Lecture 4 Point Operators

COMP6223 Computer Vision (MSc)

How many different operators are there on image points?

Book pp 72-83

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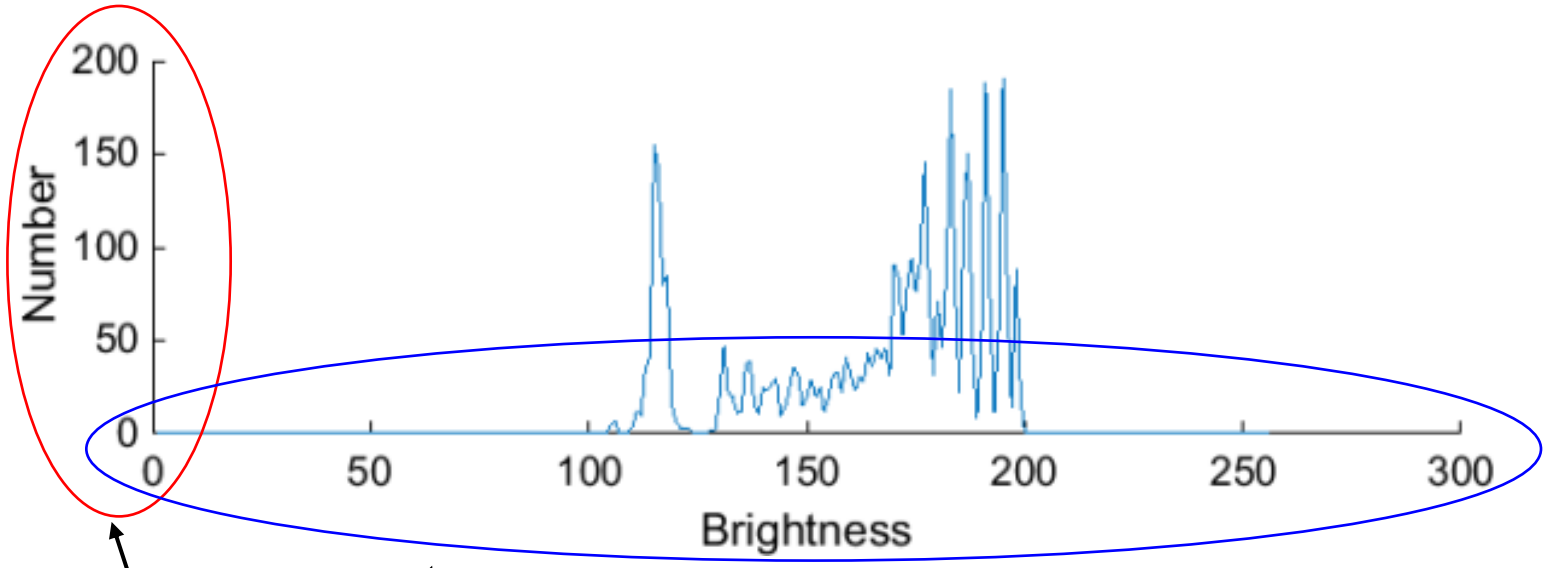
Content

1. How do we best display images?
2. What operators are available; which work solely on image points?

An image and its histogram

(a) image of an eye



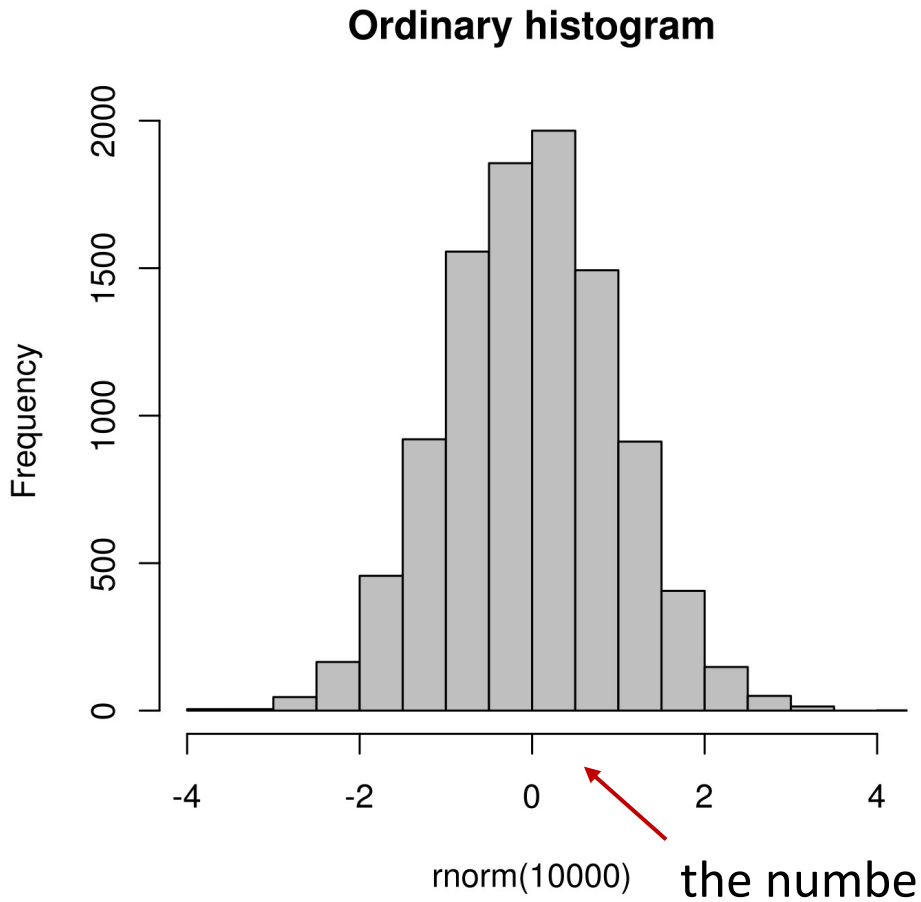
(b) histogram of eye image

- The histogram plots the number of pixels with a particular brightness level
- The histogram shows contrast (the range of brightness levels)

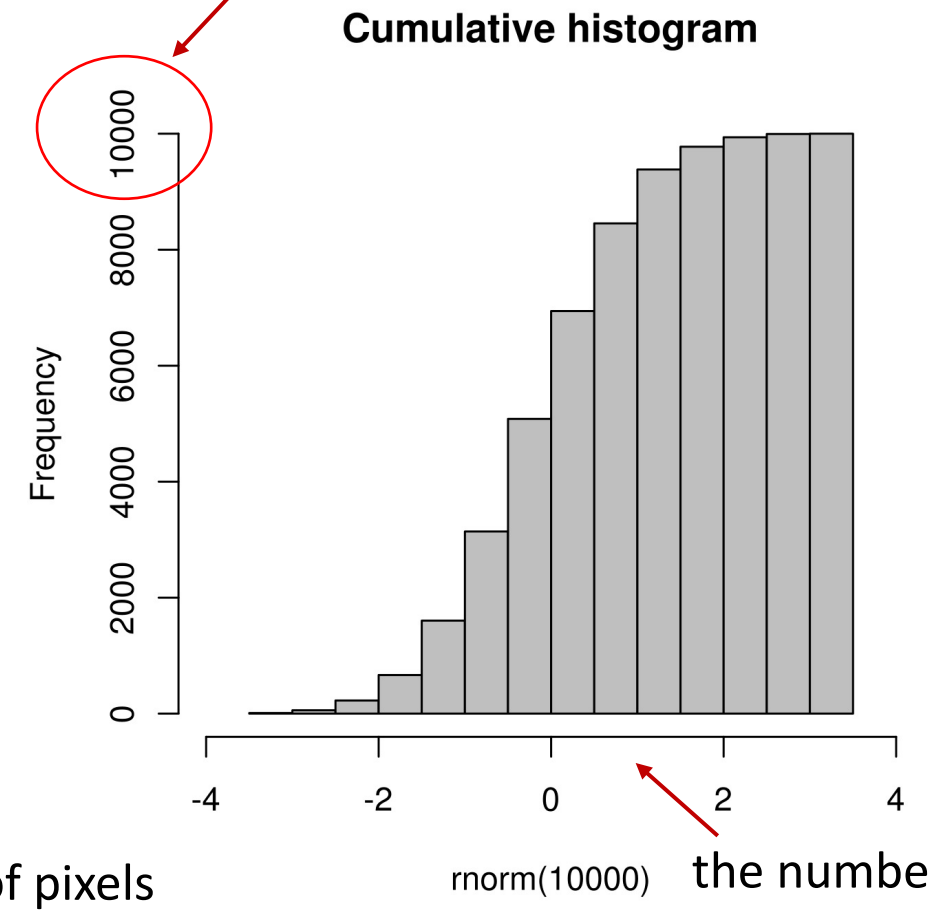
Different Histograms

- Example: Histogram of 10000 points in [-4, 4]

Can also be scaled so that the highest frequency is 1 by dividing the total number of pixels/points



the number of pixels with a particular value



the number of pixels ≤ a particular value

[Credit: Wikipedia]

Modifying Image Intensity

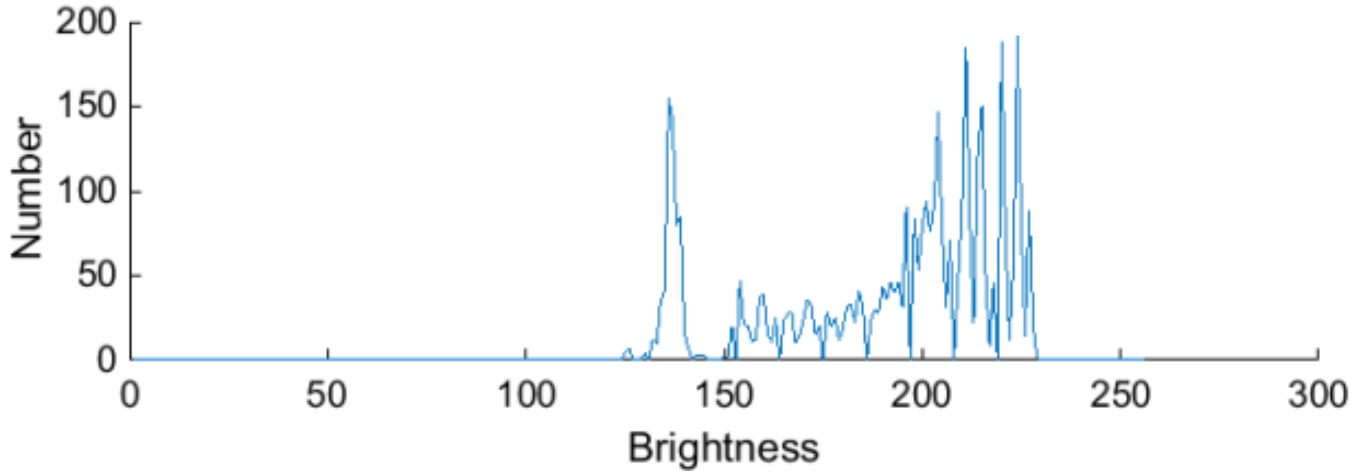
by choosing values for k and l

new image — scalar and level

$$\mathbf{N}_{x,y} = k \times \mathbf{O}_{x,y} + l$$

coordinates — old image

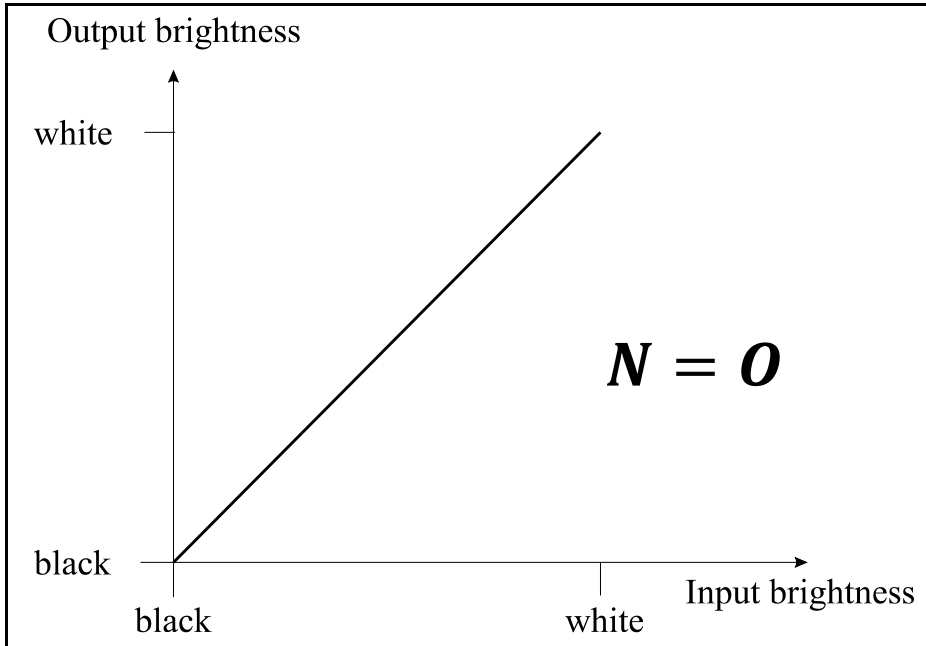
(a) image of brighter eye



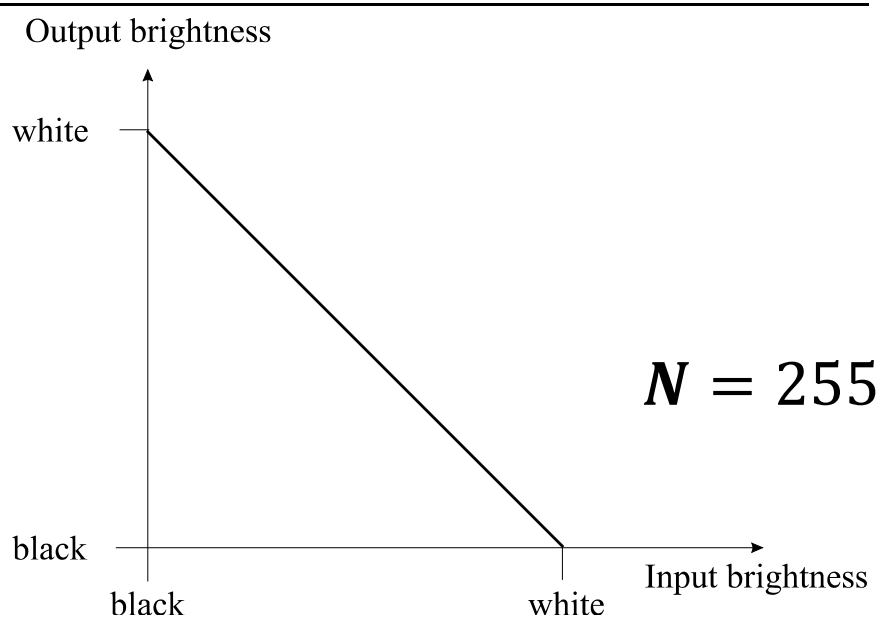
(b) histogram of brighter eye

Brightening an Image

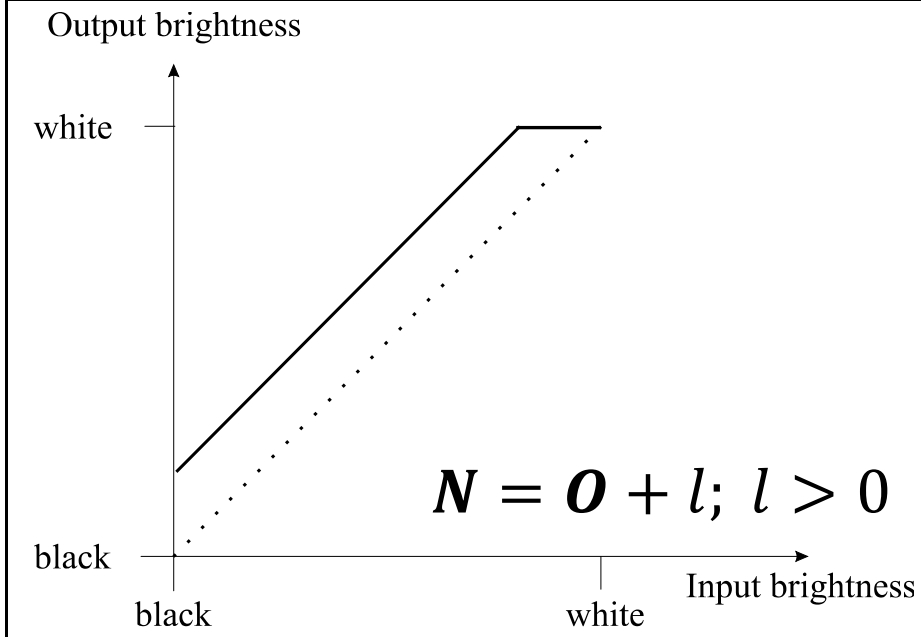
Intensity mappings



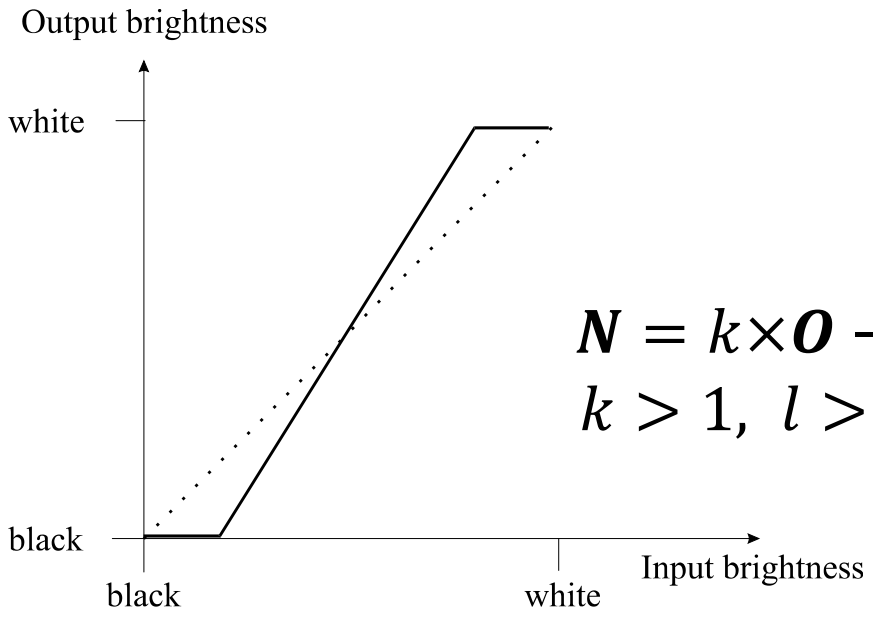
(a) copy



(b) brightness inversion



(c) brightness addition



(d) brightness scaling by multiplication

Applying exponential and logarithmic point operators

Brightness compression

$$\mathbf{N}_{x,y} = \log\left(\mathbf{O}_{x,y}\right)$$

(a) logarithmic compression

Brightness expansion

$$\mathbf{N}_{x,y} = \exp\left(\mathbf{O}_{x,y}\right)$$

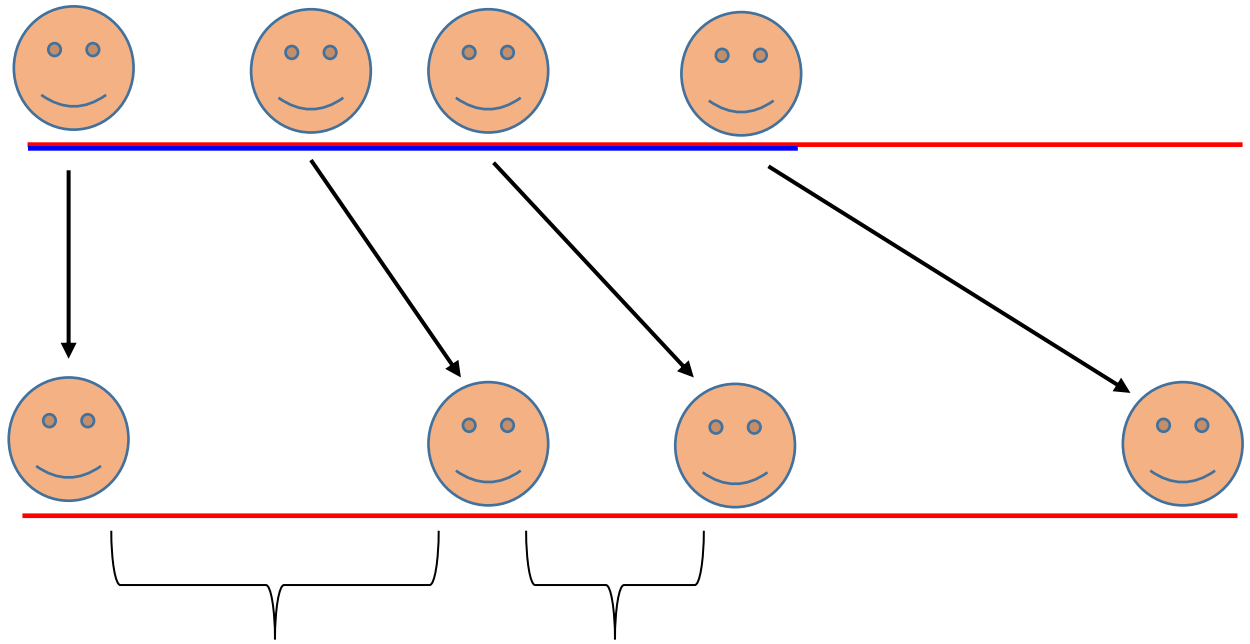
(b) exponential expansion

Intensity normalisation

Toy example

Before normalization:

After normalization
(whole range used):



The ratio between the distances of these smileys is kept

Intensity normalisation

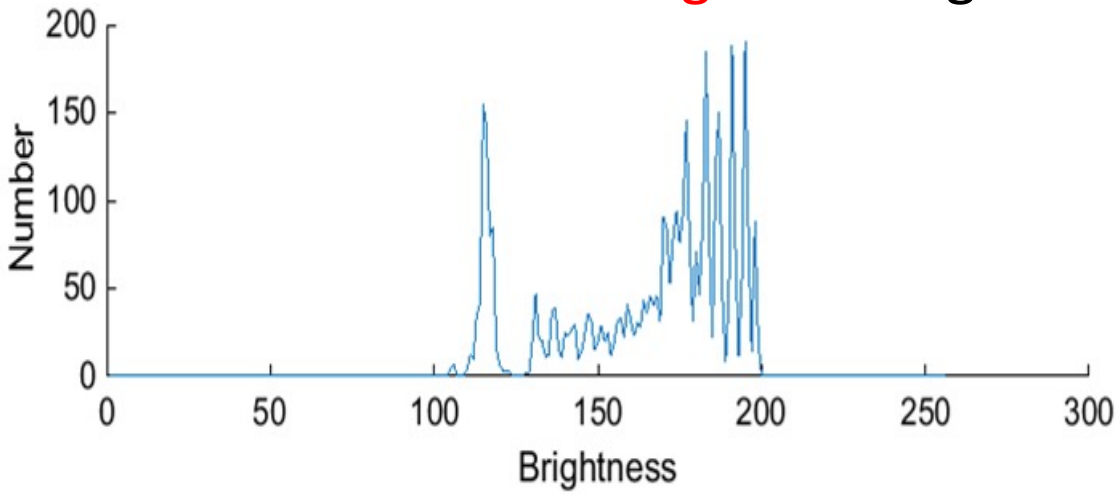
Aim is to use all available grey levels for display

Min and Max of the new image

$$\mathbf{N}_{x,y} = \frac{\mathbf{N}max - \mathbf{N}min}{\mathbf{O}max - \mathbf{O}min} \times \left(\mathbf{O}_{x,y} - \mathbf{O}min\right) + \mathbf{N}min$$

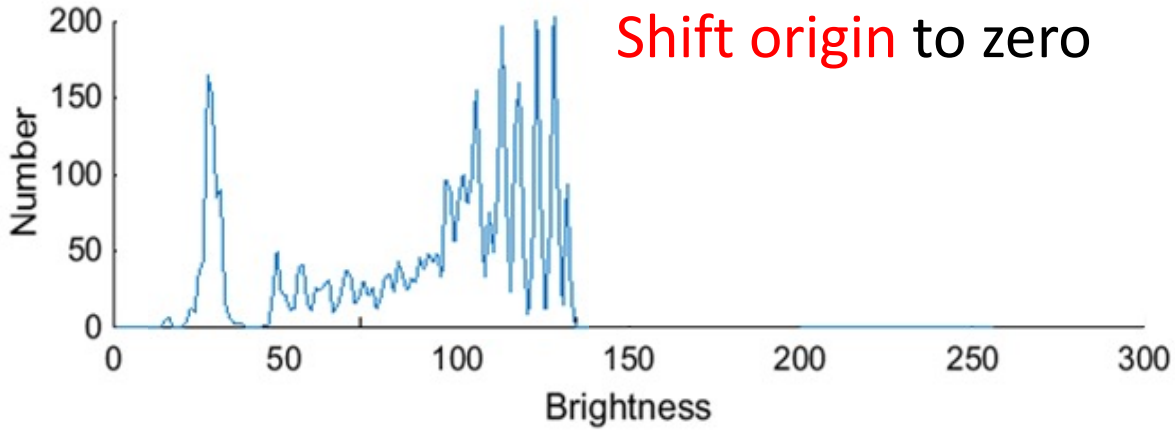
Min and Max of the original/old image

Original histogram

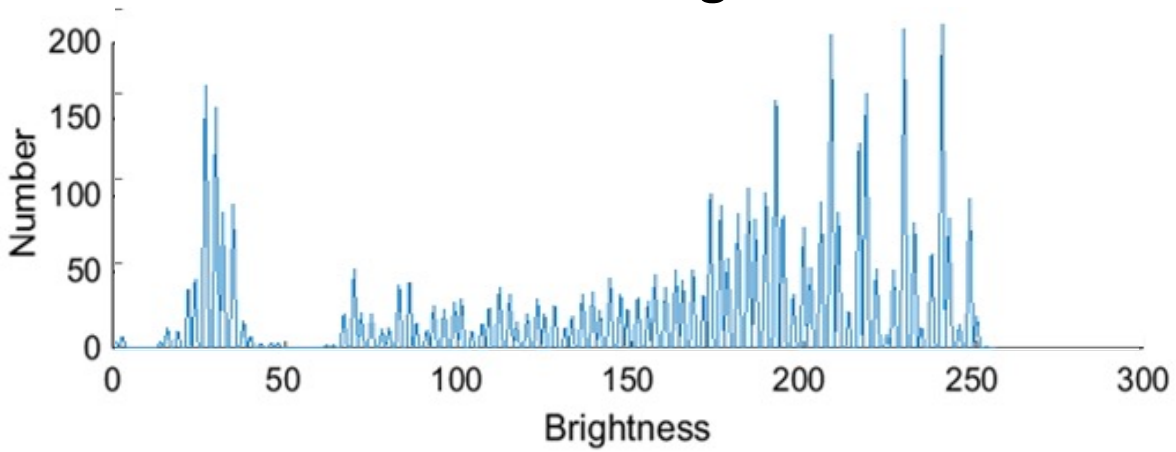


E.g.: $\mathbf{N}max = 255$;
$\mathbf{N}min = 0$

Shift origin to zero



Scale brightness to use the whole range

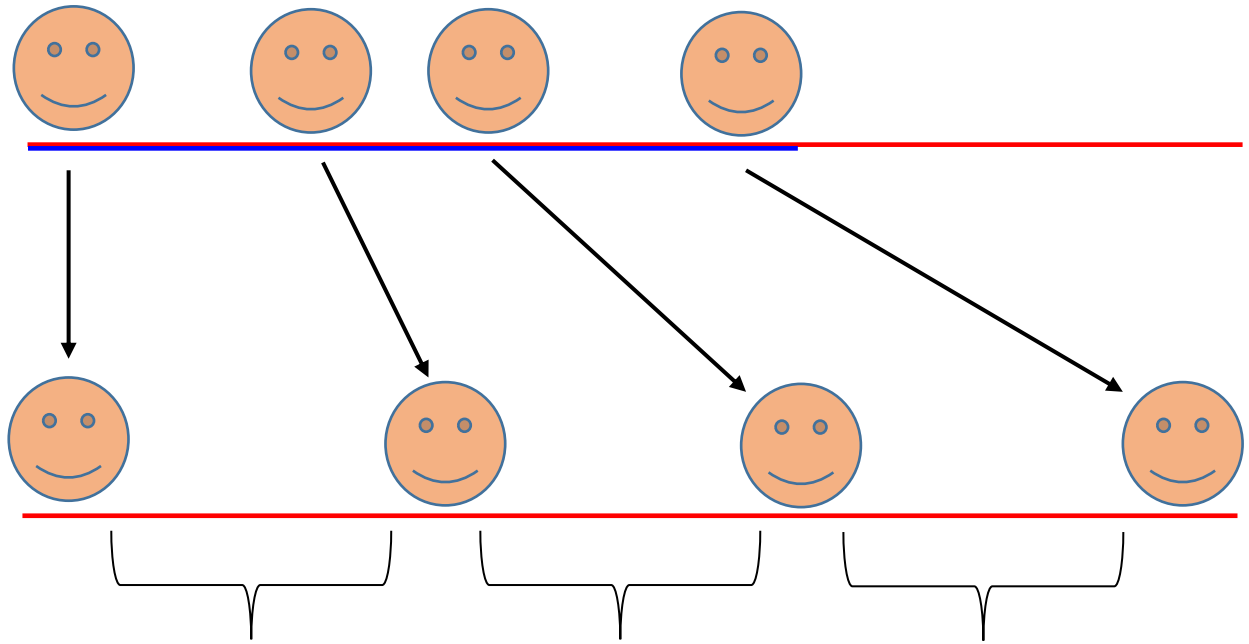


Histogram Equalisation

Toy example

Before normalization:

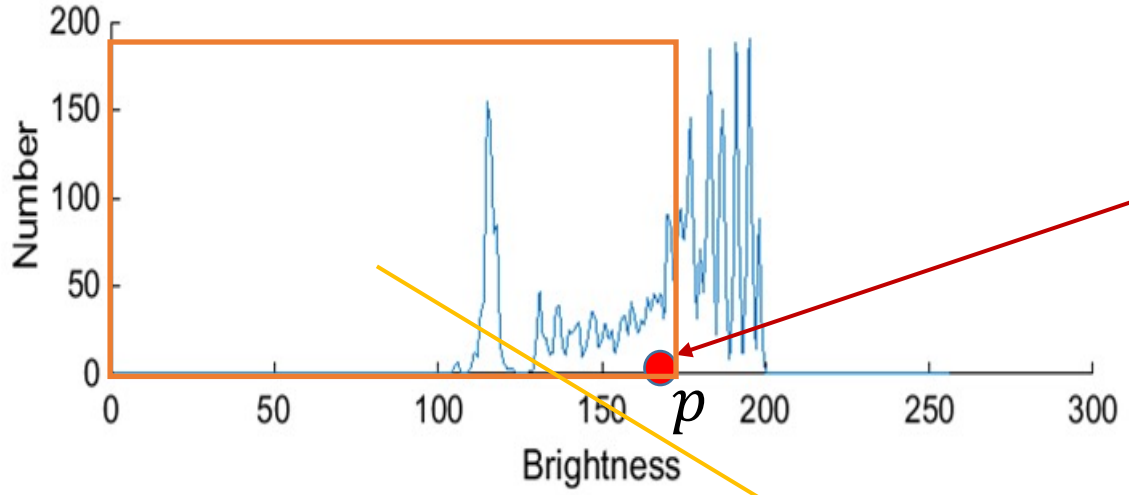
After equalisation
(whole range used):



Same distance between two adjacent smileys

Histogram Equalisation – aim is a flat histogram

Original histogram



N^2 points in the original and equalised images

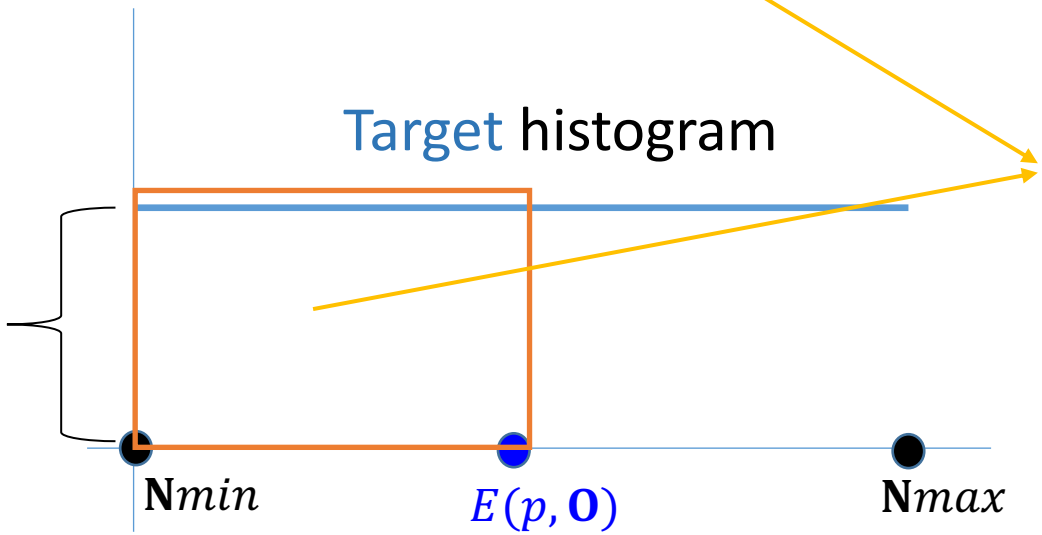
$\mathbf{O}(p)$: the histogram at level p

$\sum_{l=0}^{p} \mathbf{O}(l)$: the cumulative histogram up to level p

$E(p, \mathbf{O})$: the level after equalisation

$$\frac{N^2}{\mathbf{N}max - \mathbf{N}min}$$

Target histogram

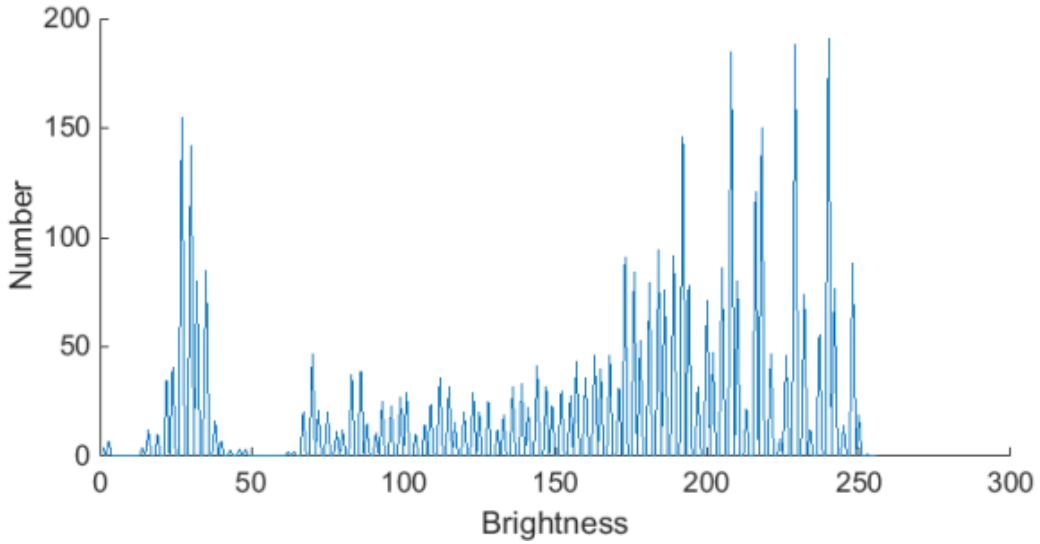


$$\frac{N^2}{\mathbf{N}max - \mathbf{N}min}(E(p, \mathbf{O}) - \mathbf{N}min) = \sum_{l=0}^{p} \mathbf{O}(l)$$

$$E(p, \mathbf{O}) = \frac{\mathbf{N}max - \mathbf{N}min}{N^2} \sum_{l=0}^{p} \mathbf{O}(l) + \mathbf{N}min$$

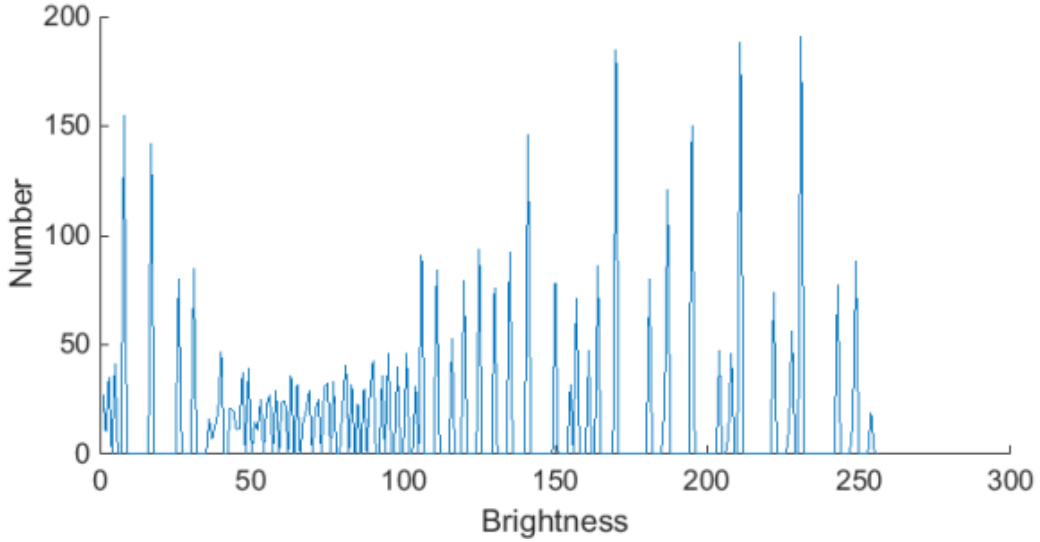
Intensity normalisation and histogram equalisation

(a) intensity normalised eye



(b) histogram of intensity normalised eye

(c) histogram equalised eye



(d) histogram of histogram equalised eye

Illustrating Intensity Normalisation and Histogram Equalisation

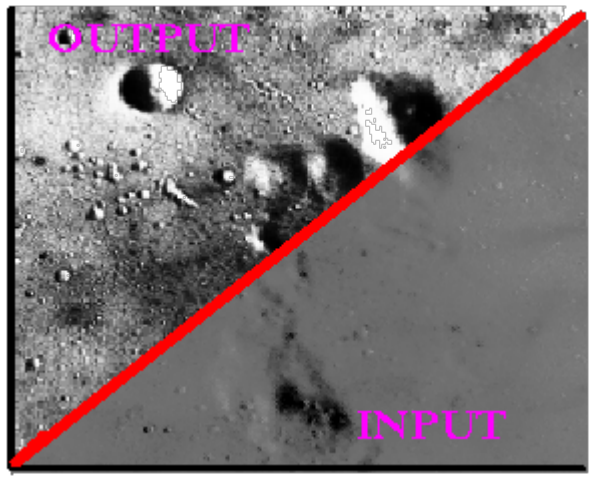
Grey levels all 'weigh' the same

Used in Matlab's `imagesc`

Grey levels have different weights

Aimed for **human vision**

Applying Histogram Equalisation



http://homepages.inf.ed.ac.uk/rbf/HIPR2/histeq.htm
http://docs.opencv.org/doc/tutorials/imgproc/histograms/histogram_equalization/histogram_equalization.html

Thresholding

Thresholding selects points that exceed a chosen threshold τ

$$\mathbf{N}_{x,y} = \begin{cases} 255, & \text{if } \mathbf{O}_{x,y} > \tau \\ 0, & \text{otherwise} \end{cases}$$

coordinates

An eye image

After thresholding

Thresholding: Manual vs Automatic

An eye image

Thresholding: $\tau = 160$

Automatic thresholding by Otsu: $\tau = 127$

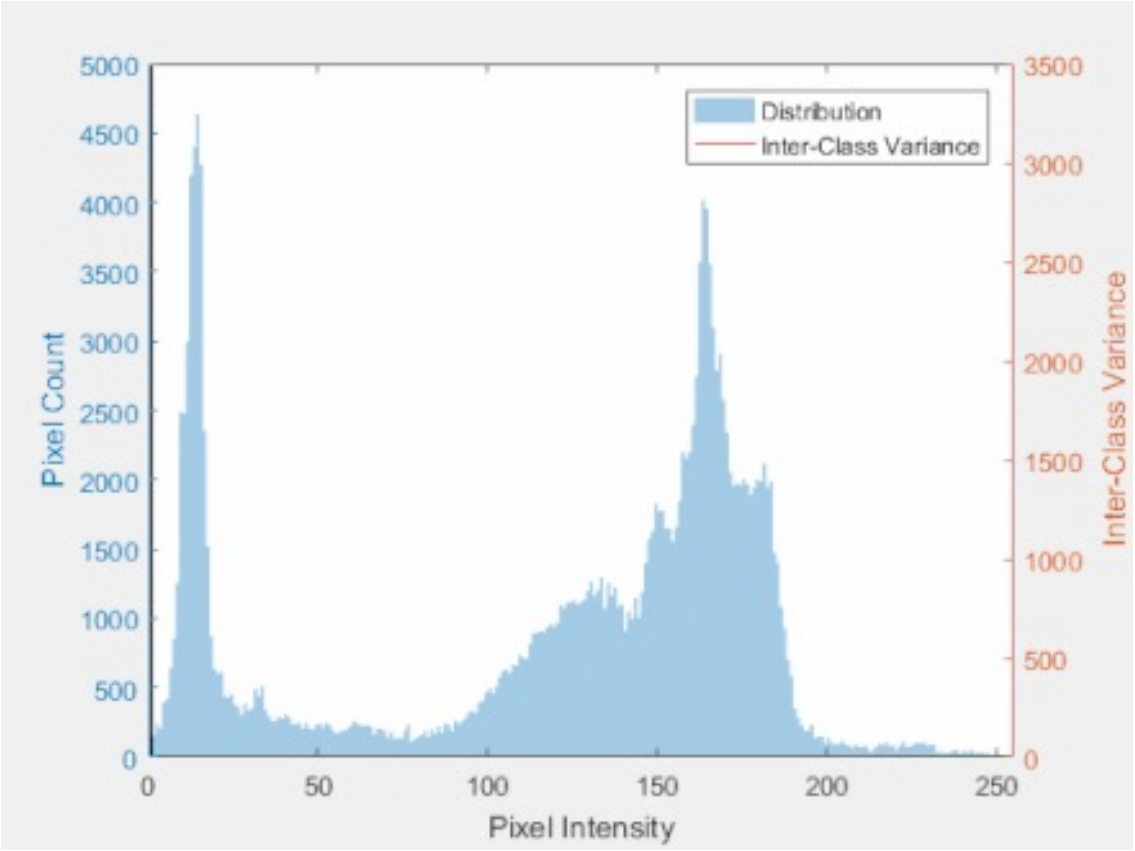
Otsu Thresholding

Per cent of the number of pixels in each group (separated by τ) against the total number of pixels

Inter-class variance

$$\max_{\tau} \omega_0(\tau)\omega_1(\tau)[\mu_0(\tau) - \mu_1(\tau)]^2$$

Mean of the two groups separated by τ



https://en.wikipedia.org/wiki/Otsu%27s_method

Thresholding an image of a walking subject

(a) walking subject

(b) automatic thresholding by Otsu

Many consider that shape concerns a higher level

Main points so far

1. point operators are largely about image display
2. concern histogram manipulation
3. thresholding used a lot
4. intensity normalisation used for display

Need sets of points. That's group operators, coming next.

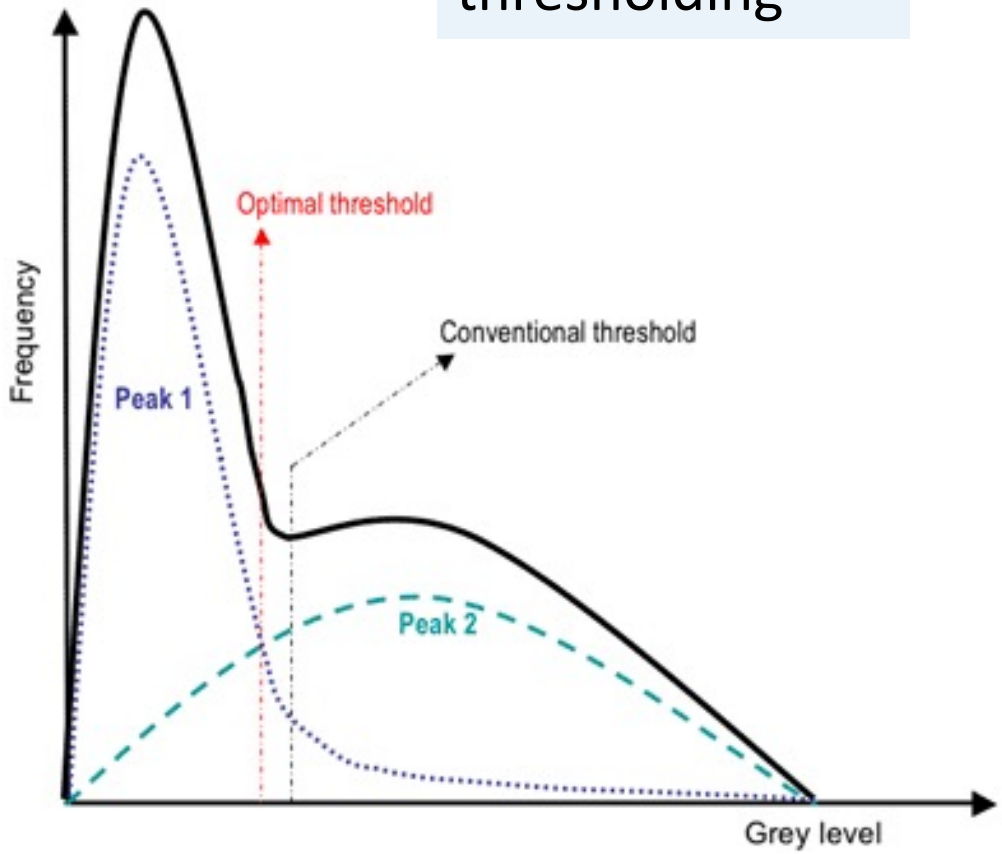
Adaptive Thresholding

Starting with an initialization $\tau^{(0)}$, e.g. the mean of given image, find a proper threshold iteratively by

Mean of the two groups separated by $\tau^{(i)}$

$$\tau^{(i+1)} = \frac{\mu_0\left(\tau^{(i)}\right) + \mu_1\left(\tau^{(i)}\right)}{2}$$

Other advanced thresholding



https://www.cs.auckland.ac.nz/courses/compsci773s1c/lectures/ImageProcessing-html/topic3.htm

Other thresholding techniques…