DIGITAL IMAGE PROCESSING FUNDAMENTALS

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A Picture is Worth 10,000 Words

Vision

Computer vision vs human vision

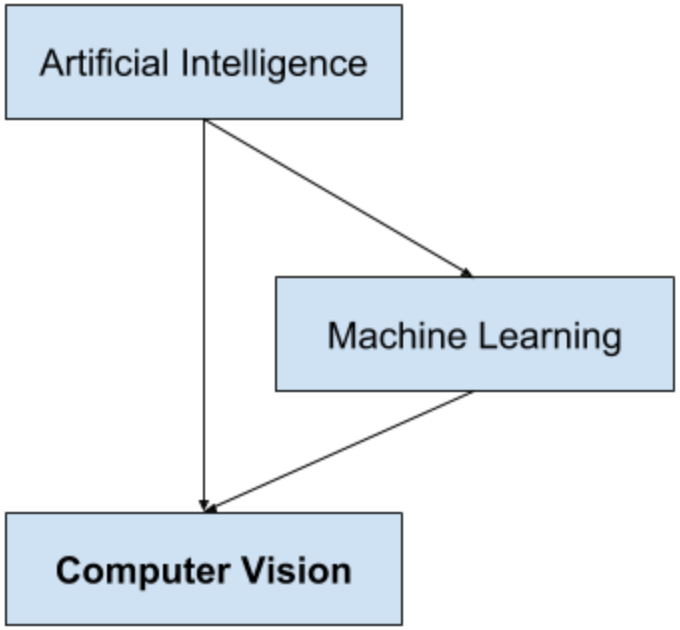
What we see

0	3	2	5	4	7	6	9	8
3	0	1	2	3	4	5	6	7
2	1	0	3	2	5	4	7	6
5	2	3	0	1	2	3	4	5
4	3	2	1	0	3	2	5	4
7	4	5	2	3	0	1	2	3
6	5	4	3	2	1	0	3	2
9	6	7	4	5	2	3	0	1
8	7	6	5	4	3	2	1	0

What a computer sees

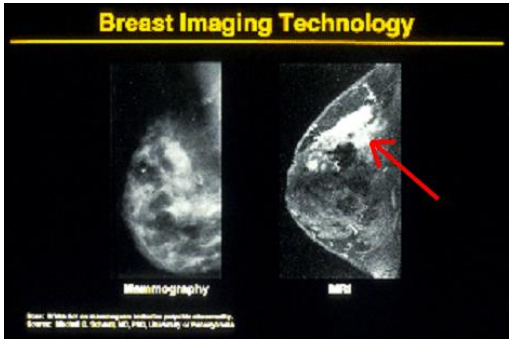
What is Computer Vision?

- Computer vision is a field of study focused on the problem of helping computers to see.
- *At an abstract level, the goal of computer vision is to use the observed image data to infer something about the world.*



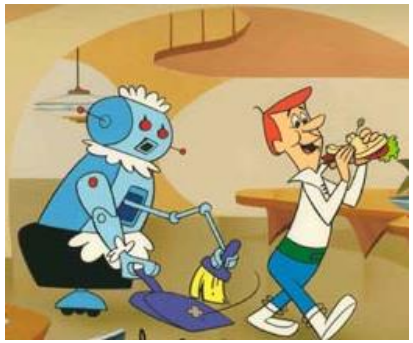
Why computer vision matters

Safety



Health

Security



Comfort

Fun

Access

Smart cars

- Mobileye - Vision systems currently in many car models

Computer Vision vs Human Vision

Computer Vision is the study of analysis of pictures and videos in order to achieve results similar to those as by men.

Human Vision Can do amazing things like:

- Recognize people and objects
- Navigate through obstacles
- Understand mood in the scene
- Imagine stories

But still is not perfect:

- Suffers from Illusions
- Ignores many details
- Doesn't care about accuracy of world

Computer Vision

Make computers understand images and video.

What kind of scene?

Where are the cars?

How far is the building?

…

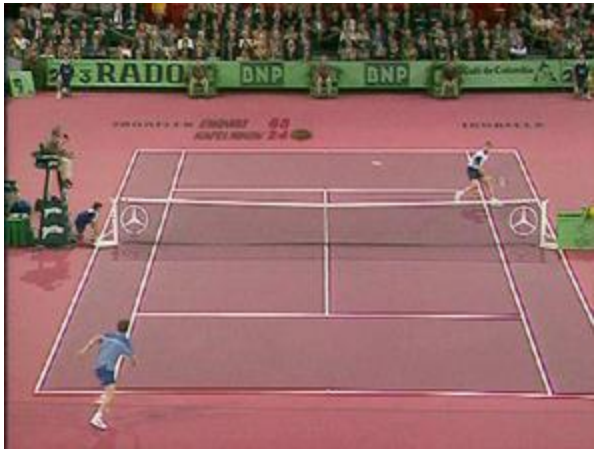
Vision is really hard

Vision is an amazing feat of natural intelligence

- Visual cortex occupies about 50% of Macaque brain
- More human brain devoted to vision than anything else

APPLICATIONS

- Detect type of Playground

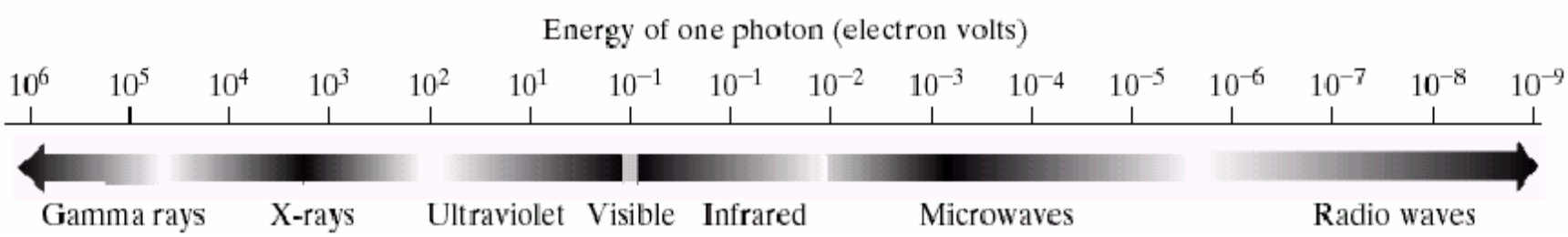


The Boom of Digital Images in the Last 20 Years

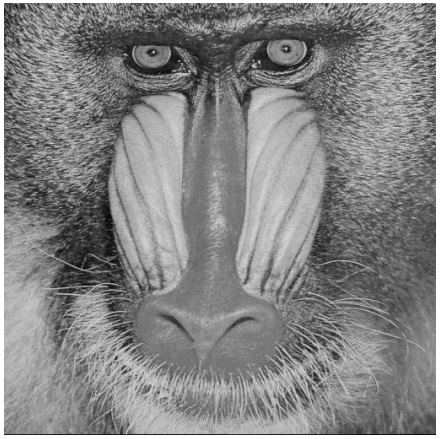
- Acquisition
  - Digital cameras, scanners
  - MRI and Ultrasound imaging
  - Infrared and microwave imaging
- Transmission
  - Internet, wireless communication
- Display
  - Printers, LCD,LED monitor, digital TV

A Physical Perspective of Image Acquisition

- Extend the capabilities of human vision systems
  - From visible spectrum to non-visible electromagnetic power spectrum
  - From close-distance sensing to remote sensing

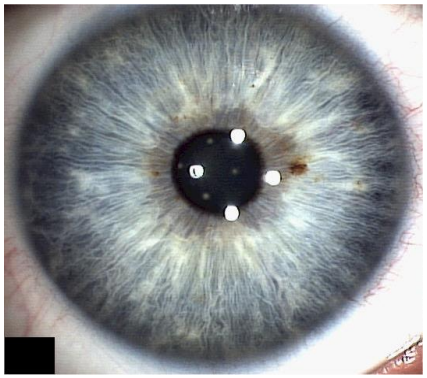


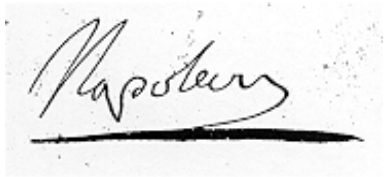
Visible (I): Photography

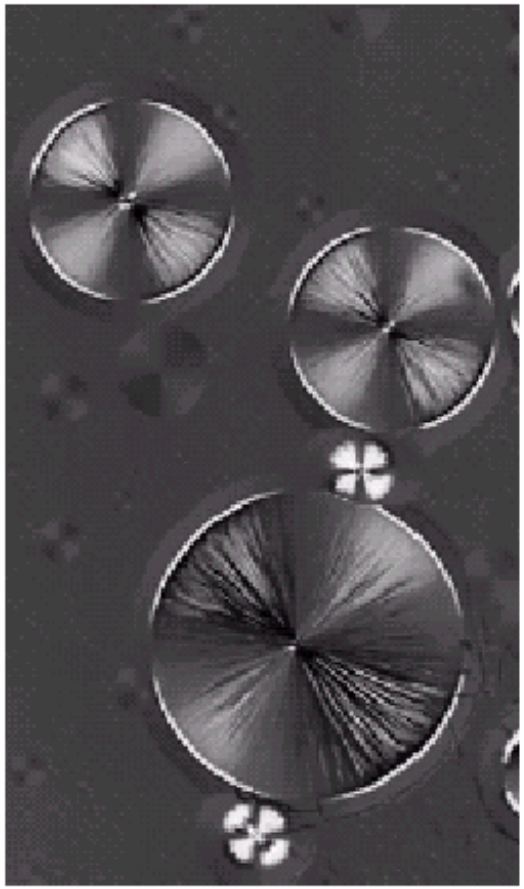

Visible (II): Motion Pictures

Visible (III): Law Enhancement and Biometrics



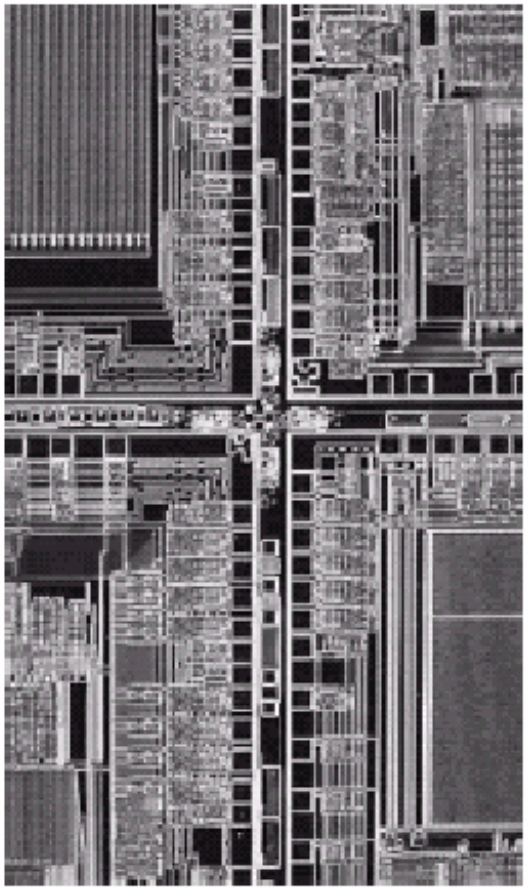


Visible (IV): Light Microscopy



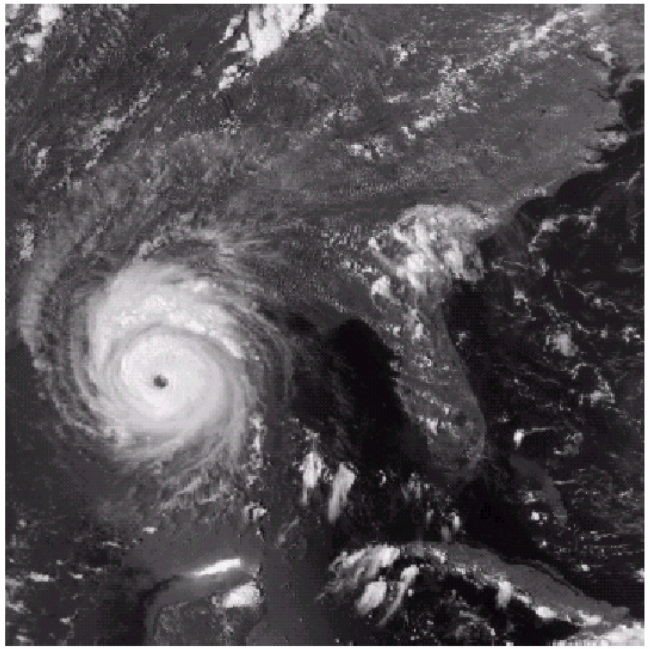
Taxol (250×)

Cholesterol (40×)



Microprocessor (60×)

Visible (V): Remote Sensing

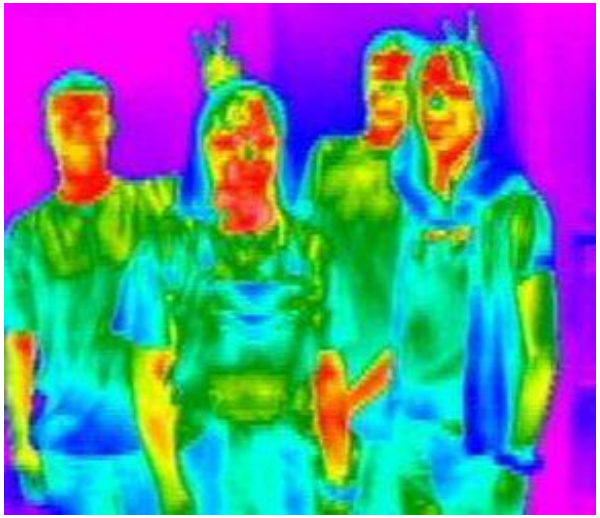


Hurricane Andrew
taken by NOAA GEOS

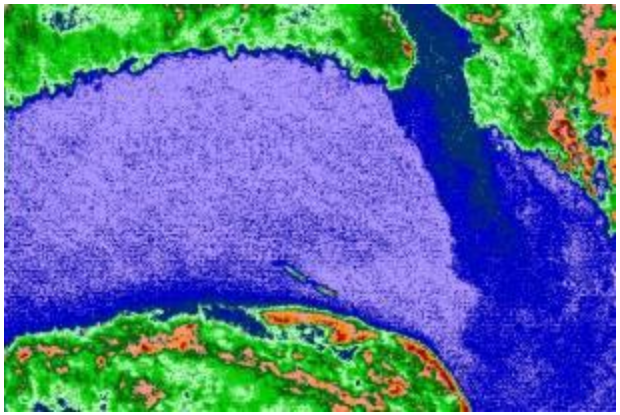
America at night
(Nov. 27, 2000)

Beyond Visible (I): Thermal Images

Operate in infrared frequency



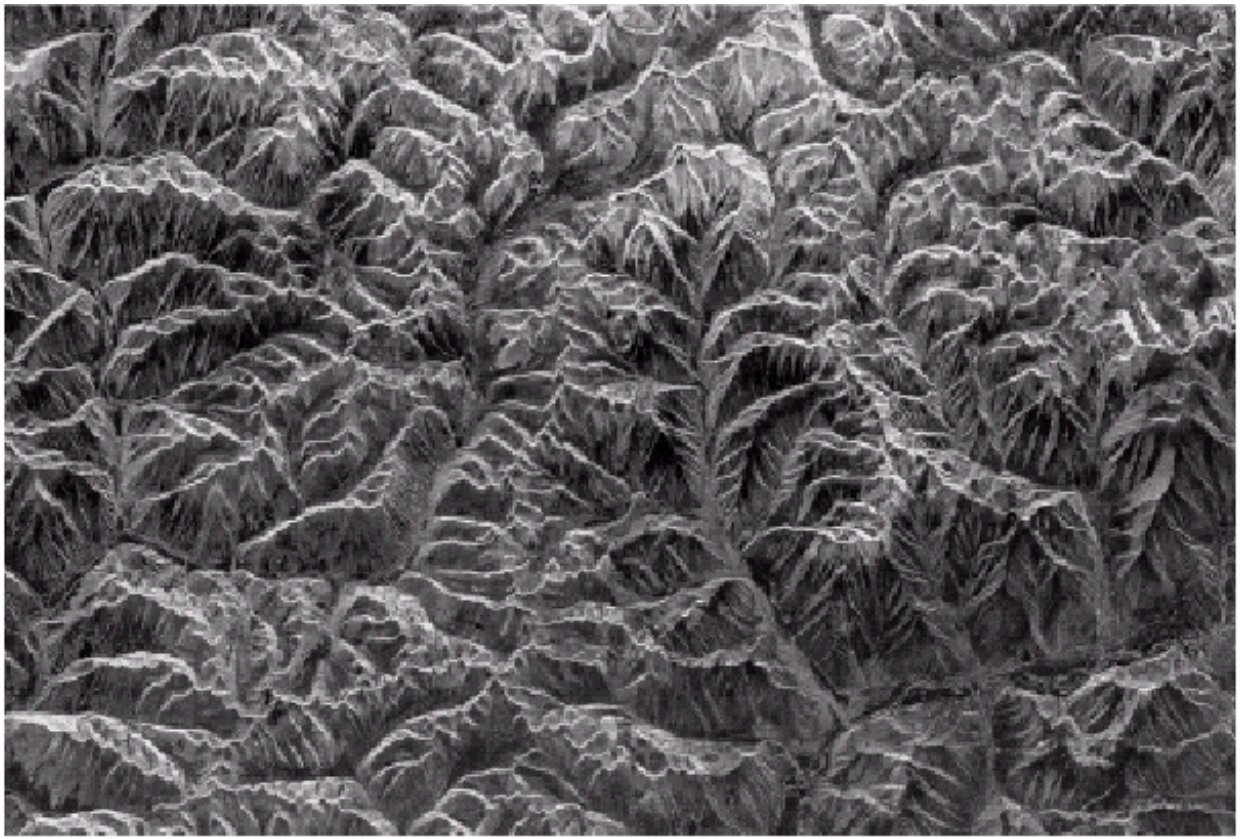
Human body disperses heat (red pixels)



Different colors indicate varying temperatures

Beyond Visible (II): Radar Images

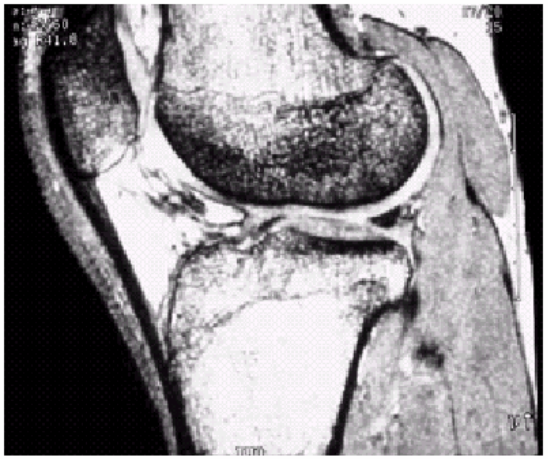
Operate in microwave frequency



Moutains in Southeast Tibet

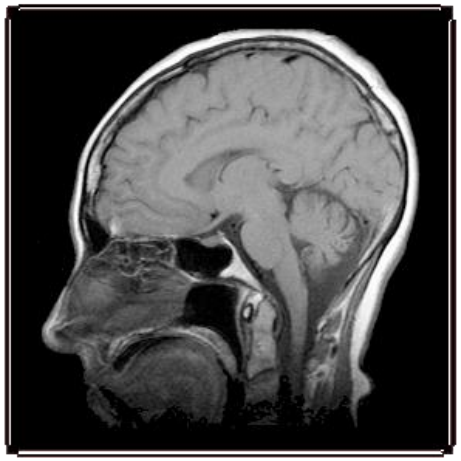
Beyond Visible (III): MRI and Astronomy

Operate in radio frequency

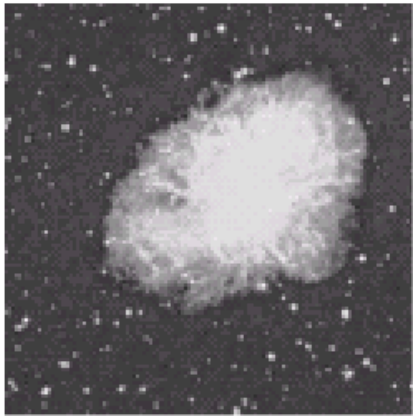


knee

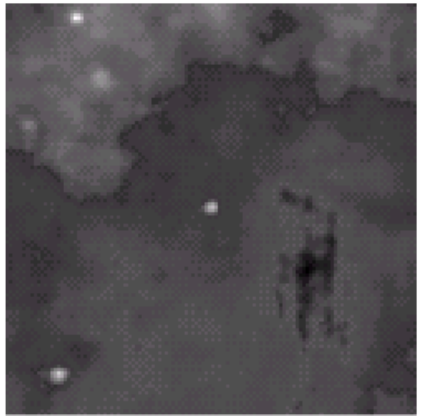
spine



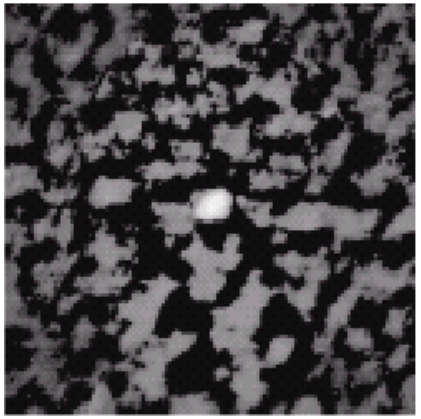
head



visible



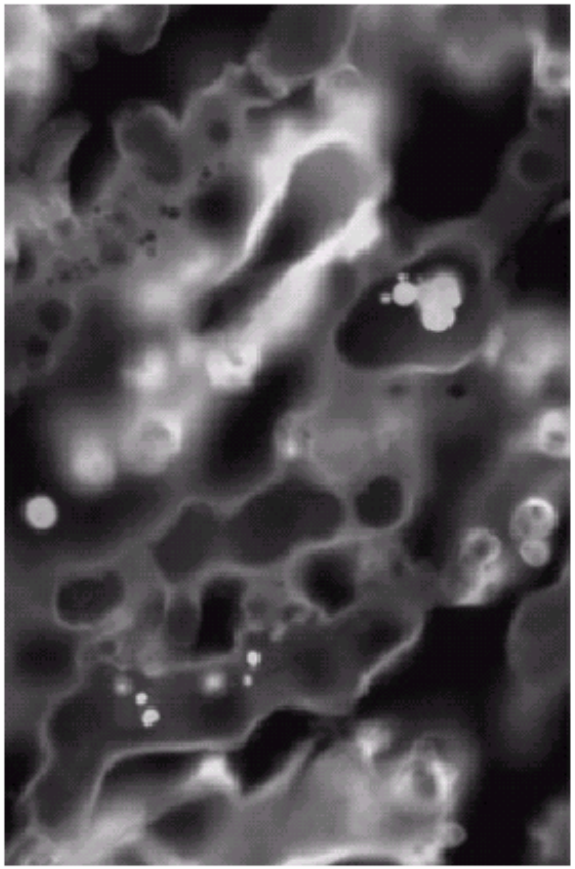
infrared



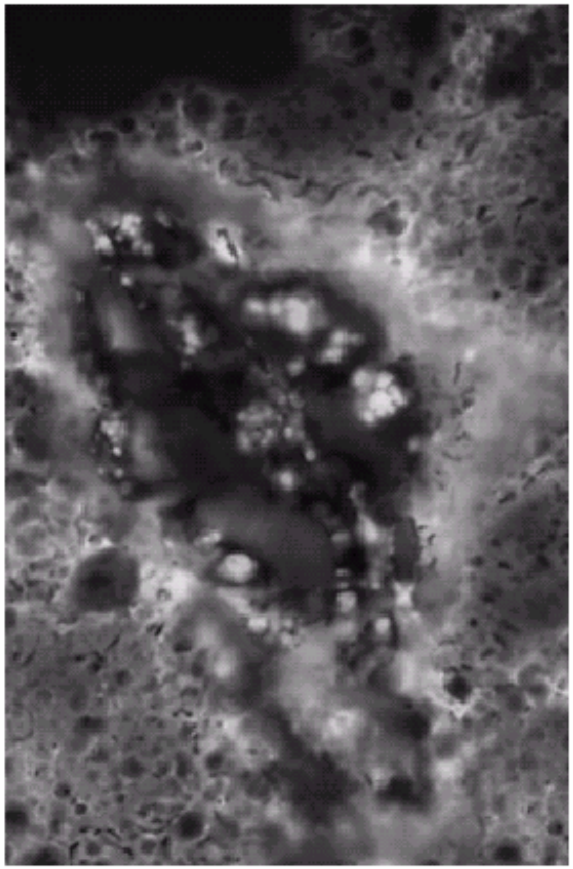
radio

Beyond Visible (IV): Fluorescence Microscopy

Operate in ultraviolet frequency



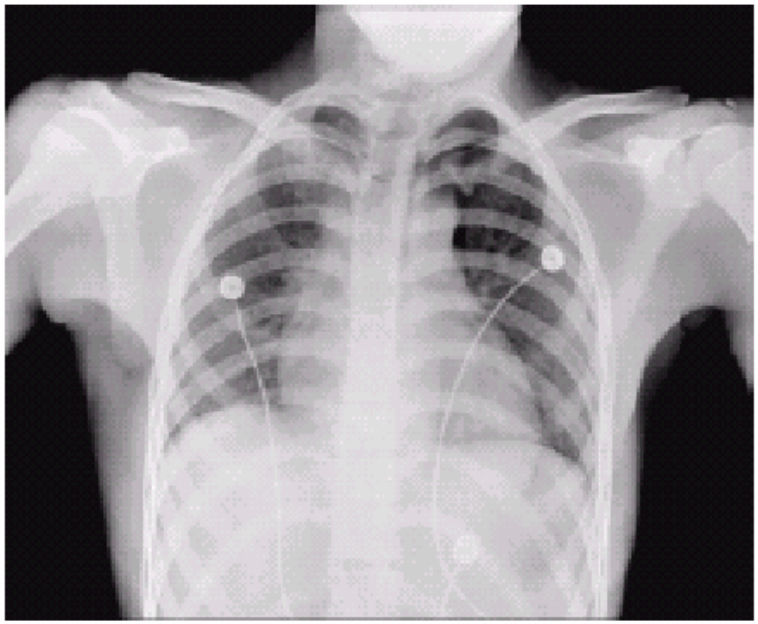
normal corn



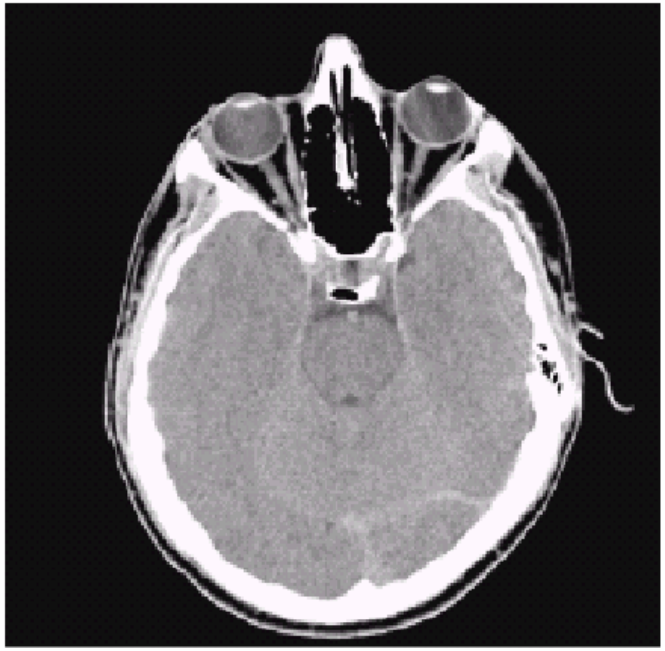
smut corn

Beyond Visible (V): Medical Diagnostics

Operate in X-ray frequency



chest

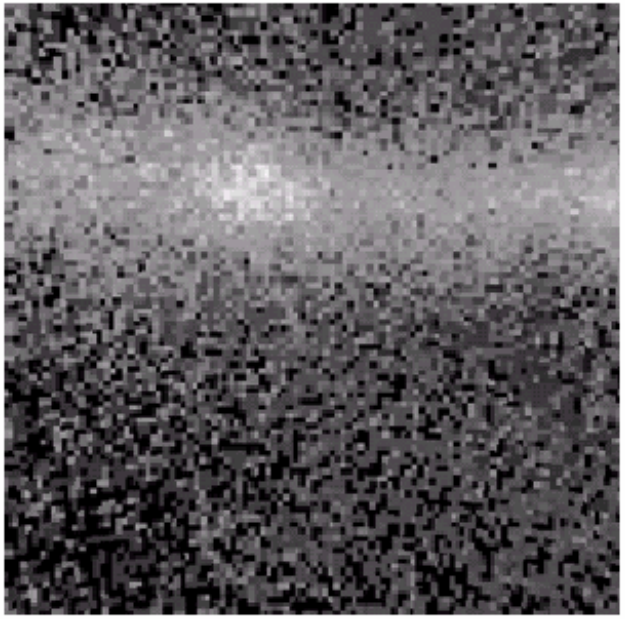


head

Beyond Visible (VI): PET and Astronomy

Operate in gamma-ray frequency

Positron Emission Tomography



Cygnus Loop in the constellation of Cygnus

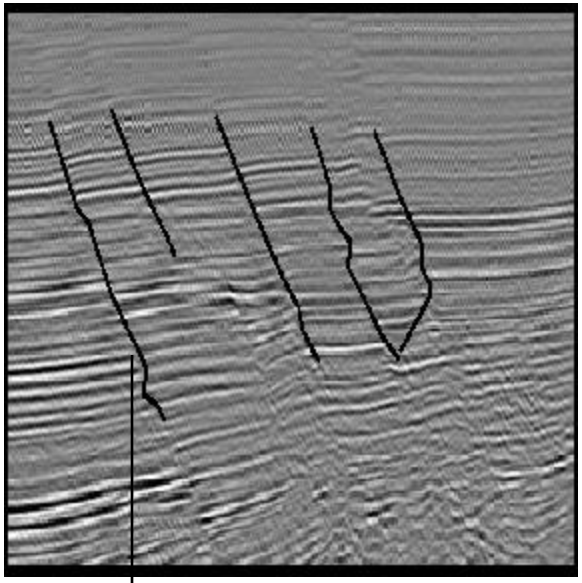
Other Non-Electro-Magnetic Imaging Modalities

- Acoustic imaging
  - Translate "sound waves" into image signals
- Electron microscopy
  - Shine a beam of electrons through a speciman
- Synthetic images in Computer Graphics
  - Computer generated (non-existent in the real world)

Acoustic Imaging

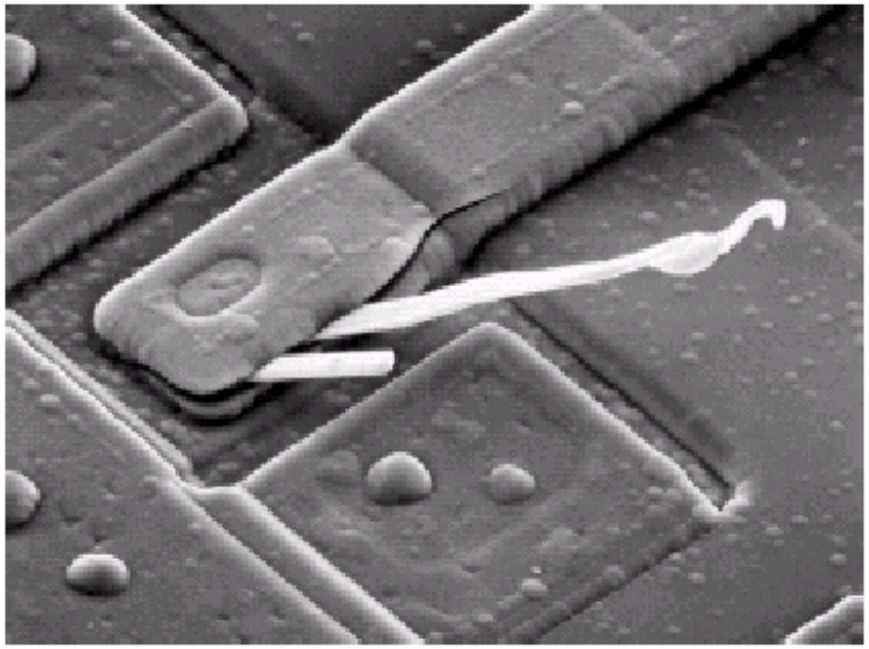
visible

seismic



potential locations of oil/gas

Electron Microscope



2500× Scanning Electron Microscopy (SEM) image of damaged integrated circuit
(white fibers are oxides resulting from thermal destruction)

Cartoon Pictures (Non-photorealistic)

Synthetic Images in Gaming

Age of Empire III by Ensemble Studios

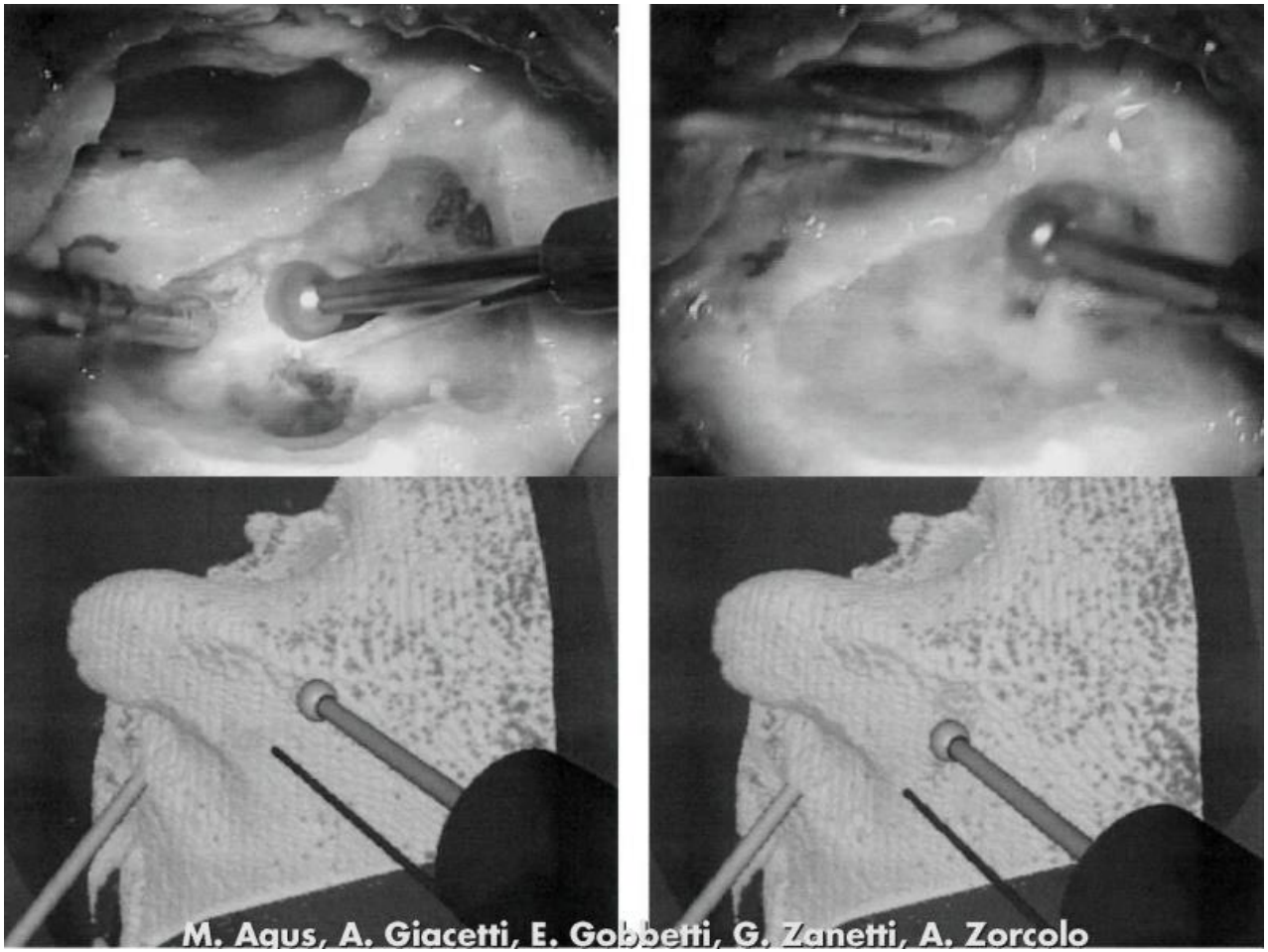
Virtual Reality (Photorealistic)

Graphics in Art

Richard Estes

Discovered by Denis Zorin

Graphics in Medicine



Mixture of Graphics and Photos

Morgantown, WV in Google Map

Summary: Why do we need images?

- Various imaging modalities help us to see invisible objects due to
  - Opaqueness (e.g., see through human body)
  - Far distance (e.g., remote sensing)
  - Small size (e.g., light microscopy)
- Other signals (e.g., seismic) can also be translated into images to facilitate the analysis
- Images are important to convey information and support reasoning

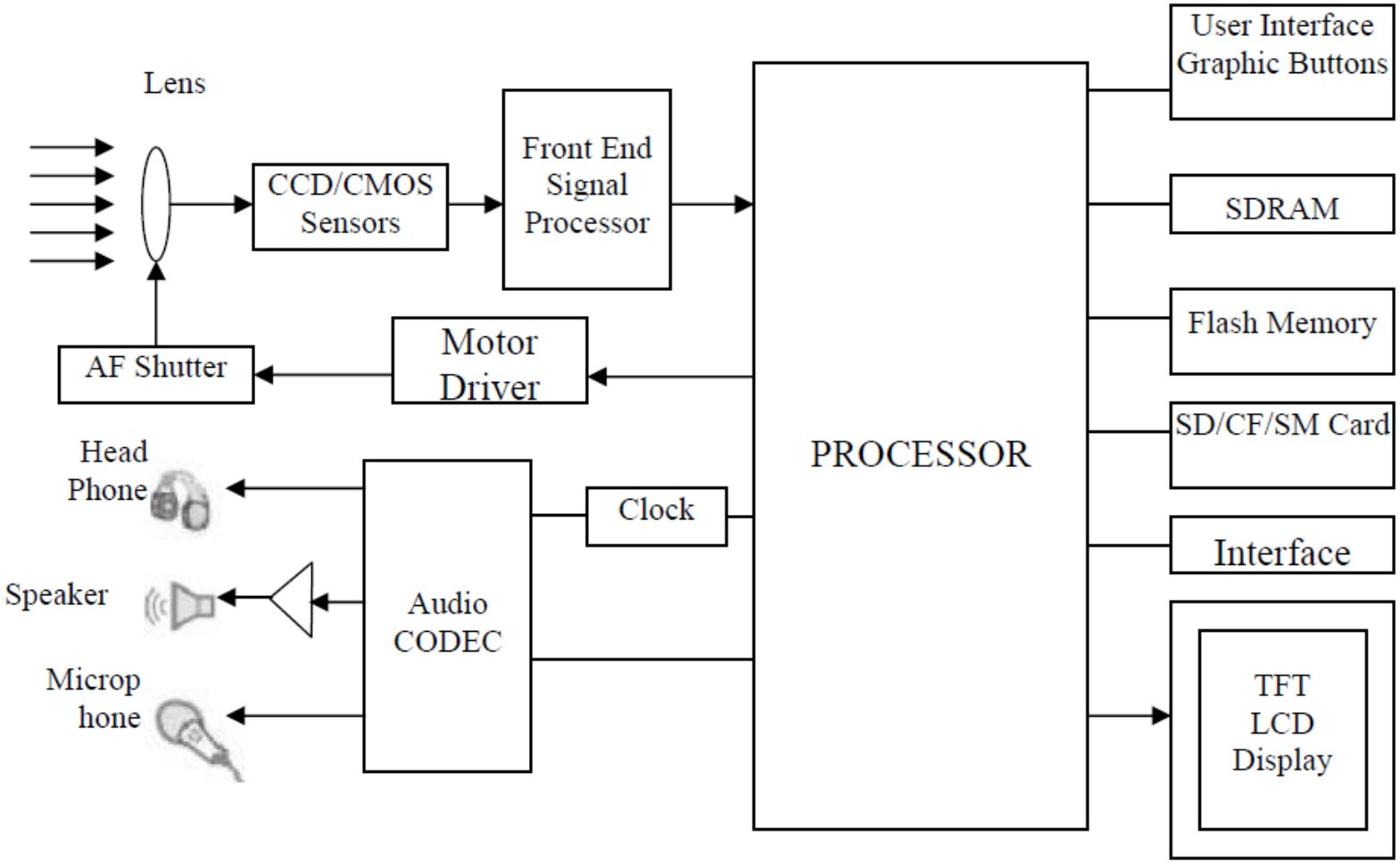
A picture is worth a thousand words!

What is digital image?

- Digital image, in which the intensity level of pixels at discrete spatial coordinates are discrete.

6	5	6	5	8	1	4
5	4	7	1	3	6	5
4	1	8	5	4	7	1
3	3	4	7	6	5	8
2	2	6	3	1	3	2
1	1	5	8	2	7	4
	1	2	3	4	5	6

Digital Camera



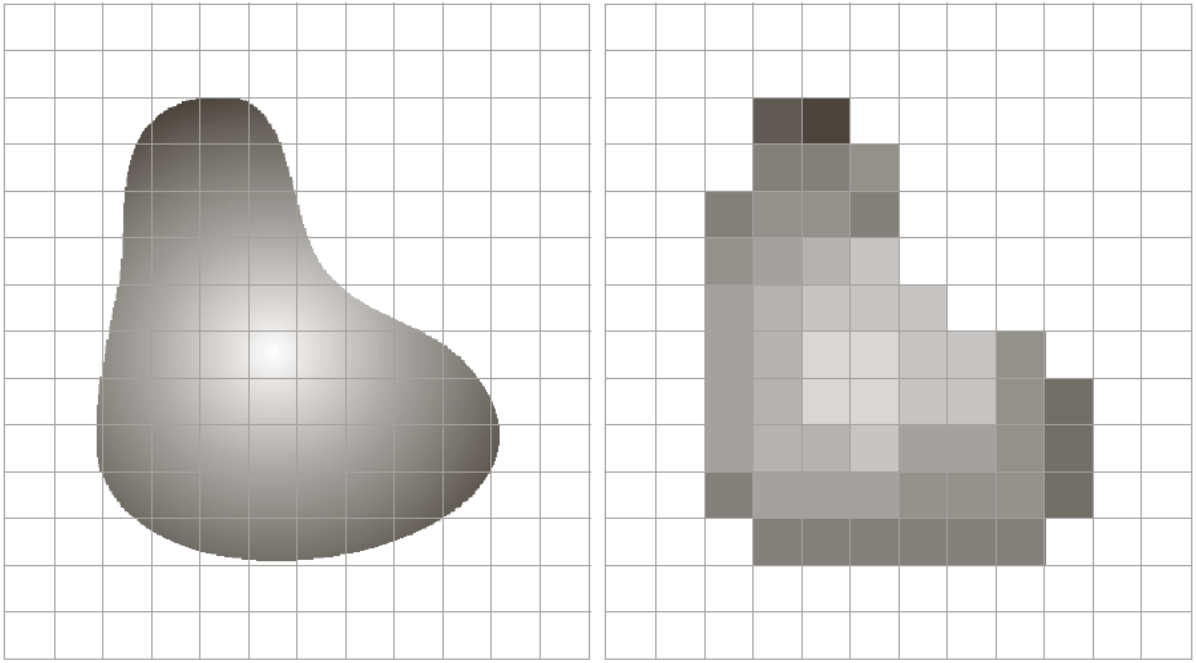
Sampling & Quantization

- Digitization of the spatial coordinates (x, y)

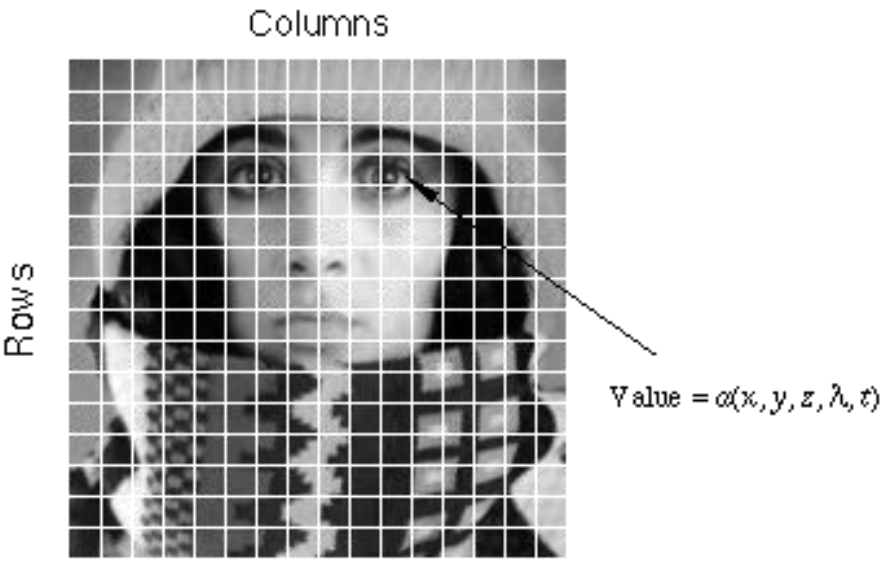
  : called *image sampling*
- Amplitude digitization

  : called *gray-level quantization*
- Resolution: *the degree of discernible detail* of an image depends strongly on the number of samples and gray-levels

Sampling



Sampling



depth (z), color (λ), time (t)

- ✓The 2D continuous image $I(x,y)$ is divided into N *rows* and M *columns*.
- ✓The intersection of a row and a column is termed a *pixel*.
- ✓The value assigned to the integer coordinates $[m,n]$ with $\{m=0,1,2,...,M-1\}$ and $\{n=0,1,2,...,N-1\}$ is $I[m,n]$.

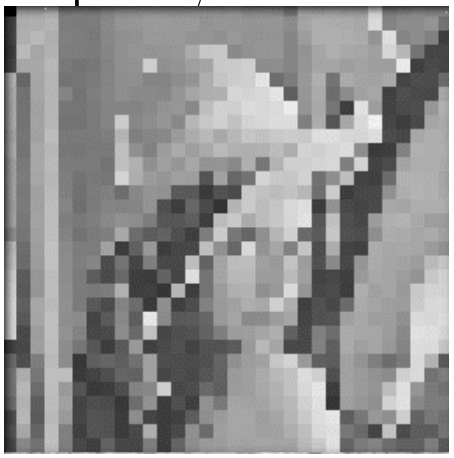
Image sampling (example)

original image

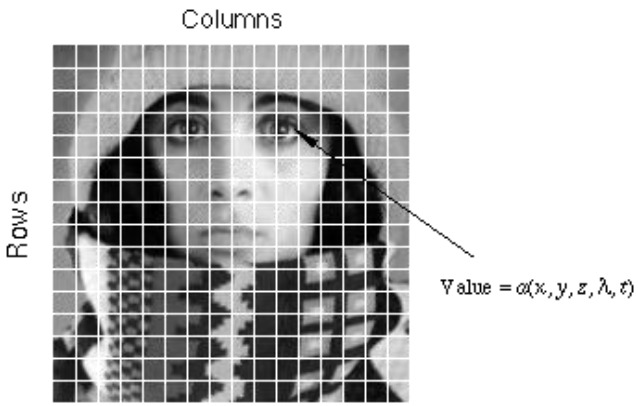
sampled by a factor of 2

sampled by a factor of 4

sampled by a factor of 8



Quantization



- Image divided into N = 16 rows and M = 16 columns.

- The process of representing the amplitude of the 2D signal at a given coordinate as an integer value with L different gray levels is usually referred to as amplitude quantization or simply ***quantization***
- The value assigned to every pixel is the average brightness in the pixel rounded to the nearest integer value.

Image quantization(example)

- 256 gray levels (8bits/pixel)

32 gray levels (5 bits/pixel)

16 gray levels (4 bits/pixel)

- 8 gray levels (3 bits/pixel)

4 gray levels (2 bits/pixel)

2 gray levels (1 bit/pixel)

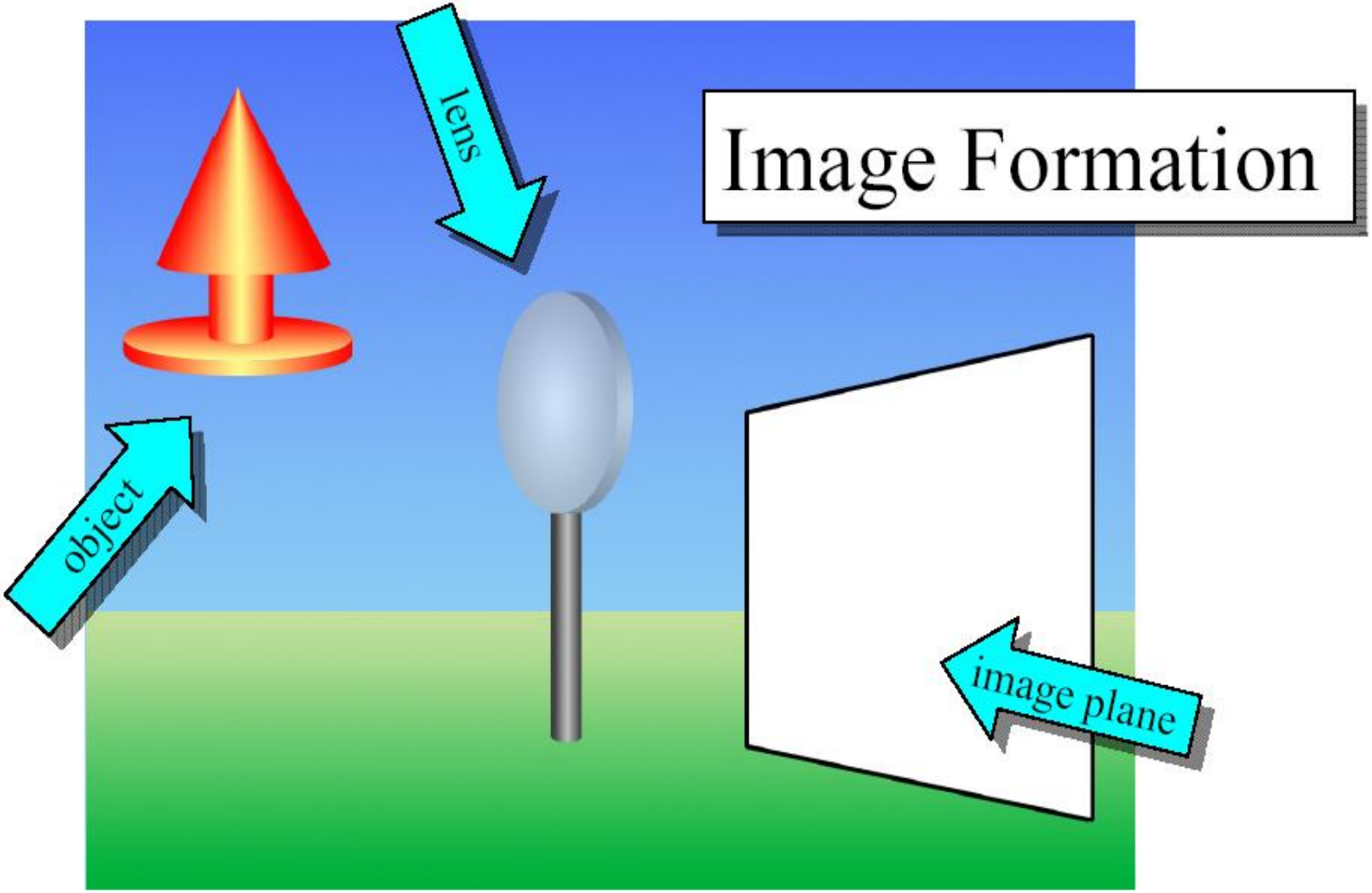


Image Formation
lens
object
image plane

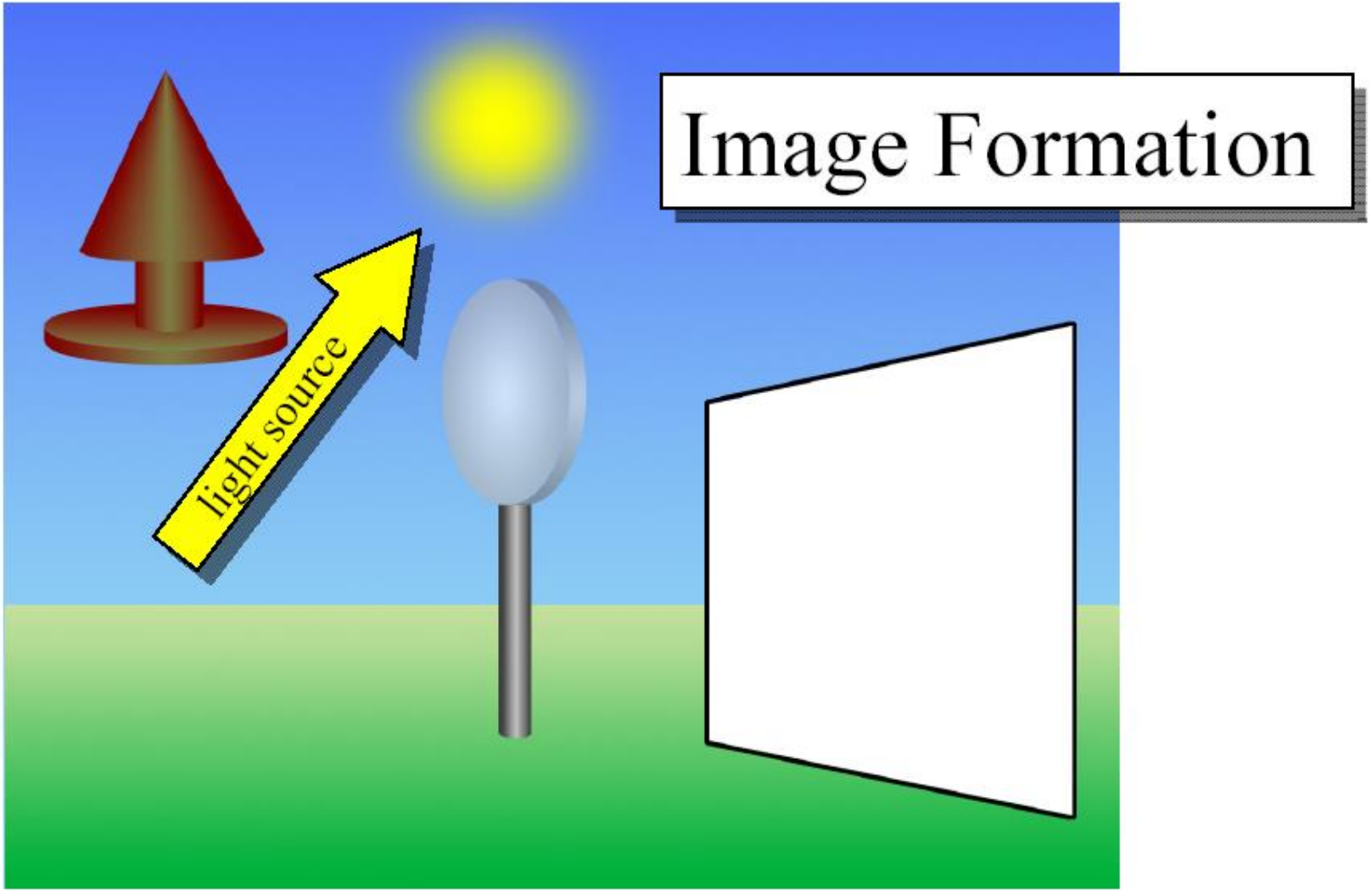


Image Formation
light source

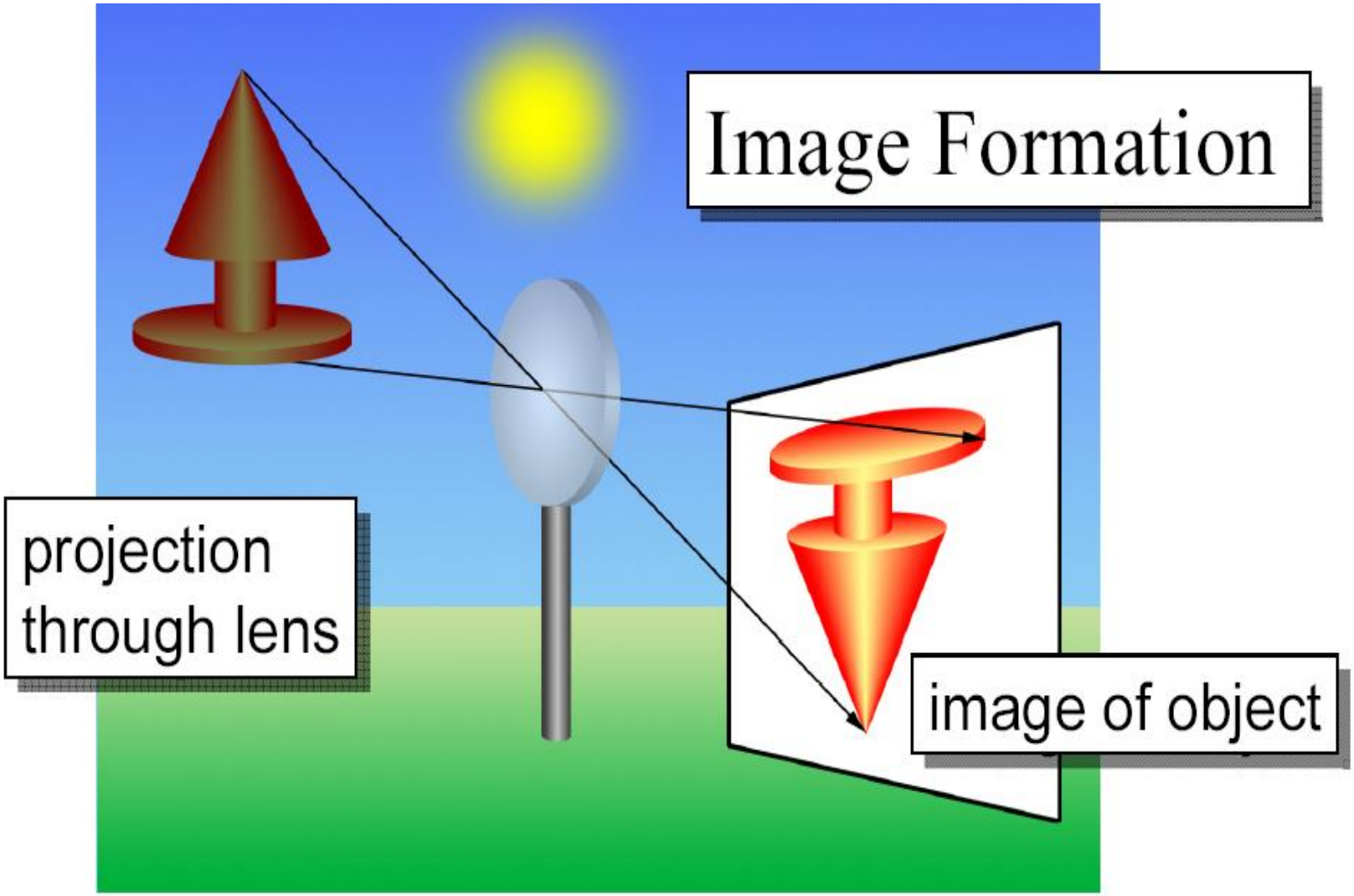


Image Formation
projection through lens
image of object

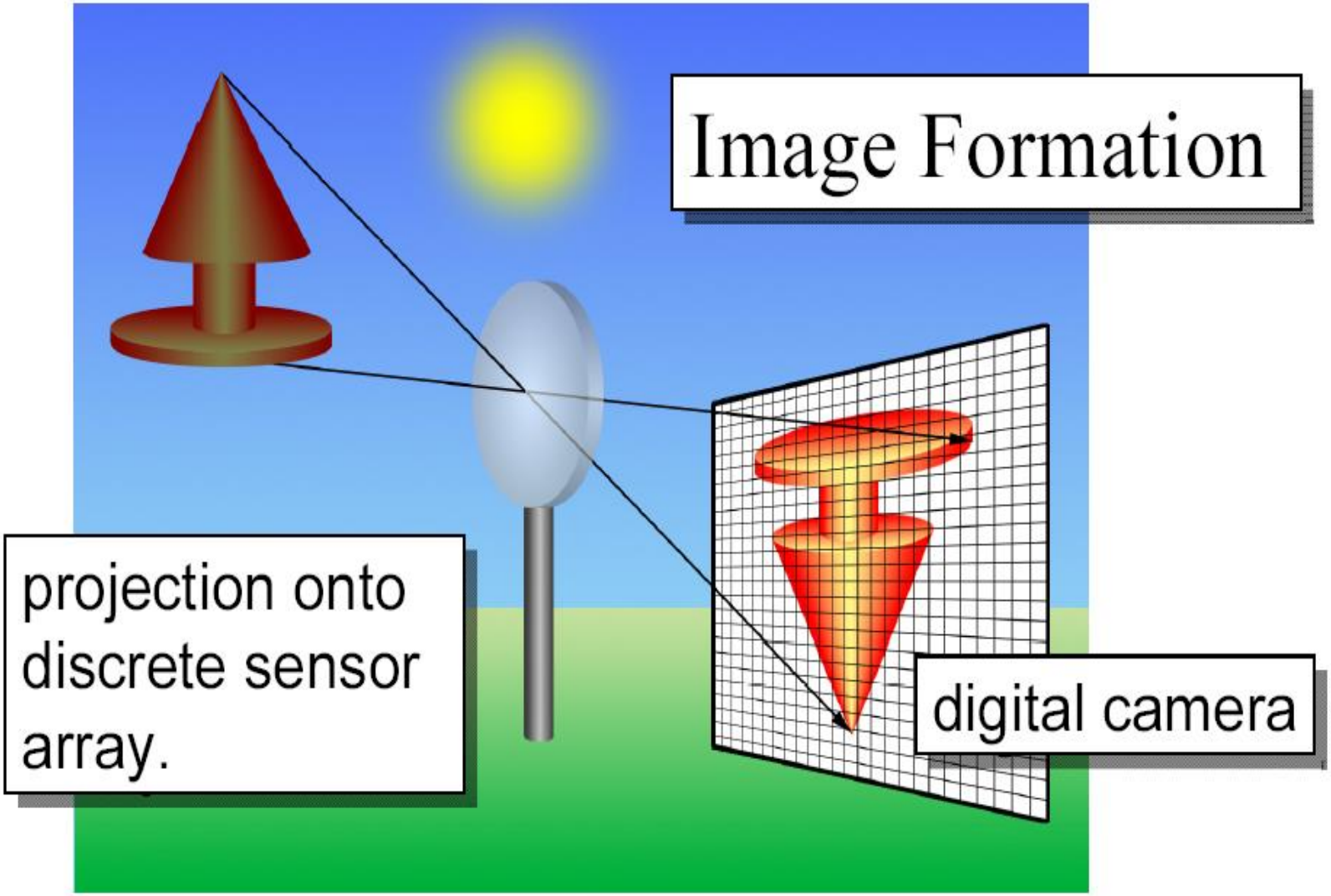


Image Formation
projection onto discrete sensor array.
digital camera

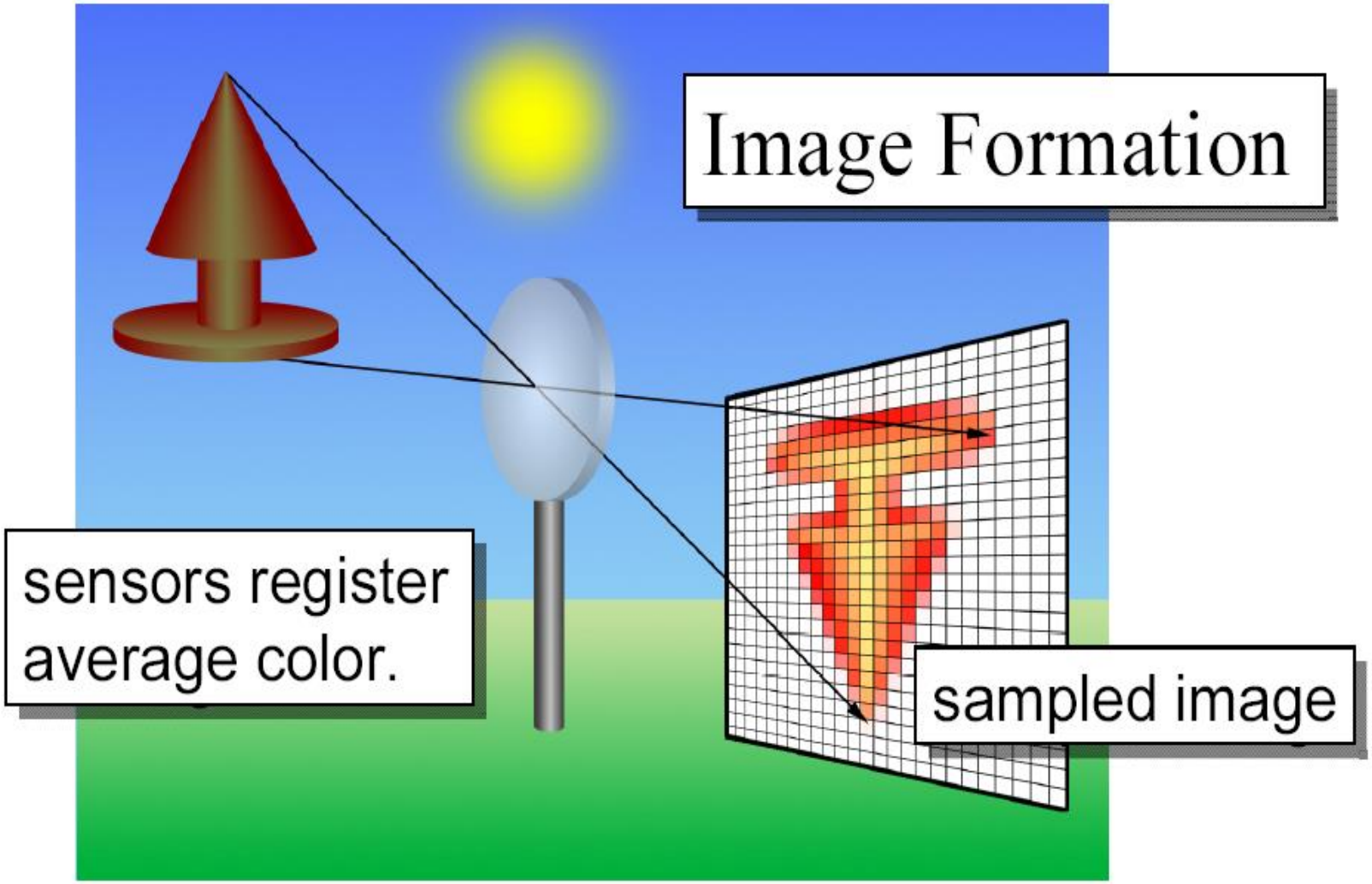


Image Formation
sensors register average color.
sampled image

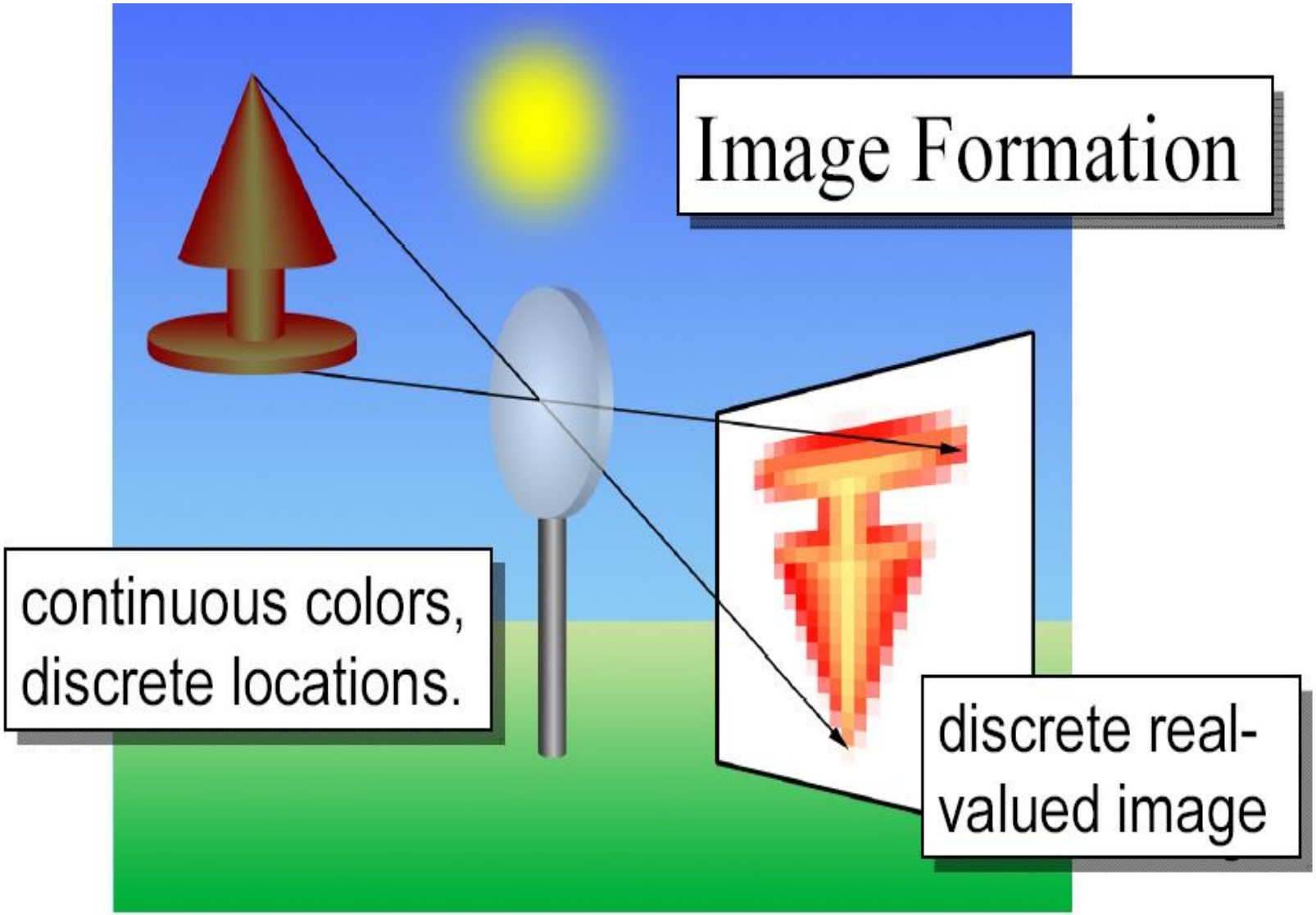
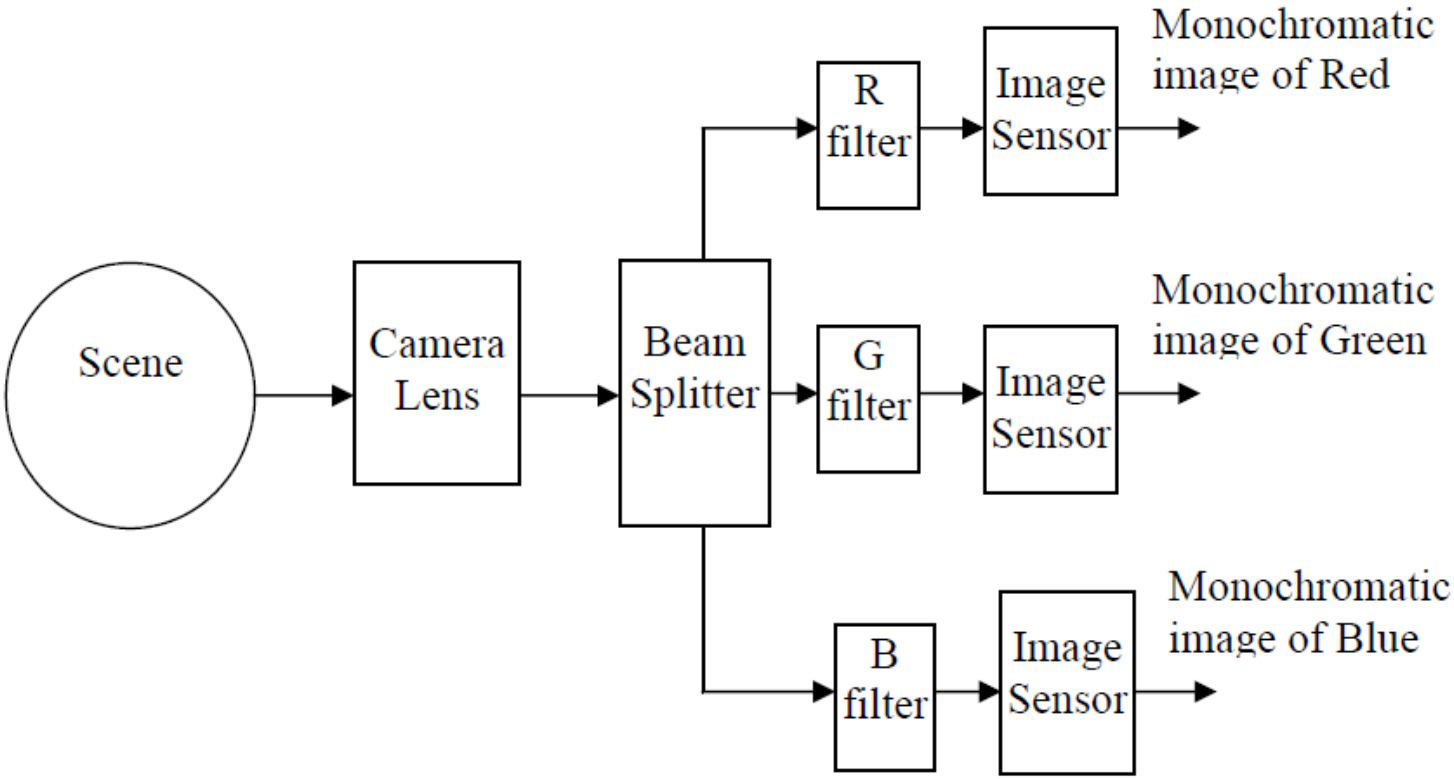


Image Formation
continuous colors,
discrete locations.
discrete real-
valued image

Image quality

- Quality of digital image proportional to:
  - **spatial resolution**
    - proximity of image samples in image plane
  - **spectral resolution**
    - bandwidth of light frequencies captured by sensor
  - **radiometric resolution**
    - number of distinguishable gray levels
  - **time resolution**
    - interval between time samples at which images captured

Color image Capturing



Why Digital?

- "Exactness"
  - Perfect reproduction without degradation
  - Perfect duplication of processing result
- Convenient & powerful computer-aided processing
  - Can perform rather sophisticated processing through hardware or software
  - Even kindergartners can do it!
- Easy storage and transmission
  - 1 CD can store hundreds of family photos!
  - Paperless transmission of high quality photos through network within seconds

What is digital image processing?

- Image processing in its broadest sense is an umbrella term for representing and analyzing of data in visual form.

- Reading, analyzing, modifying and storing of image files is called Image processing.

VARIOUS IMAGE PROCESSING OPERATIONS

General Classification

Two-level approaches

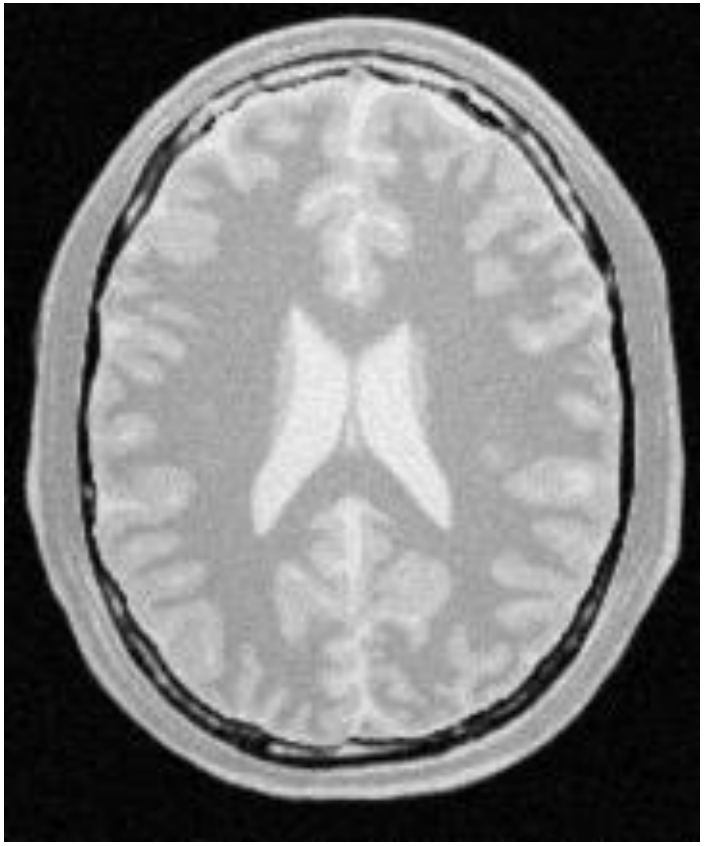
- Low level image processing. Very little knowledge about the content or semantics of images
- High level image understanding. Imitating human cognition and ability to infer information contained in the image.

Low level image processing

- Very little knowledge about the content of the images.
- Data are the original images, represented as matrices of intensity values, i.e. sampling of a continuous field using a discrete grid.

Low level image processing

- Image compression
- Noise reduction
- Edge extraction
- Contrast enhancement
- Segmentation
- Thresholding
- Morphology
- Image restoration



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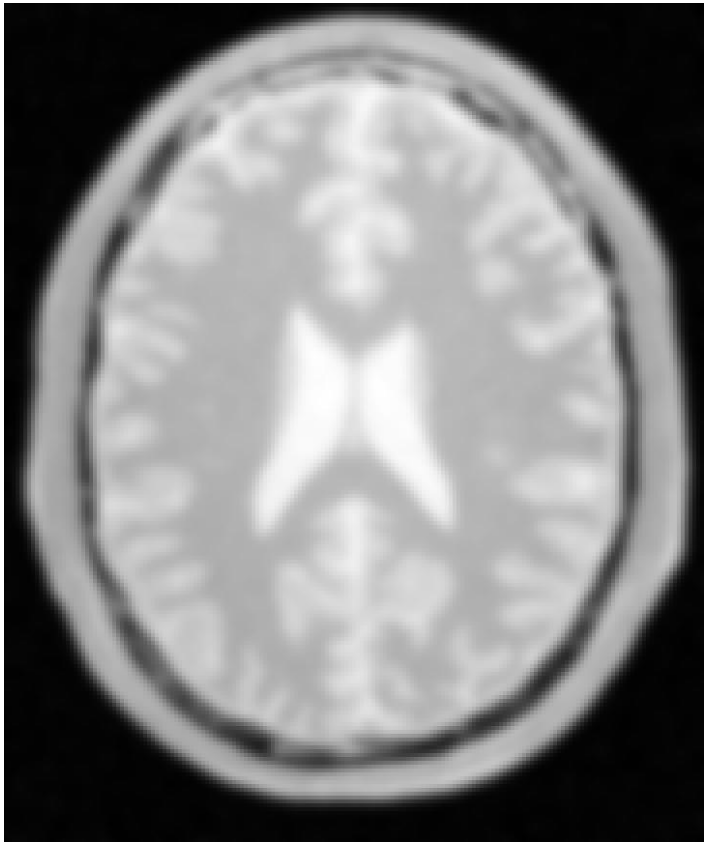

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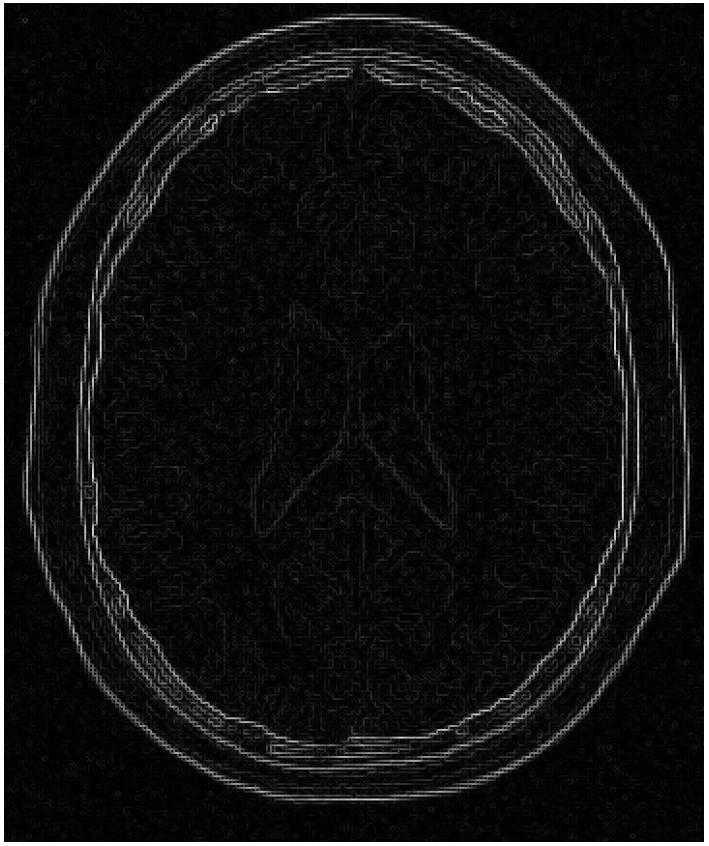

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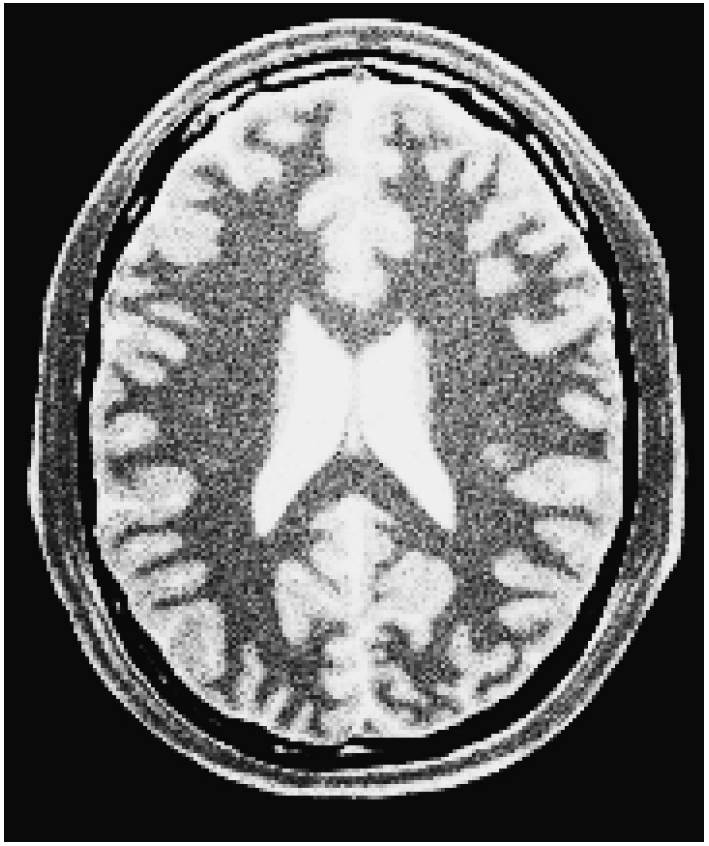

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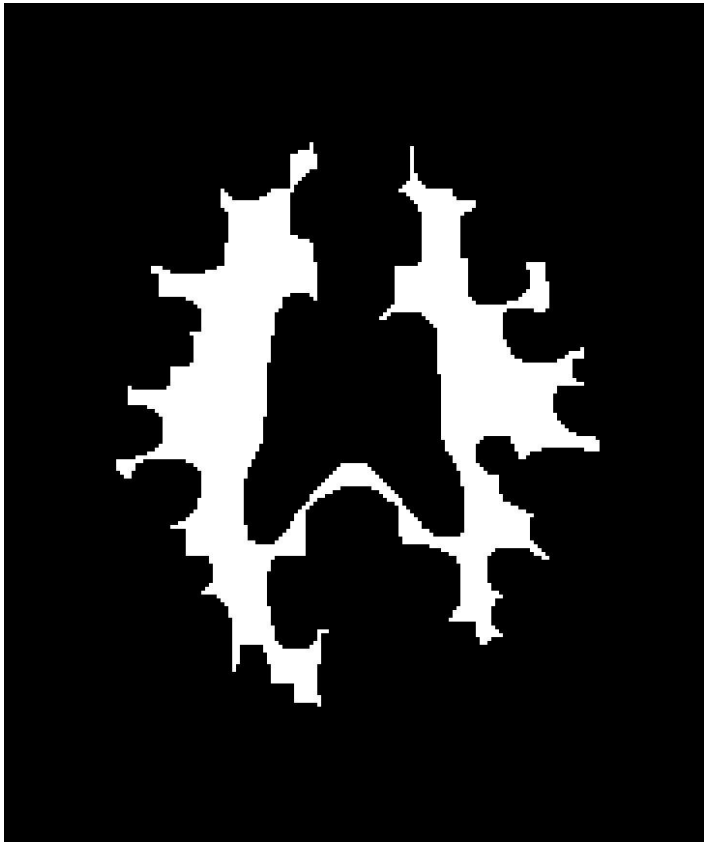

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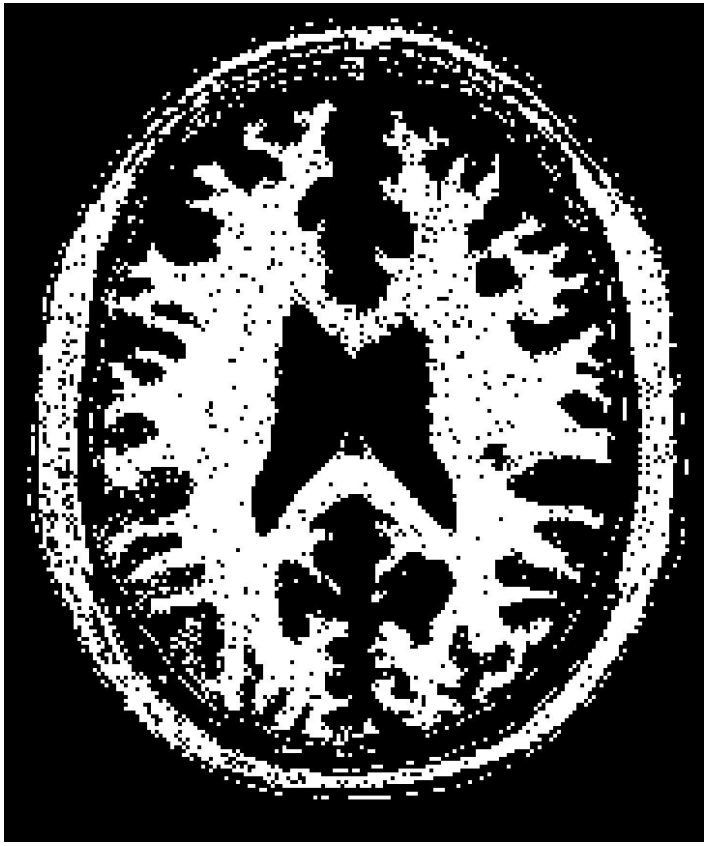
- Image compression
- Noise reduction
- Edge extraction
- Contrast enhancement
- Segmentation
- Thresholding
- Morphology
- Image restoration



Low level image processing

- Image compression
- Noise reduction
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- Thresholding
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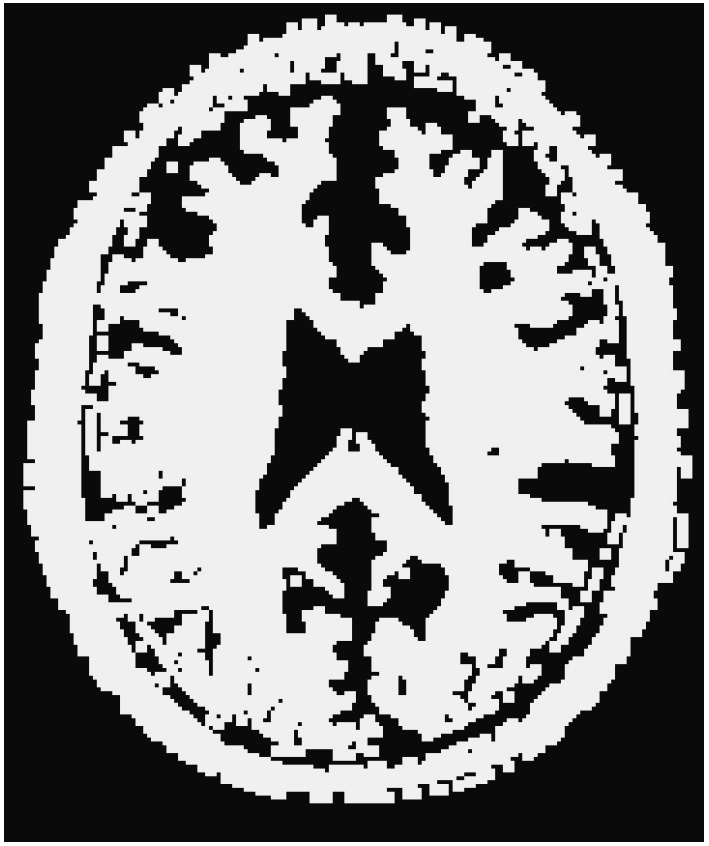

Dilation

Low level image processing

- Image compression
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- Edge extraction
- Contrast enhancement
- Segmentation
- Thresholding
- Morphology
- Image restoration

High level image understanding

- To imitate human cognition according to the information contained in the image.
- Data represent knowledge about the image content, and are often in symbolic form.
- Data representation is specific to the high-level goal.

High level image processing -Computer Vision

- Detection of classes of objects (faces, motorbikes, trees, in cheetahs) in images
- Recognition of specific objects such as Saddam Hussein
- Classification of images or parts of images for medical or scientific applications scientific applications
- Recognition of events in surveillance videos
- Measurement of distances for robotics

High-level vision uses techniques from AI

- Graph -Matching: Constraint Satisfaction, Branch and Bound Search, Simulated Annealing
- Learning Methodologies: Decision Trees, Neural Nets, SVMs, EM Classifier □
- Probabilistic Reasoning, Belief Propagation, Graphical Models

What are the difficulties?

- Poor understanding of the human vision system

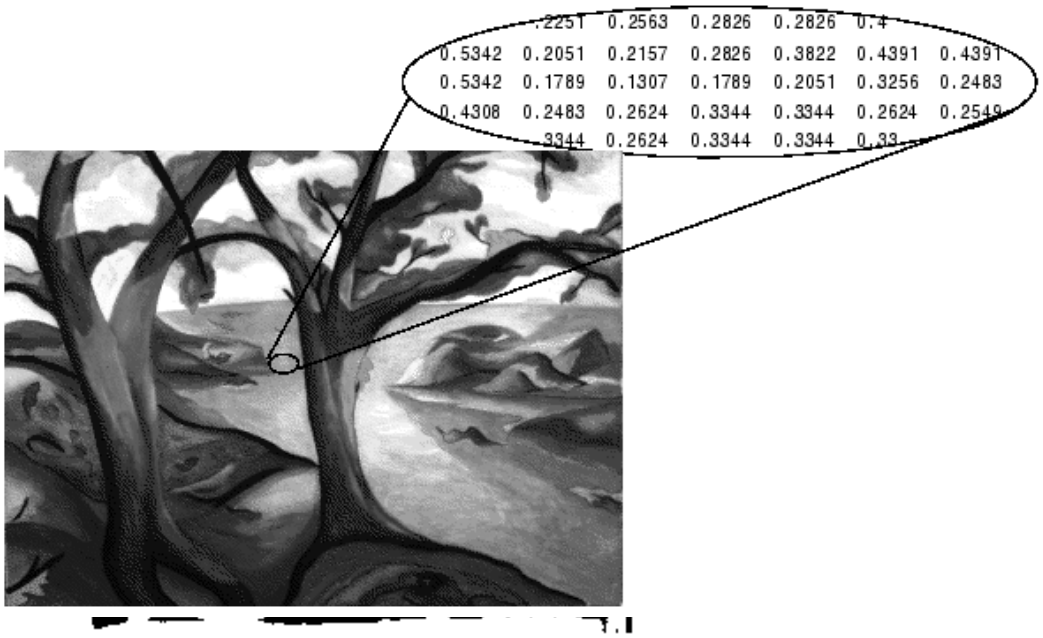
Do you see a young or an old lady?

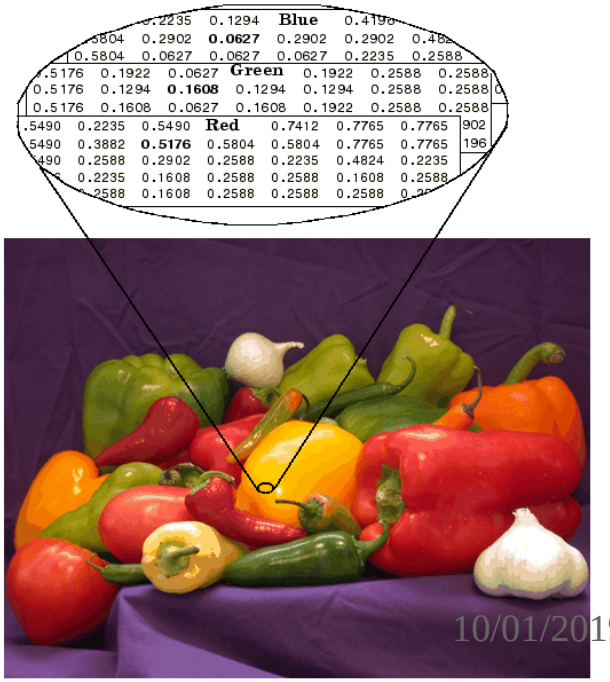
What are the difficulties?

- Human vision system tends to group related regions together, not odd mixture of the two alternatives.
- Attending to different regions or contours initiate a change of perception
- This illustrates once more that vision is an active process that attempts to make sense of incoming information.

Images - types

- Binary images : {0,1}
- Intensity images : [0,1] or uint8, double etc.
- RGB images : m-by-n-by-3
- Indexed images : m-by-3 color map
- Multidimensional images m-by-n-by-p (p is the number of layers)





Class Format – Efficiency of Learning

What we read	10%
What we hear	20%
What we see	30%
What we hear + see	50%
What we say ourselves	70%
What we do ourselves	90%

Thank you