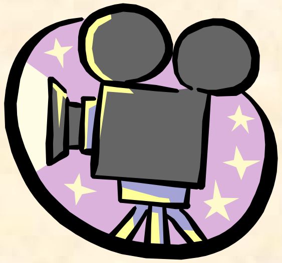
# Colour Coordinate Systems

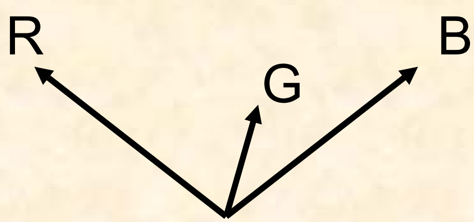
- RGB
  - component colours, used in computer monitors and cathode ray tubes
  - Cartesian coordinate system

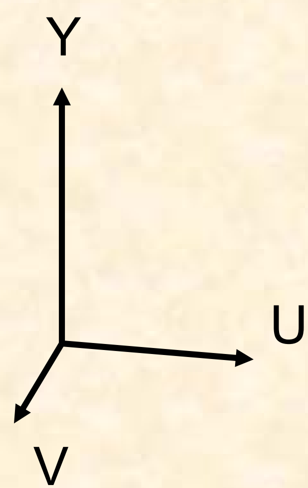
- YIQ or YUV
  - composite colour system used in PAL/NTSC colour TV transmission
  - Y denotes intensity (B&W TV signal), UV are Cartesian coordinates specifying hue and saturation

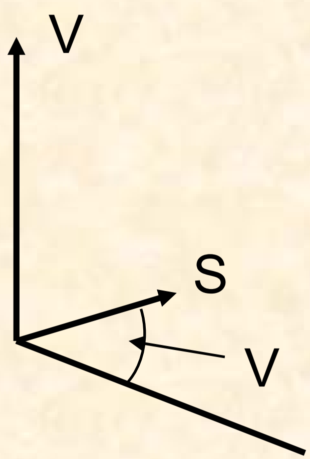


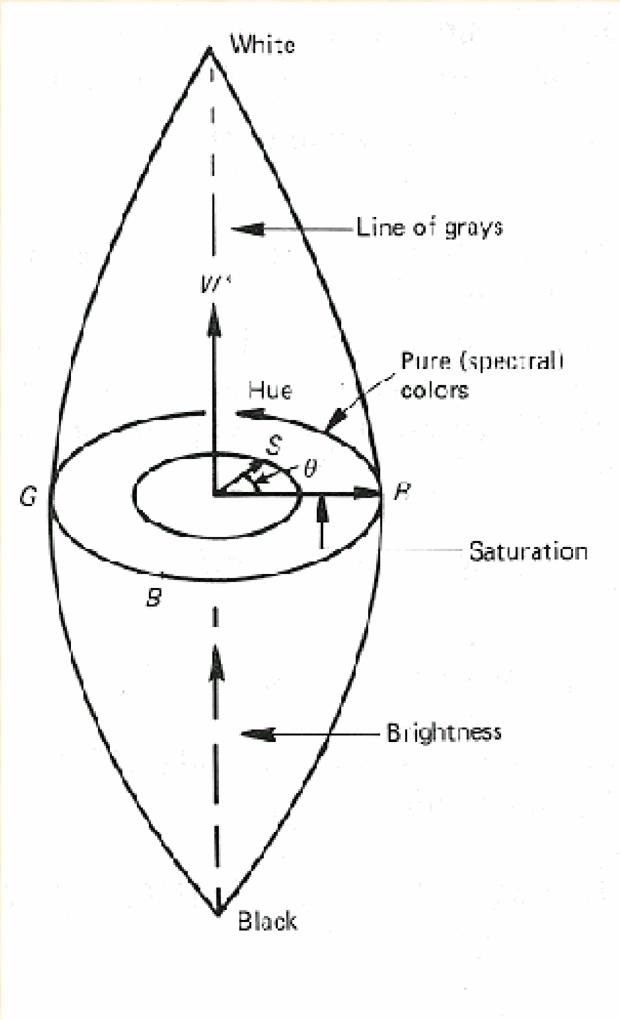
- HSV or HSI
  - similar to YUV except expressed in polar coordinates
  - H denotes hue, S denotes saturation, V (I) denotes value (intensity)
- CYMK
  - subtractive primaries for printing plus black(K)

# Colour Space



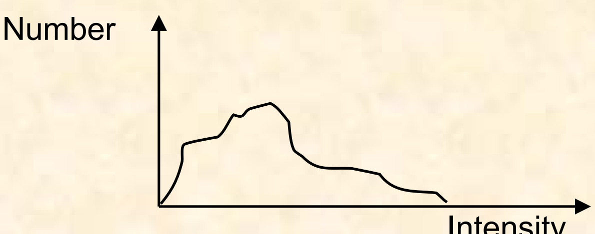



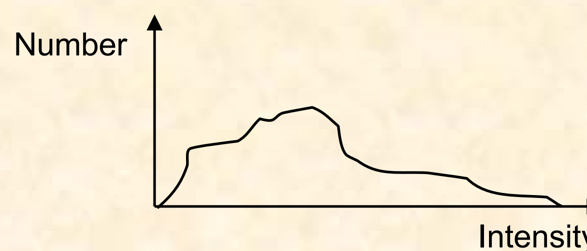
# Image Enhancement

- Operations such as image adjustment for under and overexposure are best done in, say, HSV space rather than RGB space

RGB Equalization




HSV
Histogram
Equalization

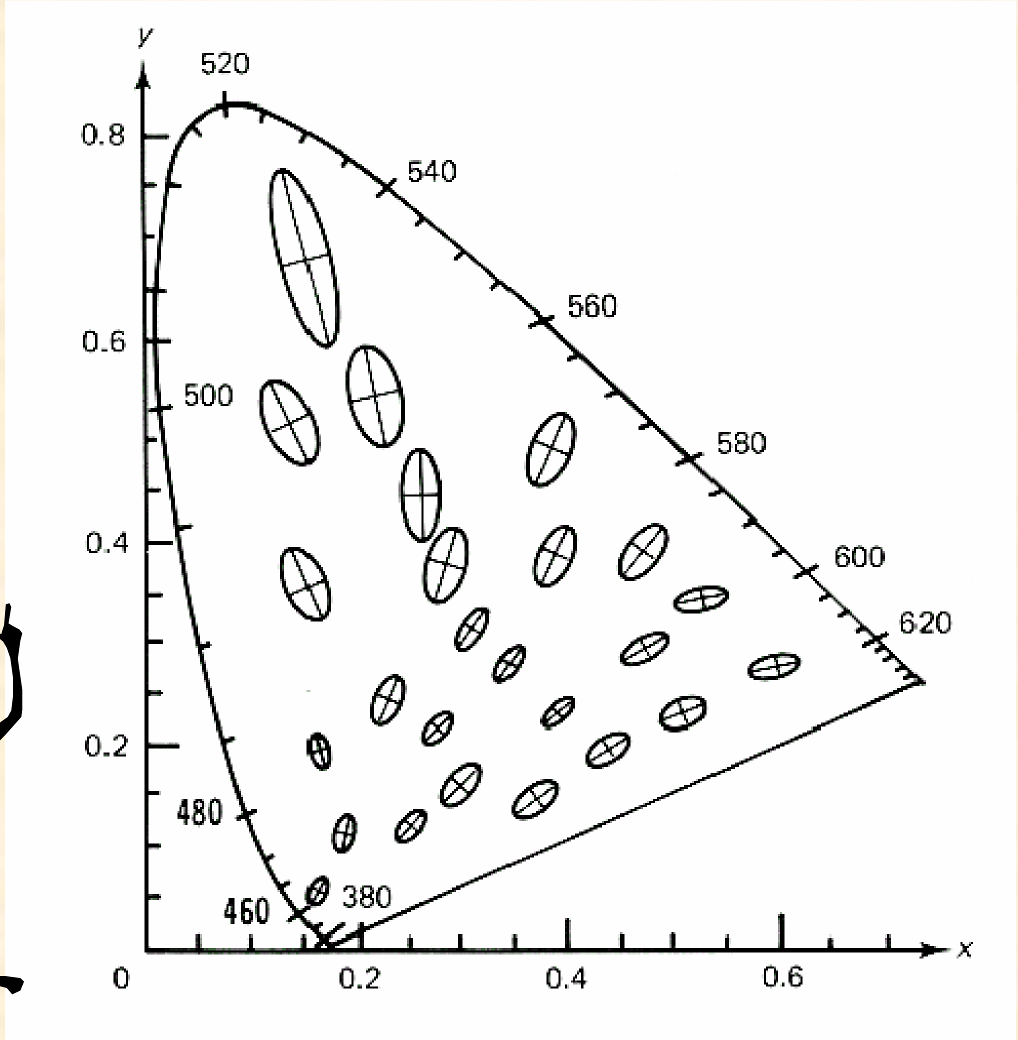


# Colour Matching

- If we wish to use these colour coordinates to compare colours we have a problem.
  - For some colours, very small changes in RGB space, say, can yield very noticeable differences
  - For other colours, large changes in RGB values cause very little colour change
  - In other words, these colour coordinate systems are perceptually non-linear
  - What we need is a warping of these spaces so that Euclidean distances correspond to colour differences
  - Use *CIE perceptually linear colour space*, sometimes called the *uniform chromaticity scale* (UCS)

# Just Noticeable Differences

This nonlinearity can be shown by plotting JND (just noticeable difference) ellipses on the chromaticity diagram.



# Conversion of YUV to UCS

$$(\Delta s)^2 = (\Delta L^*)^2 + (\Delta u^*)^2 + (\Delta v^*)^2$$

Colour Distance

$$L^* = 25\left(\frac{100Y}{Y_0}\right)^{1/3} - 16$$

$$u^* = 13L^*(u' - u_0);\; v^* = 13L^*(v' - v_0)$$

$$u' = u;\; v' = 1.5v$$

$u_0, v_0, Y_0$ corresponds to reference white

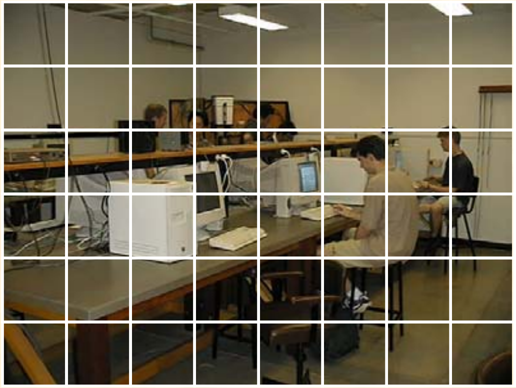
CIE 1976

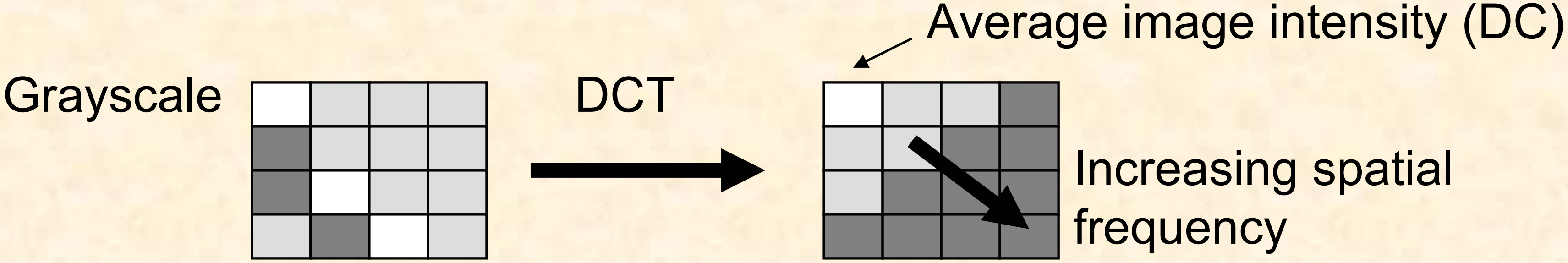
# File Formats

- PPM
  - portable pixel map, 8/24 bit colour, uncompacted (big files)
- BMP
  - windows bitmap, uncompacted
- Compuserve GIF (Generic Interchange Format)
  - 256 (8 bit) colours only, compacted (lossless compression)
- TIFF
  - 8/24 bit colour, compacted
- JPEG (Joint Photographic Experts Group)
  - 8/24 bit colour, usually compressed (lossy)
  - Usually best for photographs, very small files

# JPEG Encoding

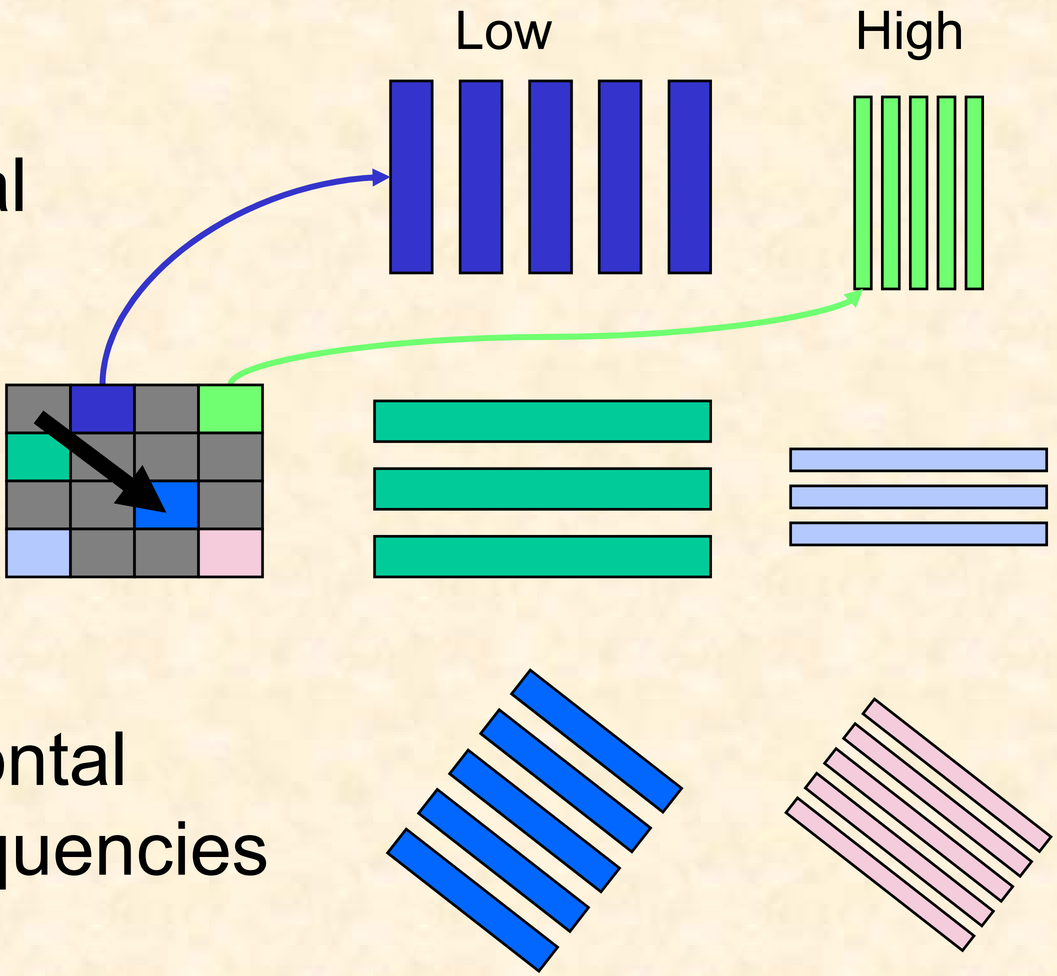
- Split Image up into RGB monochrome components
- Split monochrome components into 8x8 grayscale pixel blocks
- Perform Discrete Cosine Transform (DCT) on each block to get 8x8 spatial frequency bins (all real)





# Spatial Frequencies

- Horizontal Spatial Frequency
- Vertical Spatial Frequency
- Mixture of Horizontal and Vertical Frequencies



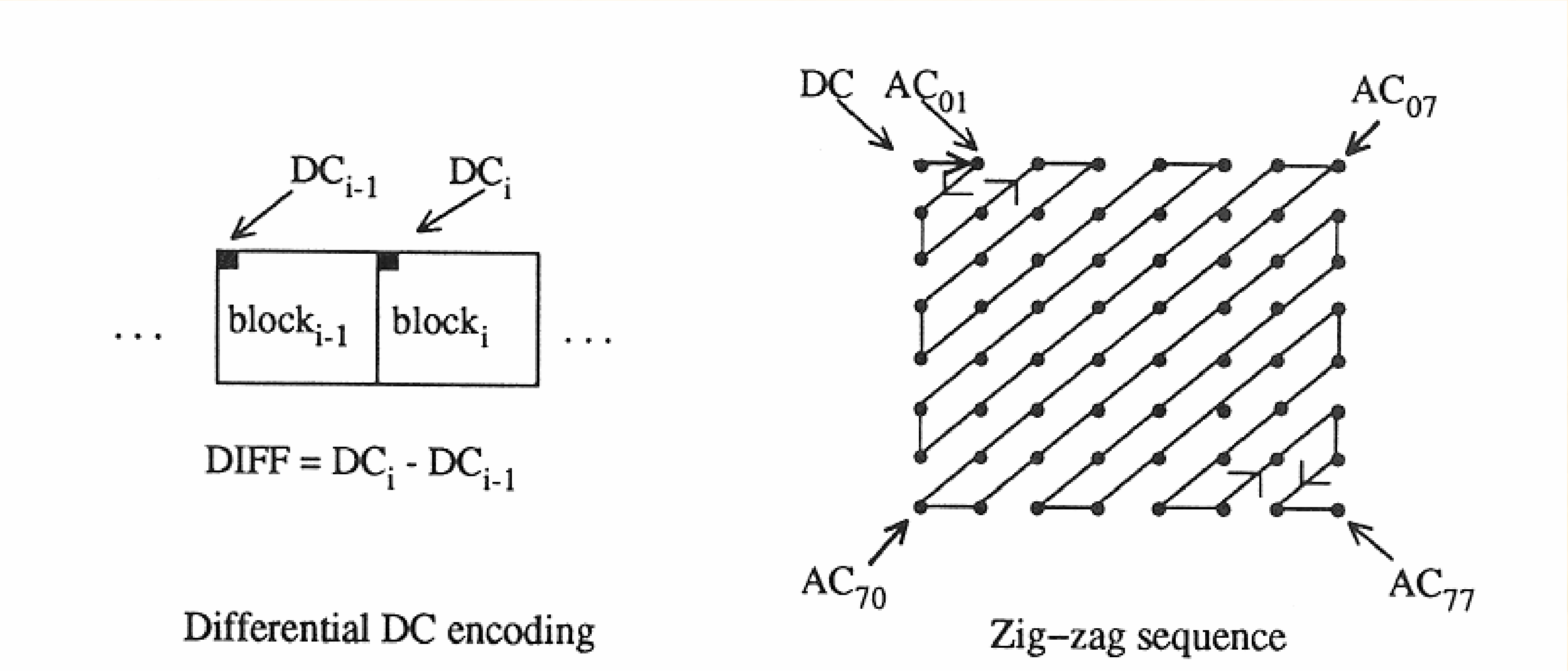
# Purpose of DCT

- Coefficient at index (0,0) corresponds to DC or average intensity and is always positive
- The other 63 coefficients correspond to AC components and can be either positive or negative
- Because pixel values typically vary slowly from point to point across an image, the DCT achieves data compression by concentrating most of the signal in the lower spatial frequencies
- For a typical 8x8 block most spatial frequencies will be zero or near zero and need not be encoded

# Quantization

- After the DCT each coefficient is quantized non-uniformly into 8 bits. The quantization levels were carefully determined from psychovisual experiments (error level below perceptual threshold)
- After quantization, the DC coefficient is handled separately.
  - This is worth while, because it always contains a significant fraction of the image energy
  - It is encoded as the difference from the last DC coefficient encoded
- AC coefficients are scanned in a zigzag pattern and then compacted with either Huffman or Arithmetic coding
  - The zigzag ordering helps the compaction by placing low-frequency coefficients (which are more likely to be non-zero) before high frequency coefficients.

# Zigzag Encoding



# JPEG Processing Chain

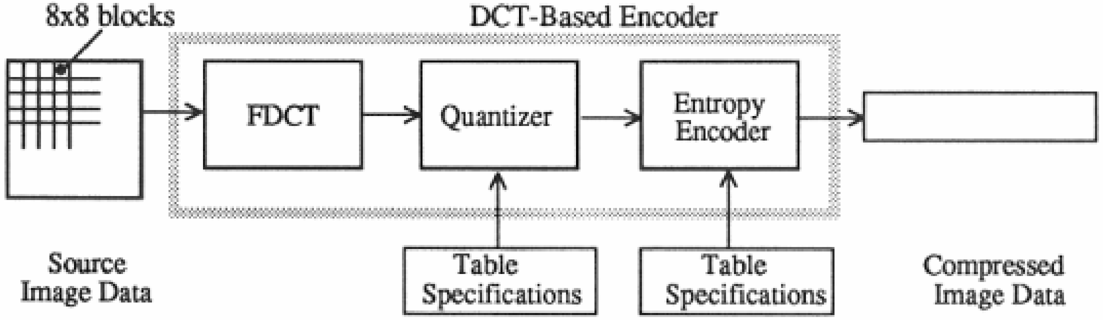



Figure 1. DCT-Based Encoder Processing Steps

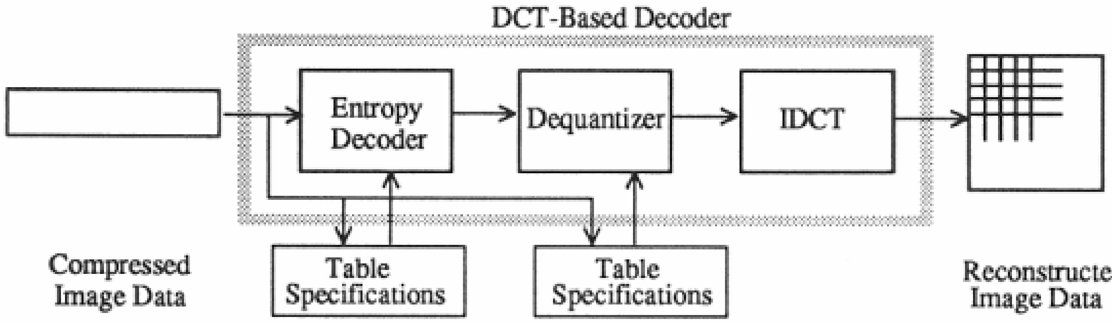


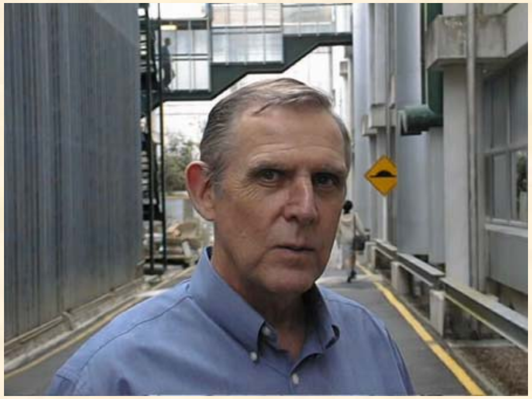

Figure 2. DCT-Based Decoder Processing Steps

# Overall Performance

- 0.25-0.5 bits/pixel: moderate to good quality
- 0.5-0.75 bits/pixel: good to very good quality
- 0.75-1.5 bits/pixel: excellent quality, sufficient for most applications

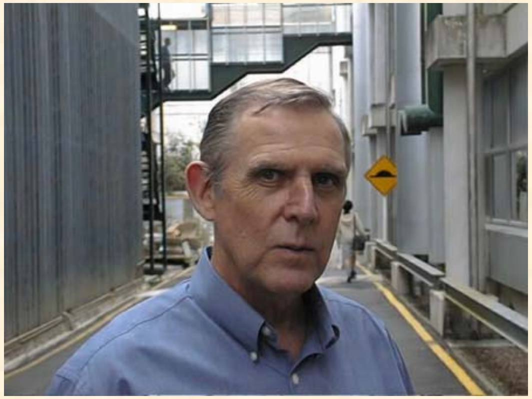
Note: JPEG can be lossless but rarely implemented

Original BMP file 1:1
448x336 pixels



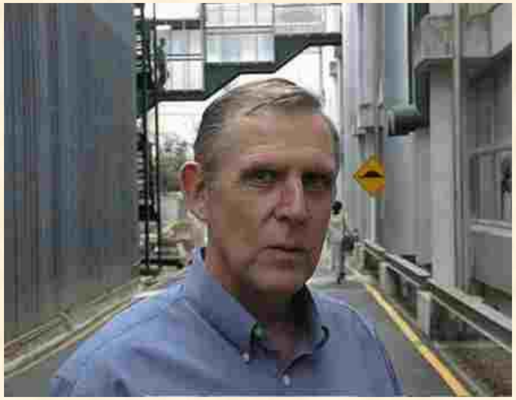
442 kB

Good JPEG 14:1



32 kB

Acceptable JPEG 63:1



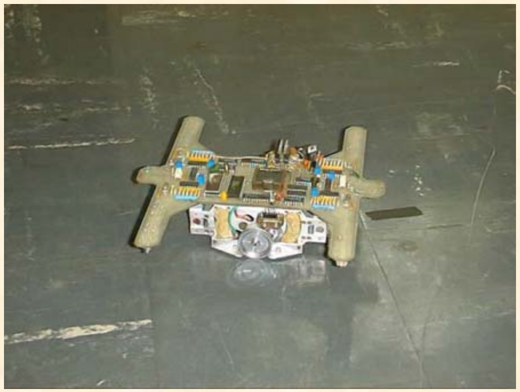
7 kB

# Common Image Processing Tasks

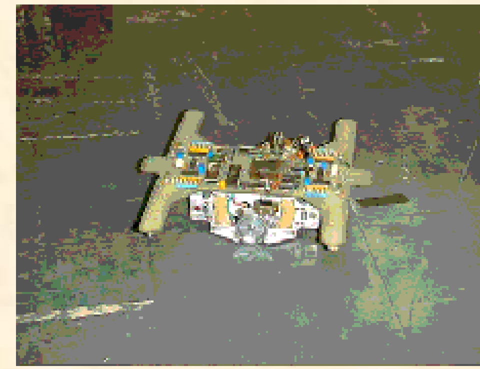
- Thresholding (2 level quantization)
- Requantizing (changing number of quantization levels)
  - sometimes called posterizing in application packages
  - necessary to convert 24 bit colour to 8 bit colour models
  - may require dither to prevent “false contours”
- Blurring
  - convolving with a 2D low pass FIR filter (point spread function)
- Sharpening
  - convolving with a 2D high boost FIR filter
  - note: do not use high pass as you will lose DC component and resultant image will have negative intensity values

# Examples

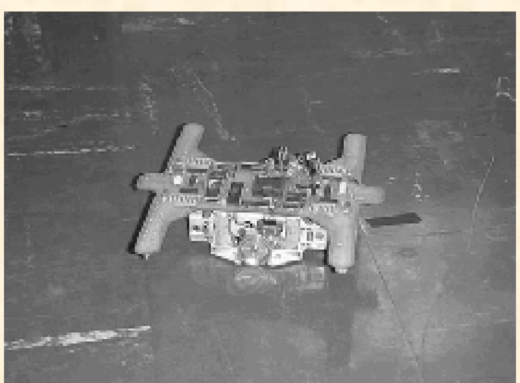
Original Image



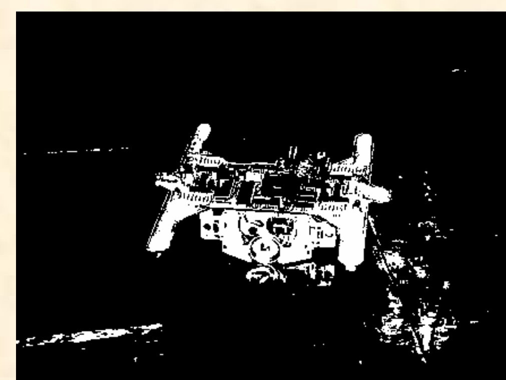
Posterizing:
reduced to
8 colours only



Grayscale
conversion

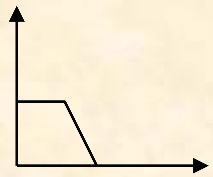


Thresholding



# Examples

**3x3 2D Filter** $\frac{1}{9}*\begin{bmatrix}1 & 1 & 1\\1 & 1 & 1\\1 & 1 & 1\end{bmatrix}$



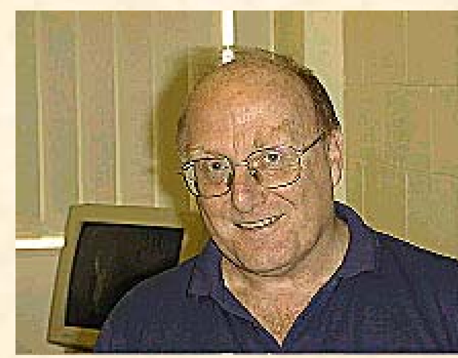
lowpass

2D CONVOLUTION

**Blurred**

2D CONVOLUTION

**Sharpened**



**3x3 2D Filter**

HIGHPASS, ALLPASS, HIGH BOOST

$$\frac{1}{10}*\begin{bmatrix}1 & -1 & 1\\-1 & 0 & -1\\1 & -1 & 1\end{bmatrix}+\begin{bmatrix}0 & 0 & 0\\0 & 1 & 0\\0 & 0 & 0\end{bmatrix}=\begin{bmatrix}0.1 & -0.1 & 0.1\\-0.1 & 1 & -0.1\\0.1 & -0.1 & 0.1\end{bmatrix}$$

highboost