CS-565 Computer Vision

Nazar Khan

PUCIT

Lecture 8: Point Operations

Point Operations

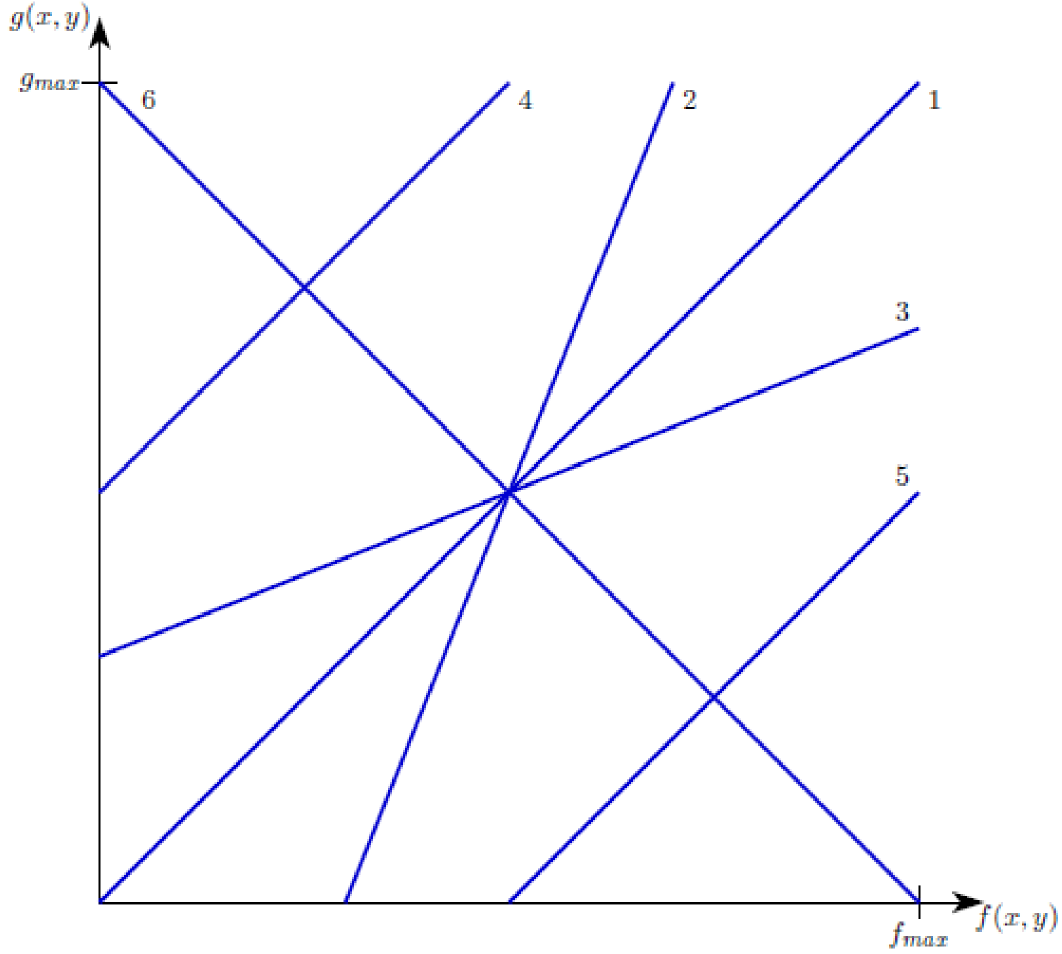
- Transform an image into another one that is more useful
  - for a human
  - or a computer
- Global grayscale transformation that uses individual pixels only – no neighborhood is used (compare with convolution)
- $\varphi: f(x,y) \longrightarrow g(x,y) = \varphi(f(x,y))$
  - Location *(x,y)* does not matter, only the gray value *f(x,y)* matters.
- Often φ is a non-linear operator.
- It is usually a good idea to try point operations as a pre-processing step.

Affine Grayscale Transformations

- $g(x,y) = af(x,y)+b$

	a	b
Identity	1	0
Contrast enhancement	>1	
Contrast attenuation	Between 0 and 1	
Brightening	1	>0
Darkening	1	<0
grayscale reversion	-1	g_{max}

Affine Grayscale Transformations



Affine greyscale transformations. **(1)** Identity. **(2)** Contrast enhancement. **(3)** Contrast attenuation. **(4)** Brightening. **(5)** Darkening. **(6)** Greyscale reversion. Author: T. Schneevoigt (2011).

Affine Grayscale Transformations

- An often used affine transformation is to the interval [0,255].
- If your image f has the range $[f_{min}, f_{max}]$ then $g(x,y)=(f(x,y)-f_{min})/(f_{max}-f_{min})*255$

Left: Underexposed original image. **Right:** After affine greyscale mapping to the interval $[0, 255]$. Author: J. Weickert (2000).

Thresholding/Binarisation

- Non-linear transformation

$$\varphi(f(x,y)) = \begin{cases} g_{\max} & \text{for } f(x,y) < T, \\ 0 & \text{otherwise} \end{cases}$$

- g_{max} is usually 1 or 255
- Simplest method for segmentation
  - Non-robust due to dependence on threshold *T*.

Thresholding/Binarisation

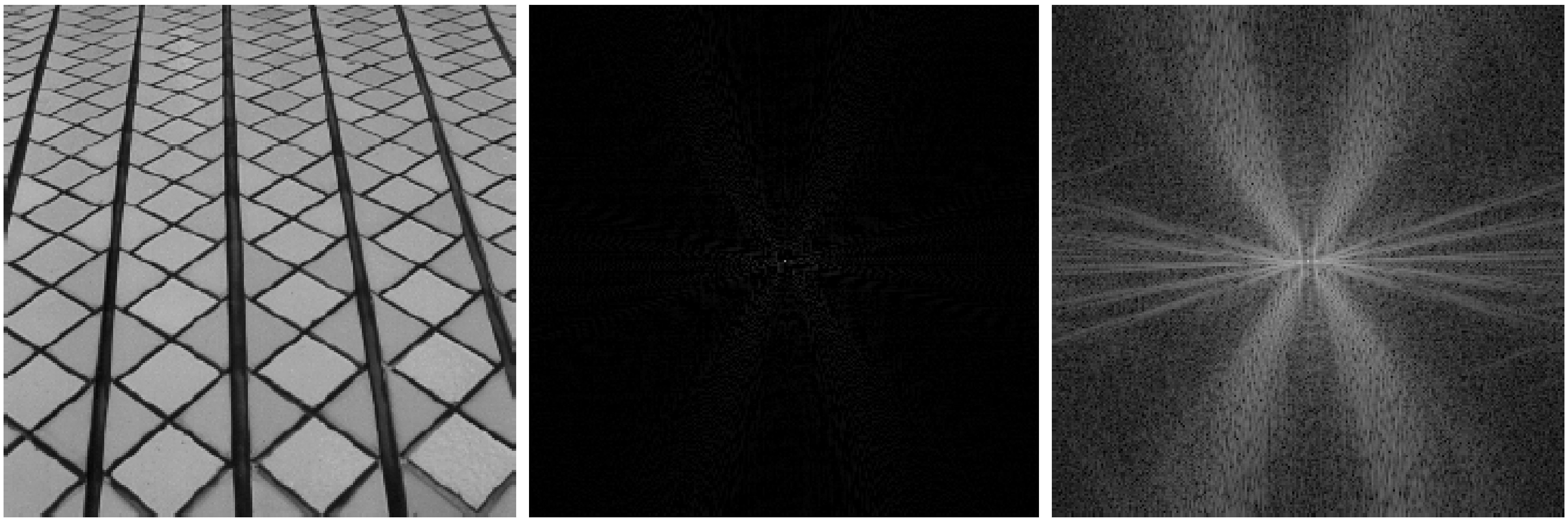
Left: Grayscale image of a road in snow. **Right**: Thresholding with *T*=140 allows us to segment out the darker looking road and trees. Author: Nazar Khan (2014)

Logarithmic Dynamic Compression

- Useful when min and max grayscale values differ by many orders of magnitude.
  - Often the case in the Fourier spectrum where $|F(0,0)|$ can dominate over the other frequencies.
- Often the ratio of two color values is more important than their difference.
- If your image f has the range $[0, f_{max}]$ then

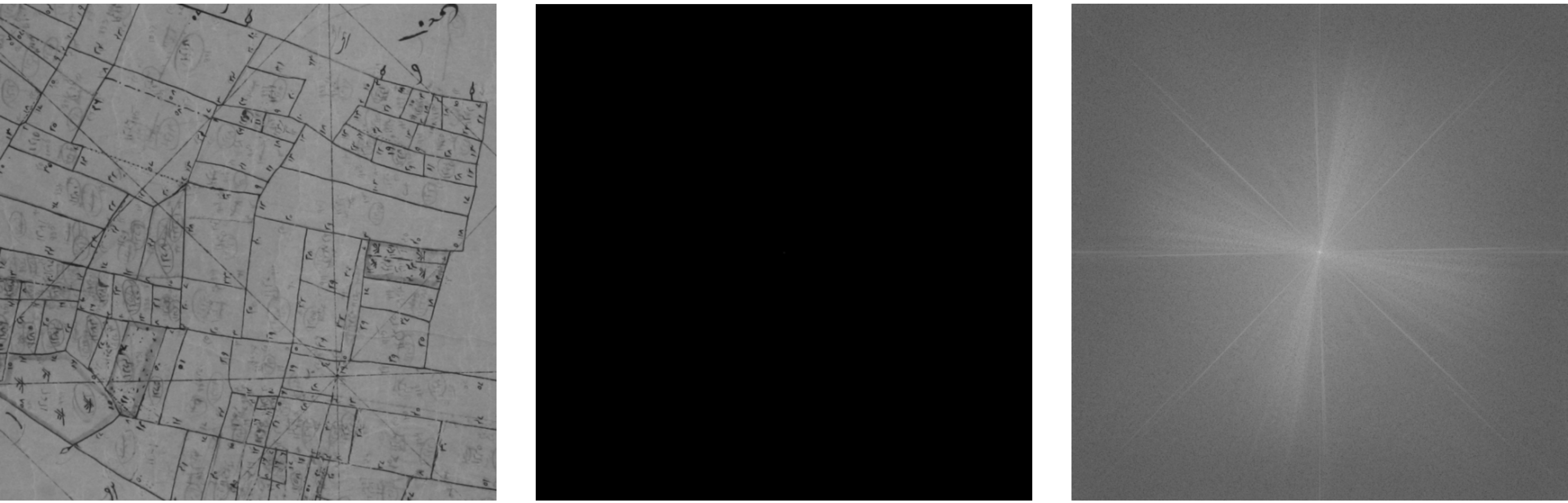
  $g(x,y) = c * \log(1+f(x,y)) / \log(1+f_{max})$ where $c>0$.
- **H.W.: To force g(x,y) to lie between [0,255], what should be the value of c?**

Logarithmic Dynamic Compression



Logarithmic dynamic compression. **Left:** Original image, 256×256 pixels. **Middle:** Fourier spectrum without logarithmic dynamic compression. The white pixel in the centre corresponds to the sum of all grey values. It dominates over all other Fourier coefficients. **Right:** After logarithmic dynamic compression, the entire Fourier spectrum is well visible. The constant c is chosen such that the range of the transformed spectrum coincides with the interval [0,255]. Author: J. Weickert (2002).

Logarithmic Dynamic Compression

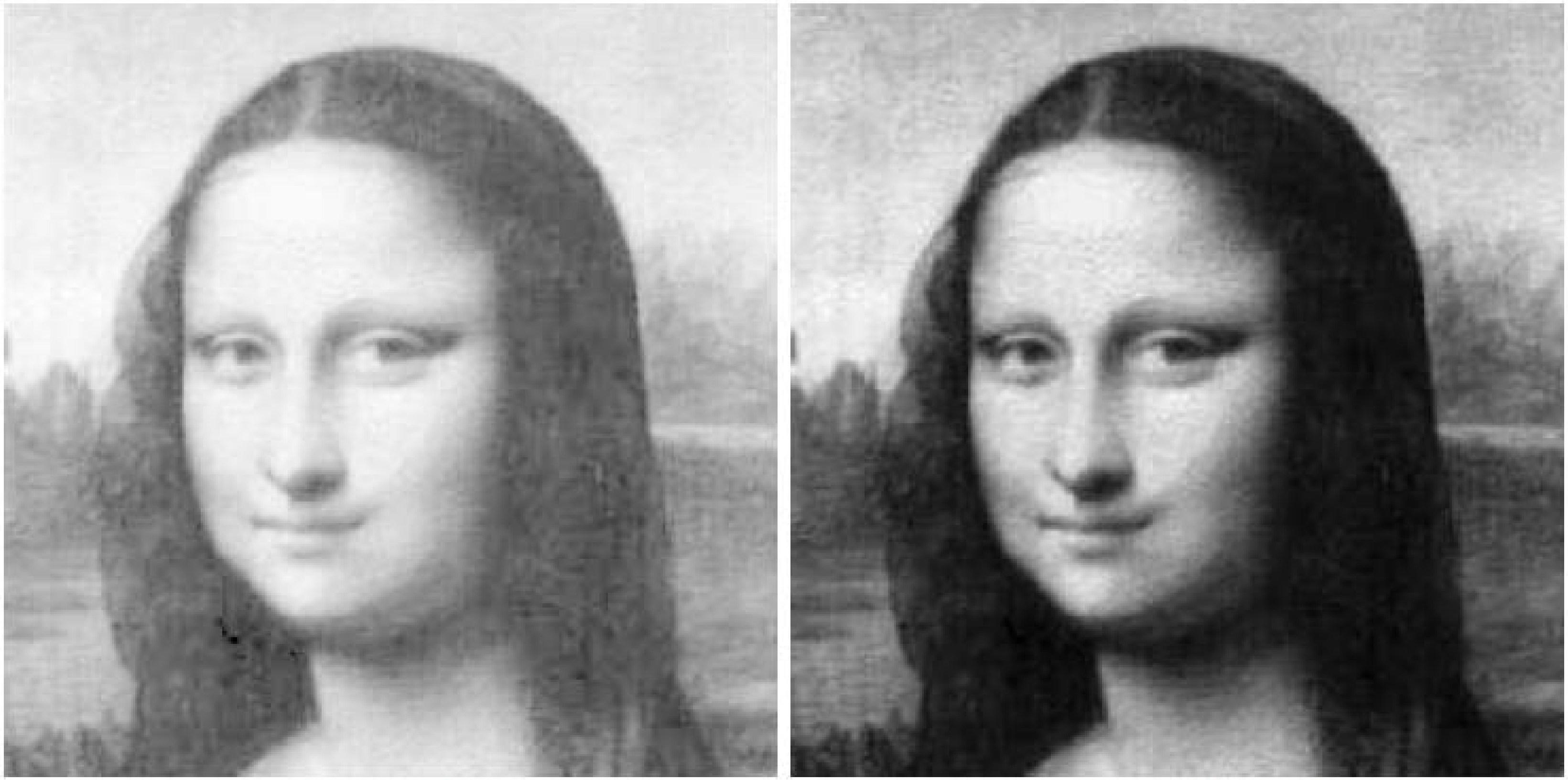


Left: Grayscale image of a map with periodic structures. **Center**: Fourier spectrum. **Right**: After logarithmic dynamic compression. Author: Nazar Khan (2014)

Gamma Correction

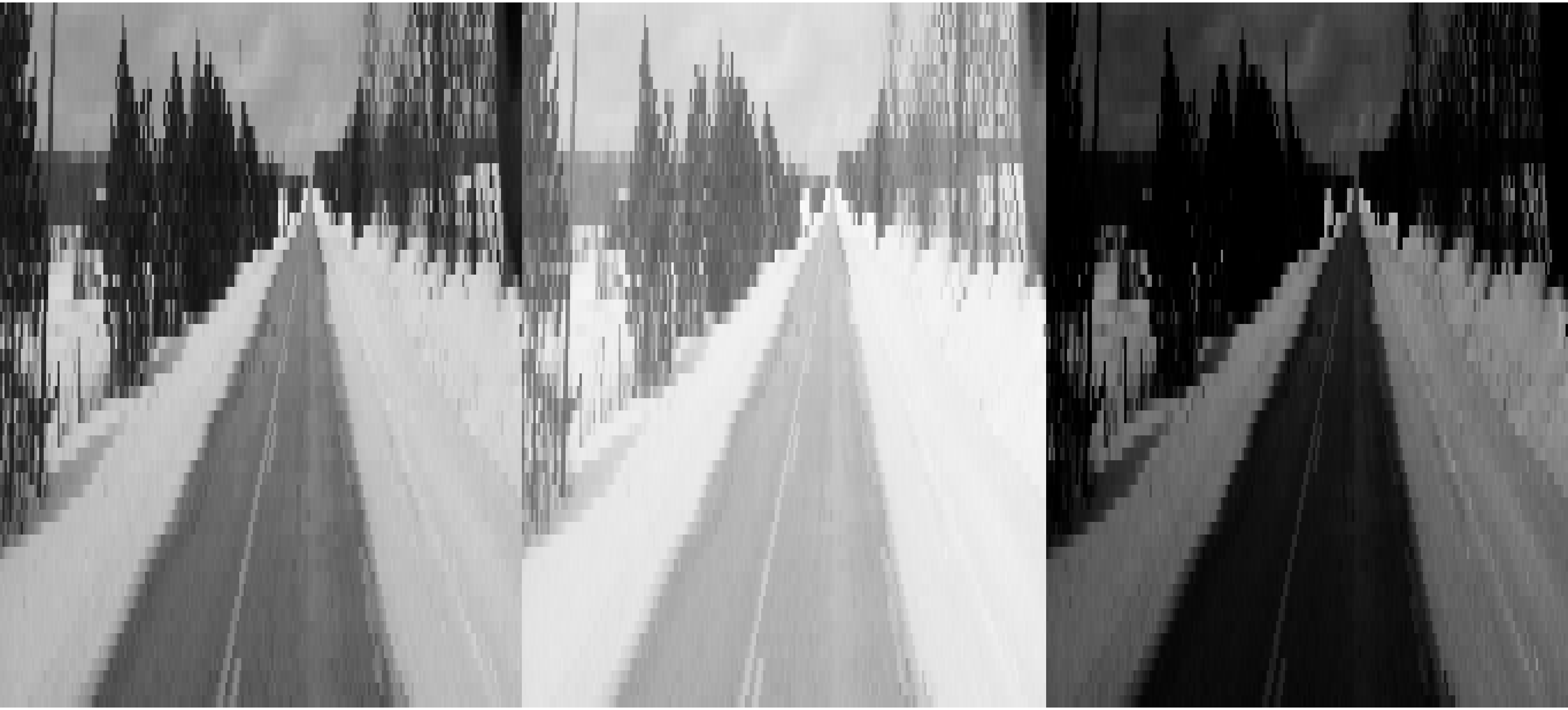
- Often video cameras and computer monitors have a (different) non-linear relationship between input light intensity I and displayed gray value f
  - $f = kI^{\gamma}$.
- To compensate for this non-linearity, the inverse process is applied – the so called **gamma correction**.
- If your image f has the range $[0,f_{max}]$ then $g(x,y)=f_{max} * (f(x,y)/f_{max})^{1/\gamma}$ where $\gamma>0$.
- Range of transformed image is still $[0,f_{max}]$.

Gamma Correction



Gamma correction. **Left:** Although the entire greyscale range $[0, 255]$ is used, the Mona Lisa image appears pale and not very rich in contrast. **Right:** A gamma correction with $\gamma = 0.4$ is a remedy. Authors: L. da Vinci (around 1505), J. Weickert (2002).

Gamma Correction

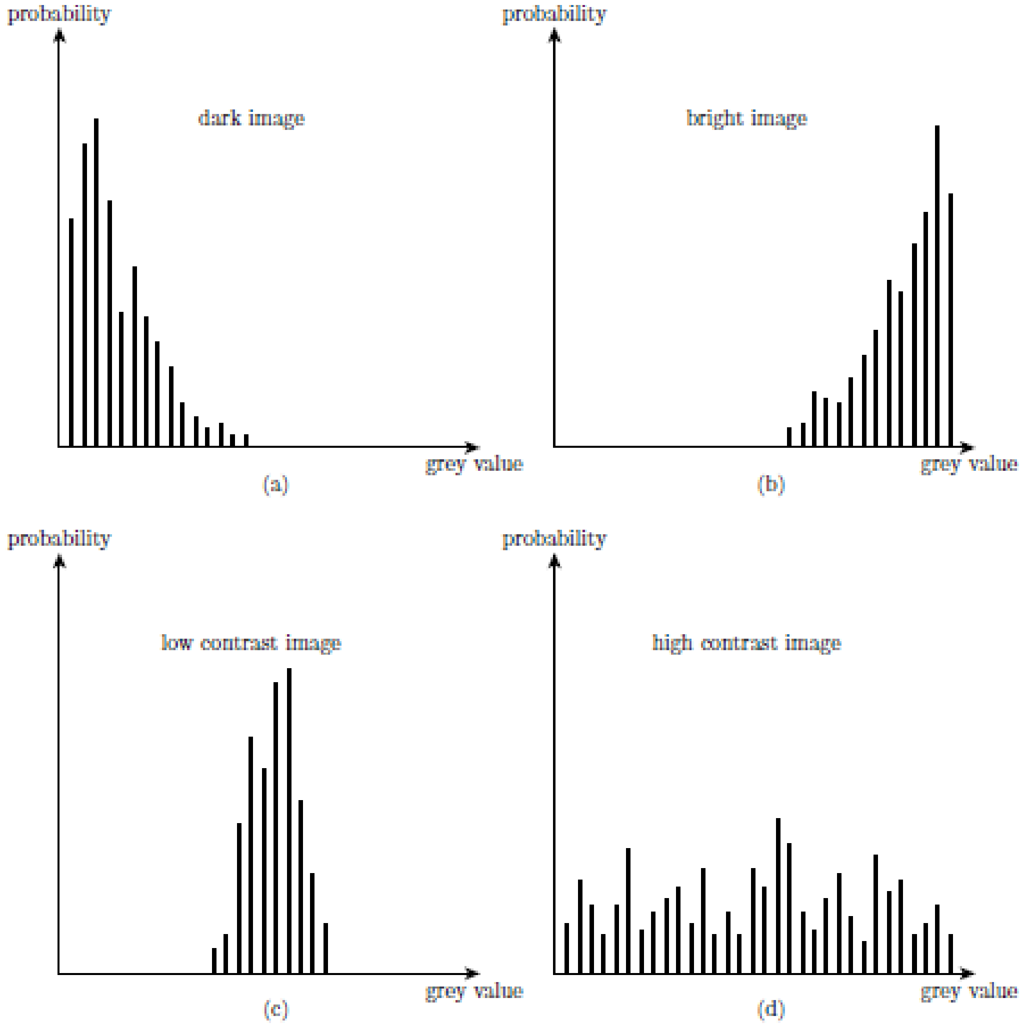


Left: Grayscale image of a road in snow. **Middle**: Gamma correction using $\gamma=0.4$.
Right: $\gamma=3$. Author: Nazar Khan (2014)

Histogram Equalization

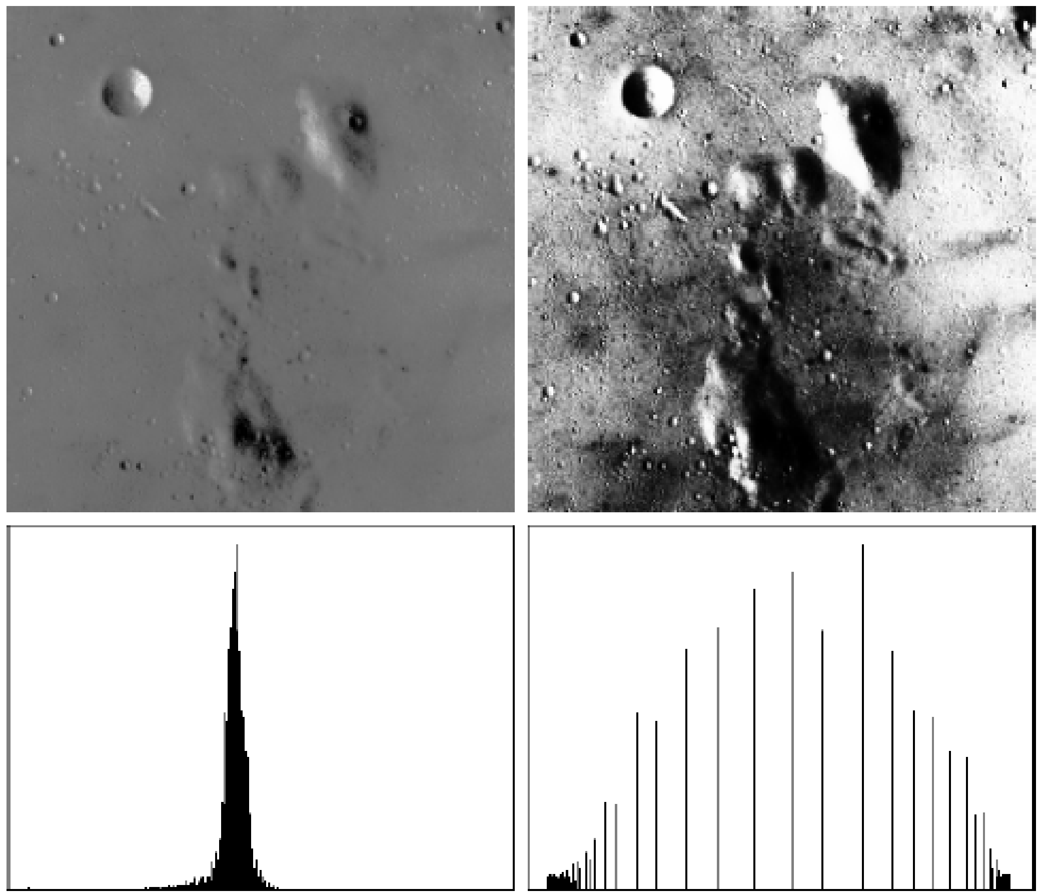
- Transform the gray values such that all gray values occur equal number of times.
- Can induce significant changes in image perception.

Histogram Equalization



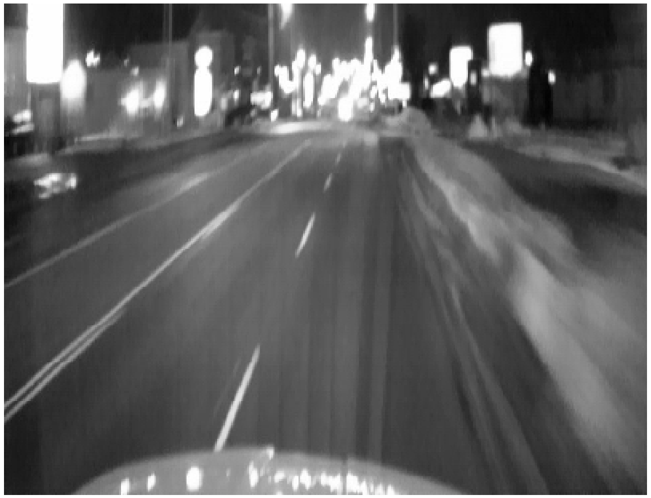
Histograms of different types of images. **(a)** Dark image. **(b)** Bright image. **(c)** Low contrast image. **(d)** High contrast image. Author: T. Schneevoigt (2011).

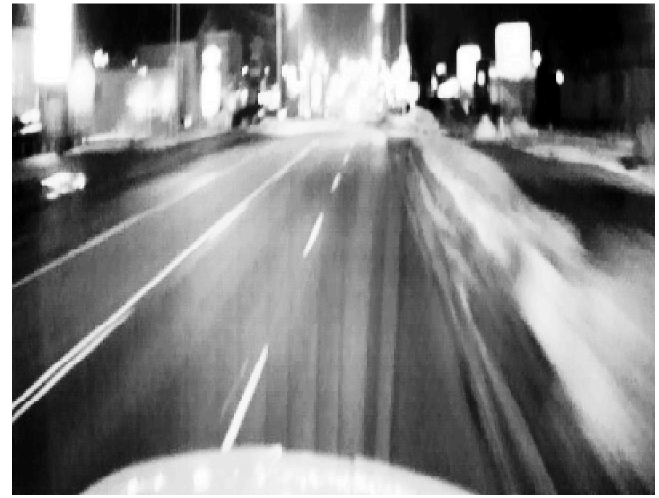
Histogram Equalization

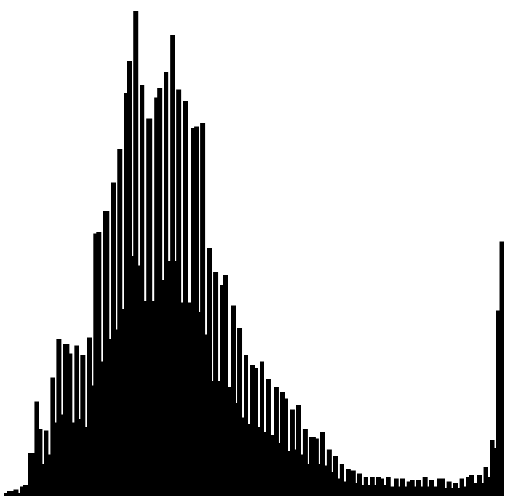


Histogram equalisation. **Top left:** Original image of the surface of the moon. **Top right:** After discrete histogram equalisation. **Bottom left:** Histogram of the original image. **Bottom right:** Histogram of the equalised image. Since the heights of the histogram bars cannot be decreased, the algorithm tries to equalise the histogram by spreading their distances. Author: J. Weickert (2009),

Histogram Equalization





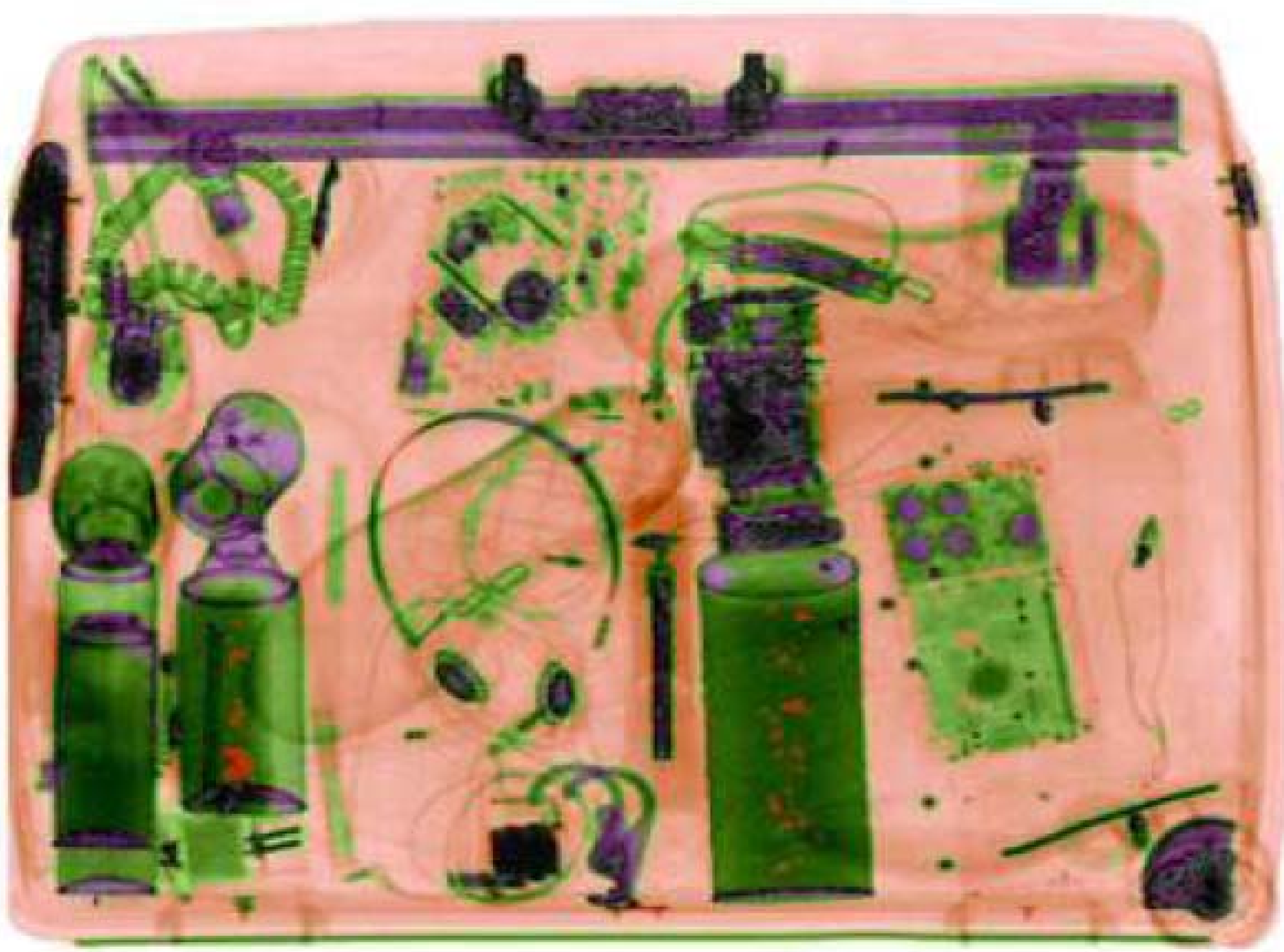


Pseudocolour Representation of Greyscale Images

- Recall from the lecture on color perception that humans can distinguish only 40 greyscales, but 2 million colours.
- Therefore, color offers better visual discrimination.
- Can be used to map X-ray or thermal images to color values.

$$f(x,y) \longmapsto \begin{pmatrix} \phi_r(f(x,y)) \\ \phi_g(f(x,y)) \\ \phi_b(f(x,y)) \end{pmatrix}$$

Pseudocolour Representation of Greyscale Images

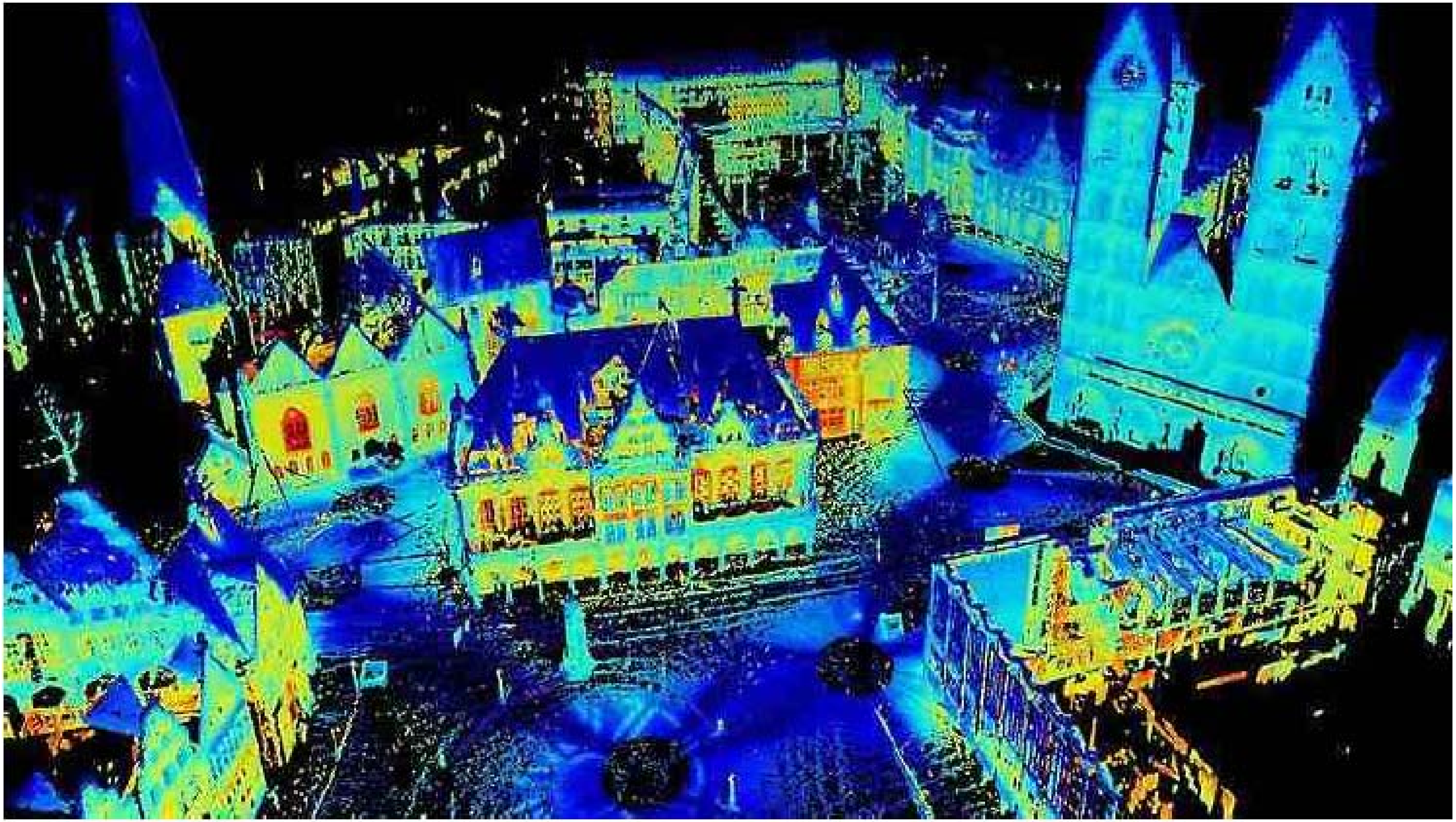


Colouring X-ray images at airport security checks allows a human observer to distinguish objects in a better way. Source: `http://static.howstuffworks.com/gif/airport-security-xray2.jpg`.

Pseudocolour Representation of Greyscale Images

Thermography allows to measure the temperature of objects by their infrared radiation. Usually low temperatures are represented in blue, and high temperatures are depicted in red. **Left:** Pseudocolour representation of the transport of nuclear waste in a train. Source: Greenpeace (2010). **Right:** The pseudocolour representation reveals that the woman freezes at her hands and her nose. Source: R. Reischuk (2007).

Pseudocolour Representation of Greyscale Images

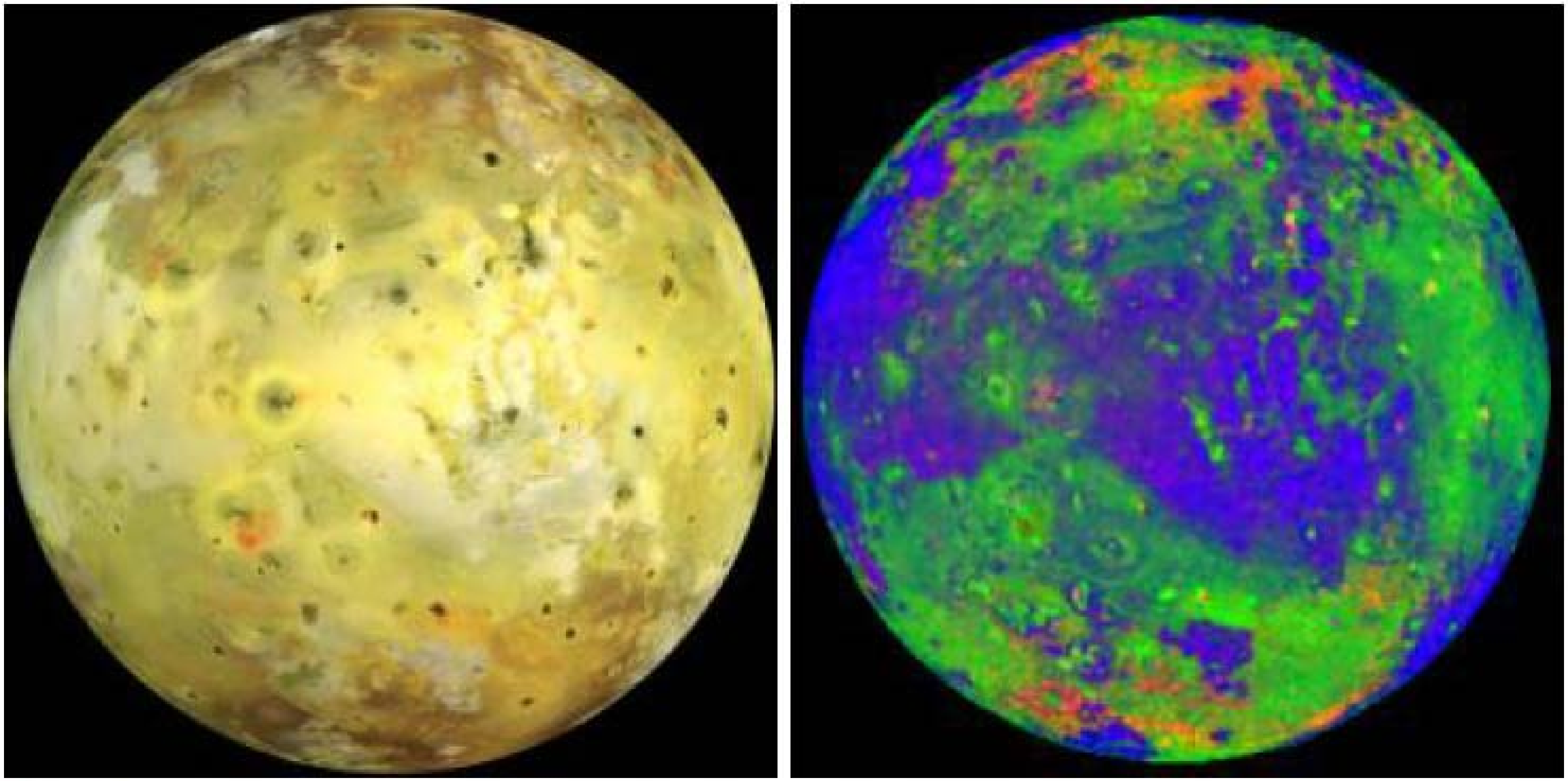


A pseudocolour representation of a thermographic measurement of the market square of Bremen. One can see that the facades of many historical buildings and in particular their windows lose too much heat. Source: Andreas Nüchter (2011).

False Coloring

- To map invisible spectrum to color values.
- Used in remote sensing where usual mode of operation is the invisible spectrum.

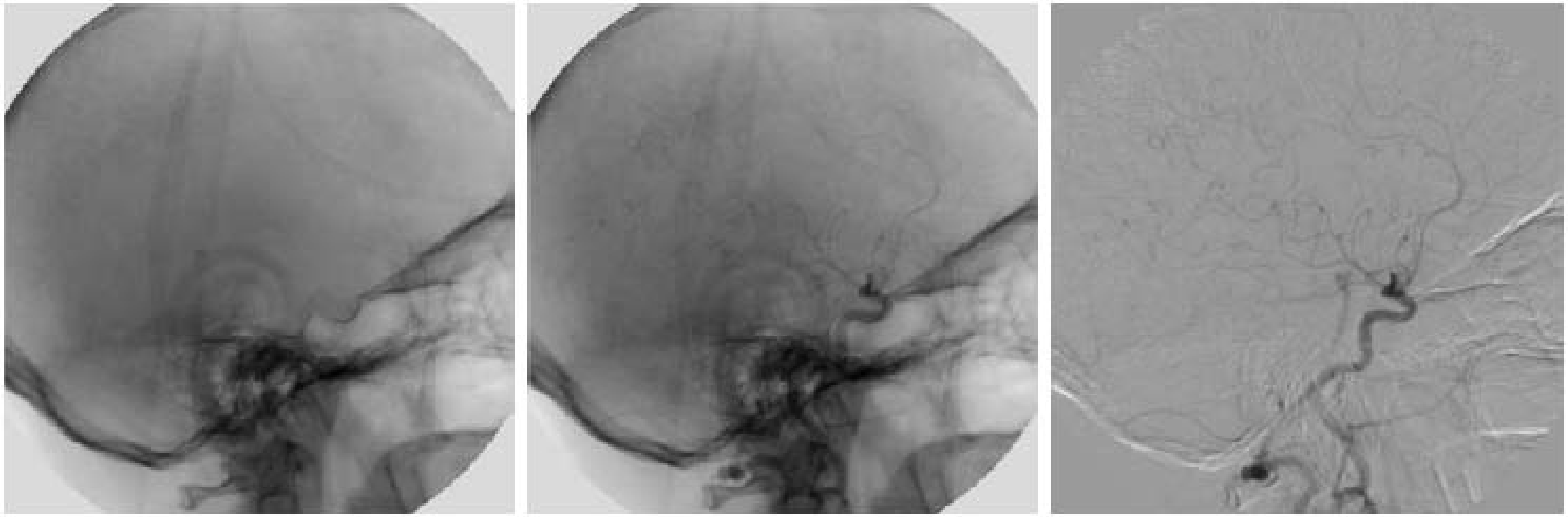
False Coloring



Left: True colour representation of Jupiter's moon Io. **Right:** False colour representation that combines information from two visible and two infrared frequency bands. The depicted colours red, green and blue shows the fraction between two of the four channels. They allow a better interpretation of the surface structure: Red depicts hot vulcanoes, green presumably characterises regions with much sulphur, and blue indicates frozen sulphur dioxide. Source: NASA, `http://www.jpl.nasa.gov/galileo/images/io/iocolor.html`.

Image Subtraction

- Digital Subtraction Angiography (DSA)
  - Medical imaging method for visualizing blood flow through vessels.
  - Take X-ray images before and after giving the patient a contrast agent.
  - Difference image will show the contrast agent in the vessels. Hence the vessels will be extracted.



Digital subtraction angiography. **Left:** Initial image (so-called mask). **Middle:** After giving a contrast agent. **Right:** The difference image removes the background and visualises vessel structures with blood flow. Source: `http://www.isi.uu.nl/Research/Gallery/DSA/`

Summary

- Very basic **point operations** can sometimes dramatically improve image quality.
- Goal is to obtain new gray value representations that are better suited for visual perception.
- It is usually a nice idea to pre-process images using these basic point operations before trying more complex image processing techniques.