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Intensity Transforms & Histogram Operations

EE551

Week 2 – Intensity Transforms & Histogram Operations

Ref. chapters 3 – Gonzalez & Woods

2023

In this section…

- Pixel-level operations
- Intensity adjustment (thresholding, contrast adjustment, histogram processing)

Pixel-Level Operations

- Addition and subtraction
- Multiplication and division
  - Watch for overflow or underflow!
- Use the correct function
- Logical operations – useful for processing binary images (1 or 0)

Intensity Transformations

- There are a number of ways in which we can process the grey-levels of the pixels in an image to achieve desired effects.
- The goal may be to get a processed image which is visually better, or it may be used as a step in a sequence of operations designed to extract information from an image.

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Grey-scale transformations

- Input grey-scale r ⟶ s, the output grey-scale

$$s = T(r)$$

- Log transformation – enhances contrast in darker regions.

$$s = clog(1 + r)$$

- Exponential

$$s = c[(1 + \alpha)^r - 1]$$

- Power law transformation

$$s = cr^{\gamma}$$

A value $\gamma < 1$ assigns more grey-scale values to the lower input values, thus increasing the contrast in the darker parts of the image. Conversely, a value $\gamma > 1$ increases the contrast of the brighter regions of the image

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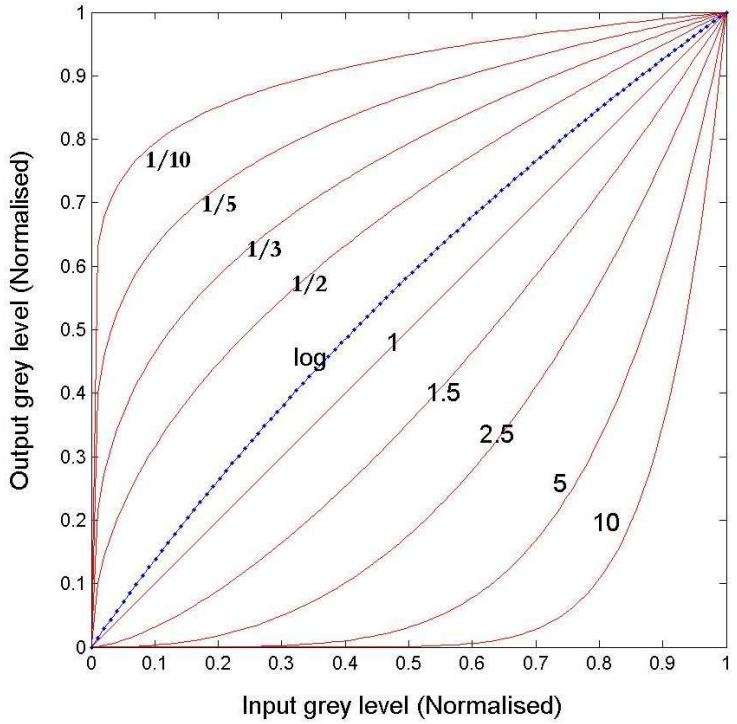
Power Law transformation



Power Law transformation

Original

gamma = 1/3

Contrast enhancement of the darker regions.
Note the increased detail visible in the coat.

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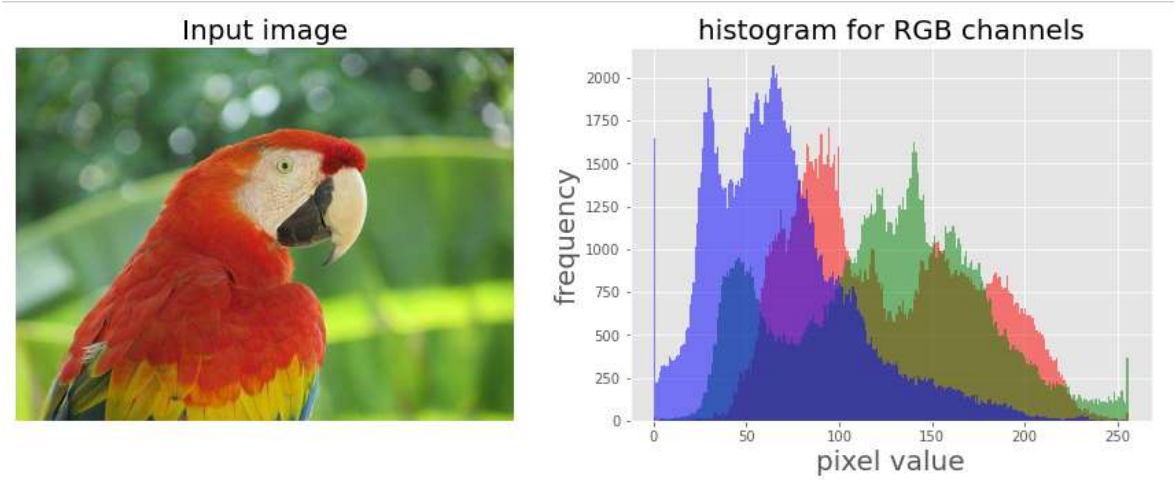
Image Histograms

- For a variety of reasons, images sometimes don't have sufficient contrast (e.g. poor quality image sensors, under/over exposure)
- The simplest way to ascertain this is by visual examination of the image and/or its histogram – this gives the relative population of all the grey levels in the image

Image Histograms

- We can consider the histogram as a discrete probability density function determining the likelihood that each grey level is occupied.



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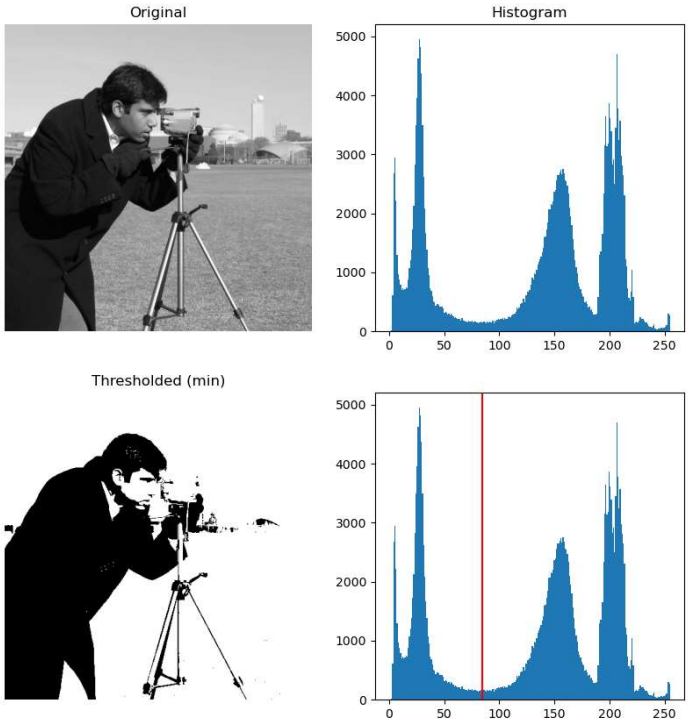
Thresholding

- Useful to produce a binary image to delineate objects in a scene (e.g. for segmentation)
- Histogram can be used to select a threshold for producing a binary image
- Automatic threshold
- Adaptive threshold
  - Based on “local statistics” in the region of the pixel of interest

Thresholding



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Thresholding example – fixed threshold

original image

binary image with threshold=100

binary image with threshold=150

binary image with threshold=200

Half-toning

- In the previous slide, you may have noticed that the binary images obtained with different gray-level thresholds are not shaded properly –resulting in an artifact known as *false contours*
- False contours are a problem in printing – e.g. a black and white newspaper print is a binary image, generated with black dots on a white background. False contours would not be acceptable for black and white printing
- One way to limit the impact of contouring is to add uniformly distributed white noise to the image prior to quantization. This is called *half-toning*

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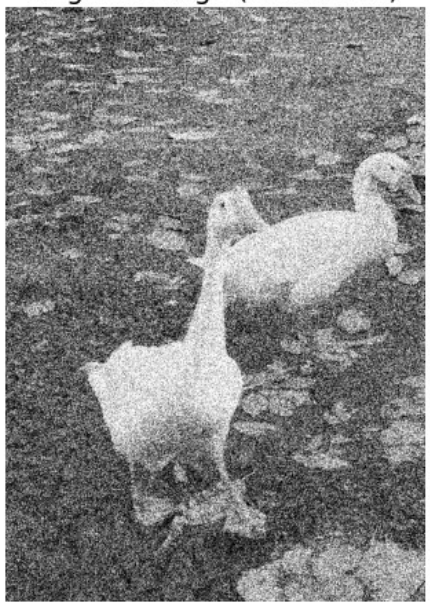
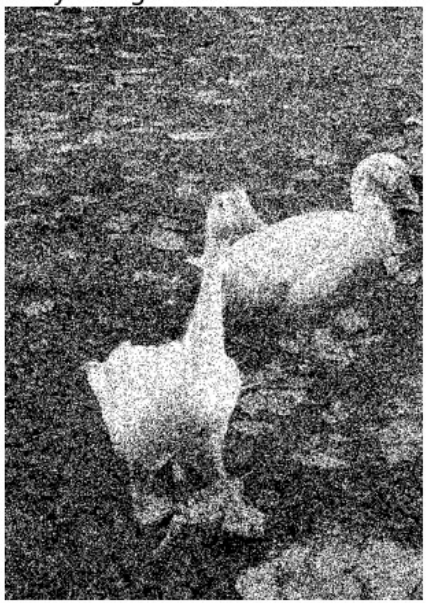
Half-toning

original image (with noise)

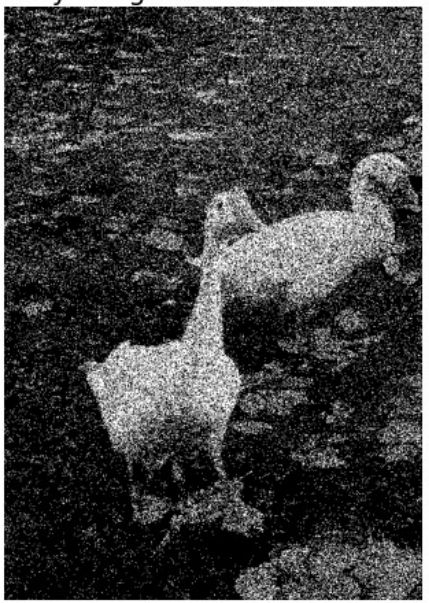


binary image with threshold=100

binary image with threshold=150



binary image with threshold=200

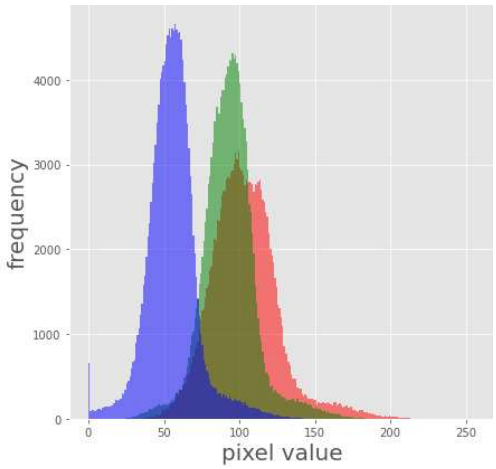


Contrast stretching

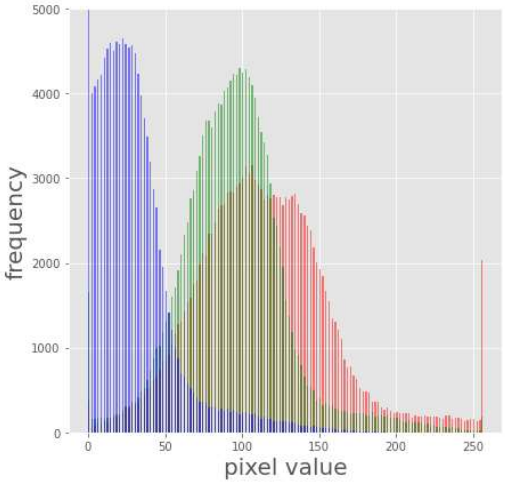
- A simple technique that effectively assigns all the permissible grey levels to the dominant region of the histogram.
- Makes the image use more of the dynamic range of the image.
- In simple terms, this involves scaling pixel values according to the actual and desired dynamic ranges
- Simple approach just looks at the max and min pixel values of the input image – but this is sensitive to outliers
- Better to look at some statistics of the input image

Contrast Stretching

Before Contrast Stretch



After Contrast Stretch



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Histogram Equalisation

- This is a more sophisticated technique which attempts to transform the distribution of input grey levels to an output distribution which conforms to a flat profile
- The probability of all grey levels being occupied is equal.
- This increases the global contrast.

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Histogram Equalisation

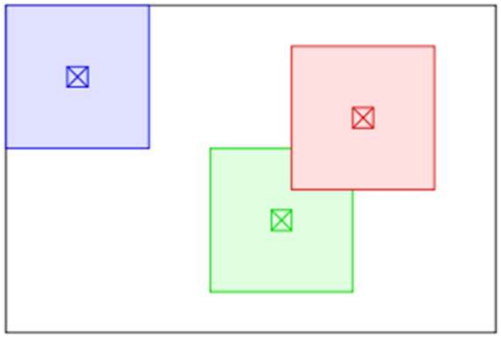
original input (earth from sky)

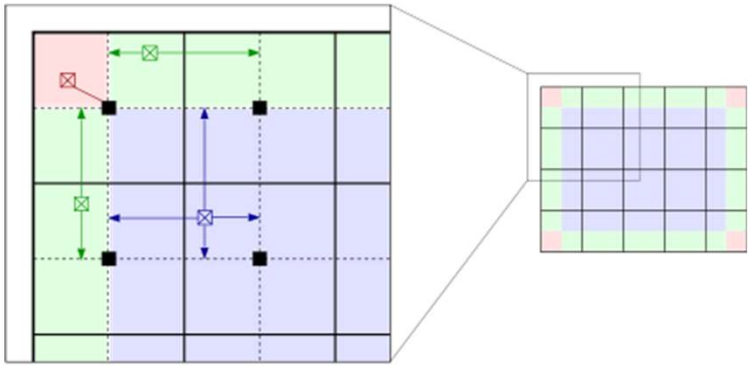
after histogram equalization

Histogram Equalisation

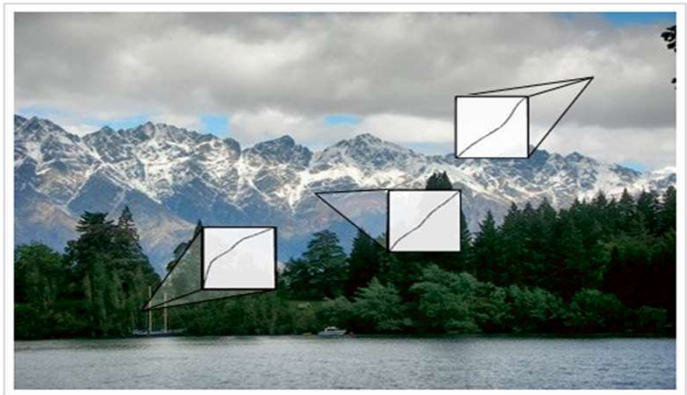
- Although a powerful and useful technique, it is limited.
- Histogram equalisation takes no account of the nature of the image (a car, a desert scene, ….), or any specific “areas of interest” in the image
- Often it is local contrast that we want to improve
- This is where adaptive histogram equalization has advantages

Adaptive Histogram Equalization – local histograms, weighted combination





Single adjustment curve applied	Iridix result
Show adjustment curve	Show Iridix local adjustments



Single adjustment curve applied	Iridix result
Show adjustment curve	Show Iridix local adjustments

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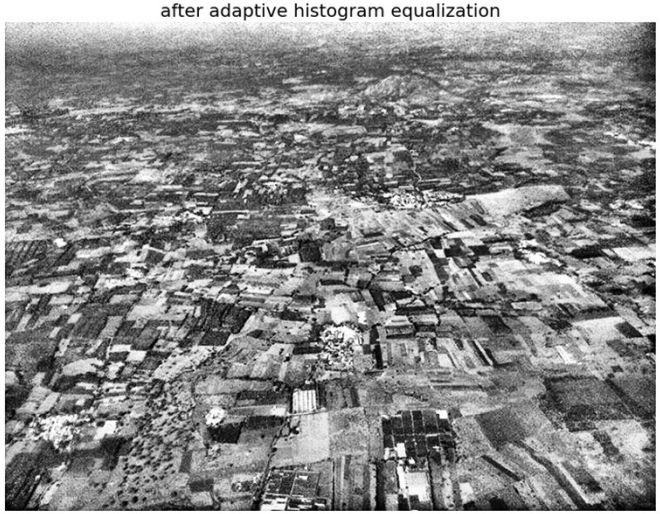
Adaptive Histogram Equalisation

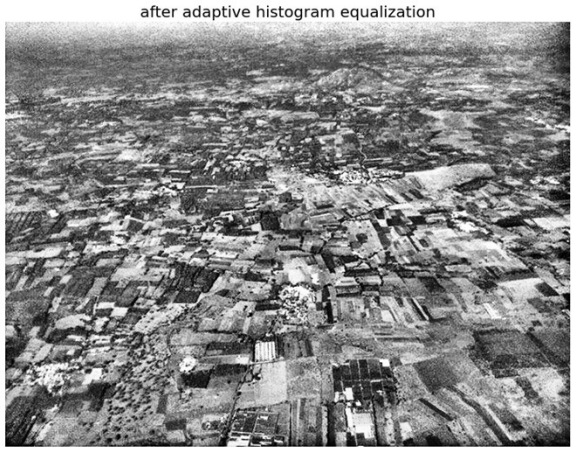
original input (earth from sky)

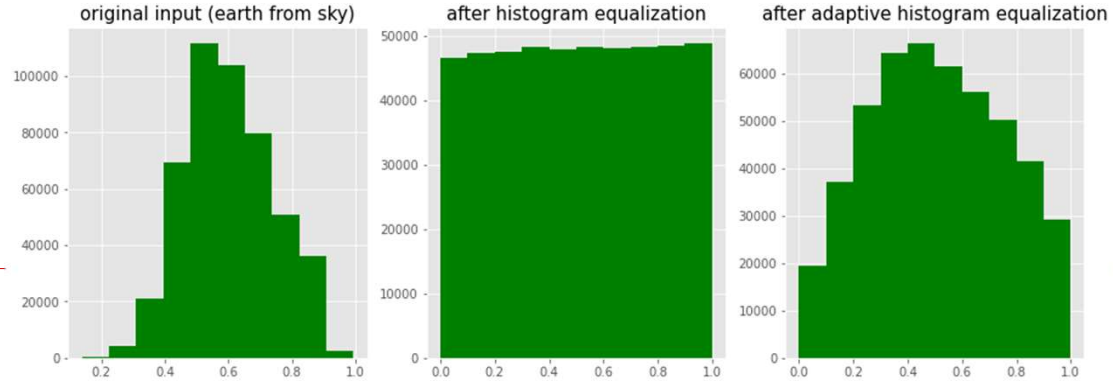
after histogram equalization

after adaptive histogram equalization



Adaptive Histogram Equalisation





Histogram Matching

- Given the original (input) image and its corresponding histogram, we seek to effect a transformation on the input intensity values such that the transformed (output) image has a desired histogram.
- Sometimes the desired histogram profile is taken from another ("reference") image, or other use case constraints e.g. biometric application where there is a known uneven illumination that must be compensated for

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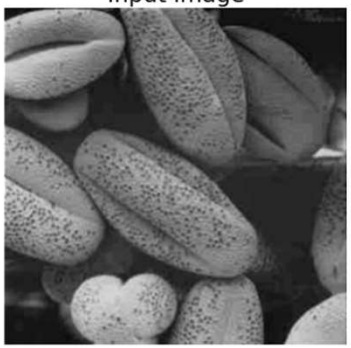
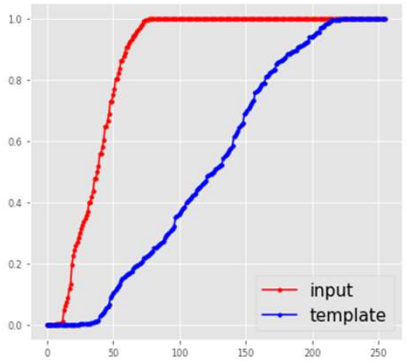
Histogram matching

Input image



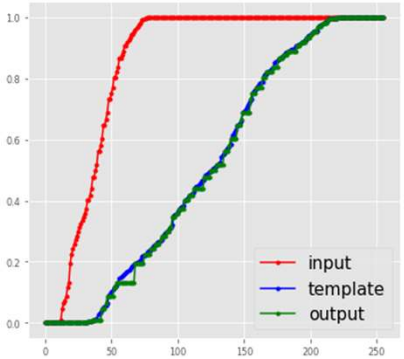
Template image

CDF



Output image with Hist. Matching

CDF



Handling Colour Images

- We need to focus on the intensity (brightness) of the image, not its colour
- Transform an RGB image to an alternative colour space where we can isolate the intensity
- Transform from RGB to (e.g.) HSV space
- Perform histogram equalisation on the V dimension of the HSV image
- Transform back to the RGB colour space
- This topic will be covered in more detail during the Colour Image Processing section of this module

Questions?