Topic III

COMPUTER VISION AND IMAGE PROCESSING

Topic Description

This topic is designed to give students all the fundamentals in 2- D digital image processing with emphasis in image processing techniques, image filtering design and applications.

The topic emphasis in:

I. Processing techniques,
II. Image filtering,
III. Image segmentation,
IV. Image enhancement,
V. Morphological processing of image and
VI. Recognition of objects in an image.

Topic Objectives

On the successful completion of the topic the students will be able to:

- Have a clear understanding of the principals the Digital Image Processing
- Understand the mathematical foundations for digital manipulation of images
- Be able to understand, and make use of, the Matlab (Octave) image processing library and MATLAB/Octave Toolbox
- Learn and understand the Image Enhancement in the Spatial and
- Frequency Domain.
- Understand Image Restoration, Compression, Segmentation, Recognition, Representation and Description.

Topic Contents

Lectures	Sub-Lectures
Lecture 1: Introduction	I. Elements of visual perception II. Image sensing and acquisition III. Image sampling and quantization
Lecture 2: Image Enhancement	I. Enhancement in spatial domain ➢ Grey level transformation ➢ Histogram processing ➢ Smoothing and sharpening Spatial filters II. Enhancement in frequency domain ➢ Fourier transforms ➢ Smoothing and sharpening frequency domain filtering
Lecture 3: Morphological Image Processing	I. Dilation and Erosion II. Morphological algorithms
Lecture 4: Image Segmentation	I. Detection of discontinuities II. Boundary detection III. Thresholding

Lecture 1:

Introduction to Image and Vision

Every picture tells a story

- Image carries vast amount of information.
- We, humans, are selective of what we consume through visual sense.
- The goal of computer vision is to ***write computer programs that can interpret images***
- Can computers match human perception?

  - Yes and No (but mostly no!)

Humans are much better at “hard” things

Computers can be better at “easy” things

What is Digital Image Processing?

- Digital image processing helps us enhance images to make them visually pleasing, or emphasize regions or features of an image to better represent the content.

  - **Region-Of-Interest is vital in image processing**

- For example, we may wish to enhance the brightness and contrast to make a better print of a photograph, similar to popular photo-processing software.

- In a magnetic resonance image (MRI) of the brain, we may want to highlight a certain region (only interesting part) of image intensities to see certain parts of the brain.

Computer Vision!

❖ Reconstruction

Receive from the real world and reconstruct it internally---Digitally

How do humans perform this task?

Recover 3D information from data

- Angle and lighting

❖ Recognition

Feature extraction

Segmentation of image parts

Detect and identify objects

❖ Understanding

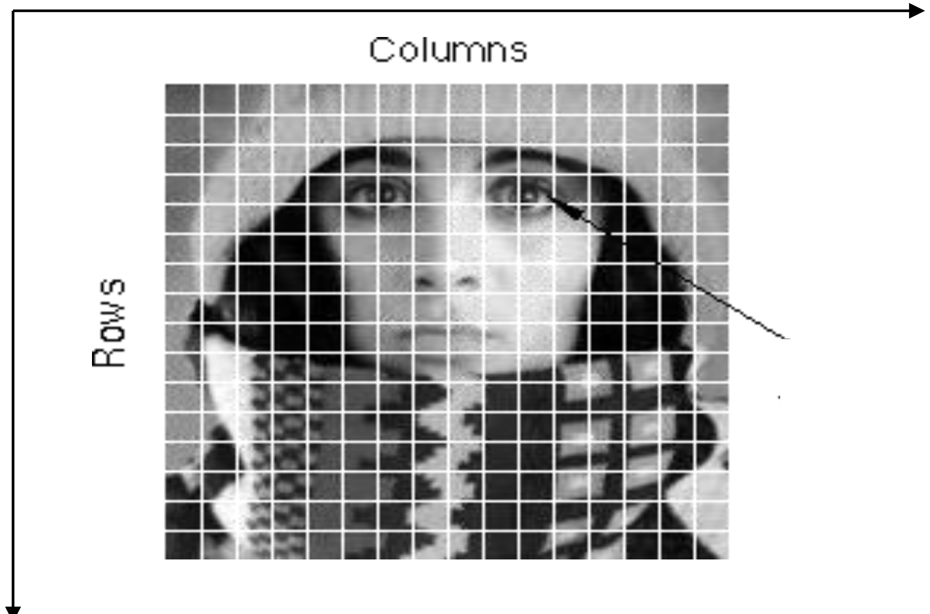
Giving context to image parts

Knowing what is happening in the scene?

What is an image?

- The pattern is defined is a coordinate system whose origin is conventionally defined as the upper-left corner of the image .

- We can describe the pattern by a function f(x,y).



Closer Look at elements of image

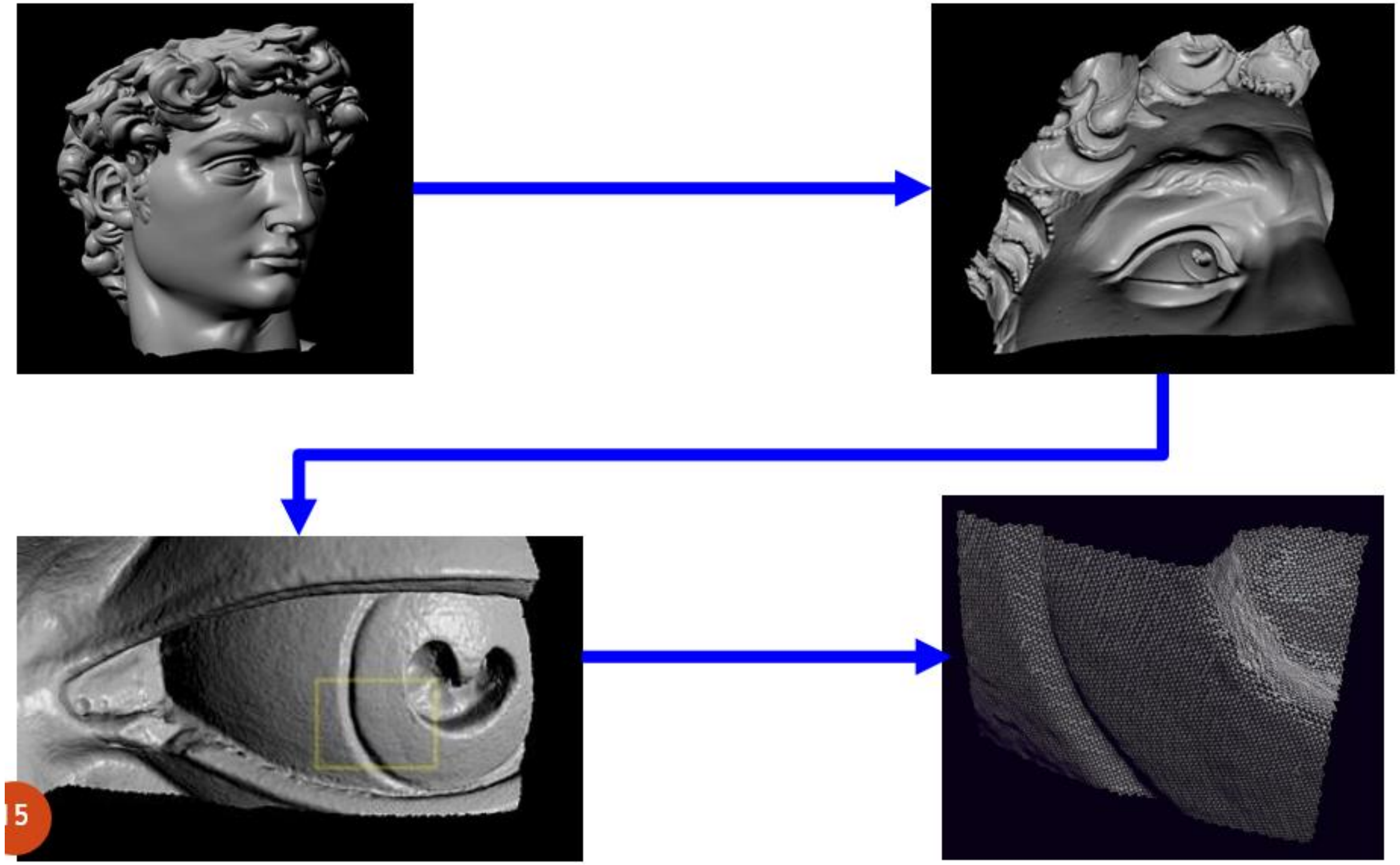


Image Processing and Related Fields

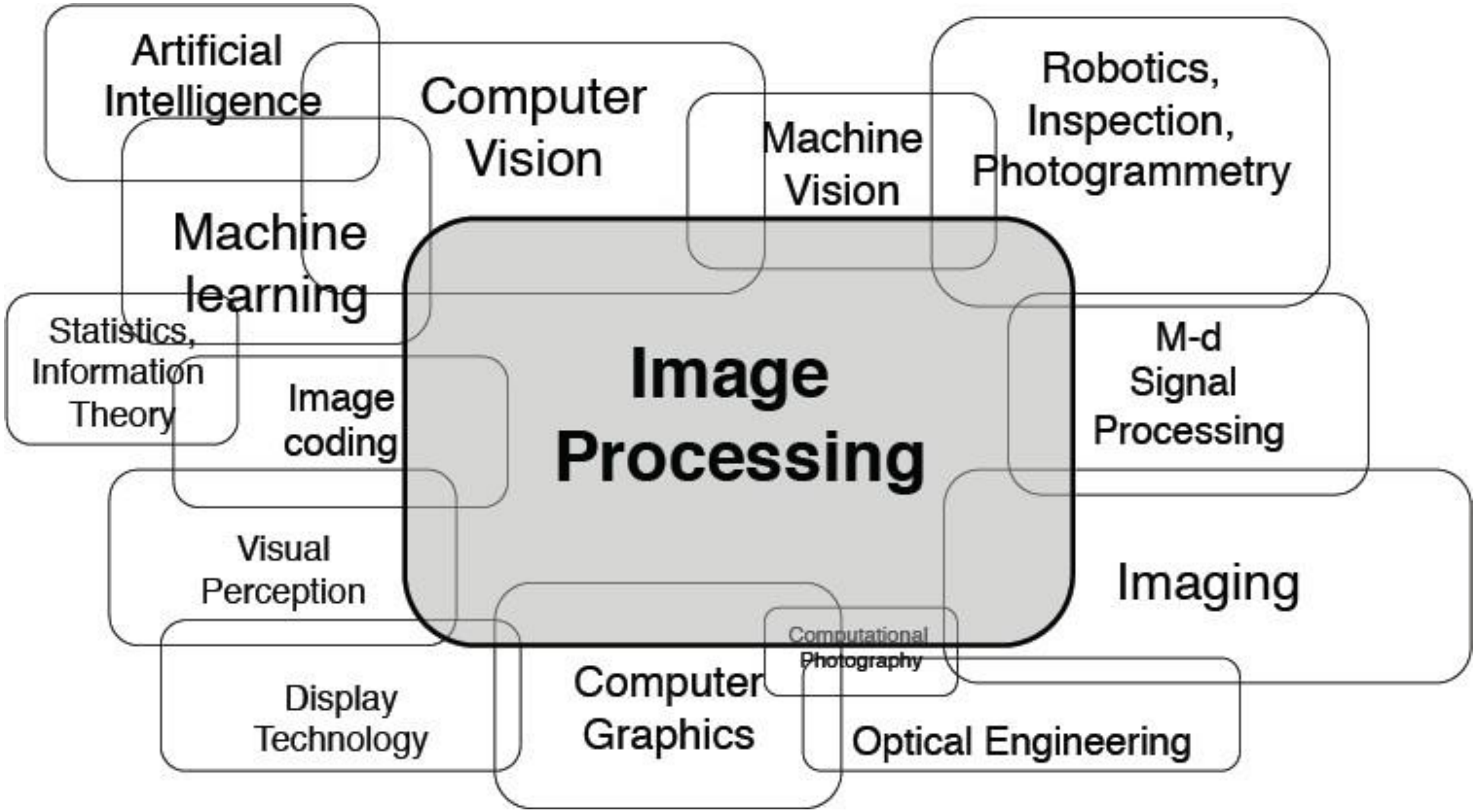
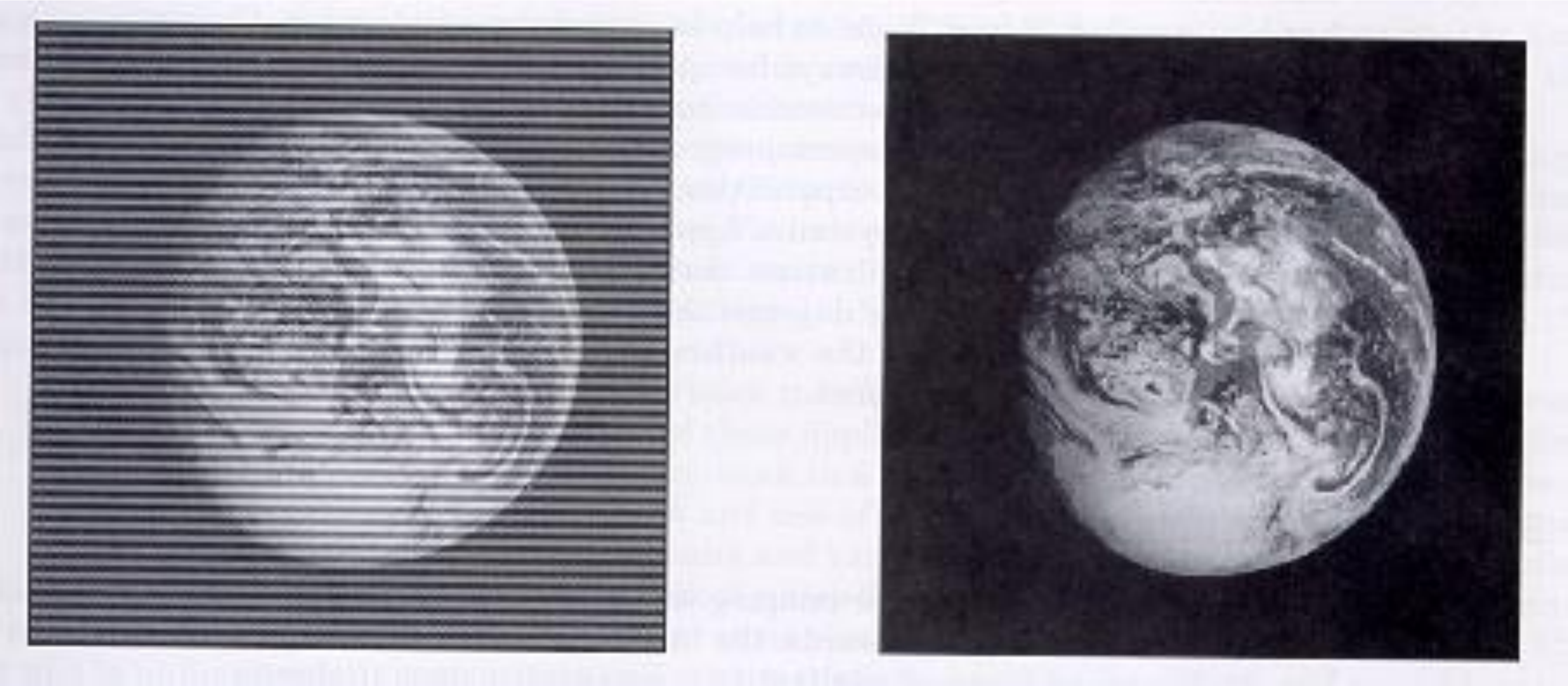


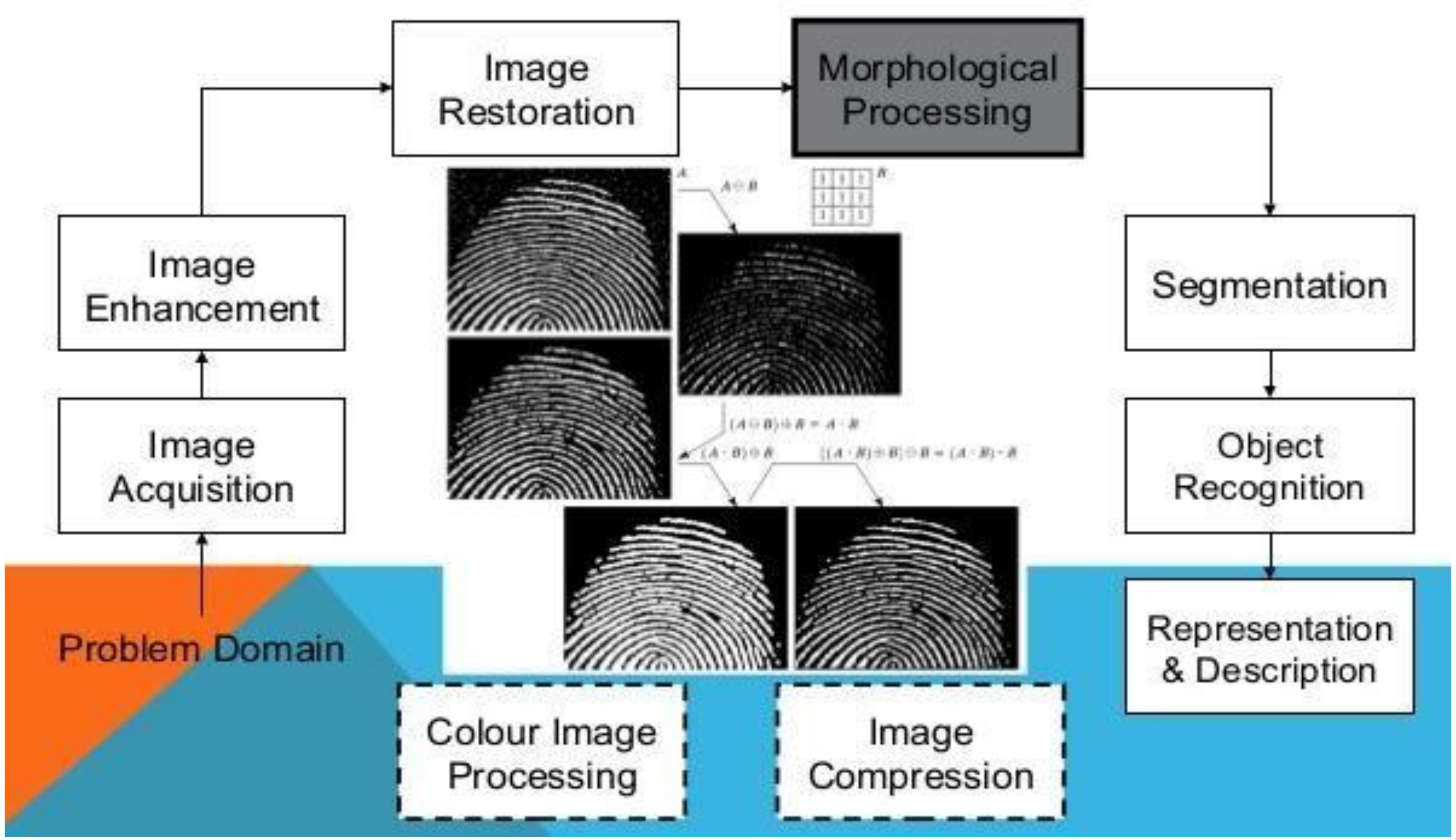
Image Restoration(e.g., correcting out-focus images)



Why is Computer Vision Difficult?

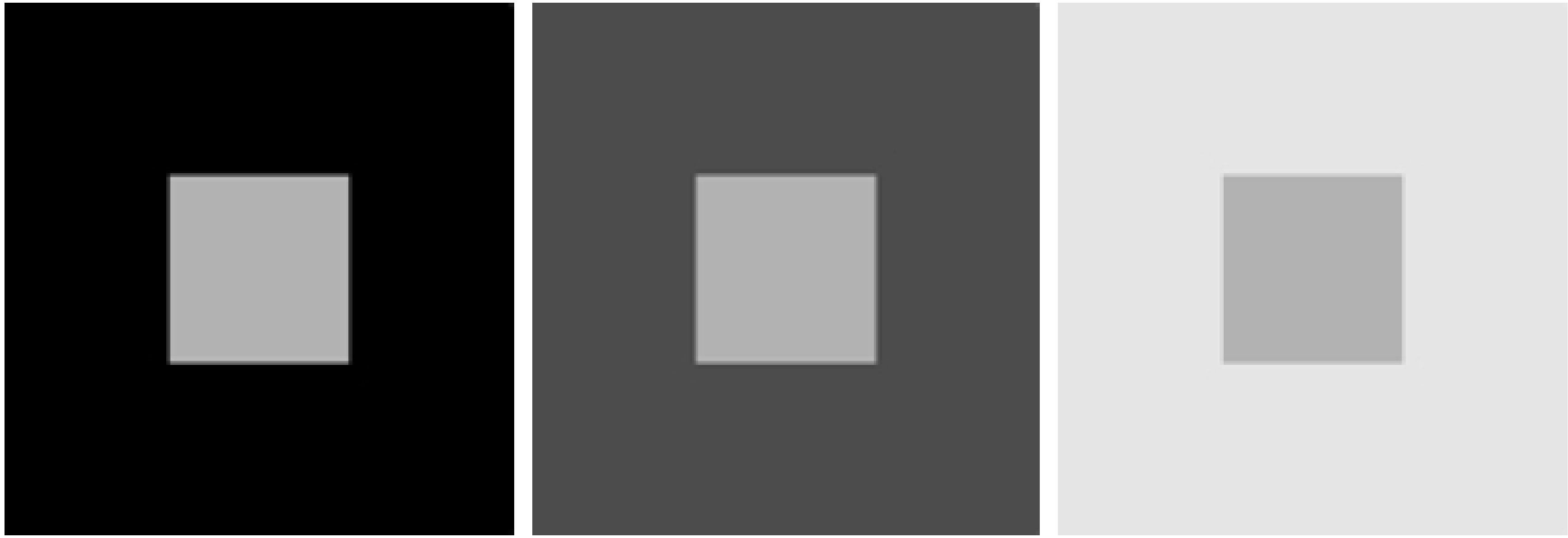
- It is a **many-to-one** mapping
  - A variety of surfaces with different *material* and *geometrical* properties, possibly under different *lighting* conditions, could lead to different images
  - Inverse mapping has non unique solution (a lot of information is **lost** in the transformation from the ***3D world to the 2D image***)
- It is **computationally intensive**
  - *Needs relatively higher processing machine*
- We **might not understand** the recognition problem as the need depends on the application and particular circumstance during image acquisition

Computer Vision



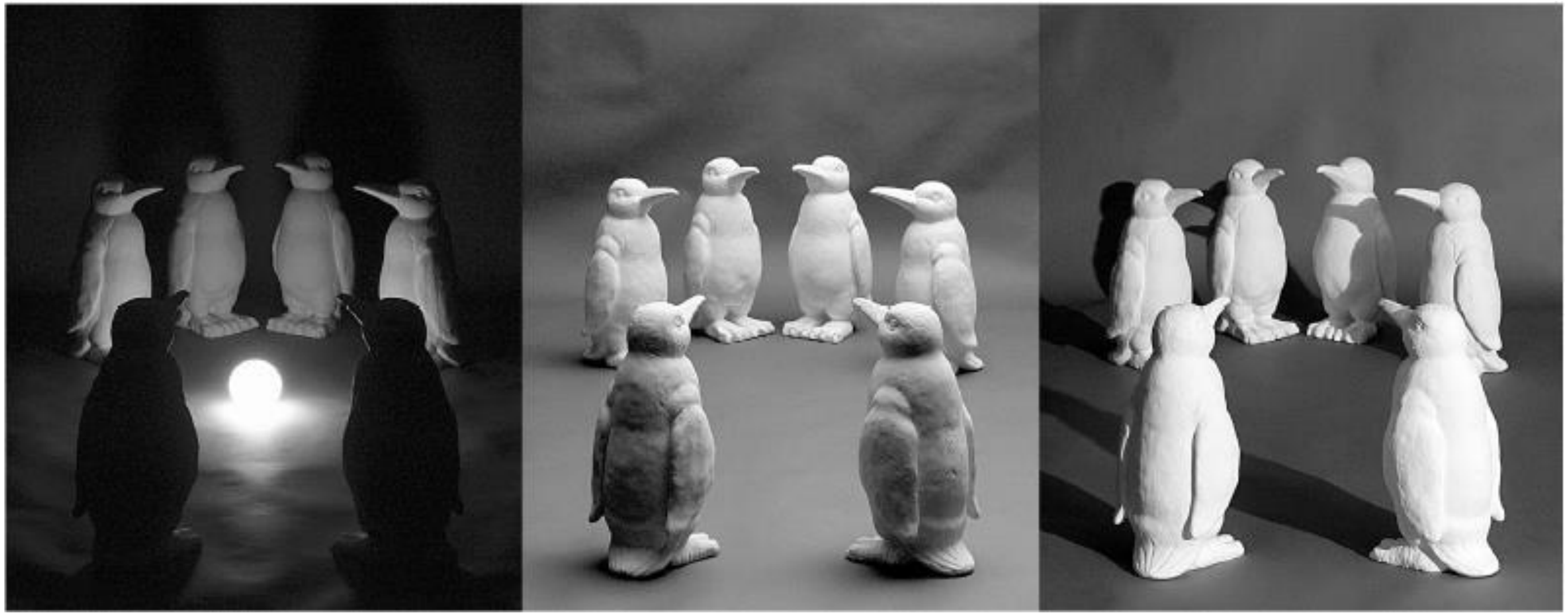
Issue of Contrast

- Objects appear to the eye to become darker as the background gets lighter.
- The example below is a piece of paper that seems white when lying on a desk, but can appear totally black in a lighter background



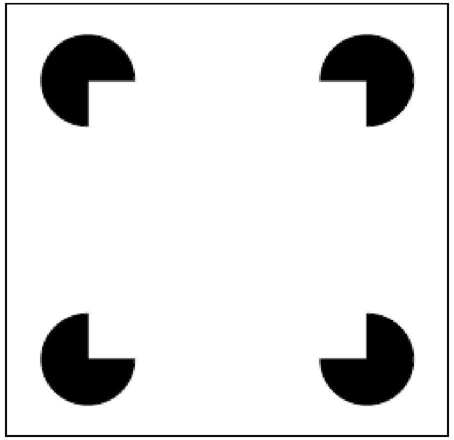
Issue of Illumination

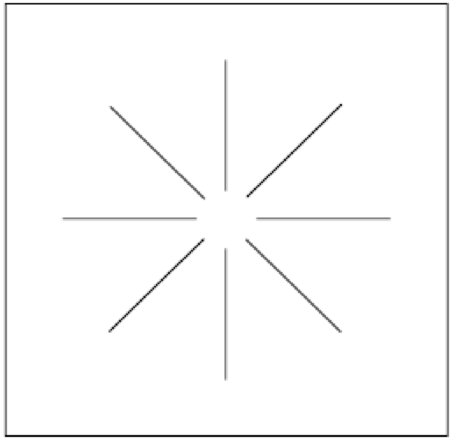
- Same objects and arrangement
- Different angle of light



Perception—Illusions

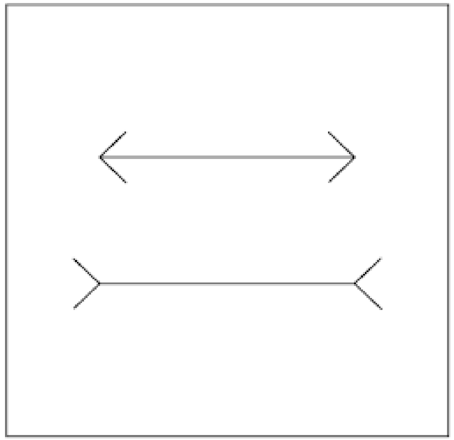
The border of the square is visible despite there is no border line

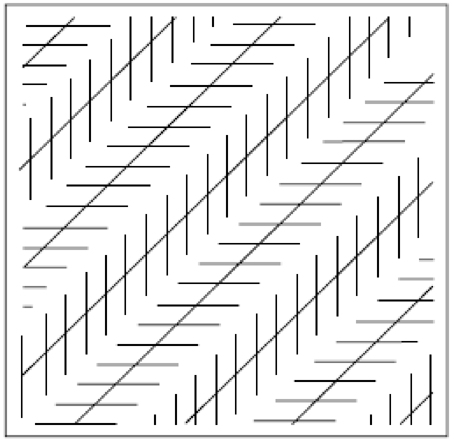




There seems to be a circle in the middle

The horizontal line of the lower line seems longer





The short lines seems to be slant but actually parallem

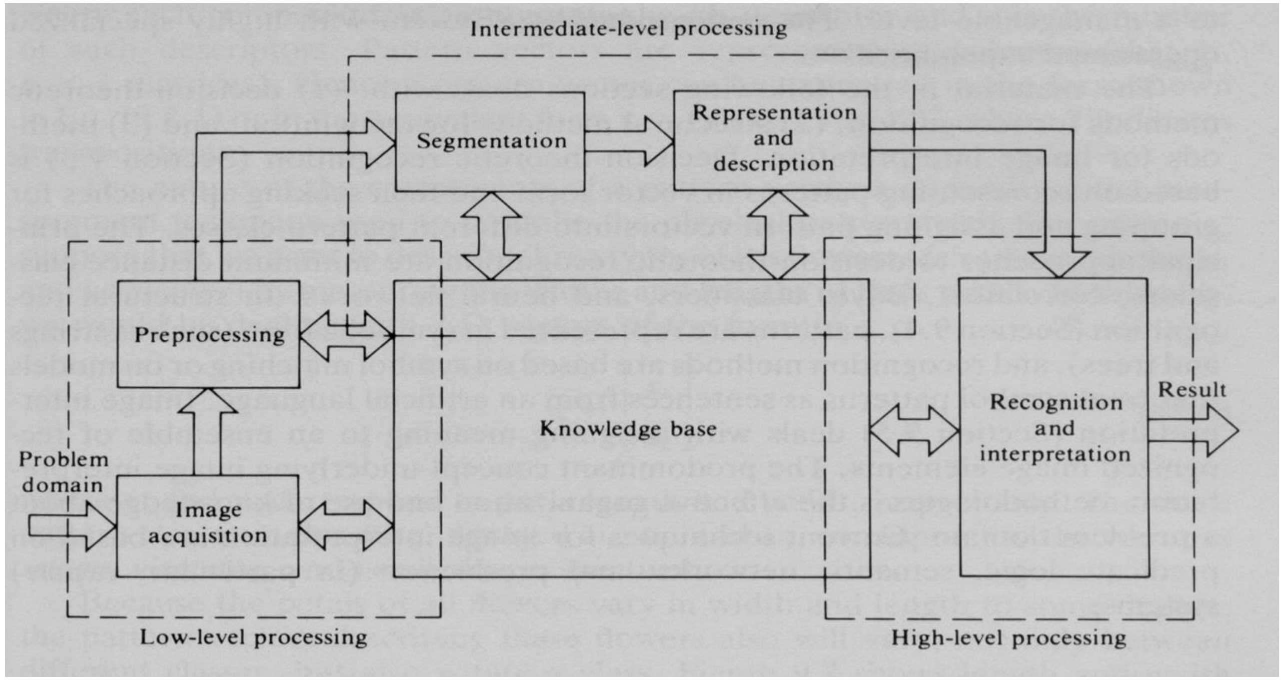
What is Computer Vision?

- Deals with the development of the **theoretical** and **algorithmic** basis by which useful information about the 3D world can be automatically extracted and analyzed from a **single** or **multiple** 2D images of the world.

The Three Image Processing Levels

1. Low-level processing

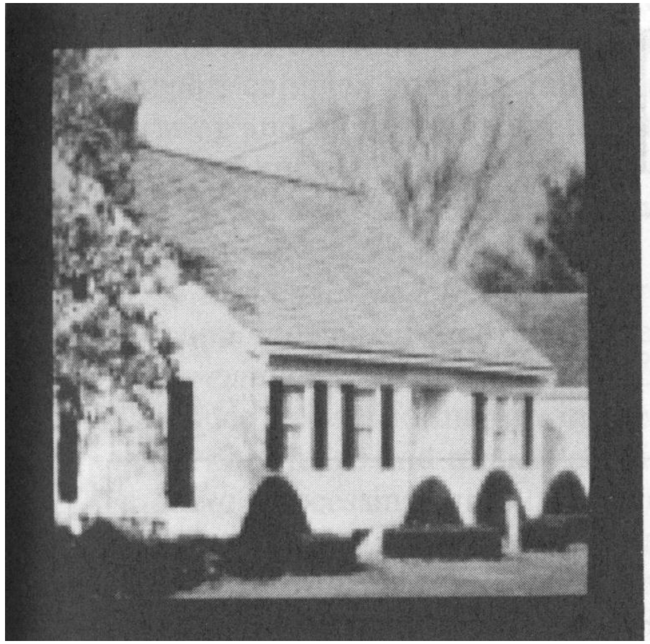
Standard procedures are applied to improve image quality.
Procedures are required to have no intelligent capabilities.

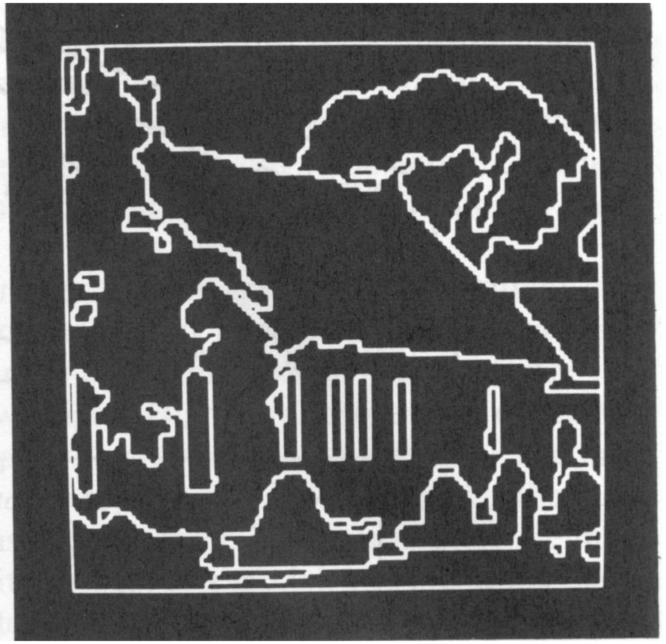


The Three Image Processing Levels (2)

2. Intermediate-level processing

- Extract and characterize components in the image
- Some intelligent capabilities are required.

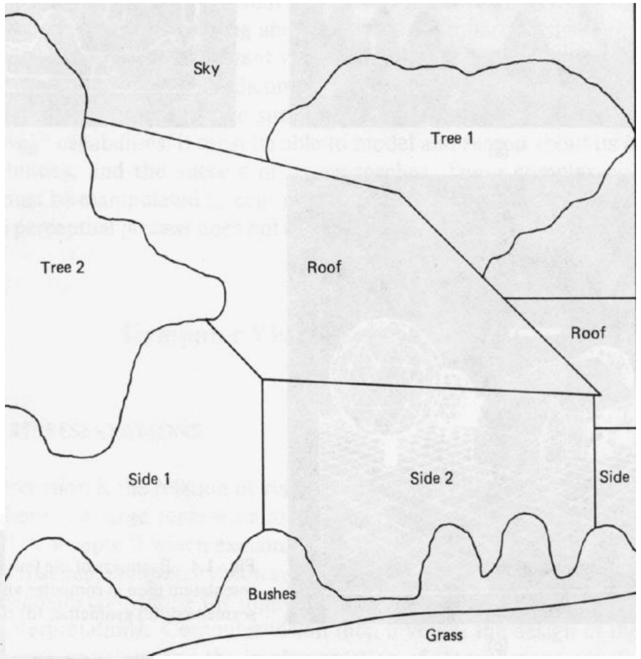




The Three Image Processing Levels (3)

3. High-level processing

- Recognition and interpretation of segments of the image
- Procedures require high intelligent capabilities.



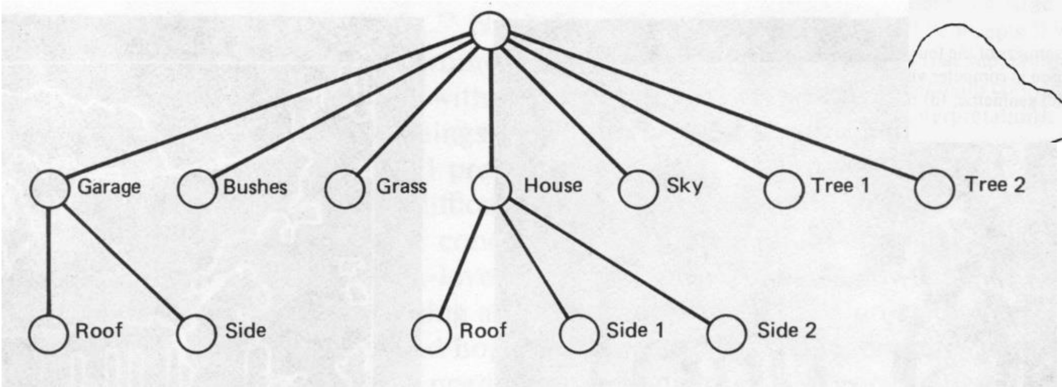


Image Processing

Real world

Sample

Discrete samples (pixels)

Reconstruct

Reconstructed function

Transform

Transformed function

Filter

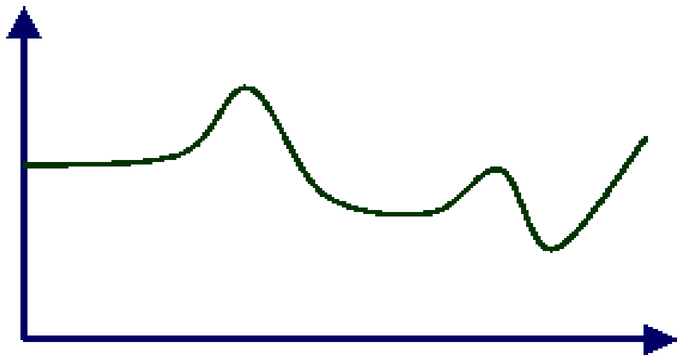
Bandlimited function

Sample

Discrete samples (pixels)

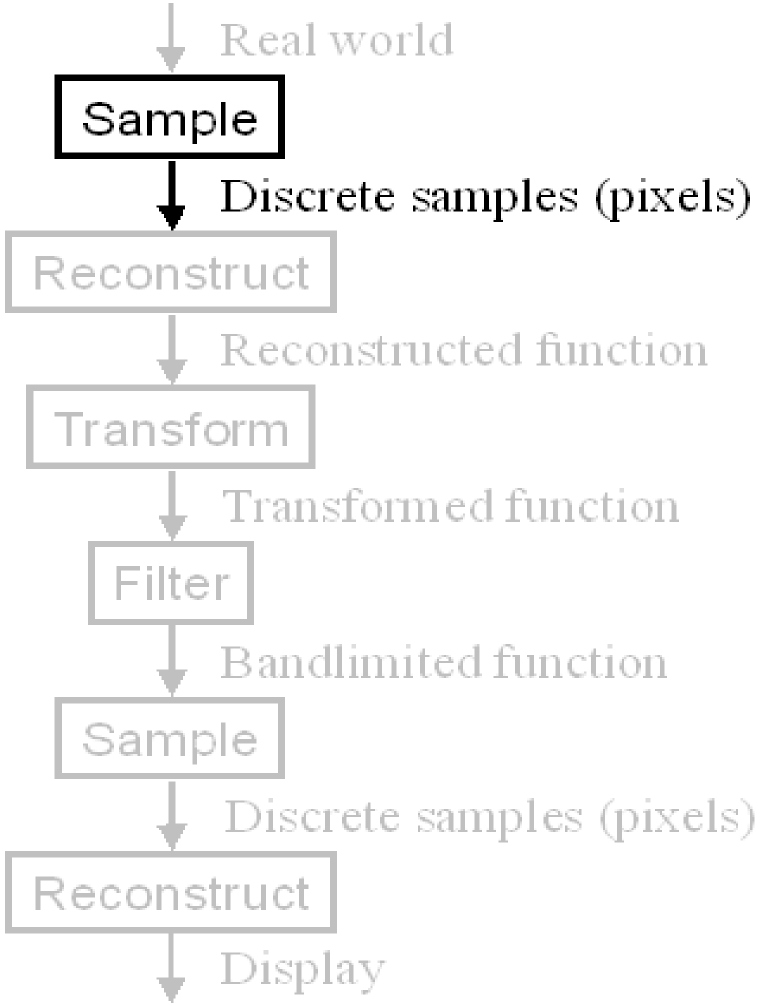
Reconstruct

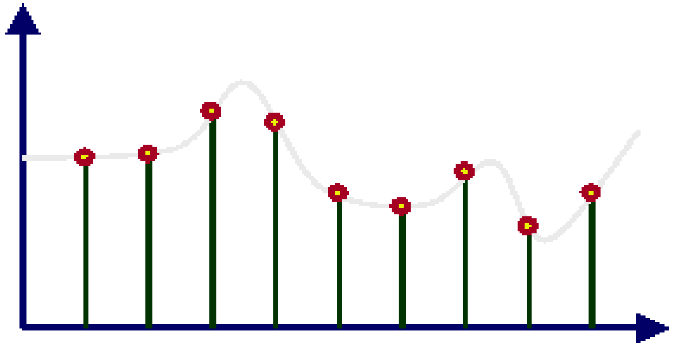
Display



Continuous Function

Image Processing

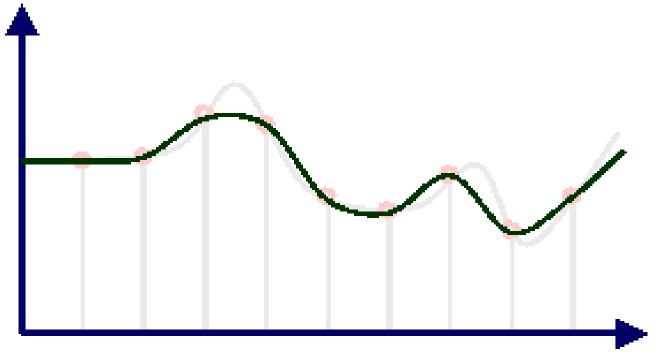




Discrete Samples

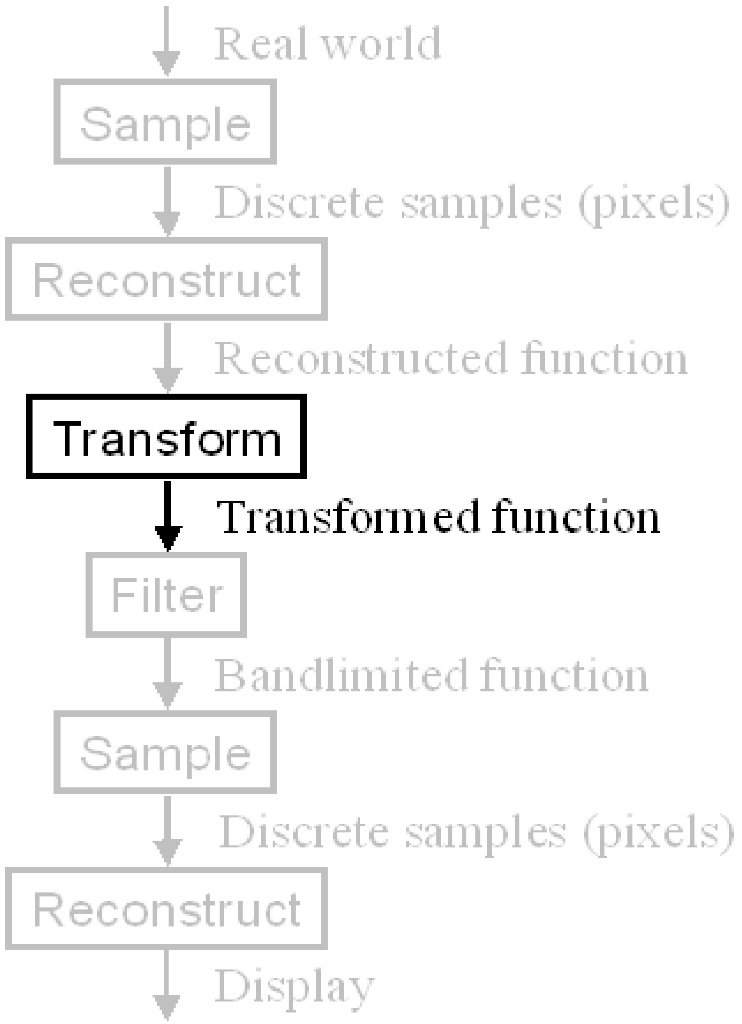
Image Processing

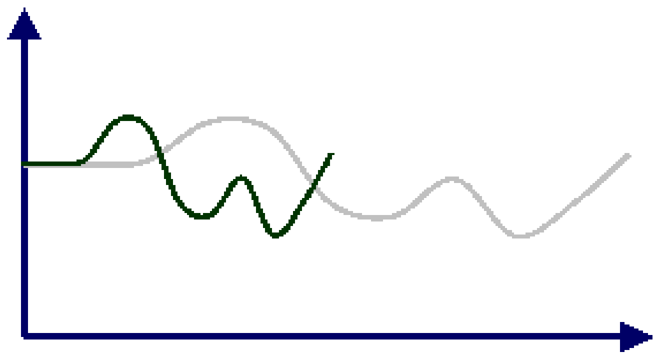
Real world
Sample
Discrete samples (pixels)
Reconstruct
Reconstructed function
Transform
Transformed function
Filter
Bandlimited function
Sample
Discrete samples (pixels)
Reconstruct
Display



Reconstructed Function

Image Processing





Transformed Function

Image Processing

Real world

Sample

Discrete samples (pixels)

Reconstruct

Reconstructed function

Transform

Transformed function

Filter

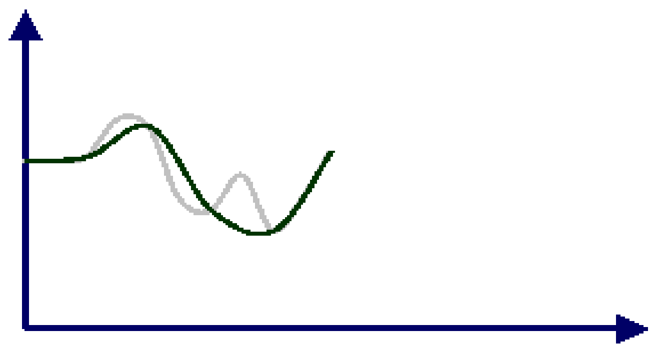
Bandlimited function

Sample

Discrete samples (pixels)

Reconstruct

Display



Bandlimited Function

Image Processing

Real world

Sample

Discrete samples (pixels)

Reconstruct

Reconstructed function

Transform

Transformed function

Filter

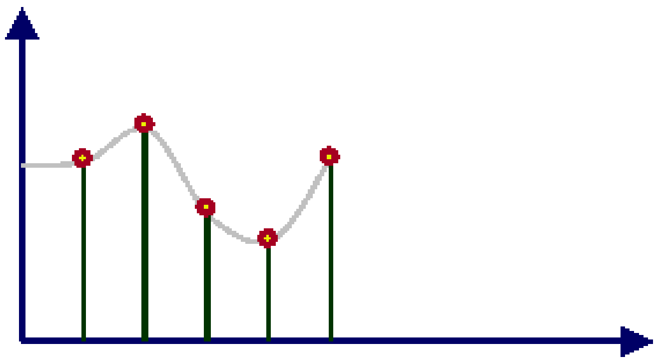
Bandlimited function

Sample

Discrete samples (pixels)

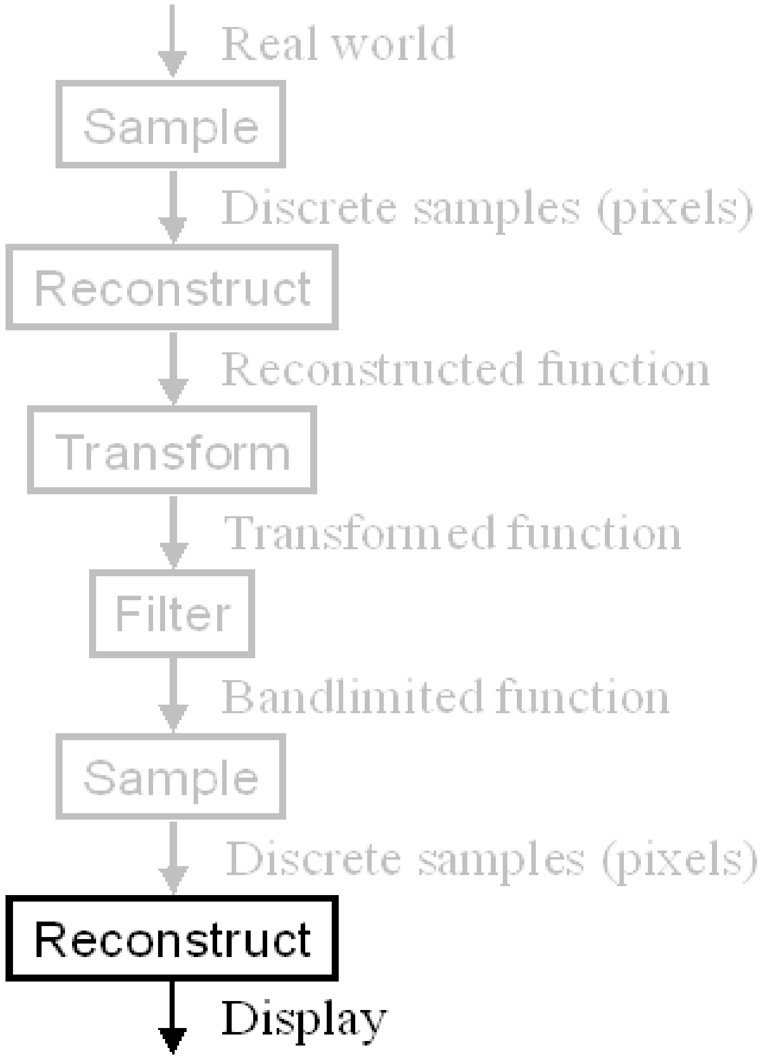
Reconstruct

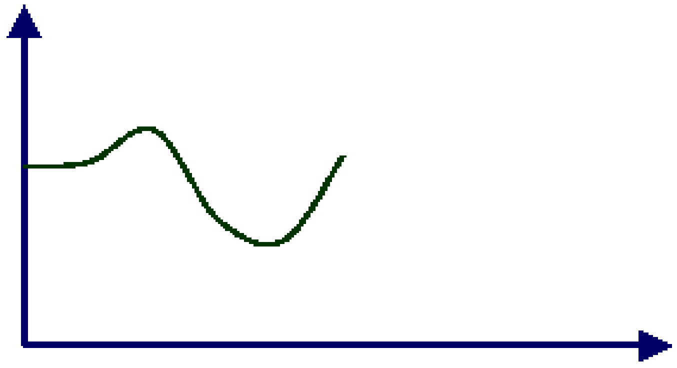
Display



Discrete samples

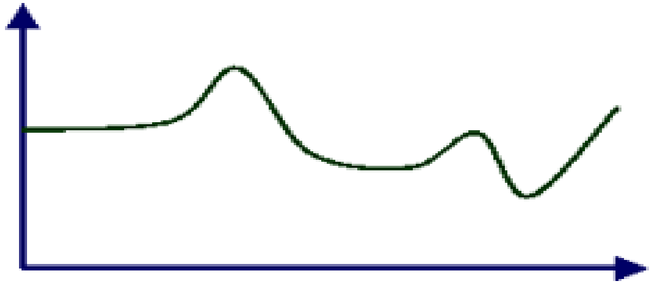
Image Processing





Display

Versus



Continuous Function

Mathematics in Computer Vision

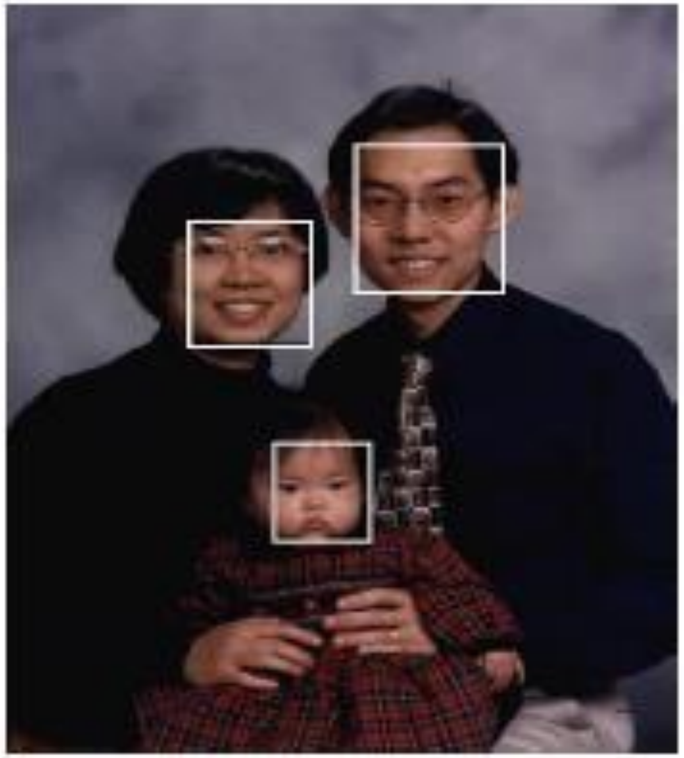
- In the early days of computer vision, vision systems employed simple heuristic methods.
- Today, the domain is heavily inclined towards theoretically, well-founded methods involving non-trivial mathematics.
  - Calculus
  - Linear Algebra
  - Probabilities and Statistics
  - Signal Processing
  - Projective & Computational Geometry
  - Optimization Theory
  - Control Theory

Computer Vision Applications

- Industrial inspection/quality control
- Surveillance and security/ biometrics
- Face recognition
- Gesture recognition
- Space Science applications
- Medical image analysis
- Autonomous vehicles (self-driving car like Tesla)
- Virtual reality and much more …...

Face Detection Vs Face Blurring

On Facebook



on NEWS

Passport photo

Select photo

~~~~
× The photo you want to upload does not meet our criteria because:

- Subject eyes are closed

**Please refer to the technical requirements.**
**You have 9 attempts left.**

Check the photo requirements.

Read more about common photo problems and how to resolve them.

After your tenth attempt you will need to start again and re-enter the CAPTCHA security check.

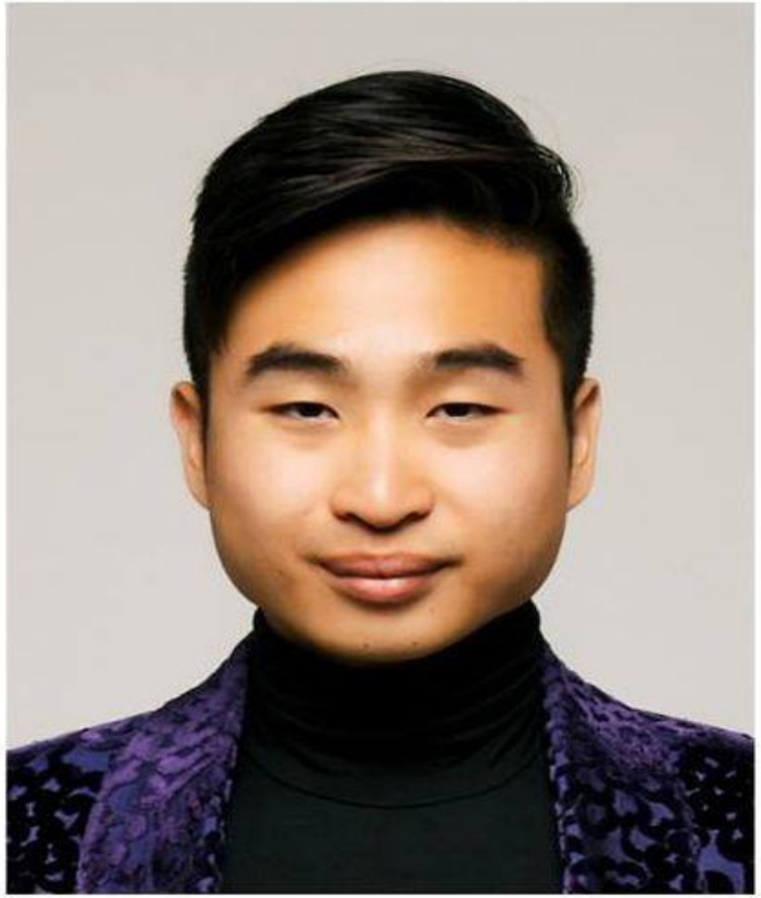
**Reference number: 20161206-81**

Filename: Untitled.jpg

If you wish to contact us about the photo, you must provide us with the reference number given above.

Please print this information for your records.

Print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Passport photo

Select photo

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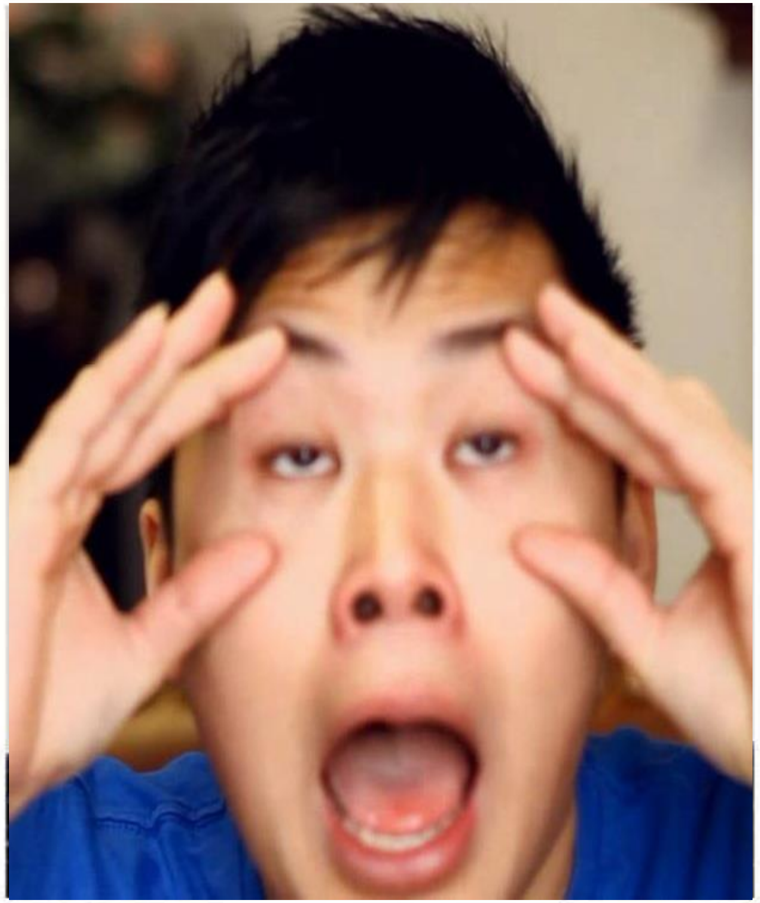
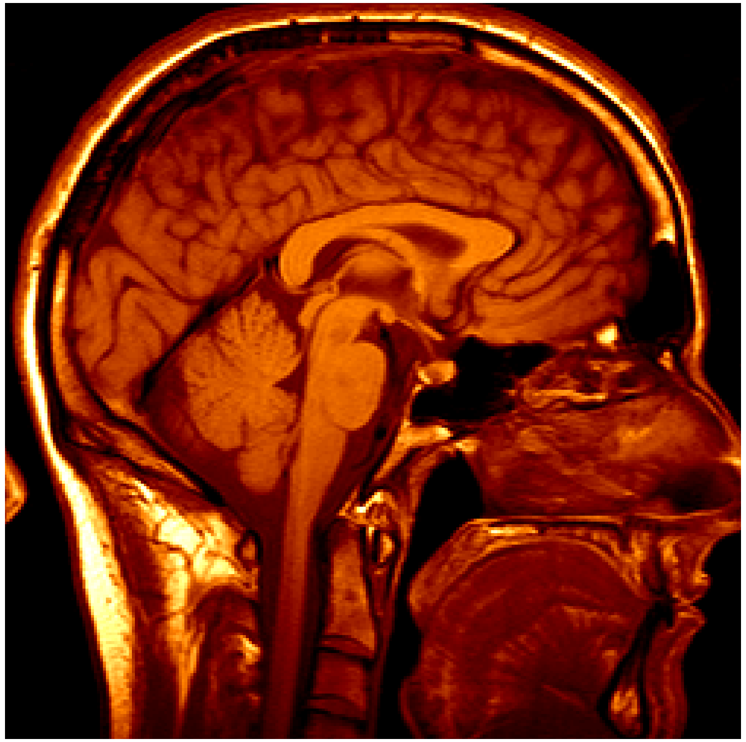
Print



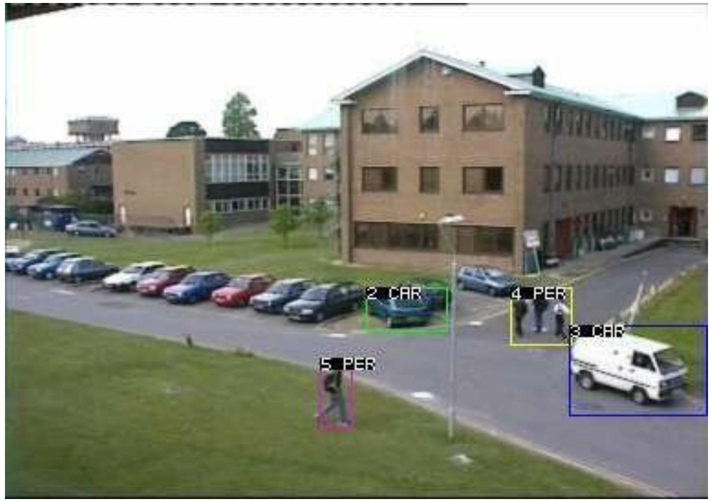
Medical image analysis

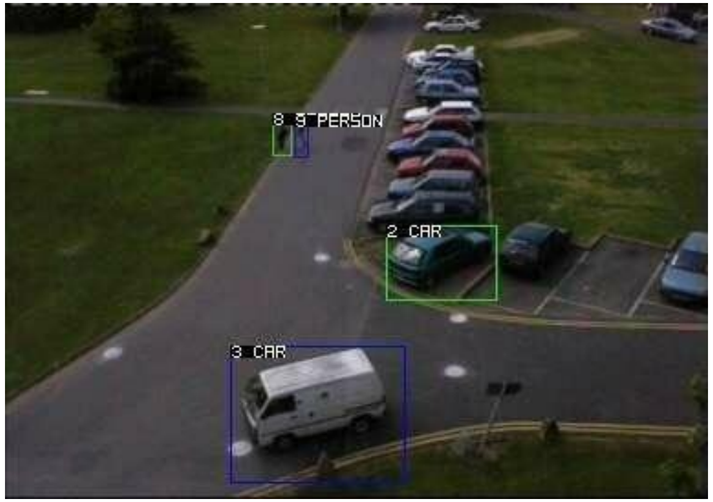


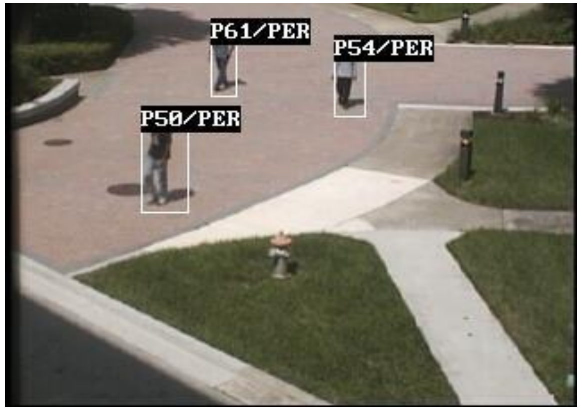
3D imaging: MRI, CT

Image guided surgery
Grimson et al., MIT

Surveillance and tracking







Surveillance and tracking

Vehicle and pedestrian protection

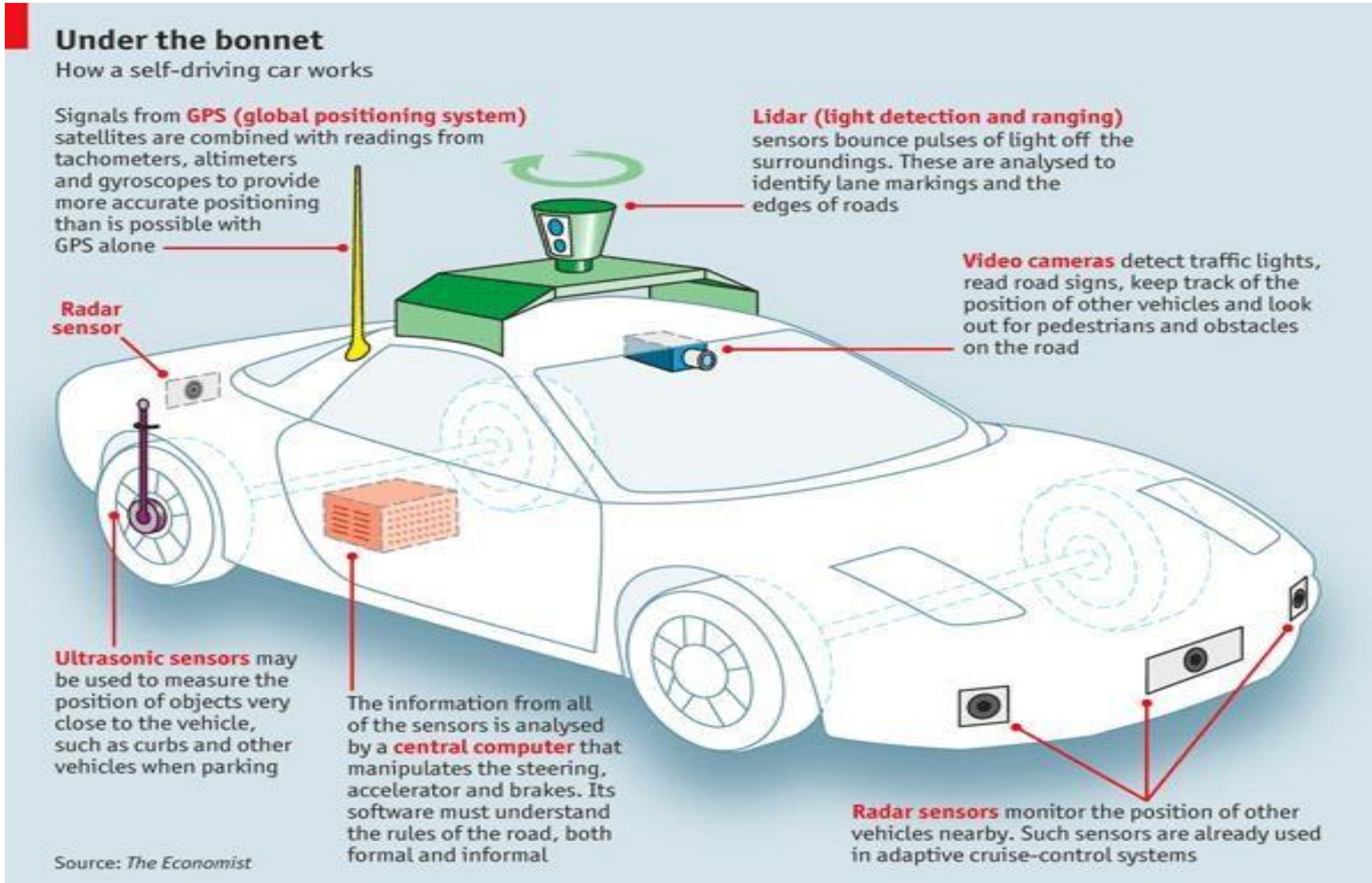
Lane departure warning, collision warning, traffic sign recognition, pedestrian recognition, blind spot warning

Smart cars

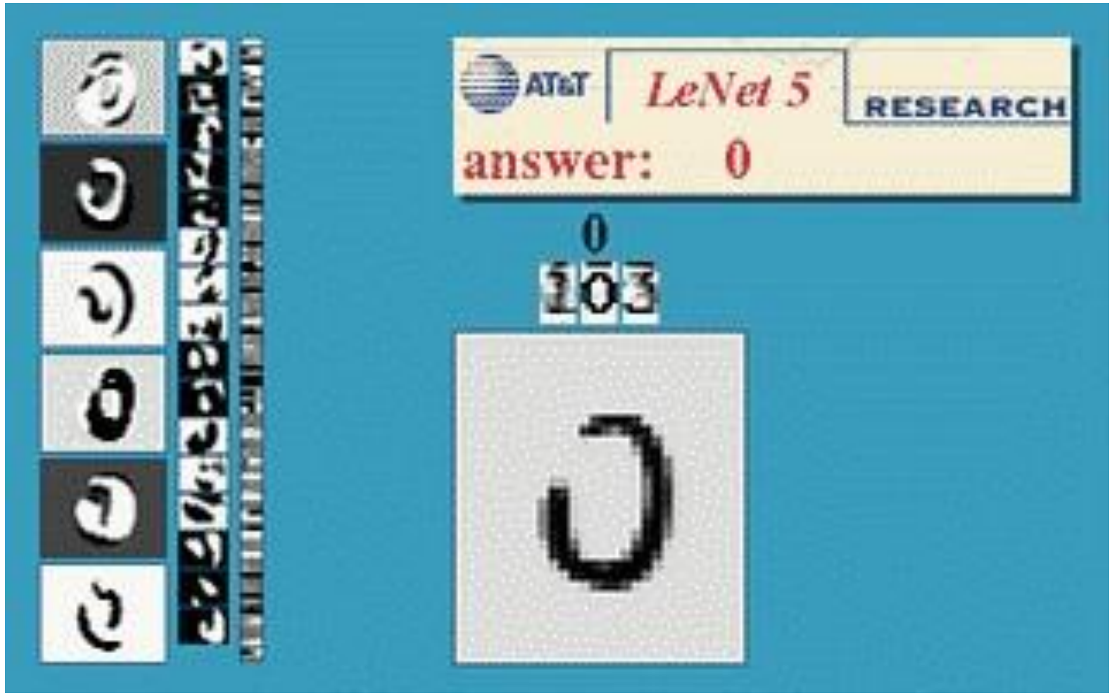
https://www.theguardian.com/technology/2018/mar/31/tesla-car-crash-autopilot-mountain-view

Self-driving cars

Self-driving cars



Optical character recognition



Digit recognition, AT&T labs
http://www.research.att.com/~yann

License place recognition

Sports video analysis

Tennis review system

Virtual Reality…… Augmented Reality

Image Sensing and Acquisition

- The types of images in which we are interested are generated by the combination of an "*illumination*" source and the *reflection* or *absorption* of energy from that source by the elements of the "scene" being imaged.

What do computers see?

Number…..

47	49	51	47	41	41	41	38	42	54	66	66	58	56	53	48	43	43	45	47	50	47	47	47
45	44	39	38	37	48	67	95	138	151	156	157	165	157	125	79	36	38	47	48	48	43	38	36
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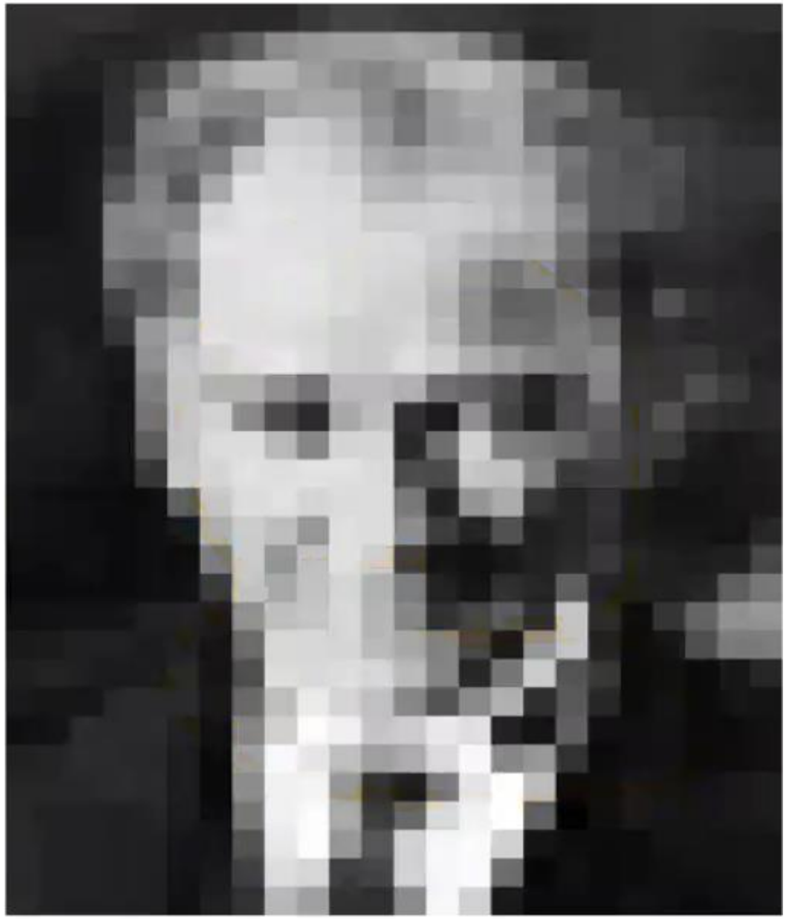
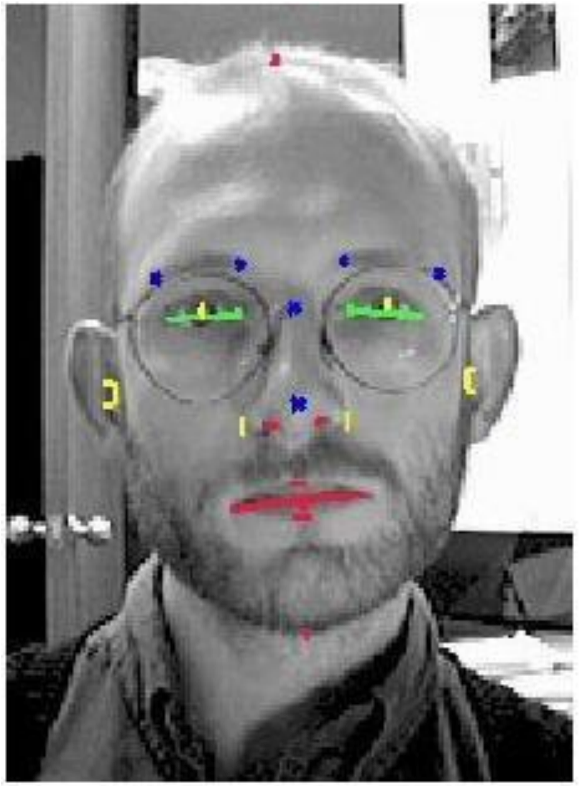
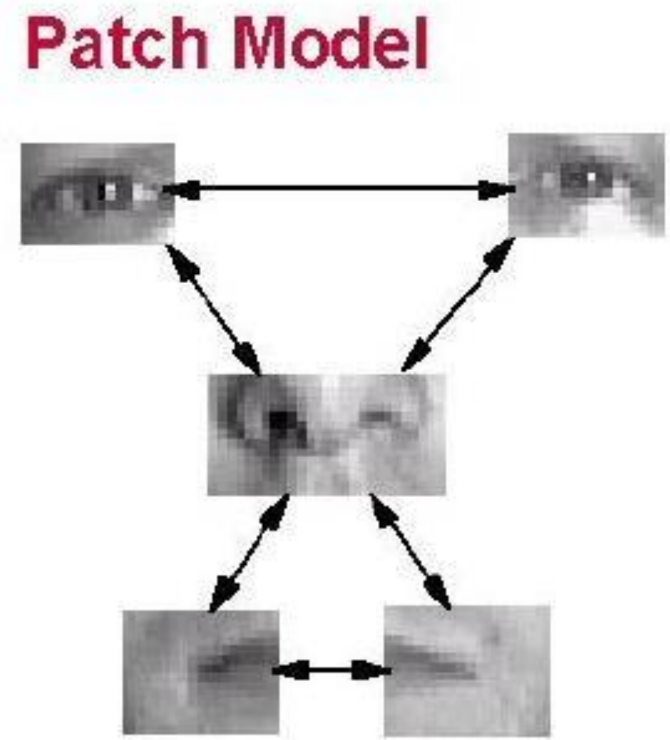


What do these numbers represent?

Parts and relations





http://www.research.ibm.com/ecvg/biom/facereco.html

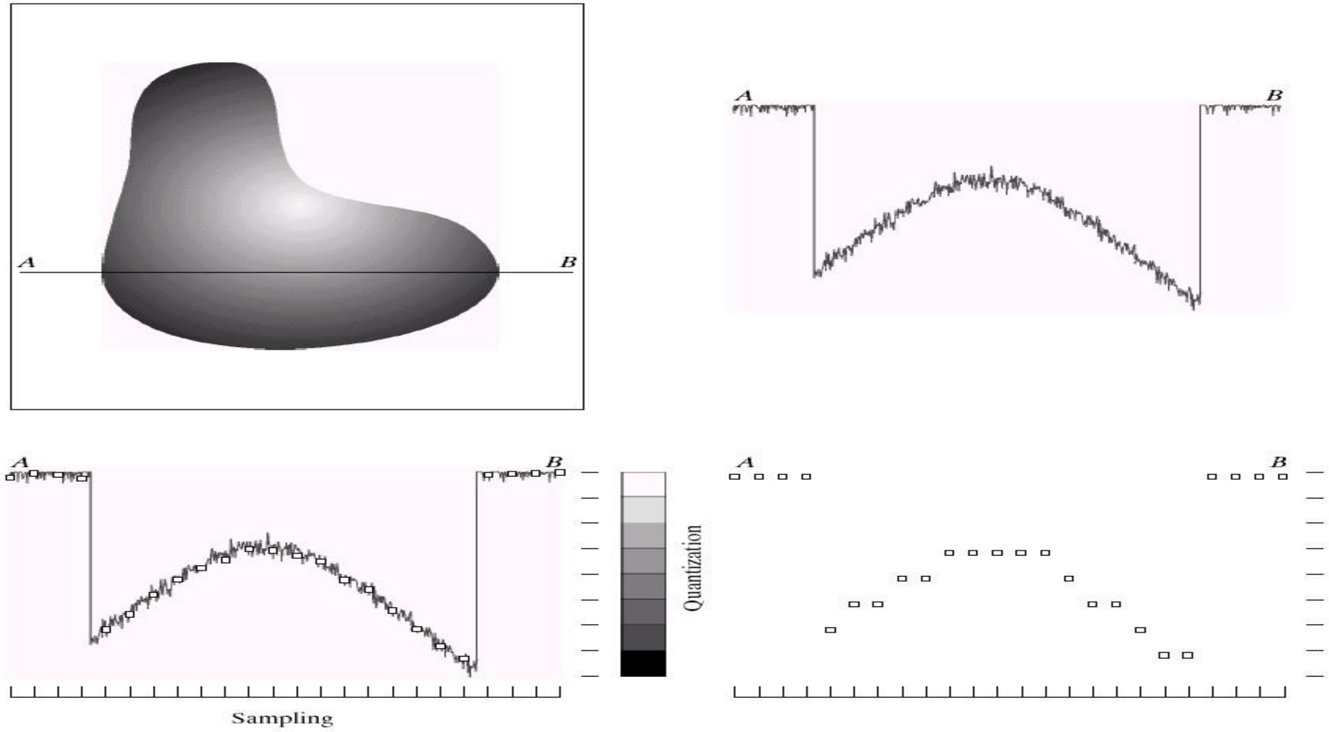
Image Sampling and Quantization

Objective of imaging is to generate digital images (representation) from sensed data (observation)

- In creating digital image, there is a need to convert the continuous sensed data into digital form.
- This involves two processes: ***sampling*** and ***quantization***.
- An image may be continuous with respect to the x- and y- coordinates, and also in amplitude.
- To convert it to digital form, **we have to sample** the function in both coordinates and in amplitude.

1. Digitizing the coordinate values is called ***sampling***.
2. Digitizing the amplitude(color intensity) values is called ***quantization***.

Image Sampling and Quantization



a b
c d

FIGURE 2.16 Generating a digital image. (a) Continuous image. (b) A scan line from A to B in the continuous image, used to illustrate the concepts of sampling and quantization. (c) Sampling and quantization. (d) Digital scan line.

Image Sampling and Quantization

- Take sample pixels and change the light intensity of the selected pixel to some predefined range
  - this could be the average intensity in the selected pixel

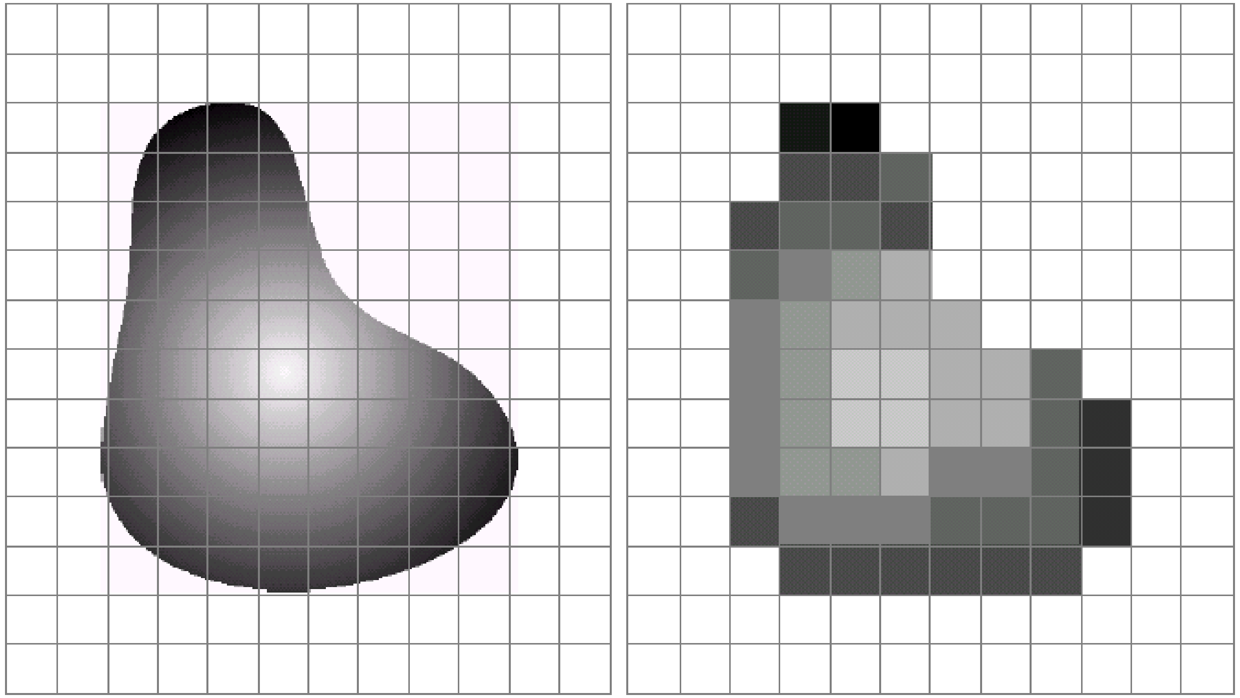


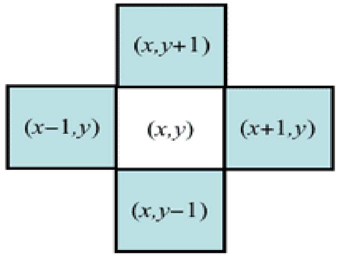
FIGURE 2.17 (a) Continuos image projected onto a sensor array. (b) Result of image sampling and quantization.

Some Basic Relationships Between Pixels

Neighbors of a pixel

- $N_4(p)$: 4-neighbors of p

$(x+1, y)$, $(x-1, y)$, $(x, y+1)$, $(x, y-1)$

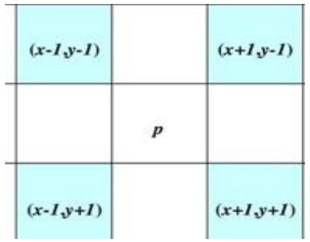


4-neighbourhood

$N_D(p)$: four diagonal neighbors of p

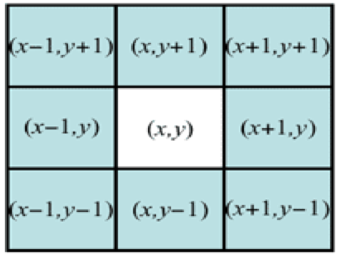
$(x+1, y+1)$, $(x+1, y-1)$, $(x-1, y-1)$,

$(x-1, y+1)$



$N_8(p)$: 8-neighbors of p

$N_4(p)$ and $N_D(p)$



8-neighbourhood

Distance Measures

- Euclidean distance

$$D_e(p,q) = [(x-s)^2 + (y-t)^2]^2$$

- City-block distance

$$D_4(p,q) = |(x-s)| + |(y-t)|$$

- Chessboard distance

$$D_8(p,q) = \max(|(x-s)|, |(y-t)|)$$

Distance/Similarity Measures

Method	Description
`'chessboard'`	In 2-D, the chessboard distance between (x_1, y_1) and (x_2, y_2) is $$max(\lvert x_1 - x_2\rvert, \lvert y_1 - y_2\rvert)$$
`'cityblock'`	In 2-D, the cityblock distance between (x_1, y_1) and (x_2, y_2) is $$\lvert x_1 - x_2\rvert + \lvert y_1 - y_2\rvert$$
`'euclidean'`	In 2-D, the Euclidean distance between (x_1, y_1) and (x_2, y_2) is $$\sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}$$ This is the default method.
`'quasi-euclidean'`	In 2-D, the quasi-Euclidean distance between (x_1, y_1) and (x_2, y_2) is $$\lvert x_1 - x_2\rvert + (\sqrt{2} - 1)\lvert y_1 - y_2\rvert, \lvert x_1 - x_2\rvert > \lvert y_1 - y_2\rvert$$ $$(\sqrt{2} - 1)\lvert x_1 - x_2\rvert + \lvert y_1 - y_2\rvert, otherwise$$

Region/Boundary/Edge

- ***Region***
  - We call R a region of the image if R is a connected set
- ***Boundary***
  - The boundary of a region R is the set of pixels in the region that have one or more neighbors that are not in R
- ***Edge***
  - Pixels with derivative values that exceed a preset threshold

Image Representation

1. Image capture
2. Image quality measurements
3. Image resolution
4. Colour representation
5. Camera calibration
6. Parallels with human visual system

The End