DCS
UNIVERSITY OF JAFFNA

CSC310S3/305M3: Image Processing & Computer Vision

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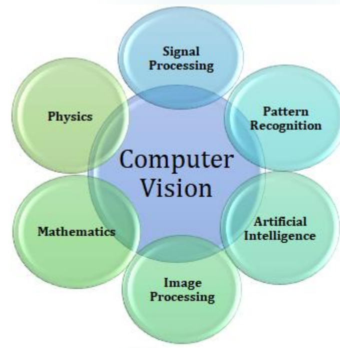
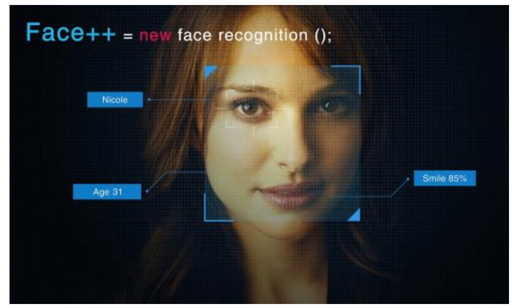


Course Structure

Hourly Breakdown:	Theory	Practical	Independent Learning
	30	30	90
Objectives:	Provide in-depth knowledge in image processing and computer vision techniques to solve real-world problems, and develop skills for research in these fields		
Intended Learning Outcomes:	• Describe the basic concepts of image processing and computer vision • Perform visual tasks in sequences of image analysis operations, representations, specific algorithms, and inference principles • Explain image processing techniques in the spatial and frequency domain • Analyse a range of algorithms for image processing and computer vision • Develop basic computer vision algorithms for image retrieval and image recognition • Apply image processing and computer vision techniques to solve real-world problems		

Contents

1. Digital Image Fundamentals
2. Image Enhancement in Spatial Domain
3. Image Enhancement in Frequency Domain
4. Morphological Image Processing
5. Image Segmentation
6. Introduction to Computer Vision and its Applications
7. Introduction to Object Recognition



https://www.csc.jfn.ac.lk/courses-direct-intake

Course Structure …

Teaching/Learning Methods:	Lectures, Assignments, Poster presentation, Guided learning
Assessment Strategy:	• In-course Assessment (Theory) ———————————15% • In-course Assessment (Practical) ———————————15% • End-of-course Examination —————————————-70%
References:	• W. Burger and M.J. Burge, Principles of Digital Image Processing: Fundamental Techniques, Springer, 3rd Ed., 2009. • M. Sonka, R. Boyle and V. Hlavac, Image Processing, Analysis and Machine Vision, 3rd Ed., Springer, 2008. • R.C. Gonzalez and R.E. Woods, Digital Image Processing, 3rd Ed., Pearson, 2007. • L.G. Shapiro and G. Stockman, Computer Vision, Prentice Hall, 2001.

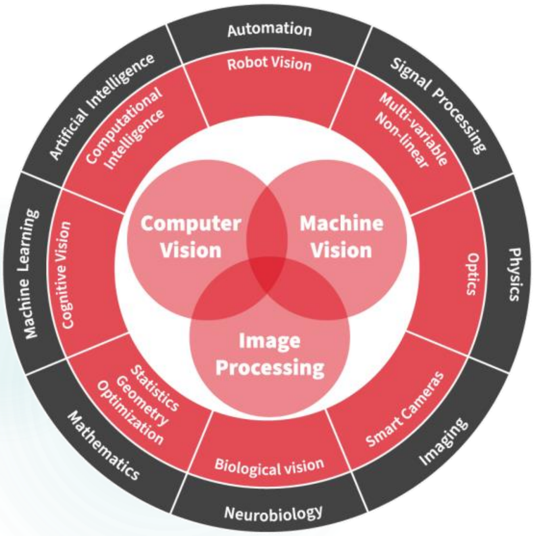
Journals & Conferences in IP & CV

- **Journals:**
  — IEEE Transactions on Image Processing
  — IEEE Transactions on Medical Imaging
  — International Journal of Computer Vision (IJCV)
  — IEEE Transactions on Pattern Analysis and Machine Intelligence (TPAMI)
  — Computer Vision And Image Understanding (CVIU)
  — Image And Vision Computing
  …
- **Conferences:**
  — Computer Vision and Pattern Recognition (CVPR)
  — International Conference on Computer Vision (ICCV)
  — International Conference on Image Processing (ICIP)
  — European Conference on Computer Vision (ECCV)
  — International Conference on Computer Analysis of Images and Patterns (CAIP)
  …

Digital Image Fundamentals

1

- **Digital image editing** or as it is sometimes referred to, digital imaging, is the manipulation of digital images using an existing software application such as Adobe Photoshop, Adobe Illustrator, Gimp, CyberLink PhotoDirector 365, and ACDSee Photo Studio Ultimate.
- **Digital image processing** is the conception, design, development, and enhancement of digital imaging programs.
- **Computer graphics** concentrates on the synthesis of digital images from geometrical descriptions such as three-dimensional object models

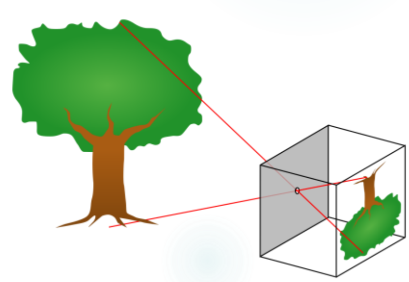


	Input	Output
Image processing	Image is processed using algorithms to correct, edit or process an image to create a new better image.	Enhanced image is returned.
Computer vision	Image/video is analysed using algorithms in often uncontrollable/unpredictable circumstances.	Image understanding, prediction & learning to inform actions such as segmentation, recognition & reconstruction.
Machine vision	Use of camera/video to analyse images in industrial settings under more predictable circumstances.	Image understanding & learning to inform manufacturing processes.

Image Acquisition

- The process by which a scene becomes a digital image.
- The Pinhole Camera Model:

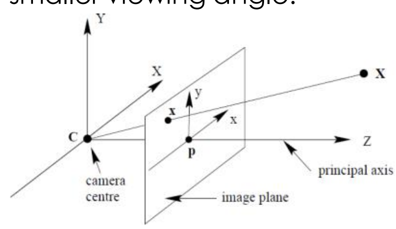
The pinhole camera consists of a closed box with a small opening on the front side through which light enters, forming an image on the opposing wall. The light forms a smaller, inverted image of the scene.

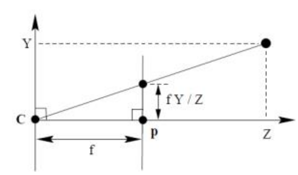


The Pinhole Camera Model …

Assume a visible object located at a horizontal distance Z from the pinhole and vertical distance Y from the optical axis. The height of the projection y is determined by two parameters: the depth of the camera box f and the distance Z of the object from the origin of the coordinate system. For a fixed scene, a short focal length results in a small image and a large viewing angle. In contrast, increasing the "focal length" results in a larger image and a smaller viewing angle.

$$y = -f\frac{Y}{Z}$$

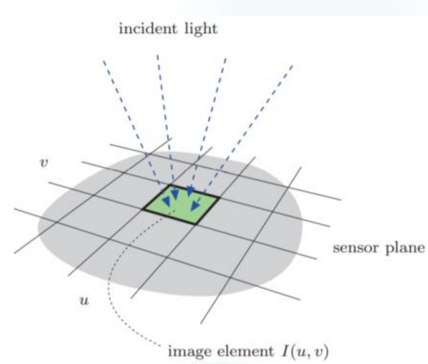




Going Digital

In order to obtain a "digital snapshot" of a two-dimensional, time-dependent, continuous distribution of light energy for processing it on a computer, three main steps are necessary:

1. Spatial sampling
2. Temporal sampling
3. Quantization of pixel values



Going Digital …

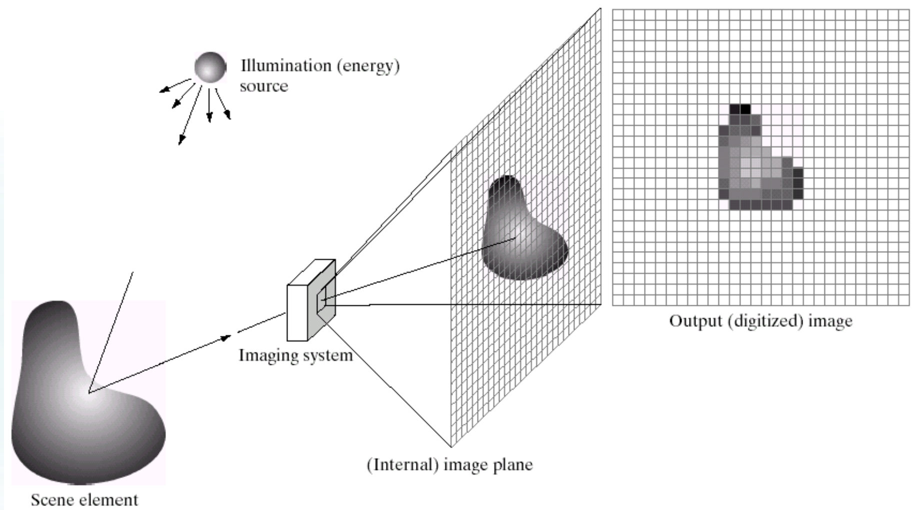
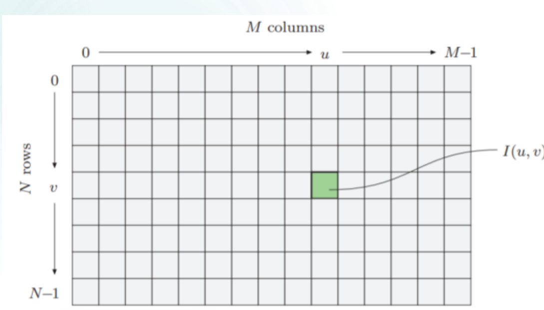
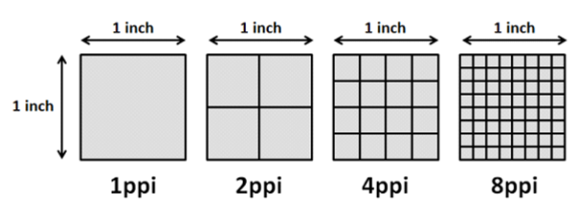


Image Size and Resolution

- The **size** of an image is determined directly from the width M (number of columns) and the height N (number of rows) of the image matrix I.
- The **resolution** of an image specifies the spatial dimensions of the image in the real world and is given as the number of image elements per measurement.





Pixel Values

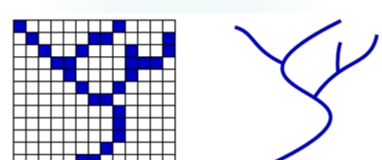
Pixel values are always binary words of length k so that a pixel can represent any of 2k different values. The value k is called the bit depth of the image.

- Binary images
- Grayscale images
- Colour images

color greyscale black and white

Image File Formats

- Raster versus Vector Data
- Raster images are comprised of individual pixels of color. Each colour pixel contributes to the overall image.
- Vector images are comprised of coloured pixels arranged to display an image, vector graphics are made up of paths, each with a mathematical formula (vector) that tells the path how it is shaped and what colour it is bordered.



Raster Vector

Image File Formats …

- Tagged Image File Format (TIFF)
- Graphics Interchange Format (GIF)
- Portable Network Graphics (PNG)
- JPEG File Interchange Format (JFIF)
- Exchangeable Image File Format (EXIF)
- Windows Bitmap (BMP)
- Portable Bitmap Format (PBM)

Histograms of Images

2

- Histograms in general are frequency distributions, and histograms of images describe the frequency of the intensity values that occur in an image.
- A histogram h for a grayscale image I with intensity values in the range $I(x, y) \in [0, K-1]$ would contain exactly K entries,
- $h(i)$ = the number of pixels in I with the intensity value I for all $0 \leq i < K$.
- More formally stated, $h(i) = \text{card}\{(x, y) \mid I(x, y) = i\}$

Histograms …

- Since a histogram encodes no information about where each of its individual entries originated in the image, histograms contain no information about the spatial arrangement of pixels in the image.

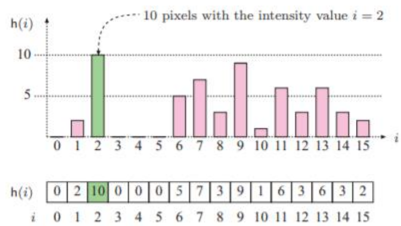


Figure Histogram vector for an image with $K = 16$ possible intensity values. The indices of the vector element $i = 0 \ldots 15$ represent intensity values. The value of 10 at index 2 means that the image contains 10 pixels of intensity value 2.

Histograms …

- Is it possible to reconstruct an image using only its histogram?

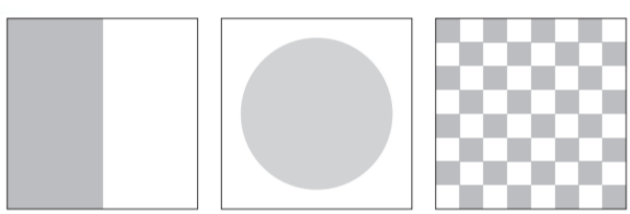


Figure Three very different images with identical histograms.

Given the loss of spatial information, it is not possible to reconstruct an image using its histogram

Image Acquisition

Exposure

A histogram where a large span of the intensity range at one end is largely unused while the other end is crowded with high-value peaks is representative of an improperly exposed image.

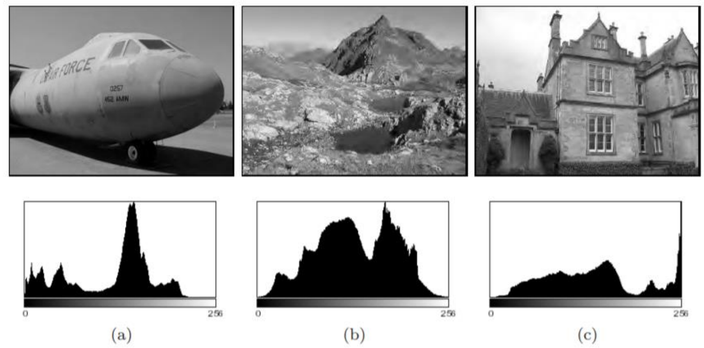


Figure Exposure errors are readily apparent in histograms. Underexposed (a), properly exposed (b), and overexposed (c) photographs.

Image Acquisition …

Contrast

Contrast is understood as the range of intensity values effectively used within a given image, that is the difference between the image's maximum and minimum pixel values. A full-contrast image makes effective use of the entire range of available intensity values from a = 0…K − 1.

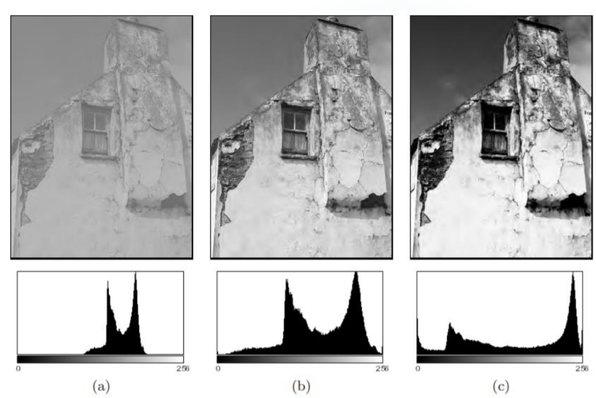


Figure How changes in contrast affect a histogram: low contrast (a), normal contrast (b), high contrast (c).

Image Defects

Saturation

Illumination outside of the sensor's contrast range, arising for example from glossy highlights and especially dark parts of the scene, cannot be captured and is lost. The result is a histogram that is saturated at one or both ends of its range. The illumination values lying outside of the sensor's range are mapped to its minimum or maximum values and appear on the histogram as significant spikes at the tail ends.

Histogram Binning

Normally histograms are computed in order to visualize the image's distribution on the screen. When an image uses a larger range of values, for instance 16- and 32-bit or floating-point images, then the growing number of necessary histogram entries makes this no longer practical. Instead let a given entry in the histogram represent a range of intensity values. This technique is often referred to as "binning" since you can visualize it as collecting a range of pixel values in a container such as a bin or bucket. In a binned histogram of size B, each bin h(j) contains the number of image elements having values within the interval $a_j \leq a < a_{j+1}$, and therefore

$$\mathsf{h}(j) = \mathrm{card}\left\{(u,v) \mid a_j \leq I(u,v) < a_{j+1}\right\}, \quad \text{for } 0 \leq j < B.$$

Histogram Binning …

Typically the range of possible values in B is divided into bins of equal size k_B = K/B such that the starting value of the interval j is

$$a_j = j \cdot \frac{K}{B} = j \cdot k_B.$$

As an index to the appropriate histogram bin h(j), we require an integer value

$$j = \left\lfloor \frac{I(u,v) \cdot B}{K} \right\rfloor$$

Cumulative Histogram

- The cumulative histogram H is defined as: $\mathsf{H}(i) = \sum_{j=0}^{i} \mathsf{h}(j) \quad \text{for } 0 \le i < K.$
- Alternatively, we can define H recursively $\mathsf{H}(i) = \begin{cases} \mathsf{h}(0) & \text{for } i = 0 \\ \mathsf{H}(i-1) + \mathsf{h}(i) & \text{for } 0 < i < K. \end{cases}$