Ce	1.2
Da	0.8
Db	-1.0
Dc	0.4
Dd	0.5
De	0.6

[5 marks]

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Output of the controller is 0.2 + 0.7 + 0.2 + 0.5 = 1.6

14. The controller generates an output which is 1.0 units too large for the input ($1m$, 45^o). Assuming the standard CMAC learning algorithm with no momentum term ($(f - f')/|A^*|$), show which table entries will be modified and show the new values. Leave unchanged values blank.

[10 marks]

Label	Value
Aa	
Ab	-0.05
Ac	
Ad	0.45
Ae	
Ba	
Bb	
Bc	
Bd	
Be	
Ca	
Cb	-0.05
Cc	
Cd	0.25
Ce	
Da	
Db	
Dc	
Dd	
De	

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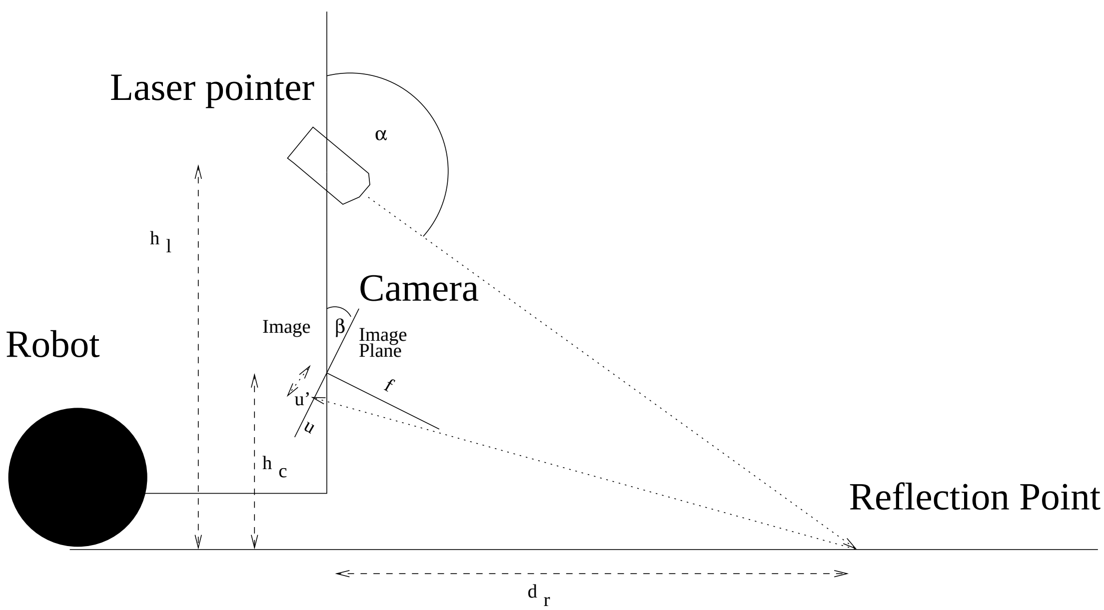
Section F: Computer Vision

The following questions concern issues in computer vision and camera calibration. A robot is supposed to navigate on a soccer field. Since the walls and ground of the playing field are black, a vision based approach can not be used to detect the distance of the robot to a wall.

A student suggests to mount a laser pointer on top of the robot. She claims that by looking for the point projected by the laser pointer in the image, the distance from the robot to the wall can be determined.

The setup is shown in the figure below. h_l is the height of the laser pointer above ground which is tilted with angle α against the vertical. h_c is the height of the camera. The angle between the vertical and the camera is β. The laser pointer is directly on top of the camera, and the camera is aligned with the ground. The focal length of the camera is f.



Given are $h_l = 100$mm, $h_c = 50$mm, $\alpha = 120^o, \beta = 45^o, f = 20mm$.

15. Assuming that the reflection point is on the ground plane, what is the distance d_r between the edge of the robot and the reflection point.

[3 marks]

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```
-->b = (180-120)/180*%pi
 b  =

    1.0471976

-->hl=100
 hl  =

    100.

-->hl*tan(b)
 ans  =

    173.20508
```

16. Compute the camera coordinate u' of the reflection point in the image.

[7 marks]

$u' = 12.64$

17. Assuming that a wall is 100mm in front of the robot, compute the coordinates of the reflection point u'' in the camera coordinate system.

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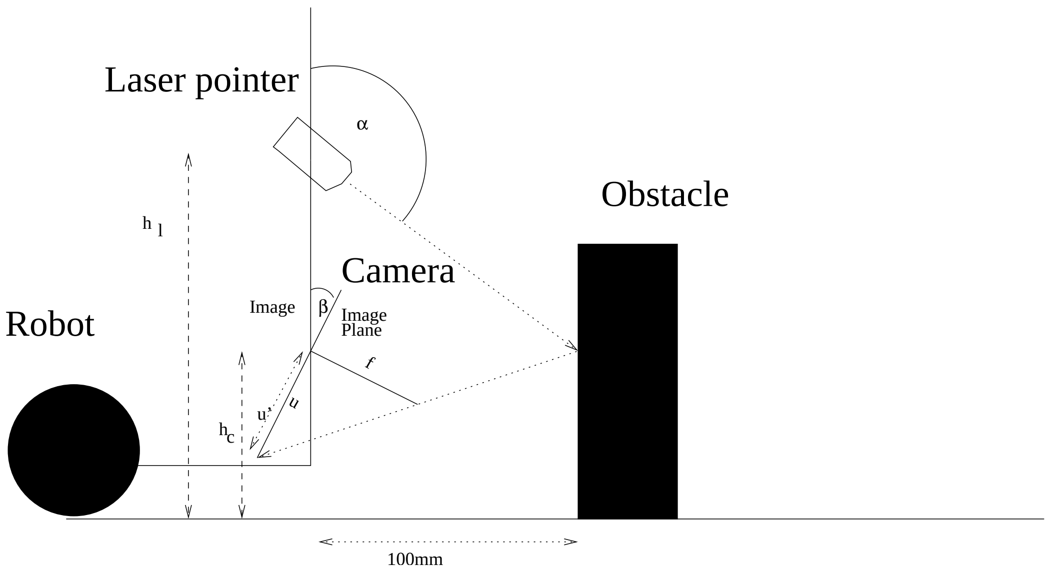

[10 marks]

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Additional work pages

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Additional work pages