Image Processing

Lecture 7

Terminology

- resolution (spatial)
- grey levels
- brightness
- contrast
- noise
- filtering

Image Processing Techniques

- The simplest algorithms operate on each pixel in isolation.
- Most algorithms take into account a pixel's neighbours using various weights to compute a new pixel value.
- These algorithms typically use *kernels* (templates) which indicate the relative weight of nearby pixels.

Kernels

- Each pixel is processed in turn and placed at the centre of the kernel. The *original* image pixel values are multiplied by the kernel weights, summed and divided by the kernel sum.
- Positive numbers *tend* to produce averaging effects, negative numbers *tend* to produce difference/edge detection effects.
- Examples:

	1	
1	2	1
	1	

1	2	1
2	4	2
1	2	1

-1	0	1
-1	0	1
-1	0	1

Spatial vs Fourier Domain

- Applying a kernel in the spatial domain is the same as applying a convolution in fourier domain.
- Applying a kernel (ie convolution) is a reversible procedure. This forms the basis of many image correction techniques in which the problem (eg blurring) can be expressed as a convolution
- Example: Hubble Space Telescope

Image Capture Problems

- Images requiring processing are typically digitized from cameras.
- The process of capturing a images introduces problems. Some of the problem areas are:
  - Lighting
    - insufficient / non-uniform
  - Geometric
    - spatial distortion (pincushion, barrel, keystone etc)

Image Correction

Image Correction

- Correct before digitizing if possible
- Post digitization works but has limitations
- Common types of correction include:
  - Contrast adjustment
  - Noise reduction
  - Background subtraction
  - Geometric correction
    - requires some form of fiducial marks.

Image Noise

- Image noise often occurs in statistical image collection where individual photons are gathered. Insufficient time integration leads to low signal-noise ratio.
- Noise may also occur as the result of insufficient digitization resolution or low quality equipment.
- Several different types of noise (eg shot)

Original

Noisy Picture

Noise Reduction Algorithms

- Key requirement of noise reduction algorithms:
  - pixel size << interesting object size
  - neighbouring pixels are generally of the same object
- Methods of noise reduction include
  - neighbourhood averaging
  - neighbourhood ranking.

Neighbourhood Averaging

- Common kernels

Simple

1	1	1
1	1	1
1	1	1

Gaussian

1	2	1
2	4	2
1	2	1

- Problems
  – edge shift, reduced image contrast.

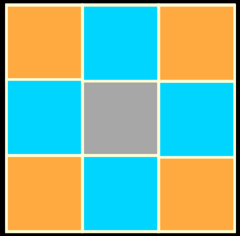
Neighborhood Ranking (Median)

- Median Filter
  - rank pixels in kernel based on intensity.
  - set median value is the new value
- Benefits:
  - maintains intensity and edge location
  - Reduces shot noise
- Problems:
  - loss of fine detail (lines narrower than filter half-width)
  - corners become rounded
  - repeated application reduces grey scales, resulting in posterisation / contouring effects.

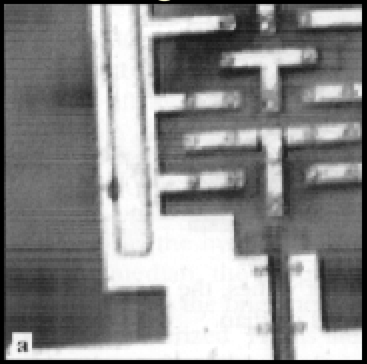
Hybrid Median Filter

- Ranks ‘x’ and ‘+’ components of kernel separately.
  - Reduces corner rounding
  - Reduces shot noise

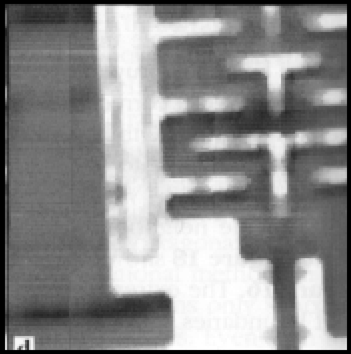
Median Filter

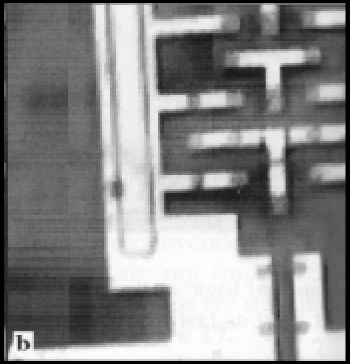


Original



Median





Hybrid Median

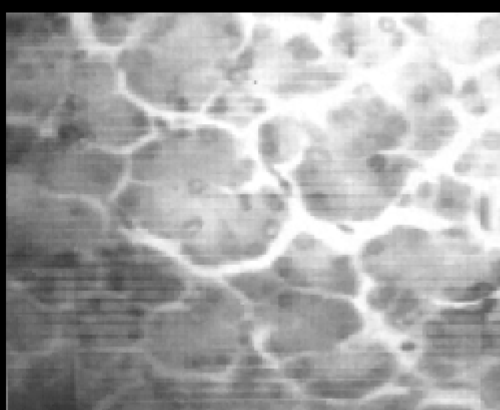
Background Subtraction

- Used to remove non-uniform background levels due to lighting problems.
- Removal technique depends on camera / digitizing system
- Eyes respond logarithmically to intensity, some systems therefore acquire on a log scale, others use a linear scale.
- To remove background (per pixel calculation)
  - Linear: divide by the background image
  - Log: subtract background.

Background Subtraction…

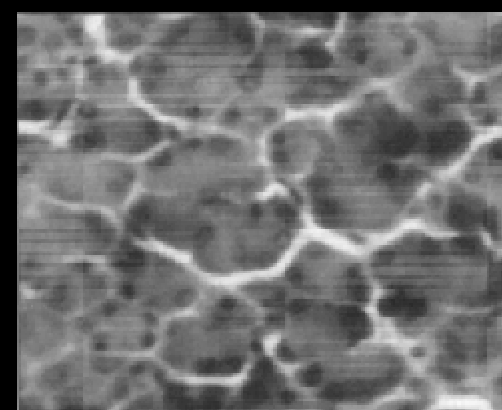
- Background may be acquired as a separate image or computed from a low order polynomial fitted to image.
- Other techniques include low pass filter.
- Background removal reduces the dynamic range (available grey scale levels)

Original



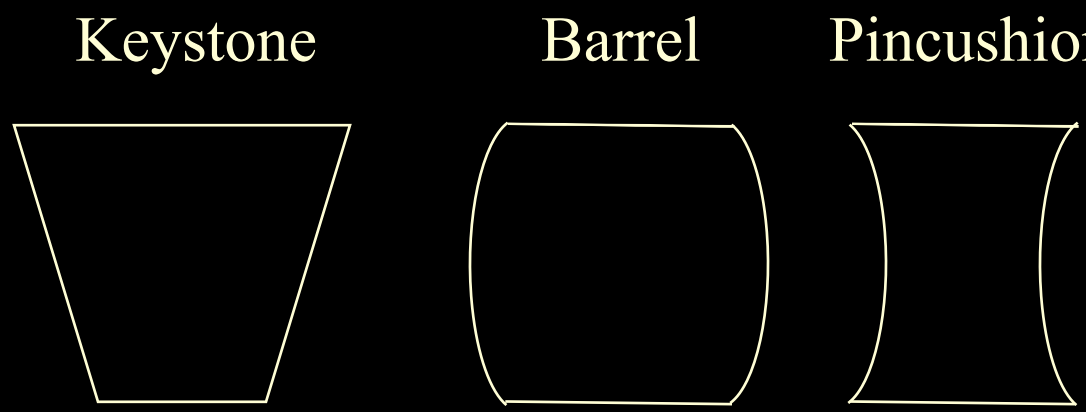
Background

Corrected



Geometric Distortion

- An obvious category of geometric distortion is satellite images which typically require complex projection calculations.
- Simpler situations also exist with digitized images
- Examples:



Adaptive Filters

- Adaptive filters change their algorithm depending on image content to produce the best result.
- This may mean selecting from a set of algorithms or having one algorithm with adjustable weights (for example).

Image Enhancement

Image Enhancement

- Having corrected the image as close as possible to a theoretical ideal, the process can be taken further to actively enhance the image.
- The distinction between correction and enhancement is often blurred.
- Example: Image may have low contrast (little dynamic range between darkest and lightest colours in the image.

Image Look Up Tables (LUTs)

- Greyscale images (and pseudo colour) typically have LUTs which can be modified to enhance the image.
- LUTs map the pixel value to an intensity and are typically 8 bits in size (values range from 0 - 255)
  - (0 off, 255 white)
- Default LUTs are typically linear (f(i) = i), but sometimes log f(i) = log(i).

Contrast Enhancement

- Low contrast images do not use all of dynamic range available, detail may be hidden in small pixel value variations which the eye cannot perceive.
- The interesting range of pixel values may be remapped to cover a larger range (compressing uninteresting detail).
- One of the basic variation is gamma correction

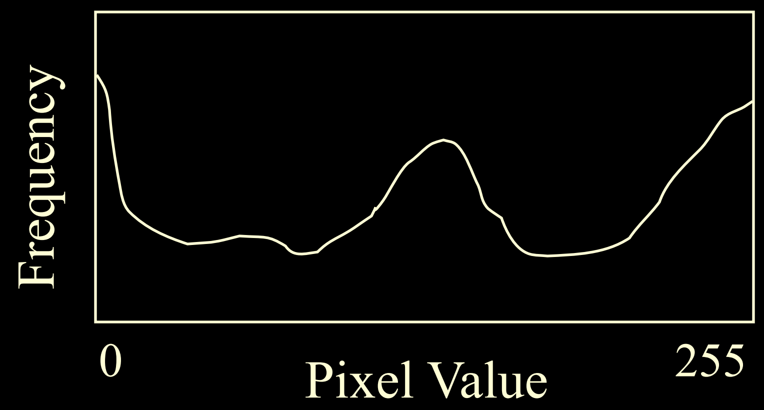
Gamma Correction

- Eye responds to *ratios of intensities* **not** absolute value.
  - Eg perceived difference between 0.1 and 0.11 is same as difference between 0.9, 0.99
- Intensity levels should be spaced logarithmically (rather than linearly) to produce even intensity steps.
- Enter the gamma function.

$$\text{new} = \text{old}^{\,1/\text{gamma}}$$

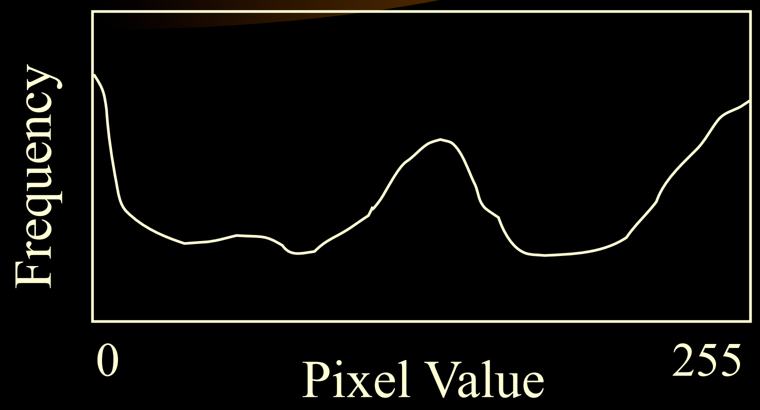
Histogram

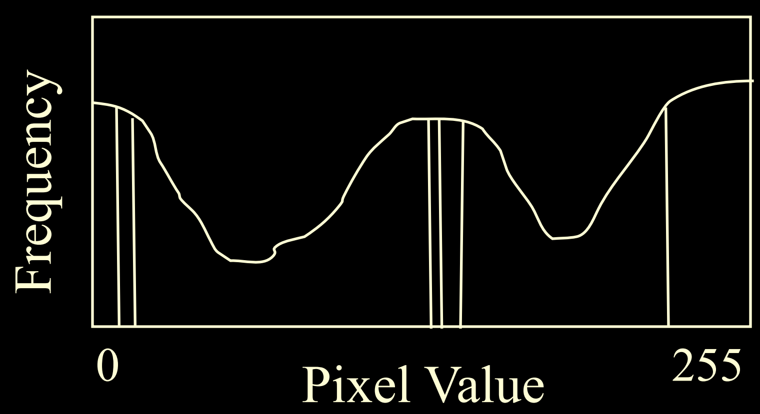
- Histogram is an intensity analysis tool
- Records the number of times each pixel value occurs in an image.
- From this we can determine how the dynamic range might better be utilised.
- Other uses include identification of intensity regions (eg a binomial distribution).
- Be aware that histograms of same scene will vary depending on illumination (peak shifts).



Histogram Equalization

- Assumes information at each grey level is equally important, and thus should be equally visible.
- Aim: make each intensity value (0-255) have same number of pixels in the image.
- In the histogram domain: Narrow spikes become wider, large areas of low intensity are compressed together.
- Due to the stretching, some pixel values may no longer be used in image.





Histogram Equalization

- Equalization may only be required on a region in the image.
- Problems:
  - irreversible, loss of information occurs as many values may be compressed into one shade.
  - If intensity gives classification information, no longer true

Laplacian

- Take locality of histogram equalization to a limit and apply it on a per pixel basis using kernels.
- Can be useful in edge detection / enhancement
- Subtracts the brightness of neighbouring pixels.
- Result: all uniform areas become dark, edges
- Laplacian Examples (3x3)
  - Note: Previous kernels were all symmetric and positive

	-1	
-1	4	-1
	-1	

-1	-1	-1
-1	8	-1
-1	-1	-1

Laplacian…

- Resultant pixel value may be <0, typically offset by 128.
- As implied by name the Laplacian operator approximates the 2nd derivative of intensity (in both directions)
- In Fourier domain this is termed a high-pass filter
- Laplacian is not the ideal edge detection tool.
  - It responds more to points and lines than edges, a problem with noisy images.

Laplacian sharpening operator

- This is simply the original image with the Laplacian subtracted from it.
- The operation can be performed in one step by a modified kernel, termed the *sharpening operator*

1	1	1
1	-7	1
1	1	1

Unsharp Masking

- Performs local region contrast enhancement.
- Similar to the Laplacian.
  - Subtract a smoothed (low passed) image from original.
- Suppresses slow variations in brightness to enhance detail.
- Used in Astronomy (originally a film developing technique)

Asymmetric Kernels

- Directional derivative kernels used to enhance edge detection in specific directions.
- May be applied in up to 8 orientations (45^{o} apart)

1	0	-1
1	0	-1
1	0	-1

0^{o}

1	1	0
1	0	-1
0	-1	-1

45^{o}

1	1	1
0	0	0
-1	-1	-1

90^{o}

etc…

Other Kernel Operators

- Many other kernels and operators
- Examples:
  - Robert’s Cross
  - Sobel Operator
  - Difference of Gaussian (DOG)

- Performing derivatives using kernels is a cross-correlation (template matching) process.
- The template gives a maximum response when it matches the brightness pattern in the image.