Outline: Image Processing

- Efford, N., 2000. *Digital image processing, a practical introduction using Java*, Addison-Wesley, Harlow, UK.
- First developed by NASA to aid moon landings.
- Applications.
- Contrast enhancement.
- Filtering.
- Baxes, G. A., 1994. *Digital Image Processing: Principles and Applications*, John Wiley & Sons, New York.

Applications

- There are many applications:
  - remote sensing;
  - medical applications;
  - intelligence gathering / law enforcement / 'smart' weapons;
  - document processing;
  - artistic;
  - car guidance and
  - optical correction (Hubble telescope).
- This is a growing and non-exhaustive list!

Image processing

- Two main classes:
  - image enhancement
  - image restoration
  - but could include image compression and image analysis.
- Image restoration is concerned with the correction of
  - camera induced errors (photogrammetric correction)
  - viewing induced errors (geometric correction)
- Inherently a very statistical subject, which this introduction ignores!

Contrast enhancement

- Aim is to change the contrast in an image.
- Attained by changing the distribution of the image brightness histogram.
- Stretching the histogram produces increased contrast.
- Often used to improve the look of digital photographs.
- Binary thresholding produces a black and white image, often used prior to some pattern analysis.
- Thresholds, etc may be set adaptively (that is to vary across the image).

Image Filtering

- Filtering is used to change the (local) properties of the image.
- Usually locally applied (in space or frequency).
- Can be expressed as a matrix representing the weights applied to the central pixels neighbourhood.
- A smoothing or blur filter is given by:

$$\frac{1}{9}\begin{bmatrix}1 & 1 & 1\\ 1 & 1 & 1\\ 1 & 1 & 1\end{bmatrix}.$$

- Applied to each 3×3 pixel portion of the image.

Filtering

$$\frac{1}{9}\begin{bmatrix}1 & 1 & 1\\ 1 & 1 & 1\\ 1 & 1 & 1\end{bmatrix}.$$

- Sum of the filter values is 1, thus no change to the overall brightness.
- Called a low pass filter (noise filter) since it leaves low frequency components unchanged.
- Another low pass filter that is frequently used is the median filter, which replaces the central pixel with the local median value. Effective at removing speckle noise.

Filtering

- The opposite is the high pass filter, which acts to sharpen details:

$$\begin{bmatrix}-1 & -1 & -1\\ -1 & 9 & -1\\ -1 & -1 & -1\end{bmatrix}.$$

- This sharpening filter also has unit sum, thus preserves image brightness.
- Used to enhance the look of digital images – note it also changes their entropy.

Edge filtering / detection

- An edge filter is often used prior to edge detection.
- The most simple edge filters are:

$$\begin{bmatrix}0 & -1 & 0\\ 0 & 1 & 0\\ 0 & 0 & 0\end{bmatrix}, \quad \begin{bmatrix}0 & 0 & 0\\ -1 & 1 & 0\\ 0 & 0 & 0\end{bmatrix}$$

- These find either horizontal or vertical edges – can you see why?

Edge filtering / detection

- A more effective, but still directional filter is the Prewitt gradient filter:

$$\begin{bmatrix} 1 & 1 & 1 \\ 1 & -2 & -1 \\ 1 & -1 & -1 \end{bmatrix}$$

- A non-directional edge filter is the Laplacian filter:

$$\begin{bmatrix} 1 & 1 & 1 \\ 1 & -8 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

Image processing – there must be more?

- Relatively new field, based on statistical concepts, but can use empirical methods.
- Contrast enhancement - alter the image histogram.
- Filtering - alter the image locally (in space or frequency).
- Many uses, typically applied prior to further (statistical) processing.

Summary

- Having finished this lecture you should:
  - be able to discuss the role and application of image processing;
  - be able to apply basic contrast enhancement and filtering;
  - define appropriate filters to use for simple tasks;
- Image processing is a very exciting area of computer science research with many useful outcomes.