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Computer Graphics and Image Processing

Lecture B3

Region Processing

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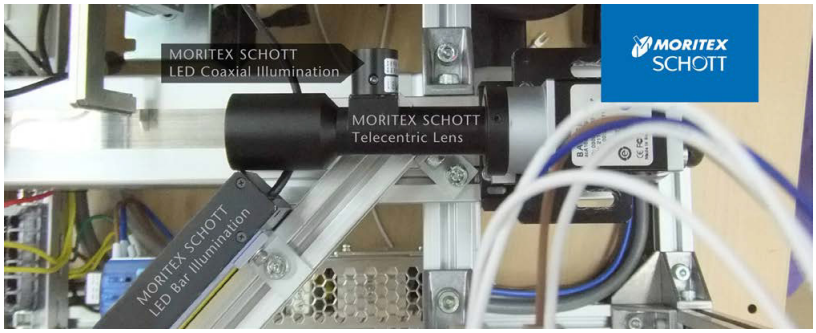
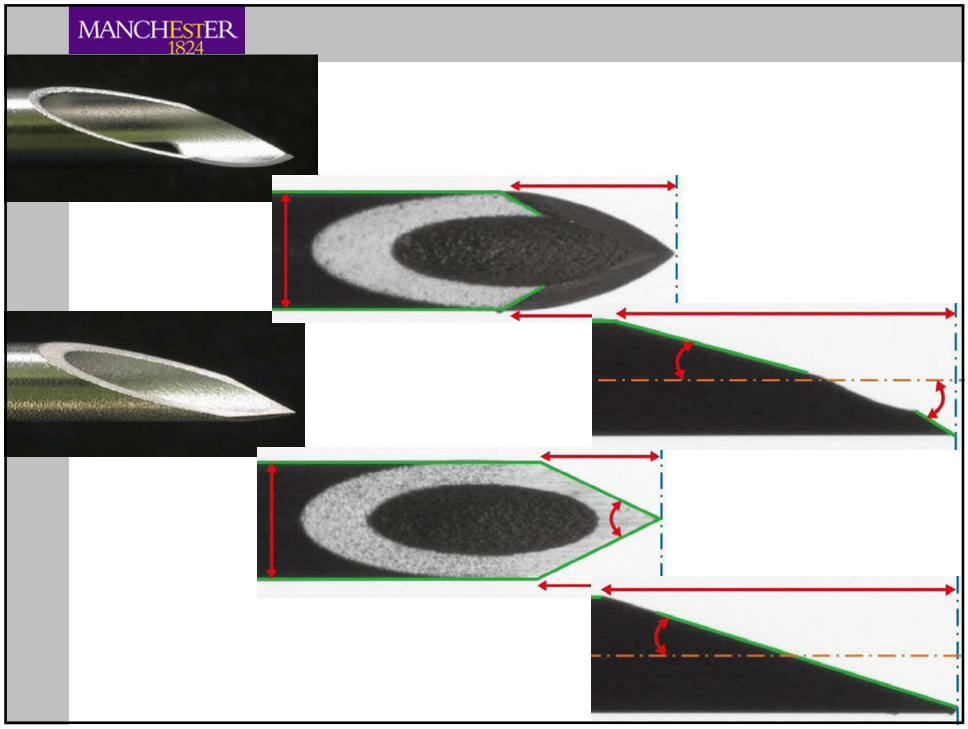
Hypodermic needle inspection
http://www.baslerweb.com





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Contents

- Convolution
- Smoothing
- Edge detection
- Template Matching
- Rank Filters

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Convolution Definition

$$g'(r,c) = \sum_{x=-\infty}^{\infty} \sum_{y=-\infty}^{\infty} g(r-x, c-y) \cdot t(x,y)$$

Place template on image

Multiply overlapping values in image and template

Limits are template size

Sum products (and normalise)

Templates usually small

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Example

Image	Template	Result
... .		... .
... 3 5 7 4 4 ...		... .
... 4 5 8 5 4 ...	1 1 1	... . 6 6 6 . ...
... 4 6 9 6 4 ...	1 2 1	... . 6 7 6 . ...
... 4 6 9 5 3 ...	1 1 1	... . 6 7 6 . ...
... 4 5 8 5 4 ...		... .
... .		... .

3*1 + 5*1 + 7*1 +
4 *1 + 5*2 + 8*1 +
4*1 + 6*1 + 9*1

Divide by template sum (10) = 5.6

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Normalisation

- Lab example of smoothing without normalisation
- Convolve with $\begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$
- Maximum pixel value is 255
- Smoothed value would be 255*9
- What is output?

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- Therefore either normalise the output
- Or convolve with $\begin{bmatrix} 1/9 & 1/9 & 1/9 \\ 1/9 & 1/9 & 1/9 \\ 1/9 & 1/9 & 1/9 \end{bmatrix}$

Separable Templates (Aside)

- Convolve with n x n template
  - n^2 multiplications and additions per output pixel
- Convolve with two n x 1 templates
  - 2n multiplications and additions per output pixel
- Results in faster processing

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Example

- Laplacian template

$$\begin{matrix} 0 & -1 & 0 \\ -1 & 4 & -1 \\ 0 & -1 & 0 \end{matrix}$$

- Separated kernels

$$\begin{matrix} -1 & 2 & -1 \end{matrix} \qquad \begin{matrix} -1 \\ 2 \\ -1 \end{matrix}$$

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Composite Filters

- Convolution is distributive

$$A \otimes (B \otimes C) = (A \otimes B) \otimes C$$

- Can create a composite filter and do a single convolution
- ***Don't*** convolve image with one filter and convolve result with second.
- Efficiency gain

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Example

- Two n x n filters convolved with a m x m image
- Option 1
  - Convolve image and template ≈ n^2 x m^2 multiplications and additions
  - Convolve image and template ≈ n^2 x m^2 multiplications and additions
- Option 2
  - Convolve template and template ≈ n^2 x n^2 multiplications and additions
  - Convolve image and template ≈ n^2 x m^2 multiplications and additions

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Applications of Convolution

- Usefulness of convolution is in the effects generated by different templates
- Examples:
  - Smoothing
    - Noise reduction
  - Sharpening
    - Edge enhancement
  - Template matching
    - Finding objects

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Smoothing

- Aim is to reduce noise
- A digression
  - What is "noise"?
- How is it reduced
  - Addition
  - Adaptively
  - Weighted

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Noise Definition

- Noise is deviation of a value from its expected value
  - Random changes
    - x → x + n
    - n can be positive or negative
    - Random distribution and mean is zero
    - Usually much smaller than max(x)
  - Salt and pepper
    - x → {max, min}
    - *Much* less common
  - Imaging artefacts
    - Streaks and blooms

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Noise Sources

- Two schools of thought:
  - Anything *within the imaging system* that causes a change
    - Electrical interference
    - Optical aberration
  - *Anything* that causes a change
    - Atmospheric disturbance
- First is preferred definition

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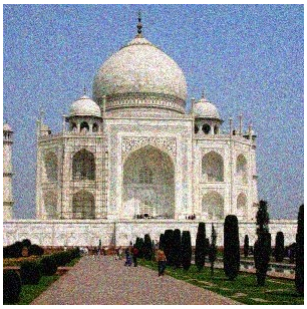
System Noise



Random noise

Streaks:
coding or transmission noise

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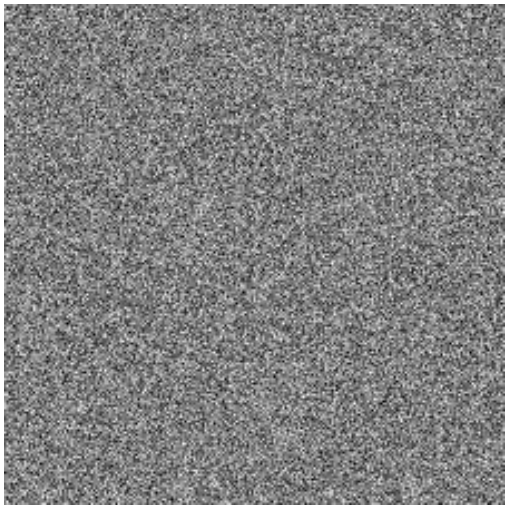

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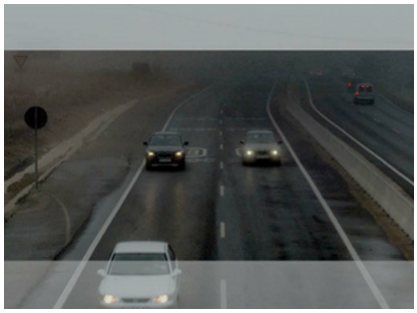
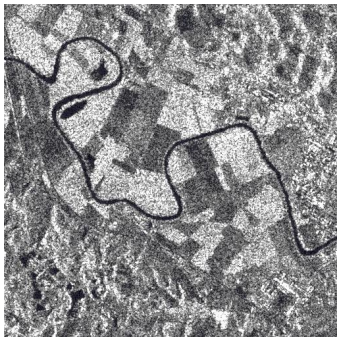
External Noise



Fog



Blur

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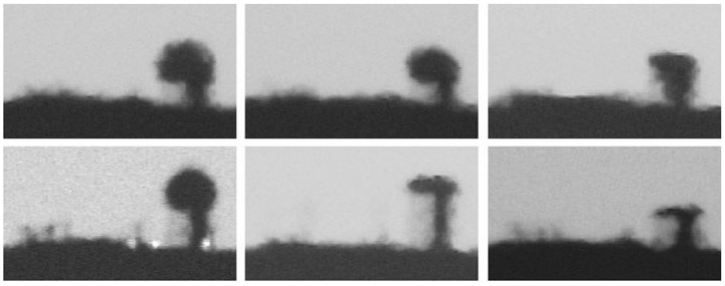

Images of a radar dome at 128 km taken at about 1 minute intervals

Vertical white line is an artefact caused by the capturing

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Noise Reduction

- By smoothing

  $\Sigma(x + n) = \Sigma(x) + \Sigma(n) \approx \Sigma(x)$

  – Since noise is random and zero mean
- Smooth locally or temporally
- Local smoothing
  – Convolve with what template?
    - Suggestions?
  – Removes detail
  – Introduces ringing
- Noise amplitude reduced by template length

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Examples

- Laboratory exercises
- And below

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Adaptive Smoothing

- Compute smoothed value, s

Output = s if $|s - x| < T$

x otherwise

Rank Filters: Median Smoothing

Median is one value in an ordered set, X:

$$X\left(\frac{n+1}{2}\right) \qquad n\,odd$$

$$average\left(X\left(\frac{n}{2}\right), X\left(\frac{n+1}{2}\right)\right) \quad n\ even$$

1 2 3 4 5 6 7 → median = ?

2 3 4 5 6 7 → median = ?

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Original

Smoothed

Median Smoothing

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Gaussian Smoothing

- Used
  - To reduce ringing
- Uses
  - Weighted smoothing
- Weights
  - Derived from Gaussian (normal) distribution
- Template
  - Suggestions?

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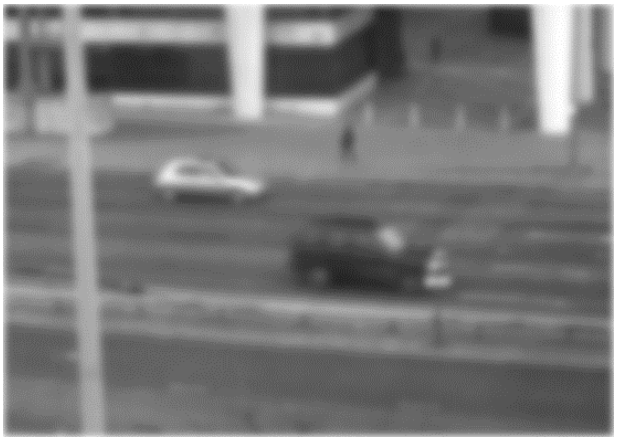
Example



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Sharpening

- What is it?
  - Enhancing discontinuities
  - Edge detection
- Why do it?
  - Perceptually important
  - Computationally important

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Everything that can be invented has been invented

Charles Duell, Commissioner U.S. Office of Patents, 1899