Robot Vision

Robot Vision

- The aim of robot vision is to transform radiation reflected from objects into an internal representation of the objects, appropriate for the robot's task

- Three steps are involved:

  1. Image Formation

  2. Image Analysis

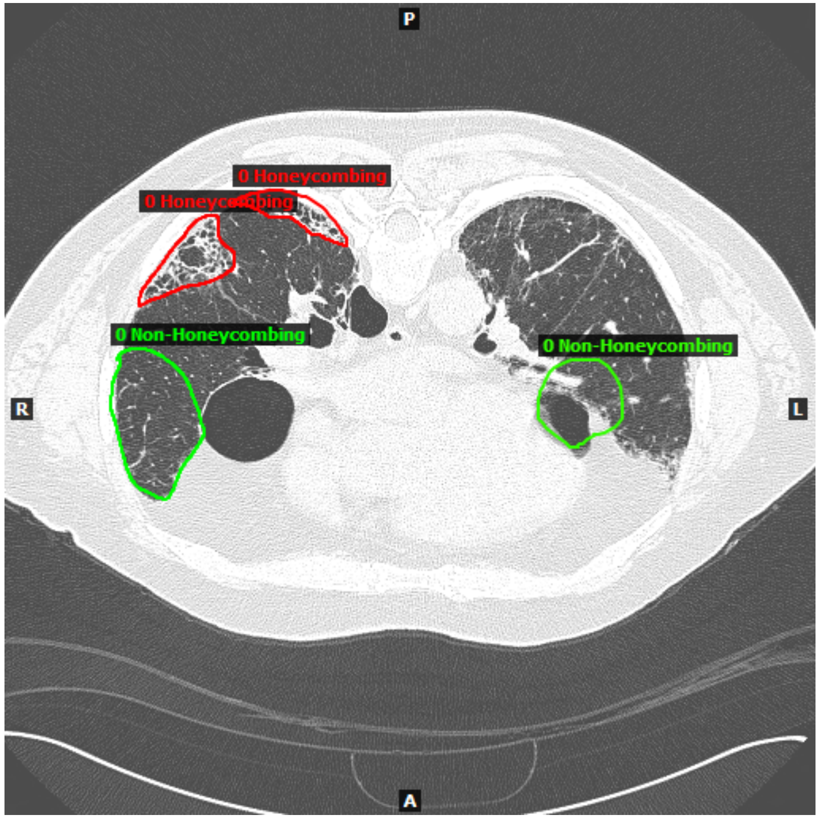
  3. Understanding

The State of Computer Vision

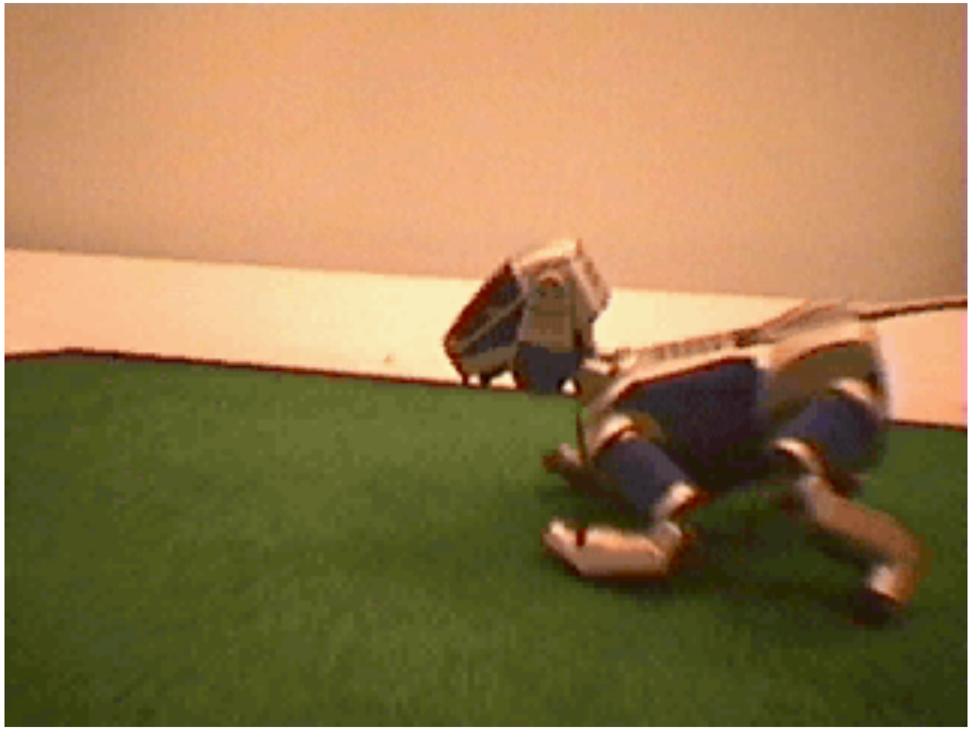
- The general computer vision problem is unsolved
  - Develop a visual system as good as humans
- A lot of progress in specific computer vision problems
  - face recognition
  - Inspection in Automation
- Recent progress in neural networks
  - Becoming very good at object recognition
  - Still not good at generalisation and abstraction

Robot Vision and Image Processing

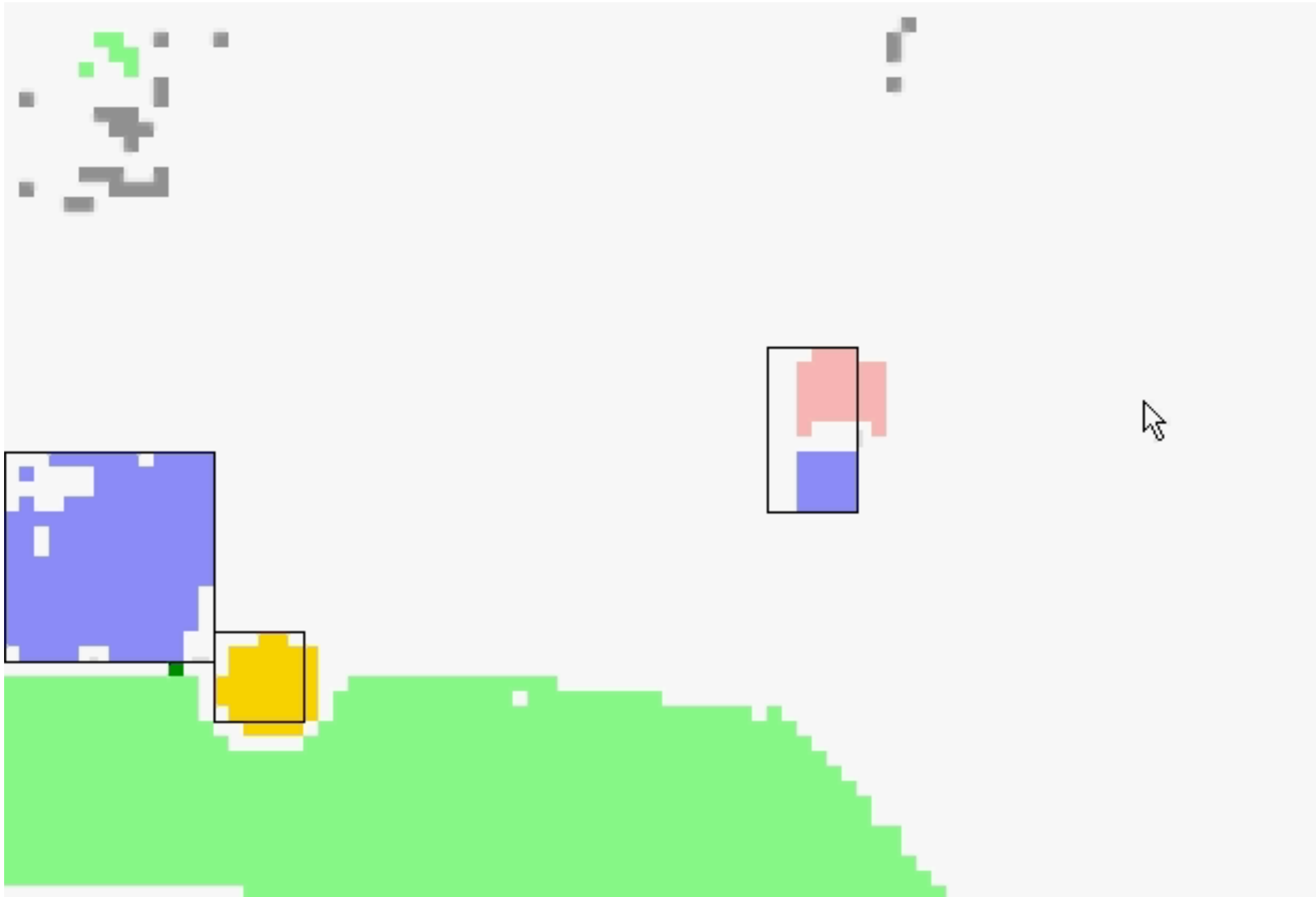
- Robot Vision is in an embedded system and ultimately should work in real time
- Image Processing can be off-line and is not time critical



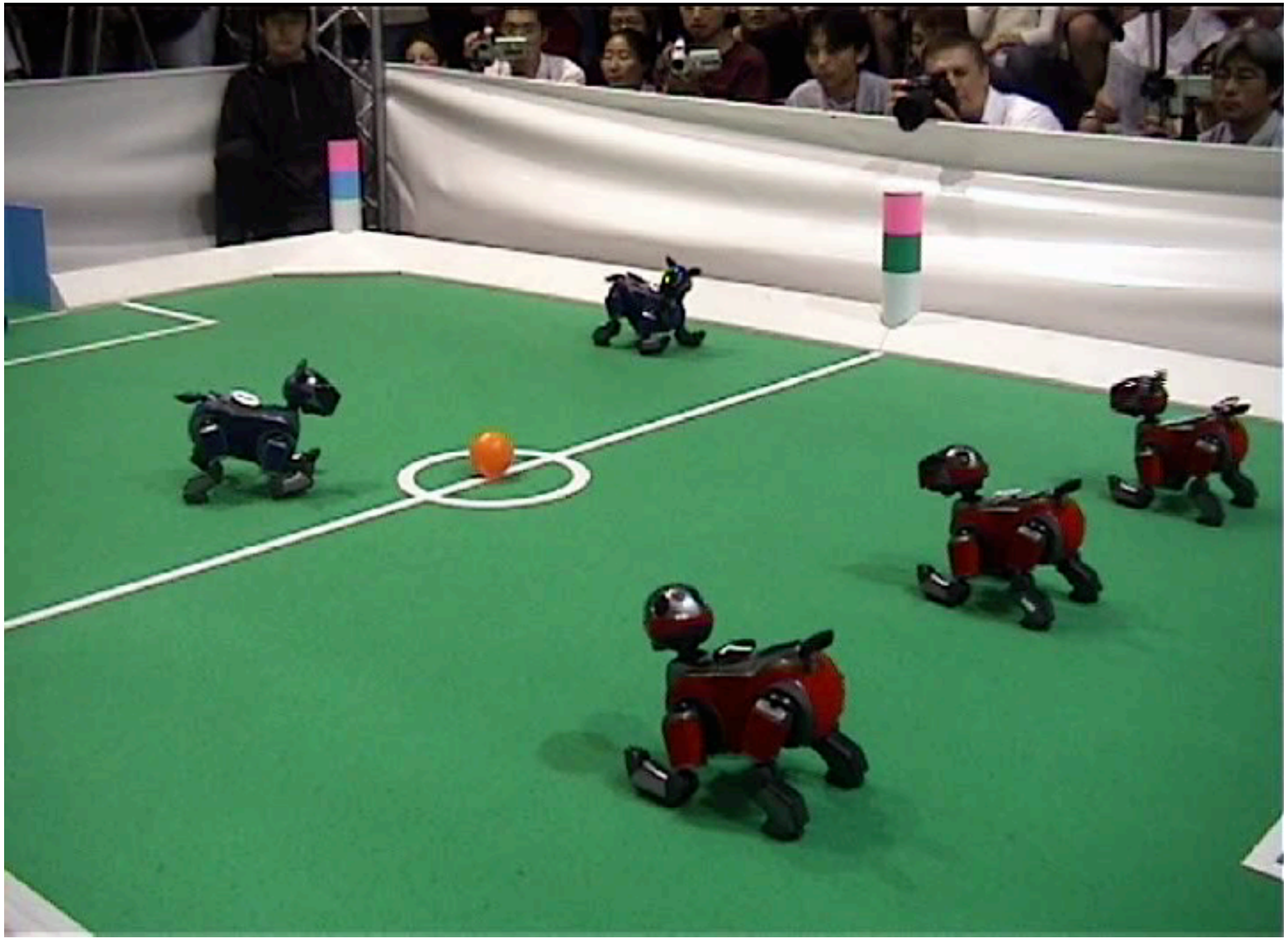
Doggie Cam (1)



Object Recognition



Computer Vision in Action



Doggie Cam (2)

What the robot sees

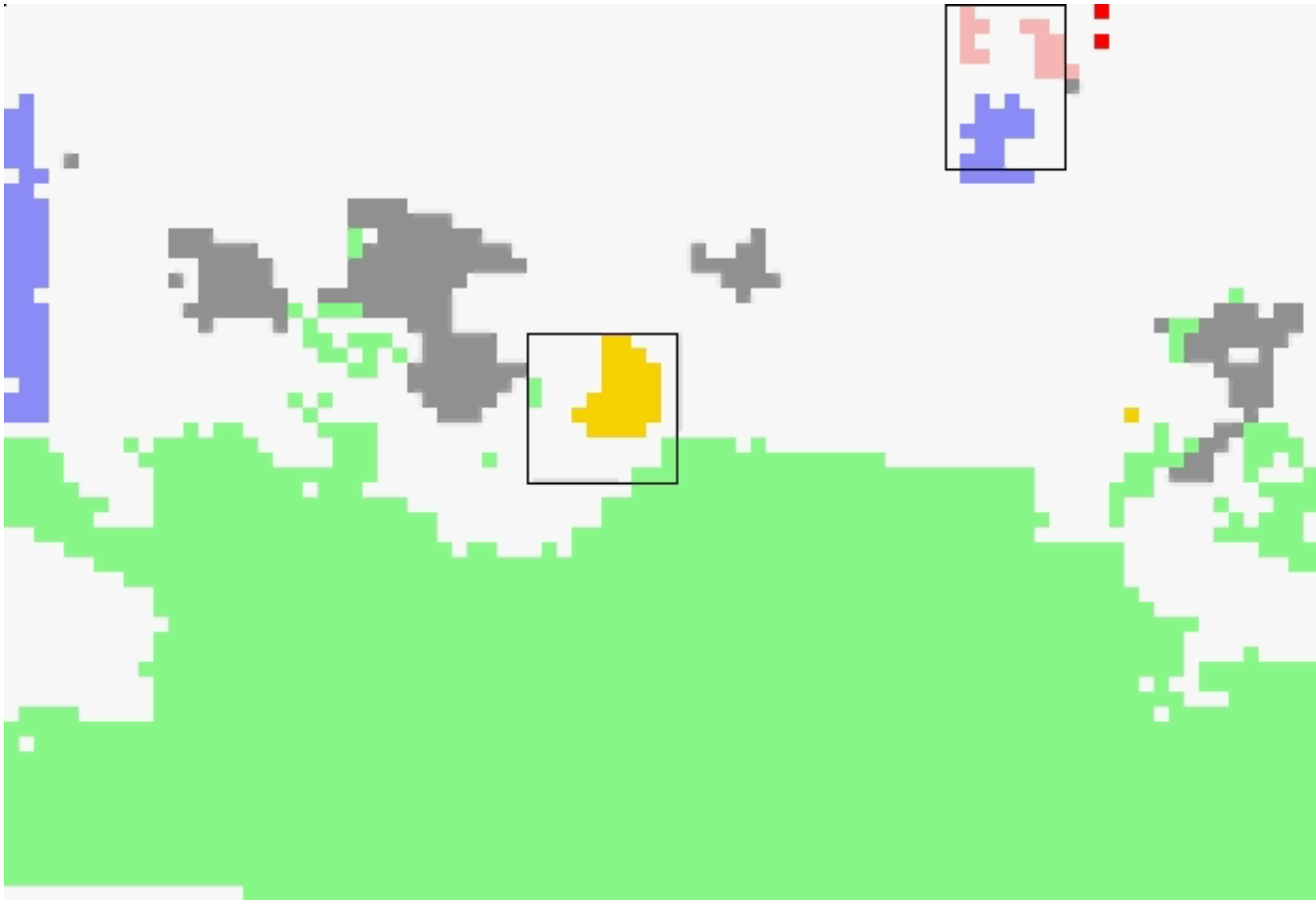
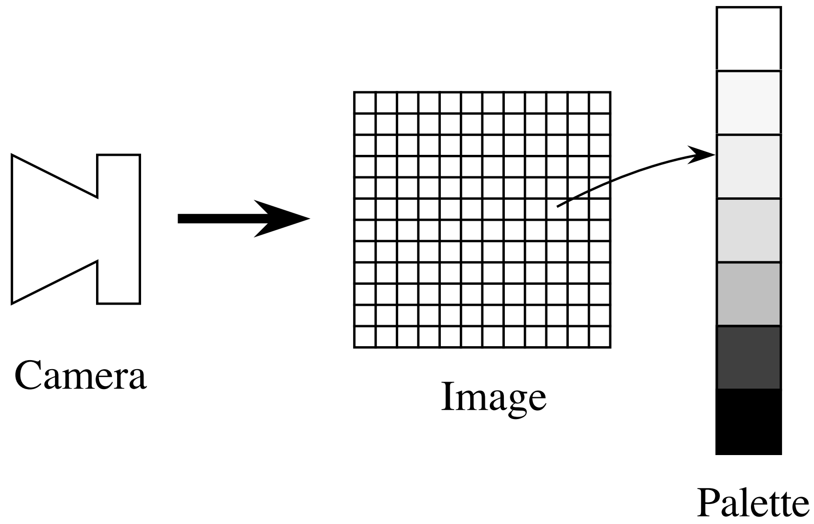


Image Formation

Image Formation

Light image is created by camera



Each pixel is a number that is an index into a palette of colours or grey scales.

A “frame grabber” captures camera image and stores it in special purpose memory.

Image Features

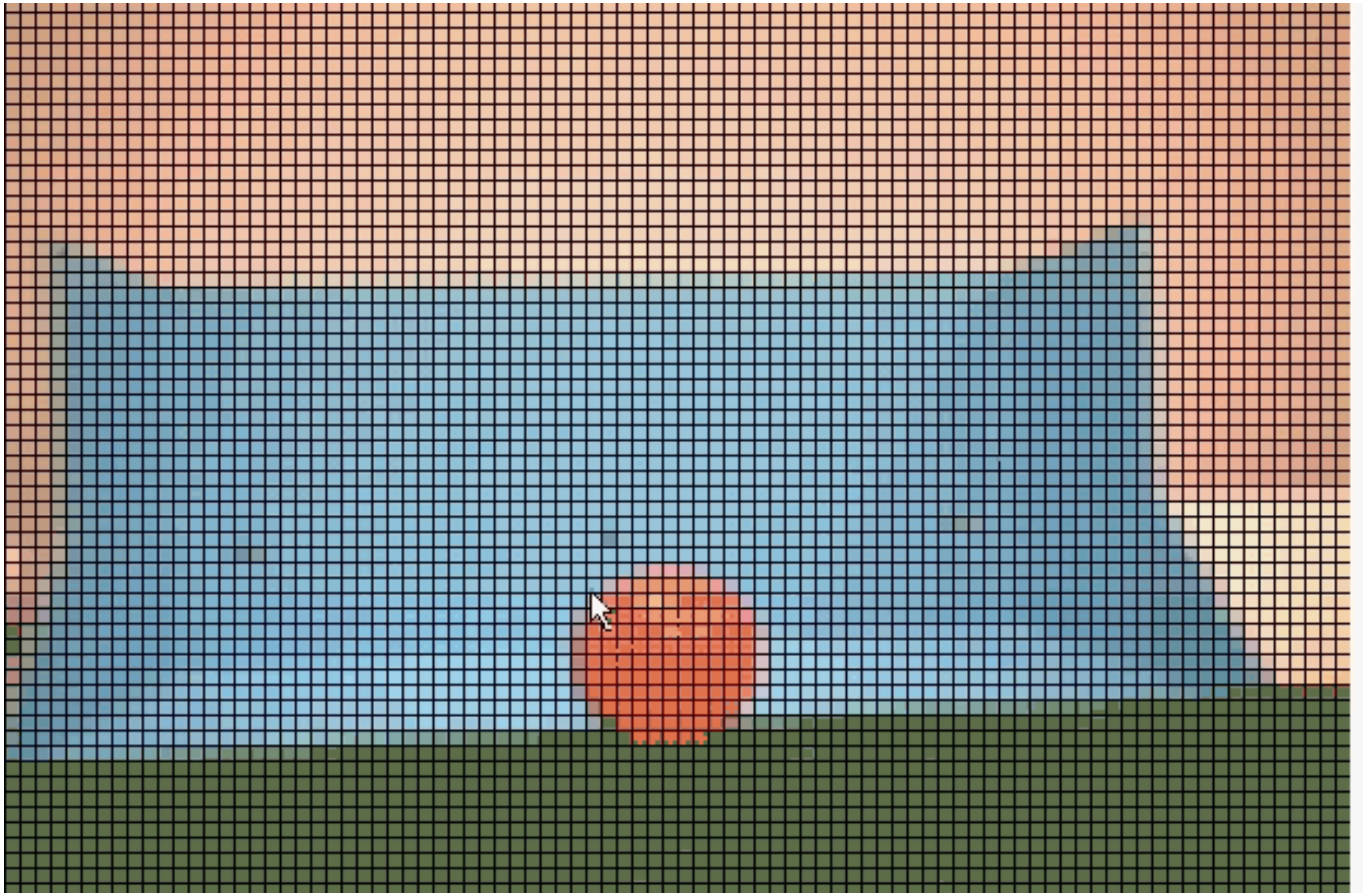
- Contrast
  - dullness or sharpness
  - e.g. if picture contains a lot of white and lot of black
- Dynamic Range
  - how much of grey scale is used
- Frequency
  - amount of change between pixels on a line

Object Features

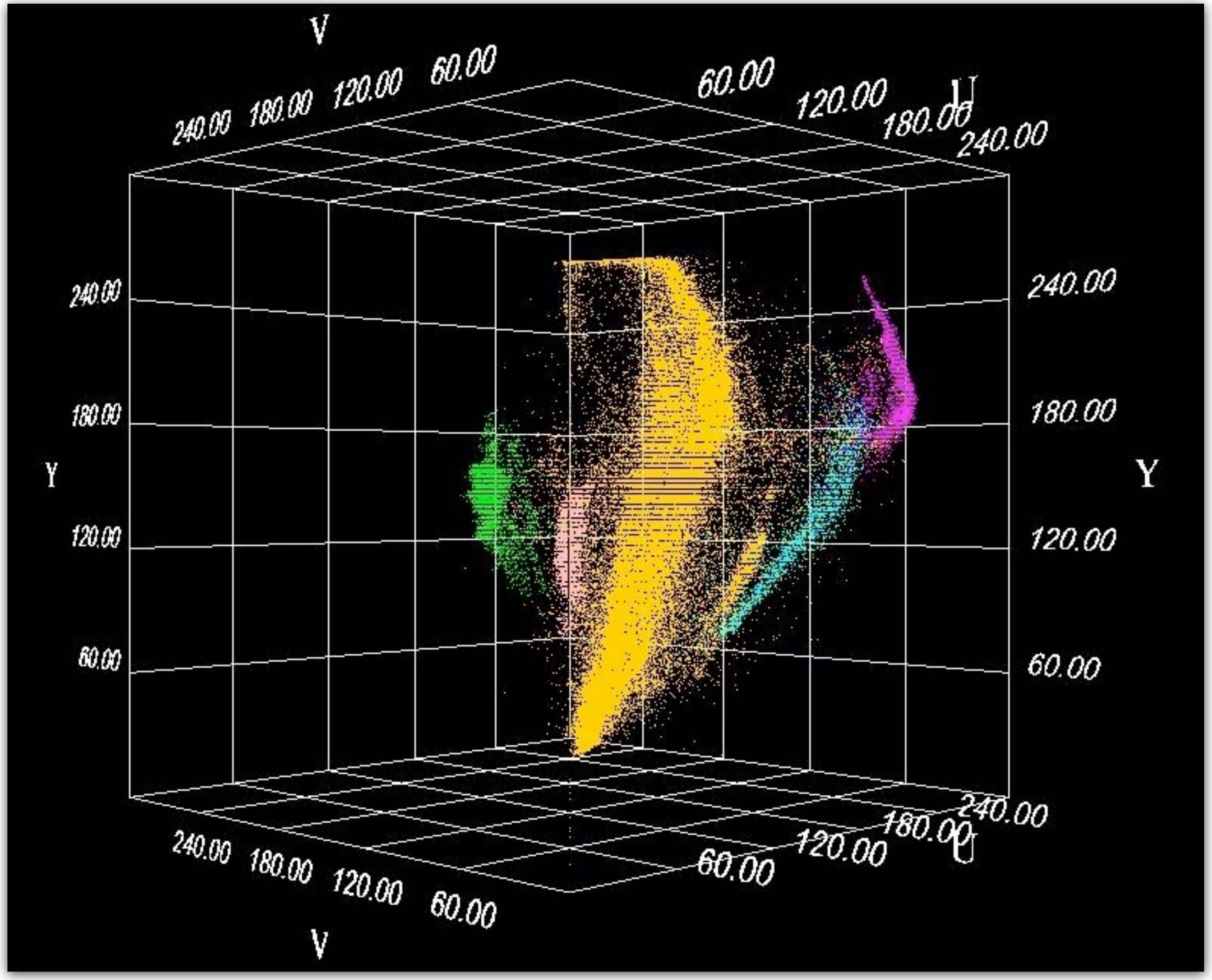
- Illumination (incident light)
- Reflectance (reflected light)
- Depth (distance from camera)
- Orientation (angle of normal to surface)
- Other features:
  - shading
  - colour
  - texture

Colour Recognition

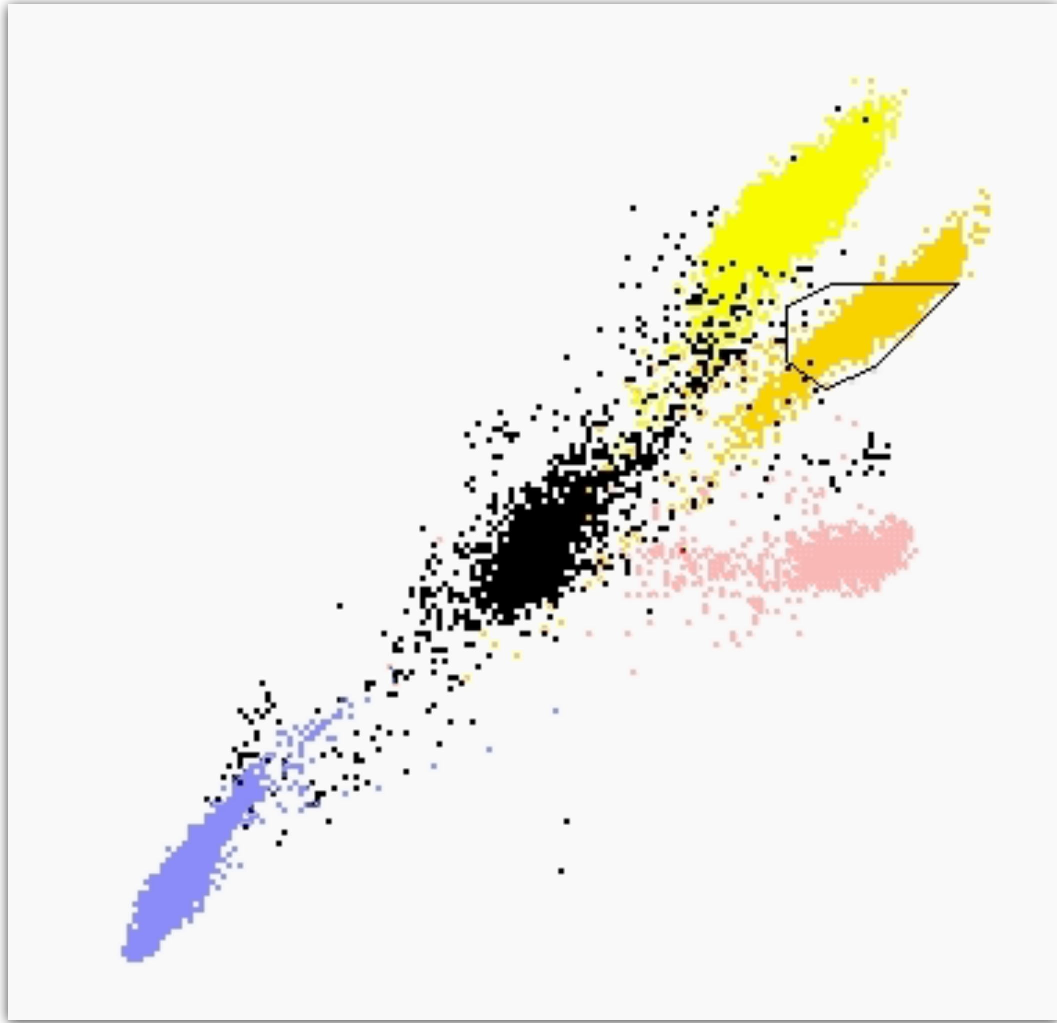
Camera Image



YUV Colour Space

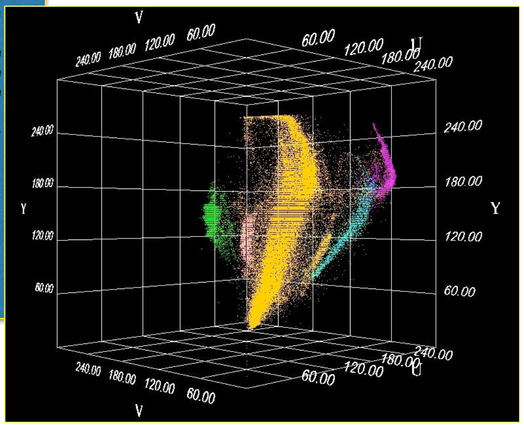


Polygons in UV Plane



Learning in Perception

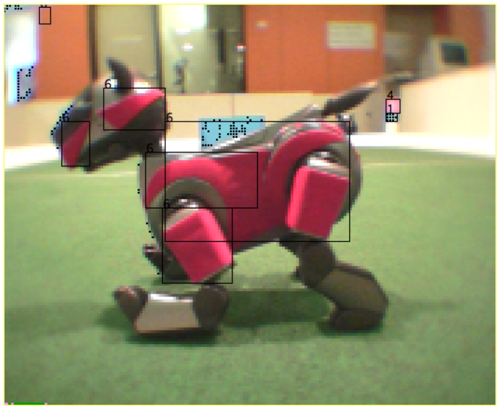
105, 117, 113, orange
105, 116, 112, orange
102, 117, 113, orange
102, 116, 114, orange
103, 117, 111, orange
103, 117, 112, orange
103, 118, 110, orange
99, 117, 112, orange
98, 116, 118, orange
99, 116, 117, orange
106, 111, 114, orange
114, 115, 123, yellow
128, 111, 124, yellow
150, 112, 121, yellow
173, 111, 117, yellow
171, 110, 110, yellow
145, 112, 108, yellow
121, 111, 110, yellow
106, 111, 112, orange
107, 112, 112, orange
104, 114, 114, orange
100, 115, 114, orange
100, 117, 117, orange
98, 115, 113, orange
100, 114, 116, orange
97, 117, 112, orange
102, 115, 109, orange
104, 118, 109, orange
100, 114, 108, orange
97, 115, 110, orange
101, 114, 110, orange
99, 116, 113, orange
98, 116, 113, orange



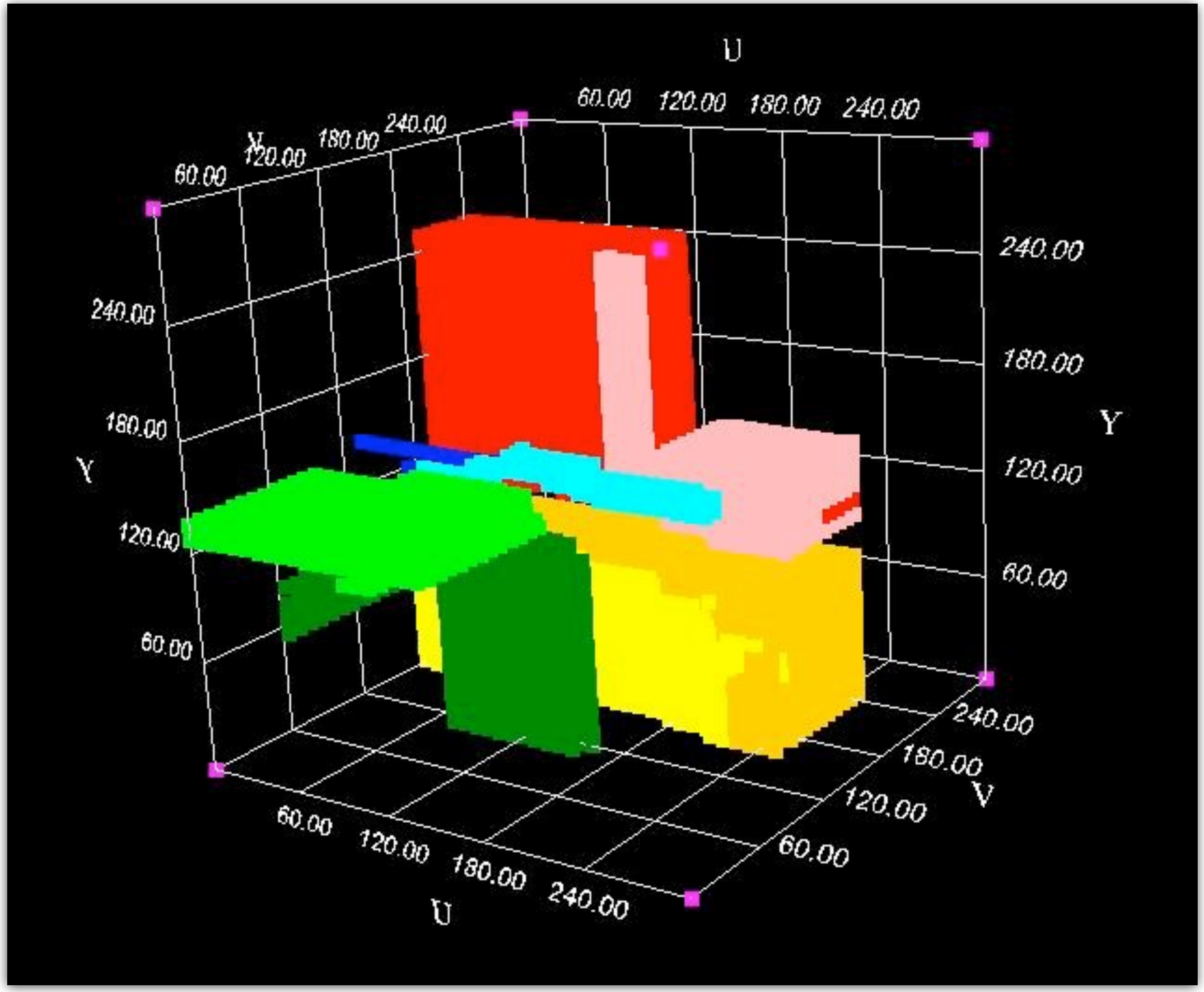
C4.5

Warning: In practice data sets and decision trees are much larger than this example!

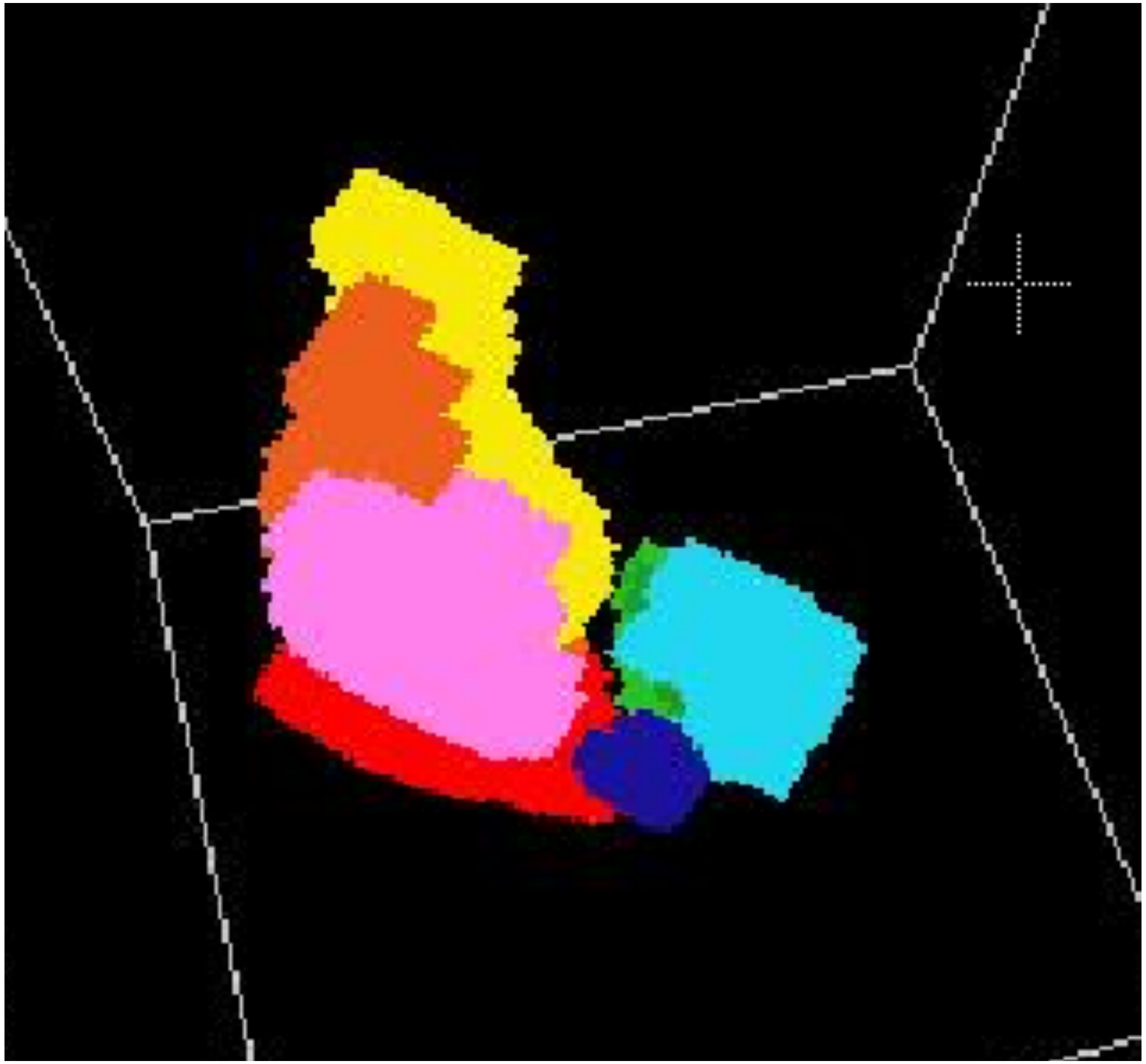
```
if (u <= 107)
      yellow;
else
      if (v <= 100)
            orange;
      else
            if (y <= 136)
                  orange;
            else
                  yellow;
```



Colour Classes using C4.5



Nearest Neighbour



Binary Vision

Binary Vision

- The original image is “thresholded”, i.e.

  new[x, y] = (old[x, y] > threshold)

- Every pixel brighter than a certain threshold is given a value of 1 otherwise it is zero.

- Easy to process and powerful enough to use in some industrial applications

  - e.g. picking parts from an assembly line.

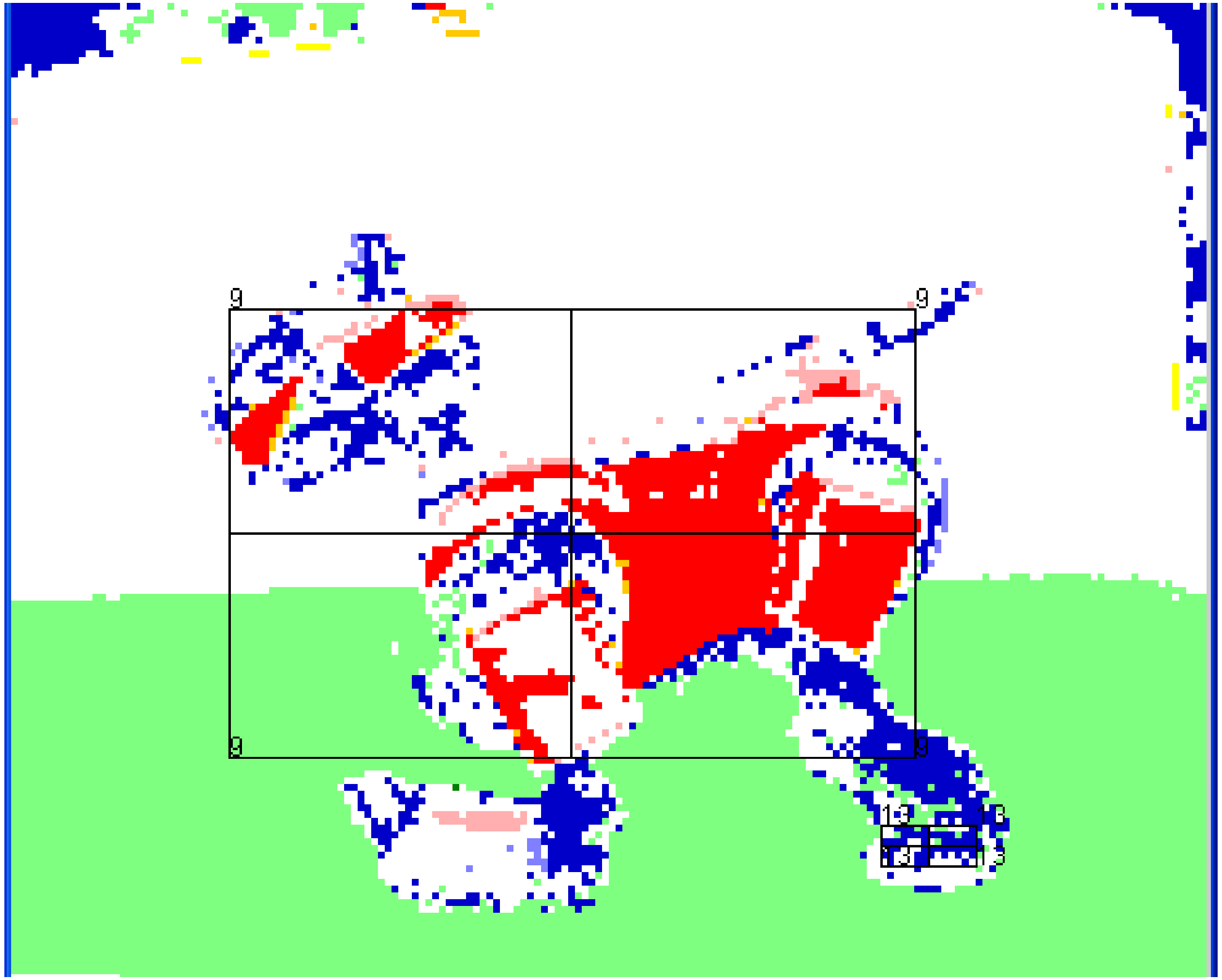
Binary Vision

- Or use colour to create binary image

  new[x, y] = (old[x, y, u] is orange)

- Use colour lookup as before to determine colour

Blob Finding



Blob Finding

(Connected Component Analysis)

- How do we find a region in an image?
  - e.g. find the orange ball
- Assign a different number to every connected component of an image
- Requires two passes.
- First scan a 2 x 2 window over the binary image and observe the pattern:

C	**B**
D	**A**

- Scan along each row from left to right, starting at the top.
- When we inspect cell A, cells B, C and D have already been labelled.

First Pass

C	B
D	A

```
000000000000000000000000000000
000000000000000000000011110000
001110000000000000111111111110
011111111000001111111111111111
011111111111111111111111111111
```

- A is 0 if the image is 0, otherwise the number identifies the component.
- If the three neighbours of A are all 0 a new label is assigned to A.
- If C has been labelled we label A similarly.
- If C is 0 and either B or D has been labelled we label A similarly.

C	B
D	0

or

C	B
D	N

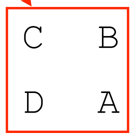
0	0
0	N

N	-
-	N

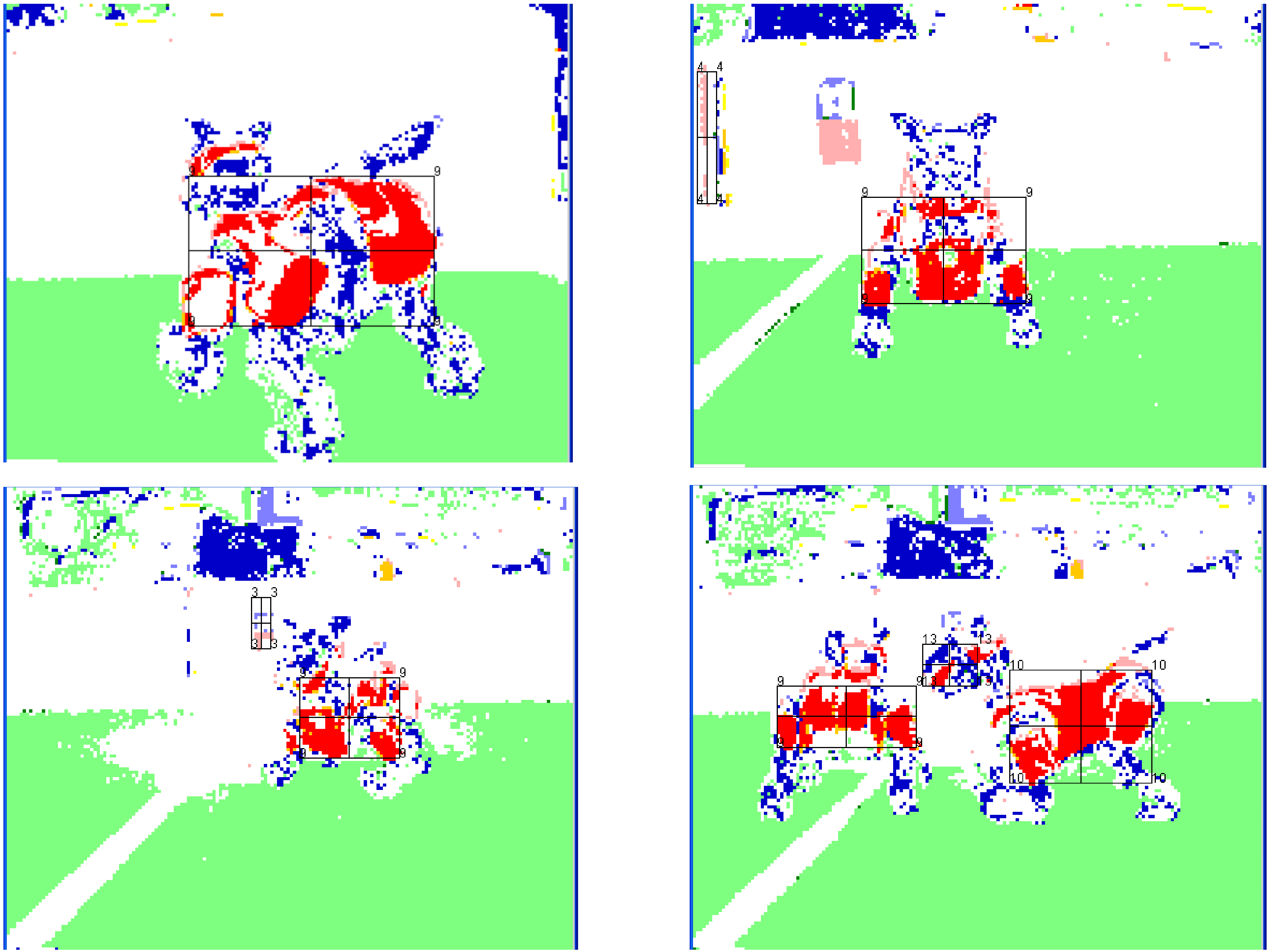
0	N
N	N

Second Pass

```
000000000000000000000000000000
000000000000000000000011110000
002220000000000000333311111110
022222222000004444111111111111
022222222222222111111111111111
```



- Second pass re-labels objects uniformly.
- If B and D have different labels
    - we have given two labels to the same object
    - make the two labels are equivalent.



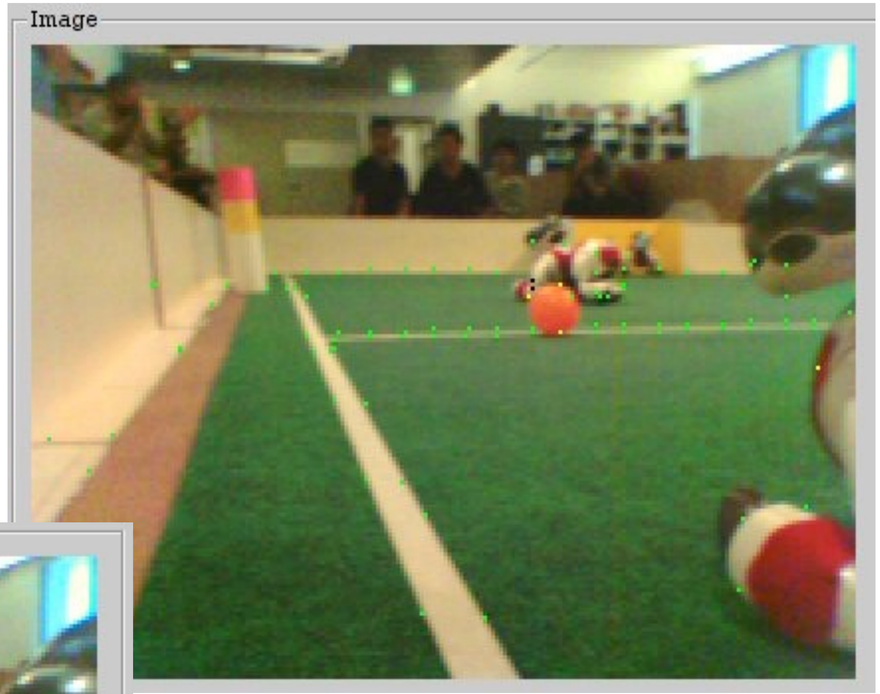
9
4
9
3
9
9
13
10

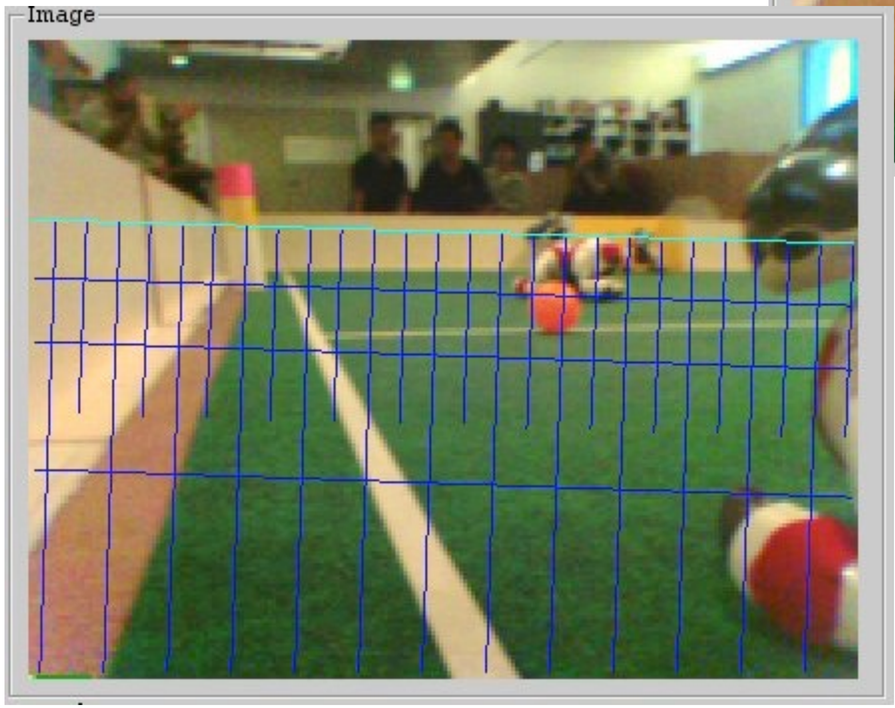
Edge Detection

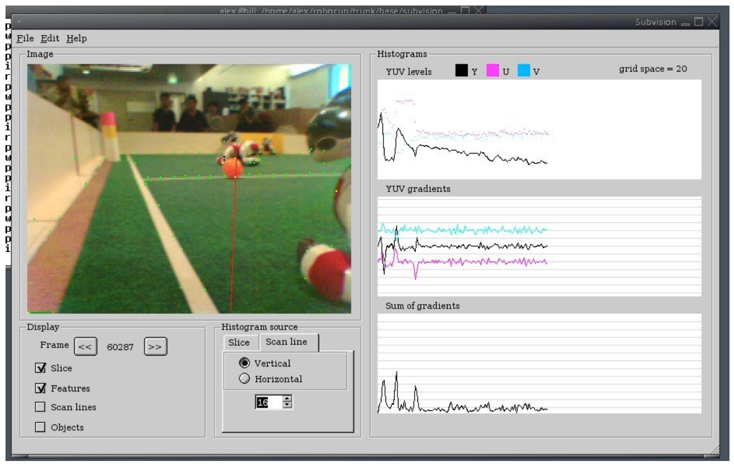
Edge Detection

- The first step in robot vision system is to recognise the intrinsic features of the image.
- Some of the most important features are edges.
- There is evidence that the human vision system has edge detectors.

Looking for Edges







Edge detection requires several steps

1. Smoothing and sharpening of the image to remove noise.
2. Finding the edges by filtering the image.
3. Connecting lines from the edges found in the previous step.

Smoothing

- Real images always contain noise.
- Smoothing tries to remove isolated bright and dark regions of a picture.
- One smoothing method is to replace the brightness value at each pixel by average brightness of eight neighbours.
- Called local averaging.
- Has side-effect of blurring image.

Smoothing Example

- Given a simple 4 x 4 picture matrix:

9	9	9	3
9	9	3	3
9	3	3	3
3	3	3	3

- Smooth this matrix using a local-averaging technique and a 3 x 3 pixel window.

Solution

- There are four 3 x 3 pixel windows in the matrix.
- Replace middle value in each window by average of all the values in the window.

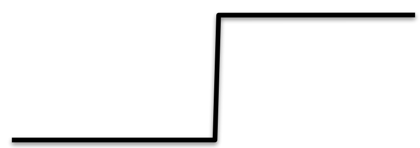
9	9	9	3
9	9	3	3
9	3	3	3
3	3	3	3

→

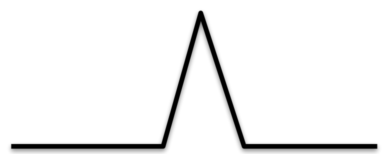
9	9	9	3
9	7	5	3
9	5	4	3
3	3	3	3

Edge Detection Operators

- The ideal edge can be graphed on a grey-scale as:



- To find the edges in a grey-scale image we calculate the first-derivative of the adjacent grey-scale values, i.e. the gradient.



The Roberts Cross Operator

The Roberts cross operator approximates the first derivative.

$$R(i,j) = \sqrt{\left[i(m+1,n+1) - i(m,n)\right]^2 + \left[i(m,n+1) - i(m+1,n)\right]^2}$$

where $i(m,n)$ is the image intensity of pixel (m,n).

Roberts Operator Example

- Replace grey-scale values with values obtained using the Roberts operator.
- If a Roberts value cannot be obtained for given pixel, replace that pixel with an X.

9	9	9	3
9	7	5	3
9	5	4	3
3	3	3	3

Roberts Operator Example (Solution)

- Applying the Roberts operator to each 2 x 2 window in the picture gives:

2.0	4.5	6.3	X
4.5	3.0	2.2	X
6.3	2.2	1.0	X
X	X	X	X

- Apply threshold to get a binary image.

Thresholding

With a threshold of 4:

0	1	1	X
1	0	0	X
1	0	0	X
X	X	X	X

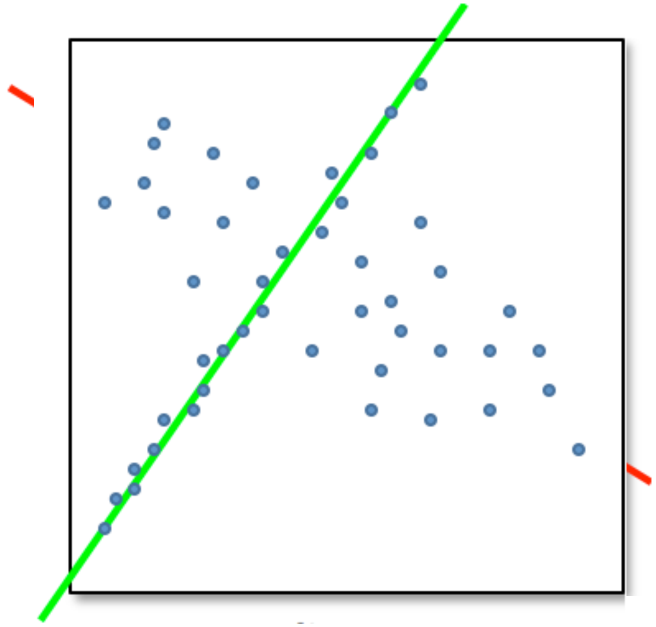
With a threshold of 6:

0	0	1	X
0	0	0	X
1	0	0	X
X	X	X	X

- In both matrices connecting ones gives the edge.
- 6 is better.

Line Finding

RANSAC



RANSAC

(RANdom SAmple Consensus)

- Select randomly the minimum number of points required to determine the model parameters.
- Solve for the parameters of the model.
- Determine how many points from the set of all points fit with a predefined tolerance ε.
- If the fraction of the number of inliers over the total number points in the set exceeds a predefined threshold τ, re-estimate the model parameters using all the identified inliers and terminate.
- Otherwise, repeat steps 1 through 4 (maximum of N times).