SCSV3213

FUNDAMENTAL OF IMAGE PROCESSING SEM1- 20202021

Image Acquisition

Lecture 2 Dr. Md Sah Hj Salam

Acknowledgements

Most of the slide are taken and modified from Brian Mac Namee from Dublin Institut of Technology and other resources including books and slides from others lectures. It is rearranged to suit the syllabus of the course.

Contents

- •This lecture will cover:
 - The human visual system
 - Light and the electromagnetic spectrum
 - Image representation
 - Image sensing and acquisition

1. HUMAN VISUAL SYSTEM

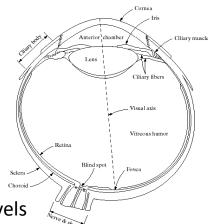
Human Visual System

- •The best vision model we have!
- •Knowledge of how images form in the eye can help us with processing digital images
- •We will take just a whirlwind tour of the human visual system

Structure Of The Human Eye

•The lens focuses light from objects onto the retina

- •The retina is covered with light receptors called cones (6-7 million) and rods (75-150 million)
- •Cones are concentrated around the fovea and are very sensitive to colour
- •Rods are more spread out chord and are sensitive to low levels of illumination



Blind-Spot Experiment

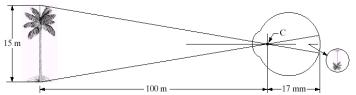
•Draw an image similar to that below on a piece of paper (the dot and cross are about 6 inches apart)



- •Close your right eye and focus on the cross with your left eye
- •Hold the image about 20 inches away from your face and move it slowly towards you
- •The dot should disappear!

Image Formation In The Eye

- Muscles within the eye can be used to change the shape of the lens allowing us focus on objects that are near or far away
- An image is focused onto the retina causing rods and cones to become excited which ultimately send signals to the brain

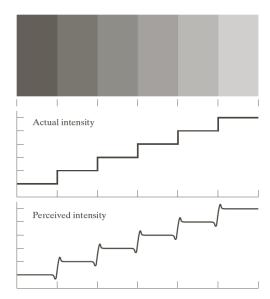


Brightness Adaptation & Discrimination

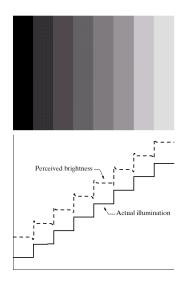
- •The human visual system can perceive approximately 10¹⁰ different light intensity levels
- However, at any one time we can only discriminate between a much smaller number – brightness adaptation
- •Similarly, the *perceived intensity* of a region is related to the light intensities of the regions surrounding it

Brightness Adaptation & Discrimination (cont...)





Mach Band Effect

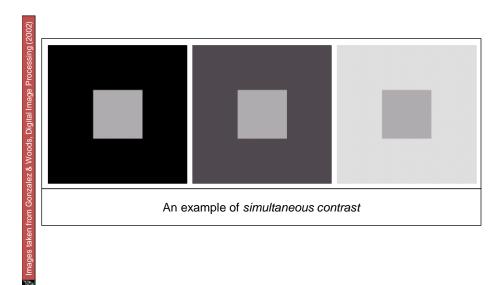


Intensities of surrounding points effect perceived brightness at each point.

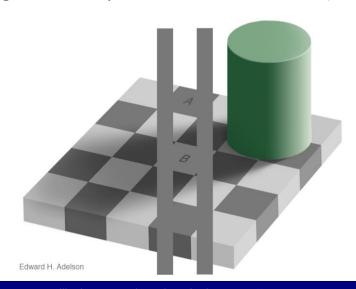
In this image, edges between bars appear brighter on the right side and darker on the left side.

(Images from Rafael C. Gonzalez and Richard E. Wood, Digital Image Processing, $2^{\rm nd}$ Edition.

Brightness Adaptation & Discrimination (cont...)



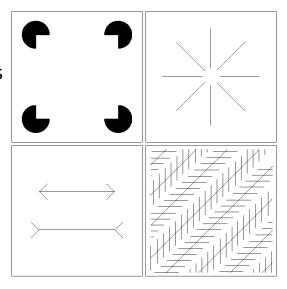
Brightness Adaptation & Discrimination (cont...)



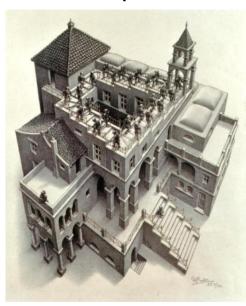
For more great illusion examples take a look at: http://web.mit.edu/persci/gaz/

Optical Illusions

Our visual systems play lots of interesting tricks on us



Optical Illusions (cont...)





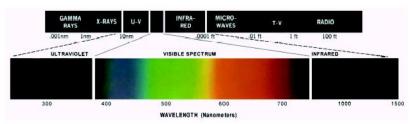
Optical Illusions (cont...)



Stare at the cross in the middle of the image and think circles

2. LIGHT AND ELECTROMAGNETIC SPECTRUM

The Electromagnetic Spectrum



- EM radiation is produced by the oscillation of electrically charged material, and has wave-like properties.
- At shorter wavelengths, EM radiation carries larger energies.

The Electromagnetic Spectrum

- EM radiation travels rapidly, at approximately 300,000 kilometers per second, allowing near instantaneous imaging of events as they occur.
- Another useful property of EM radiation, for imaging purposes, is its tendency to travel in straight lines.
- This means that many of the geometric characteristics of objects in a scene are preserved in images of that scene.

The Electromagnetic Spectrum

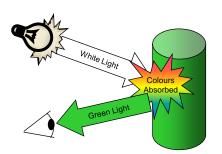
- Radiation can interact with matter in different ways, depending on its wavelength.
- Images acquired at different wavelengths may have very different properties, and we may need to be aware of these differences when seeking appropriate image processing techniques.

Light And The Electromagnetic Spectrum

- Light is just a particular part of the electromagnetic spectrum that can be sensed by the human eye
- The electromagnetic spectrum is split up according to the wavelengths of different forms of energy
- The visible portion of the spectrum occurs between wavelengths of approximately 400 and 700 nanometres (nm)'.
- Within this region, wavelength is perceived as colour;
- light at 550 nm appears green, whereas light at 700 nm is seen as red.

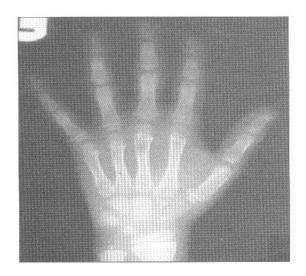
Reflected Light

- •The colours that we perceive are determined by the nature of the light reflected from an object
- •For example, if white light is shone onto a green object most wavelengths are absorbed, while green light is reflected from the object



The Electromagnetic Spectrum

- In the x-ray region of the spectrum (at a wavelength, of around 10- 10 nm), it carries sufficient energy to penetrate a significant volume of material.
- X-ray images therefore reveal the internal structure of objects – i.e. information on anatomy and internal structure of human body.



A sample image of a hand from an X-Ray

The Electromagnetic Spectrum

- At shorter wavelengths, EM radiation manifests itself as gamma rays, which are a common product of radioactive decay.
- Gamma rays are highly penetrating and, like x-rays, have medical applications.
- Gamma rays are used to trace diseased tissue such as a tumor which often appear as a bright region in images.

- EM radiation with wavelengths longer than that of light also has its uses.
- 'Synthetic aperture radar' (SAR) imaging techniques use an artificially generated source of microwaves to probe a scene.
- Radar is unaffected by cloud cover, and it has provided us with detailed images of the surface of the Earth.
- Radar images can be difficult to interpret, owing to geometric distortions inherent in the imaging process.

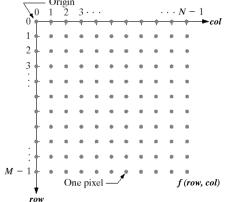
3. IMAGE REPRESENTATION

•Before we discuss image acquisition recall that a digital image is composed of M rows and N columns

of pixels

each storing a value

- •Pixel values are most often grey levels in the range 0-255(black-white)
- •We will see later on that images can easily be represented as matrices



Digital image representation

Image coordinate convention (not valid for MATLAB!)



NB: There is no universally accepted convention or notation. Always check carefully!

Mathematical notation

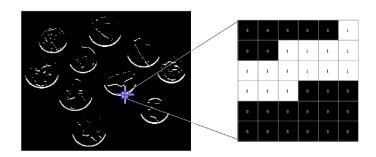
$$f(x,y) = \begin{bmatrix} f(0,0) & f(0,1) & \cdots & f(0,N-1) \\ f(1,0) & f(1,1) & \cdots & f(1,N-1) \\ \vdots & \vdots & & \vdots \\ f(M-1,0) & f(M-1,1) & \cdots & f(M-1,N-1) \end{bmatrix}$$

Digital image representation

MATLAB representation

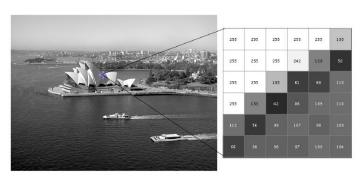
$$f(p,q) = \begin{bmatrix} f(1,1) & f(1,2) & \cdots & f(1,N) \\ f(2,1) & f(2,2) & \cdots & f(2,N) \\ \vdots & & \vdots & & \vdots \\ f(M,1) & f(M,2) & \cdots & f(M,N) \end{bmatrix}$$

- Binary (1-bit) images
 - 2D array, one bit per pixel, a 0 usually means "black" and a 1 means "white".
 - In MATLAB: binary images are represented using a logical array of 0s and 1s.



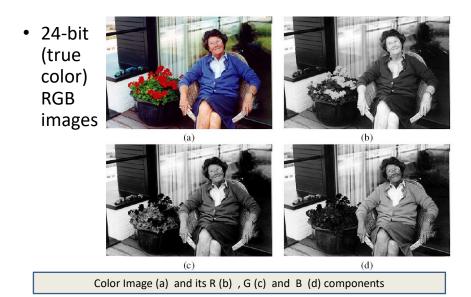
Digital image representation

- Gray-level (8-bit) images
 - 2D array, 8 bits per pixel, a 0 usually means "black" and a 255 means "white".
 - In MATLAB: intensity images can be represented using different data types (or classes): uint8, uint16, or double.

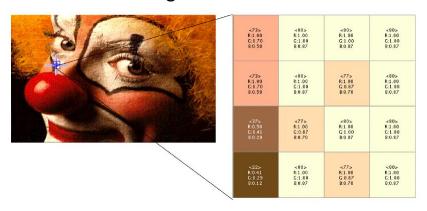


- Color images
 - RGB representation: each pixel is usually represented by a 24-bit number containing the amount of its Red (R), Green (G), and Blue (B) components
 - Indexed representation: a 2D array contains indices to a color palette (or look-up table, LUT).

Digital image representation



Indexed color images



Compression

- Most image file formats employ some type of compression.
- Compression methods can be:
 - Lossy: a tolerable degree of deterioration in the visual quality of the resulting image is acceptable.
 - Lossless: the image is encoded in its full quality.
- As a general guideline:
 - lossy compression should be used for general purpose photographic images;
 - lossless compression should be used for line art, drawings, facsimiles, or images in which no loss of detail may be tolerable (e.g., space images and medical images).

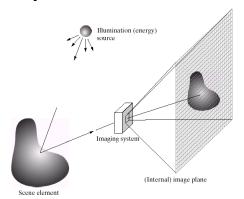
Image file formats

- Image file contents:
 - File header
 - Pixel data (often compressed)
- Most common file types:
 - BIN, PPM, PBM, PGM, PNM, BMP, JPEG, GIF, TIFF, PNG
- From a MATLAB perspective, it doesn't really matter much...
 - Prof. Alasdair McAndrew: "You can use MATLAB for image processing very happily without ever really knowing the difference between GIF, TIFF, PNG, and all the other formats."

4. IMAGE SENSING AND ACQUISITION

Image Acquisition

•Images are typically generated by *illuminating* a *scene* and absorbing the energy reflected by the objects in that scene

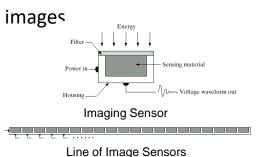


- Typical notions of illumination and scene can be way off:
 - · X-rays of a skeleton
 - Ultrasound of an unborn baby
 - Electro-microscopic images of molecules

Image Sensing

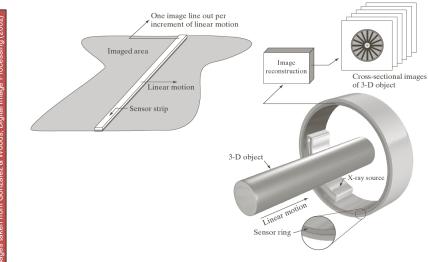
 Incoming energy lands on a sensor material responsive to that type of energy and this generates a voltage

Collections of sensors are arranged to capture



Array of Image Sensors

Image Sensing



Using Sensor Strips and Rings

Image Sampling And Quantisation

- •A digital sensor can only measure a limited number of **samples** at a **discrete** set of energy levels
- Quantisation is the process of converting a continuous analogue signal into a digital representation of this signal

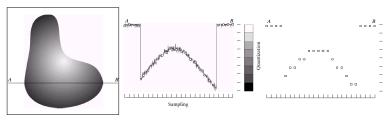


Image Sampling And Quantisation



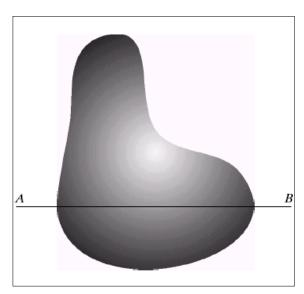
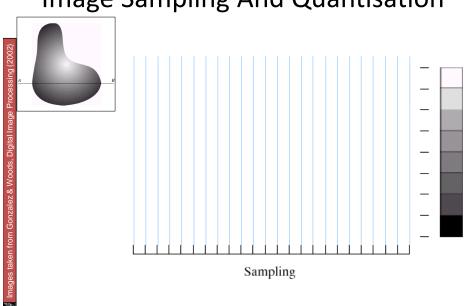


Image Sampling And Quantisation



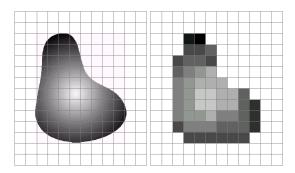


Image Representation

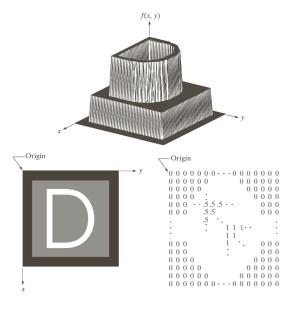


Image Representation

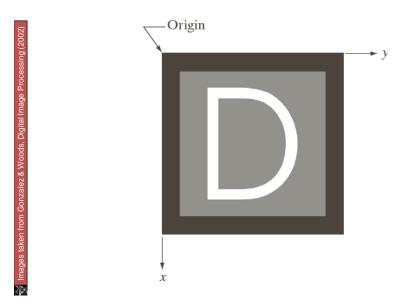


Image Representation

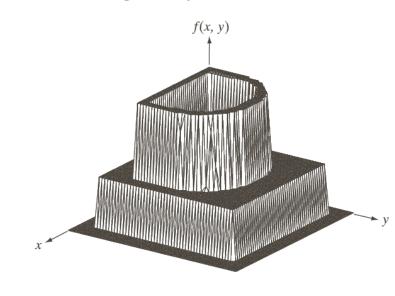
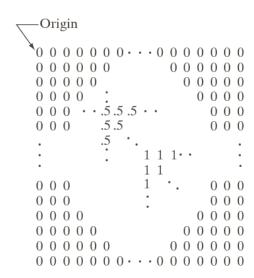


Image Representation

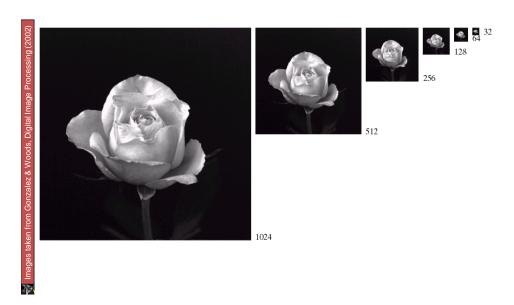


Spatial Resolution

- •The spatial resolution of an image is determined by how sampling was carried out
- •Spatial resolution simply refers to the smallest discernable detail in an image
 - Vision specialists will often talk about pixel size
 - Graphic designers will talk about dots per inch (DPI)



Spatial Resolution (cont...)



Spatial Resolution (cont...)

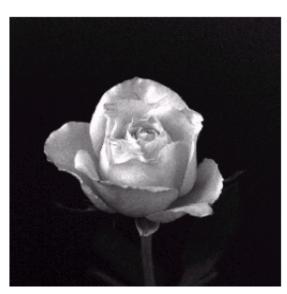


| Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Spatial Resolution (cont...)

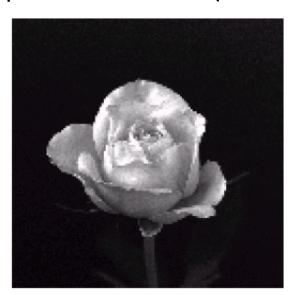


Spatial Resolution (cont...)

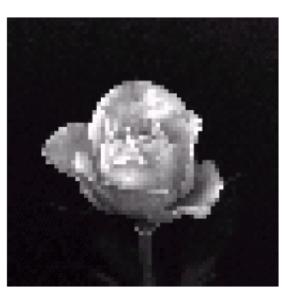


Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Spatial Resolution (cont...)



Spatial Resolution (cont...)



wages taken from Gonzalez & Woods, Digital Image Processing (2002)

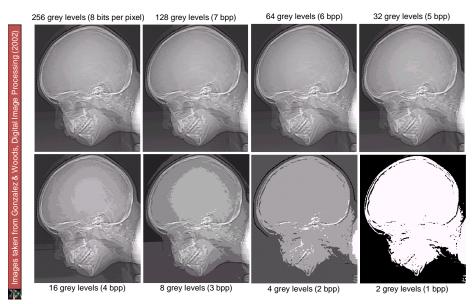
Spatial Resolution (cont...)



Intensity Level Resolution

- •Intensity level resolution refers to the number of intensity levels used to represent the image
 - The more intensity levels used, the finer the level of detail discernable in an image
 - Intensity level resolution is usually given in terms of the number of bits used to store each intensity level

Number of Bits	Number of Intensity Levels	Examples
1	2	0, 1
2	4	00, 01, 10, 11
4	16	0000, 0101, 1111
8	256	00110011, 01010101
16	65,536	1010101010101010



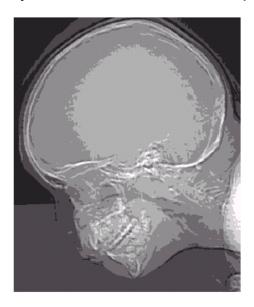








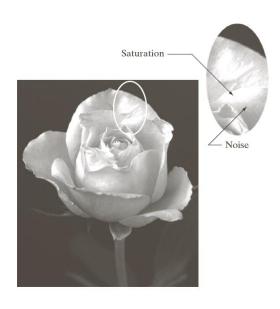








Saturation & Noise



Resolution: How Much Is Enough?

- •The big question with resolution is always how much is enough?
 - This all depends on what is in the image and what you would like to do with it
 - Key questions include
 - · Does the image look aesthetically pleasing?
 - Can you see what you need to see within the image?

Resolution: How Much Is Enough? (cont...)





•The picture on the right is fine for counting the number of cars, but not for reading the number plate





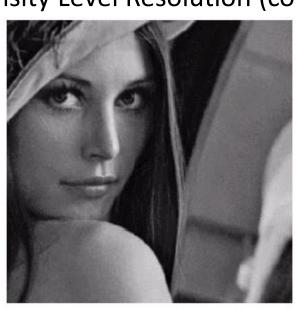


Low Detail

Medium Detail

High Detail









Summary

- •We have looked at:
 - Human visual system
 - Light and the electromagnetic spectrum
 - Image representation
 - Image sensing and acquisition
 - Sampling, quantisation and resolution

End of Image Acquisition SCSV 3213