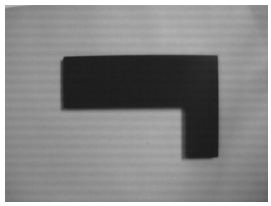
Vision I

Keypoints:

- The problem and the approach
- Basics of image capture
- Problems in image capture
- Convolution as a general image processing function

The problem we will focus on:
classification of objects



The approach we will take:

- Capturing a good image
- Differentiating the object from the background
- Computing descriptive properties of the object
- Using these properties to learn a classification

Image capture

Signal available depends on:

- light source,
- scene structure
- surface reflectance properties
- viewing angle

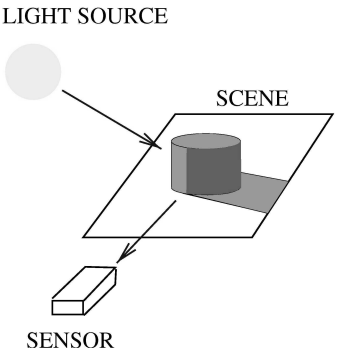


Image capture

Sensor capability:

- lens angle
- focus range
- Photosensors:
  - density/distribution
  - wavelength range
  - amplitude range
- quality of digitization
- speed of data transfer

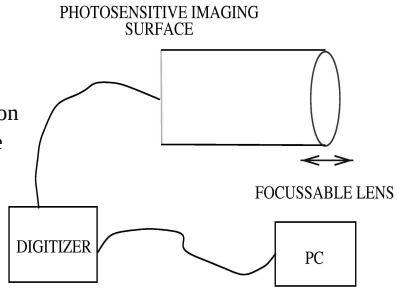


Image capture

Limits of standard transducers:

- Not constant across wavelengths
- Sensitive beyond (human) visible range

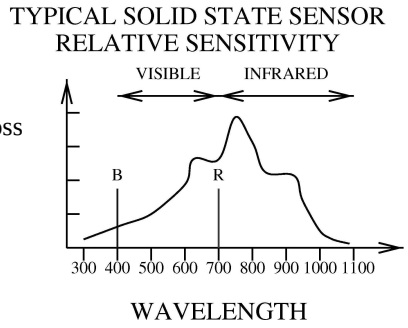


Image capture

Sensor array:

- Photons converted to electrons
- Three colour filters for each pixel
- Shift electrons along row for readout

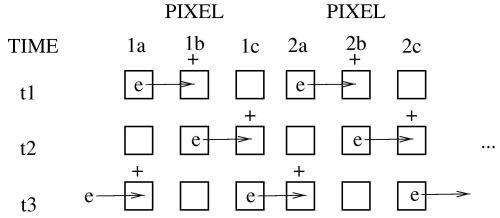
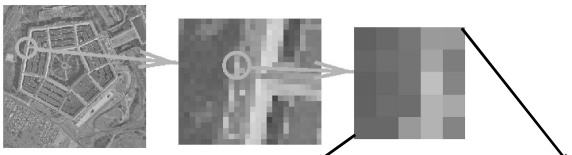


Image capture

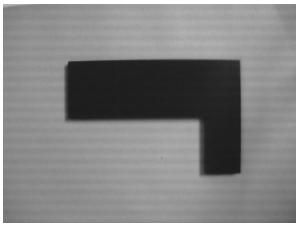
Result: array of pixel values (0-255)



96	105	118	155	152
102	110	115	164	125
96	105	115	191	134
98	108	109	178	168
103	103	152	178	131

Image capture problems

Aim is to build vision system to recognise simple flat parts:



What could go wrong in image capture?

Image capture problems

Focus problems: focus set to one distance. Nearby distances in focus (depth of focus). Further or closer not so well focused.

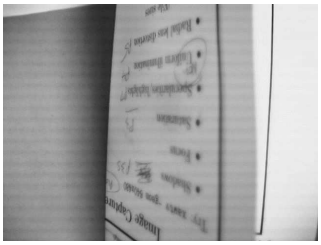


Image capture problems

Shadow problems (false colour to emphasis). May be hard to separate shadow from part.

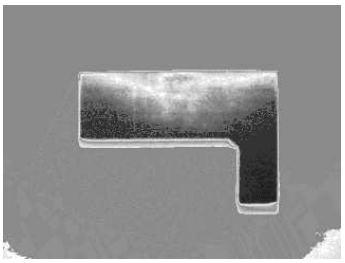


Image capture problems

Saturation problems: pixels clip at 255

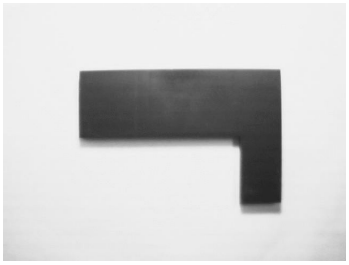


Image capture problems

Specularities/highlights (saturated pixels set to red)

Image capture problems

Non-uniform illumination:

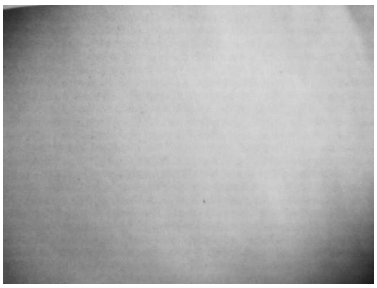


Image capture problems

Radial lens distortion: straight lines in world not straight in image

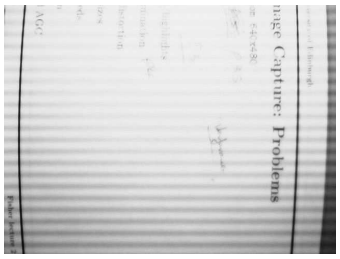


Image capture problems

Motion blur

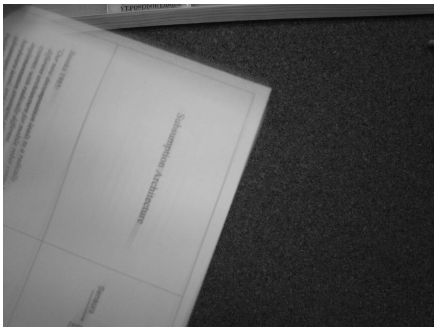


Image capture: overcoming problems

Shadows, specularities, non-uniform illumination: increase ambient lighting by using diffusing panels or many point lights

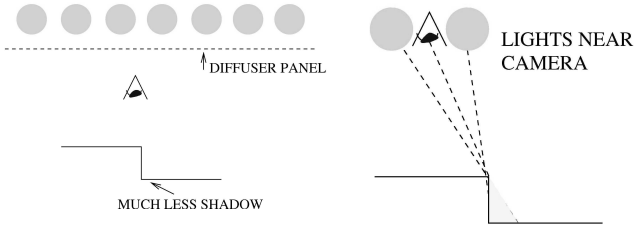


Image capture: overcoming problems

Depth of focus: use smaller aperture and brighter light

Motion blur: use shorter capture time and brighter light

Saturation: use smaller aperture, reduce gain and adjust gamma (i.e. introduce nonlinearity into intensity coding)

Lens distortion: more expensive lens or view from further away

Convolution

- General purpose image (and signal) processing function: compute the weighted sum of image data and a fixed mask

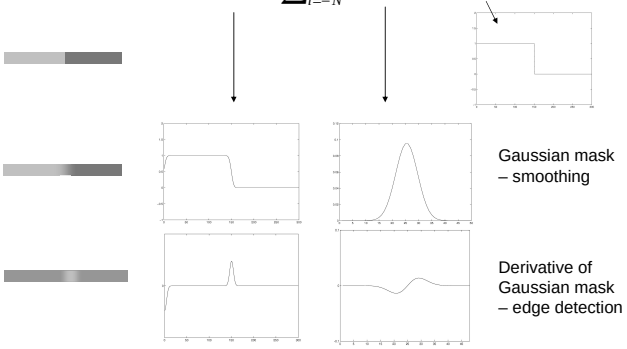
1	1	1	1	1
1	1	1	1	1
1	10	1	1	1
1	1	1	10	1
1	1	1	1	1

0.1	0.1	0.1
0.1	0.2	0.1
0.1	0.1	0.1

- Linear operator: conv(a*B,C)=a*conv(B,C)
- Used in many processes: noise removal, smoothing, feature detection, differentiation

Convolution in 1D

$$Output(x) = \sum_{i=-N}^{N} weight(i) * input(x-i)$$

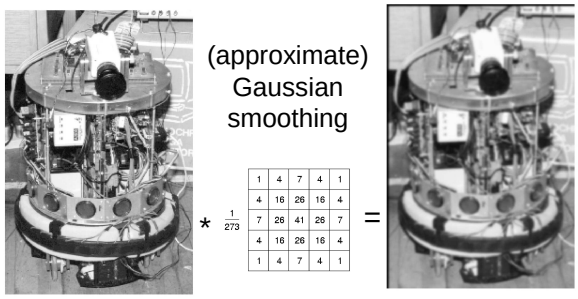


Gaussian mask – smoothing

Derivative of Gaussian mask – edge detection

Convolution in 2D

$$Output(x,y) = \sum_{i=-N}^{N} \sum_{j=-N}^{N} weight(i,j) * input(x-i, y-j)$$

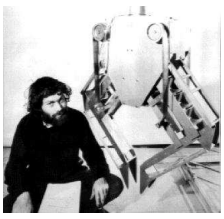


(approximate) Gaussian smoothing

$$\frac{1}{273}\begin{bmatrix} 1 & 4 & 7 & 4 & 1 \\ 4 & 16 & 26 & 16 & 4 \\ 7 & 26 & 41 & 26 & 7 \\ 4 & 16 & 26 & 16 & 4 \\ 1 & 4 & 7 & 4 & 1 \end{bmatrix}$$

Convolution in 2D

$$Output(x,y) = \sum_{i=-N}^{N} \sum_{j=-N}^{N} weight(i,j) * input(x-i, y-j)$$



$$*\begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix} =$$

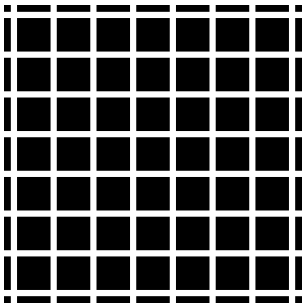
Edge detection

$$*\begin{bmatrix} 1 & 0 & -1 \\ 2 & 0 & -2 \\ 1 & 0 & -1 \end{bmatrix} =$$

Convolution in 2D

Edge enhancement in human vision

Centre-surround receptors - convolved with retinal image



Hermann grid illusion – full explanation more complex

Summary

- Important task for vision is object recognition
- Capturing an image: light source, reflected light, photoreceptor array, digitisation.
- Problems in image capture
- Convolution: simple operation to modulate image in useful ways