

# *Computer Vision*

## Course 1

## **Online instruments**

- ✓ **Zoom – course, lab, article presentation**
- ✓ **Discord – lab, offline messages**
- ✓ **[anca.ignat@info.uaic.ro](mailto:anca.ignat@info.uaic.ro), [ignata@uaic.ro](mailto:ignata@uaic.ro),  
[ancai\\_fii@yahoo.ro](mailto:ancai_fii@yahoo.ro)  
  
<https://edu.info.uaic.ro/computer-vision/>**

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### **Evaluation**

**4 (course test) + 3 (lab activity)+ 3 (article presentation)**

**$\geq 4.5$**

**Course test (onsite!!!) – week 15 or 16**

**Lab activity – 6 projects**

**Lab evaluation (onsite+online) – deadline week 12**

**Article presentation – weeks 13 and 14 (online)**

**At the end of the semester, send an archive with (code lab activity + emoji as .jpg file + article related documents) to [ancai\\_fii@yahoo.ro](mailto:ancai_fii@yahoo.ro)**

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### **Bibliography**

- **E.R. Davies**, *Computer vision: principles, algorithms, applications, learning*, 5-th ed., Academic Press (2017)
- **D.A.Forsyth & J. Ponce**, *Computer vision: a modern approach*, Prentice Hall (2002)
- **R. Klette**, *Concise computer vision* (Vol. 233). London: Springer (2014)
- **R. Szeliski**, *Computer vision: algorithms and applications*. Springer Nature (2022).
- **R.C. Gonzales, R.E. Woods**, *Digital Image Processing*, Pearson India, 2018, 4<sup>th</sup> ed.
- **R. Shanmugamani**, *Deep Learning for Computer Vision: Expert techniques to train advanced neural networks using TensorFlow and Keras*, Packt Publishing Ltd. (2018).
- **J. Brownlee**, *Deep learning for computer vision: image classification, object detection, and face recognition in python*, Machine Learning Mastery (2019).

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- **Barbara J. Grosz (Harvard, USA):**

**“An AI and Computer Science Dilemma: Could I? Should I?”**

**(DIGHUM Lectures Program)**

- **face recognition ethic problem**

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“A very real concern for everyone involved in imaging, particularly in scientific and forensic fields, is the question of what constitutes proper and appropriate processing, and what constitutes unethical or even fraudulent manipulation. **The short answer is that anything that alters an image so as to create a false impression on the part of the viewer is wrong.** The problem with that answer is that it does not take into account the fact that different viewers will see different things in the image anyway, and that what constitutes a false impression for one person may not for another. The first rule is always to store a permanent copy of the original image along with relevant data on its acquisition. The second rule is to carefully document whatever steps are taken to process the image and generally to report those steps when the processed image is published.”

John C. Russ, F. Brent Neal – *The Image Processing Handbook*, 7-th ed., CRC Press, 2016

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Meet [Lena!](#)

**The First Lady of the Internet**



<https://www.g4media.ro/o-fotografie-playboy-din-1972-interzisa-de-o-comunitate-stiintifica-fotografia-cu-modelul-lena-forsen-a-devenit-standardul-jpeg-e-considerata-acum-o-imagine-sexista.html>

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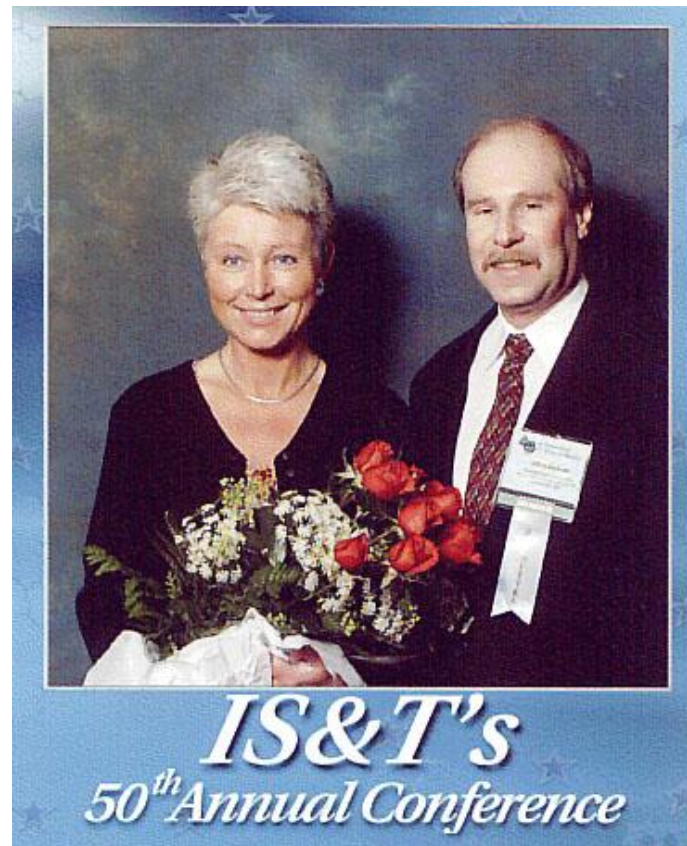
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**Lenna Soderberg (Sjööblom) and Jeff Seideman taken in May 1997**

**Imaging Science & Technology Conference**

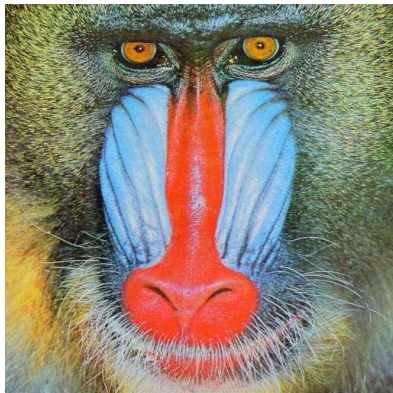


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### **What is Computer Vision?**

**image processing , image analysis , computer vision ?**

Image processing = discipline in which both the input and the output of a process are images

Computer Vision = use computer to emulate human vision (AI) – learning, making inferences and take actions based on visual inputs

Image analysis (image understanding) = segmentation, partitioning images into regions or objects  
(link between image processing and computer vision)

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Distinction between image processing , image analysis , computer vision:

low-level, mid-level, high-level processes

Low-level processes:

image preprocessing to reduce noise, contrast enhancement,  
image sharpening; both input and output are images

Mid-level processes:

- segmentation, partitioning images into regions or objects,
- description of the objects for computer processing,
- classification/recognition of individual objects;
- inputs are, generally, images, outputs are attributes extracted from the input image (e.g. edges, contours, identity of individual objects)

High-level processes:

- “making sense” of a set of recognized objects;
- performing the cognitive functions associated with vision

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According to Gonzales + Woods (Digital Image Processing)

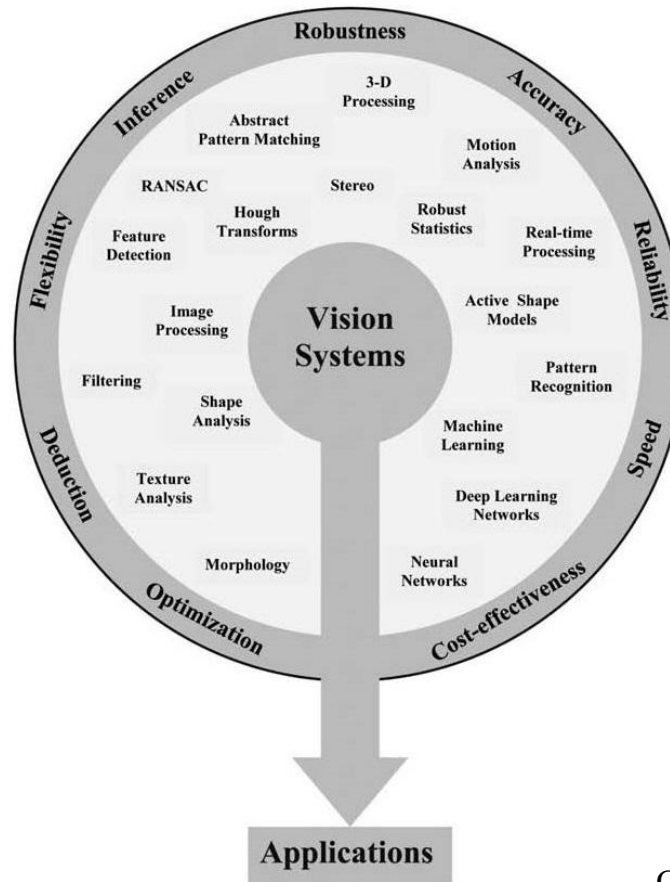
Digital Image Processing = low-level processes + mid-level processes

Computer Vision = low-level processes + mid-level processes +  
+ high-level processes

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### INFLUENCES IMPINGING UPON INTEGRATED VISION SYSTEM DESIGN



Computer Vision Principles, Algorithms, Applications, Learning (E.R. Davies)

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<https://www.ibm.com/topics/computer-vision>

**Computer vision** is a field of artificial intelligence (AI) that enables computers and systems to derive meaningful information from digital images, videos and other visual inputs — and take actions or make recommendations based on that information. If AI enables computers to think, computer vision enables them to see, observe and understand.

Computer vision works much the same as human vision, except humans have a head start. Human sight has the advantage of lifetimes of context to train how to tell objects apart, how far away they are, whether they are moving and whether there is something wrong in an image.

Computer vision trains machines to perform these functions, but it has to do it in much less time with cameras, data and algorithms rather than retinas, optic nerves and a visual cortex. Because a system trained to inspect products or watch a production asset can analyze thousands of products or processes a minute, noticing imperceptible defects or issues, it can quickly surpass human capabilities.

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### **ChatGPT**

Computer Vision is a field of **artificial intelligence (AI)** and **computer science** that focuses on enabling computers to **see, interpret, and understand visual information** from the world, much like humans do with their eyes and brain.

At its core, computer vision involves teaching machines to:

- **Acquire** images or video (via cameras, sensors, scanners).
- **Process** visual data (remove noise, enhance quality, normalize).
- **Analyze** the content (detect objects, recognize faces, classify scenes).
- **Understand** the context (e.g., "this is a cat sitting on a sofa" rather than just "pixels with certain colors").

## **Key Tasks in Computer Vision**

- **Image classification** – deciding what an image contains (cat vs. dog).
- **Object detection** – finding and locating multiple objects in an image.
- **Segmentation** – dividing an image into meaningful parts (e.g., separating a tumor from healthy tissue in a scan).
- **Face recognition** – identifying or verifying individuals by their facial features.
- **Optical character recognition (OCR)** – extracting text from images.
- **Action recognition** – understanding movements in videos (e.g., someone running, waving).

### Applications

- **Healthcare:** diagnosing diseases from X-rays, MRIs, CT scans.
- **Autonomous vehicles:** detecting pedestrians, traffic signs, and obstacles.
- **Retail & security:** surveillance, customer analytics, theft detection.
- **Agriculture:** monitoring crop health from drone images.
- **AR/VR & entertainment:** real-time gesture tracking, filters, immersive experiences.

In short, computer vision is about making **machines "see" and make sense of the visual world**, turning pixels into knowledge.

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Jason Brownlee - Deep Learning for Computer Vision - Image Classification, Object Detection, and Face Recognition in Python

### 1.3 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 problems is to use the observed image data to infer something about the world.

— Page 83, *Computer Vision: Models, Learning, and Inference*, 2012.

It is a multidisciplinary field that could broadly be called a subfield of artificial intelligence and machine learning, which may involve the use of specialized methods and make use of general learning algorithms.

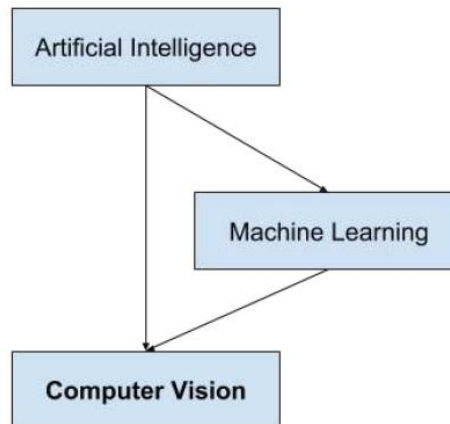


Figure 1.1: Overview of the Relationship of Artificial Intelligence and Computer Vision.

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### 1.4. Challenge of Computer Vision

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As a multidisciplinary area of study, it can look messy, with techniques borrowed and reused from a range of disparate engineering and computer science fields. One particular problem in vision may be easily addressed with a hand-crafted statistical method, whereas another may require a large and complex ensemble of generalized machine learning algorithms.

Computer vision as a field is an intellectual frontier. Like any frontier, it is exciting and disorganized, and there is often no reliable authority to appeal to. Many useful ideas have no theoretical grounding, and some theories are useless in practice; developed areas are widely scattered, and often one looks completely inaccessible from the other.

— Page xvii, *Computer Vision: A Modern Approach*, 2002.

The goal of computer vision is to understand the content of digital images. Typically, this involves developing methods that attempt to reproduce the capability of human vision. Understanding the content of digital images may involve extracting a description from the image, which may be an object, a text description, a three-dimensional model, and so on.

Computer vision is the automated extraction of information from images. Information can mean anything from 3D models, camera position, object detection and recognition to grouping and searching image content.

— Page ix, *Programming Computer Vision with Python*, 2012.

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What is a Digital Image?

$$f : D \rightarrow \mathbb{R} / \mathbb{R}^{3/4}$$

$f(x,y)$  = intensity, gray level, color of the image at spatial point  $(x,y)$

$x, y, f(x,y)$  – finite, discrete quantities  $\rightarrow$  digital image

Digital Image Processing = processing digital images by means of a digital computer

A digital image is composed of a finite number of elements (location, value of intensity):

$$(x_i, y_j, f_{ij})$$

These elements are called *picture elements*, *image elements*, *pels*, *pixels*

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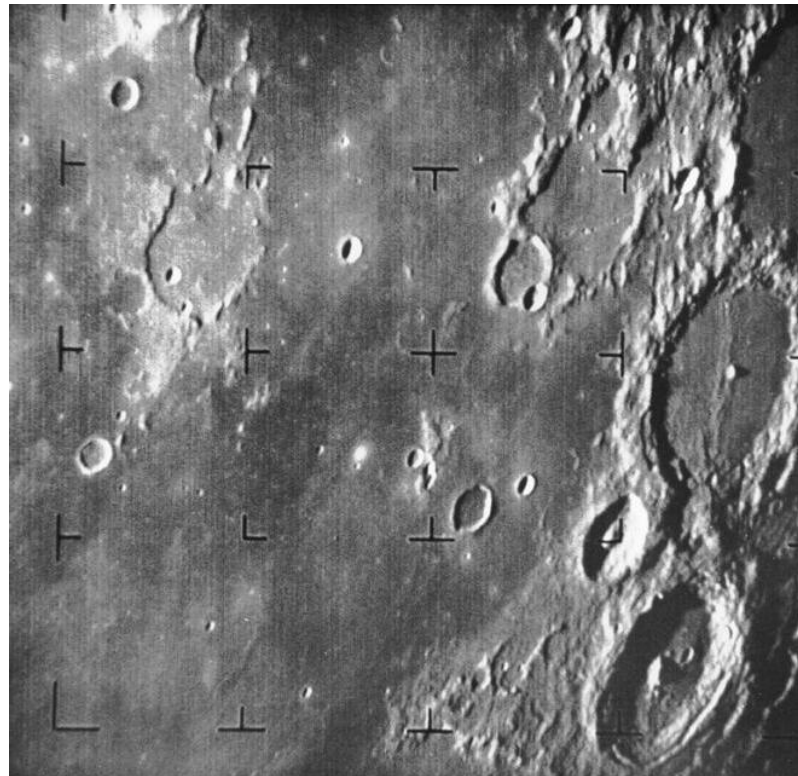
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### The Beginning

1964, Jet Propulsion Laboratory (Pasadena, California) processed pictures of the moon transmitted by Ranger 7 (corrected image distortions)



The first picture of the moon by a U.S. spacecraft. *Ranger 7* took this image July 31, 1964, about 17 minutes before impacting the lunar surface.  
(Courtesy of NASA)

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1960-1970 – image processing techniques were used on medical images,  
remote Earth resources observations, astronomy

1970s – invention of CAT (computerized axial tomography)

CAT is a process in which a ring of detectors encircles an object (patient), and an X-ray source, concentric with the detector ring, rotates about the object.

The X-ray passes through the patient and the resulted waves are collected at the opposite end by the detectors. As the source rotates the procedure is repeated.

Tomography consists of algorithms that use the sense data to construct an image that represents a “slice” through the object. Motion of the object in a direction perpendicular to the ring of detectors produces a set of “slices” which can be assembled in a 3D information of the inside of the object.

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- ◇ geographers use CV to study pollution patterns from aerial and satellite imagery
- ◇ archeology – DIP+CV allowed restoring blurred pictures that recorded rare artifacts  
lost or damaged after being photographed
- ◇ physics – enhance images of experiments (high-energy plasmas, electron microscopy)
- ◇ astronomy, biology, nuclear medicine, law enforcement, industry
- ◇ automatic character recognition, industrial machine vision for product assembly  
and inspection, military recognizance, automatic processing of fingerprints,  
automatic processing of aerial and satellite imagery for weather prediction, Internet

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### *Examples of CV Applications*

Images can be classified according to the energy sources that reveals the scene (visual, X-ray, ...)

Energy sources for images:

electromagnetic energy spectrum,

acoustic,

ultrasonic,

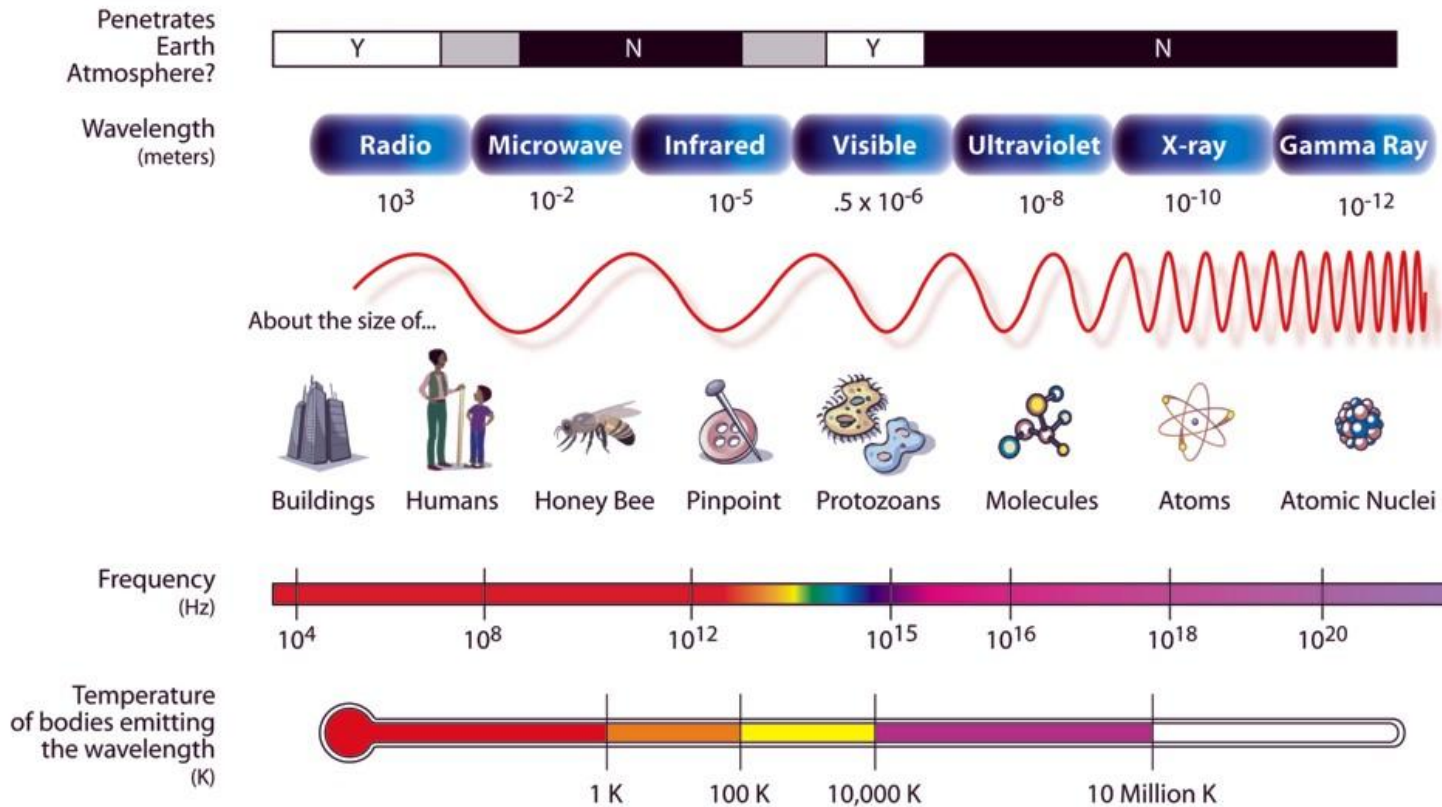
electronic,

computer-generated

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### THE ELECTROMAGNETIC SPECTRUM



## **Gamma-Ray Imaging**

Nuclear medicine, astronomical observations

Nuclear medicine

The approach is to inject a patient with a radioactive isotope that emits gamma rays as it decays. Images are produced from the emissions collected by gamma-ray detectors.

Images of this sort are used to locate sites of bone pathology (infections, tumors)

PET (positron emission tomography) – the patient is given a radioactive isotope that emits positrons as it decays

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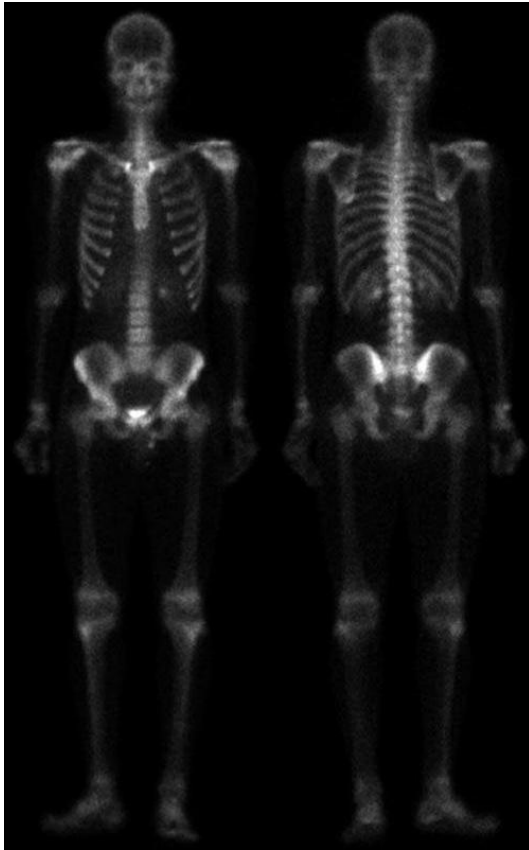
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### **Examples of gamma-ray imaging**

Bone scan



PET image



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### **X-ray imaging**

Medical diagnostic, industry, astronomy

An X-ray tube is a vacuum tube with a cathode and an anode. The cathode is heated, causing free electrons to be released. The electrons flow at high speed to the positively charged anode. When the electrons strike a nucleus, energy is released in the form of an X-ray radiation. The energy (penetrating power) of the X-rays is controlled by a voltage applied across the anode, and by a current applied to the filament in the cathode. The intensity of the X-rays is modified by absorption as they pass through the patient and the resulting energy falling develops it much in the same way that light develops photographic film.

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Angiography = contrast-enhancement radiography

Angiograms = images of blood vessels

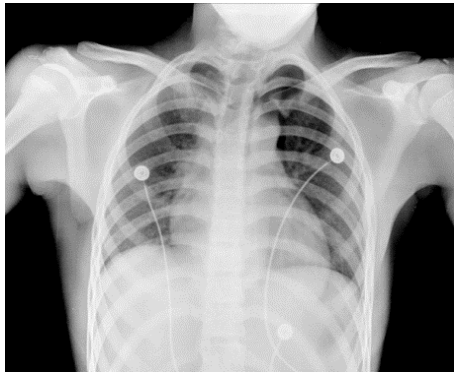
A catheter is inserted into an artery or vein in the groin. The catheter is threaded into the blood vessel and guided to the area to be studied. When it reaches the area to be studied, an X-ray contrast medium is injected through the catheter. This enhances contrast of the blood vessels and enables radiologist to see any irregularities or blockages.

X-rays are used in CAT (computerized axial tomography)

X-rays used in industrial processes (examine circuit boards for flaws in manufacturing)

Industrial CAT scans are useful when the parts can be penetrated by X-rays

**Examples of X-ray images**



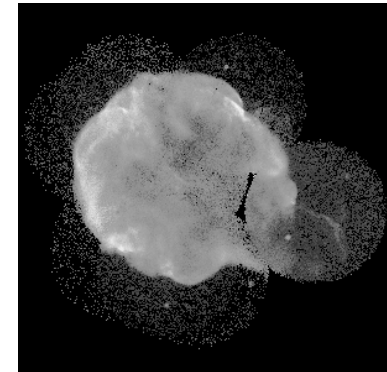
Chest X-ray



Aortic angiogram



Head CT



Cygnus Loop

**Imaging in the Ultraviolet Band**

→ industrial inspection, microscopy, biological imaging, astronomical observations

Ultraviolet light is used in fluorescence microscopy. Ultraviolet light is not visible to human eye but when a photon of ultraviolet radiation collides with an electron in an atom of a fluorescent material it elevates the electron to a higher energy level. After that the electron relaxes to a lower level and emits light in the form of a lower-energy photon in the visible (red) light region.

Fluorescence = emission of light by a substance that has absorbed light or other electromagnetic radiation of a different wavelength

Fluorescence microscope = uses an excitation light to irradiate a prepared specimen and then it separates the much weaker radiating fluorescent light from the brighter excitation light.

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### **Imaging in the Visible and Infrared Bands**

→ Light microscopy, astronomy, remote sensing, industry, law enforcement

LANDSAT satellite – obtained and transmitted images of the Earth from space

for purpose of monitoring environmental conditions on the planet

Weather observations and prediction produce major applications of multispectral image from satellites

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<b>Band No.</b>	<b>Name</b>	<b>Wavelength (<math>\mu\text{m}</math>)</b>	<b>Characteristics and Uses</b>
1	Visible blue	0.45–0.52	Maximum water penetration
2	Visible green	0.52–0.60	Good for measuring plant vigor
3	Visible red	0.63–0.69	Vegetation discrimination
4	Near infrared	0.76–0.90	Biomass and shoreline mapping
5	Middle infrared	1.55–1.75	Moisture content of soil and vegetation
6	Thermal infrared	10.4–12.5	Soil moisture; thermal mapping
7	Middle infrared	2.08–2.35	Mineral mapping

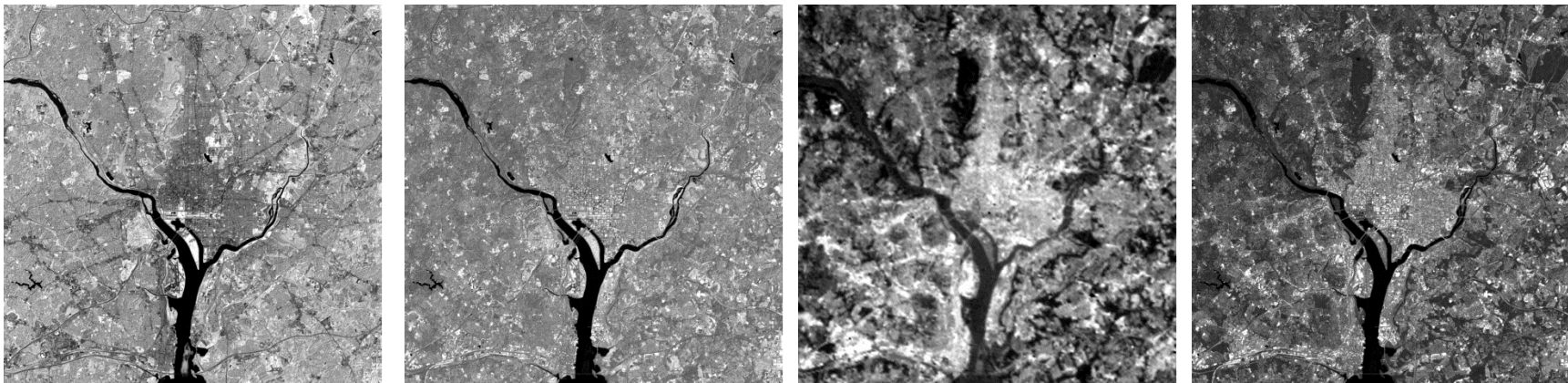
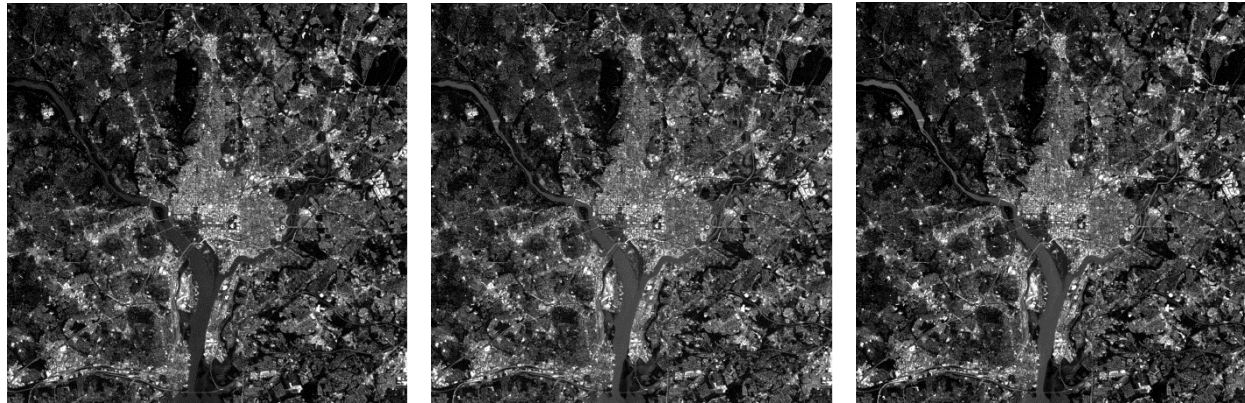
Thematic bands in NASA's LANDSAT satellite

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Satellite images of Washington D.C. area in spectral bands of the above table

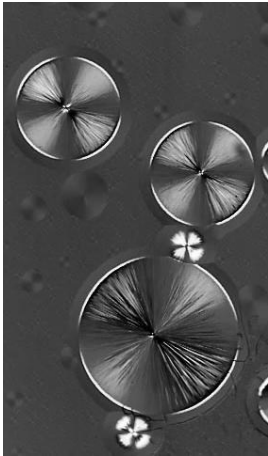
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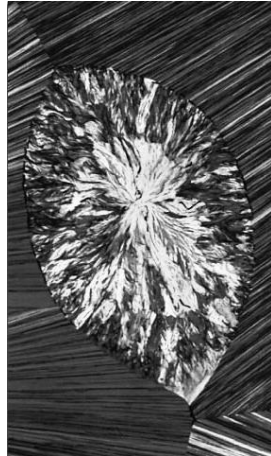
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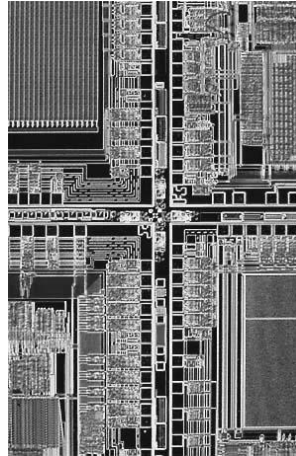
### Examples of light microscopy images



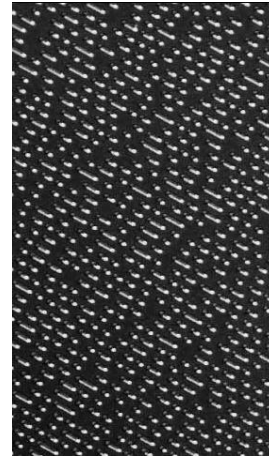
Taxol  
(anticancer agent)  
magnified 250X



Cholesterol  
(40X)



Microprocessor  
(60X)



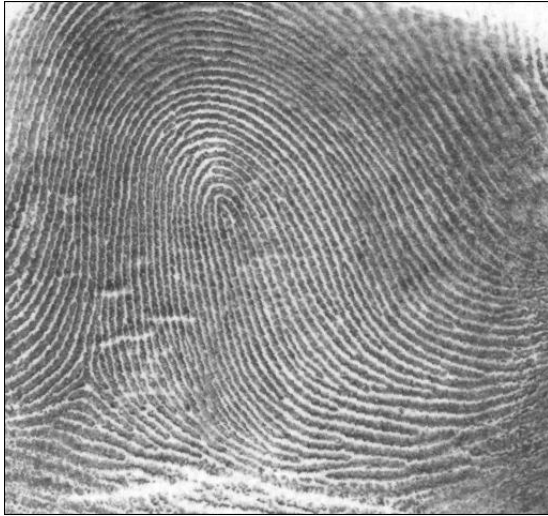
Surface of  
audio CD  
(1750X)



Organic  
superconductor  
(450X)

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### **Imaging in the Microwave Band**

The dominant application of imaging in the microwave band – radar

- radar has the ability to collect data over virtually any region at any time, regardless of weather or ambient light conditions
- some radar waves can penetrate clouds, under certain conditions can penetrate vegetation, ice, dry sand
- sometimes radar is the only way to explore inaccessible regions of the Earth's surface

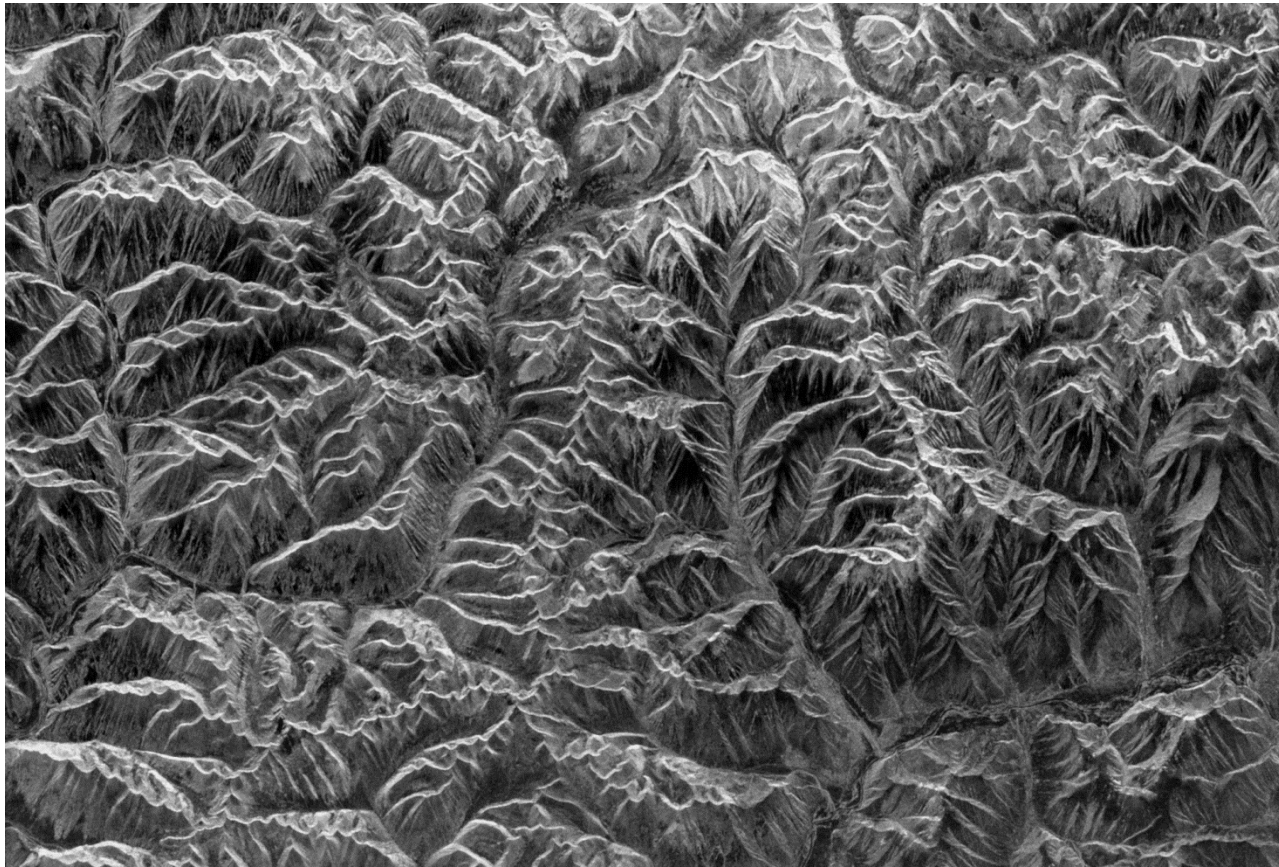
An imaging radar works like a flash camera: it provides its own illumination (microwave pulses) to light an area on the ground and take a snapshot image. Instead of a camera lens, a radar uses an antenna and a digital device to record the images. In a radar image one can see only the microwave energy that was reflected back toward the radar antenna.

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Spaceborne radar image of mountains in southeast Tibet

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### **Imaging in the Radio Band**

→ medicine, astronomy

**MRI = Magnetic Resonance Imaging**

This technique places the patient in a powerful magnet and passes short pulses of radio waves through his or her body. Each pulse causes a responding pulse of radio waves to be emitted by the patient tissues.

The location from which these signals originate and their strength are determined by a computer, which produces a 2D picture of a section of the patient.

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MRI images of a human knee (left) and spine (right)

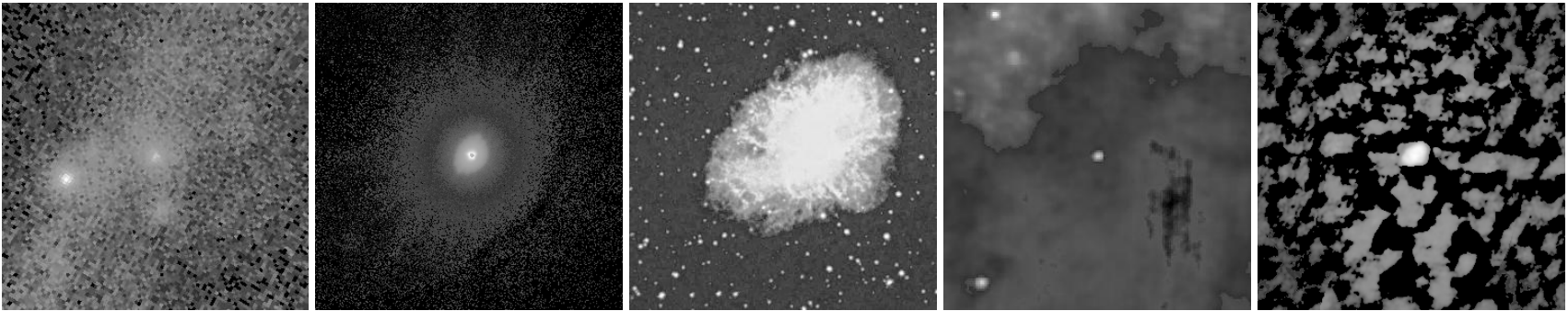
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Images of the Crab Pulsar covering the electromagnetic spectrum



Gamma

X-ray

Optical

Infrared

Radio

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### **Other Imaging Modalities**

→ acoustic imaging, electron microscopy, synthetic (computer-generated) imaging

Imaging using sound → geological explorations, industry, medicine,  
mineral and oil exploration

For image acquisition over land one of the main approaches is to use a large truck a large flat steel plate. The plate is pressed on the ground by the truck and the truck is vibrated through a frequency spectrum up to 100 Hz. The strength and the speed of the returning sound waves are determined by the composition of the Earth below the surface. These are analyzed by a computer and images are generated from the resulting analysis.

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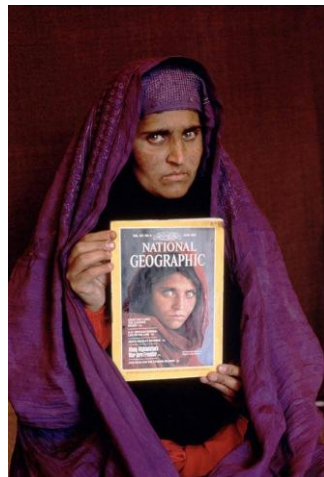
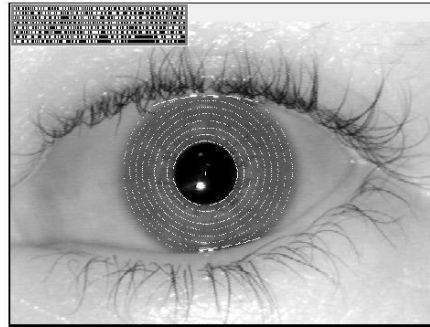
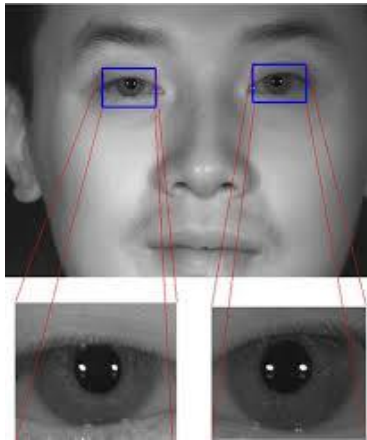
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### Biometry – iris



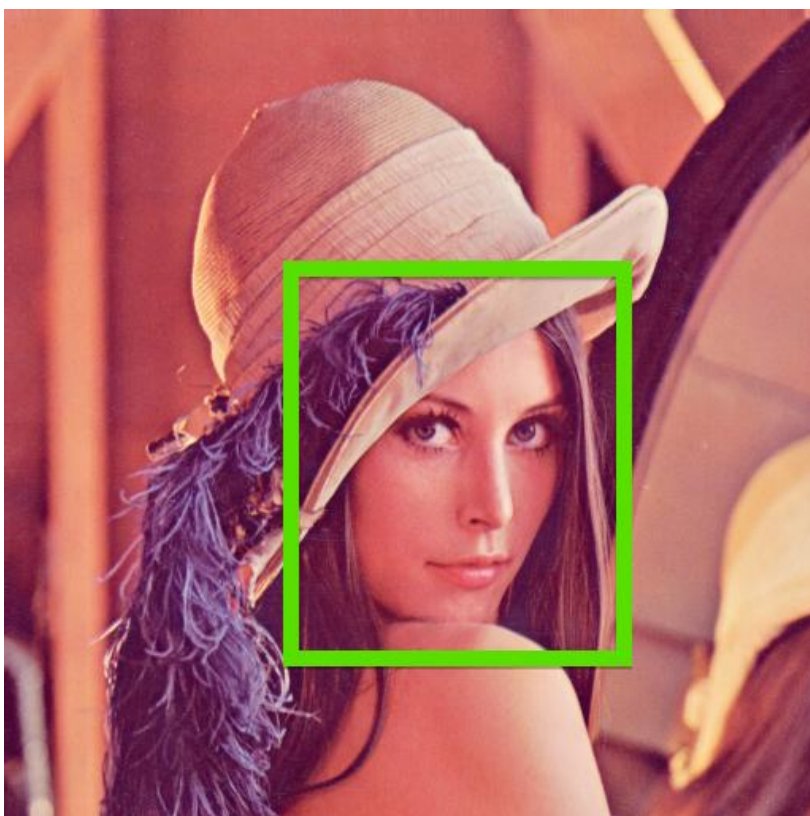
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### **Face detection and recognition**



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### **Gender identification**



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### **Palmprint authentication**



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### Object detection/tracking



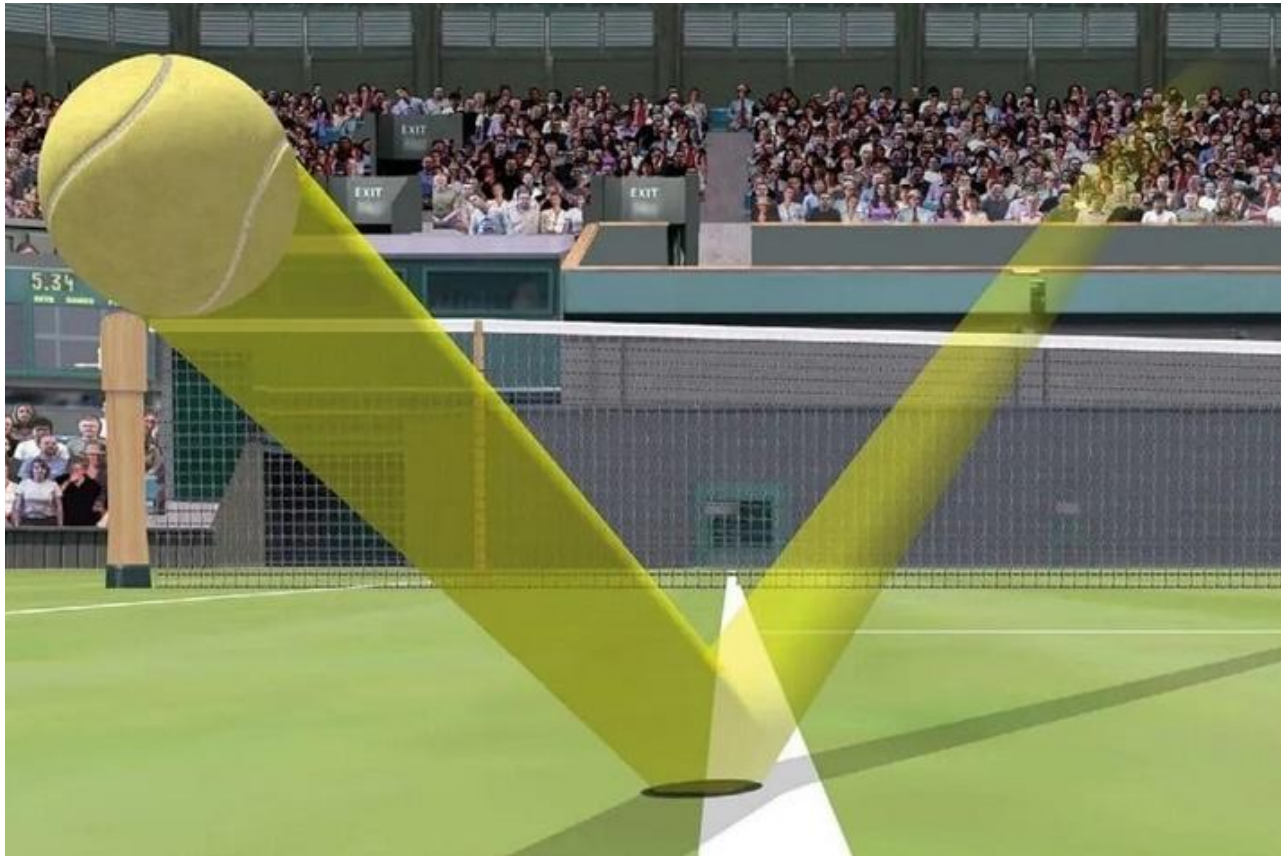
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### **Hawk-Eye Systems**



# Deepfake

<https://youtu.be/oxXpB9pSETo?si=JIJcG8IXccZq615X>

<https://youtu.be/iyiOVUbsPcM?si=Uj9WM200GT-VX1Lu>