Digital Image Processing
Image Enhancement. Part 1

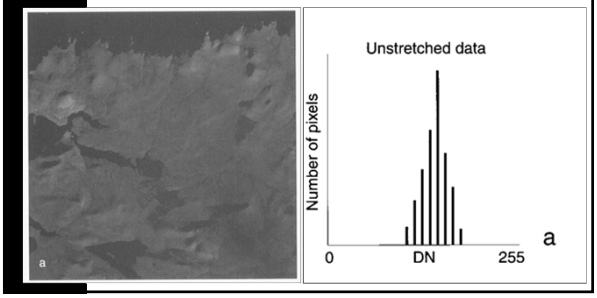
Prof. D. Nagesh Kumar
Dept. of Civil Engg.
IISc, Bangalore – 560 012, India
URL: http://www.civil.iisc.ernet.in/~nagesh

Image Enhancement

- There is no single enhancement procedure which is best
- Best one is that which best displays the features of interest to the Analyst
- Enhancement Procedures
  - Contrast stretching
  - Density slicing
  - Thresholding
  - Filtering techniques
  - Edge enhancement
  - Intensity, Hue, Saturation (IHS) images
  - Time composite images
  - Synergetic images
  - Non-image datasets

Contrast Stretching

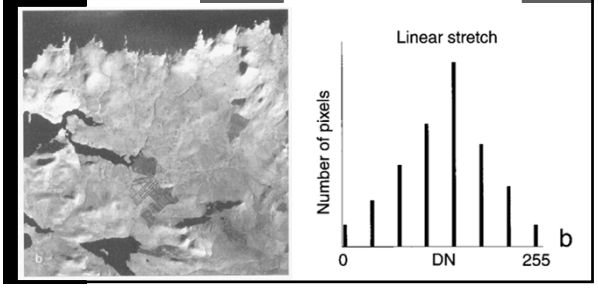
- TM B5 image
- Image is very dark
- Low contrast
- Sensor calibration



Linear Stretching

Linear contrast stretch assigns new digital numbers to an output image by assigning to the lowest and highest DN in the input image values of 0 and 255 respectively in the output image and stretching all intervening digital numbers accordingly

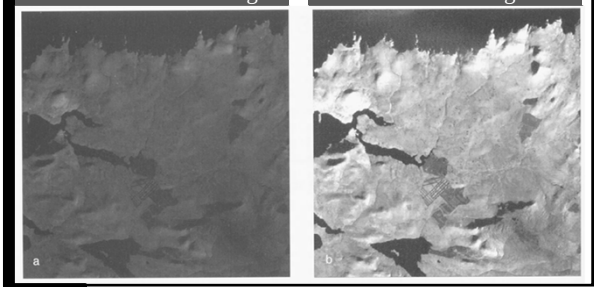
$$DN_{st} = 255 \times \frac{(DN - DN_{min})}{(DN_{max} - DN_{min})}$$



Linear Stretching

Unstretched TM B5 Image

Linear stretched Image



Linear Stretching

A more efficient stretch would be one that mapped the range 40-110 to 0-255

Example

A histogram for a non-enhanced image is shown in Figure 3.3. Calculate the output DNs in a contrast-stretched image for the input values 60, 80 and 200.

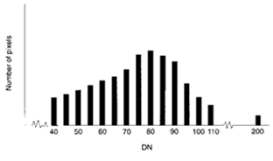


Figure 3.3 Simplified frequency histogram for use with in-text question.

The input range of 160 (200 − 40) is mapped to an output range of 0–255. Therefore each input unit is equivalent to 255/160 output units. The value 40 (lowest) in the input range is assigned a DN of zero (lowest) in the output, therefore:

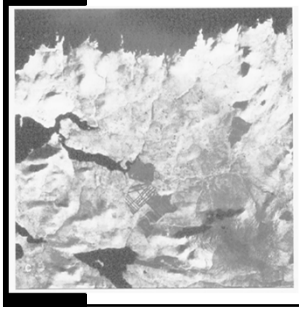
60 in the input is equal to
$20 \times (255/160) = 32$

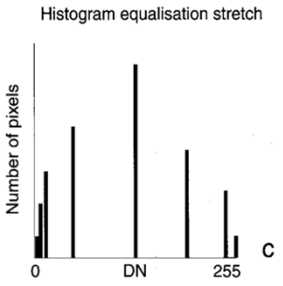
80 in the input is equal to
$40 \times (255/160) = 64$

200 in the input is equal to
$160 \times (255/160) = 255.$

Non-linear Stretching

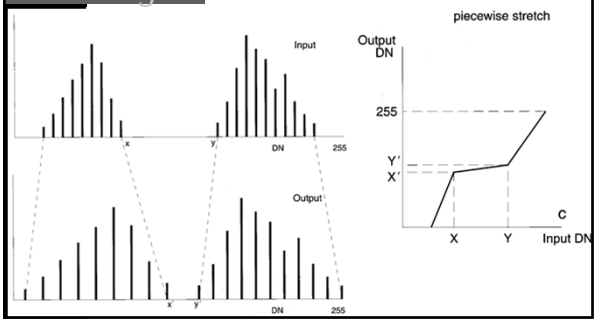
- Linear stretch does not take account of the number of pixels in each DN bin
- Over 85 per cent of the pixels are within the 0—30 range in the input image but they are compressed into only 33 per cent of the output
- A histogram equalisation stretch, however, stretches the input data in proportion to the population of the DN bins and thus provides a better contrast over the most populated part of the scene





Piecewise Linear Stretching

- Bimodal DN histogram and piecewise Stretch which stretches different parts of the original histogram by different amounts
- Note how x-y has been compressed to x'-y'



Non-linear Stretching

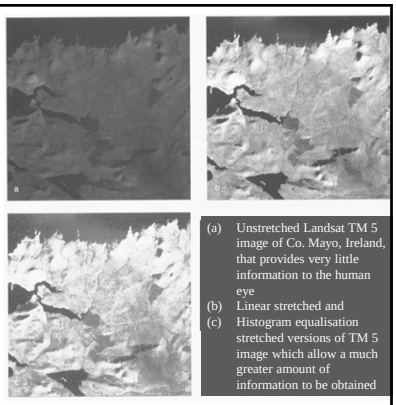
- Logarithmic Stretch
- Power-law Stretch
- Gaussian Stretch

- Log stretch is greater for the low digital numbers (5 and 10) than for the high digital numbers (220 and 225). It preferentially screeches the dark parts of the scene
- Power-law stretch has the opposite effect. It will preferentially stretch the brighter parts of the scene

DN	log DN	DN^3
5	0.699	125
10	1.0	1,000
Difference	**0.301**	**875**
220	2.342	1.06×10^7
225	2.352	1.14×10^7
Difference	**0.01**	$\mathbf{7.4 \times 10^5}$

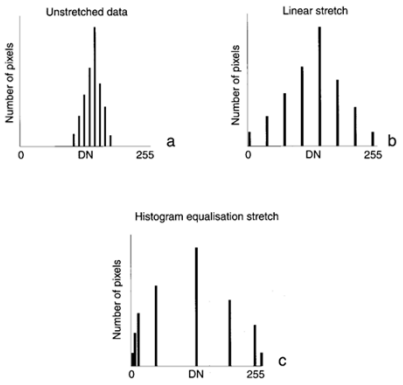
Contrast Stretching

TM B5 Image

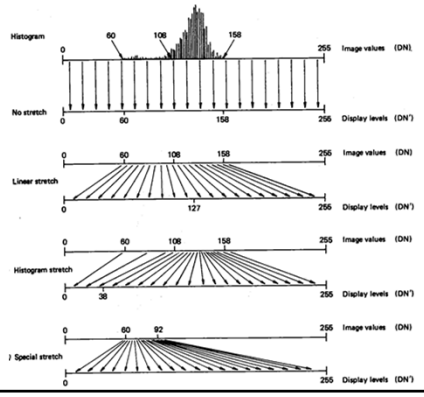


(a) Unstretched Landsat TM 5 image of Co. Mayo, Ireland, that provides very little information to the human eye
(b) Linear stretched and
(c) Histogram equalisation stretched versions of TM 5 image which allow a much greater amount of information to be obtained

Contrast Stretching



Contrast Stretching



Lookup Table

A computer can use the equation to calculate the digital numbers in a stretched image

However, it may take long time.

- A 60 X 60 km multispectral SPOT image would require new DNs to be calculated for 27 million pixels. Assuming 500,000 arithmetic operations a second, this procedure would take nearly four minutes

However, this procedure can be speeded up greatly by the use of look-up tables

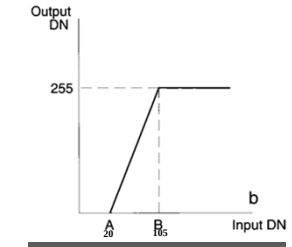
Look-up table for determining output DN for every input DN

LOOK-UP TABLE

Input DN	Output DN
20	0
21	3
22	6
23	9
103	249
104	252
105	255
106	255
120	255

A on graph → (20)

B on graph → (105)



a Graphical representation of look-up table

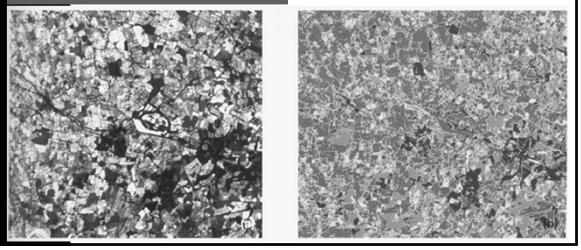
Density Slicing

Introducing color to a single-band image

Density sliced image shows much more clarity than the black and white image

Look-up Table

Colour	DN range
Blue	0–75
Pale blue	76–83
Green	84–102
Yellow	103–116
Orange	117–124
Red	125–136
Pink	137–225



Thresholding

Threshold can be applied to an image to isolate a feature represented by specific range of DNs.

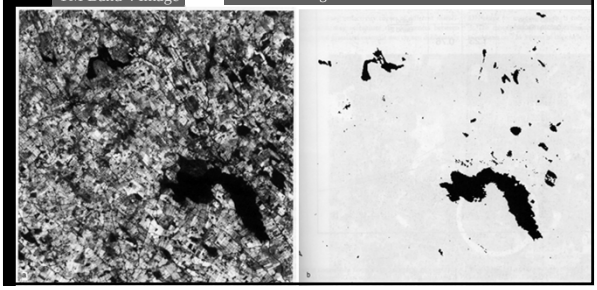
To calculate the area of lakes, DNs not representing water are a distraction

Highest DN for water is 35 and is used as the threshold

All DNs > 35 are assigned 255 (saturated to white); DNs<=35 are assigned zero (black)

The lakes are much more prominent in the image after thresholding

TM Band 4 Image



Filtering Techniques

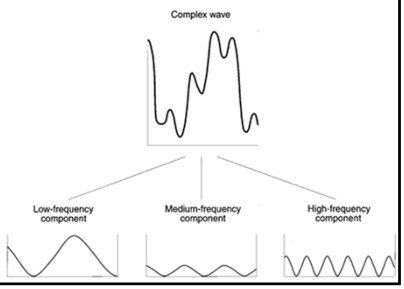
If a vertical or horizontal section is taken across a digital image and the DNs plotted against distance, a complex curve is produced

An examination of this curve would show sections where the gradients are low, correspond with smooth tonal variations on the image and sections where the gradients are high, are where the digital number values change by large amounts over short distances

Filtering is a process that selectively enhances or suppresses particular wavelengths within an image

Two approaches to digitally filtering data

- Convolution filtering in the spatial domain
- Fourier analysis in the frequency domain



Convolution Filtering

A filter is a regular array or matrix of numbers which, using simple arithmetic operations, allows the formation of a new image by assigning new pixel values depending on the results of the arithmetic operations

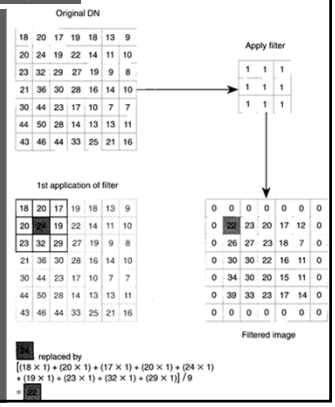
The convolution matrix in the example is a 3 X 3 square though rectangular matrices can also be used but they must contain an odd number of rows and columns

The matrix is initially positioned in the top left corner of the image and a new digital number calculated for the pixel covered by the central matrix cell (row 2, column 2)

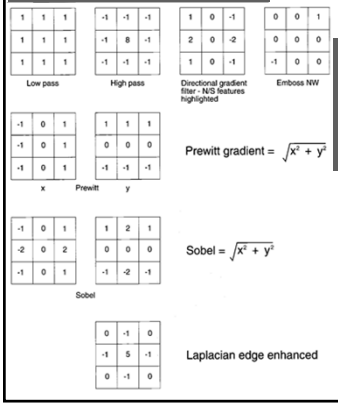
The matrix (also called Filter or Kernel) is then passed through the image data set by shifting one column and the same calculation is performed and a new DN applied to the pixel in row 2, column 3

Averaging filter reduces the effects of the noise component of an image

Filtering decreases the size of image



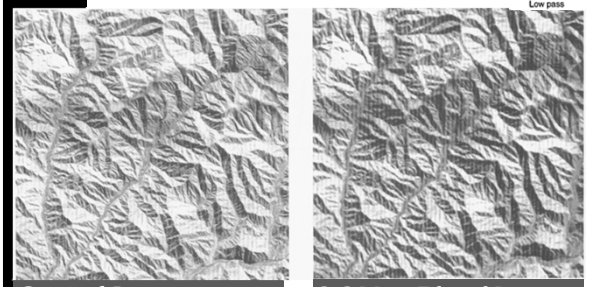
Convolution Filters



Edges are generally formed by long linear features such as Ridges, Rivers, Roads, Railways, Canals, Folds, Faults.

Edges are important to geologists and Civil Engineers

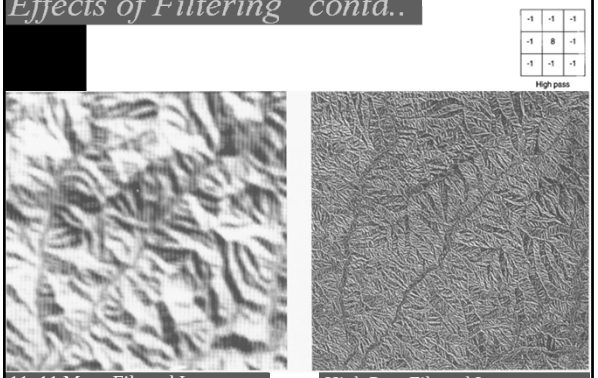
Effects of Filtering



Original Image

3x3 Mean Filtered Image (Low Pass)

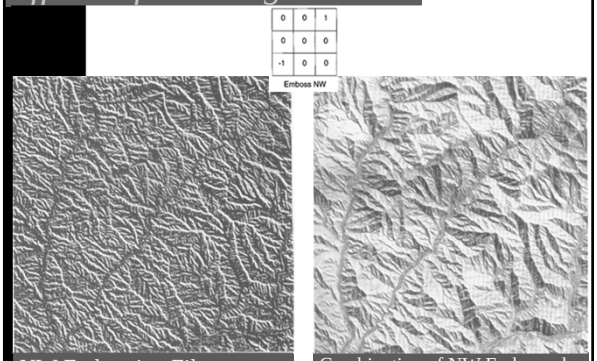
Effects of Filtering contd..



11x11 Mean Filtered Image (Low Pass)

High Pass Filtered Image (3x3)

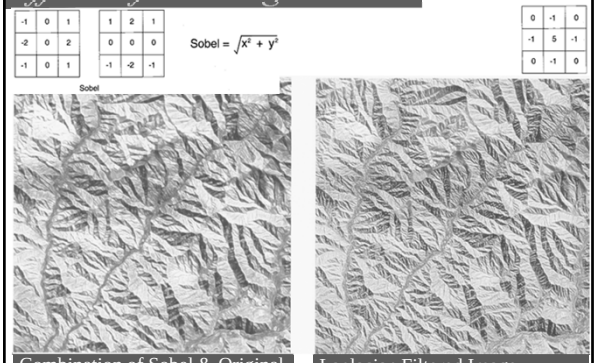
Effects of Filtering contd..



NW Embossing Filter

Combination of NW Embossed & Original Image

Effects of Filtering contd..



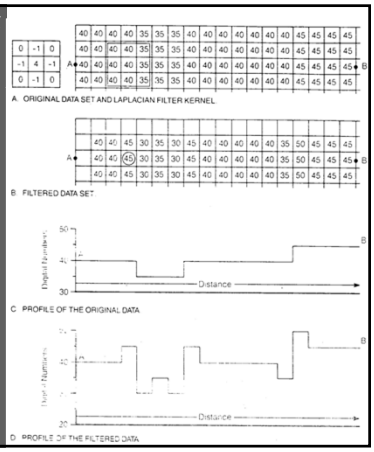
Combination of Sobel & Original Image

Laplacian Filtered Image

Edge Enhancement

Non Directional Filters - Laplacian

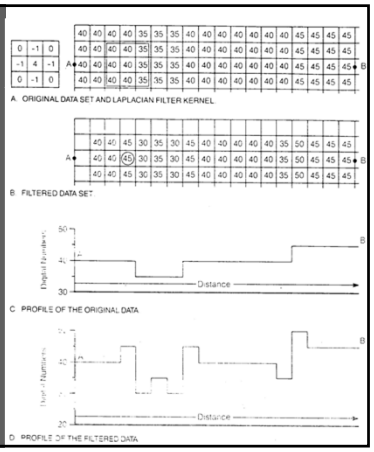
- Laplacian filter is a kernel with a high central value, 0 at each corner and –1 at the center of the edge.
- Laplacian filter is placed over 3x3 array of original pixels and each pixel is multiplied by the corresponding value in the kernel.
- The nine resulting values are summed (4 of them are zeros)
- Resulting kernel value is combined with the central pixel of 3x3 array and this number replaces the original DN of central pixel and the process is repeated.



Edge Enhancement

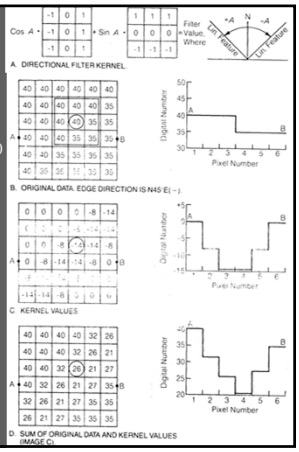
Non Directional Filters - Laplacian

- Original data has a regional background value of 40 that is intersected by a darker, north trending lineament of 3 pixels wide and DN value is 35.
- Contrast ratio between the lineament and background is 40/35 or 1.14. In the enhanced profile it is 45/30 or 1.50 which is good (32% enhancement).
- In addition, lineament in the original was 3 pixels wide whereas in the enhanced image, it is 5 pixels which further enhances its appearance.
- Weighted Filter (<1 to diminish; >1 to accentuate the effect of filter)
- No enhancement of linear features in the direction of movement of kernel



Edge Enhancement: Directional Filters

- Place the right filter kernel over the array of original pixels and multiply each pixel by the corresponding filter value. When these nine values are summed, the filter result is 10.
- Determine the sine of the angle (sin -45^0=-0.71) and multiply this by the filter result (-0.71 x 10) to give a filter value of -7.
- Place the left filter kernel over the pixel array and repeat the process; the resulting value is -7.
- Sum the two filtered values (-14); this value replaces the central pixel in the array of the original data. When steps 1 through 4 are applied to the entire pixel array, the resulting filtered values are those shown in the array and profile of Figure C.
- The filtered values for each pixel are then combined with the original value of the pixel to produce the array and profile of Figure D.
- Contrast ratio of lineament in the original data (40/35=1.14) is increased in the enhanced data set to 1.90 (40/21) which is an enhancement of 67% {100*(1.90-1.14)/1.14}
- Lineament width: 1 pixel to 4 pixels



Assignment –2

Digital Filters for Edge Enhancement

1. Consider an array of 8x10 with the following DN values.
   - Rows 1-2 : 30
   - Rows 3-5 : 35
   - Rows 6-8 : 30

   Apply Laplacian filter and check whether it has any effect.
2. For the data given in Problem 1, apply N89E directional filter and compare the contrast ratio enhancement with that obtained from problem 1.
3. For the data given in Problem 1, apply N45W directional filter and comment on edge enhancement
4. Consider an array of 6x15 as follows
   - Columns 1-3 : 50
   - Columns 4-5 : 60
   - Columns 6-10 : 50
   - Columns 11-13 : 40
   - Columns 14-15 : 50

   Apply Laplacian filter. Also apply any two weighing factors and compare edge enhancement capabilities.
5. For the data given in example problem for Directional filters, apply Laplacian filter and compare edge enhancement capabilities.

Last Date

30th September 2017