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Digital Image Processing

Lecture 1: Introduction to Image Processing

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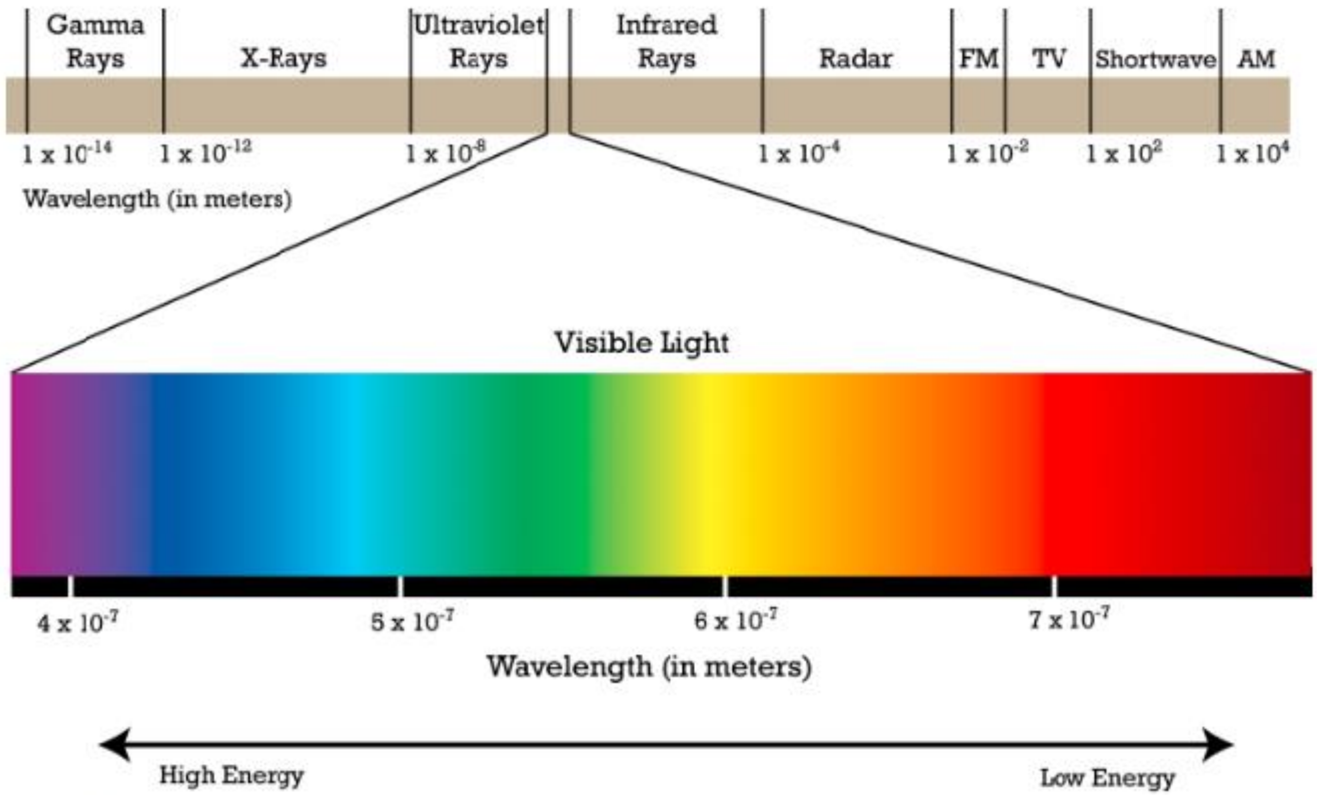
Logistics of the course

- **Welcome to the Digital Image Processing course!**
- This course is very important to students who are interested in taking any course related to Computer Vision and Machine learning and it is also related to Pattern Recognition and Artificial Intelligence.
- Image Processing algorithms constitute the building blocks of most Computer Vision and Machine learning algorithms.

- Duration: 20 lectures
- Assessment: 100% exam
- Textbook:
    - R. C. Gonzalez, R. E. Woods, Digital Image Processing, Addison Wesley.
    - There are many editions of the above book, any of them is good.

What is a digital image?

- We are mostly familiar with images that we can see with our eyes. These are the images we take with our cameras. They form a very small part of the spectrum!



The electromagnetic spectrum.

What is a digital image cont?

- Images can be captured from other parts of the spectrum. For example:
  - Gamma images
  - X ray images
  - Ultra violet images
  - Optical-microscopy (light-microscopy) images
  - Infrared images
  - Satellite images
  - Thermal images

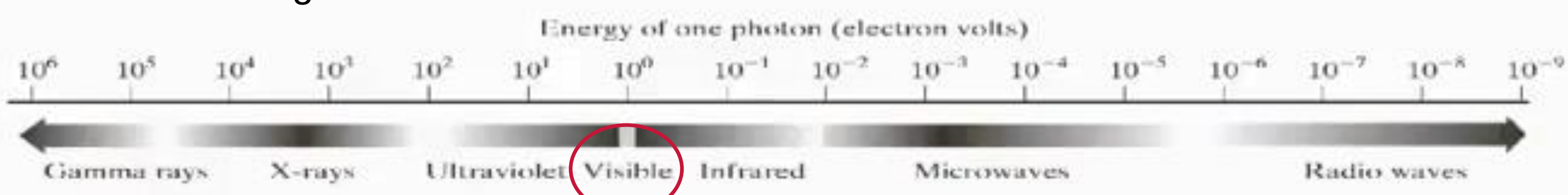


FIGURE 1.5 The electromagnetic spectrum arranged according to energy per photon.

What is Image Processing?

- Image Processing refers to a huge collection of mathematical techniques which aim at analysing digital images in order to achieve various goals.
- The mathematics involved in Image Processing are mainly discrete mathematics since we are dealing with digital images. They could be:
  - Multi-dimensional filters
  - Probabilities and statistics
  - System analysis algorithms
  - Others
- Image Processing topics include:
  - Image modelling
  - Image restoration, enhancement, reconstruction
  - Image compression
  - Analysis, detection, recognition, understanding

Image Processing and Computer Vision: what is the difference?

- Image Processing refers to a lower level (modelling/signal analysis/noise removal) of processing of an image signal compared to Computer Vision.
- For example:
  - Finding good mathematical features to describe a human silhouette is image processing.
  - Using the features which describe a human silhouette as part of a system that detects humans in an image is computer vision.
- Computer Vision refers to any type of science that attempts to make a digital computer carry human vision tasks. It is a bigger and less well-defined area compared to Image Processing. The two areas overlap.

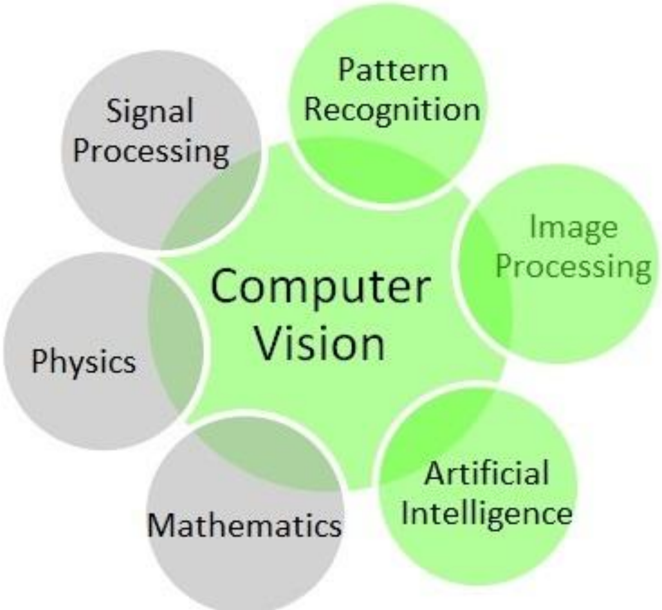


Image acquisition

- An image is a projection of a 3D scene into a 2D projection plane.
- An image can be defined as a function of two variables (x, y) as $f(x, y)\colon R^2 \rightarrow R$, where for each position (x, y) in the projection plane, $f(x, y)$ defines the light intensity at this point.

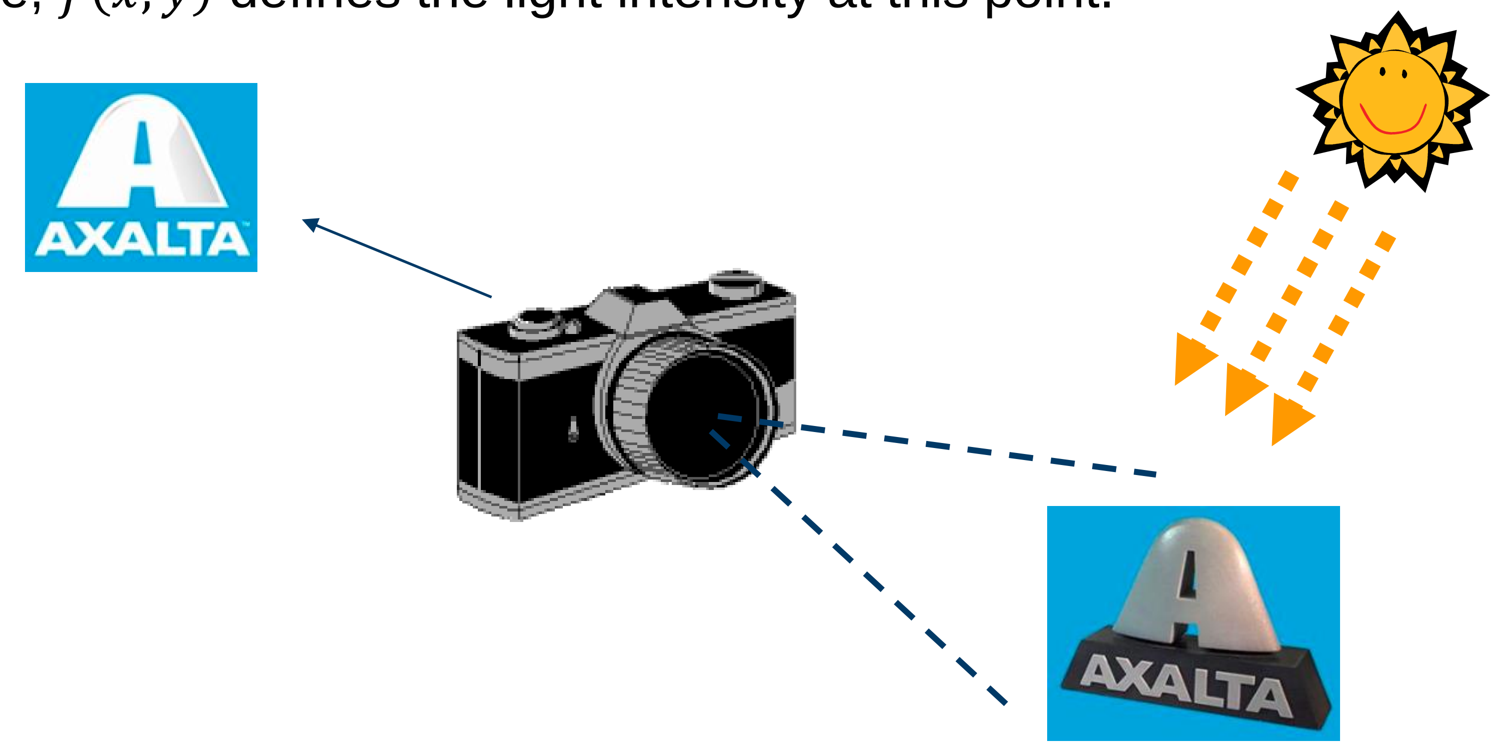


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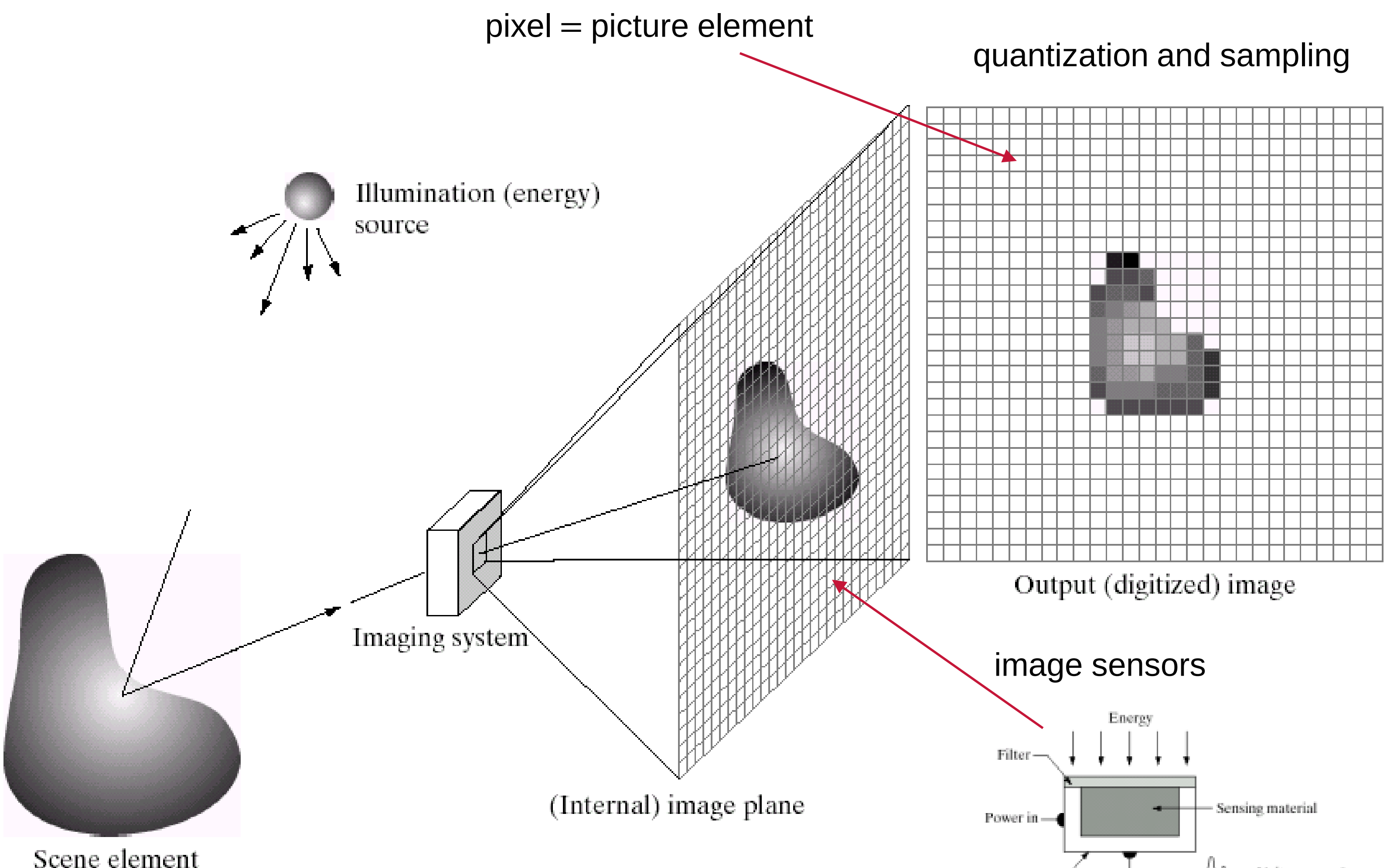
Image acquisition cont.



From analogue to digital

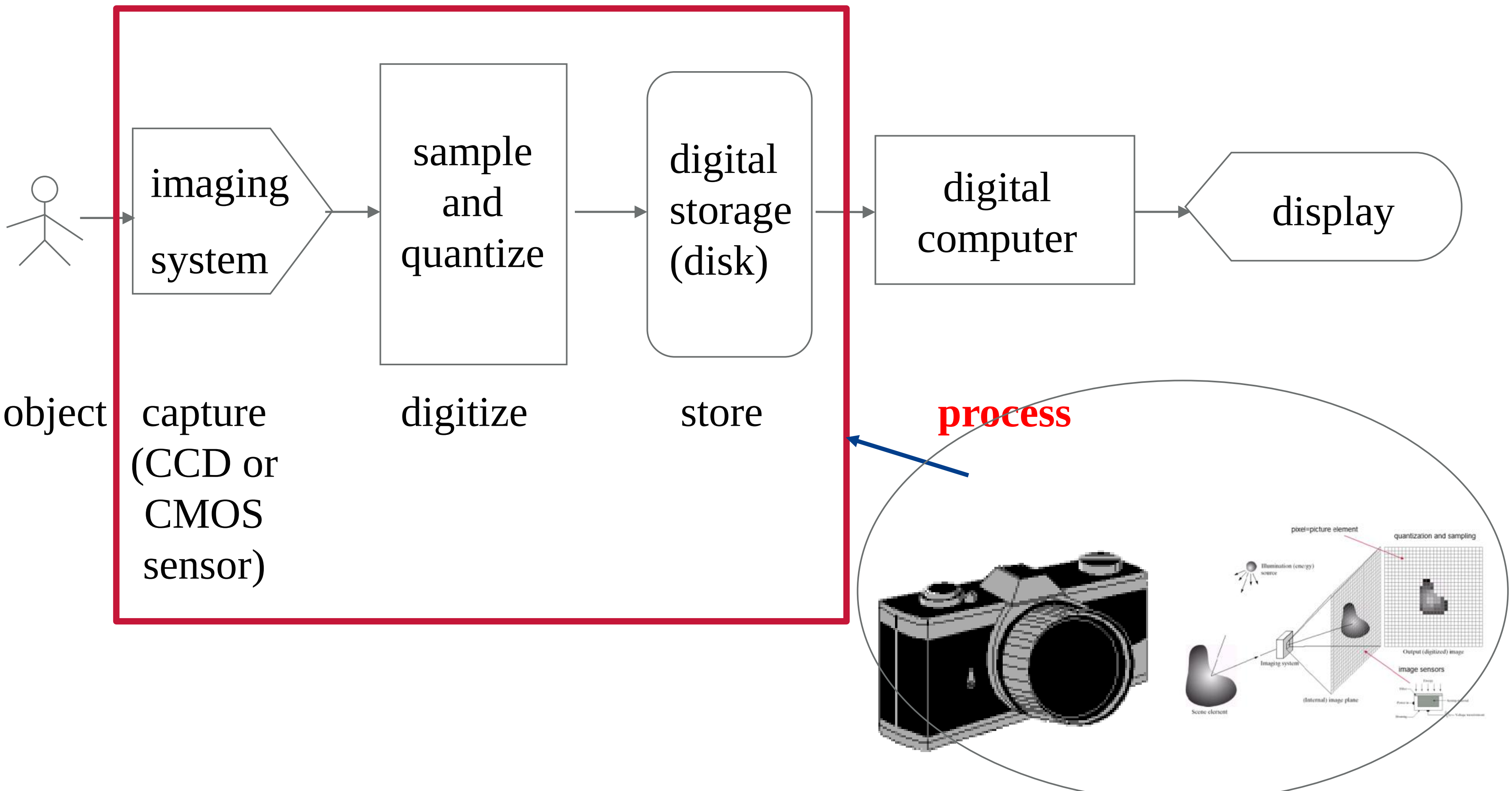


Image as a function

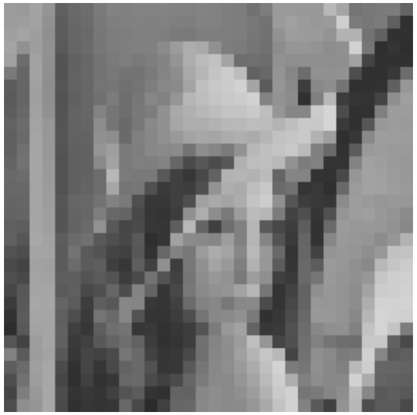
- The rectangular grid presented in previous slides implies that digital images are two-dimensional (2D) signals $f(x, y)$.
- In video the concept of time is present as well, since we acquire a sequence of frames and not a single image frame. Therefore, a video signal could be described as a three-dimensional (3D) signal $f(x, y, t)$.
- Four-dimensional (4D) image signals $f(x, y, z, t)$ also exist. It is a term used to describe the study of three-dimensional (3D) specimens as they change over time. Examples are CT and MRI scans.

2D Sampling: From analogue images to digital images (pixels)

- Sampling of an image is basically sampling of a 2D signal.
- The continuous image coordinates (x, y) are replaced with a set of discrete values.
- That means we only observe the image signal at certain locations.
- In the example below two identical images are sampled at different rates.
- Obviously the higher the sampling rate the better the quality of the image.
- After a specific sampling rate, the human eye is not able to perceive an improved image.
- For the image below sampling which yields a digital image of size 256×256 is efficient so that the human eye perceives the image as an analogue one with good quality.

256×256

64×64



Quantisation: From continuous image signal to discrete image signal

- Quantisation of an image is basically discretization of the image signal $f(x, y)$ (discretization of the image amplitude).
- After sampling and quantization both pixel coordinates (x, y) and image values $f(x, y)$ are represented with binary numbers.
- Below you see an image quantised in two levels (binary).
- For images of the so called gray level type, $f(x, y)$ is a scalar and represents all shades of the gray colour, ranging from the absolute black (0) to the absolute white (255). We often use 256 gray levels for $f(x, y)$.
- The value of $f(x, y)$ is called the intensity of the image.

0	255	255	0	0
0	0	255	0	0
0	0	255	0	0
0	0	255	0	0
0	255	255	255	0

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Quantisation cont.

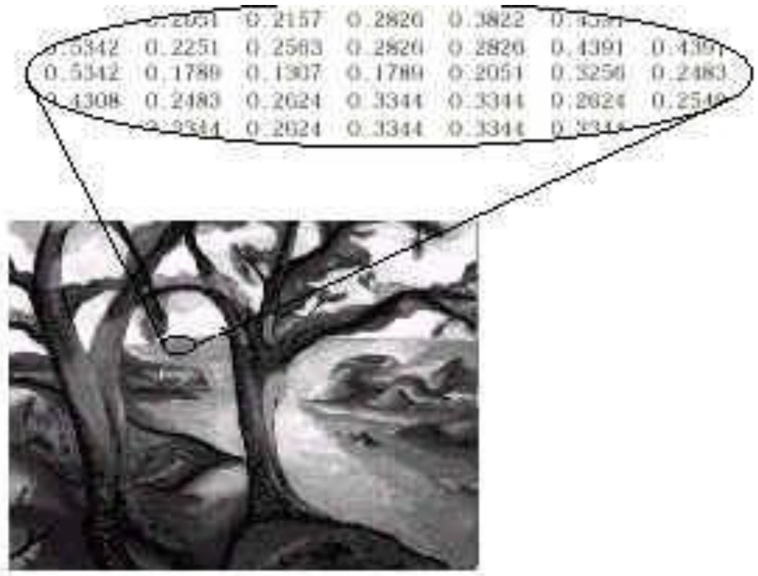
- Obviously the more quantisation levels we assign to digital images the better their quality.
- The term quality gives rooms for discussion. When can we say that an image is of good quality?
- Image processing scientists use various mathematical metrics to asses the quality of in image. We will come across with some of them later.

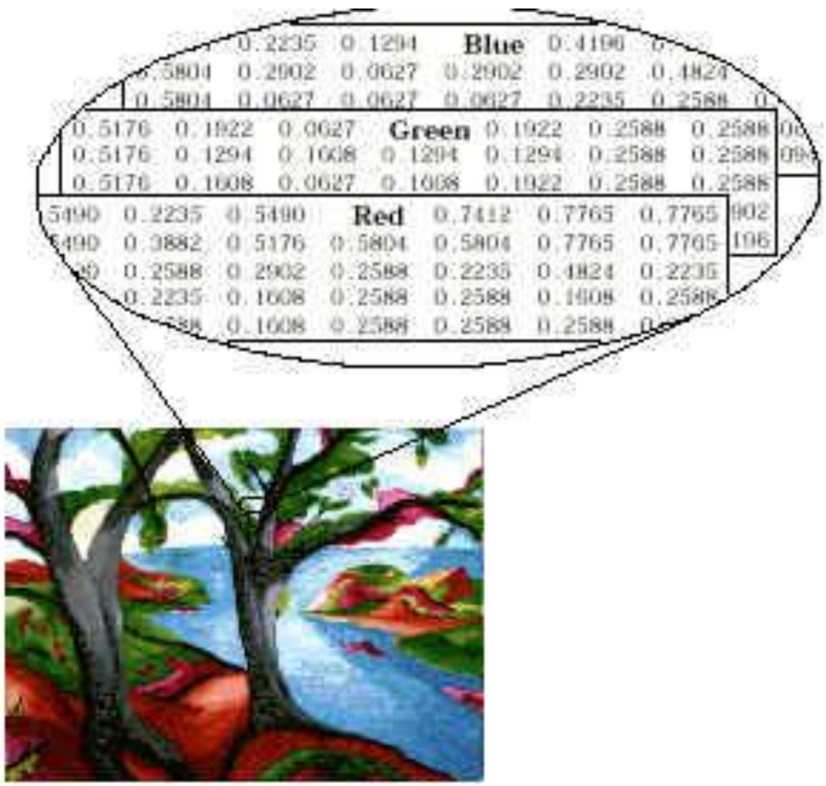
256×256 256 levels

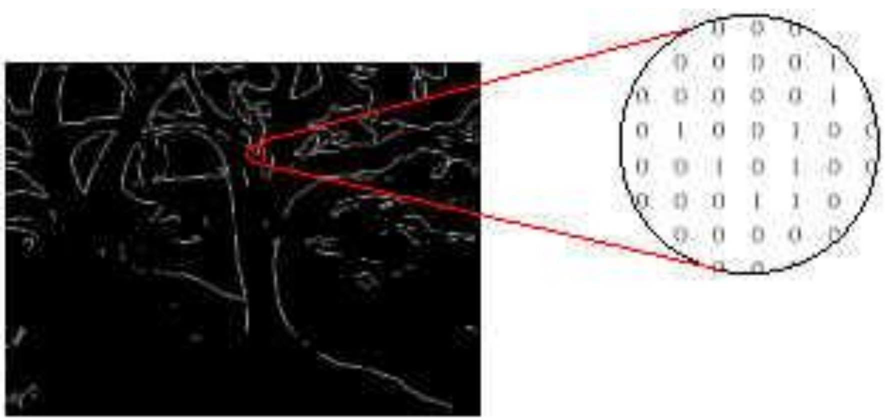
256×256 32 levels

256×256 2 levels

Image intensity: gray level images/colour images/binary images







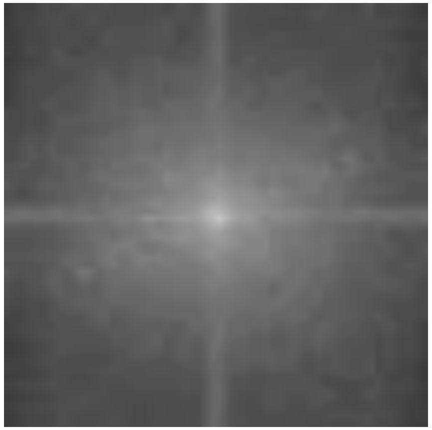
This course
Part I: Image Transforms

- Image transforms are used extensively in Image Processing.
- Very often the transform of an image gives a lot more insight into the properties of an image compared to the original spatial representation of the image.
- For example, Fourier Transform for images is very popular.
- Other transforms are popular as well, as for example, the Discrete Cosine Transform (JPEG standard).

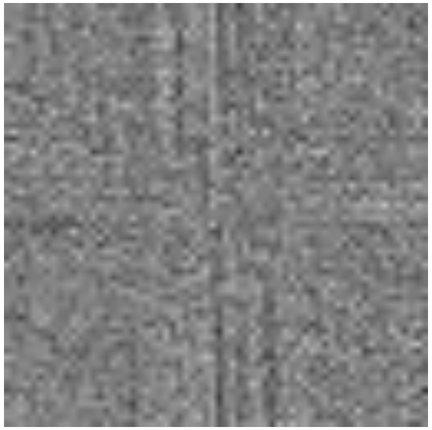
Fourier Transform

Original Image

Amplitude



Phase



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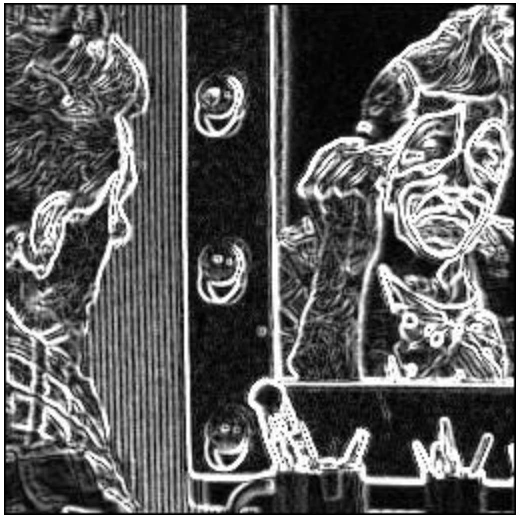
This course
Part II: Image Enhancement

- Image enhancement refers to a collection of algorithms which aim at improving the quality of a digitally stored image using mathematical techniques.
- It is quite easy, for example, to make an image lighter or darker, or to increase or decrease its contrast.
- We often want to extract certain features from an image, as for example, its edges (see figure below right.)

Original Image

High Pass Filtering



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Part III: Image Restoration

- Image restoration is the operation of taking a corrupt/noisy image and estimating the clean, original image.
- Corruption may come in many forms such as motion blur, noise and camera mis-focus.
- Image restoration is performed by reversing the process that blurred the image using system identification techniques.
- Image enhancement and image restoration have similar goals but different approaches.

Distorted Image

Restored Image

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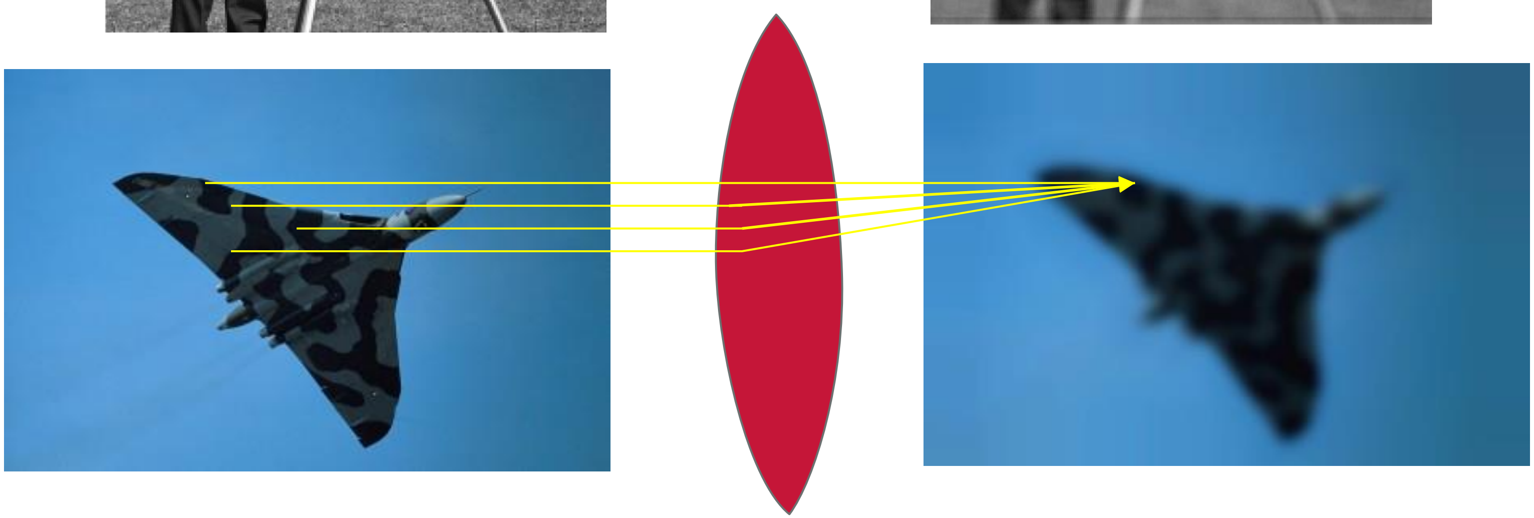
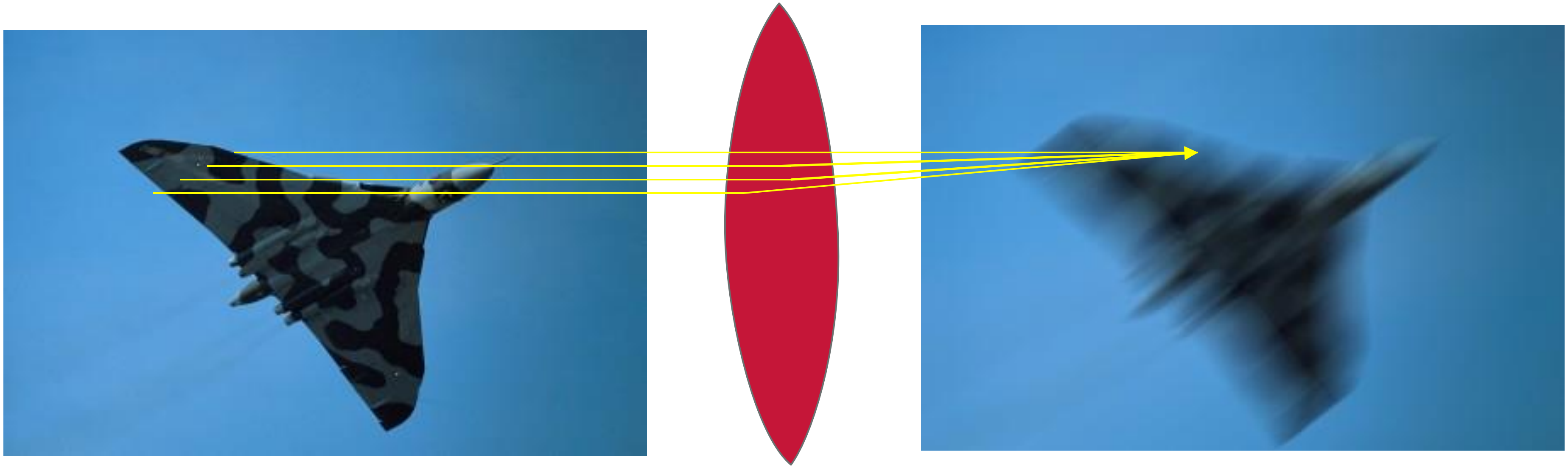
Distortion due to Camera Misfocus

Original image

Distorted image



Distortion due to object motion



Camera lens

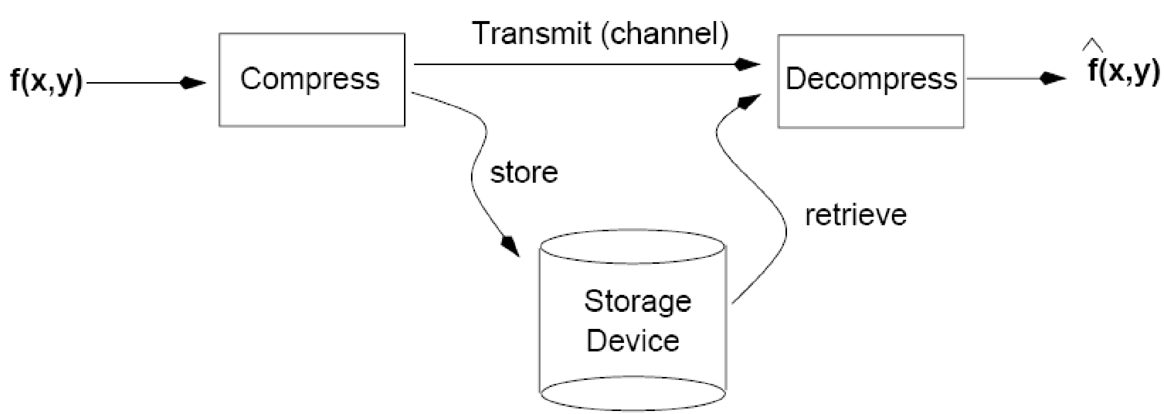
Distortion due to random noise

Original image

Distorted image

This course
Part IV: Image Compression

- The goal of image compression is to reduce the amount of data required to represent a digital image.
- Image compression aims at reducing the cost for storage or transmission of images.
- An advanced image compression algorithm may take advantage of the human visual system and the redundancies within particular image data to provide superior results compared to generic compression methods.
- It is hard to without compression since you take for granted the fact that there are billions of images available on line.



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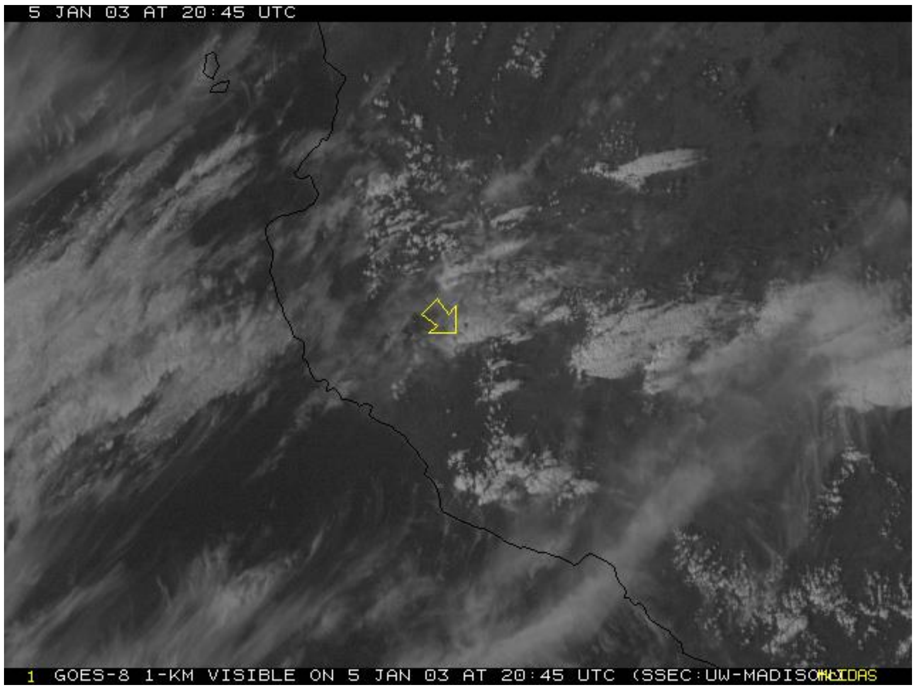
Applications of Image Processing

- Medicine
- Cultural heritage
- Environment
- Astronomy
- Security
- Defense
- Surveillance

Satellite/astronomical images: examples



Spiral Galaxy NGC 1232 - VLT UT 1 + FORS1

ESO PR Photo 37d/98 (23 September 1998)

Medical images: examples