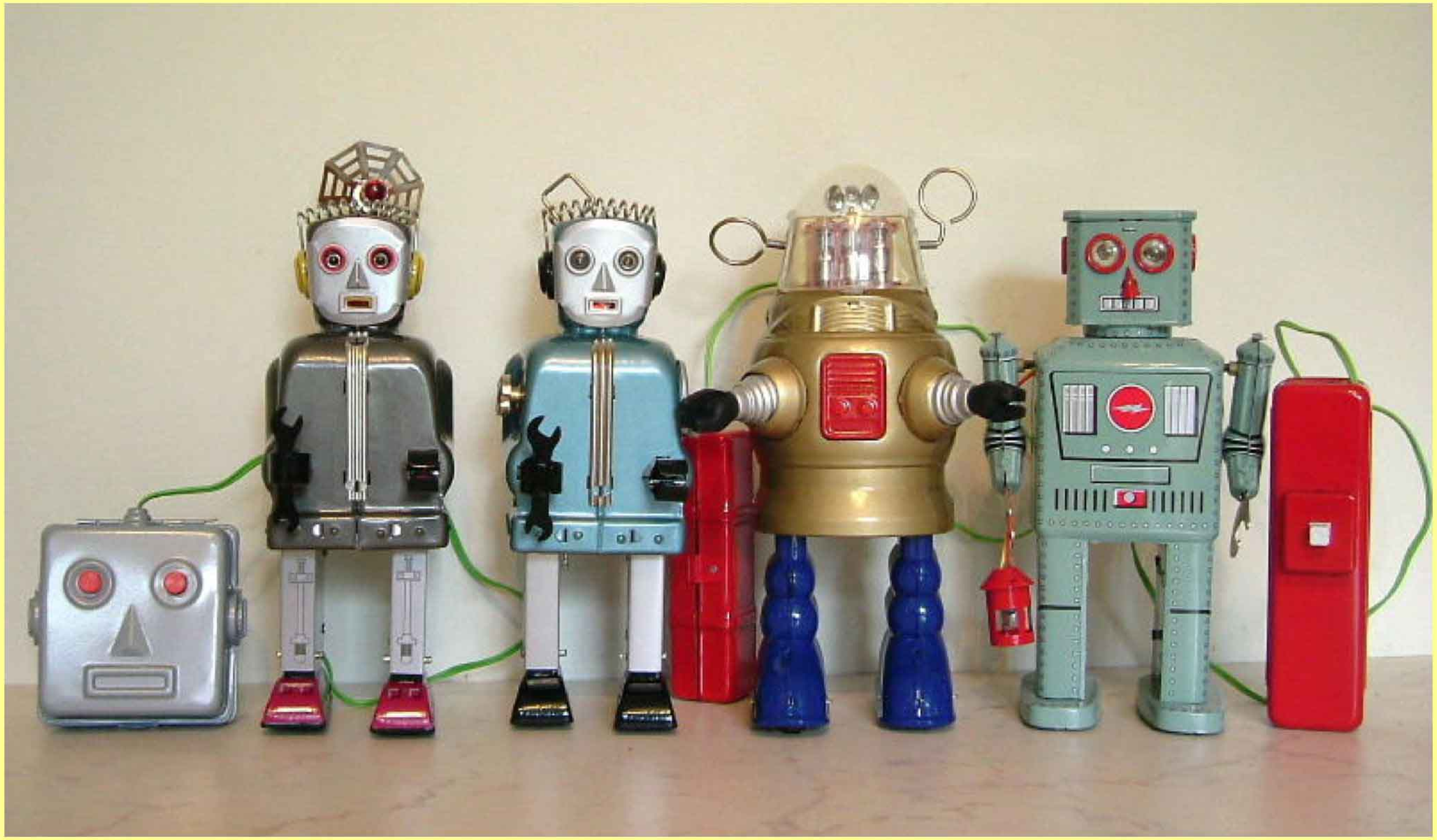
Robot vision



Will Ayliffe

Gresham College

April 2014

The *Relational Machine*

Alfred Smee (1818-1877) surgeon to Central London Ophthalmic Hospital, FRS

Electro-biology, functions of brain related to electrical stimulation *instinct* and *reason* could be *deduced* from electrobiology!

1851, ***Process of Thought Adapted to Words and Language***. Artificial system of reasoning based upon natural principles.

Each idea determined by the presence or absence of certain properties (redness, roundness, etc.)

Each property represented in the brain by electrical stimulation of a nerve fiber.

An idea is sum of electrically stimulated nerve fibers.

Smee's *Relational Machine* (represented the relationship between the various properties, comprising an idea)

Intended to represent one thought, idea, or mental image at a time; to model human thought.

Based on George Boole's Logic:

Flaps of sheet metal, divided into halves by hinges.

Half pieces represent **presence of a property**

Half **the absence:** folded out of sight until all that remained was a piece of metal representing the collection of properties that formed the idea.

Another machine to compare ideas. ***Differential Machine***

"I apprehend that the time is fast approaching, when no other system of mental science will be acknowledged but that which is based upon physical laws and the structure of the brain".

Process of Thought*..."when the vast extent of a machine sufficiently large to include all words and sequences is considered, absolute impossibility of forming one as it would cover an area exceeding probably all London*

Boole:1814-64: no general method for the solution of questions in the theory of probabilities can be established which does not explicitly recognise ... those universal laws of thought which are the basis of all reasoning

Coining of word robot

Karel Capek. Czech dramatist

1920 Play **"R.U.R"** (Rossum's Universal Robots)

ROBOT is used for the first time

displaced older words such as "automaton" or "android”

Intelligent biological machines meant to serve their human makers.

Czech, "robota” forced and slavish work.

Derived from *rab,* meaning "slave.”

Rossum is an allusion to the Czech word *rozum,* meaning "reason, wisdom”

Robots take over the world and destroy humanity.

He distinguishes the robot from man by the absence of emotion

doughboy will have become the "iron boy."

Between the wars, American newspapers reported how robots would battle in wars of the future.

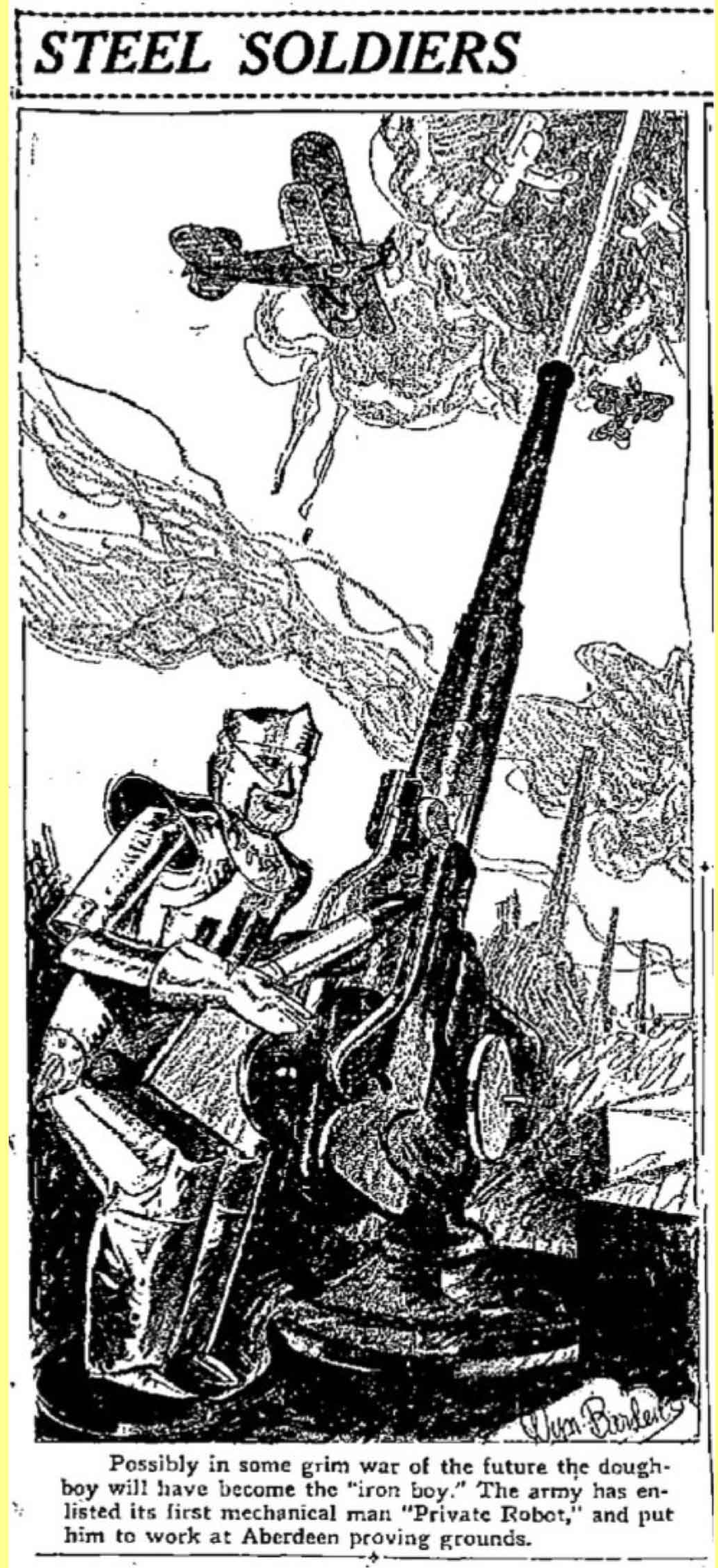
Ambition robots would fight in the place of humans.

only your side wouldn't see casualties

Others predicted wars would be decided by whichever nation's robots could conquer those of another; no human casualties.

December 25, 1926 ***San Antonio Light*** illustration of mechanical man

RUR on its front.



STEEL SOLDIERS

Possibly in some grim war of the future the dough-boy will have become the "iron boy." The army has enlisted its first mechanical man "Private Robot," and put him to work at Aberdeen proving grounds.

Maschinenmensch

1927: **Thea Gabriele von Harbou** 1888–1954) actress, author & film director. Husband **Fritz Lang**

Metropolis: Set in a futuristic urban dystopia,

Wealthy industrialists rule the vast city of Metropolis from high-rise tower complexes

Lower class of underground-dwelling workers operate the machines that provide its power

Freder, son of ruler, falls in love with worker **Maria**.

For revenge the inventor Rotwang gives a robot the likeness of Maria who creates havok.

Mob capture robot Maria burned at stake; Freder watches, horrified until covering melts revealing robot underneath.

Use of art deco architecture was highly influential

5m Reichsmarks most expensive film-date

Unknown actors, tough regime by Lang

Brigitte Helm played robot form and human incarnation.

the first robot ever depicted in cinema

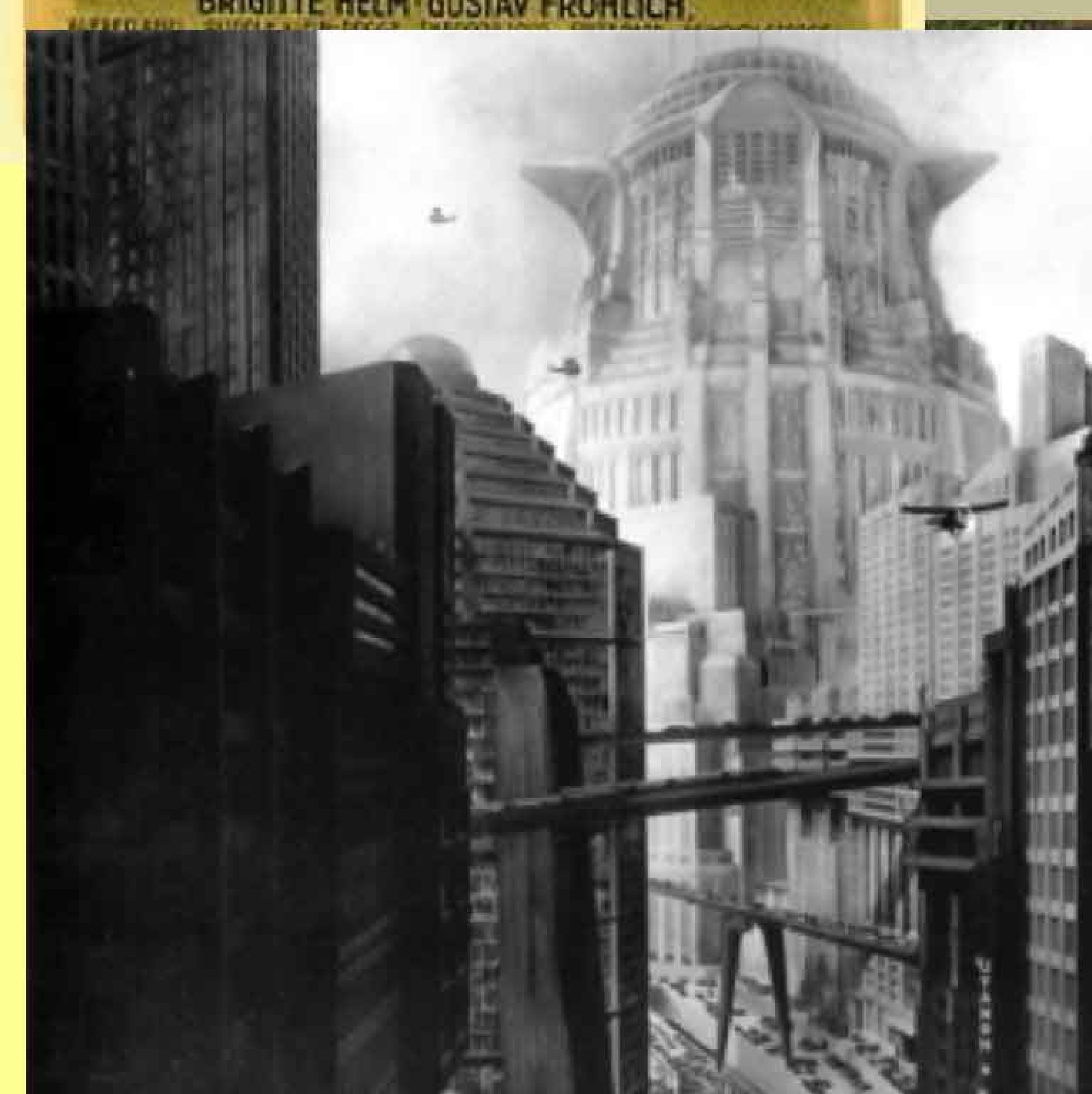
Times review of cut version by H. G. Wells

"foolishness, cliché, platitude, and muddlement about mechanical progress and progress in general.”

Automation created drudgery rather than relieving it, wondered who was buying the machines' output if not the workers, parts of the story derivative of Shelley's *Frankenstein* Karel Čapek's robot stories, and his own *The Sleeper Awakes*

"quite the silliest film."

"Maria" from "Metropolis" movie. Statue in Babelsberg



Alpha

1932: "**Roboter"**: Mullard Valve Company stand at the London Radio Exhibition at Olympia; Holding two of company's thermionic valves, forerunner of transistors

Later modified and called **Alpha**

1 ton smoked a pack of cigs a day; to keep her weight down."

1932 American newspapers exaggerated stories about British robot that allegedly blinked to life, stood up, and **shot his inventor.** Quoting Harry May, that he knew Alpha would turn against him one day.

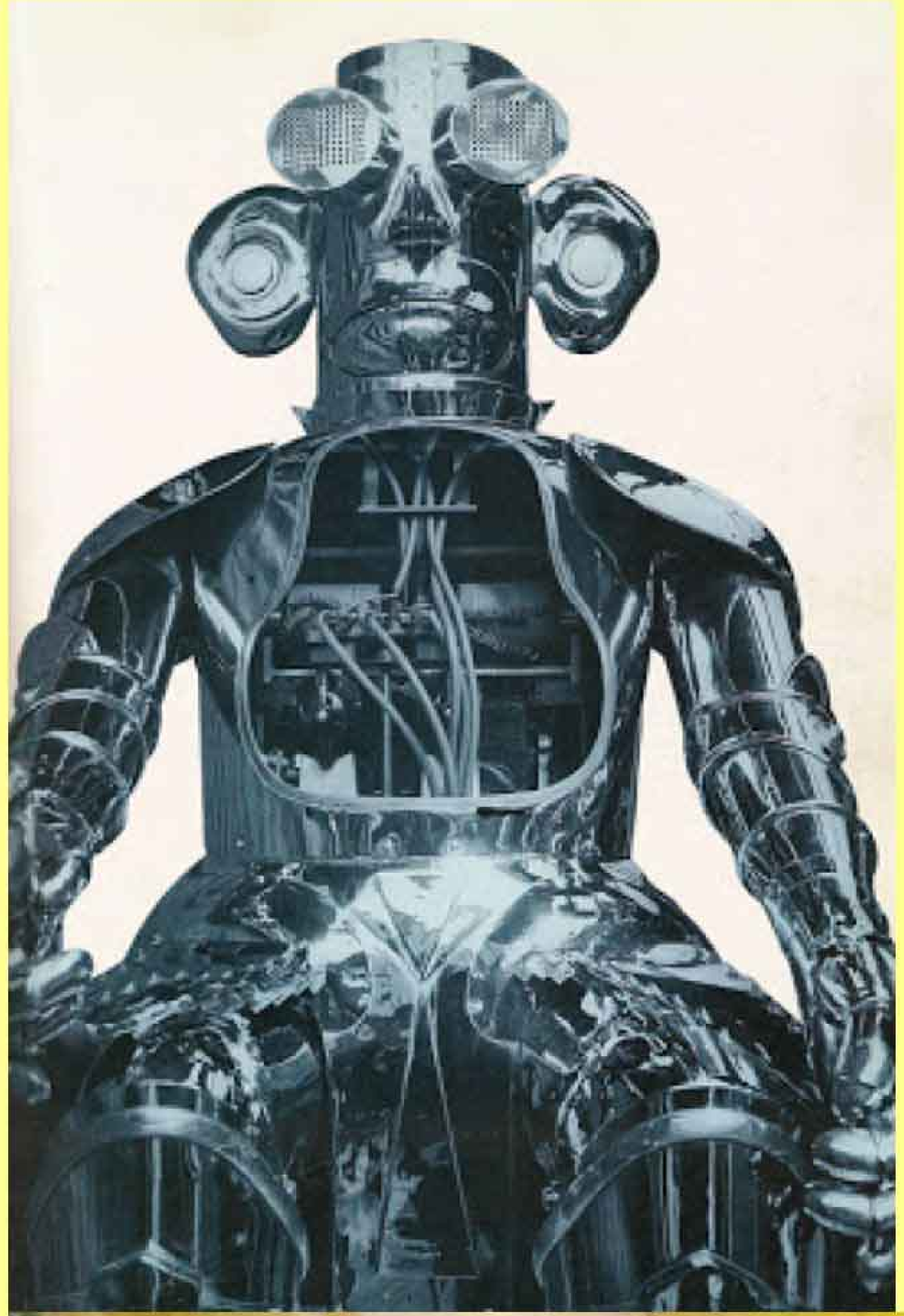
November 5, 1934 Time magazine demonstration at Macy's

One of the most ingenious automatons ever contrived by man, a grim and gleaming monster 6 ft. 4 in. tall, the robot was brought to Manhattan by its owner-inventor-impresario, Professor Harry May of London. Encased from head to foot in chromium-plated steel armor, Alpha sat with its cumbrous feet securely bolted to the floor. The creature had a great sullen slit of a mouth, vast protuberant eyes, shaggy curls of rolled metal. In one mailed fist Alpha clutched a revolver.

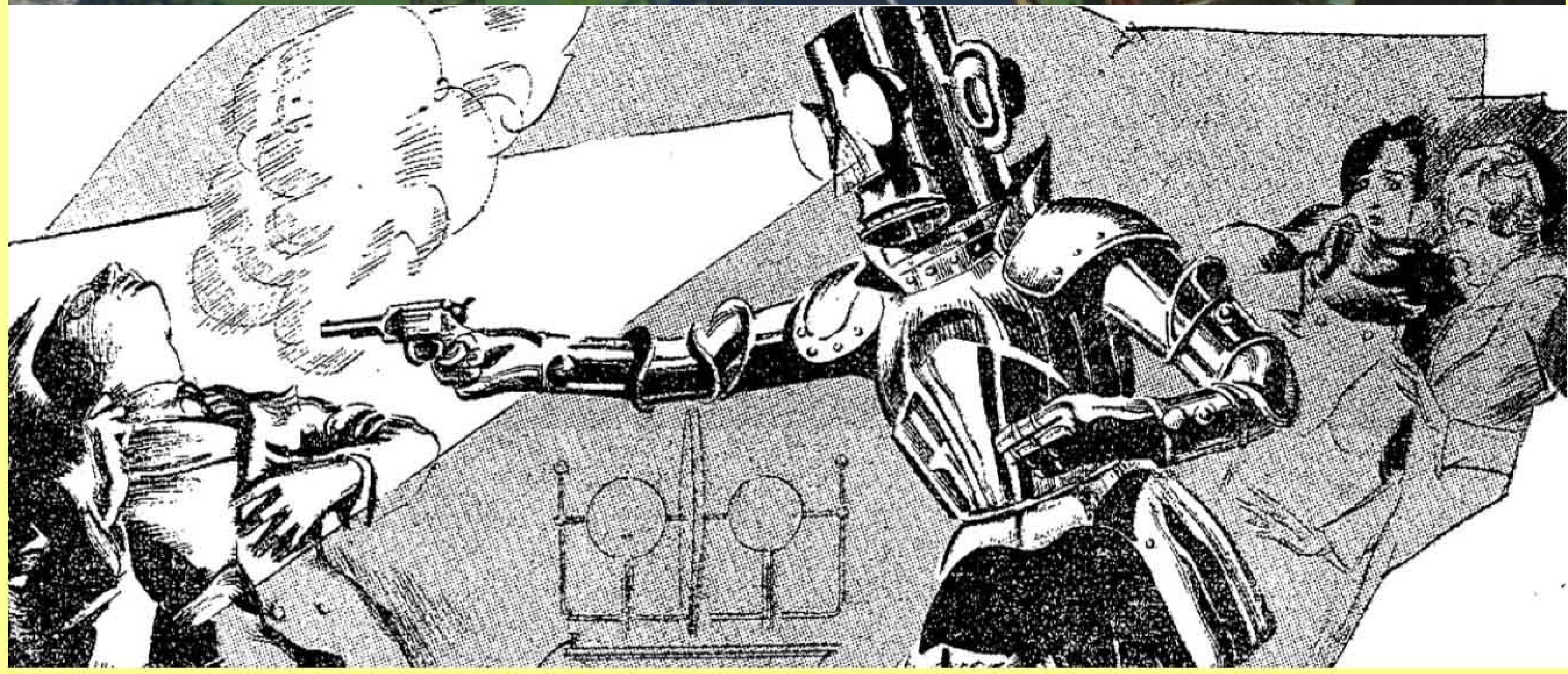
2 electric motors one for each arm, and above them two large coils probably the electromagnetic clutches to prevent the arms crashing down when the motors were turned off after upward travel. Wax cylinder?

Alpha was bugged: Pathe film: responds to normal, rather than carefully intoned speech,

Used off stage assistant to switch the motors on and off and to answer into a microphone.



Exhibited 1935 San Diego Fair Palace of Science Guidebook: Harry May, could make the 6 ft. 2 in., 2,000 pound mechanical man roll its eyes, open and close its mouth, shake its head, sit down, stand up, move its arms, fire a revolver, and answer questions with amazing precision.



Elektro

Teleoperated robots: cable-controlled by humans.

Westinghouse Electric Corporation

1939: **Elektro**: New York World's Fair.

Series of record players, photo voltaic cells, motors and telephone relays

Performed 26 routines; responded to commands spoken into a microphone. each word set up vibrations which were converted into electrical impulses; which in turn operated the relays controlling eleven motors

Fingers, arms and turntable for talking operated by nine motors and another small motor worked the bellows so the giant could smoke. The eleventh motor drove the four rubber rollers under each foot, enabling him to walk

Vocabulary of 700 words. Sentences were formulated by a series of 78 RPM record players connected to relay switches.

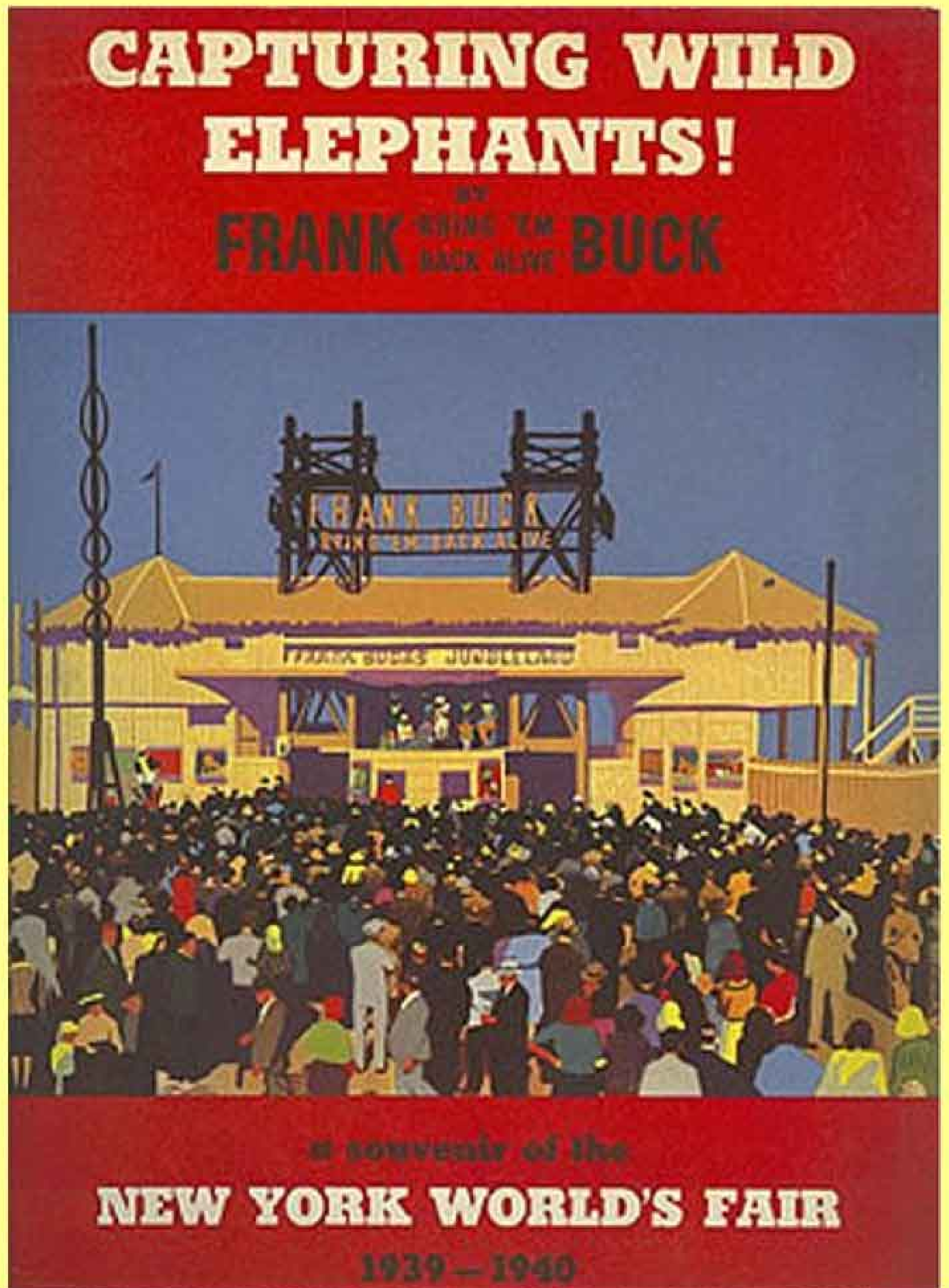
The chest cavity lit up as it recognized each word.

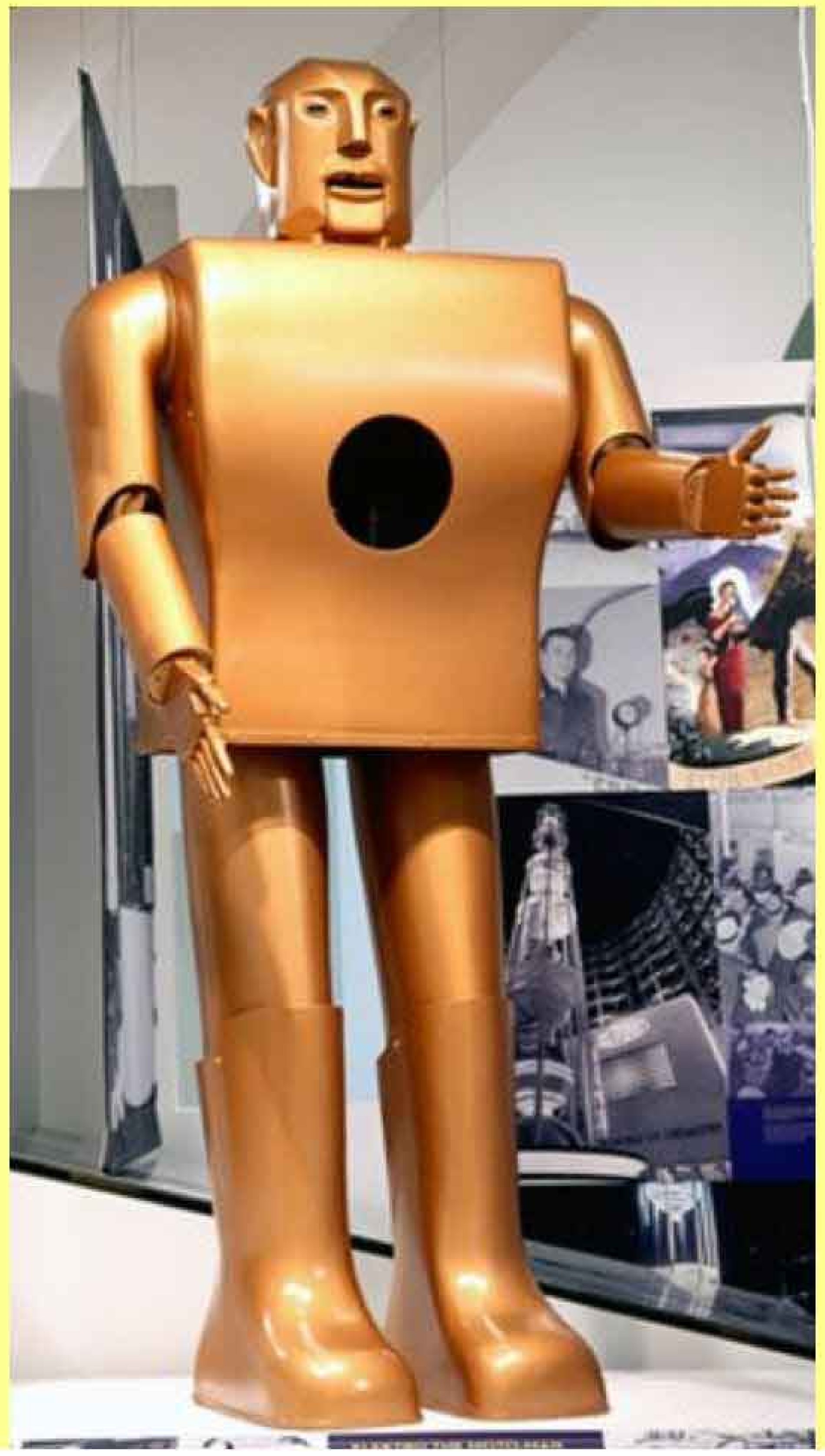
Movie "sex kittens go to Hollywood"

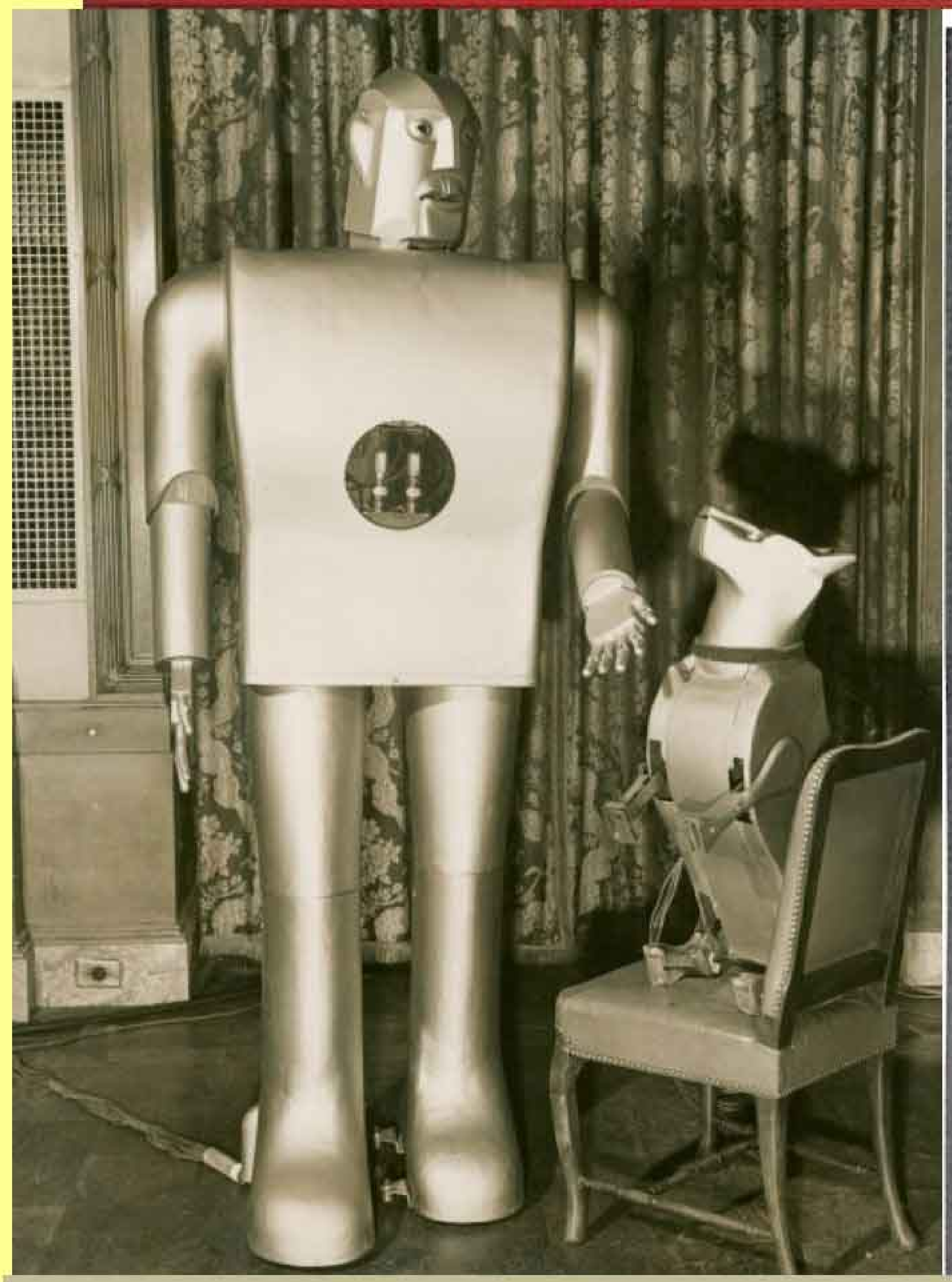
1940: **Sparko** robot dog bark, sit and beg.

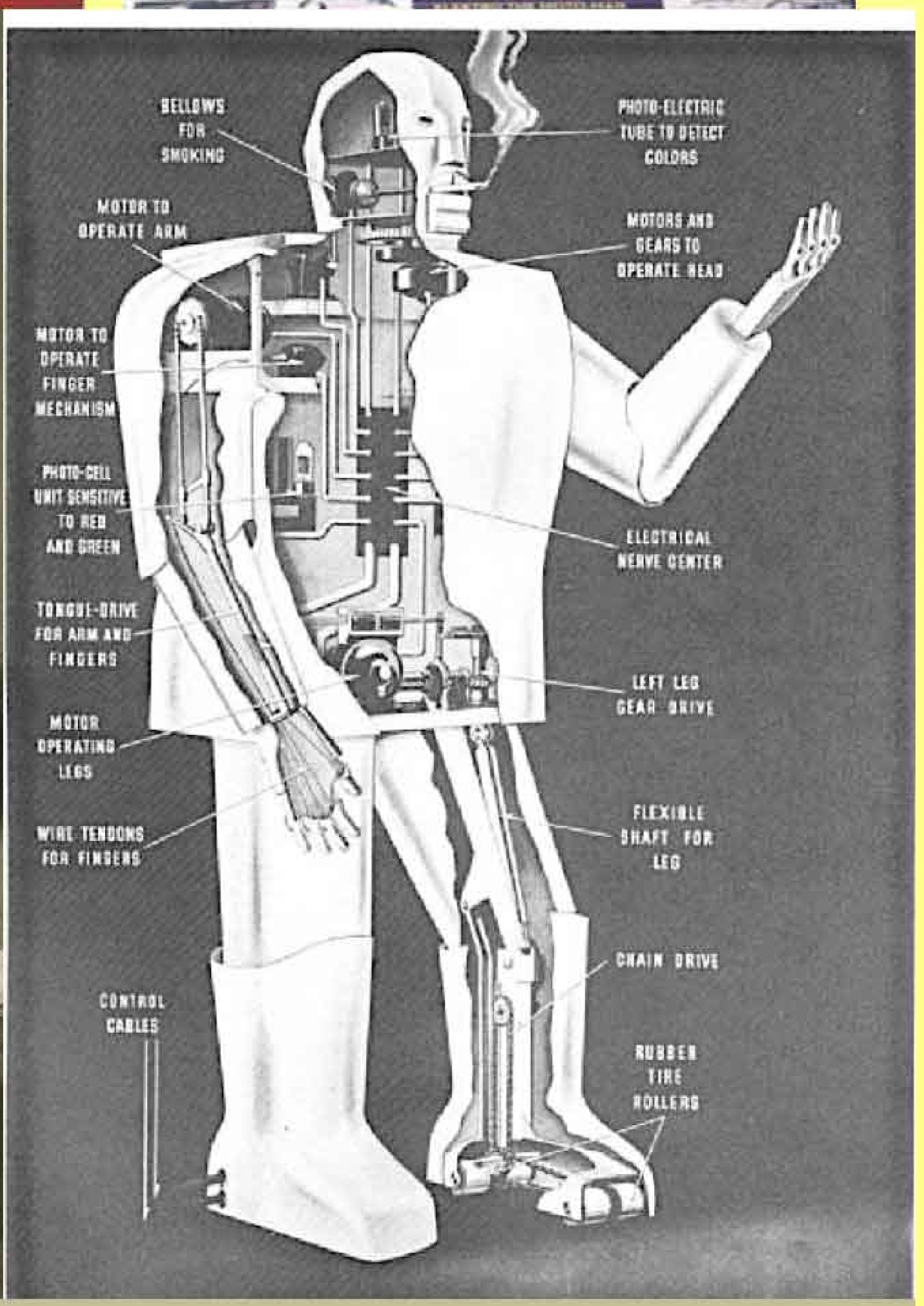
Would walk toward bright light.

Wandered out of the Westinghouse pavilion and was run over when he tried to catch a car's headlamps.









Two-word commands started an action. One-word commands stopped it. Four words returned all relays to their normal positions.

Remote control

1877. **Brennan torpedo:** Powered by two contra-rotating propellers spun by pulling out wires connected to shore station, from drums inside the torpedo.

Differential speed on the wires guided torpedo to its target, up to 2,000 yards away, at 27 knots.

Standard harbour defense throughout Empire for decades.

Nicola Tesla 1856-1943

discovered remote control

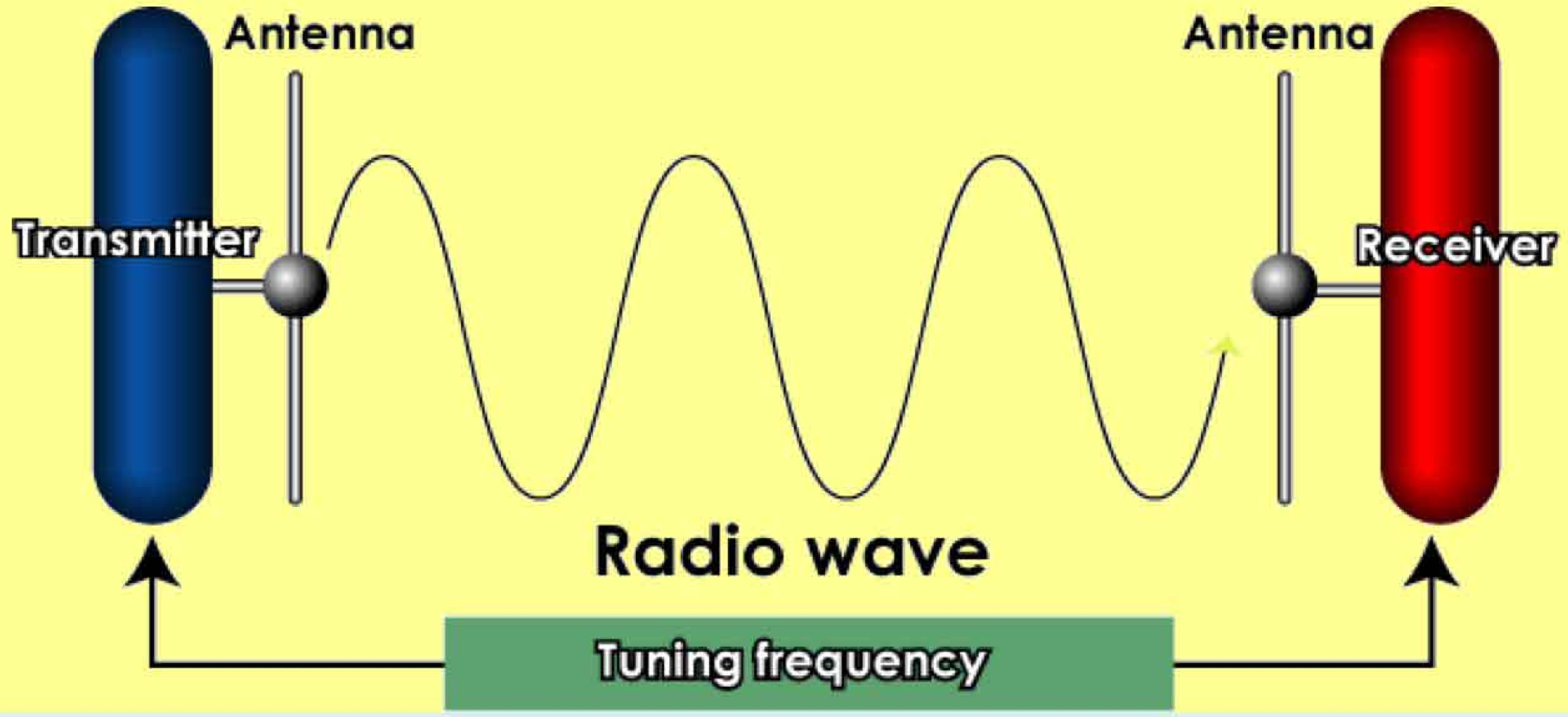
Nov 8, 1898 (Patent #: 613.809).

Used radio waves to move a robot-boat in a small pool of water in Madison Square Garden, New York City during the Electrical Exhibition in 1898.

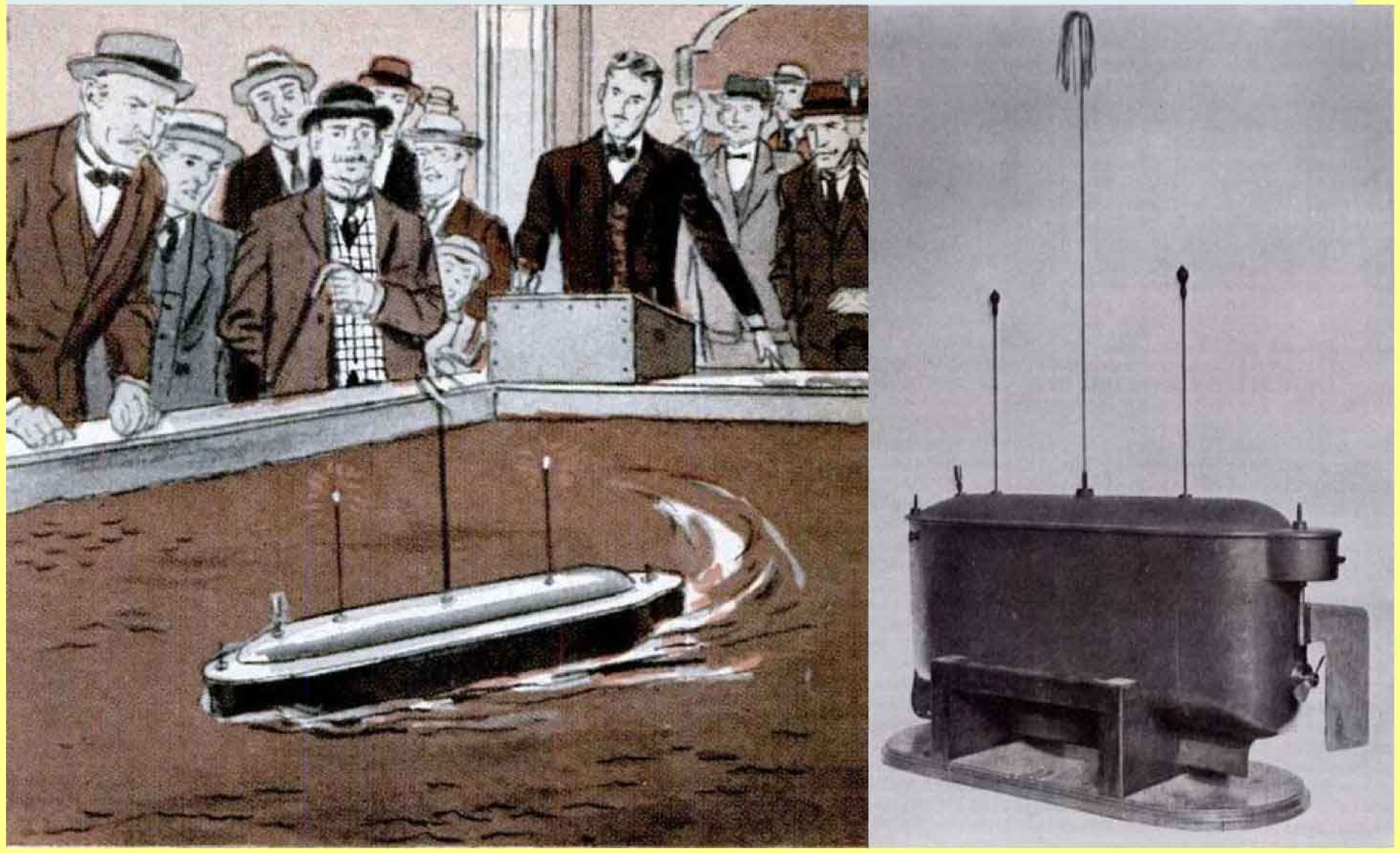
First time a machine not wired to controller.

“Wireless” control

Cliffe Fort: Kent



Nikola Tesla demonstrating wireless transmission of power and high frequency energy. After continued research, Tesla presented the fundamentals of radio in 1893



First industrial robot

(Int Stds Org) *automatically controlled, reprogrammable, multipurpose manipulator programmable in three or more axes*.

1938: **"Bill" Griffith Taylor** Meccano Magazine

Crane-like device built with Meccano powered by a single electric motor.

Five axes of movement were possible, including Grab and Grab Rotation.

Automation

punched paper tape energised solenoids,

moving control levers.

stack wooden blocks in pre-programmed patterns.

The number of motor revolutions required for each desired movement was first plotted on graph paper. This information was then transferred to the paper tape,

1961: George Devol: UNIMATE

First industrial robot, worked at General Motors

Its arm moved hot pieces of die-cast metal

Programmed on a set of step-by-step instructions stored on a magnetic drum

Welding these parts on auto bodies, a dangerous task

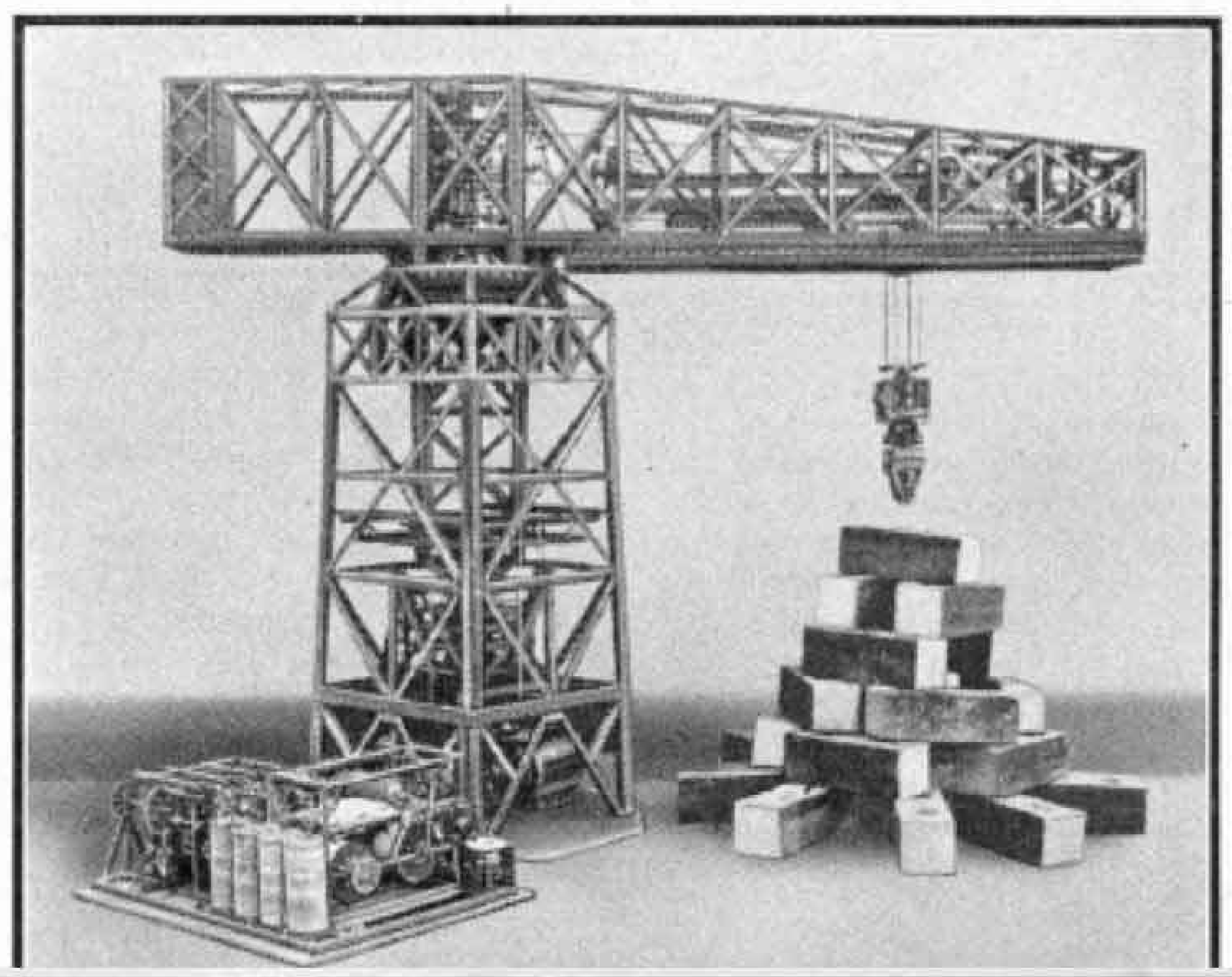
An Automatic Block-Setting Crane

Meccano Model Controlled by a Robot Unit

THE model illustrated on this page is a blocksetting crane of splendid design, but unlike other examples of this popular type it actually builds walls, simple dams or breakwaters automatically. Without any aid from its designer, it lifts up miniature blocks from piles arranged near it and places each in position with such uncanny certainty that anyone watching it at work might almost think it capable of thinking.

The builder of this astonishing model is Mr. Griffith P. Taylor, Toronto, who appears to have had a Wellsian vision of "Things To Come" in a world in which human labour will not be necessary for building up the creations of engineers and architects. He has named his model "Robot Gargantua." Its "brain centre," as it may be called, is the unit shown on the left in the illustration. This controls every movement and carries out each in its turn.

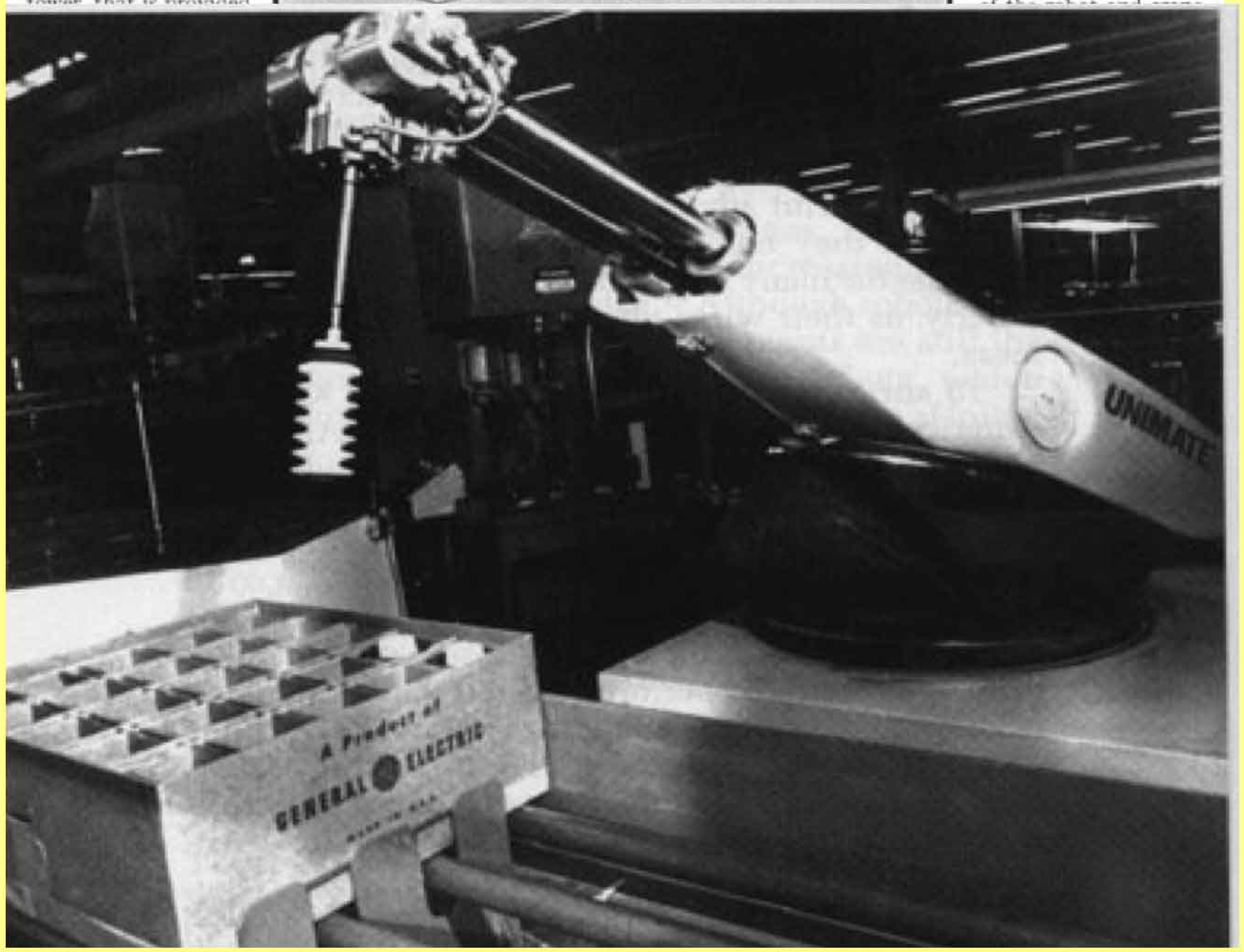
Although the chief interest lies in the robot mechanism, the crane itself incorporates many ingenious and novel constructional features. For example, the boom swivels on a vertical pillar, inside the main



with holes set out on a pre-arranged system. The roll resembles on a miniature scale those used for operating player pianos. It is drawn slowly over a brass drum and there passes under a row of spring brushes, which are connected in separate electric circuits and press lightly on the paper. When a hole passes beneath one of the brushes, this makes contact with the drum, and so completes the electric circuit through it. This current operates a solenoid that is used to move one of the control levers of the crane by means of a special differential drive operated by the crane motor.

A revolution counter gives the number of revolutions of the shaft of the robot and also of that driving the crane. The counter is used in preparing the paper roll, which is done in the robot itself.

The method by which the exact positions of the holes is determined is very complicated, but an outline of the process will make it clear. A simple structure is first designed and a plan drawing made, after which the layout of blocks from which the structure is to be built is considered. The number of revolutions



Remote control
Where is the robot's hand

Diagram of robot arm in the X-Y plane.

3 links each of length **$l_{1\text{-}3}$**.

3 joints connect the three links of the robot.

angles at each of these joints are **$Ø_{1\text{-}3}$**.

The forward kinematics problem is:

Given the angles at each of the robots joints, **where is the robot's hand**

$(X_{hand}, Y_{hand}, Ø_{hand})$?

IF IT LIES FLAT, y=0, Ø=0

so position is sum of 3 lengths.

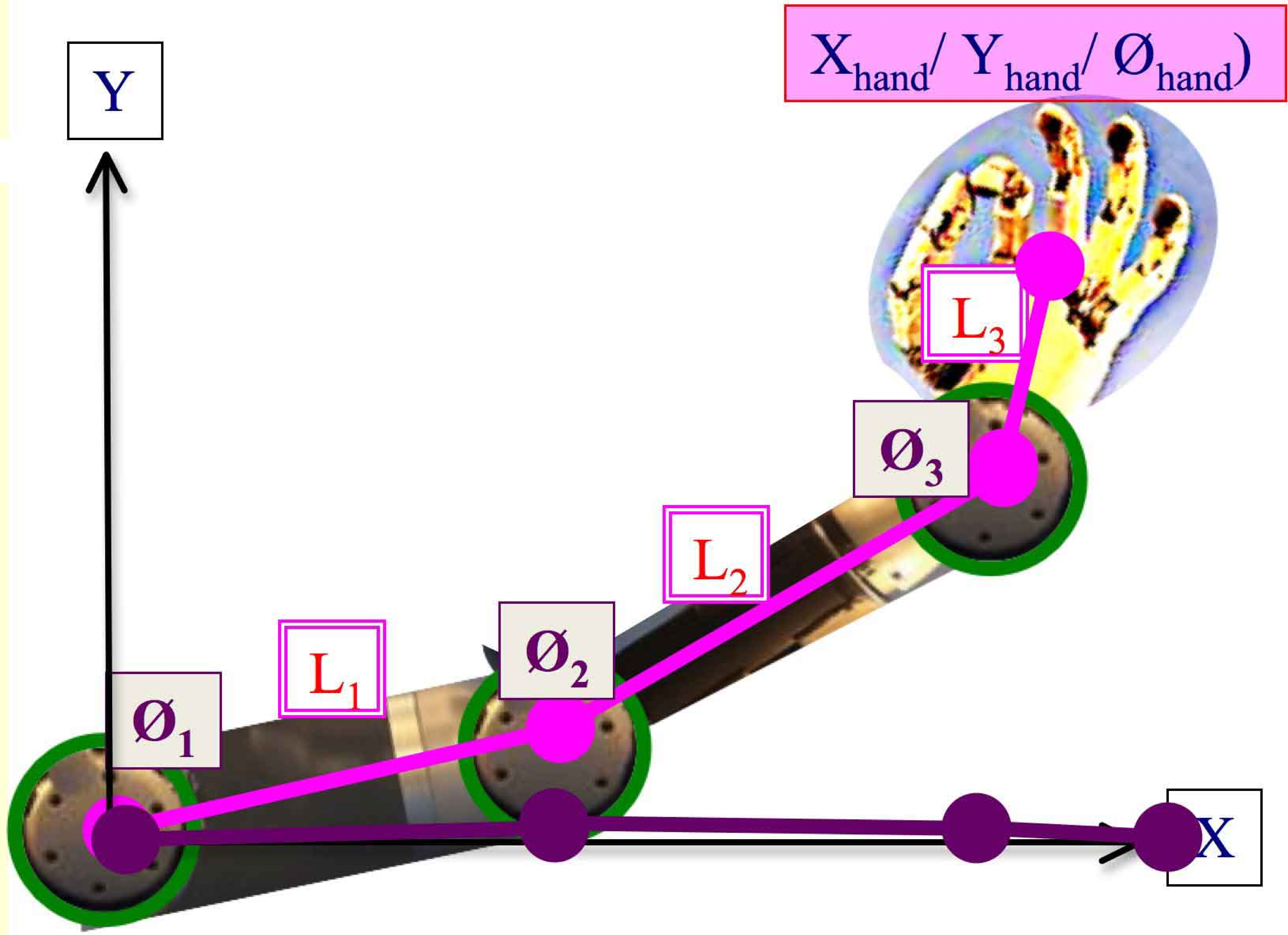
IF IT FLEXES then it has a position in Y axis dependent on Ø of joints.

For this simple planar robot, the solution to the forward kinematics problem is

$X_{hand} = l_1\cos Ø_1 + l_2\cos(Ø_1 + Ø_2) + l_3\cos(Ø_1 + Ø_2 + Ø_3)$

$Y_{hand} = l_1\sin Ø_1 + l_2\sin(Ø_1 + Ø_2) + l_3\sin(Ø_1 + Ø_2 + Ø_3)$

$Ø_{hand} = Ø_1 + Ø_2 + Ø_3$



Geometry
The maths of triangles in circles

SOHCAH

For the 3D spatial case, the solution is not so trivial.

This is because the joint angles do not simply add

1950: **Denavit and Hartenberg** used **screw theory**

the most compact representation of a general transformation between two robot joints required four parameters.

the Denavit and Hartenberg parameters (D-H parameters)

the de-facto standard for describing a robot's geometry.

Modern industrial robots

Fanuc largest maker of these type of robots

six independent joints, six degrees of freedom.

The reason for this is that arbitrarily placing a solid body in space requires six parameters; three to specify the location (x, y, z)

three to specify the orientation (roll, yaw, pitch).

welding, painting and handling materials.

American Adept Technology: world's leading producer of SCARA. Selective Compliance Articulated (Assembly) Robot Arm

Most common industrial robot

3 joints in horizontal plane enable x-y positioning and orientation parallel to the plane.

One linear joint that supplies the z positioning. "pick and place" robot.

When combined with a vision system it can move product from conveyor belt to package at a very high rate of speed

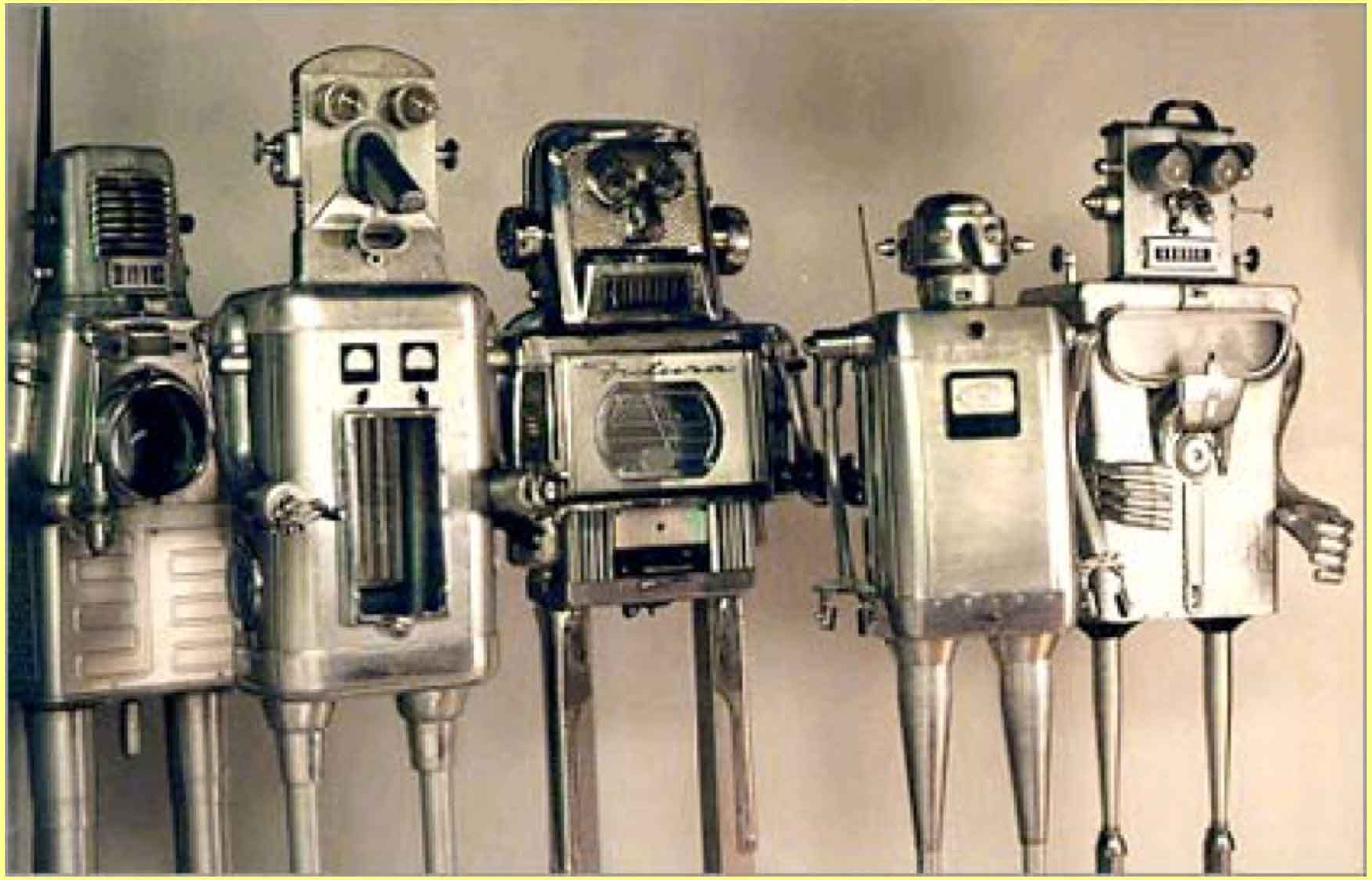
Robot vision
A cultural and historical survey

Automatic devices
Human-like Automata
Robots in art
Early robots
Early androids

Industrial robots

Sensing
Machine vision
Robots at war
Ethics

David Buckley
Wikipedia
London University
IEEE Spectrum's robotics blog

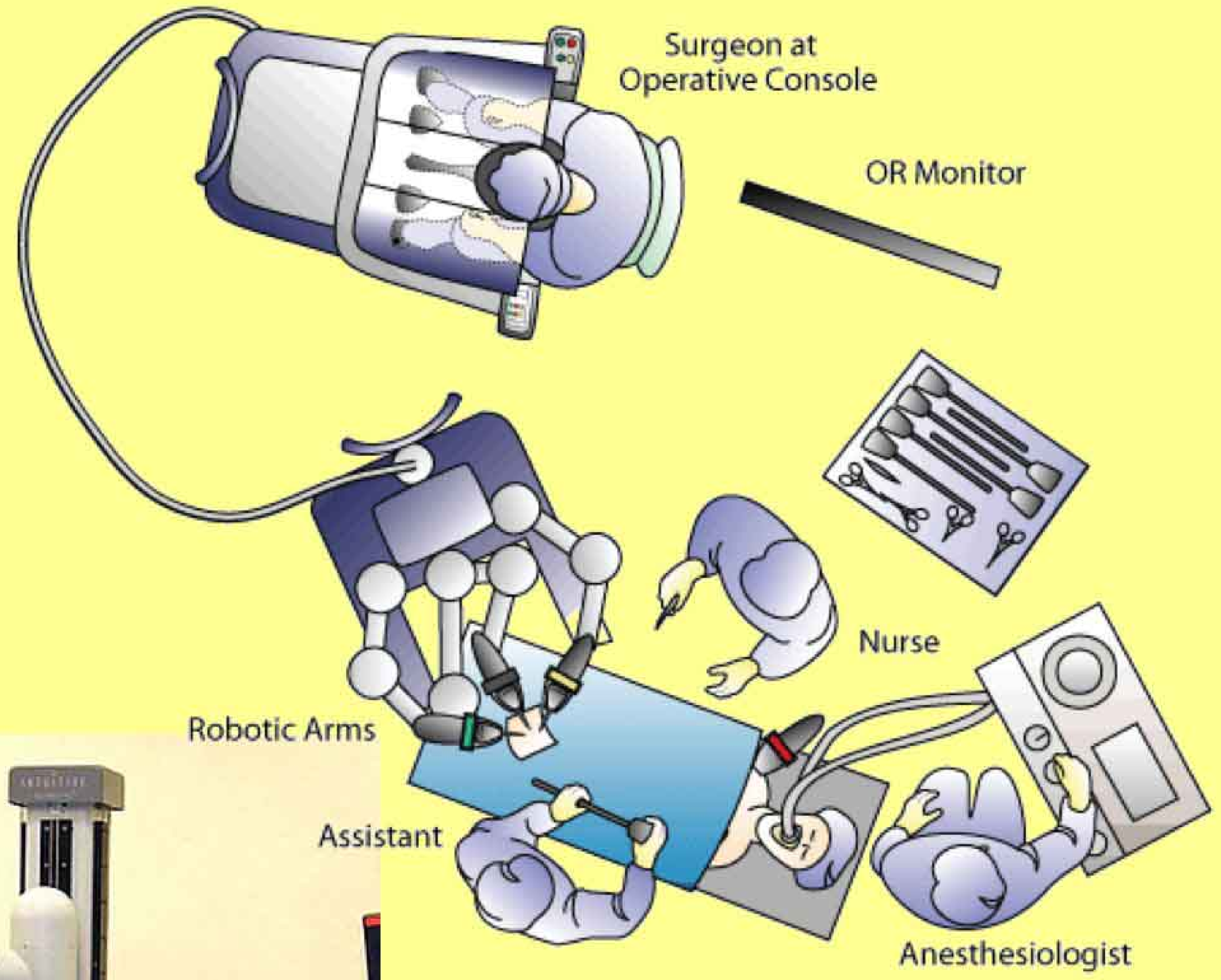


Surgical Robots

1985: Dept Mechanical Engineering Imperial College medical robotics for neurosurgery. "World First" removed tissue from a human patient in operating theatre.

1992: the **PROBOT**, Imperial College London,

Prostatic surgery by **Mr. Senthil Nathan** Guy's and St Thomas'



da Vinci Surgical System Intuitive Surgical $1.5m

2012: 200,000 hysterectomies and prostate:

Human surgeon inserts 4 stainless-steel tubes.

Robotic arms hold the rods in place.

One holds 2 endoscopic cameras **stereoscopic** image,

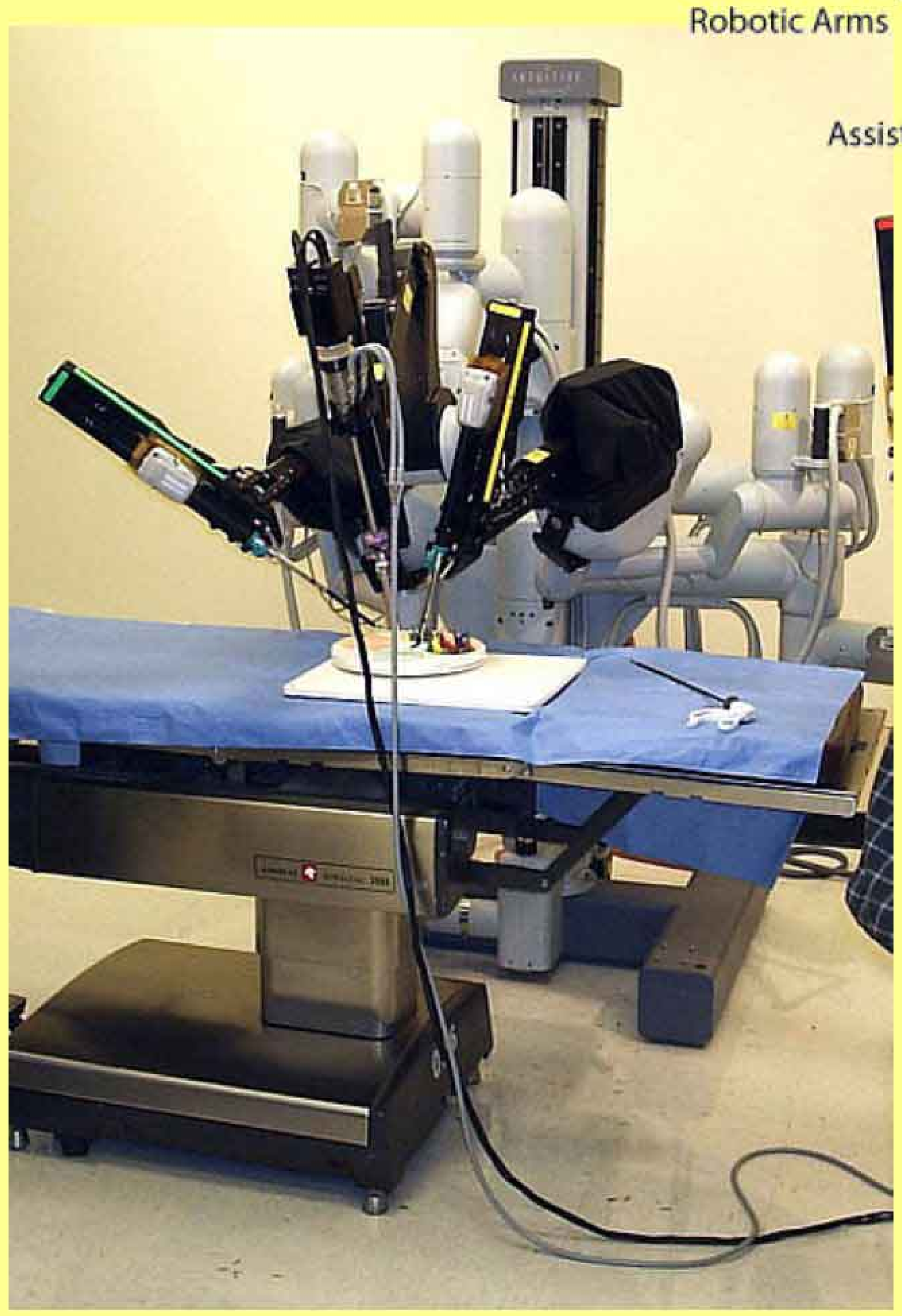
Other rods surgical instruments

Surgeon sits at the console 3D image moves the arms with two foot pedals and two hand controllers.

System translates hand movements into precise micro-movements of the instruments

Does not move without the surgeon's direct input.

2003, Intuitive Surgical merged with Computer Motion, after latter filed lawsuits on patent infringements.



Summary

Automatons

Machines that can move without human help

Can Perform limited number of pre-programed tasks or calculations

Water power, Sand power, Clockwork

Electrical power

Cables

Batteries (technology)

Remote control

Wire

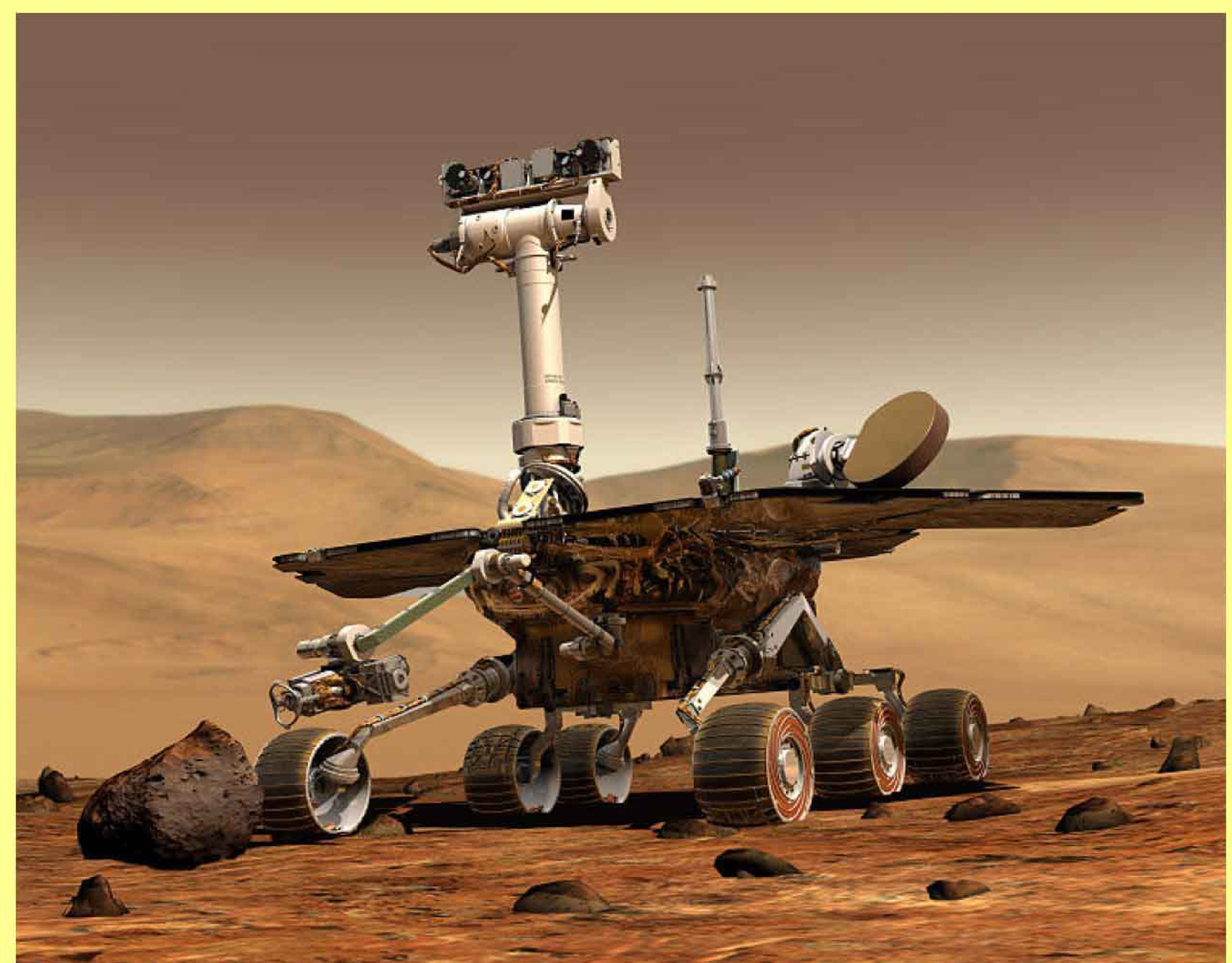
Wireless

Mathematics of positional sense

Industrial applications

If robots could “see”, improve their performance and allow greater autonomy.

Mars is covered with inconvenient rocks



Mars rover Spirit: 2004-10

Early modern robots

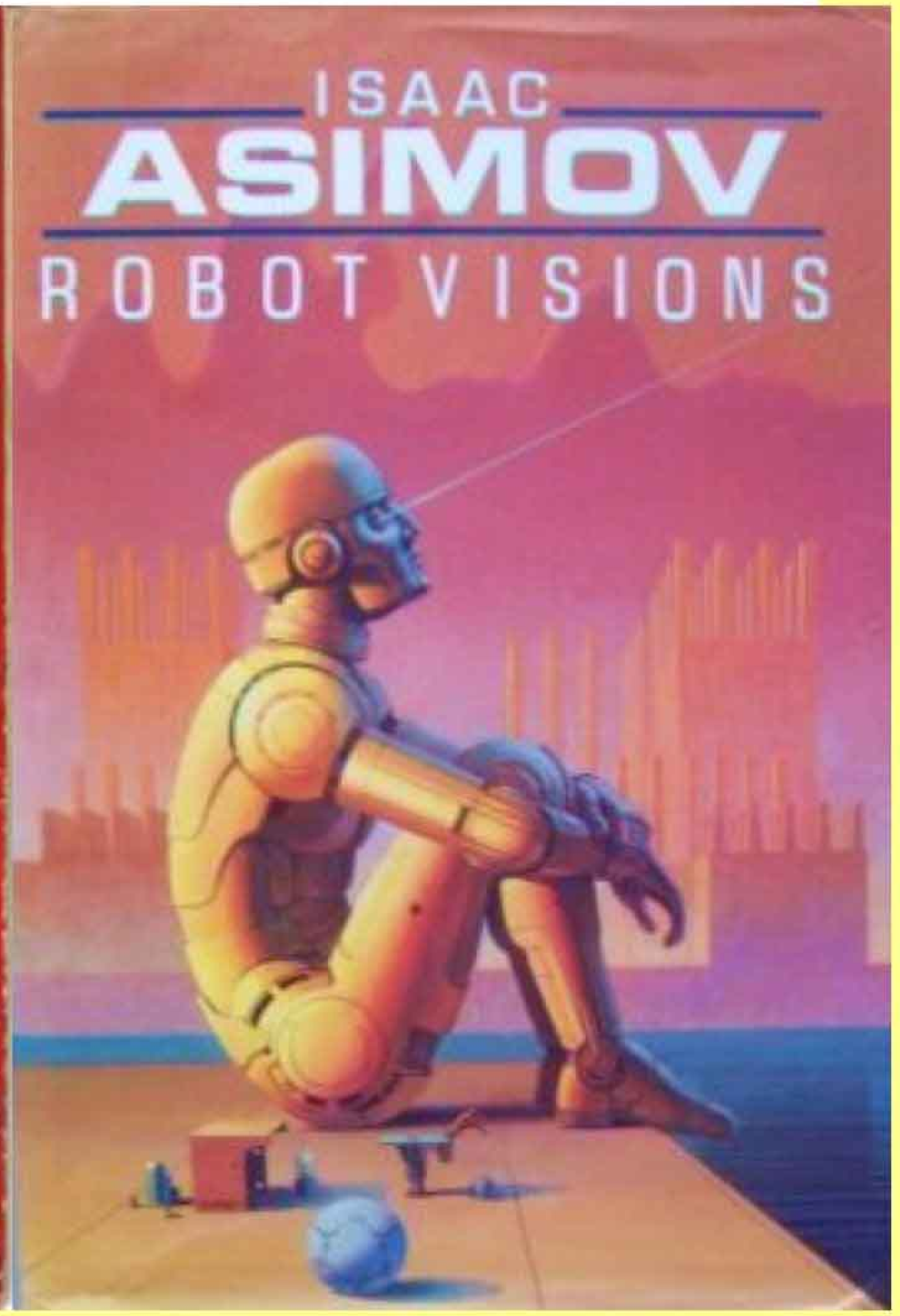
History of robotics dominated by the machine tool.
Not by androids, as Leonardo intended.

What is a robot?
a goal oriented machine that can **sense**, **plan** and **act**

Early robots:
components and joints from machine tools

large, immobile, inflexible, blind,
not human.

Evolved into more versatile general purpose robots



Why robots need sensors

Same as humans: independence from pre-programming

For a robot to act successfully in the real world it needs to be able to perceive the world, and itself in the world.

environmental analysis, navigation, object identification and tracking.

Recognition– Finding out **what** is out there:

is there danger?

Location

Finding out **where** things are:

Where is the screw and how can I get to it;

"Global Machine Vision and Vision Guided Robotics Market (2010 - 2015)", (www.marketsandmarkets.com), the total global machine vision system and component market is expected to be worth 15.3 billion USD by 2015

Machine vision

Can use senses humans cannot

Imaging-based automatic analysis for robot guidance

Applications: quality assurance, sorting, material handling, robot guidance, and optical gauging

- Acquisition of image
- Image processing
- Decision making:

A common output from machine vision systems

- pass/fail decisions,
- object position
- orientation information

Sense: Sound waves

SONAR SOund Navigation And Ranging

Lazzaro Spallanzani 1729-99: Bats navigate by hearing not vision

Donald Griffin: 1944: Echolocation higher freq than human

Moving Unmanned systems will encounter obstacles

Sonar/Ultrasound: Robot sonar cheap, $20-$30 each.

Emits inaudible sound, detects the return echo.

Sends a voltage signal to microcontroller; time delay calculate the distance of the object(s)

Calculating Distance vs Time Speed of sound: in air 343 m/s, temp and humidity.

in saltwater 1500 m/s, in freshwater 1435 m/s.

Sonar sends out a sound to an object

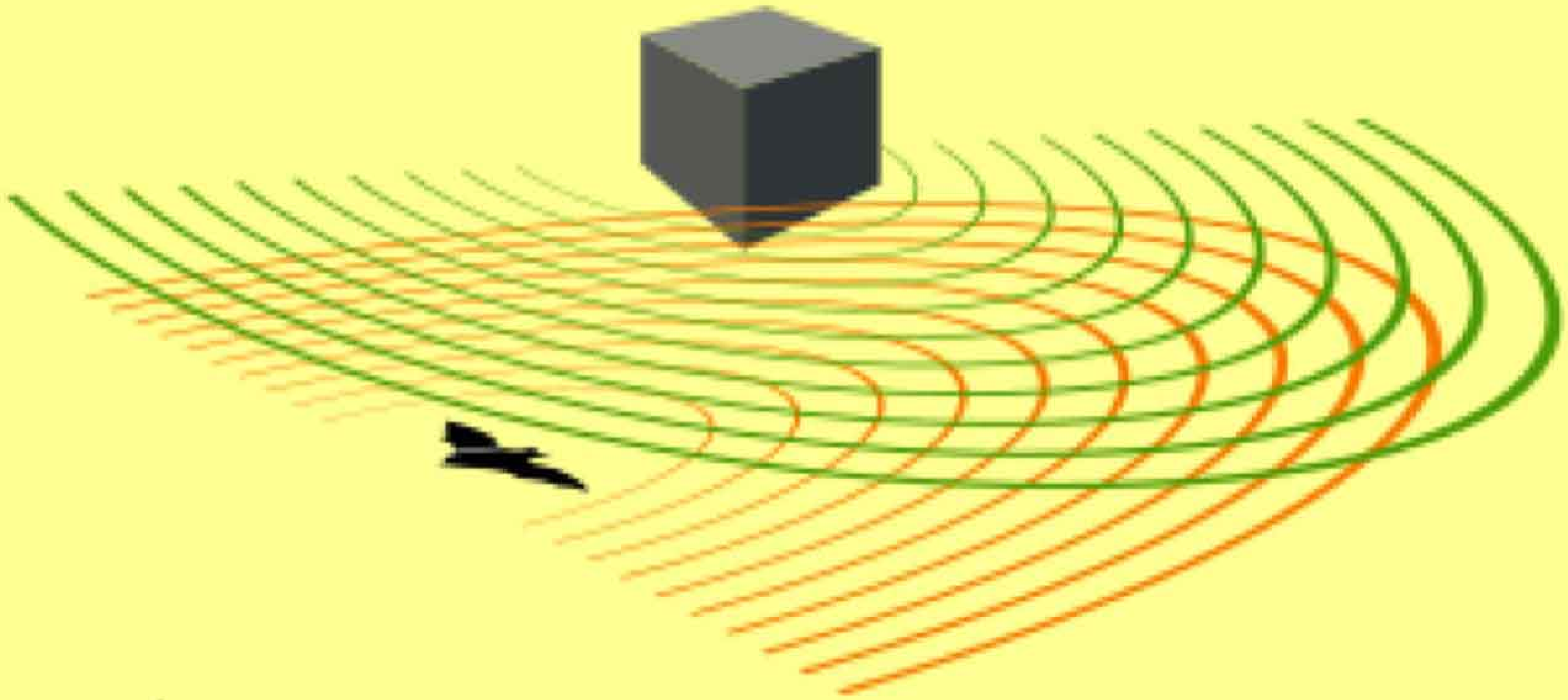
Sound travels this unknown distance there and back.

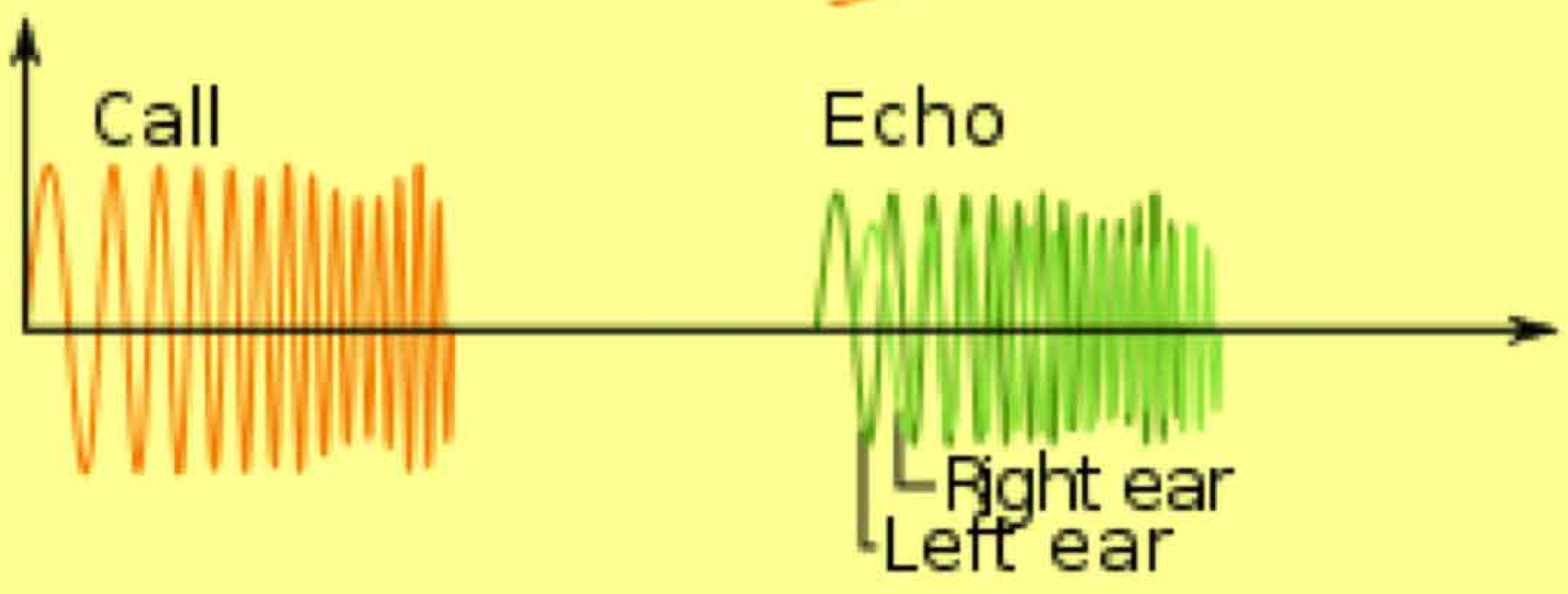
Microcontroller: time elapsed .03 seconds.

calculation:

Speed_of_Sound xTime_Passed / 2 = Distance_from_Object

343 m/s x .03 s / 2 = 5.145 m

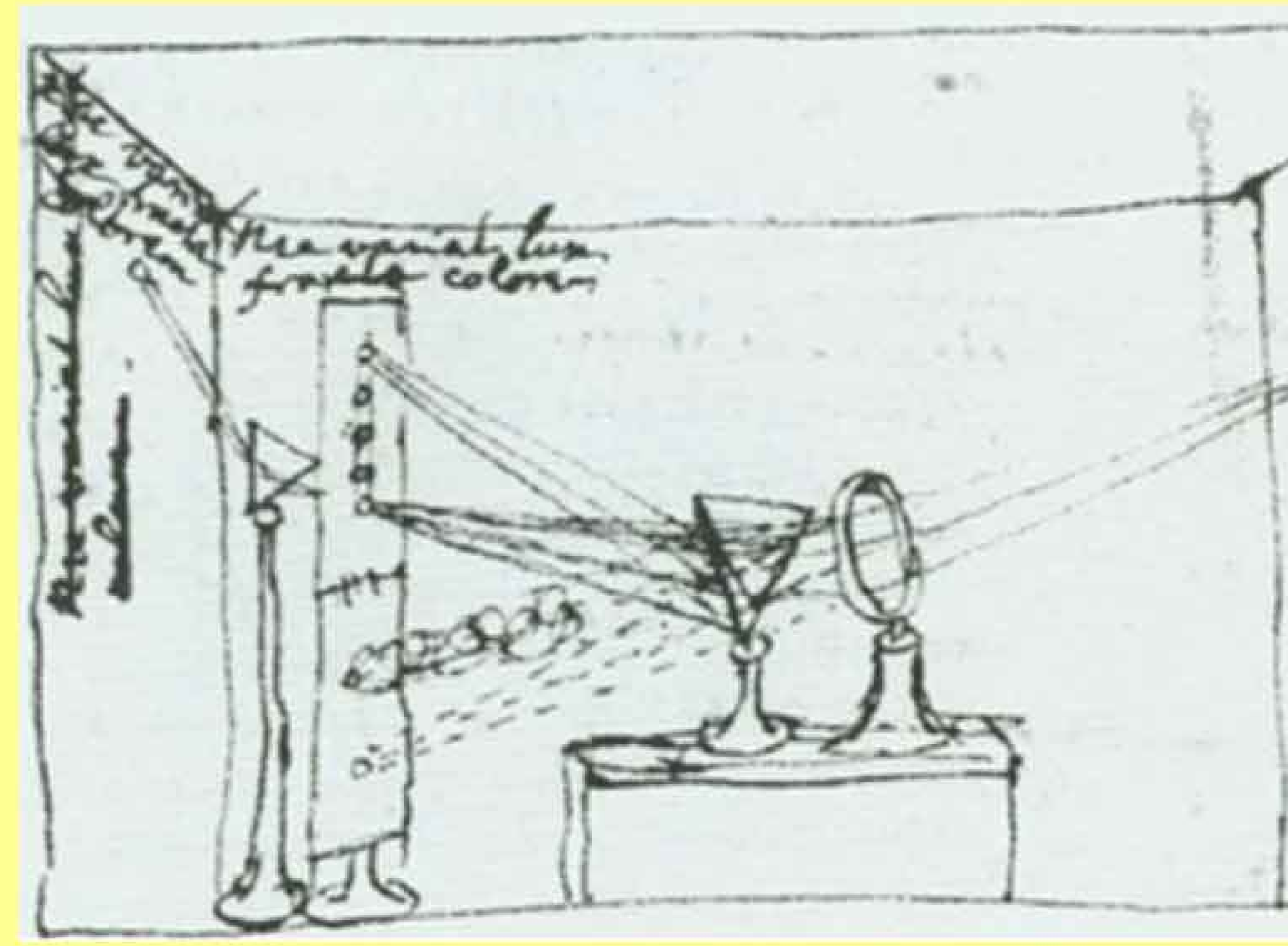




Lidar Light Detection & Ranging: remote sensing technology that uses the time delay and scattering properties of reflected laser pulses to identify characteristics of surrounding objects.

Sensing using Light

Isaac Newton (1704) *Opticks or a Treatise of the Reflections, Refractions, Inflections and Colours of Light.*

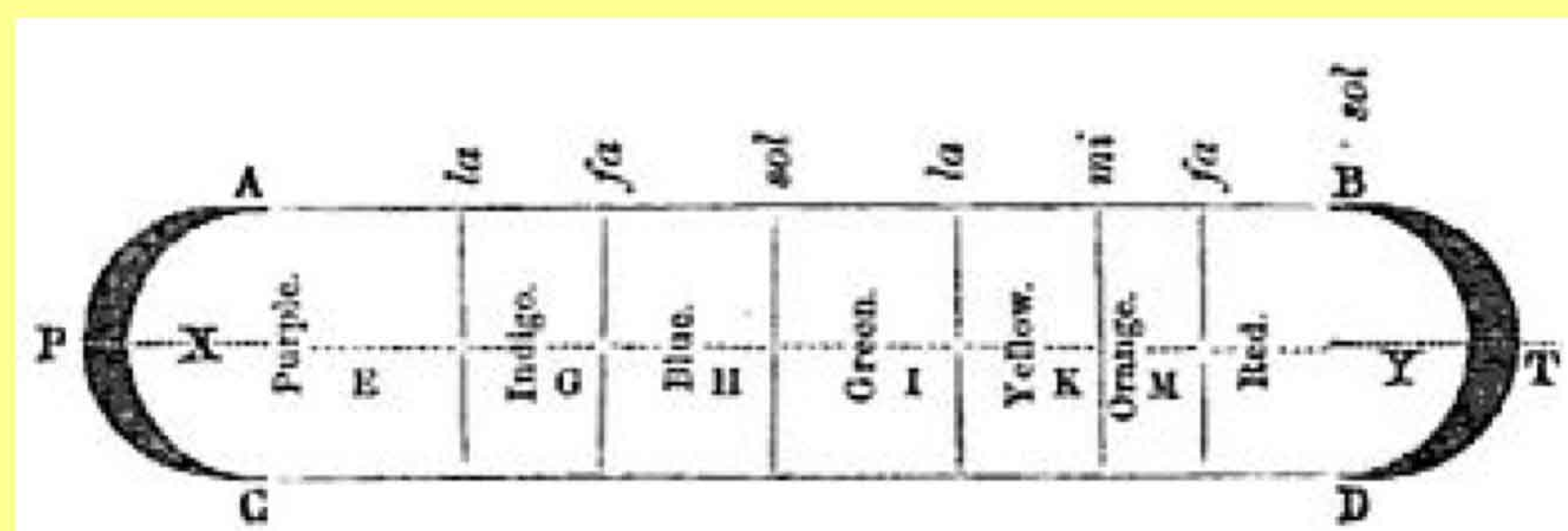


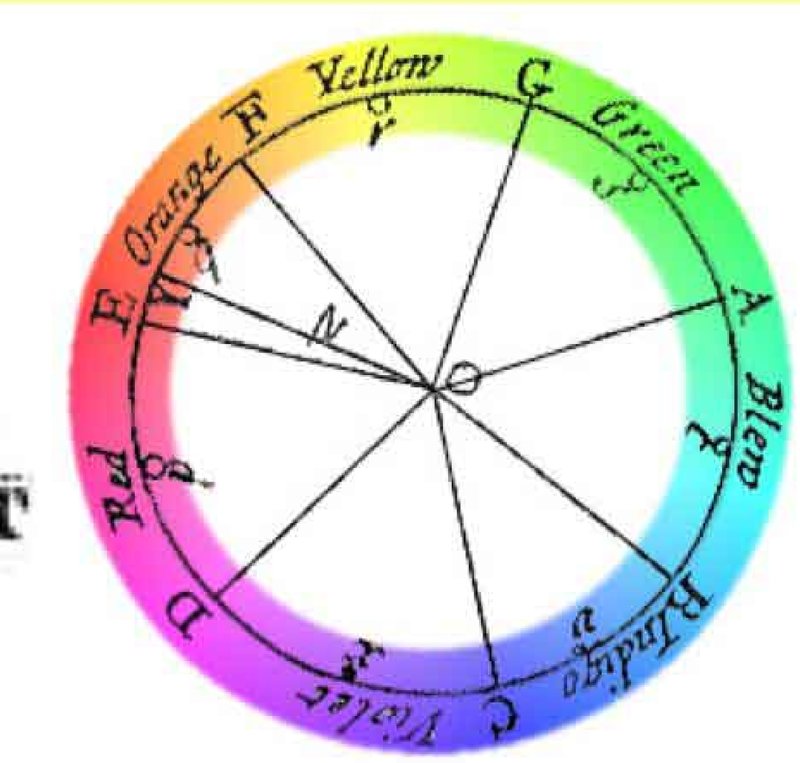
In a very dark Chamber at a round Hole, about one third Part of an Inch broad, made in the Shut of a Window, I placed a Glass Prism, whereby the Beam of the Sun's Light, which came in at that Hole, might be refracted upwards toward the opposite Wall of the Chamber, and there form a colour'd Image of the Sun.

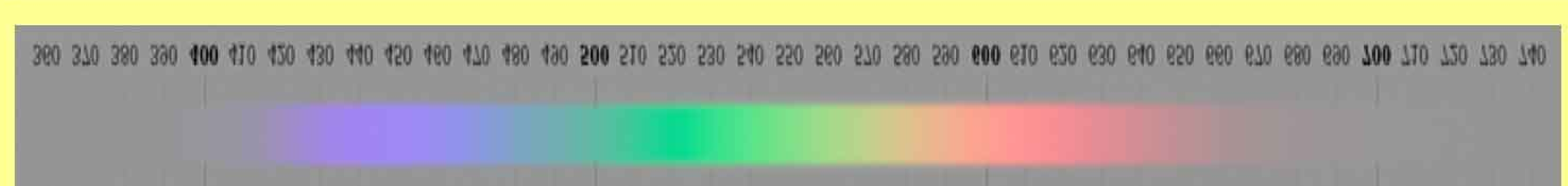
Blake, William (c. 1805) *Newton.* Colour print in ink and watercolour. Tate Gallery,
Critical of scientific thought. Sharp lines and angles of Newton's profile suggest that he cannot see beyond the rules of his compass. Behind, colourful, textured rock represent the creative world, to which he is blind.

Classified spectrum into seven named colours: red, orange, yellow, green, blue, indigo, and violet.

Chose seven derived from ancient Greek sophists, a connection between colours, the musical notes, the known objects in the solar system, and the days of the week







Infra red/ultra violet

F. William Herschel:

11 Feb 1800: Slough Experiment Testing filters for the sun so he could observe sun spots.

When using a red filter he found there was a lot of heat produced

There must be an invisible form of light beyond the visible spectrum.

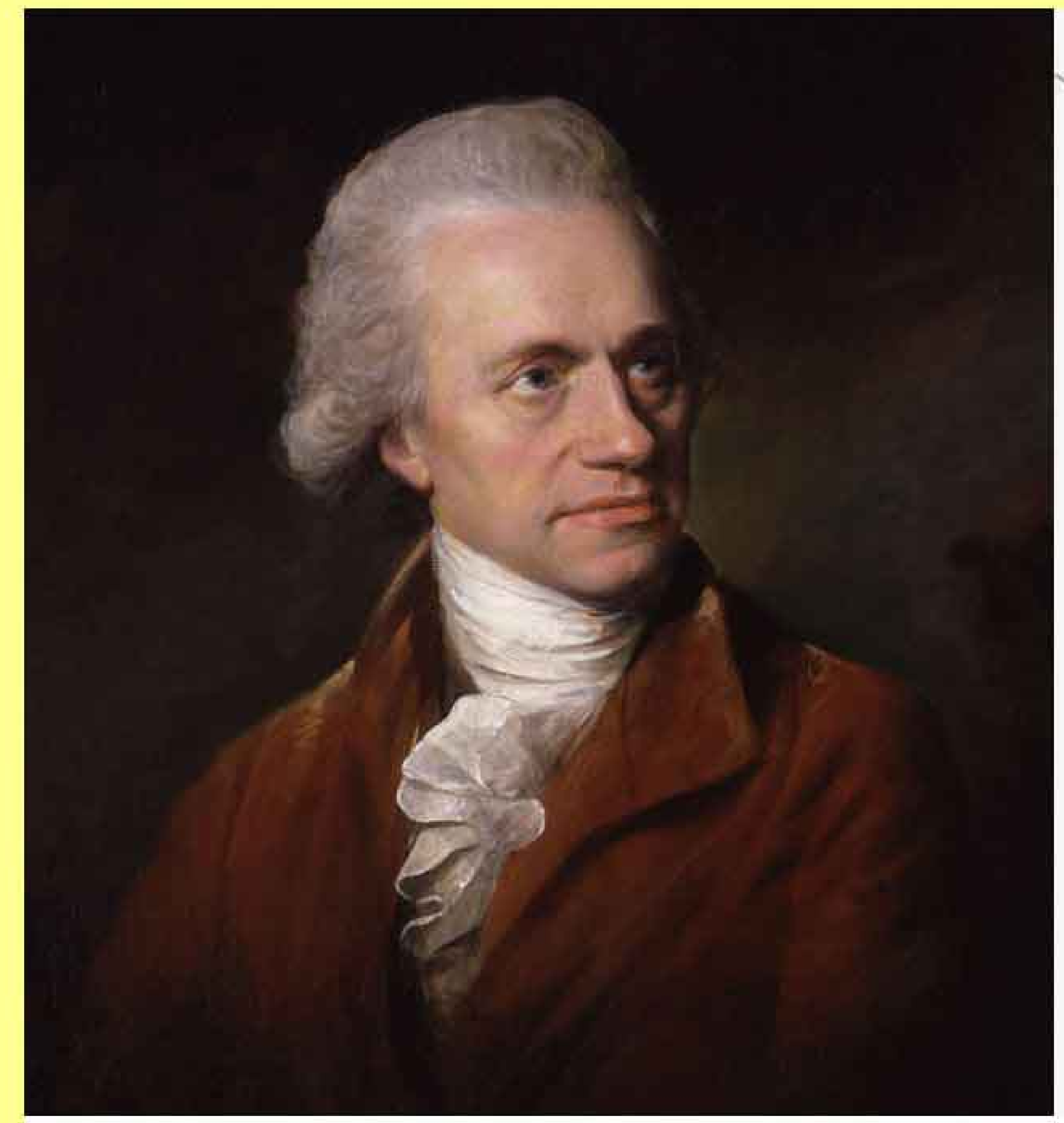
TV Remote controls: Invisible to us, not camera

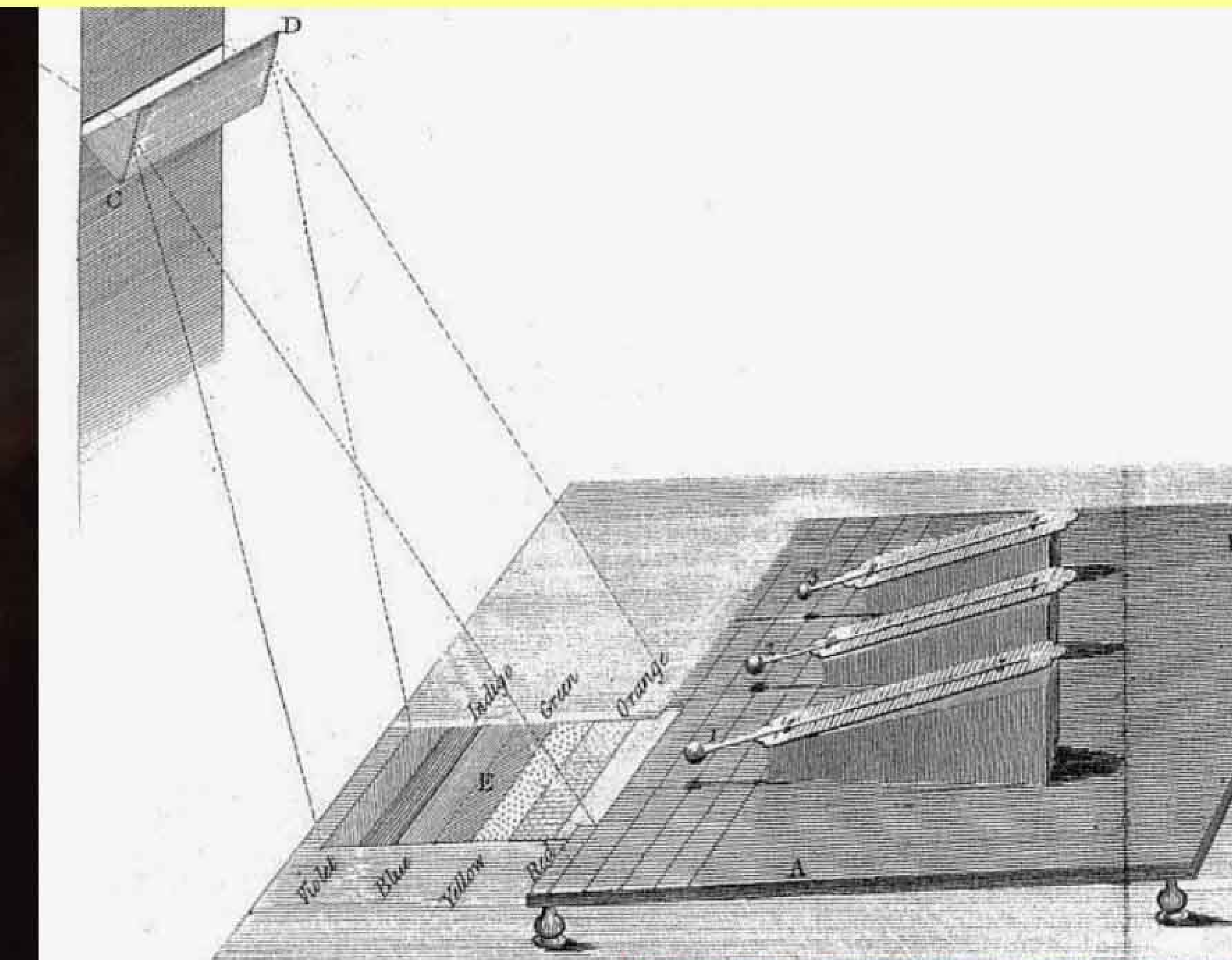
Black light:

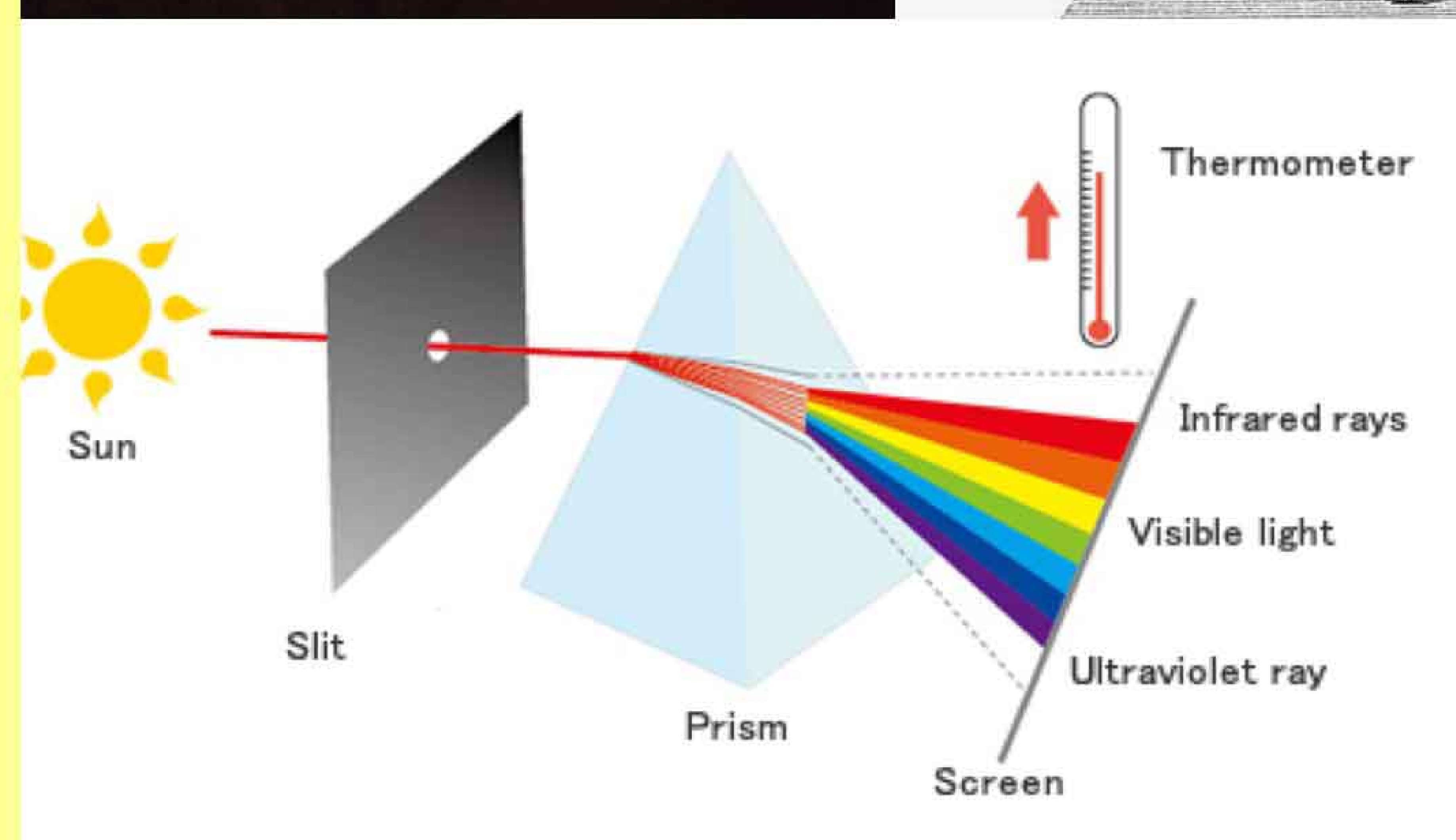
1801: **Johan Ritter:** Apothocary then Medical School. Looked for an opposite of heat rays at the other end of the visible spectrum.

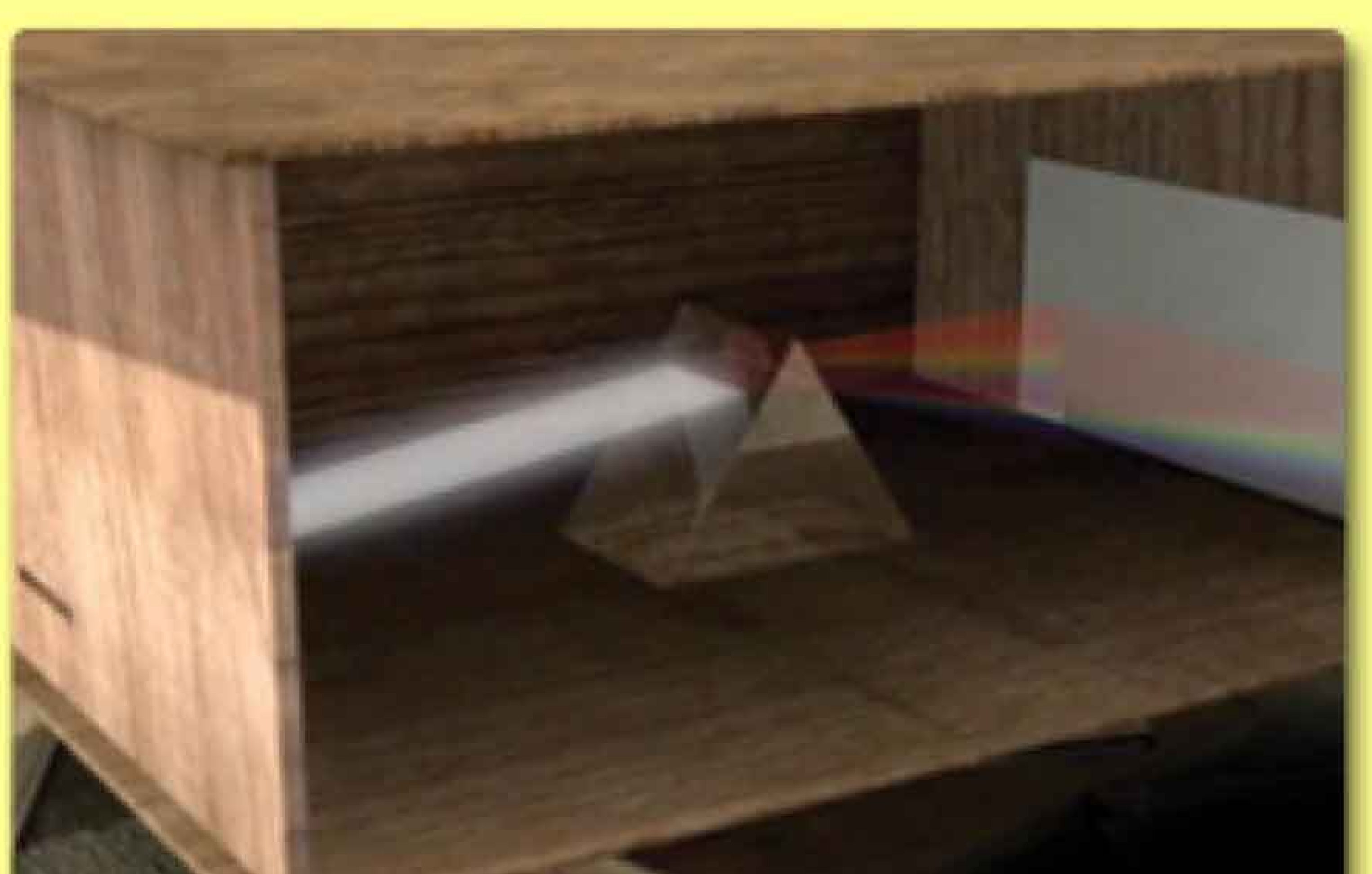
Silver chloride was transformed faster from white to black when placed at the dark region of the Sun's spectrum, close to its violet end.

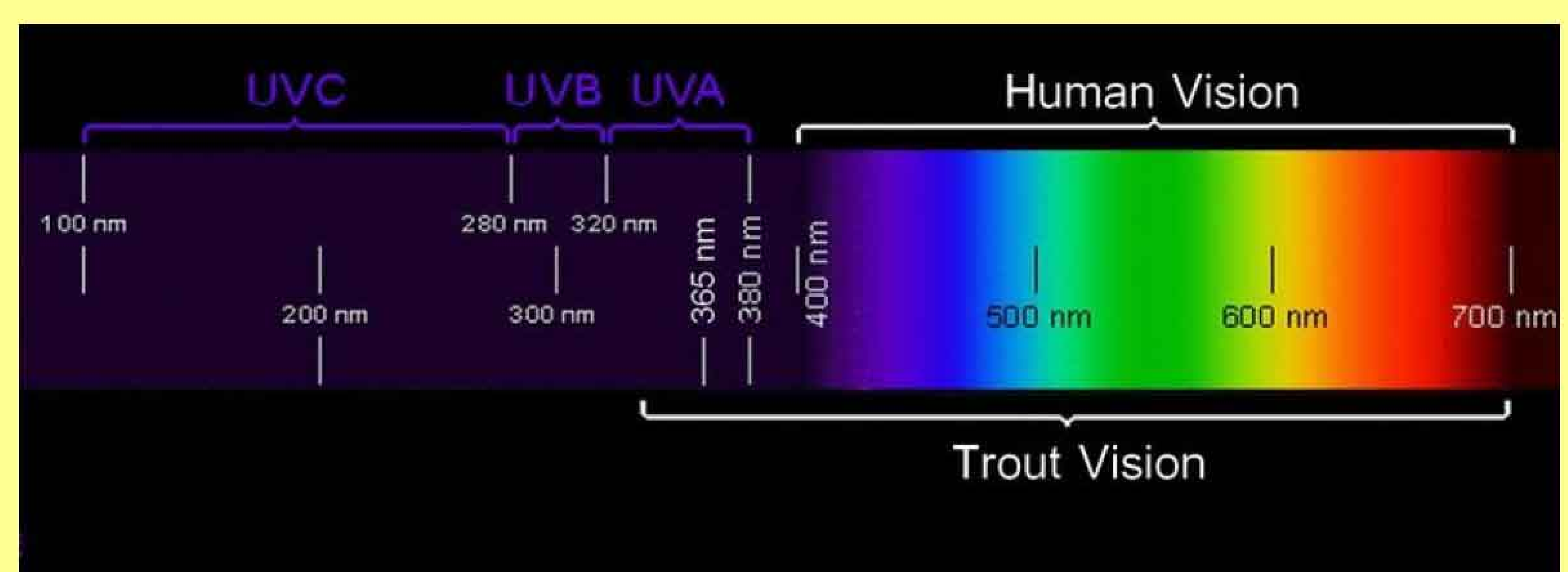
The "**chemical rays**" ultraviolet radiation











Radio waves

1799: Ørsted: Dissertation on Kant ***"The Architectonics of Natural Metaphysics"***.

Unity of nature: Fundamental relationships between natural phenomena

Compass needle deflected when electric current from a battery was switched on and off: direct relationship between electricity and magnetism

1860: James Clerk Maxwell

Mathematically predicted that electrical fields and magnetic fields couple together to form EM waves.

"**Maxwell's Equations**." EM waves could propagate through free space.

1892: Heinrich Hertz: Made electric and magnetic fields detach themselves from wires and go free as Maxwell's electromagnetic waves.

Sparks of the coil transmitter, release waves picked up by the receiving antenna, also sparks

These signals possessed properties of EMR

Velocity of Hertzian (radio) waves same as light!

Radio waves are a form of "light"!

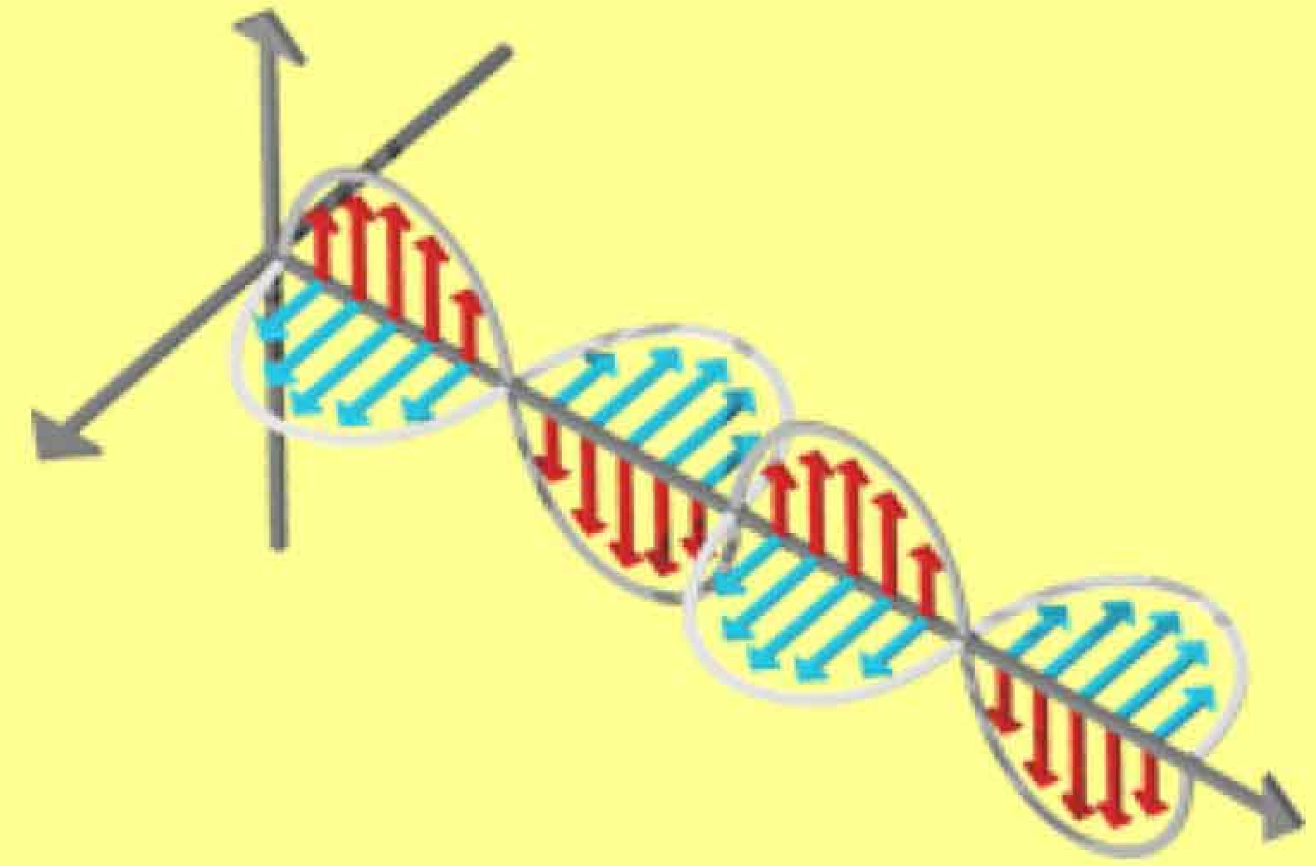
Longest wavelengths in spectrum.

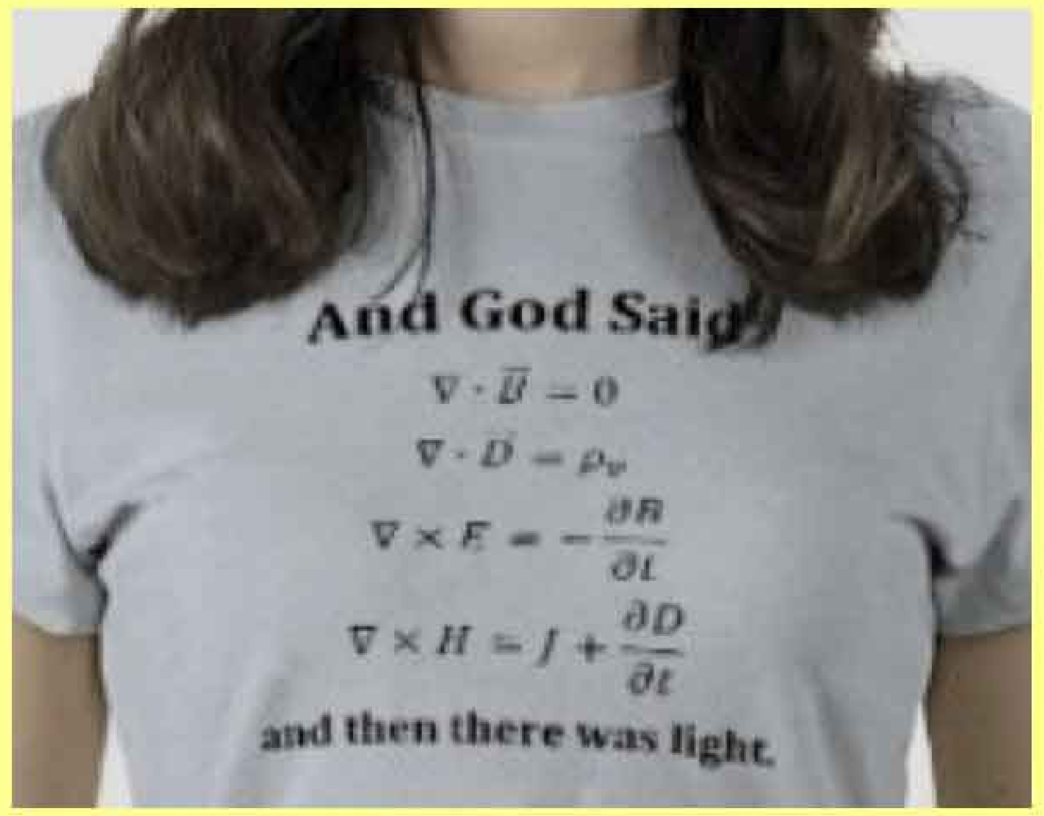
λ: Football to larger than a planet.

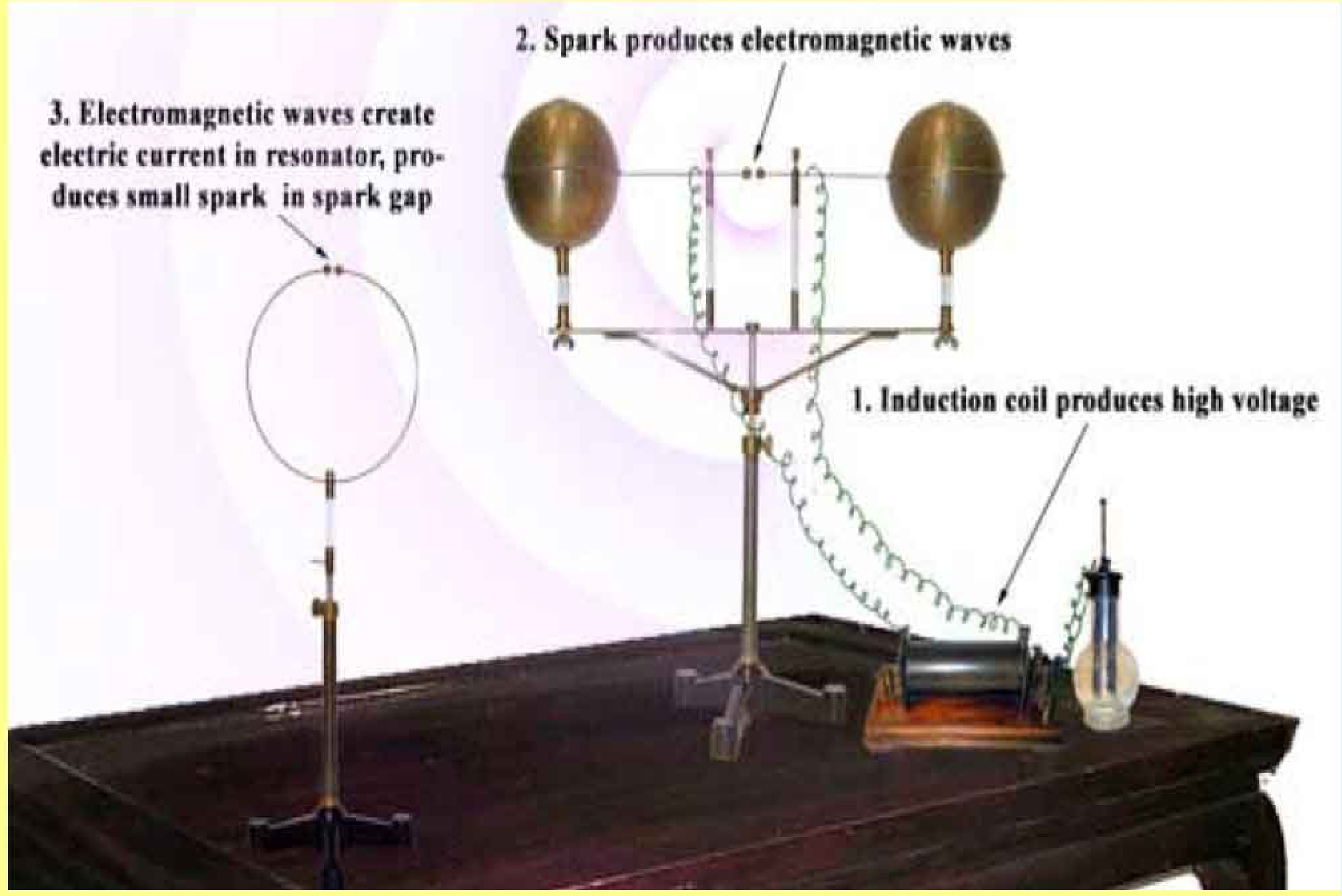
Astronomical objects that have a changing magnetic field can produce radio waves

RADAR: **Ra**dio **D**etection **a**nd **R**anging

Microwave radar: insensitive to clouds

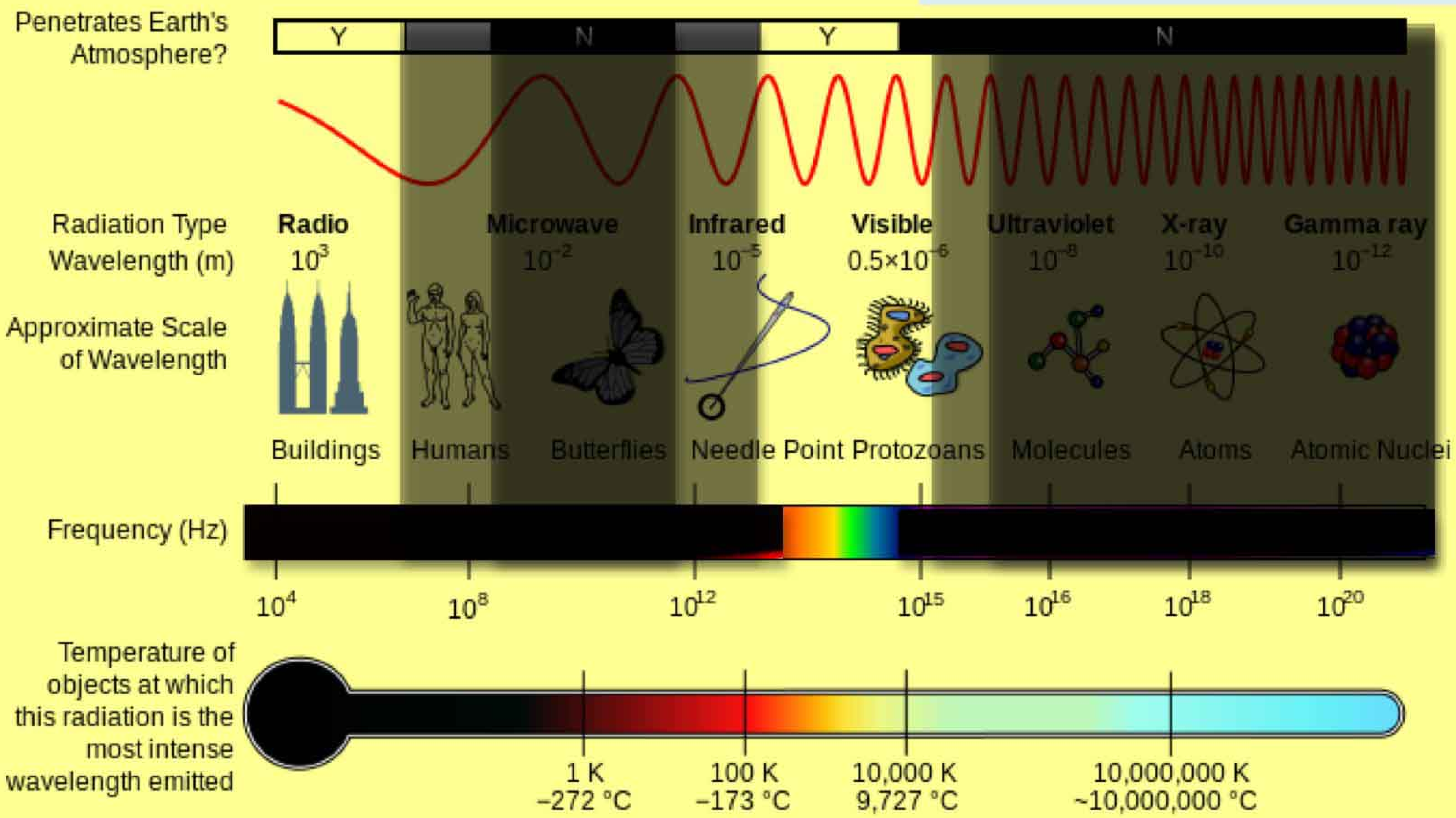






Electromagnetic waves are formed by the vibrations of electric and magnetic fields. perpendicular each other

Once formed, travel speed of light until further interaction with matter.



X-ray based machine vision

x-ray system can see inside the objects

Robots seeing what human cannot see

X-rays: electromagnetic radiation λ 10 to 0.1 nm

Object between x-ray tube and detector

Shadow recorded x-ray detector.

Digital image transferred to computer

Image processing in machine vision systems.

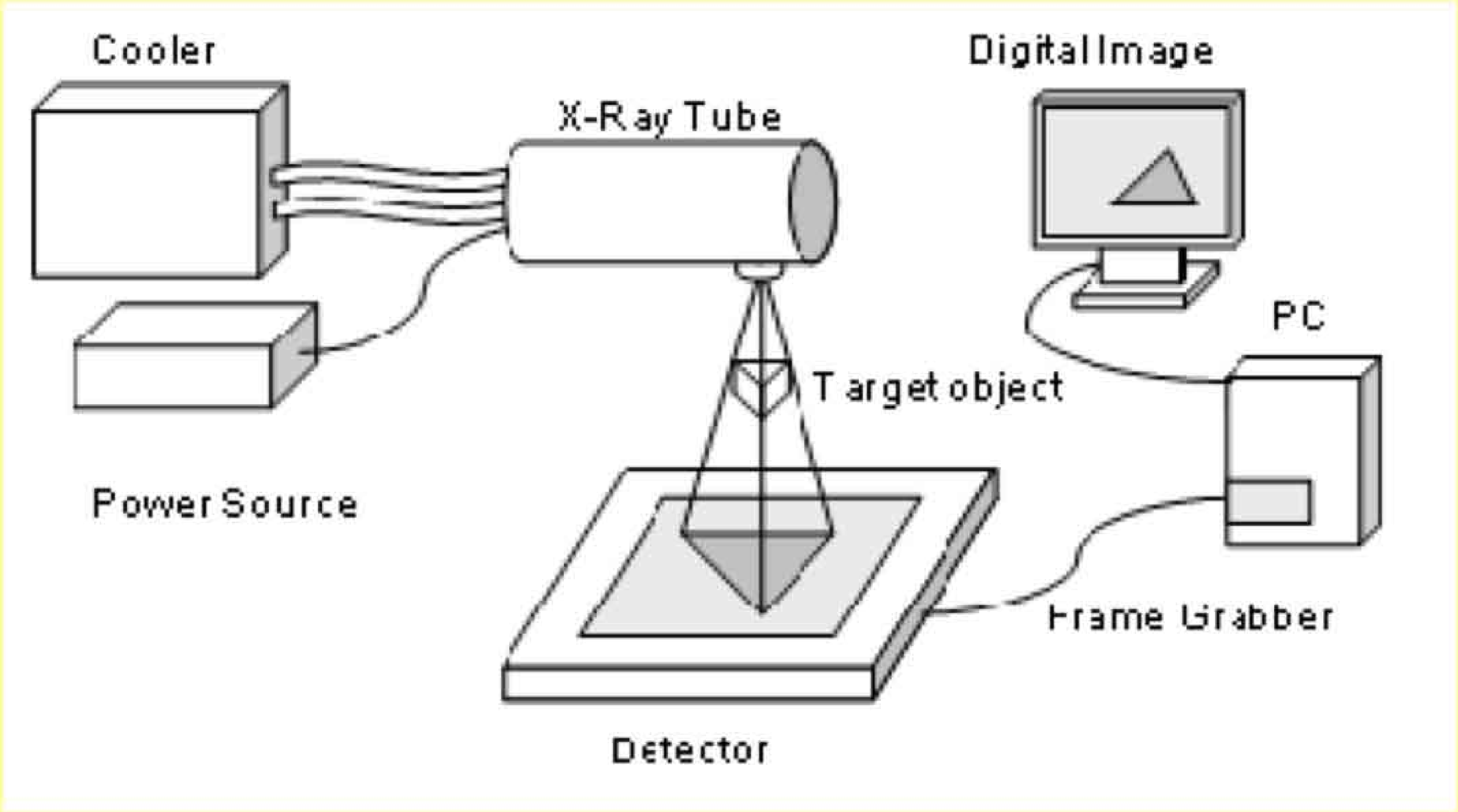
Substitute for some traditional metal detectors in security and industrial applications

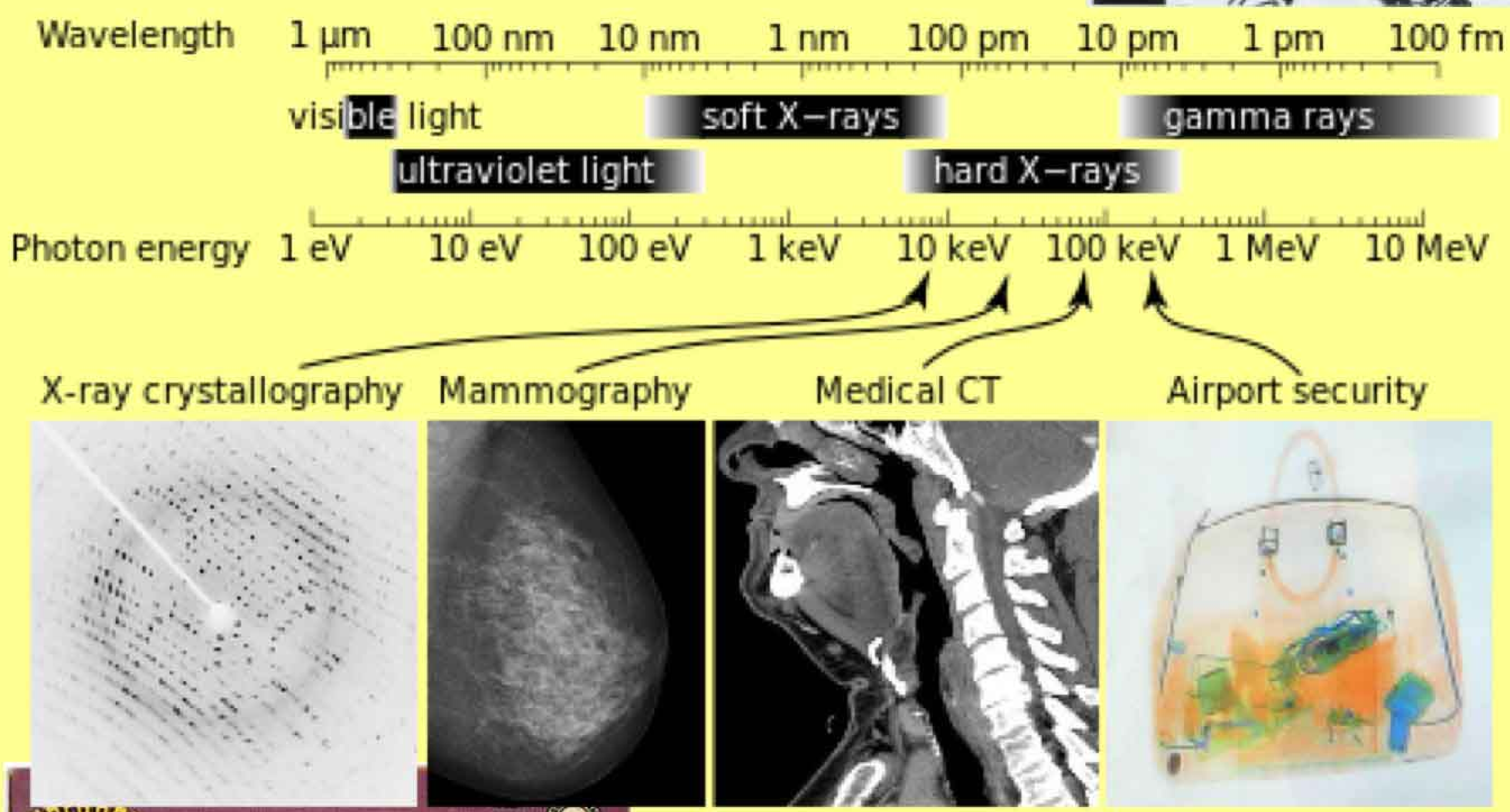
1937: The Astounding Adventures of Olga Mesmer, the Girl with the X-Ray Eyes: pulp magazine Spicy Mystery Stories

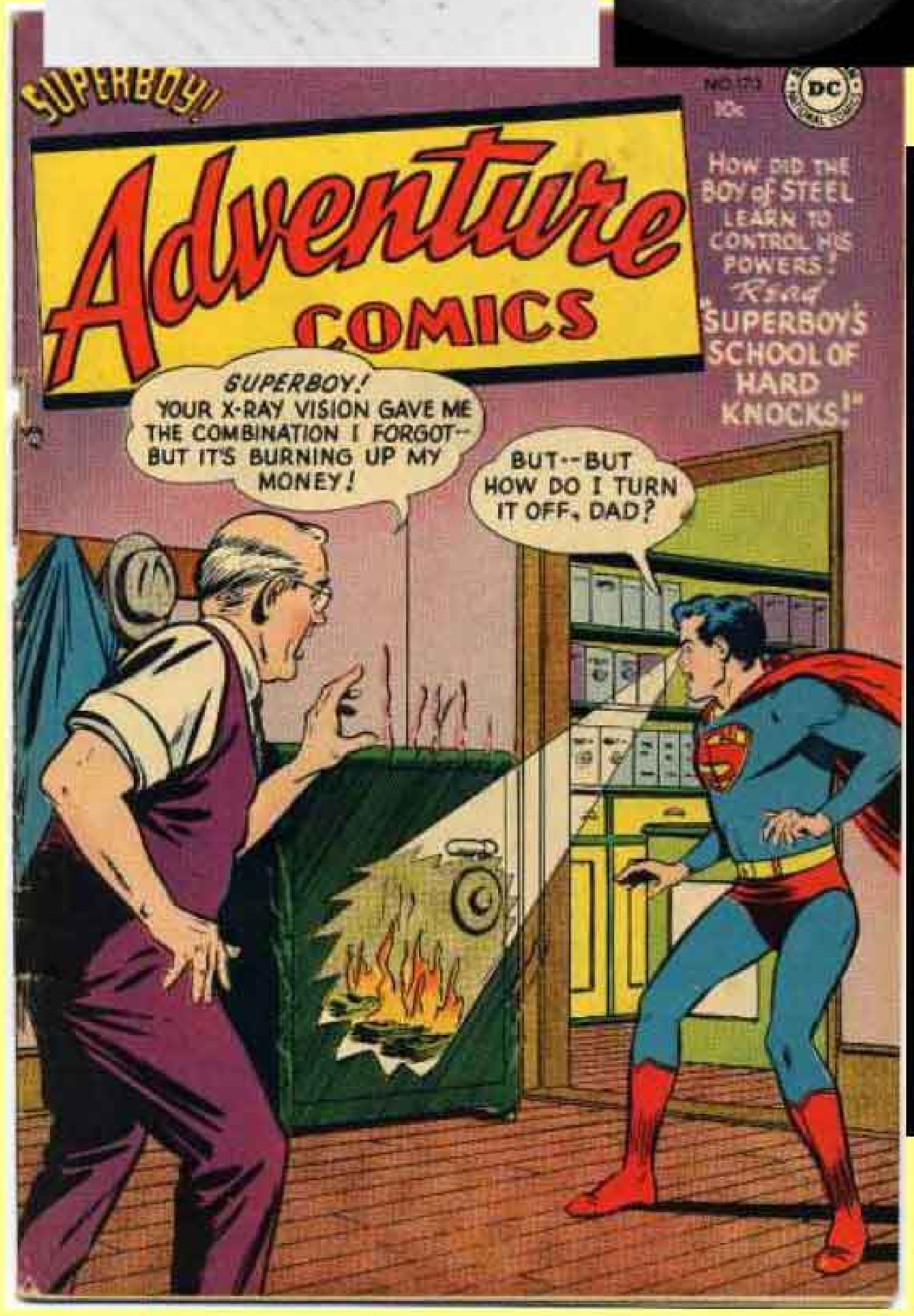
1933: Superman created by Jerry Siegel drawn by Joe Shuster, Cleveland high school students

Based in Metropolis; after the film.

April 1939: Develops X-ray vision







Ancient automatic devices

Complex mechanical devices are known to have existed in ancient Greece, though the only surviving example is the Antikythera mechanism.

Pindar (c. 522–443 BCE), lyric poet from Thebes.

Seventh Olympic Ode:

THE ANIMATED FIGURES STAND
ADORNING EVERY PUBLIC STREET
AND SEEM TO BREATHE IN STONE, OR
MOVE THEIR MARBLE FEET.

C270BCE: **Ctesibius** Engineer Alexandria makes water clocks with moving figures

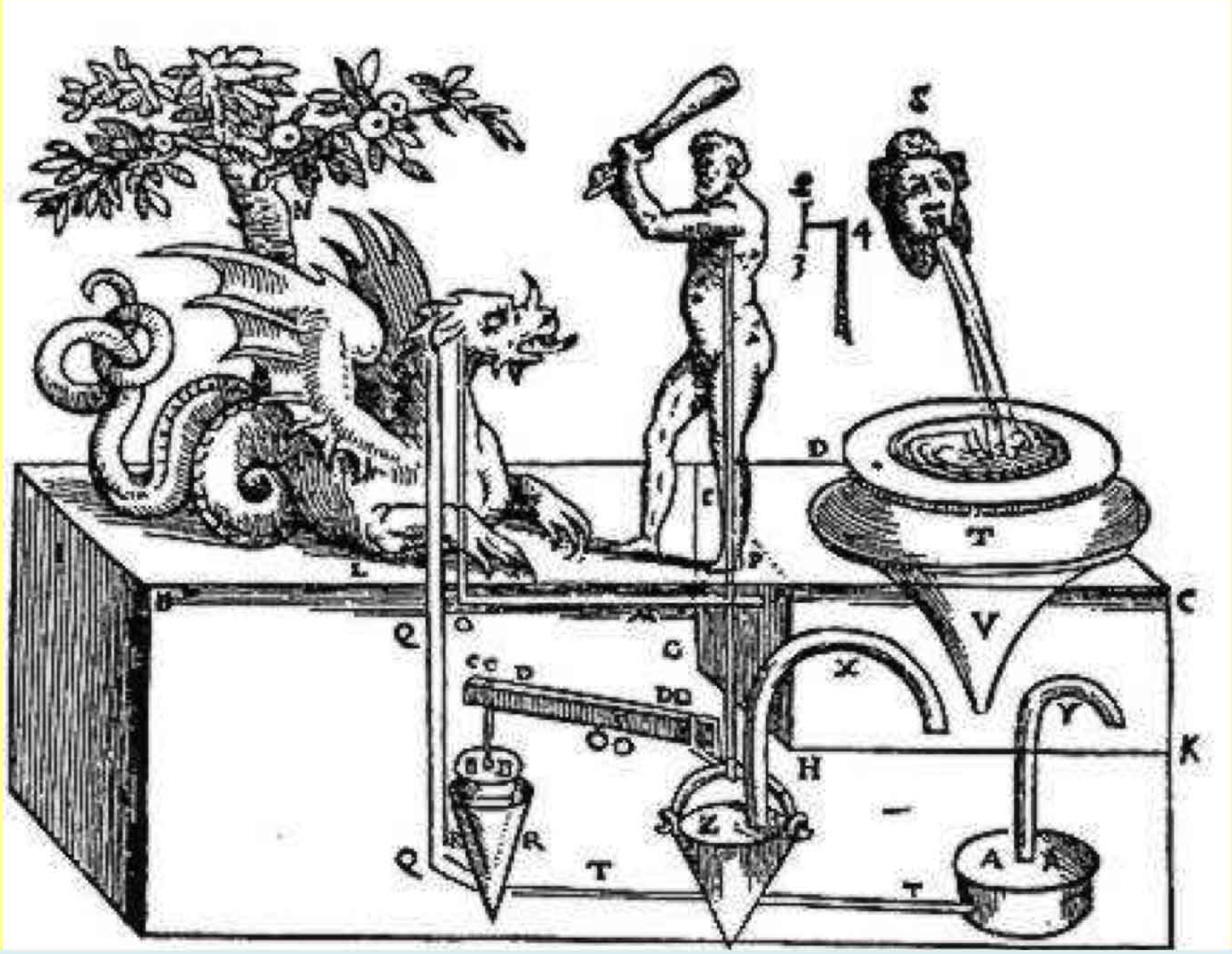
Hero of Alexandria: 10-70AD

Steam engine (aeolipile)

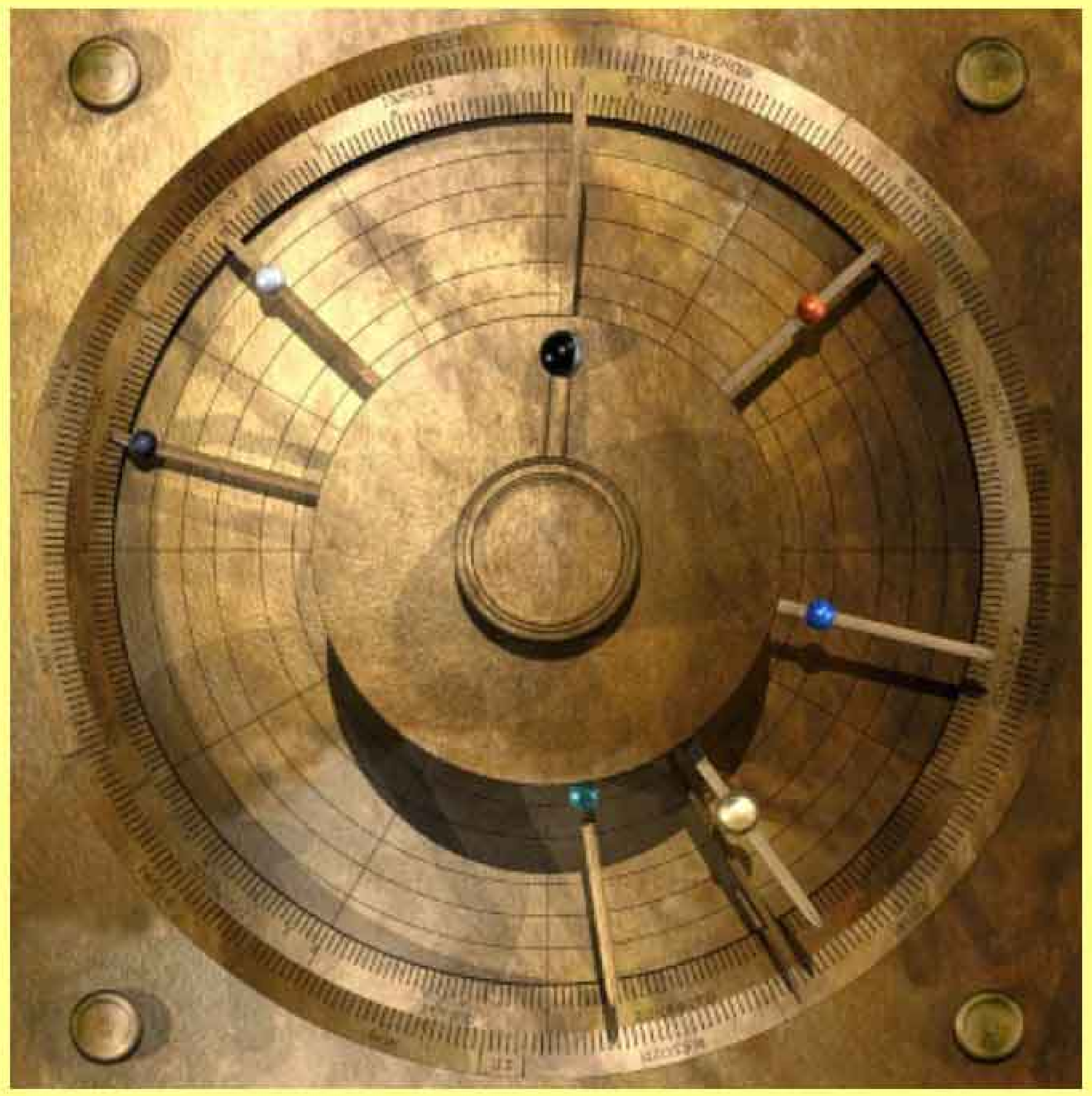
On automatic Theatres

C87 BCE. **Antikythera mechanism** ancient analog computer designed to calculate astronomical positions.

Recovered 1900 from the Antikythera wreck



Reconstruction of one automaton of Hero by Giovanni Battista Aleoti 1589. Hercules and the Dragon. When Hercules hits the head of the dragon the dragon shoots water on his face.



Antikythera mechanism designed to calculate the positions of astronomical objects.

Detecting light

Many metals emit electrons when illuminated

1839: **Edmond Becquerel:** Age 19 generated electricity by illuminating electrodes coated with light sensitive material

1873: **Willoughby Smith** testing underwater telegraph lines. Exposed to light; selenium conducted

Photo-electric cells convert light into electrical energy.

1905: **Albert Einstein:** Effect is result of light energy being carried in discrete quantized packets.

1921: Nobel Prize: Law of the photoelectric effect"

Photovoltaic effect, Light causes electrons to absorb energy; highly excited e^-, diffuse, and some reach a junction where they are accelerated into a different material by a built-in potential (Galvani potential).

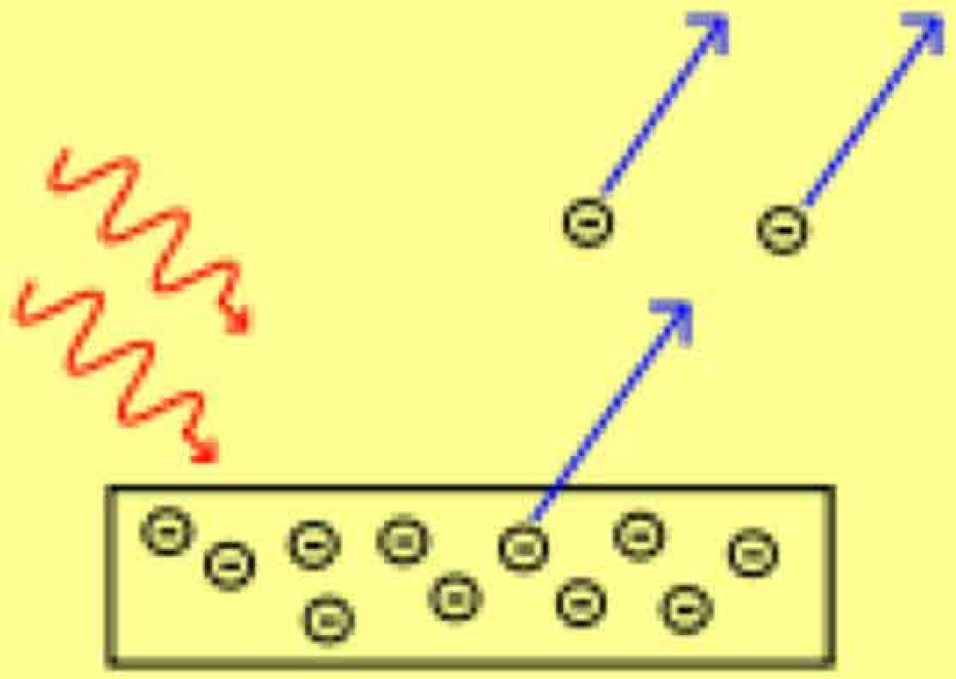
This generates an electromotive force, some of the light energy is converted into electric energy

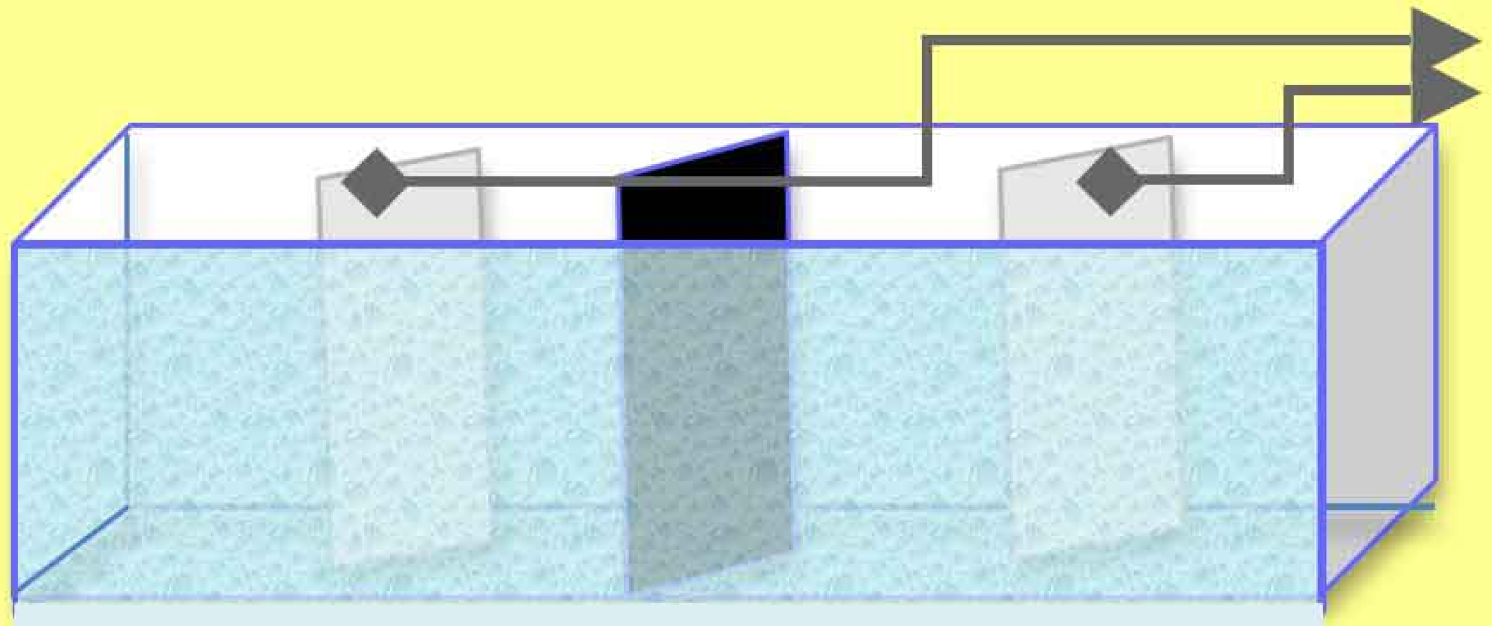
Photovoltaic cell: φῶς light, & "volt": device that converts the light energy into electricity

Requires an external load for power consumption.

1950: Czochralski method: pure crystalline silicon.

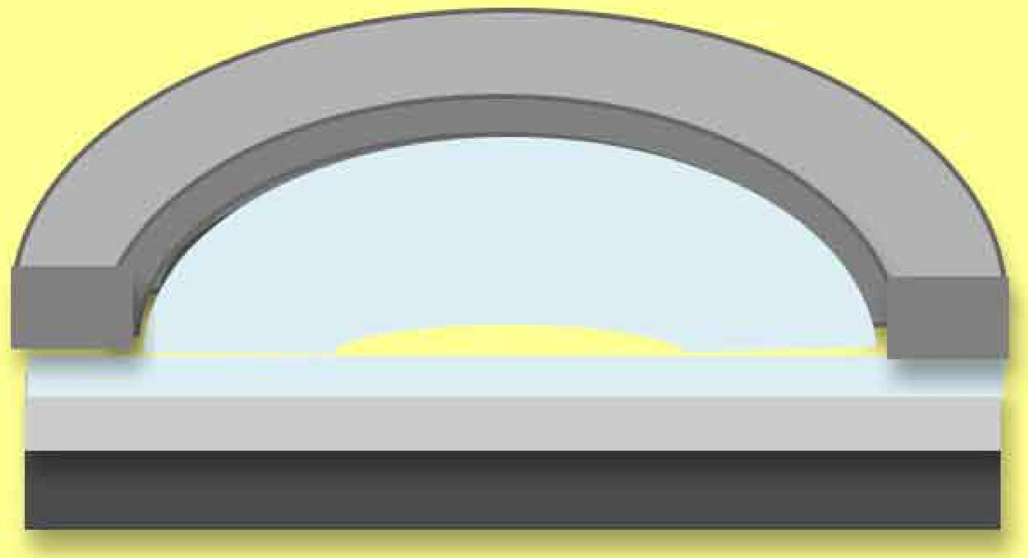
1954: Bell Telephone Labs: **silicon photovoltaic cell**

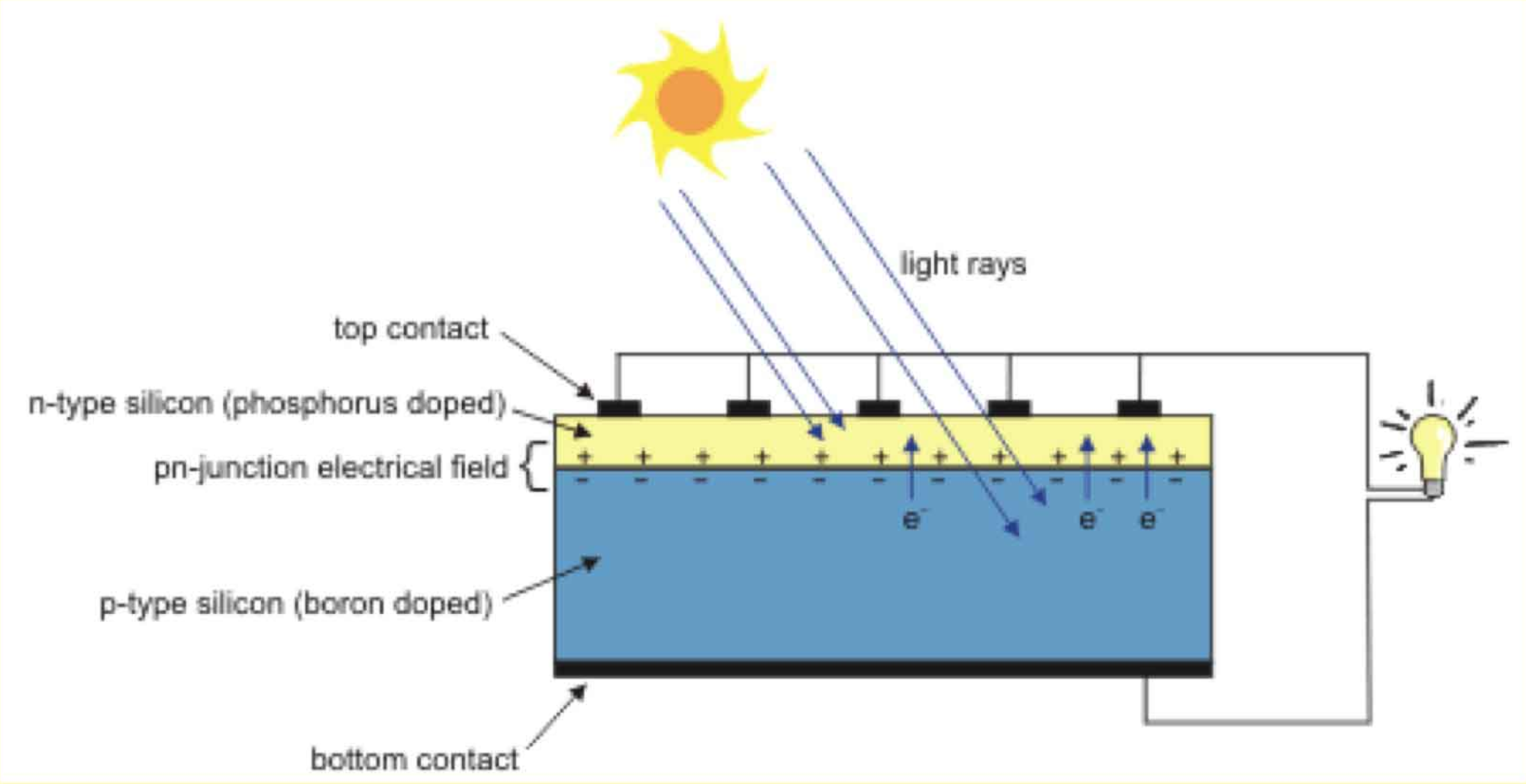




Ag^+Cl^- elctrodes in acidic bath

Selenium photocell:
A: negative contact ring
B: Transparent electrically-conductive layer;
C: Thin μm layer of metallic selenium
D: Steel support plate (+ve) contact
response close to that of the human eye: Photographer's light meter.





Phototropic self directing robot

1912: Electric dog: ancestor of phototropic robots,

John Hammond, Jr. & Ben Miessner

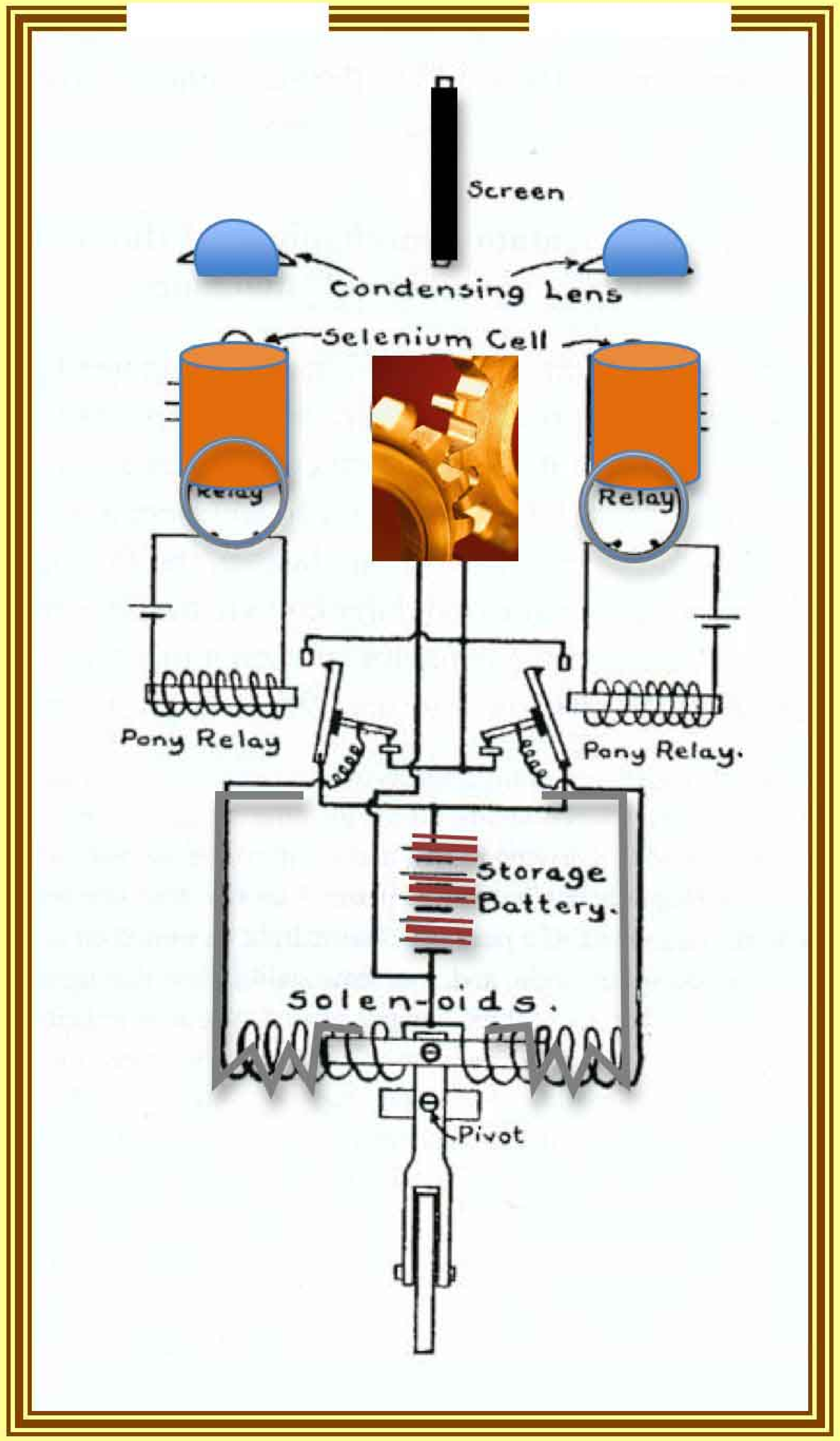
In dark Selenium cell '**eye**' received insufficient light to reduce its resistance No power to the Motor or the Solenoids and the Dog would remain OFF.

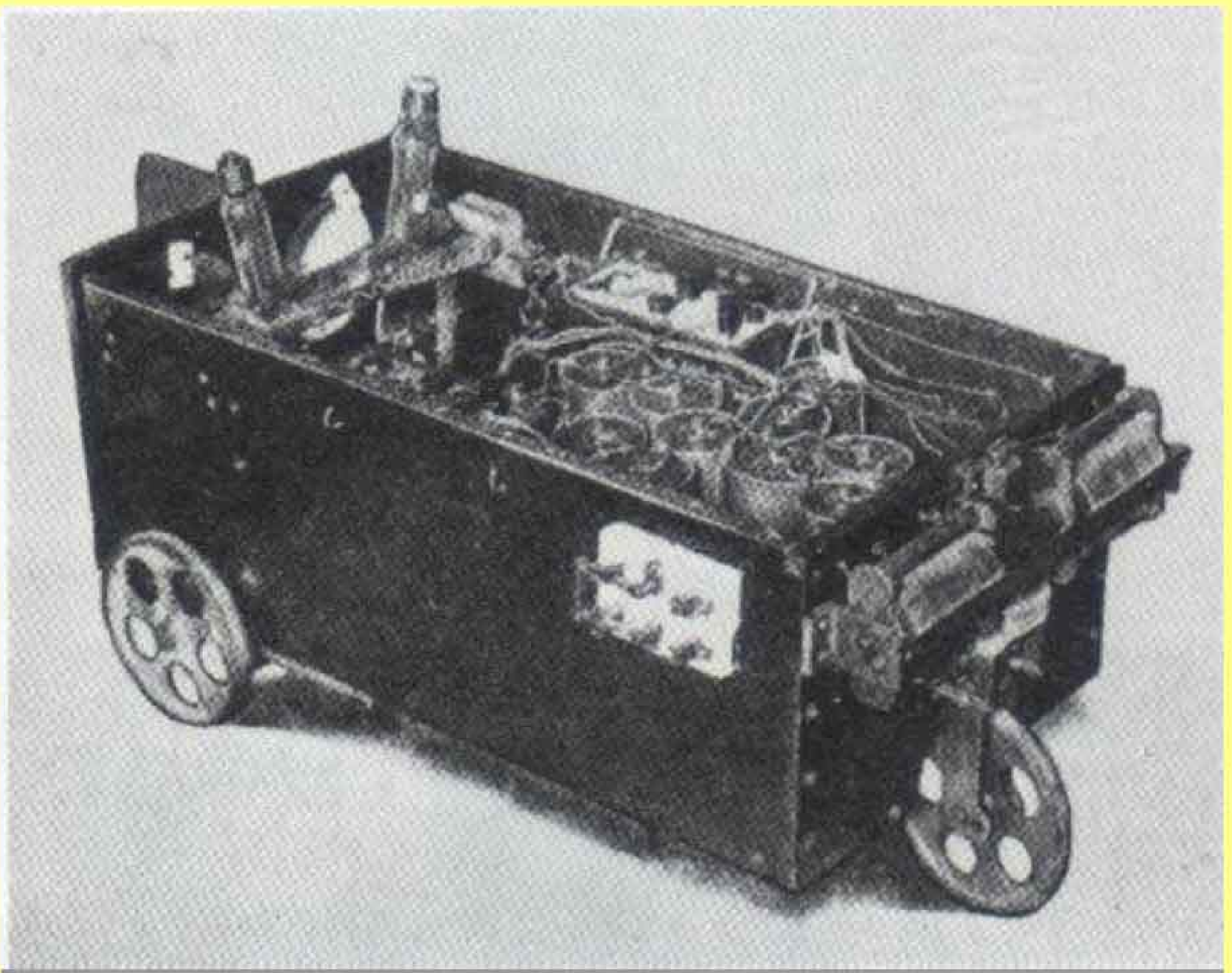
If one 'eye' received light: its Relay operated, activating the Pony Relay, then power supplied to the Motor, and to the Solenoid on the opposite side:

The Robot Dog moves forward steering towards the light.

If both 'eyes' received sufficient light then power would be supplied to the Motor

But the Solenoids would be OFF so the Dog would steer straight ahead.





Radiodynamics: *The Wireless Control of Torpedoes and Other Mechanisms* [Miessner, 1916]
Hammond's dirigible torpedo is fitted with similar apparatus
If the enemy turns search light on, it will automatically be guided toward them

Bristol Tortoises
Machina speculatrix
Elmer and *Elsie*

1948, **Grey Walter** Neurophysiologist;

Tortoises: Slow, autonomous machines

3-wheeled phototaxis, to a recharging station when low on battery power.

Avoided bumping into objects

Adding simple circuits enabled conditioned behaviour

A leap in robotics because they operated without preset directions

1951: three new tortoises were displayed at the Festival of Britain auctioned off

Owen Holland Burden Institute

Precursor of BEAM robotics

***B**iology, **E**lectronics, **A**esthetics, and **M**echanics*

Analog Robot: uses analog circuitry for a simple goal: finding more light or responding to sound

Just a few analogue circuits Not a microprocessor

Phototropes, audiotropes, thermotropes

Sit, squirm, crawl, jump, swim, fly.

iRobot Corporation: Roombas cleaning rooms, Looj for gutters and Mirra for pools.

Roomba is able to autonomously vacuum the floor while navigating and avoiding obstacles

Squee

1951: Squee: the Robot Squirrel.

Designed and constructed in 1951 by Edmund C. Berkeley & Jack Koff

Inspired by Walter's tortoise

4 sense organs (two phototubes, two contact switches),

3 acting organs (a drive motor, a steering motor, and a motor which opens and closes the scoop or "hands"),

A small brain of half a dozen relays.

Hunts a tennis ball:

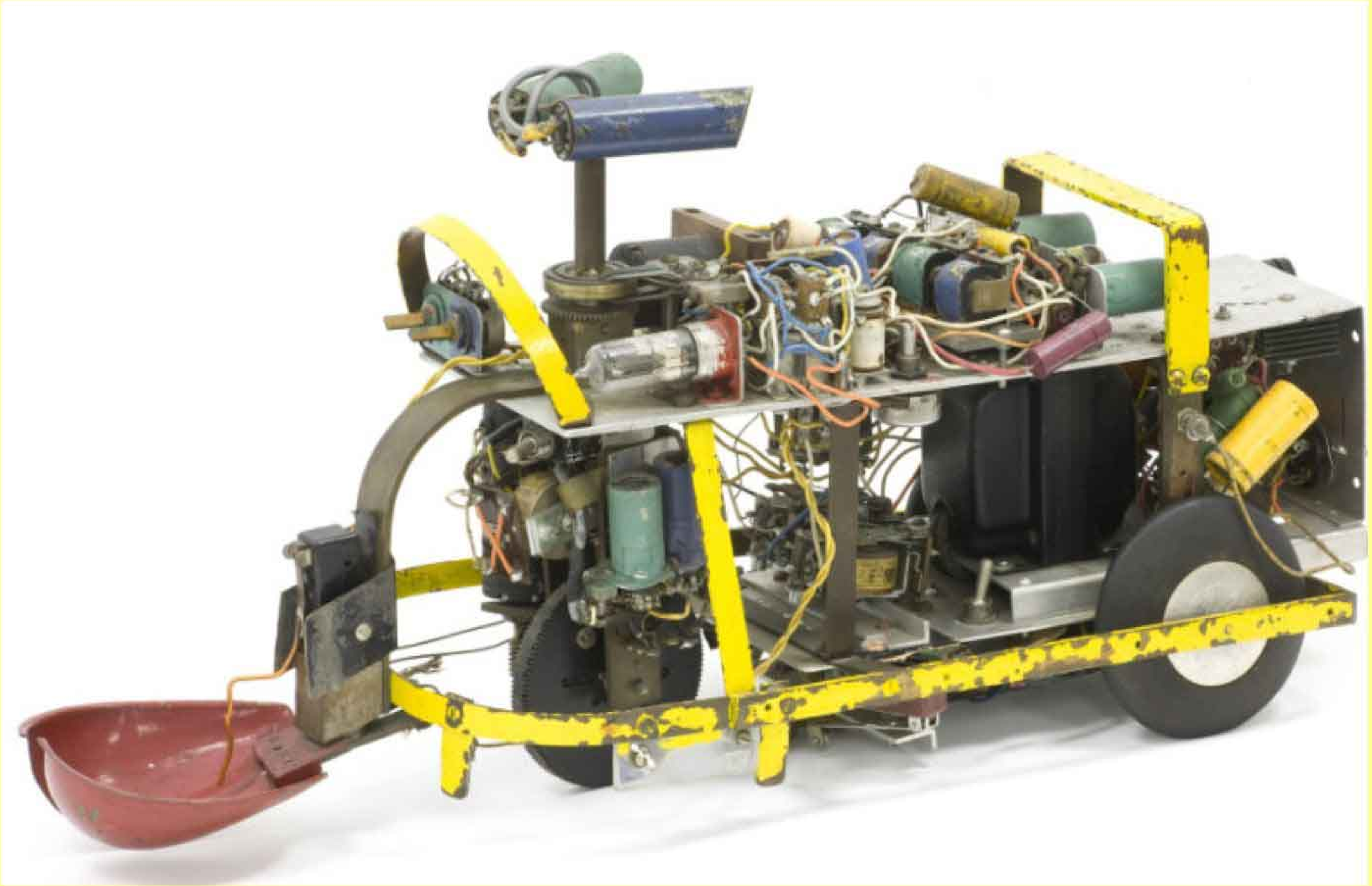
A torch shone at Squee.

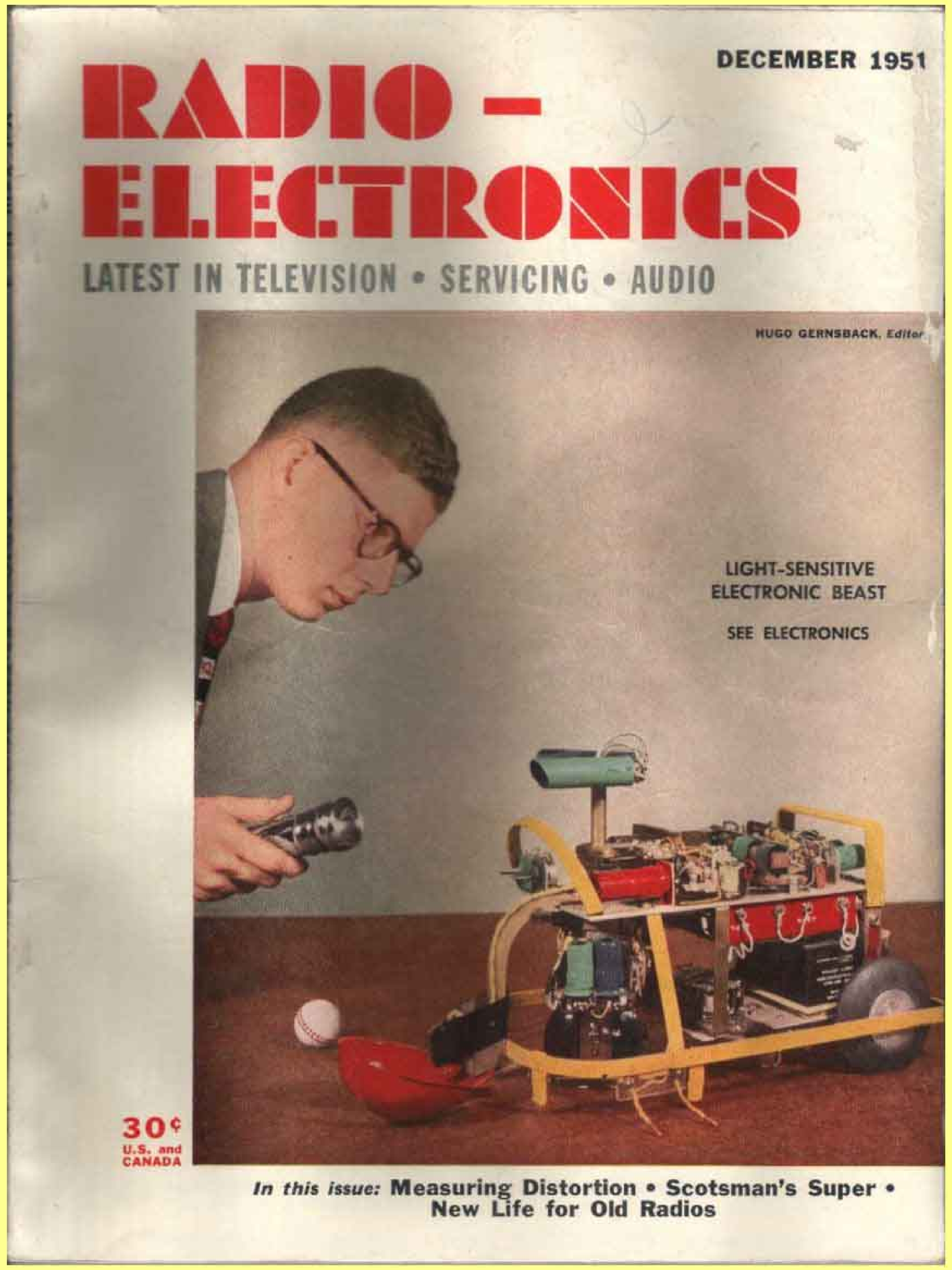
Robot approaches, scoops the ball, ignores the light, takes ball to its nest indicated by a flashing light

Then returns to hunting more "nuts".

Squee was the first robot to be able to carry out a defined task, as opposed to just steer towards light.

First robot to have a manipulator under automatic control.





Industrial Robots

Industrial robots have replaced human beings in a wide variety of industries.

Out perform humans in jobs that require precision, speed, endurance and reliability.

Robots safely perform dirty and dangerous jobs

Modern industrial robots marvels of engineering.

A robot the size of a person can quickly carry heavy loads with a repeatability of +/-0.006”

A basic problem with industrial assembly is a process: **parts feeding**.

Objects/parts required for product assembly stored in a bin.

The assembly process requires a single part to be isolated from the bin of parts.

Robots: repeatability and speed.

They take on monotonous, physically taxing, and even hazardous jobs

Structured environments fixed part presentation.

If there is variability in the way the parts are presented, blind robots need some assistance.

Robot’s guide – machine vision

Machine Vision

A stationary mounted camera, a planar work surface, and a Tray that must be grasped by the robot.

The Tray may be lying flat on that surface and mixed amongst, but not covered by, other items.

1: Acquire a suitable image.

2: "Find" the object of interest (the overall Tray, or the piece of it that must be grabbed.)

3: Determine the object's position

X vs Y

and orientation: **Rz**

4: Translate this location to the robot's co-ordinate system.

5: Send the information to the robot.

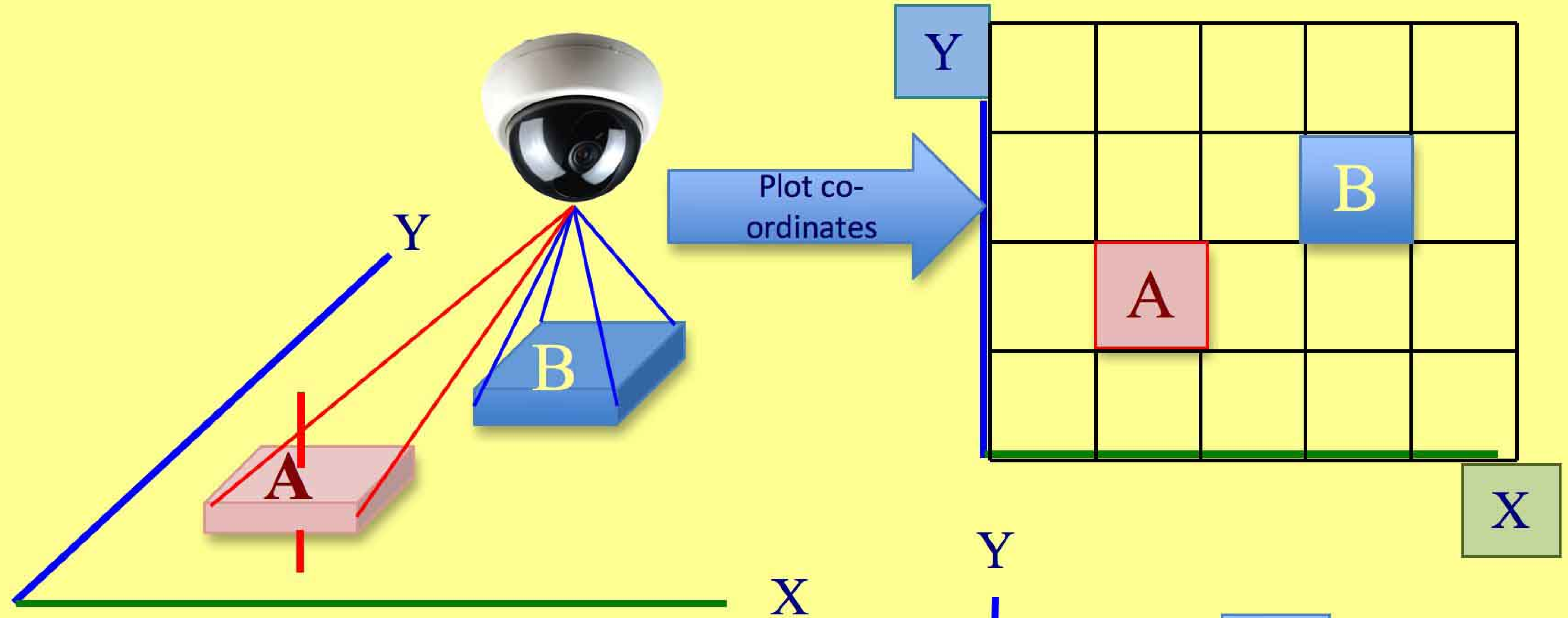
6: Using that information, the robot can then move to the proper position and orientation to grasp the object in a prescribed way.

Machine vision portion (steps #1 through #5) executed within a few hundredths of a second.

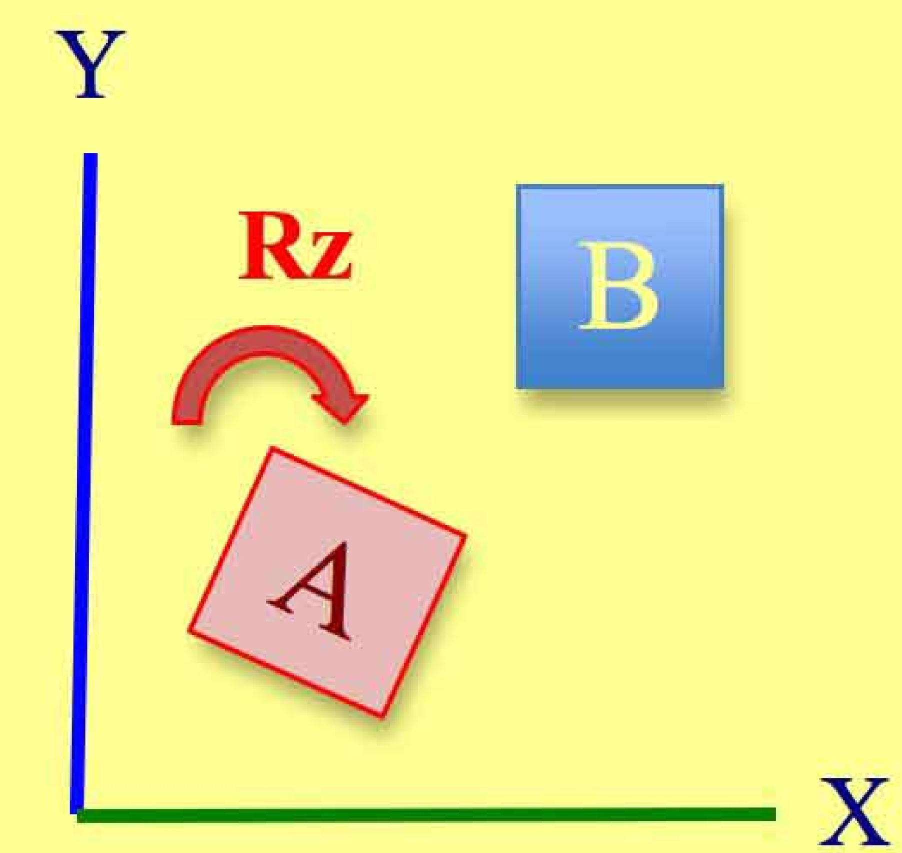
area scan imaging, conventional picture taken and processed all at once.

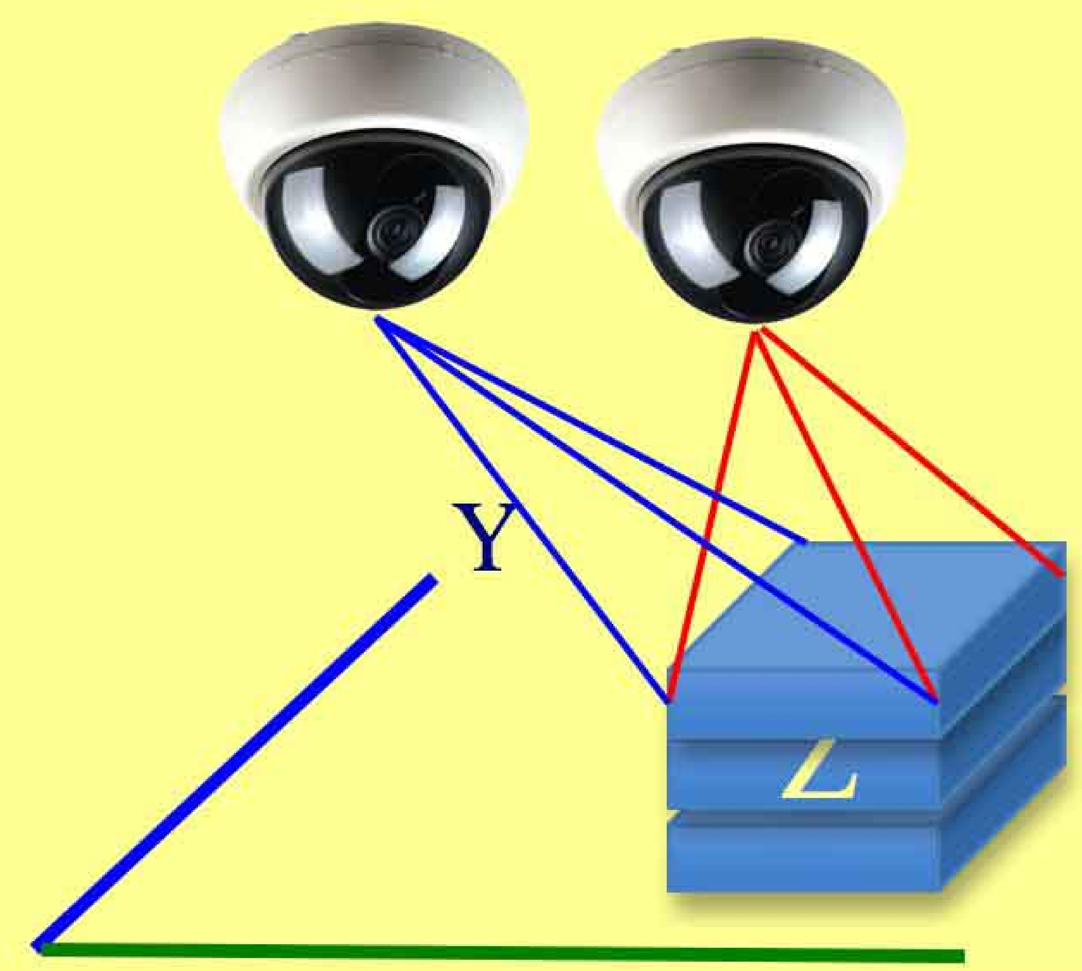
line scan imaging, image is built during motion, one line at a time

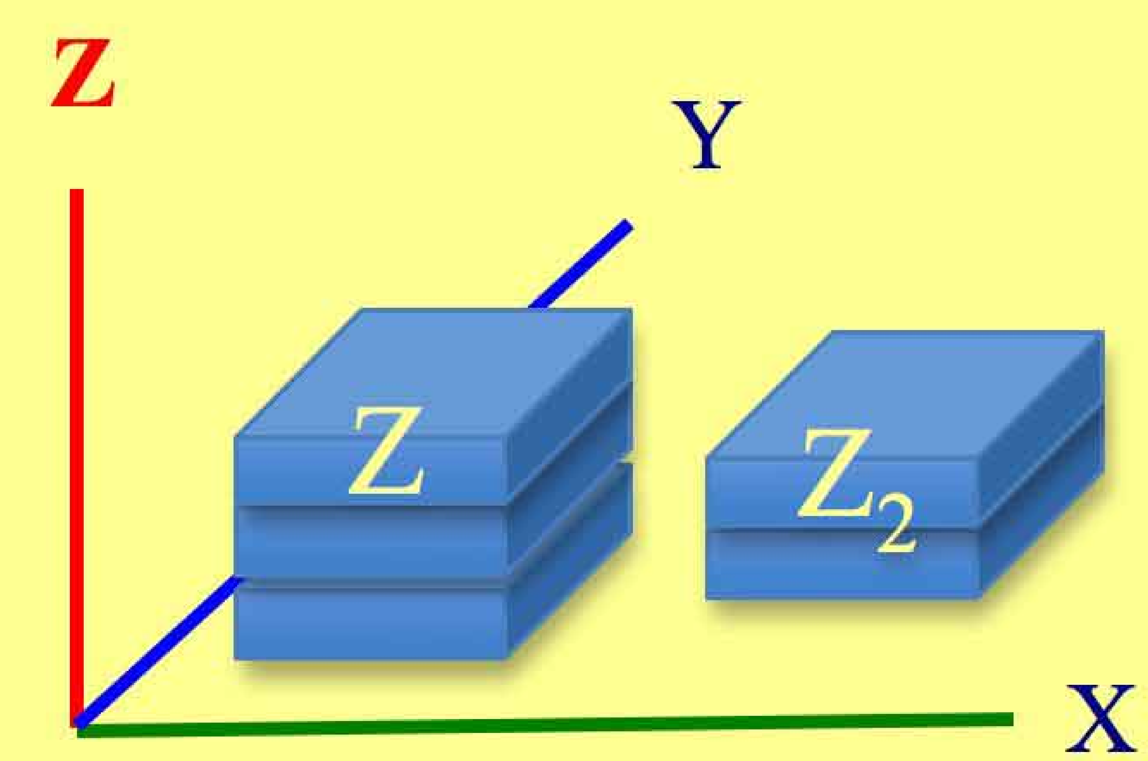
3D profiling, third dimension of an image ("Z") is coded into the value of each pixel of the figure.



2D: Need horizontal (X) and (Y) coordinates. Linear rotation around its center axis (**Rz**). This changes the angle of the object (roll). But there's no tilt. The part remains flat.

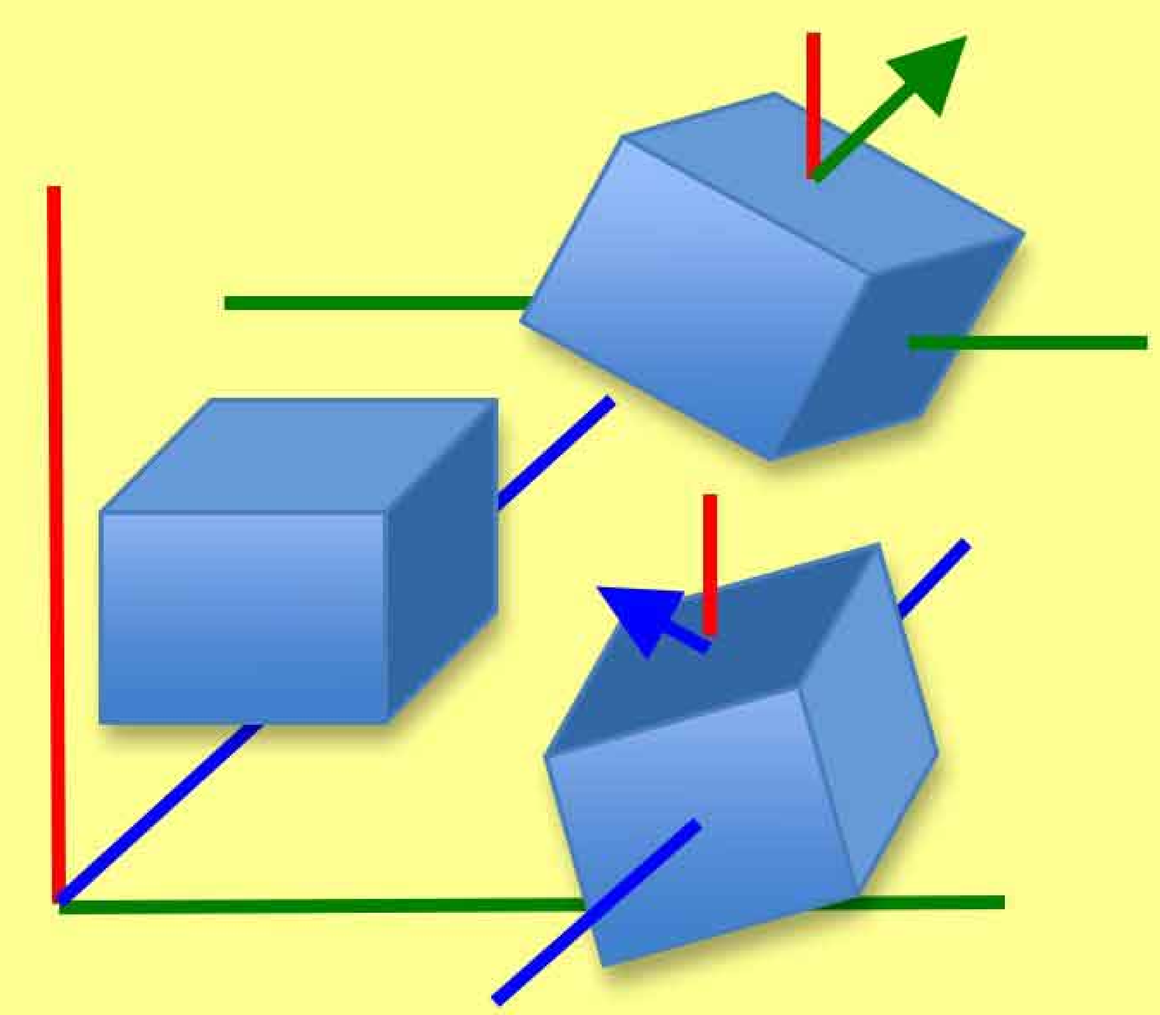






Robot removes top tray the vision system needs to measure the height of the remaining trays

3D: may 'pitch' forward, pointing its nose downward, Rx
tilt left or right, Yaw: Ry.
In 3D applications all six coordinates may come into play, called **six degrees of freedom**.



Machine vision systems

A computer capable an image capture and processing.

5 basic components:

- Illumination,
- Optics,
- Camera,
- Computer
- Software.

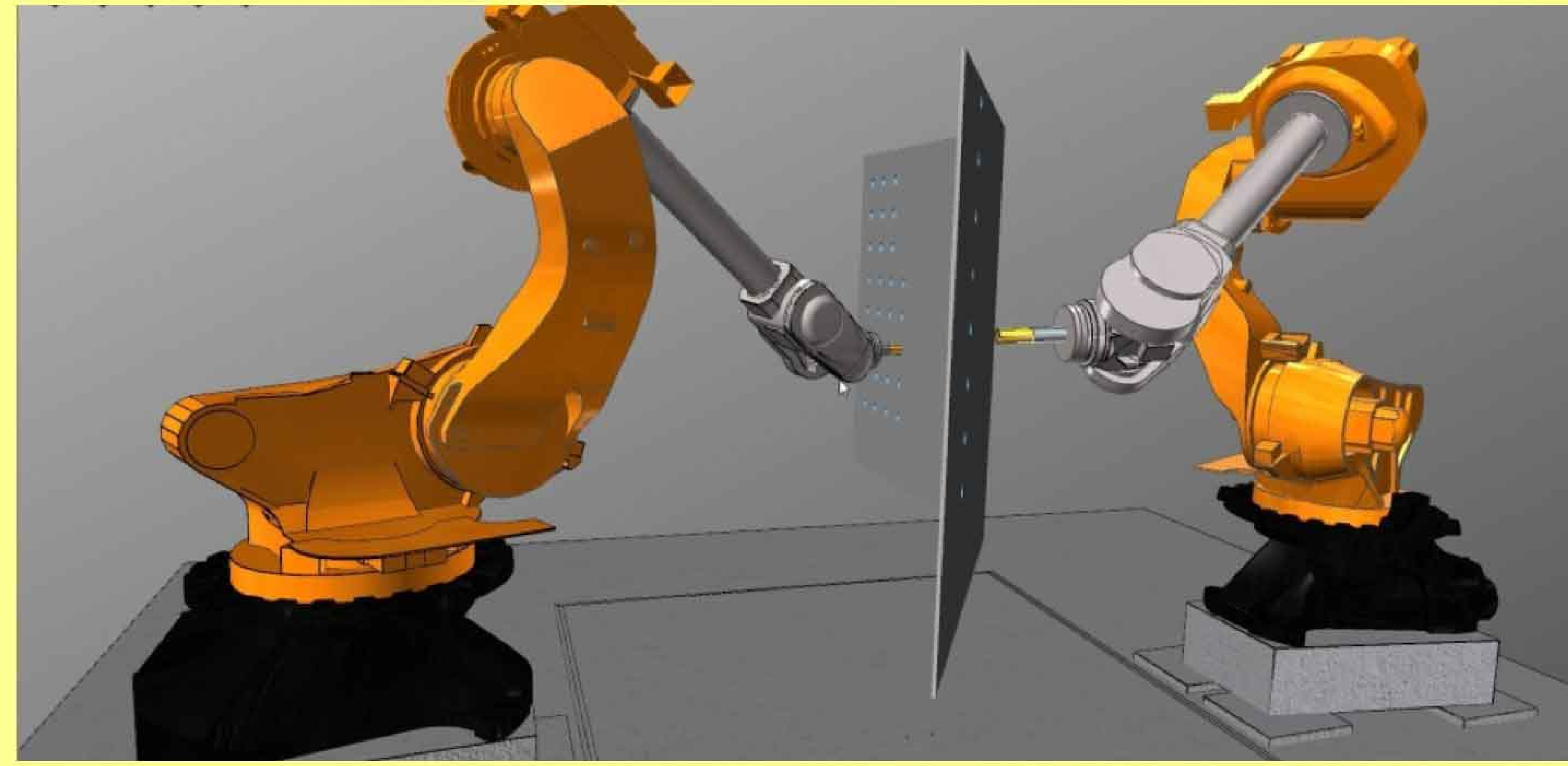


Image is created by the illumination.

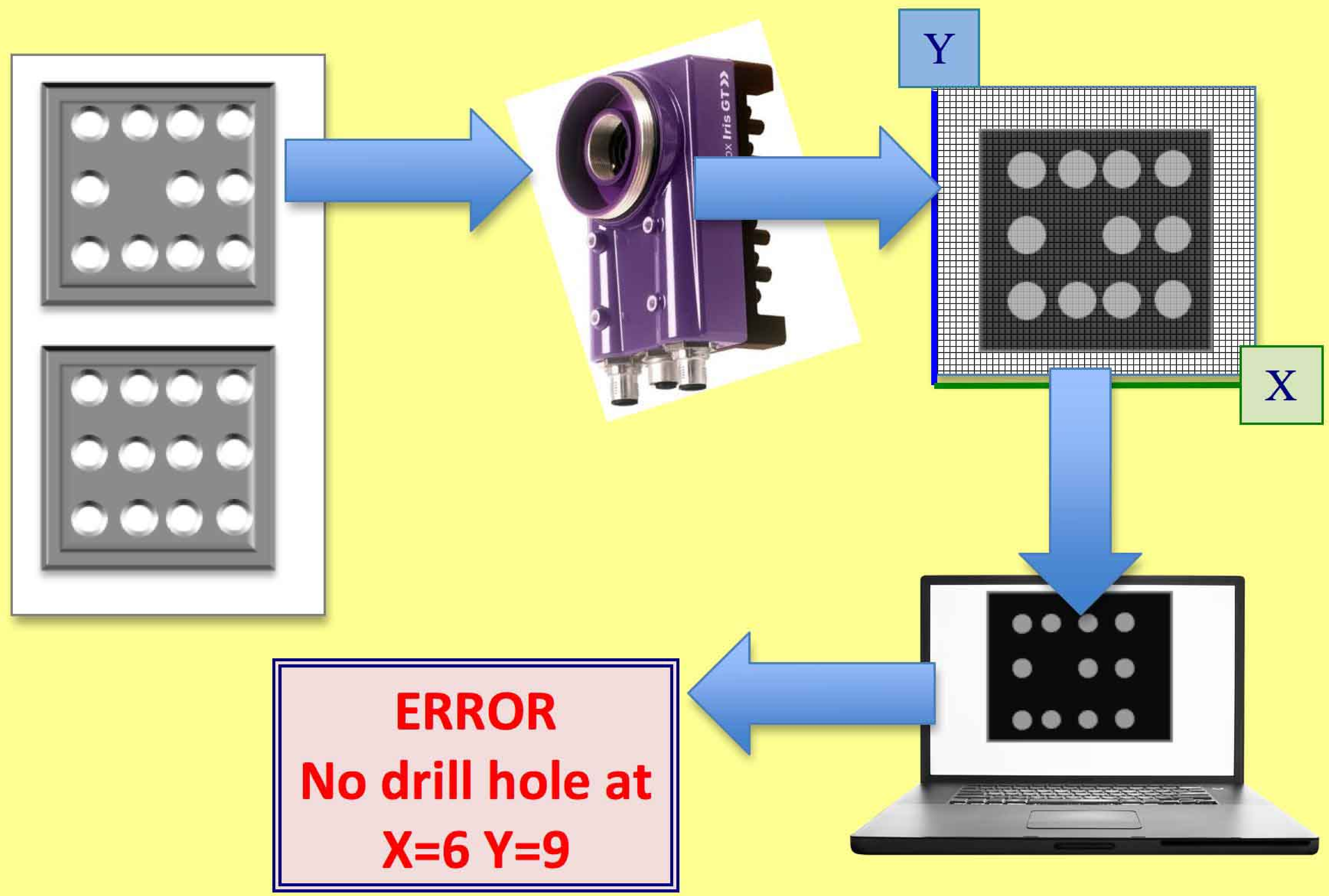
The majority of vision systems are a 2D representation of light reflected from a subject.

Image analysis techniques extract features to aid identification of the object.

Segmentation techniques: used to isolate the object from background scene.

Quantitative measurements of object features allow classification and description of the image.

Used to make decisions, controlling robot arm identifying object/face or navigating an aircraft with the aid of images on flight path.



Camera: Charge Coupled Device

Camera does not create the image:

Transforms optical signals (light) into electrical charge (voltage) and processes (digitizes them) into electronic signal (raw digital image).

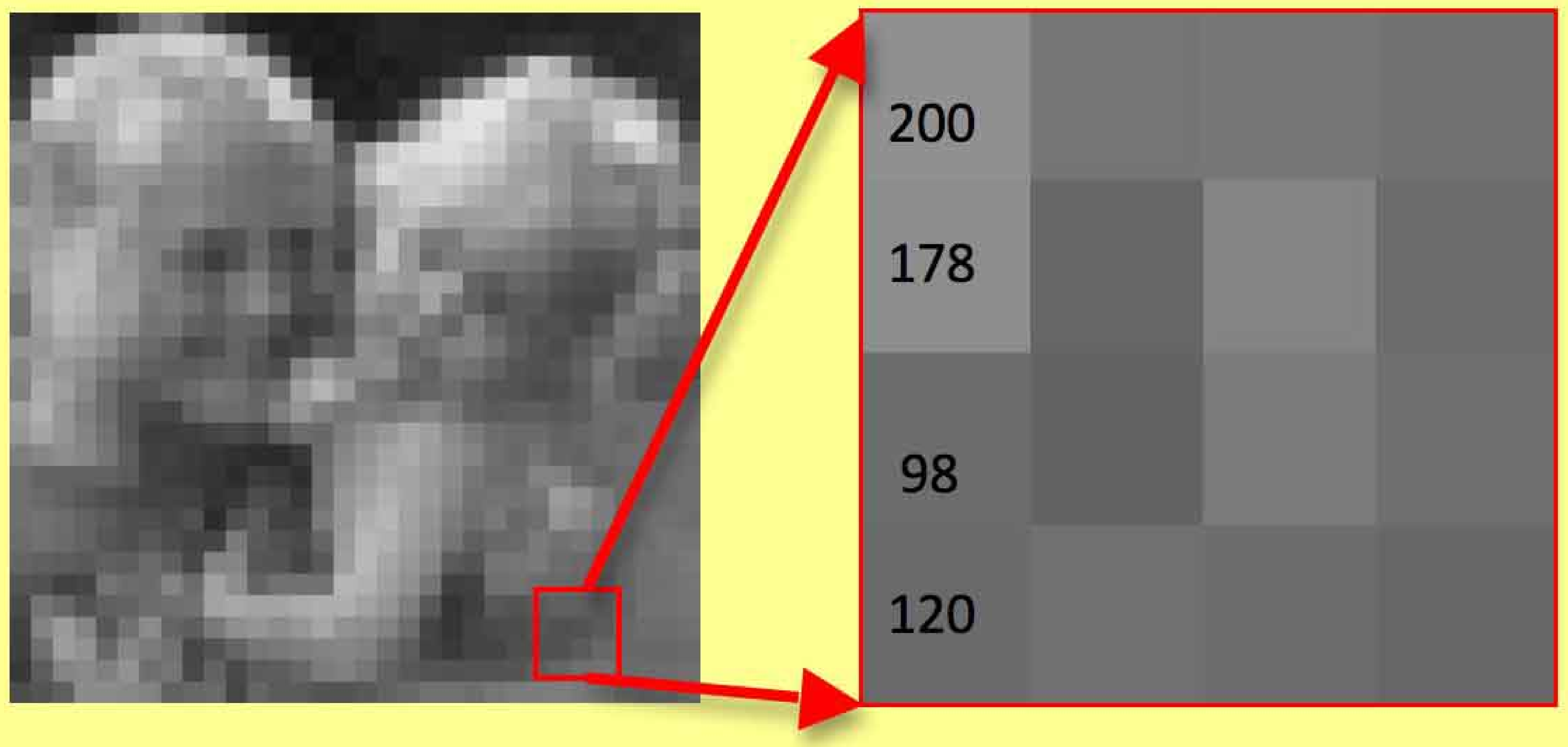
When shutter "closed" the pixels can still be read because they **store their charges**.

When shutter is open, the sensor is collecting light,

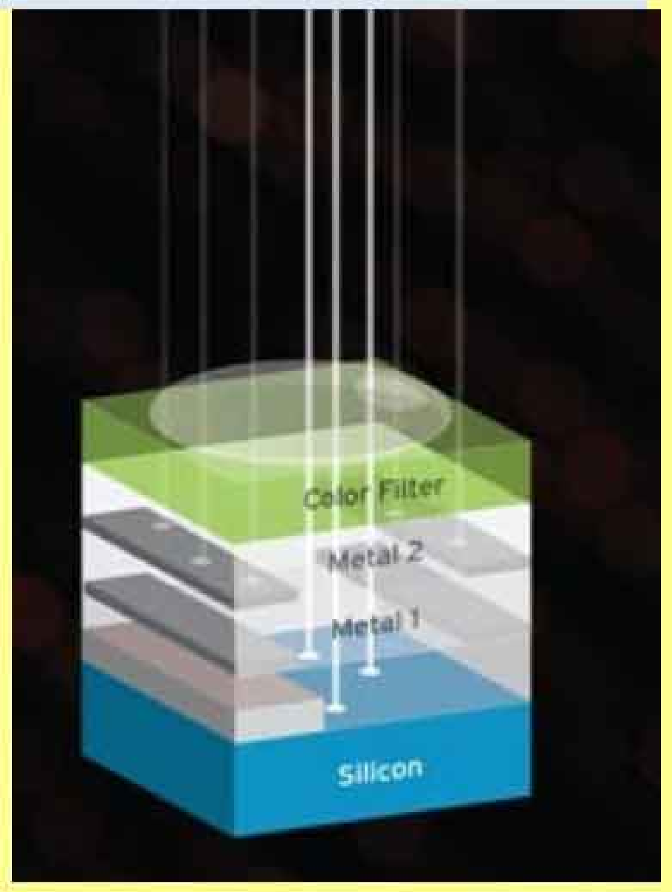
When closed, the Analog Front End reads the pixel charges one by one, dumps any excess charge, and gets the pixels ready for the next frame.

Analog-to-digital converter (ADC) converts pixel's value to digital value by measuring the amount of charge at each photosite

Captures the entire image at the same time and then reads the information after the capture is completed, The result is an image with no motion artifacts.



A typical pixel



Lights, camera, action

There is no image without light. An image is created due to the interaction between an object and photons.
Illumination is a complex technology.
Professional photo studios full of various lights not lots of cameras

Image analysis
Computer vision

Image: A matrix of **PIcture ELementS**

Arranged in columns and rows.

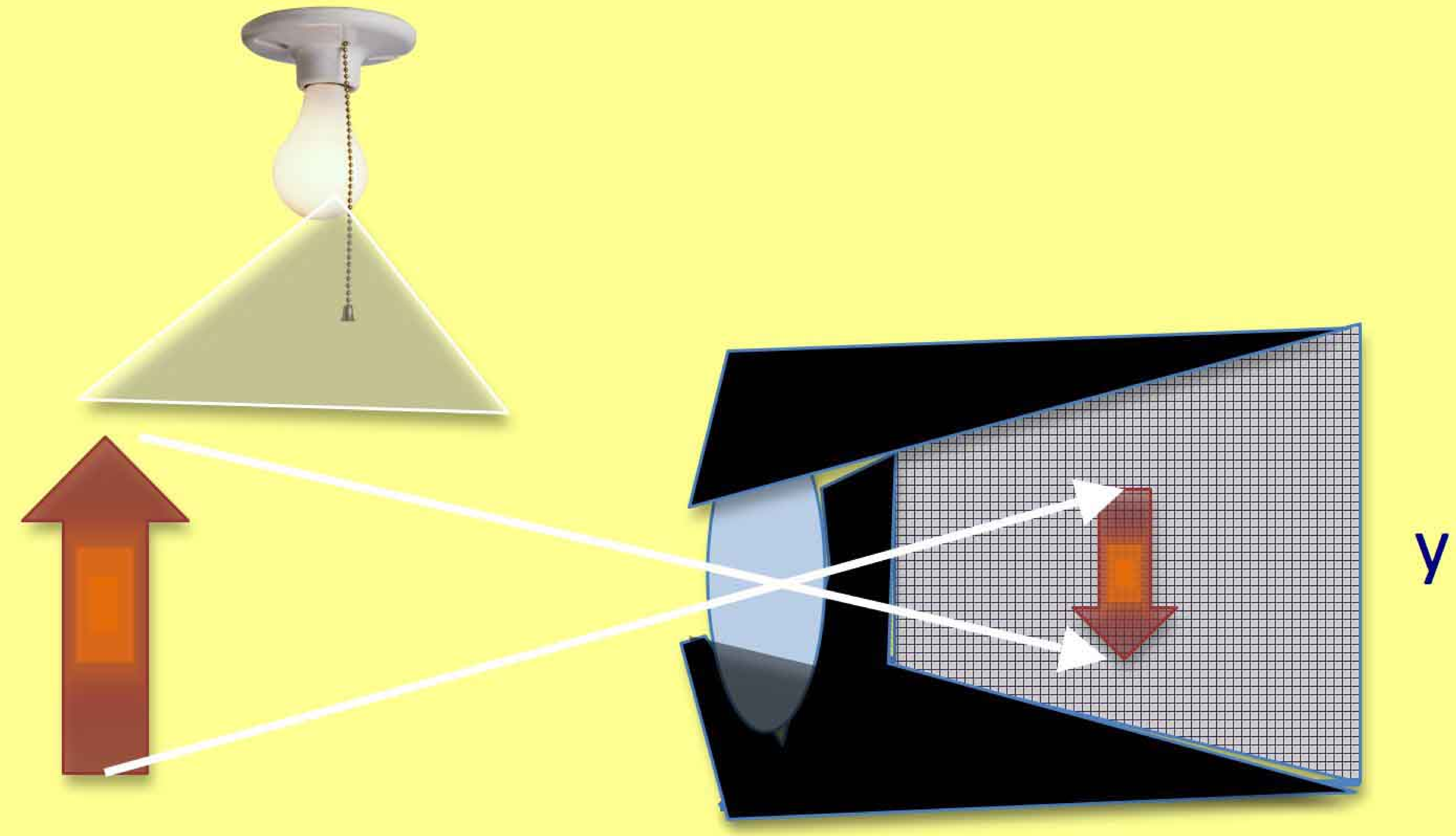
In 8-bit greyscale "black & white" image each pixel assigned intensity from 0 to 255.

A "true colour" image assembled from three greyscale images red, green and blue has 24 bit colour depth = 8 x 8 x 8 bits = 256 x 256 x 256 colours = ~16 million colours.

The image file contains information on every single pixel in that image. Includes two things: Amount of reflectance in RGB channels (colour)

And location of the pixel

Each pixel stores colour information store it in either 3 components, (Red, Green, Blue), or 4 components, CMYK (Cyan, Magenta, Yellow, blacK).



Bits are bundled into 8-bit collections, **bytes**.
Why are there 8 bits in a byte?
Agreed on through trial and error over the past 50 years.
With 8 bits in a byte, you can represent 256 values ranging from 0 to 255

0 = 00000000
1 = 00000001
2 = 00000010
...
254 = 11111110
255 = 11111111

Pixels and Resolution

The smallest element of a picture is a **pixel**.

Tiny little dots of colour on the screen,

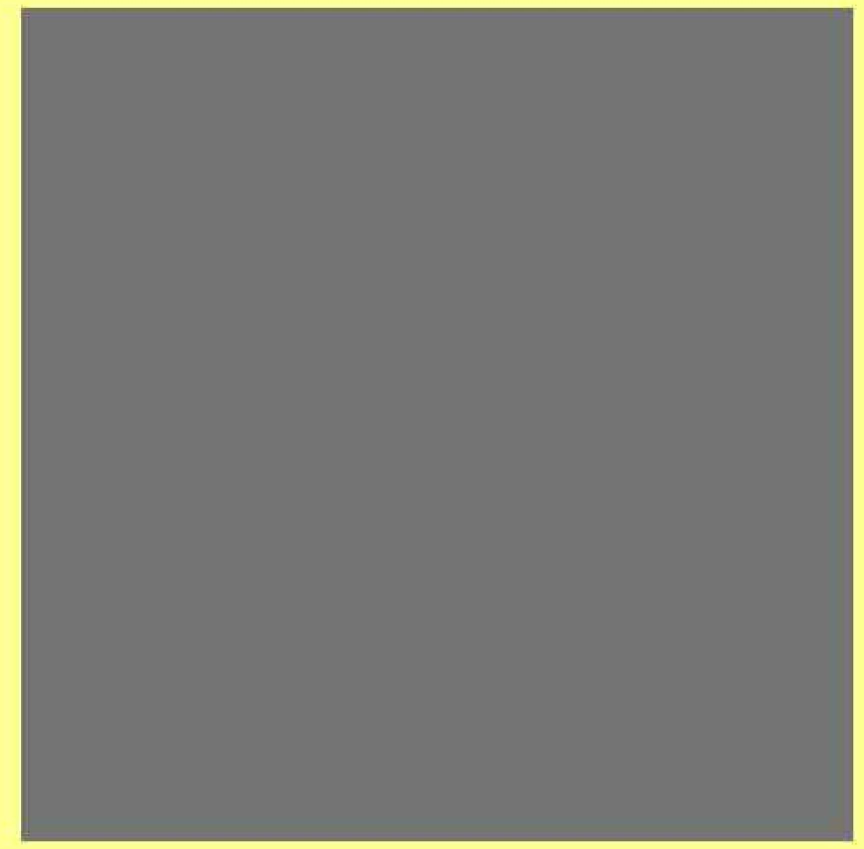
Number of pixels per size of the image, resolution.

dpi (dots (pixels) per square inch)

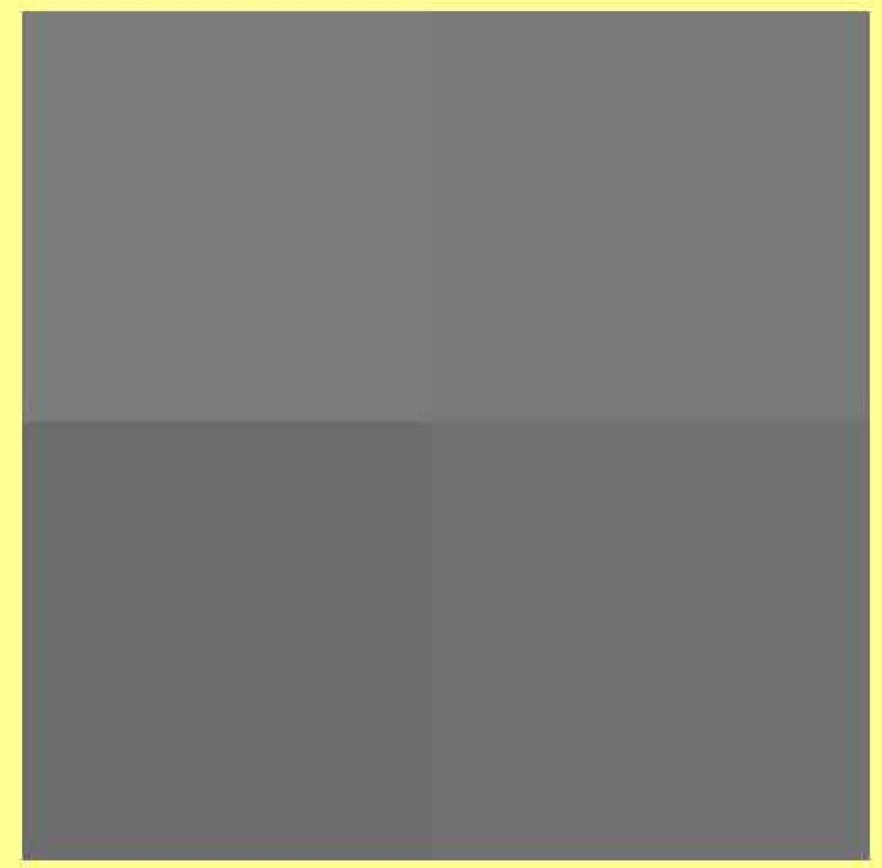
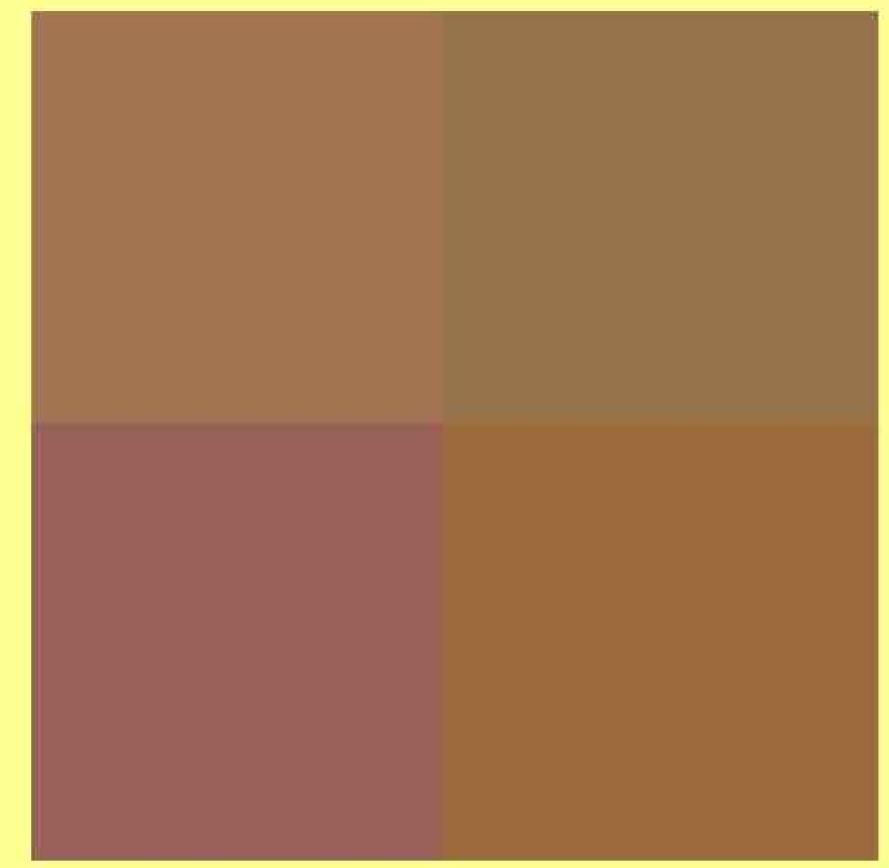
A higher resolution more pixels in a set area, resulting in a higher quality image.

The disadvantage of higher resolution is that it requires more processing power to analyze an image.

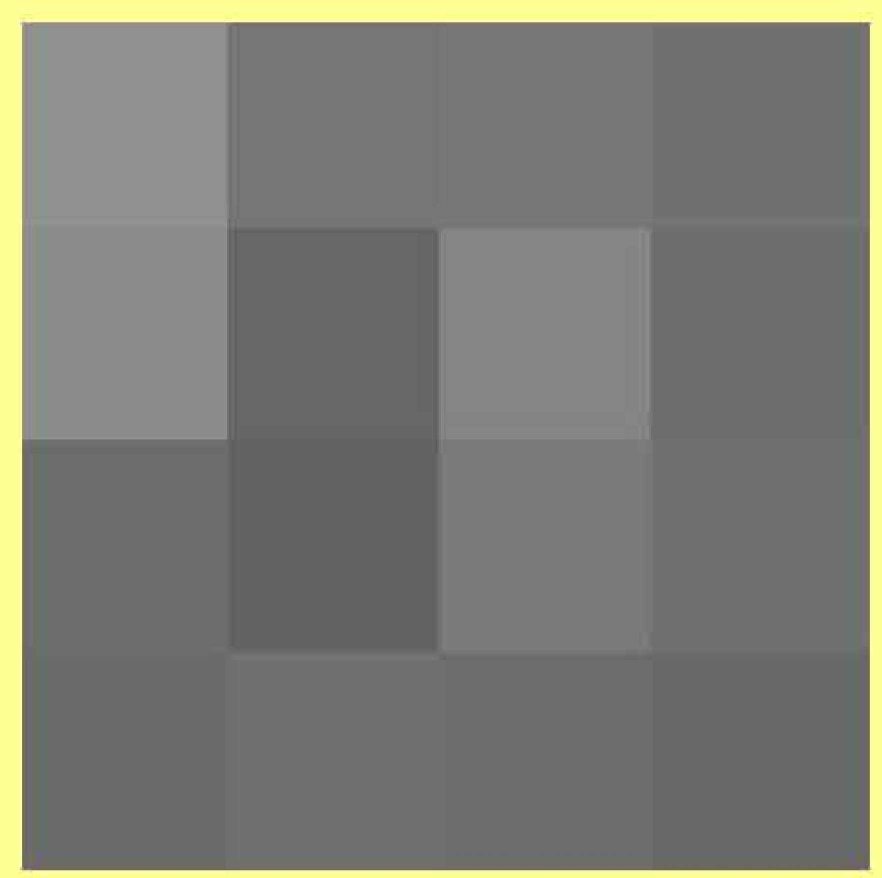
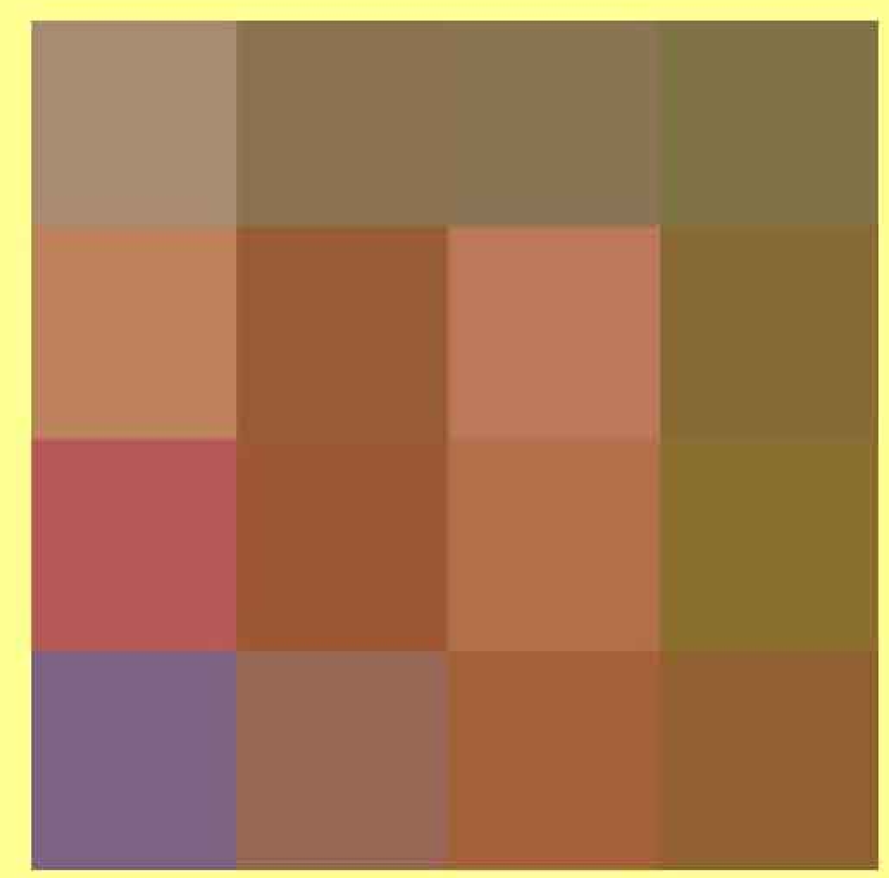
When programming computer vision into a robot, use low resolution.



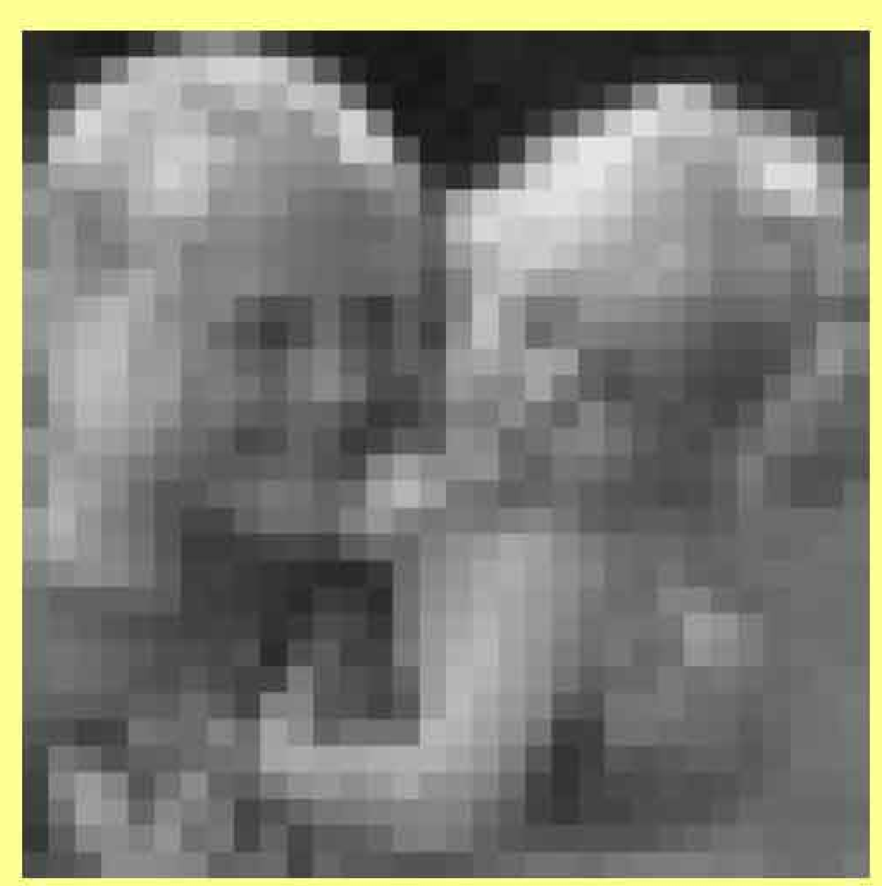

This is a one pixel image; smallest No of pixels to describe an image.
An average the brightness of the scene, cf reflectance exposure meter.
Average of the sum of the colour channels
John Henshall epi-centre.com

4 pixel image

doubling the resolution of an image requires four times as many pixels
The square law
4 x 4 pixel image




number of pixels quadruples -- from 256 to 1,024 -- filesize needed to store this image uncompressed in the computer jumps from 768 to 3,072 bytes.
everything in a digital image – even curves of a face must be described by a series of squares.

Automatons the first computers

C9th: 'Abbasid palaces automata displayed

al-Jazari's 1136-1206: *The Book of Knowledge of Ingenious Mechanical Devices: Clocks,* programmable automata drum machine with pegs operate levers

C14th: **Hongwu:** Founder of Ming Dynasty (r. 1368–1398) peasant led revolt against Mongol dynasty

Destroying Khanbaliq (Beijing) previous Yuan Dynasty, Mechanical water driven tiger automatons

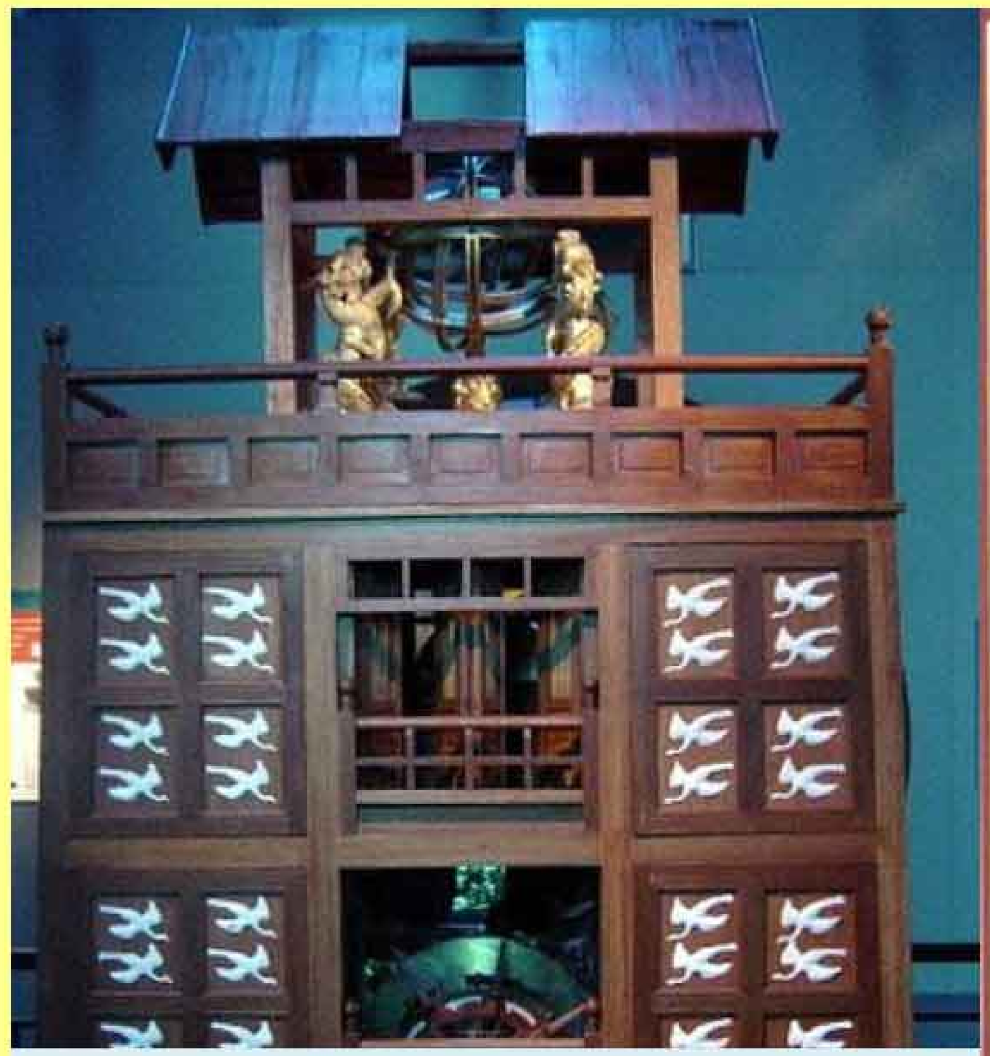
1386: Salisbury oldest working clock in the world.

1392: Wells Astronomical clock

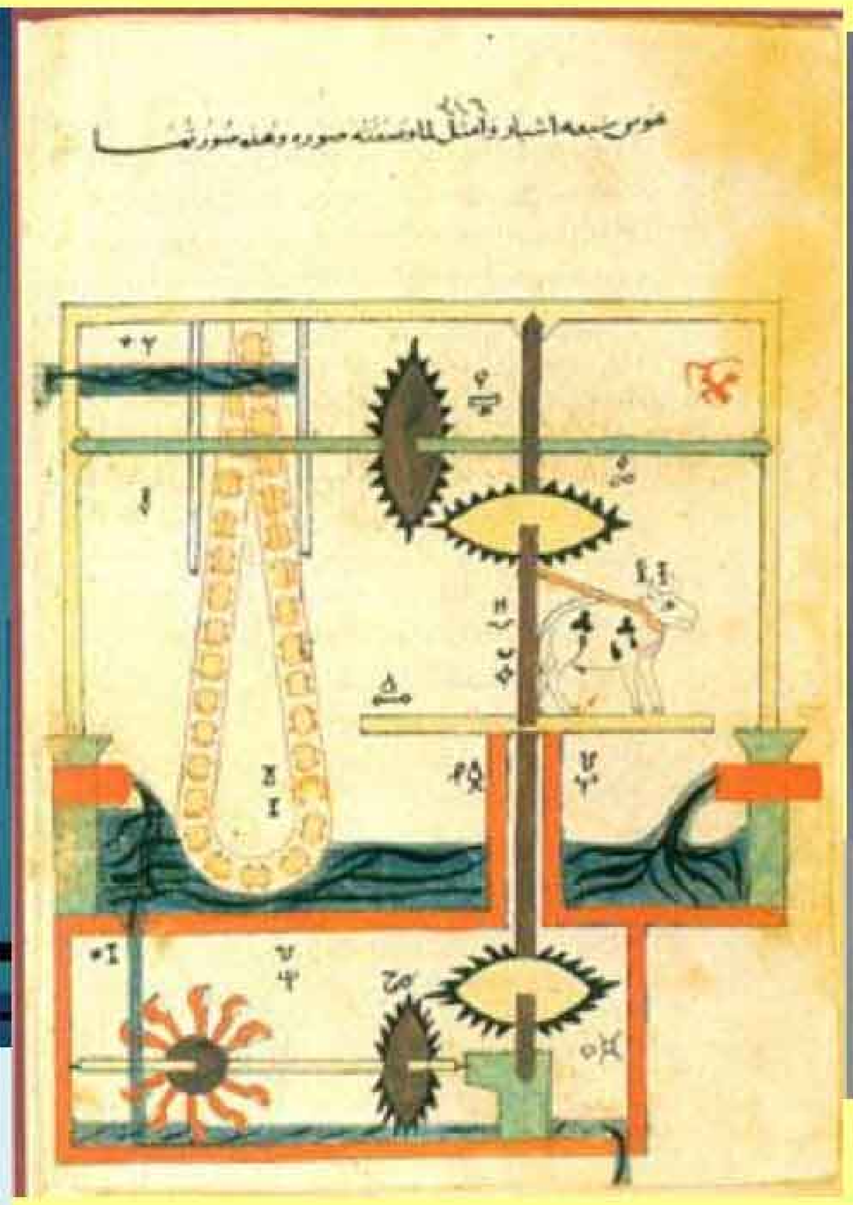
Giovanni Fontana (c1395 – c1455) Venetian physician and engineer University of Padua ***Bellicorum instrumentorum*** *liber*.

siege engines a magic lantern to project images onto walls; rocket-propelled bird, fish, and rabbit

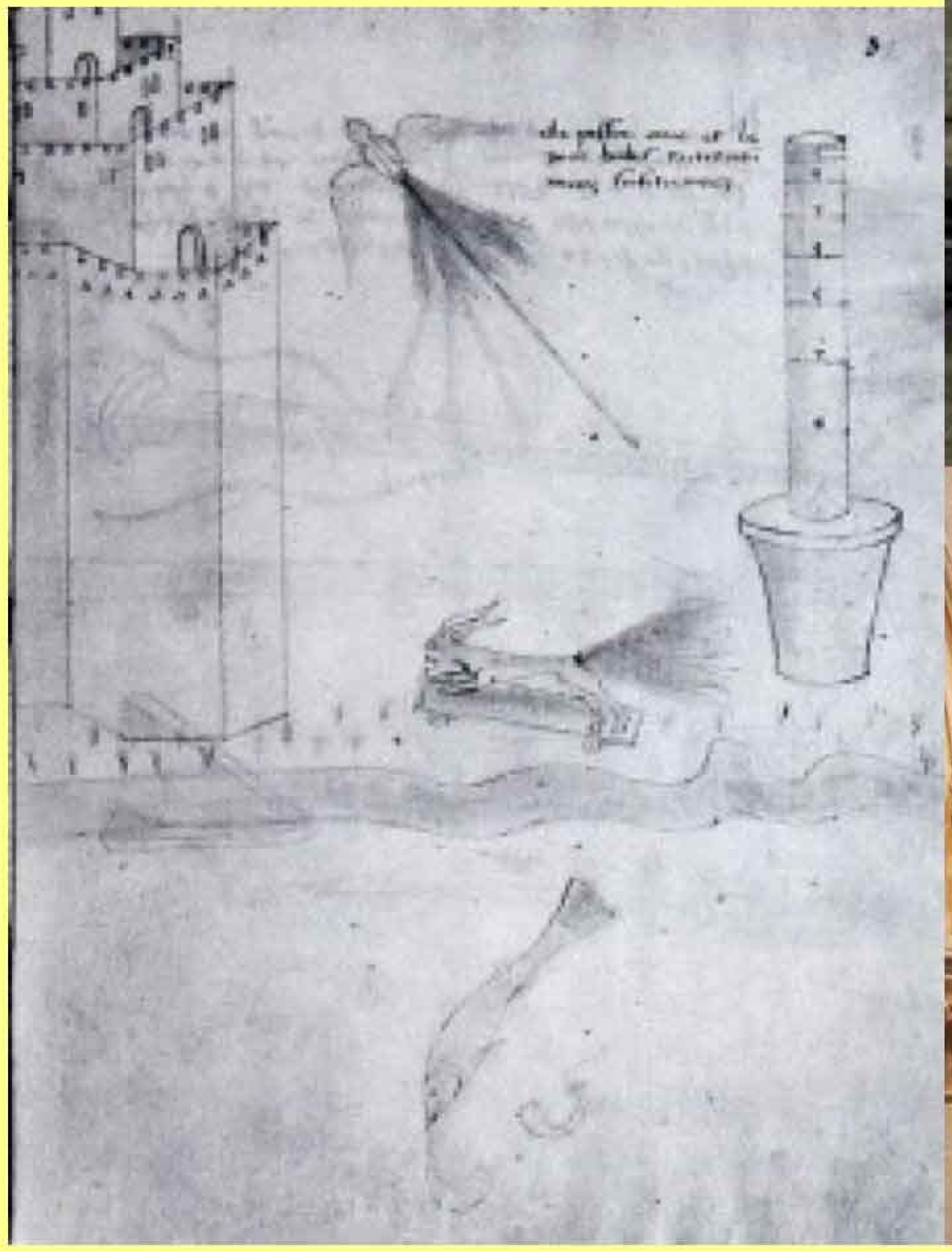
C16-18th: clockwork automata Goldsmiths of the Free Imperial Cities of central Europe

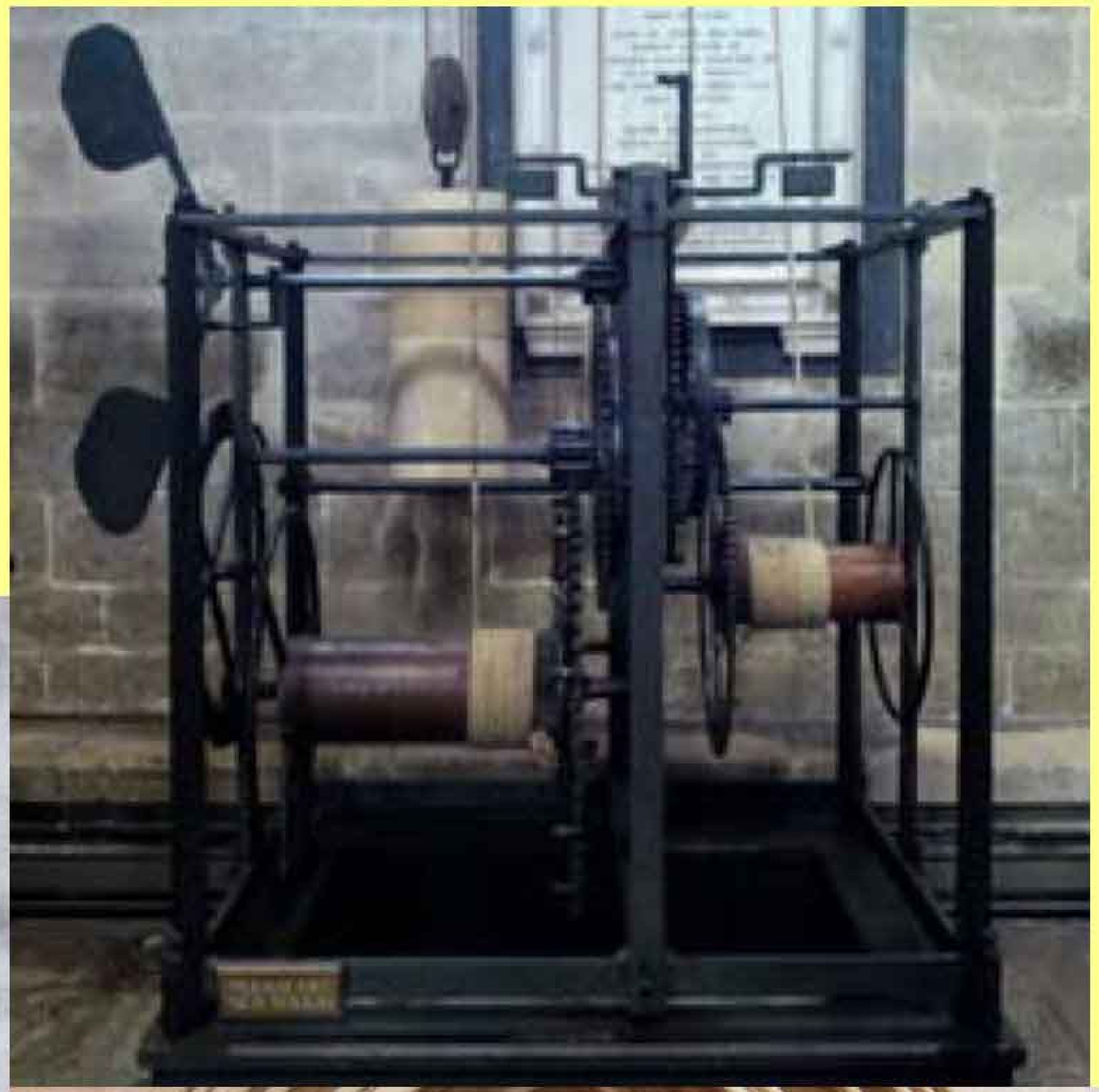


C11th: Su Song's Astronomical Clock Tower, Kaifeng, China. driven by a large waterwheel, chain drive, and escapement



Automaton: Germany: 1620





Camera

smart camera

Image capture circuitry with software to extract specific information from the images

Generating event descriptions

Making decisions

Machine vision systems getting smaller, faster and more powerful.....

Once to edit images required framegrabber to capture the image and then software to edit it.

Now the cameras contain a lot of what was previously on the PC and in the software.

Cameras can adjust the frame size, speed etc

More and more intelligence is going into the camera and the framegrabber is dying.

These cameras ubiquitous have functionality of a complete Machine Vision system from 5 yrs ago.

Early smart camera (ca. 1985, in red) with an 8MHz Z80 compared to a modern device: Texas Instruments' C64 @1GHz

XXXXXXX OXOXOXX
XXXXXXX XOXXXOX
XXXXXXX OXXOXXO
XXXXXXX XXOXOOX
XXXXXXX OXXOXXX
XXXXXXX XOXXXOX
XXXXXXX OXXOXXO
XXXXXXX XOXXXOX
XXXXXXX XXXOOXX
XXXXXXX XOXXXOX

Counting red X
Harder on right
Parallel processing
Pop out effect
Treisman 1985

Modelling human vision

2D retinal or camera image is ambiguous

"size" and distance of object:

A: angular size (subtended at retina, proportional to field of vision occupied)

B: real physical size.

For human perception concepts distinct.

Angular size of object inversely proportional to distance (Euclid's law).

If the more distant object subtends the same angle perceived as bigger.

The brain tells us (generates a percept) that the upper ball is larger.

Information about distance derived from cues

convergence of the eyes,

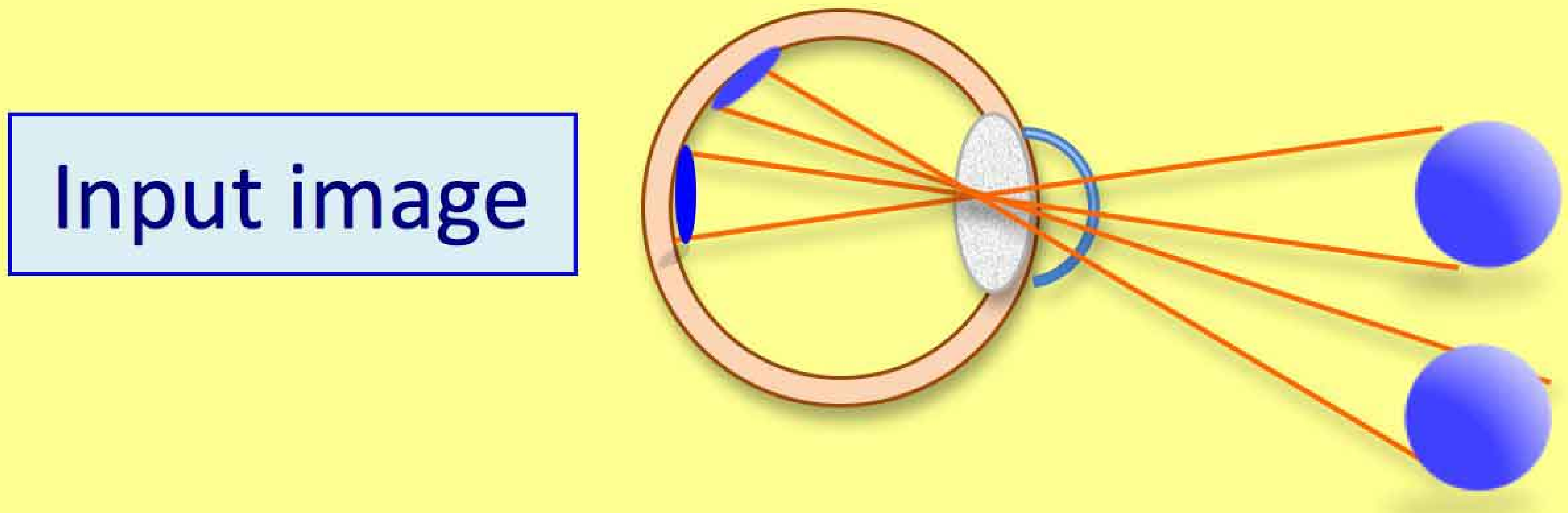
geometrical perspective (many illusion figures having converging lines),

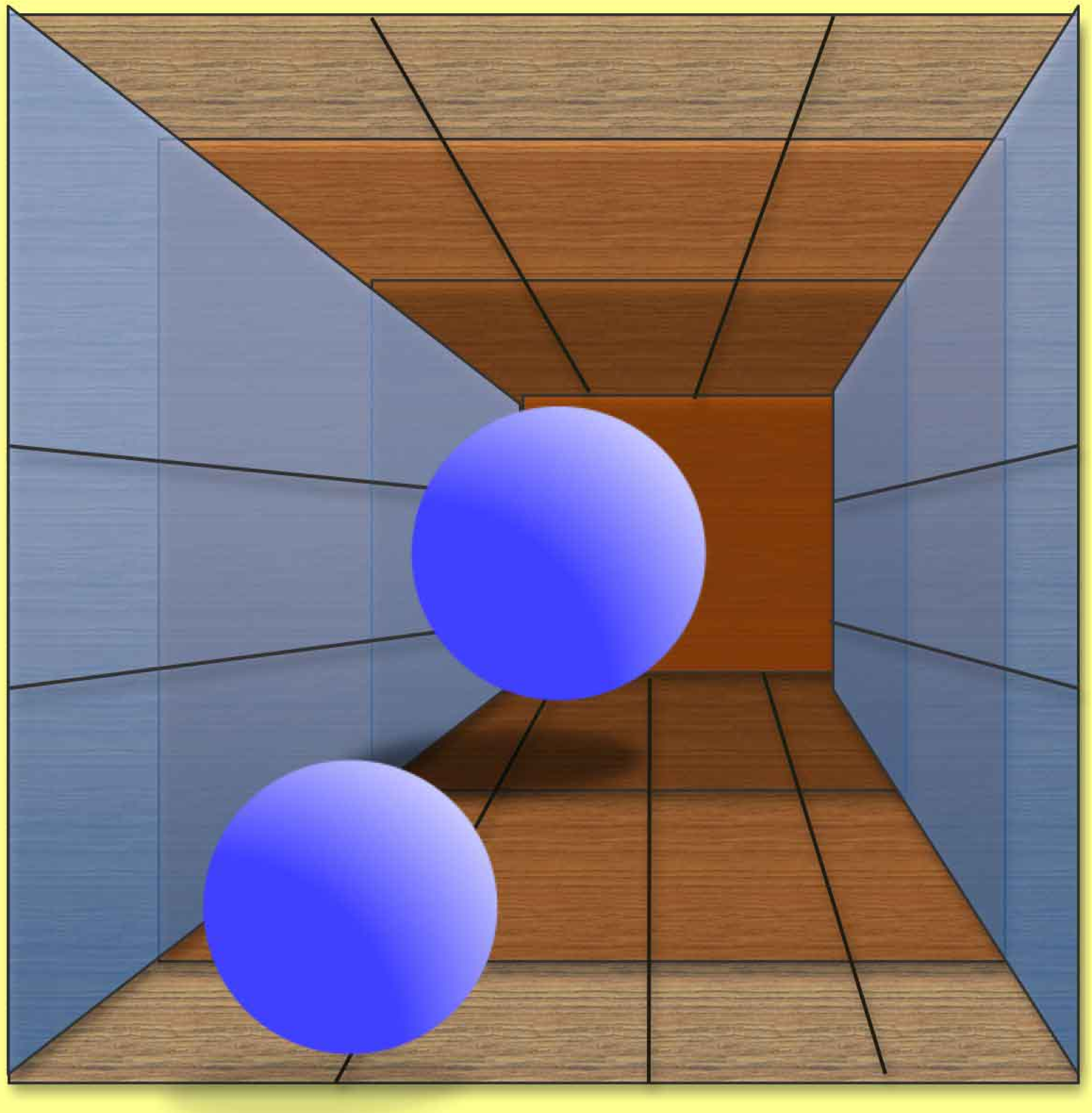
graded texture

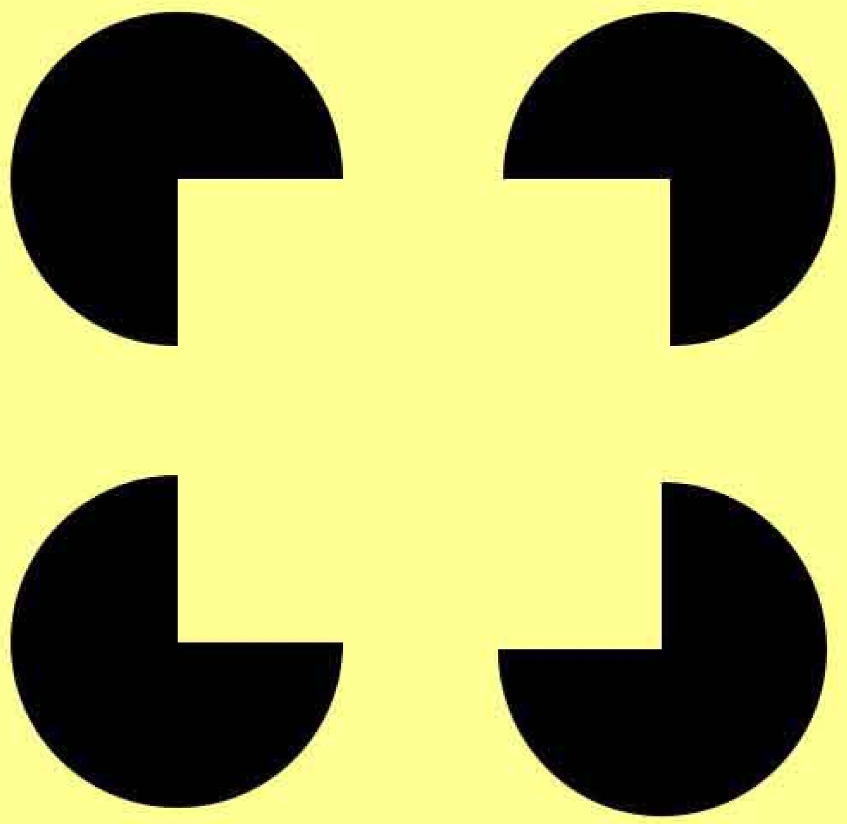
falling of sharpness ('aerial perspective').

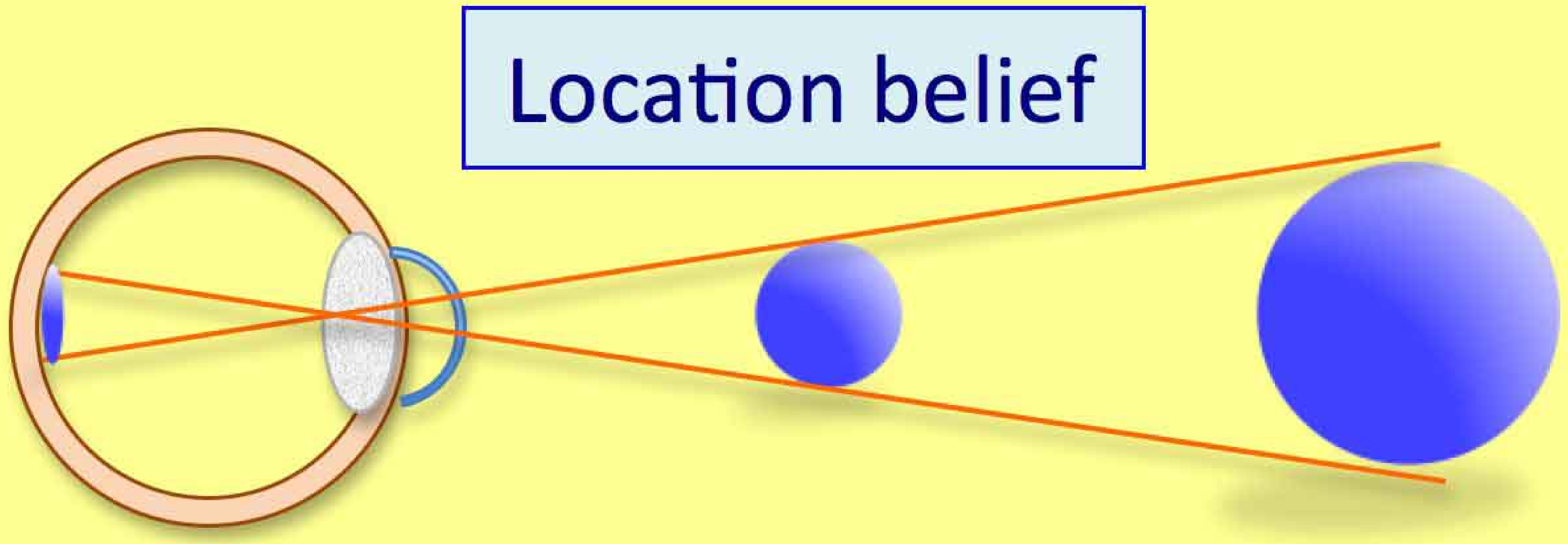
Any cue to distance can set the compensatory size-scaling mechanism

Powerful: cues such as edges don't even have to exist to generate percepts.









Computer Vision

We perceive 3D structure of the world with ease.

Image processing: mathematical analysis of 2D image

Computer vision needs to recover 3D structure of the world from images to to understand the scene

Early attempts at scene understanding involved **extracting edges** and then inferring the 3D structure of an object or a “blocks world” from the topological structure of the 2D lines

1970’s: Several *line labeling* algorithms

1980’s: Better edge detection Canny

Mathematical techniques for recovering 3D shape and appearance of objects in imagery.

stereo matching: computing a partial 3D model of an environment from thousands of partially overlapping photographs

Track moving object against a complex background.

Find and name people in a photograph using a face recognition.

Having a computer interpret an image at the same level as a two-year old (eg, counting all of the animals in a picture) remains elusive

Where’s Wally?

Where’s Molly

Feature Extraction

Mobile robot finds what is there and where it is by taking measurements with its sensors

Measurements have error, and uncertainty.

Feature extraction: uses uncertain data from sensor inputs to guide robot behavior

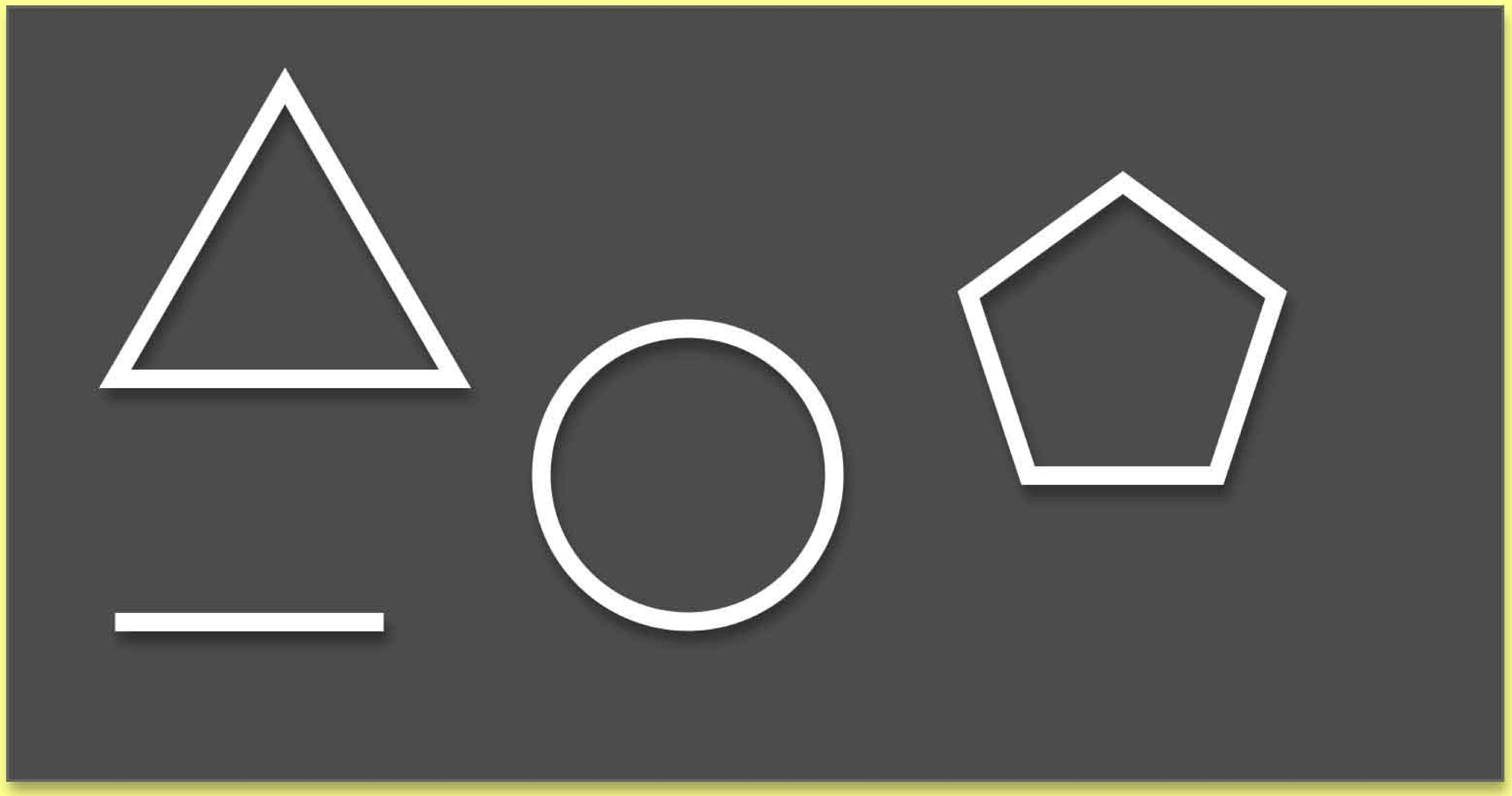
low-level features (geometric primitives)

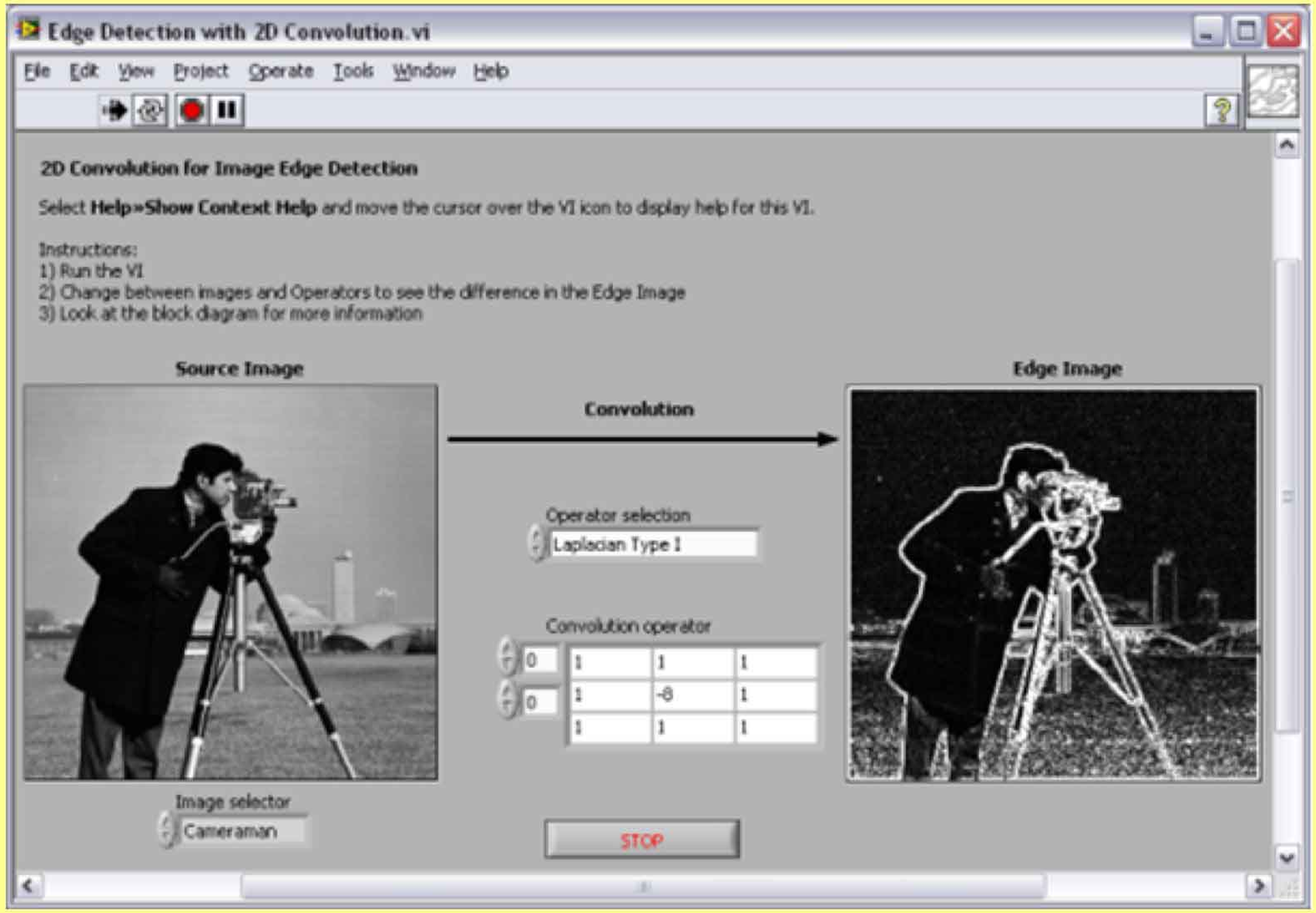
lines, circles, polygons.

high-level features (objects) such as edges, doors, or trees.

In mobile robotics, **features** have important role in the creation of environmental models.

Generate a percept that is used to create the robot's visual model





Extraction of low level features

Images are stored in 2D matrices, which represent the locations of all pixels.

All images have an X component, and a Y component.

At each point, a brightness and/or a colour value is stored.

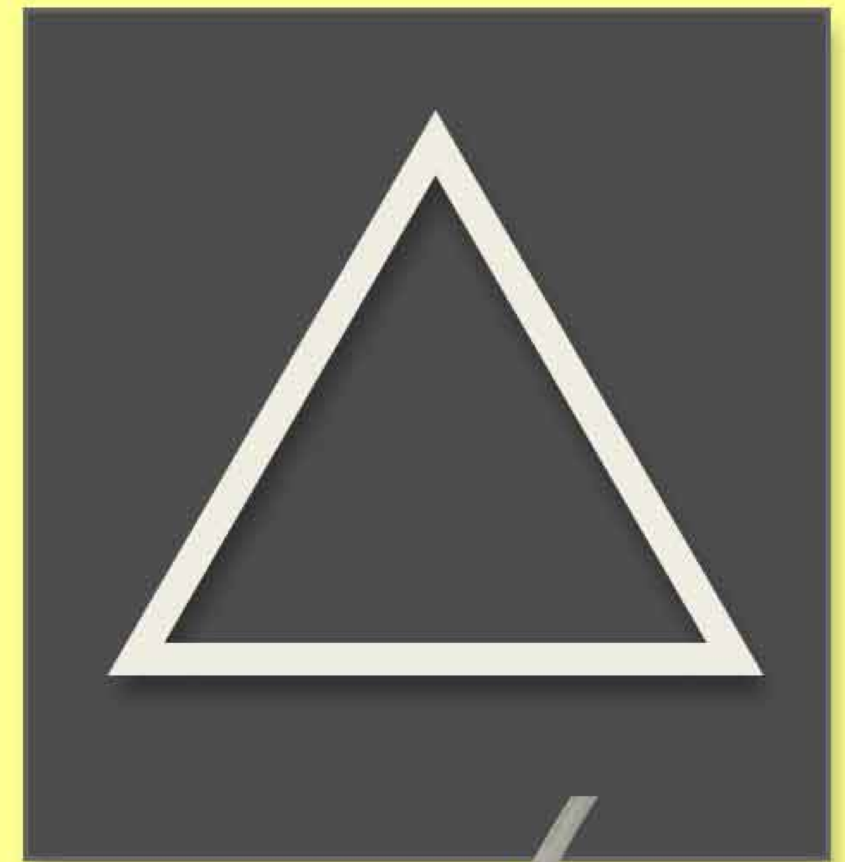
For black and white (binary), either a 1 or a 0 will be stored at each location.

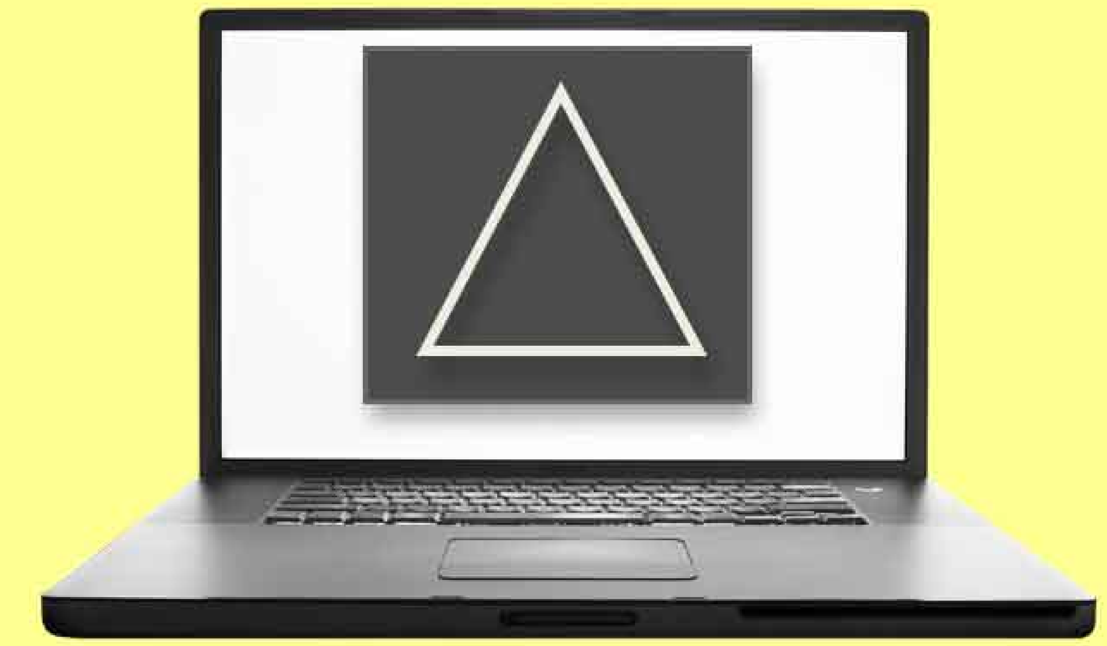
If greyscale, it will store a range of values.

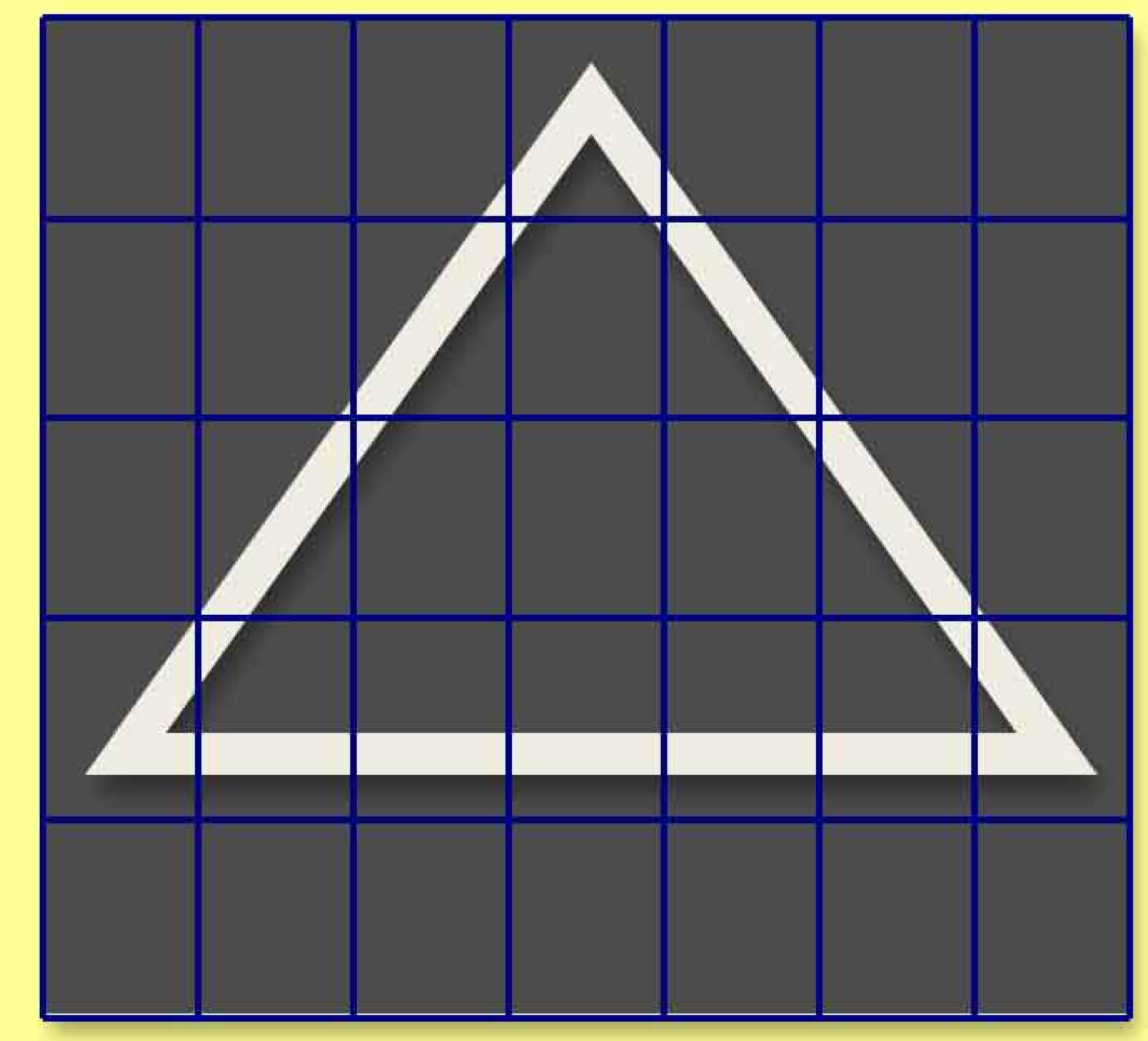
If it is a colour image (RBG), it will store sets of values.

Obviously, the less colour involved, the faster the image can be processed.

For many applications, binary images can achieve most of what you want.



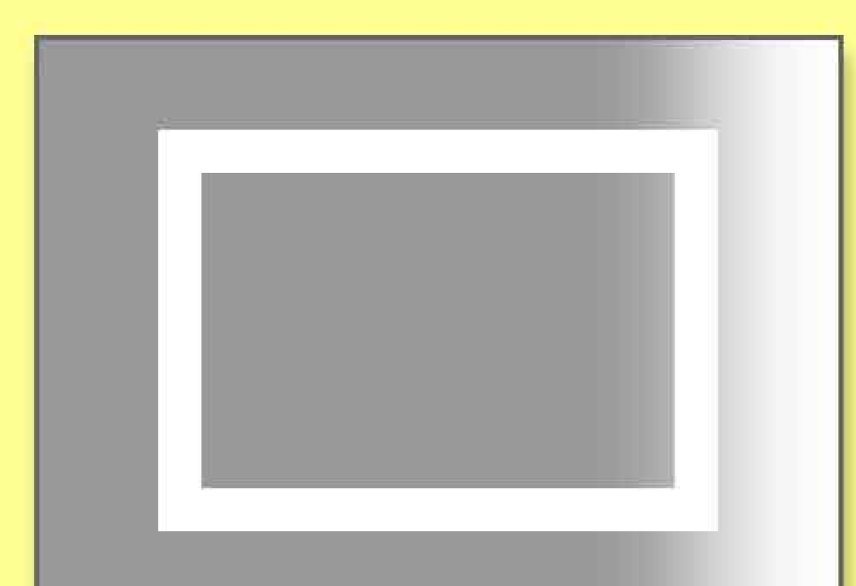




0	0	0	1	0	0	0
0	0	1	0	1	0	0
0	1	0	0	0	1	0
1	1	1	1	1	1	1
0	0	0	0	0	0	0

Matrix of a binary image of a triangle:
Resolution of 7 x 5, with a single bit stored in each location.
Memory required: 7 x 5 x 1 = 35 bits.

0	0	0	0	0	0	0
0	1	1	1	1	1	0
0	1	0	0	0	1	0
0	1	1	1	1	1	0
0	0	0	0	0	0	0



107	107	120	133	152	190	196
107	250	250	250	250	250	196
107	250	120	130	152	250	196
107	250	120	130	152	250	196
107	250	250	250	250	250	196
107	107	120	133	152	190	196

Edge detection

Edge detection essential to identify objects in image

Filters out useless information, preserves basic structural properties

Reduces the amount of data.

AN EDGE: boundary between object and background

Edges in images: Places where a jump in intensity from one pixel to the next

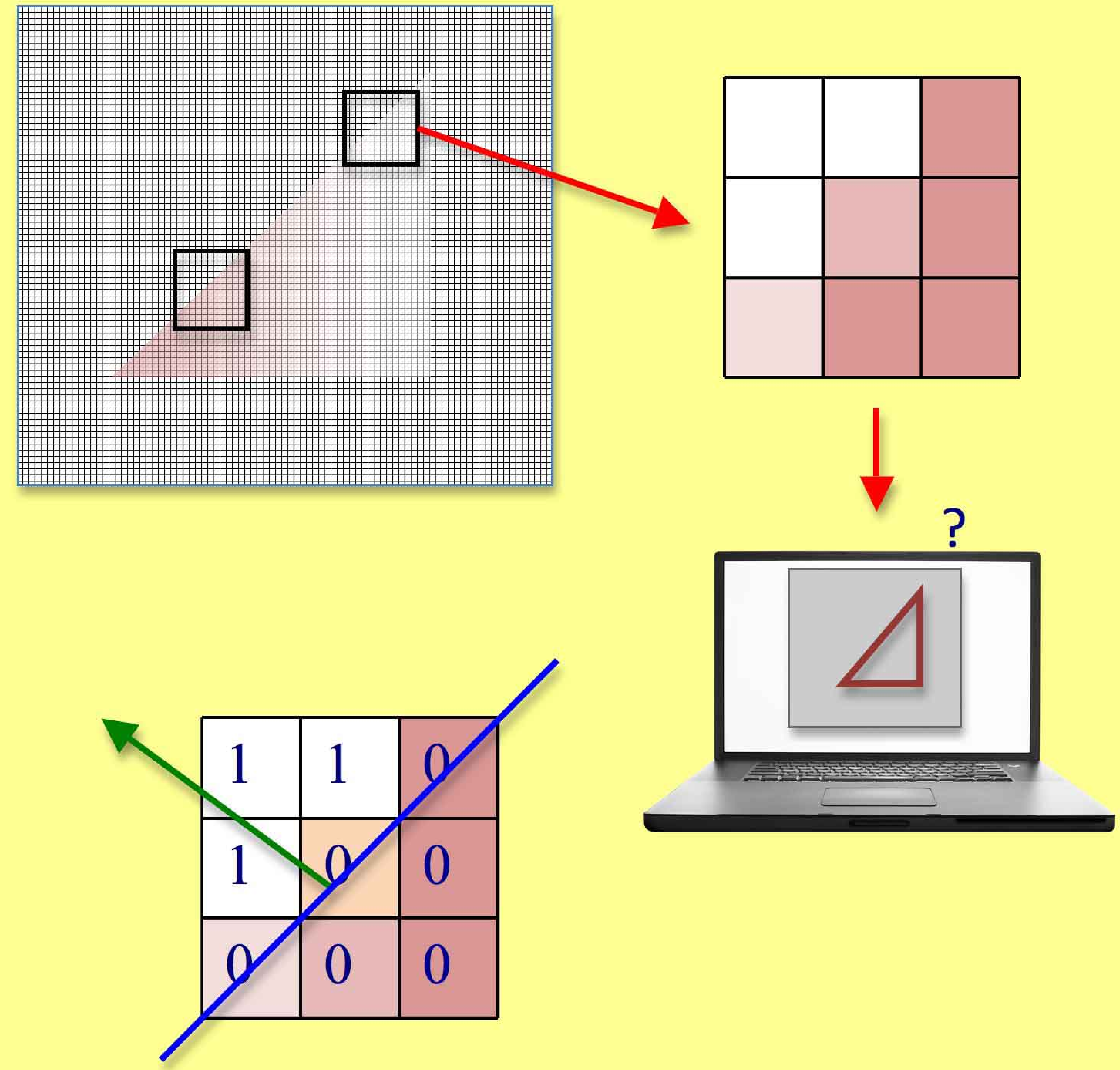
Once identified, all objects can be located and basic properties such as area, perimeter, and shape can be measured.

Edge detection: mathematical methods identify places where image brightness changes sharply

Produce a line drawing of a scene from the image.

Important features extracted from the edges of an image corners, lines, curves.

These features used by higher-level computer vision algorithms (e.g., recognition).



Edge descriptors

Edge normal: vector in the direction of maximum intensity change.

Edge direction: unit vector perpendicular to the edge normal.

Edge position: the image position at which the edge is located.

Edge strength: related to the local image contrast along the normal.

Edge Detection
Local Threshold

Edge is the **boundary** between an object and the background

Quality of edge detection dependent on:

LIGHTING,

PRESENCE OF OBJECTS OF SIMILAR INTENSITIES,

DENSITY OF EDGES IN THE SCENE

NOISE.

different edge detectors work better under different conditions

Conversion of the raw pixel value into object versus background.

3x3 window of the image

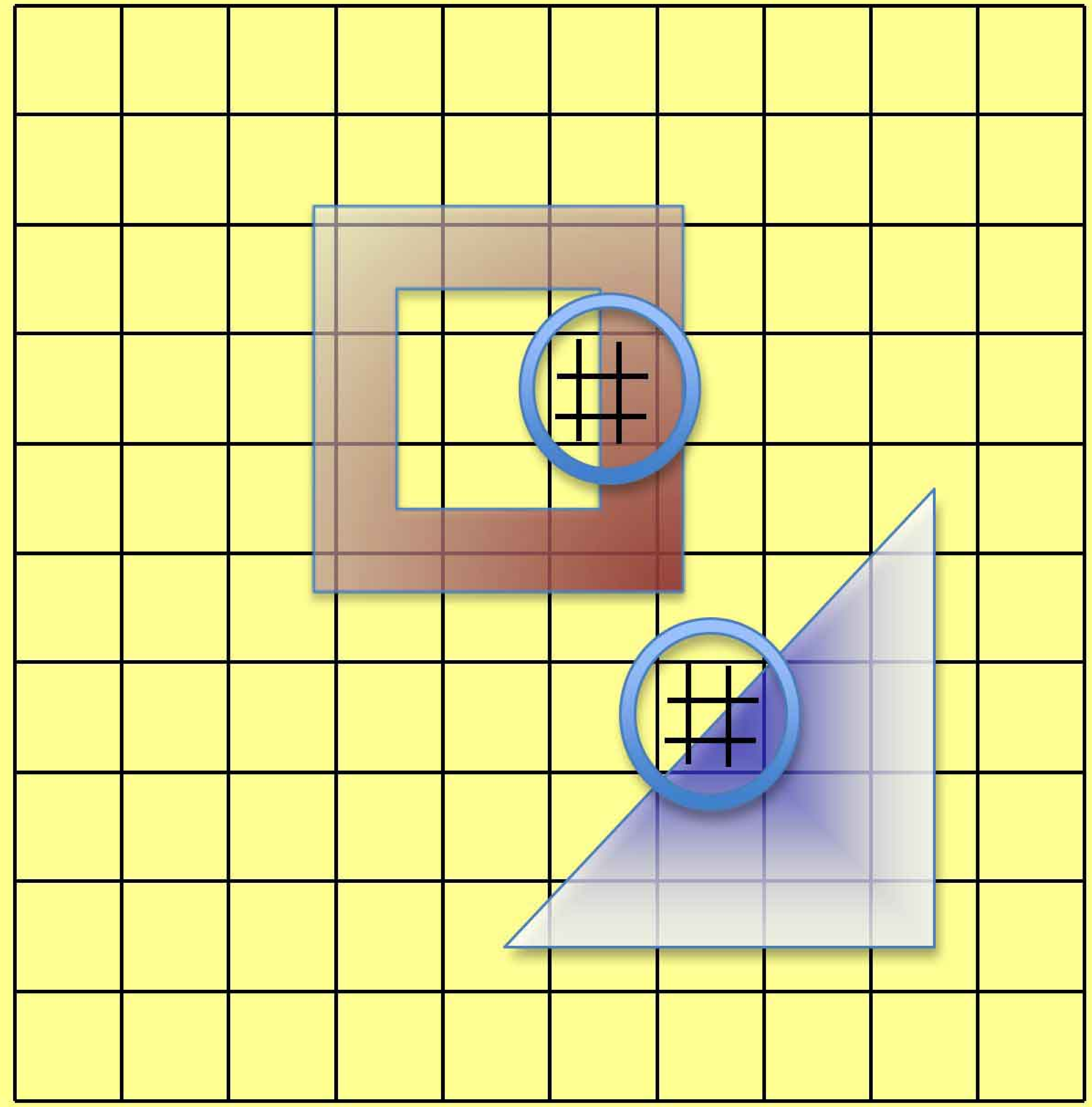
Local threshold calculated as the mean of the 9 intensity values of the pixels in the window

Converted to binary window

If a pixel has an intensity value greater than this threshold, it is set to a 1.

If a pixel intensity less than threshold, set at 0.

Generates binary pattern of the 3x3 window.



1	0	0
1	0	0
1	0	0

1	1	0
1	0	0
0	0	0

100	**54**	**20**
100	**50**	**15**
100	**40**	**10**

→

100	54	20
100	50	15
100	40	10

→

1	0	0
1	0	0
1	0	0

Total intensity of all 9 squares
489/9 = **54.3**

Any value below **54.3** set as dark: **defines edge**

Local Threshold and Boolean Function Based Edge Detection

- Only 16 edge-like patterns can occur in a 3x3 matrix
- If the binary window matches any of these sixteen patterns, the centre pixel is set to be an edge pixel.

- Global threshold to remove false edges.
- The variance for each 3x3 window is calculated, has maximum at an edge.
- If the value is greater than the threshold, it is kept as an edge.
- If less than threshold, it is removed.
- Calculating the threshold on a per pixel basis, less sensitive to variations in lighting
- It does not rely on blurring to reduce noise in the image.

0	1	1
0	1	1
0	1	1

0	0	0
1	1	1
1	1	1

1	1	0
1	1	0
1	1	0

1	1	1
1	1	1
0	0	0

0	1	1
0	1	1
0	0	1

1	0	0
1	1	0
1	1	0

1	1	1
0	1	1
0	0	0

1	1	1
1	1	0
0	0	0

1	1	1
0	1	1
0	0	1

1	0	0
1	1	0
1	1	1

0	0	1
0	1	1
1	1	1

1	1	1
1	1	0
1	0	0

0	0	0
0	1	1
1	1	1

0	0	0
1	1	0
1	1	1

0	0	1
0	1	1
0	1	1

1	1	0
1	1	0
1	0	0

Gradients

Defining edges of overlapping objects ambiguous

Edges are not cliffs but slopes

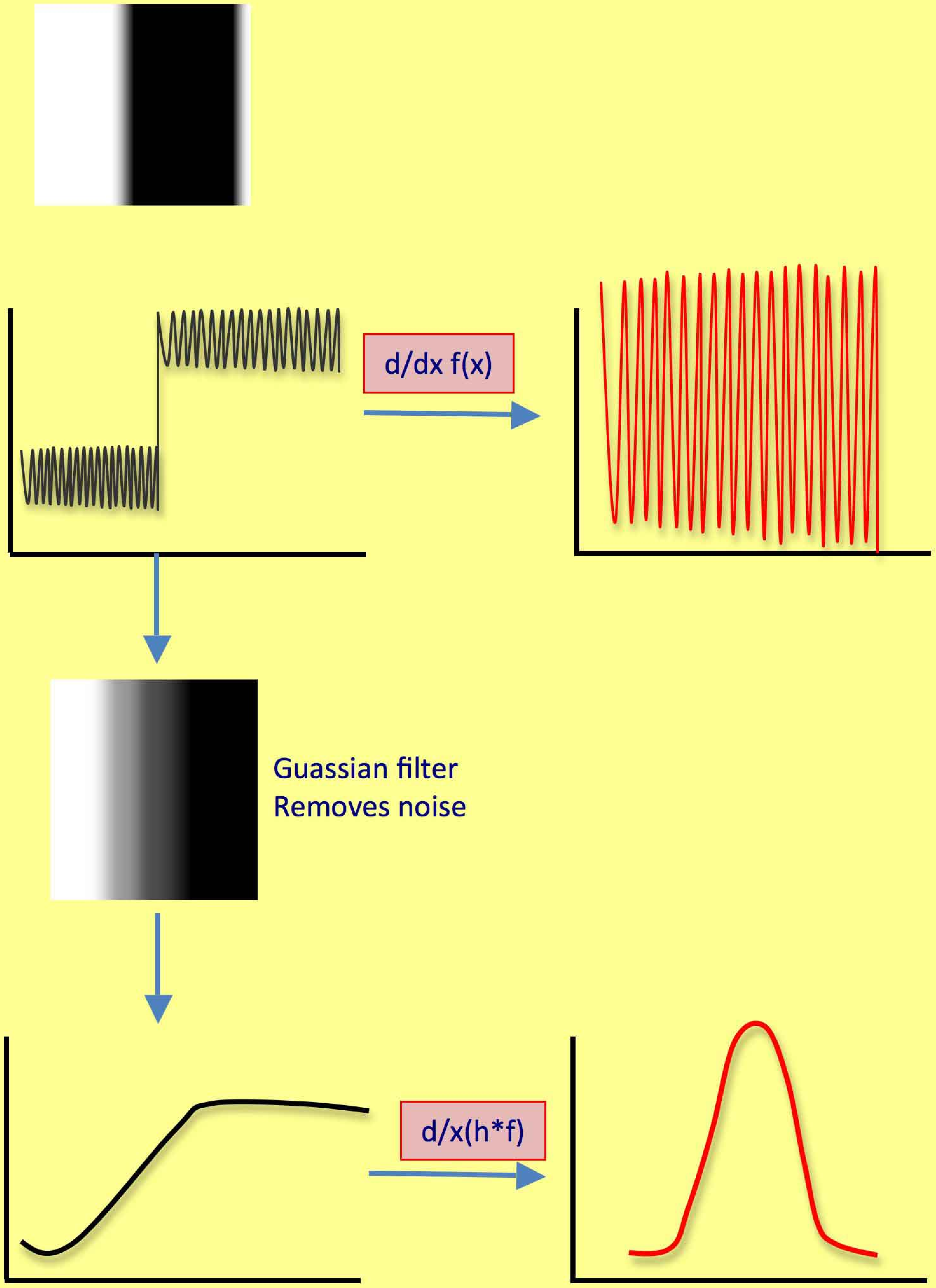
Using plot of increasing darkness or brightness

Finding where maximum gradient defines the edge.

However in raw image noise makes it impossible to determine where maximum gradient lies

Therefore smooth the image with a mathematical transform

Gaussian filter



Gradients

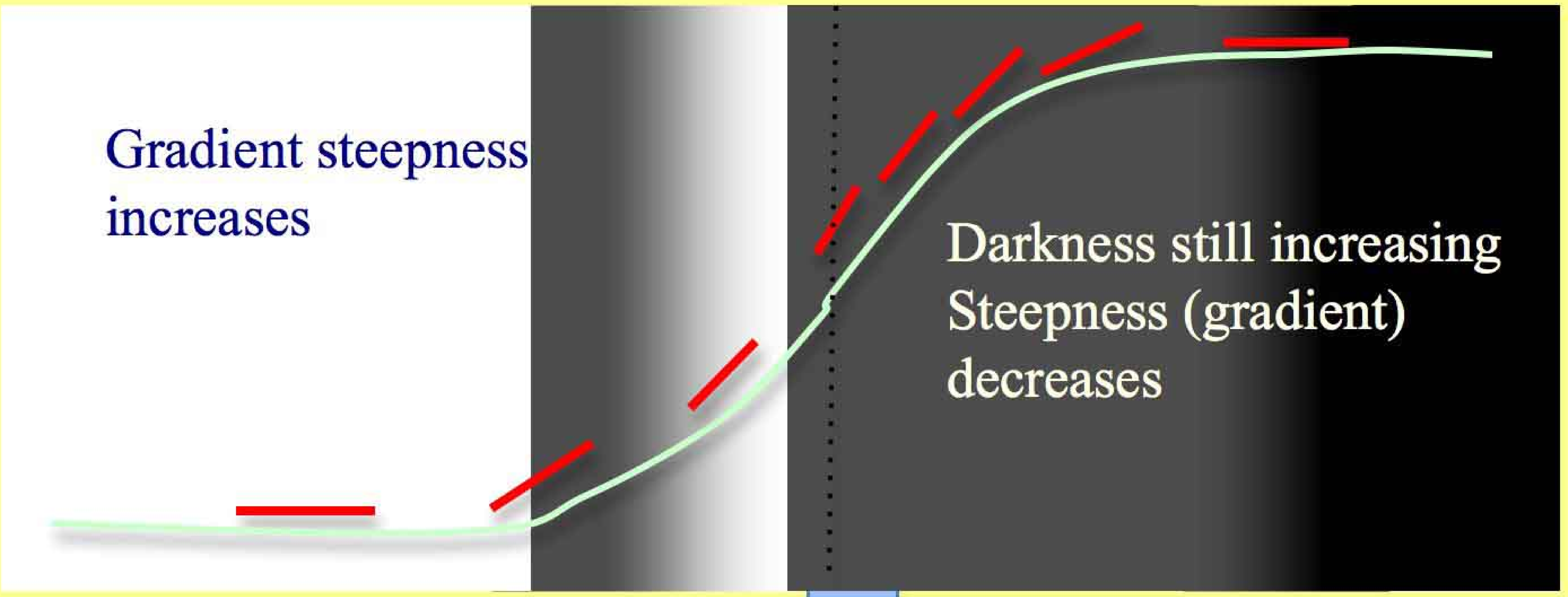
Edge detection using derivatives
Calculus describes changes of continuous functions using *derivatives*.

First derivative: tells us how whether a function is increasing or decreasing, and by how much.

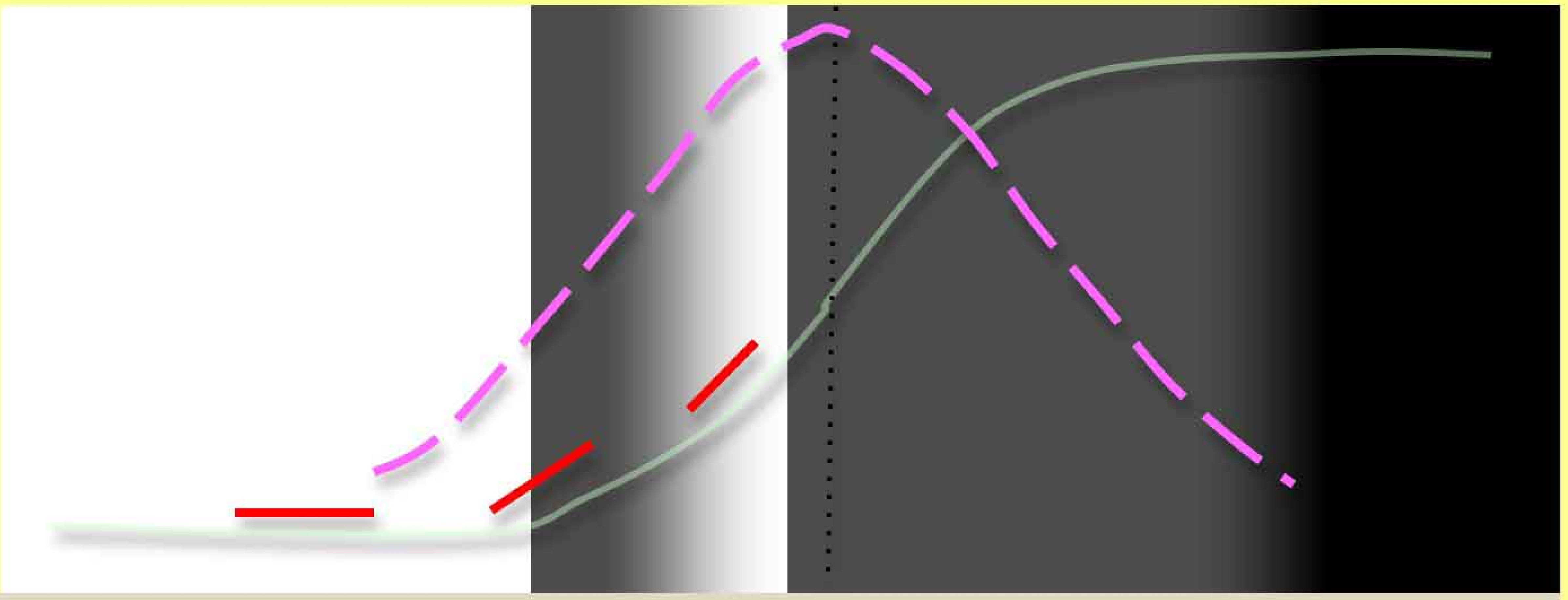
Graph of the slope of the tangent line

The first derivative of the function f(x), is the slope of the tangent line dx to the function at the point x.

Gradient method detects the edges by looking for the maximum and minimum in the first derivative of the image.



Plot of the **gradient** of brightness function is the first derivative with respect to t
Positive slope tells us that, as x increases, f(x) also increases.
Zero slope does not tell us anything in particular: the function (brightness) may be increasing, decreasing, or at a local maximum or a local minimum at that point



MAXIMUM GRADIENT
located at the center of the edge in the original signal.
“gradient filter” family of edge detection
A pixel location is declared an edge location if the value of the gradient exceeds some threshold

Leonardo's robot

Humanoid automaton: Knight clad in armour

1495: Possibly displayed at a celebration hosted by **Ludovico Sforza** Milan

Could stand, sit, raise its visor and independently maneuver its arms.

Inside the robot: two independent systems:

three-degree-of-freedom legs, ankles, knees, hips; **four-degree-of-freedom** arms with articulated shoulders, elbows, wrists, and hands.

Arms designed for grasping, all the joints in unison.

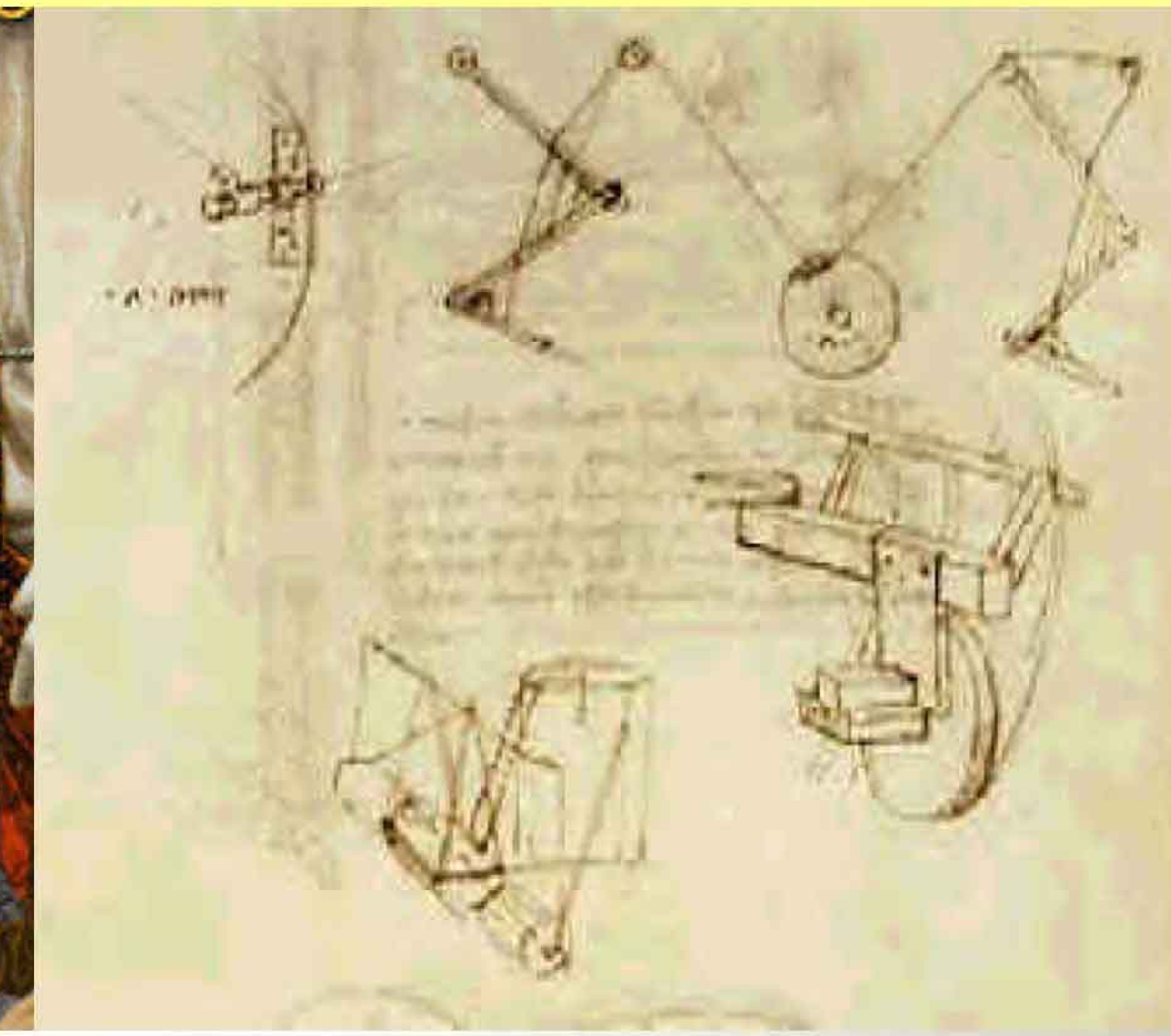
Mechanical, analog-programmable controller in chest power and control for the arms.

Legs powered by an external crank driving cable, connected to ankle, knee, and hip.

1950: Discovery of the sketchbook,

April 2000: **Mark Rosheim**

Reconstruction of Programmable Automata 40th Lettura Vinciana at Biblioteca Leonardiana; Vinci

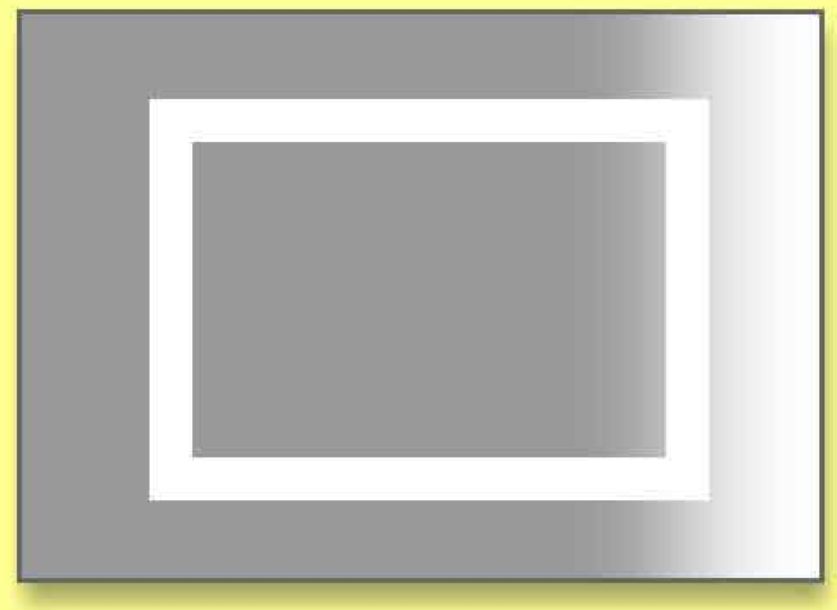


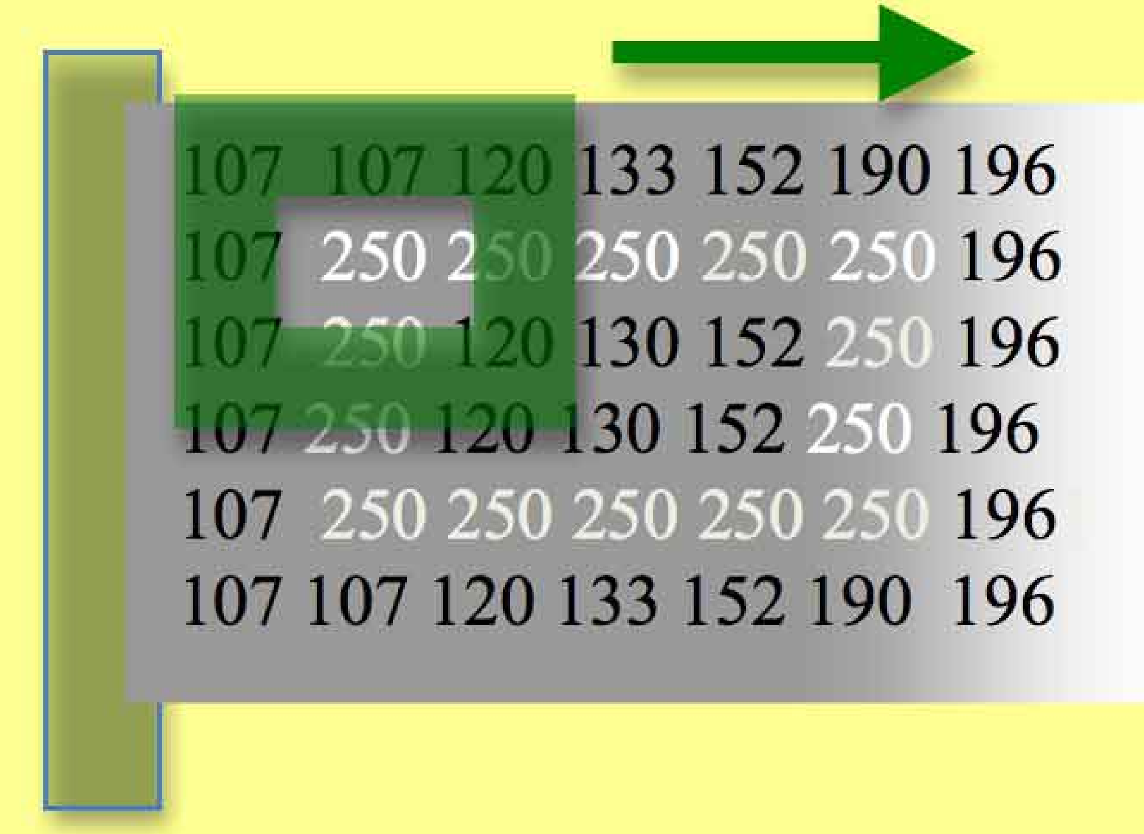
Sobel

An image gradient is a change in intensity

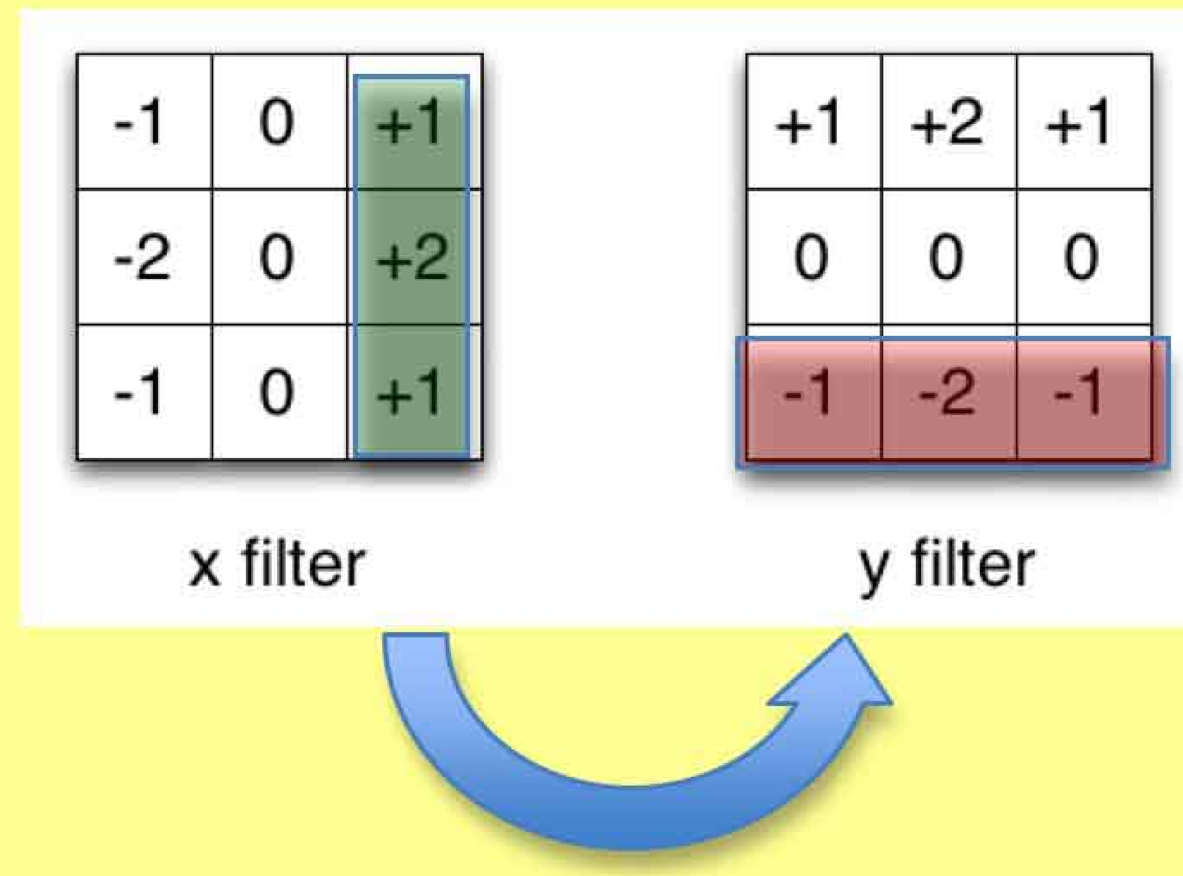
An edge in an image occurs when the gradient is greatest

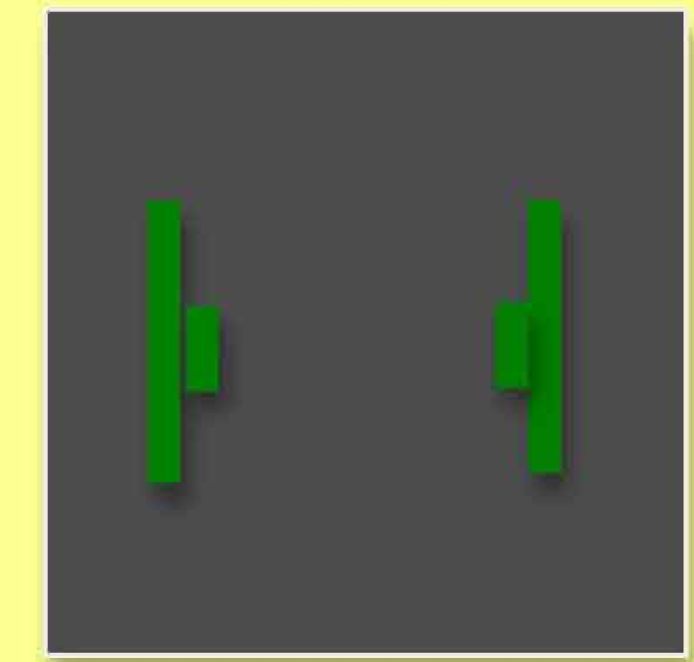
Used Sobel operator to find the edges





Calculates the approximate image gradient of each pixel by convolving the image with a pair of 3×3 filters.

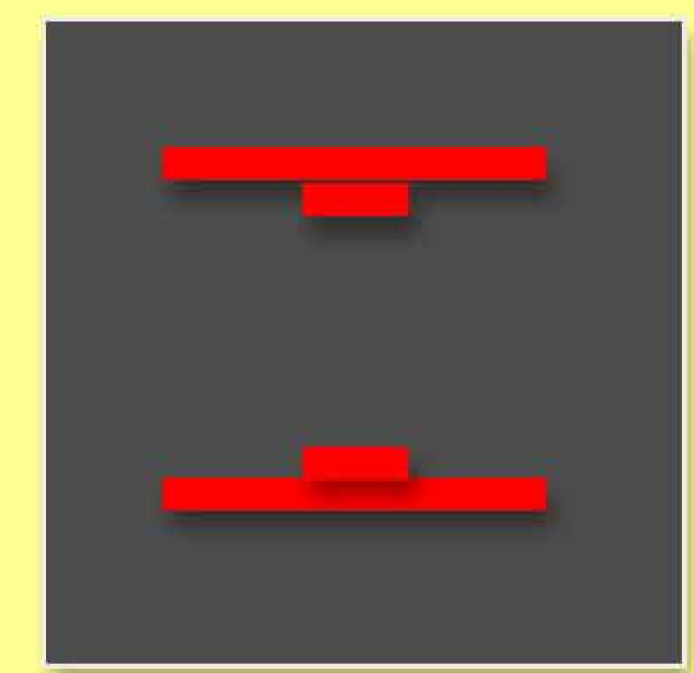




Run through each pixel in the image

Estimate the gradients in the horizontal (x) and vertical (y) directions.

The magnitude of the gradient is simply the sum of these 2 gradients.



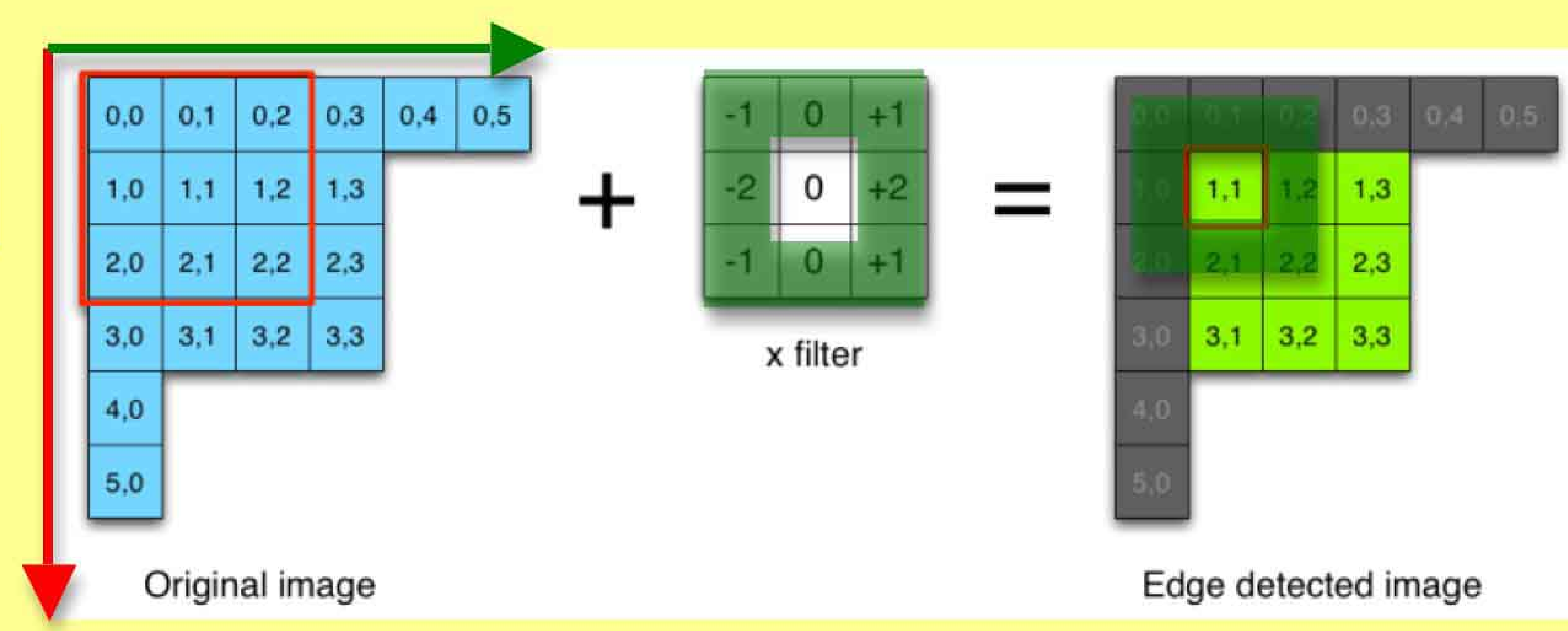
To calculate the pixel x=1/y=1 (1,1)
([0,0] x -1) + ([0,1] x 0) + ([0,2] x 1) +
([1,0] x -2) + ([1,1] x 0) + ([1,2] x 2) +
([2,0] x -1) + ([2,1] x 0) + ([2,2] x 1)

Sobel calculates not only the magnitude of the edges, but also their direction.

Because the filter is a 3×3 matrix, the pixels in the first and last rows/columns cannot be estimated

Output is 1 pixel smaller than original image.

$$|G| = \sqrt{Gx^2 + Gy^2}$$



Laplacian Transform
Edge detection

Commonly used integral transform

Applications in physics and engineering.

Converts integral and differential equations into algebraic equations

When the first derivative is at a maximum, the second derivative is zero.

If the second derivative is positive, then the first derivative is increasing

If the second derivative is negative, then the first derivative is decreasing, so that the slope of the tangent line to the function is decreasing as x increases.

An alternative to finding the location of an edge is **to locate the zeros in the second derivative.**

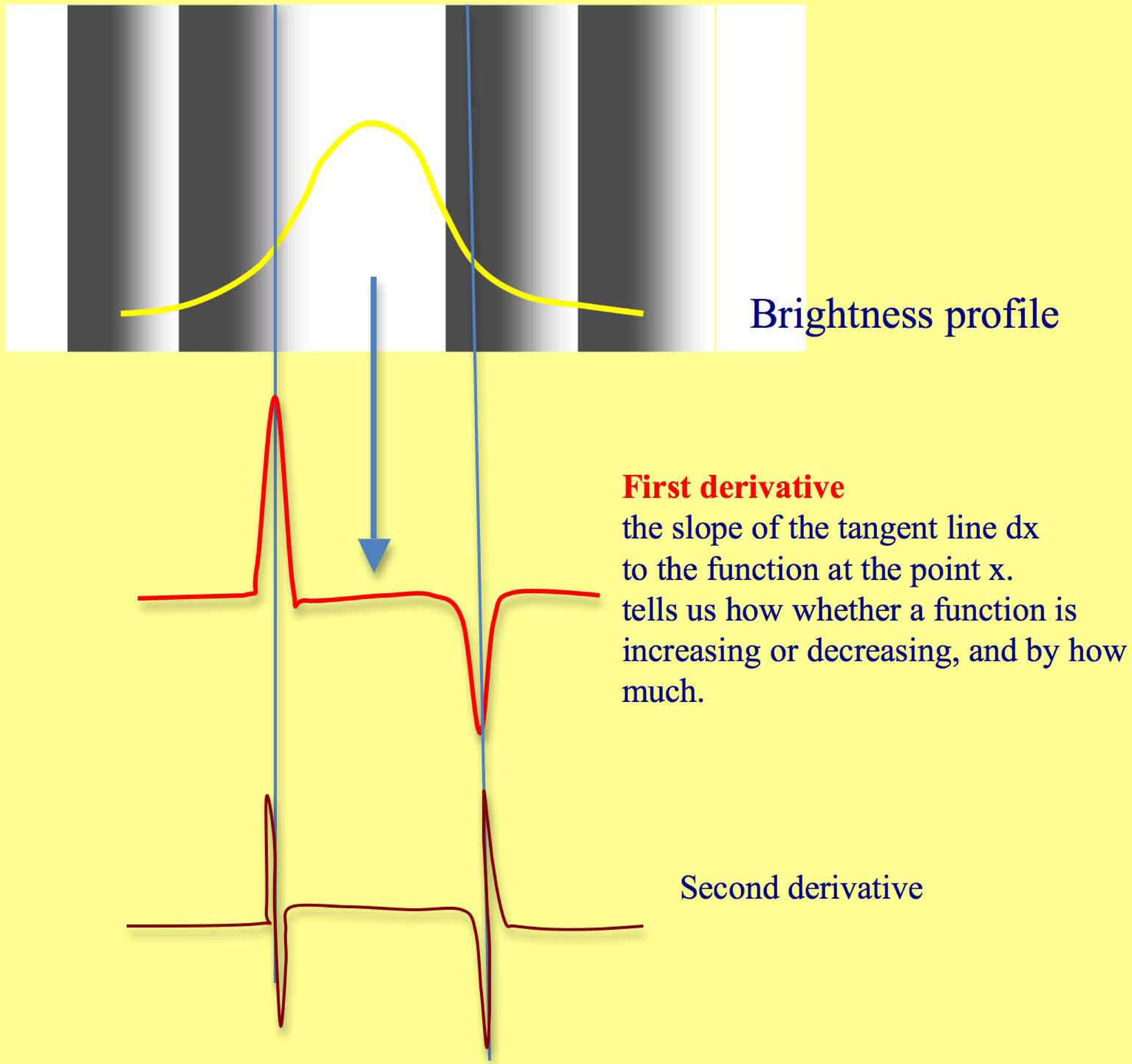
Detects rate of change in intensity gradient

Marr-Hildreth: detection of zero-crossings of the Laplacian operator applied to a Gaussian-smoothed image.

also returns false edges corresponding to local minima of the gradient magnitude.

Poor localization at curved edges.

Mainly of historical interest.



The Marr-Hildreth edge detector

Gradient based operator which uses the Laplacian to take the second derivative of an image.

If there is a step difference in the intensity of the image, it will be represented by in the second derivative by a zero crossing:

Loop through every pixel in the Laplacian of the smoothed image and look for sign changes.

If there is a sign change and the slope across this sign change is greater than some threshold, mark this pixel as an edge.

The Canny Edge Detector

1983: **John Canny** MIT Masters thesis:

Edge detection as a signal processing optimization problem

The optimal filter is a sum of four exponential terms.

This filter can be well approximated by first-order derivatives of Gaussians.

The steps in the Canny edge detector

Smooth (blur) the image Reduce noise**:** with a two dimensional Gaussian.

Approximated by two one dimensional Gaussians, one in the x direction and the other in the y direction.

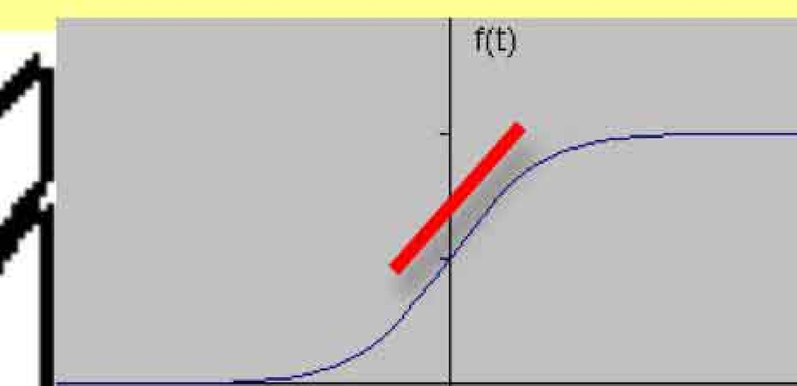
2. Take the gradient of the image. This shows changes in intensity, which indicates the presence of edges. This actually gives two results, the gradient in the x direction and the gradient in the y direction.

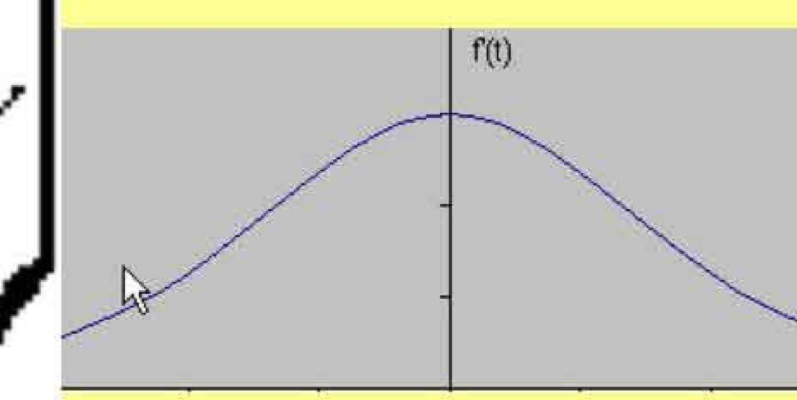
3. Non-maximal suppression. Edges will occur at points the where the gradient is at a maximum.

All other points suppressed.

Magnitude and direction of gradient computed at each pixel.

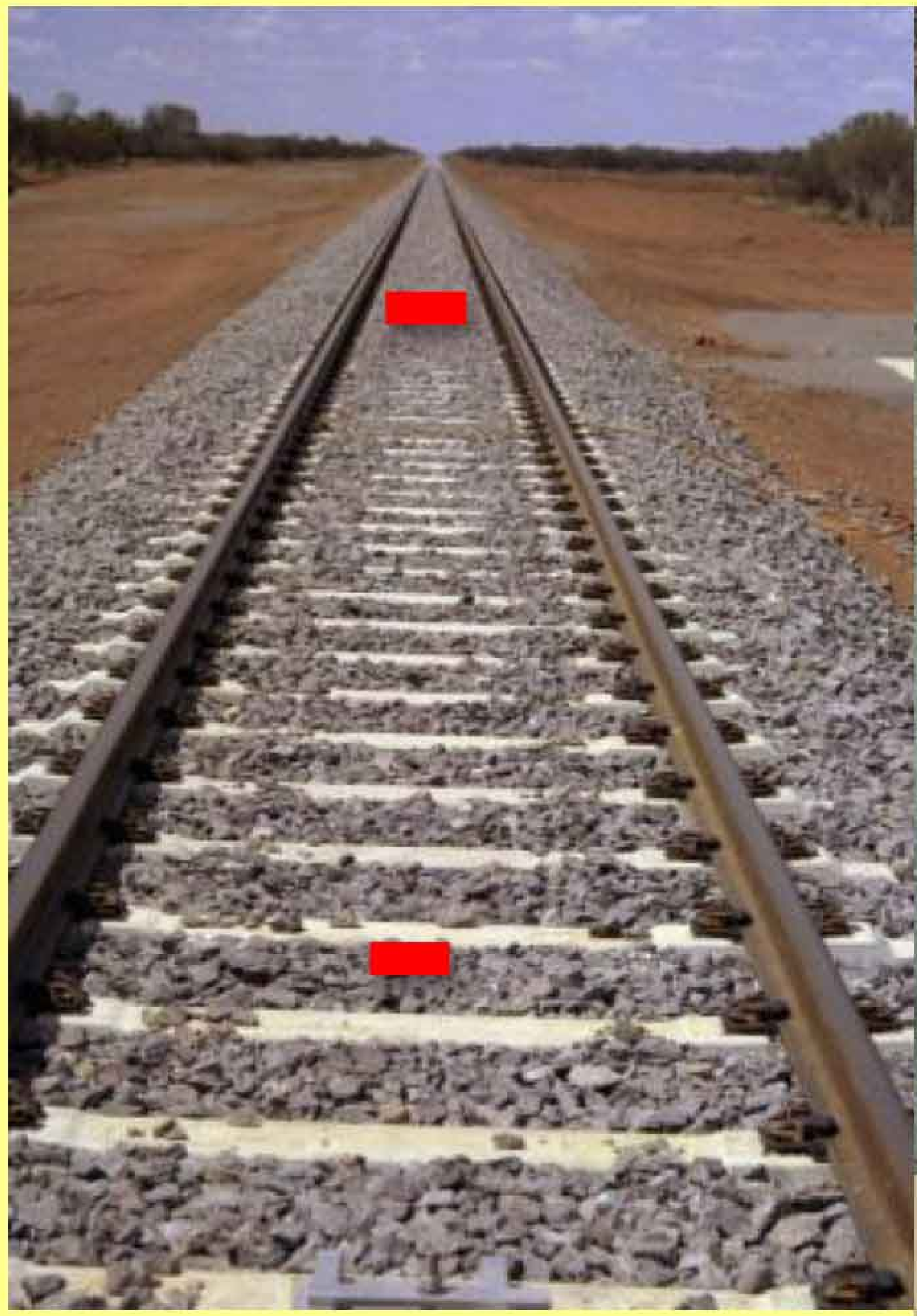
Then for each pixel check if the gradient is greater at one pixel's distance away if not greater than suppress it.

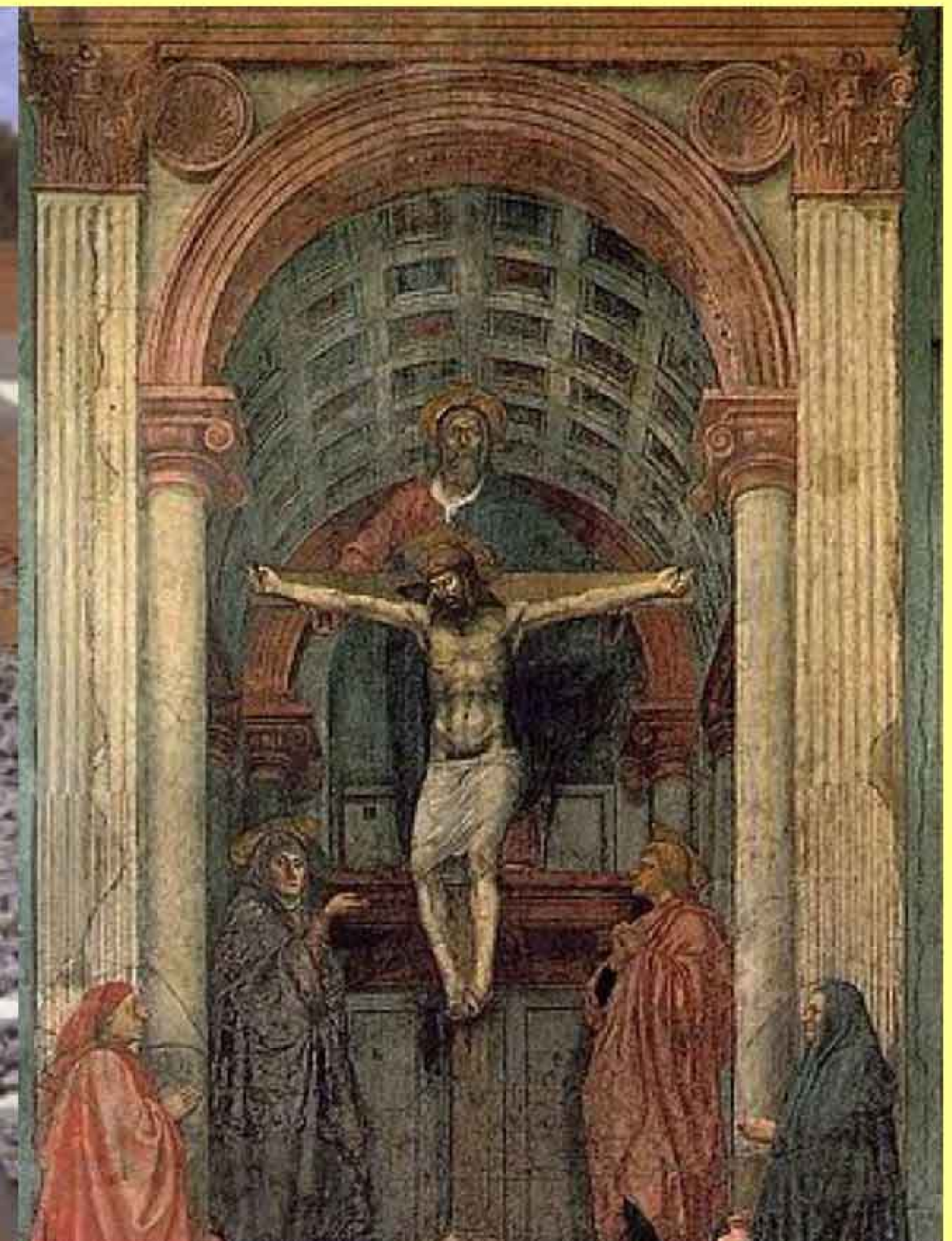




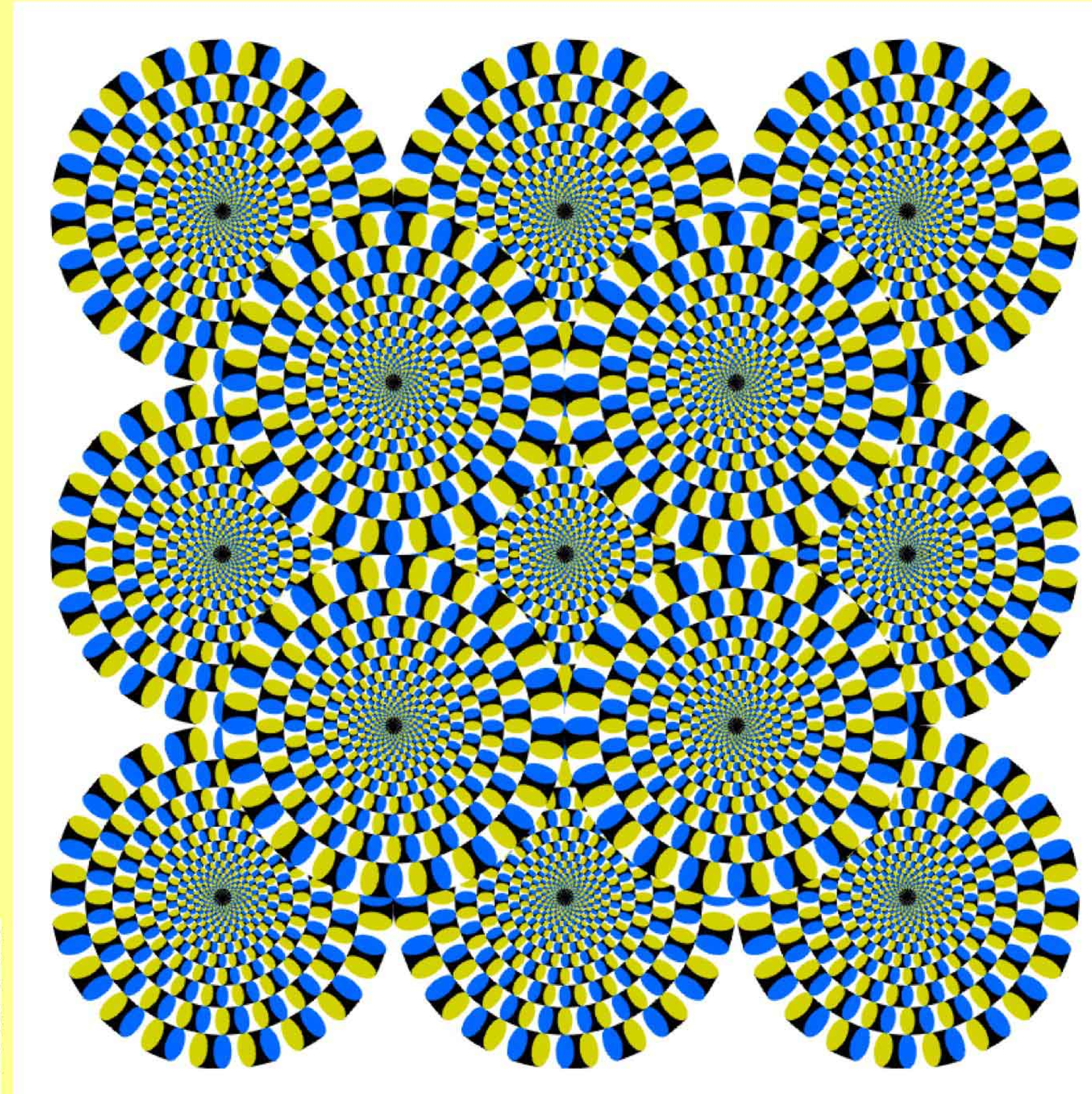
Bill Green
Drexel
University Philade
lphia

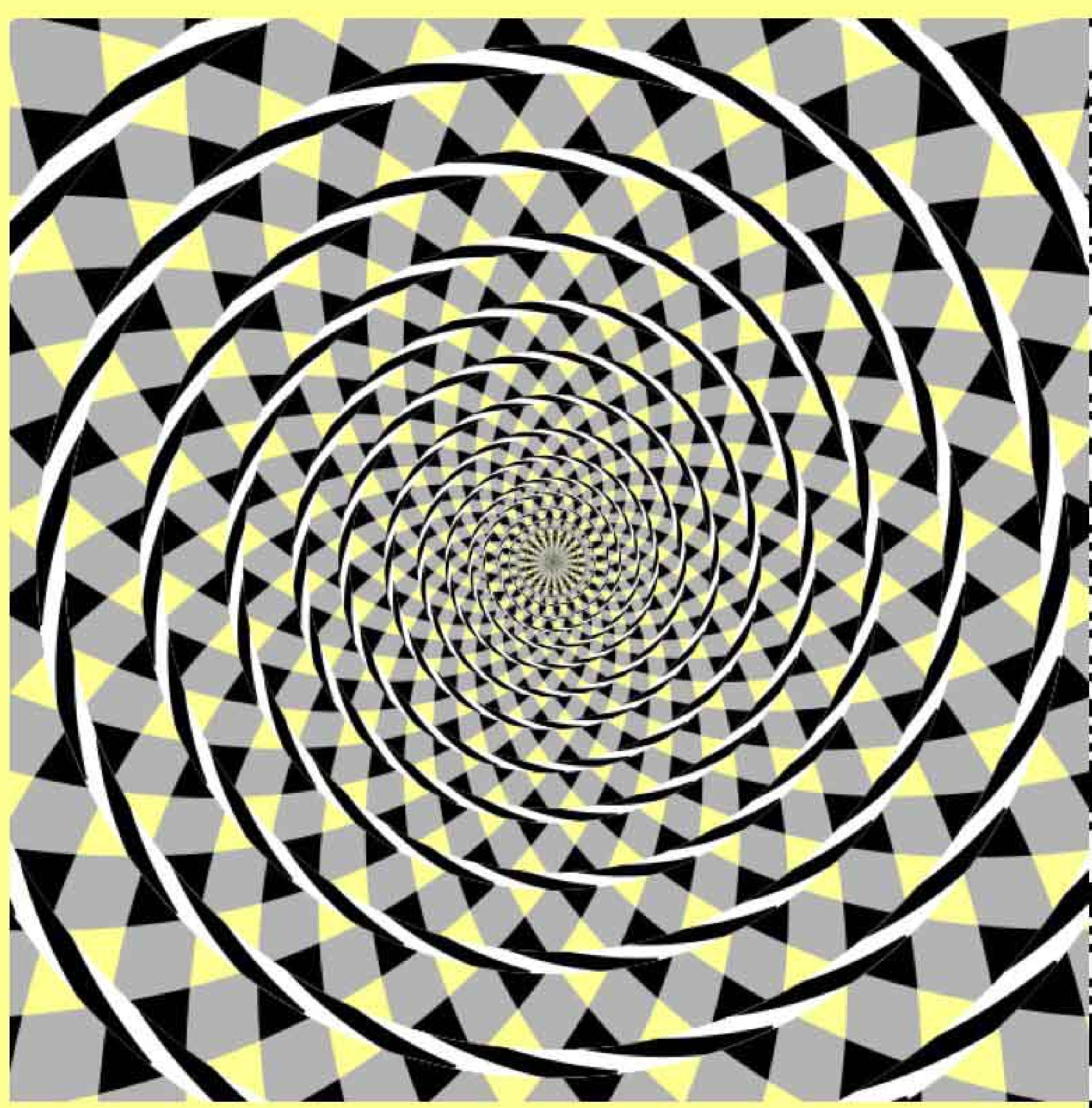
Perspective; Movement; Brightness, Colour, Textures and patterns

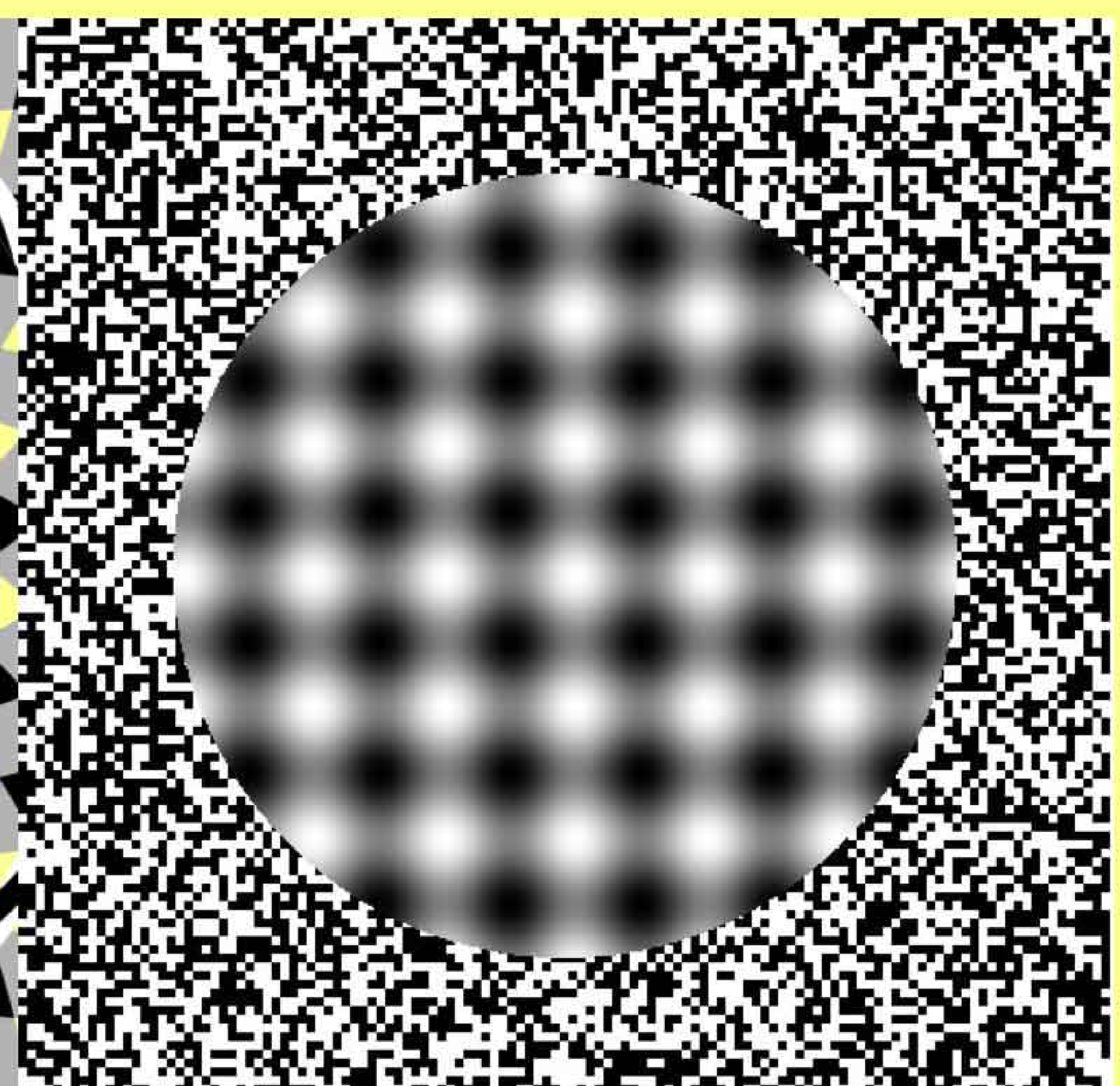




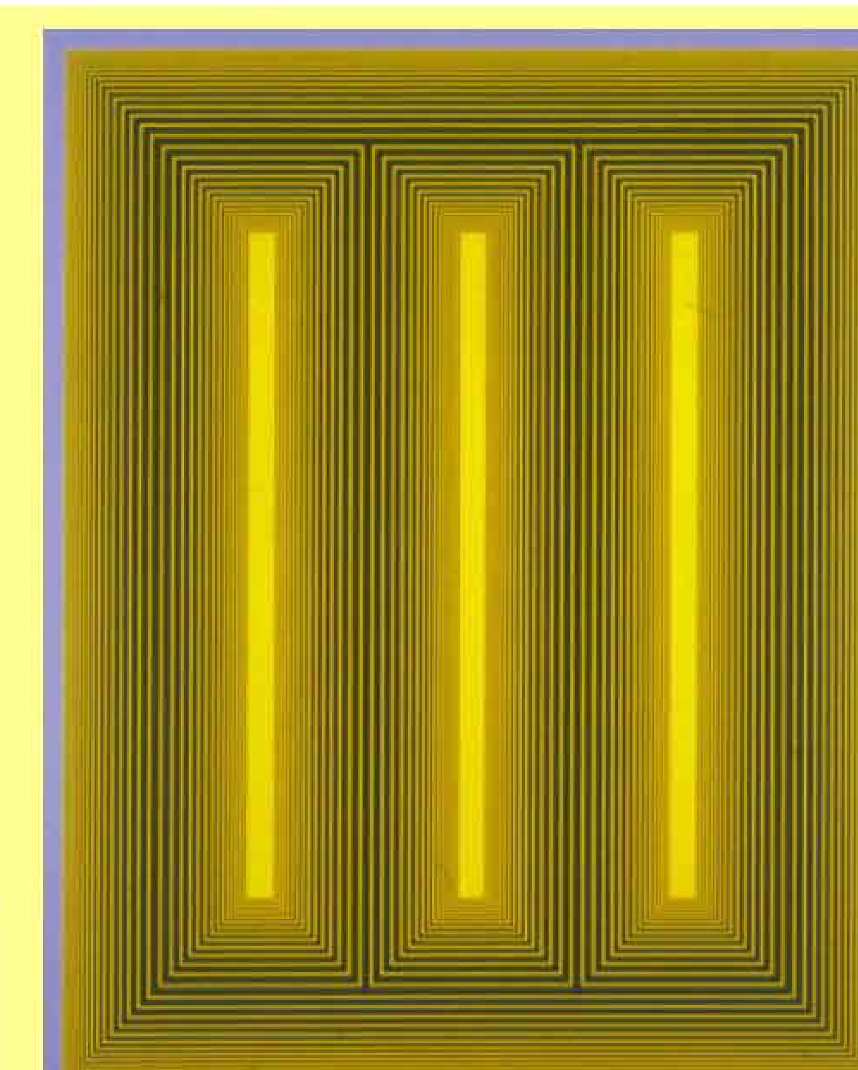
Masacchio: the Trinity
S. Maria Novello Florence







Richard Anuszkiewicz: 1985:
Temple of the Radiant Yellow



Mimicking human vision
Artificial intelligence

Challenge for engineers is getting the robot to understand and process its environment.

Detect discrete objects and actions and then interpret what it has detected.

Facial recognition to interpreting emotions.

Detecting movement to moving in a moving environment

Even more: do that in real time.

Big leap from a robot that can find objects in a box and move them to a set destination

Big leap from a robot that can steer around obstacles

Mobile robot with AI

1969: Shakey Stanford Research Institute

First mobile robot controlled by artificial intelligence.

Able to reason about its own actions. Great accomplishment
Could take general instructions (vs pre-programed steps)

Calculated how to accomplish the objective

Antenna for a radio link, sonar range finders, a television camera, on-board processors, and collision detection sensors

Connected via radio to external minicomputer.

Sensing devices driven by a problem-solving program called STRIPS, **St**anford **R**esearch **I**nstitute **P**roblem **S**olver

Operator at computer types **"PUSH THE BLOCK OFF THE PLATFORM"**. Radio to Robot

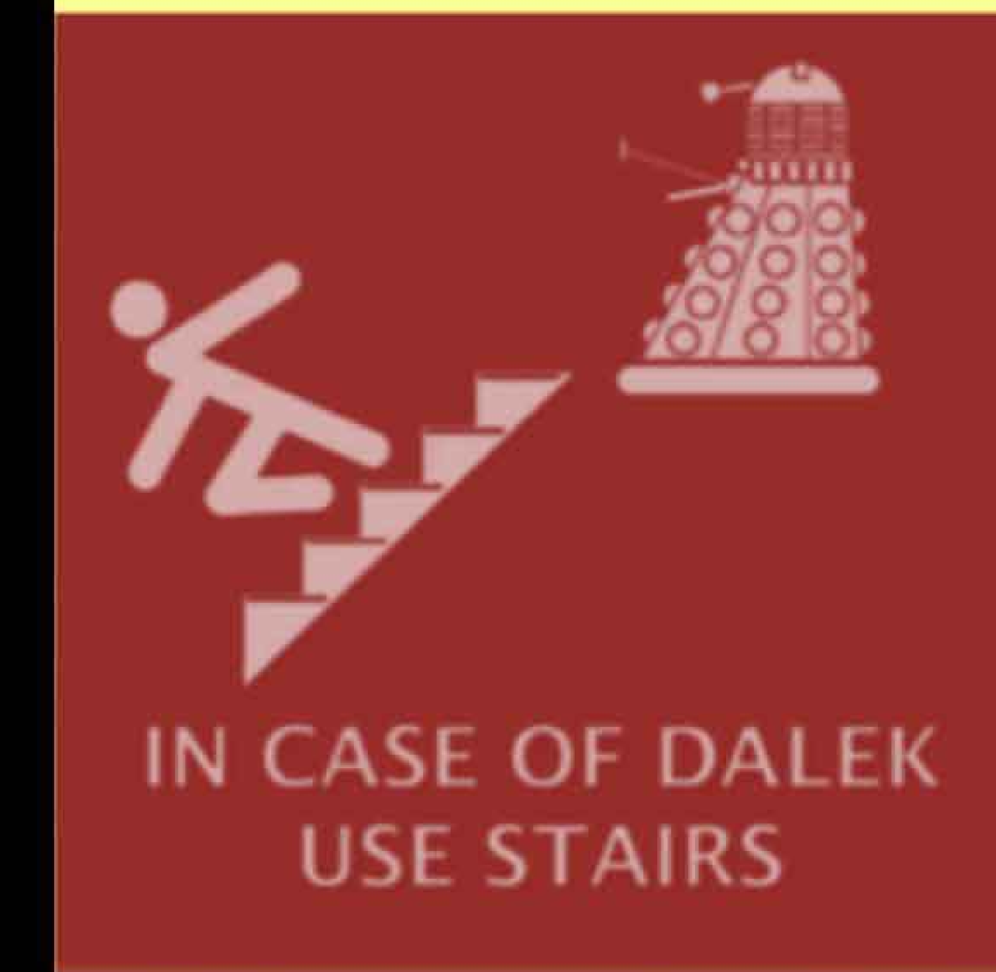
Shakey looks around, identifies a platform with a block on it, locates a ramp pushes ramp over, rolls up the ramp 2m/hr onto the platform, pushes the block off the platform.

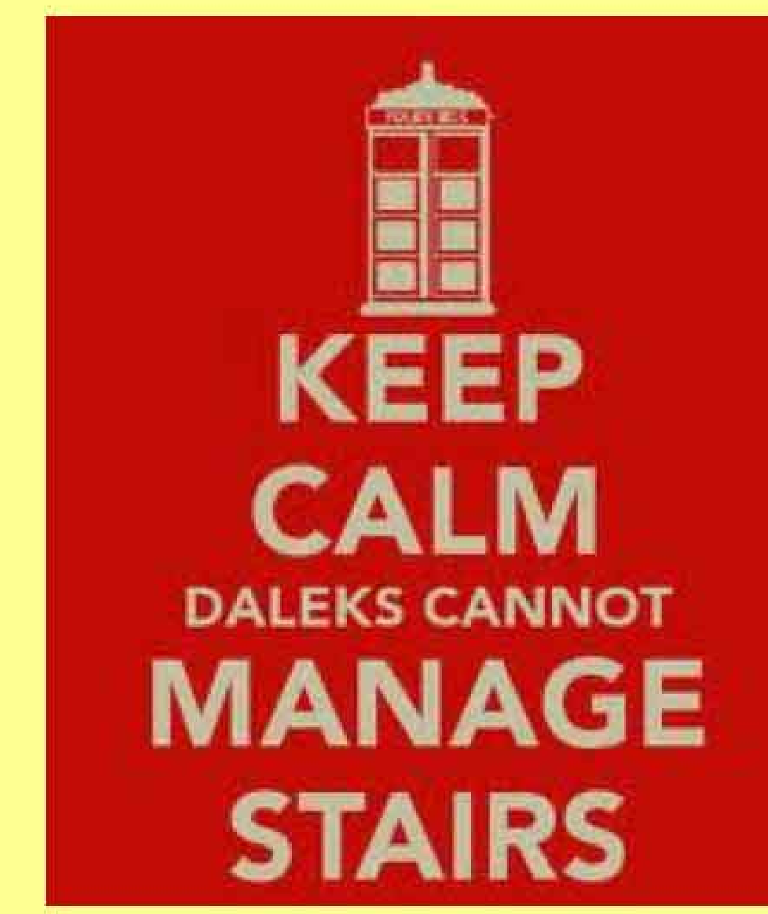
Mission accomplished.

Tall, tendency to shake

Never became a practical product,

Start for developing software for navigating an unknown space, as well as other artificial intelligence applications





Short list of available actions in program.

- Traveling between locations
- Turning light switches on and off
- Opening and closing the doors
- Climbing up and down ramps
- Pushing objects around

Robot vision

Evolution Robotics real time object recognition using SIFT points. **Scale-invariant feature transform**

The software identifies points in an image that look the same even if the object is moved, rotated or resized.

Compares to previously seen image points software recognises object

1986/87 EUREKA-project 'PROgraMme for a European Traffic of Highest Efficiency and Unprecedented Safety' (PROMETHEUS) car industry Machine vision proposed by Dickmanns, Munich

Fully autonomous vehicles are not yet available

Features offering limited autonomous functionality:

adaptive cruise control, monitors distances to adjacent vehicles, adjusting the speed with the flow of traffic;

lane assist, which monitors position in the lane, and either warns or takes corrective actions;

parking assist

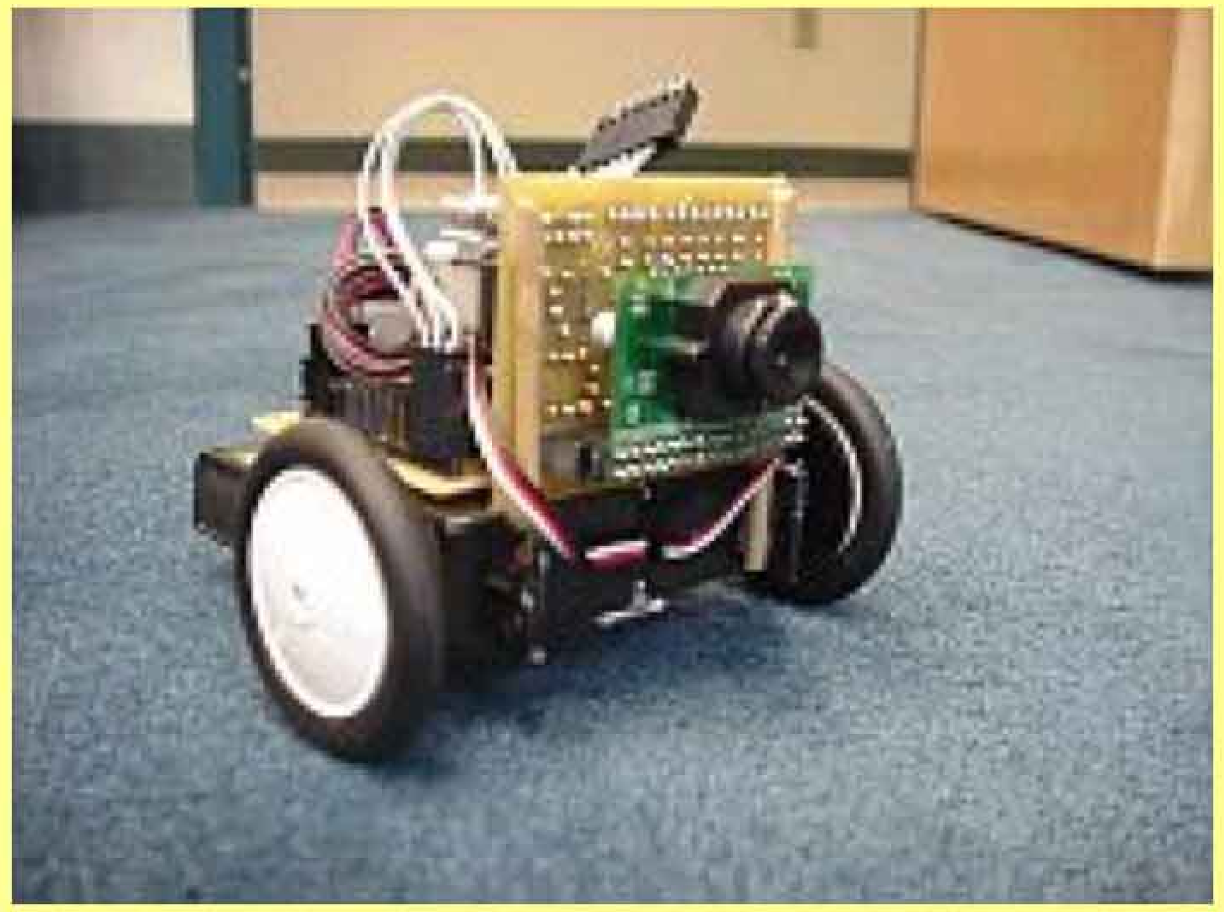
CMUCam: Carnegie Mellon University real time object tracking vision system

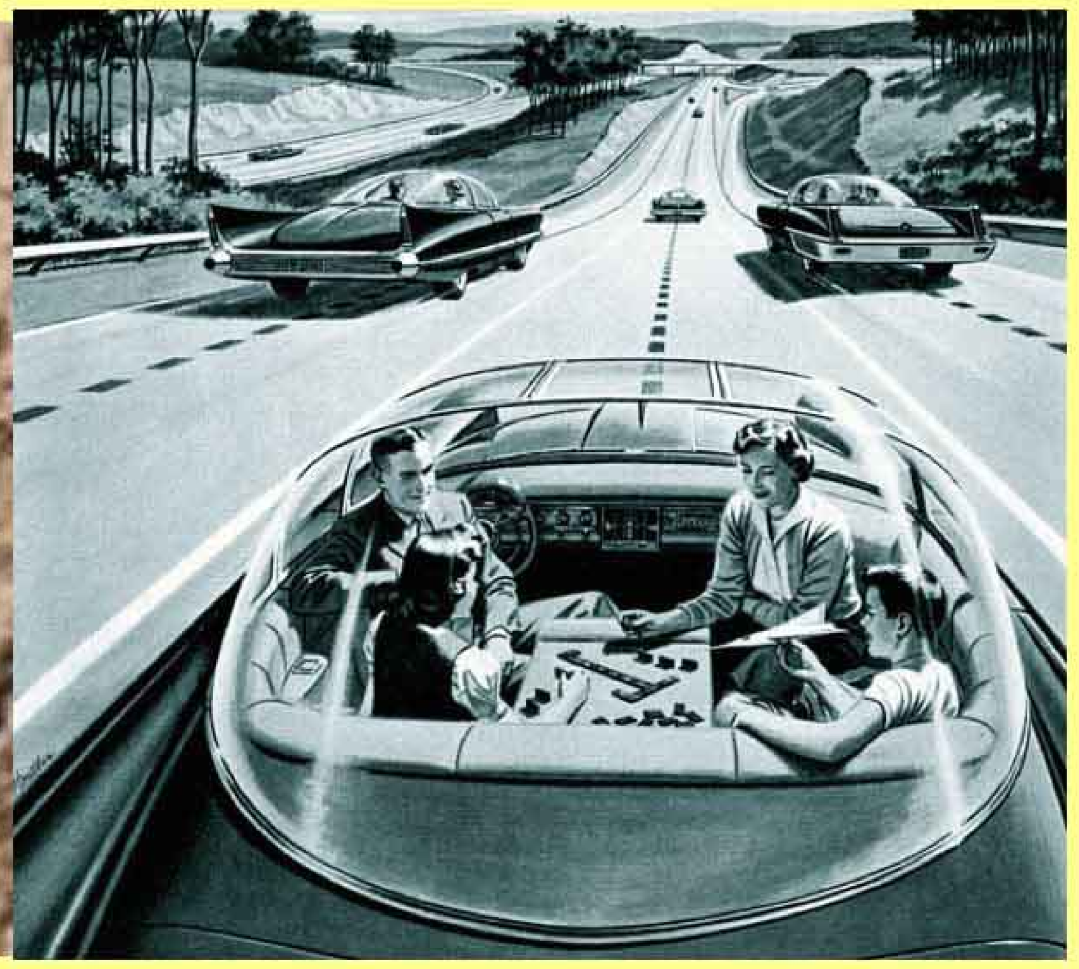
Moveable camera on small motors (servos) can track an object based on its colour.

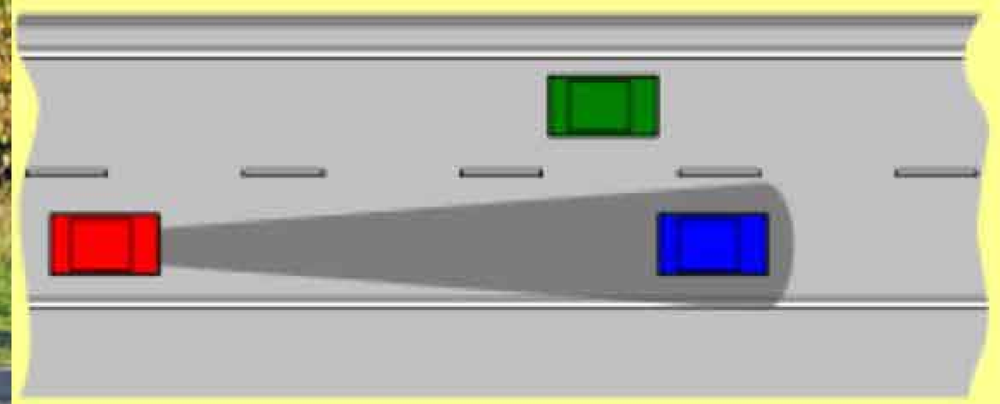
Darpa Grand Challenge desert race: robotic automobiles from California to Nevada.

Speed average of 30mph

The winner, Stanley from Stanford, used forward looking sensor to help estimate the direction the car should be going long before it got there.







Androids: ἀνδρ- man

1986: **EO Honda:** bipedal stable walking technology,

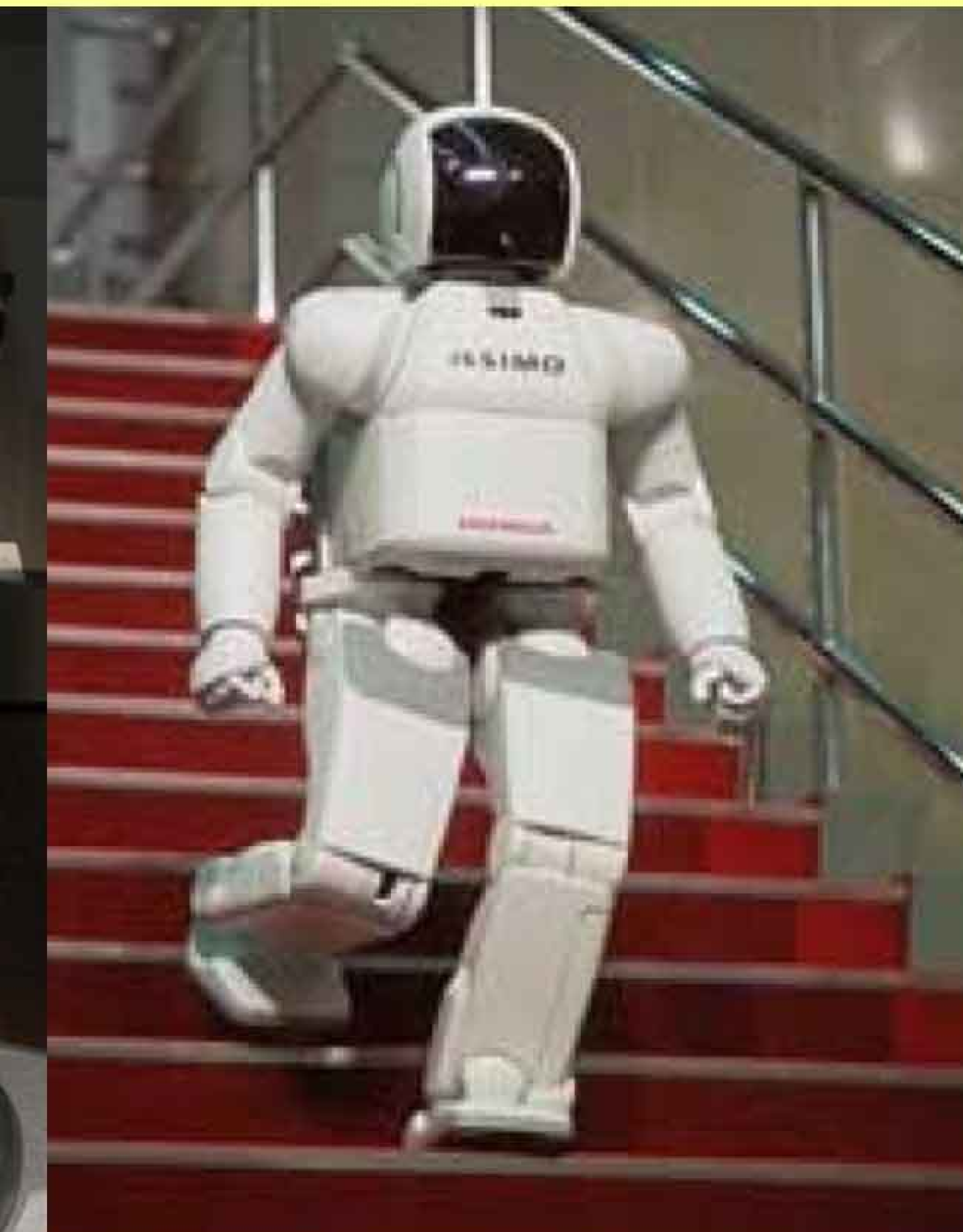
P series: two-legged humanoid walking robot –

P2 - utilised wireless 6'

2000: **ASIMO**, **Advanced Step in Innovative Mobility** the highly-advanced, stair climbing, hand shaking humanoid robot

4' moves like human, with 26 degrees of freedom. able to move 26 different joints in 26 different directions.

Guest quiz show *QI on 2 December 2011. After serving water to Stephen Fry and dancing with comedienne Jo Brand, ASIMO won with 32 points.*



2005 Hubo: A humanoid robot developed in 3yrs US$1m by Prof Jun-Ho Oh Machine Control Lab Dept of Mechanical Engineering; Korea Advanced Institute of Science.

150cm tall, 67 kg natural walk, voice recognition and synthesis faculties and advanced vision capabilities with both eyes operating independently.

on-board intelligence supplemented a wireless connection to external server.

41 degrees of freedom, far more than Asimo, which cost US$300m to develop over nearly two decades.

Actroid: 2003: Osaka Uni & Kokoro Co Ltd: External air powers movements quick to fend off poke. AI: react differently to more gentle kinds of touch, imitate human-like shifts in position, head and eye movements and the appearance of breathing in its chest. Realistic silicone skin.
Speech recognition software; verbal response via extrernal speakers

Human-like Androids

2007: **Zeno**, David Hanson robot:

Can see, hear, talk remembers who you are.

AI software, to make decisions, reason and learn.

17" 6Llb: views a 3D mental image of his environment to determine and control physical action and reactions, ability to navigate,

makes facial expressions and moves his body based on what he sees around him.

Character engine with speech recognition and conversational AI for language reasoning.

Zeno can recognize and remember speech and faces and interact accordingly

28 built-in specialized motors in legs, torso, arms and face.

Unlike ASIMO the system is not autonomous
Controlled wirelessly via a standard home PC.

Robots for football?

2004 **Tomotaka Takahash** 'Robo Garage' at Kyoto University.

sleek, manga comic (Astro Boy) inspired design human like mobility.

The Chroino: 35cm humanoid robot sophisticated movements, lithium polymer battery.

"monocoque frame” carbon and plastic cover friendly appearance, SHIN-Walk, ability to move more naturally than traditional robots that walk stiffly with constantly bent knees.

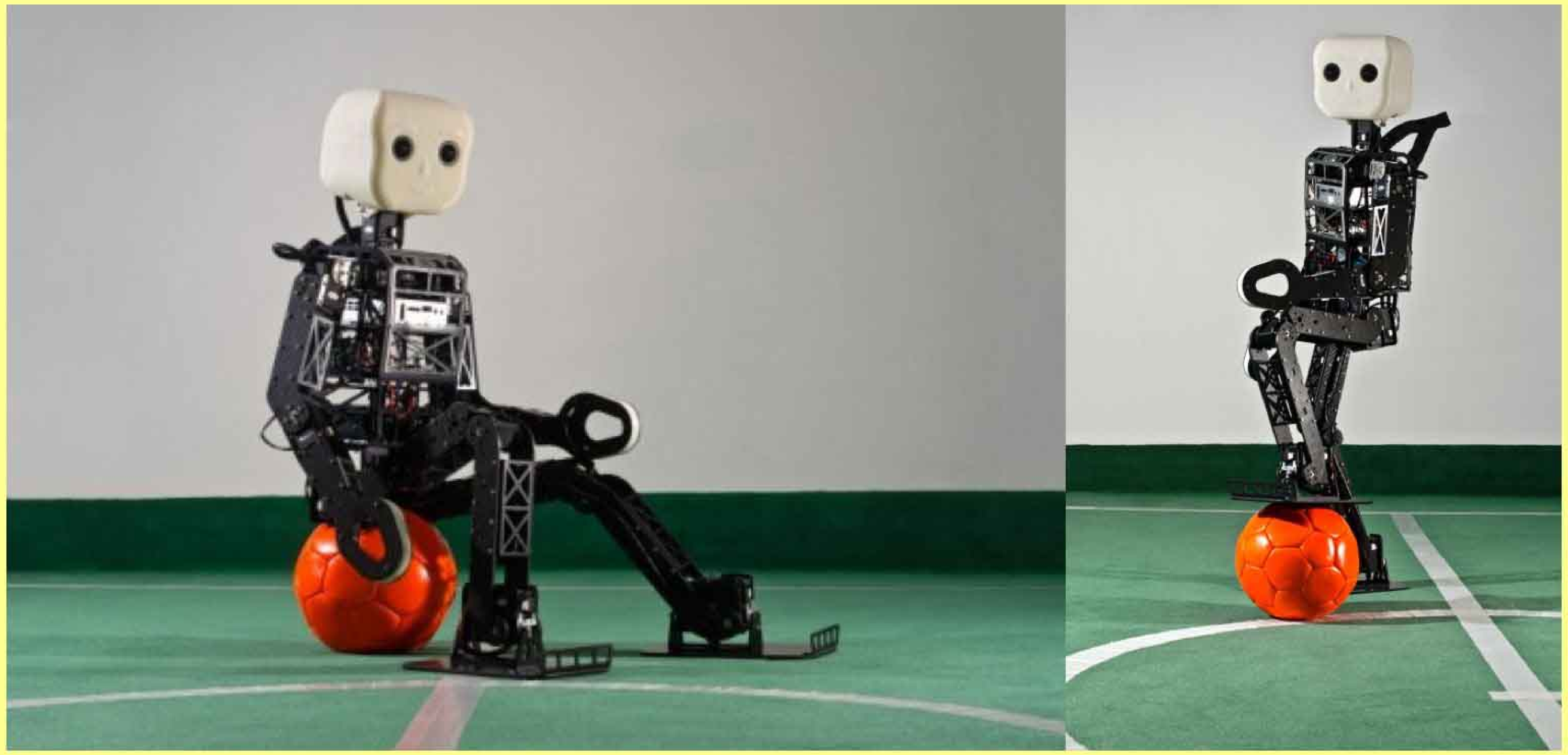
walk, balance, play soccer, and even Moonwalk

Robo Garage developed the VisiON, ENRYU, robovie-R and GUNWALKER models.

Football is a game of 6 robots and the Germans always win

2012: 5 teams qualified for RoboCup's TeenSize League Building a 3’ bipedal humanoid robot difficult for most universities.

NimbRo University of Bonn's Team



Mechanical Saint

1562: **Don Carlos**, 17-year-old crown prince of Spain; fell down stairs.

Trepanation by Andreas Vesalius

King Philip II needed a miracle.

100 yr old mummified corpse of **San Diego de Alcalá**, (died 1463) placed in sick bed.

1562 Juanelo Turriano, engineer to Philip's father: the Holy Roman Emperor Charles V

Commissioned to celebrate miraculous survival of Don Carlos.

Driven by clockwork, key-wound spring, the 15" monk walks in a square,

Strikes his chest, raises, kisses crucifix and rosary moves head, rolls eyes, and mouths silent prayers.

The inbred Don Carlos mental instability

(maternal grandmother and pat. g-father were brother and sister, his mat^{n} g-father and his pat^{n} g-mother were also brother and sister, and his two great-g-mothers were sisters)

Plots against his father

1568: Solitary confinement dies 6m later

Perhaps murdered as in the French-language Opera by Guiseppi Verdi

1588: Petition of Philip, to Pope Sixtus V the only canonization of C16th, first of a lay brother of the Order of Friars Minor.

Franscican Mission of San Diego California

Smithsonian Institution

Don Carlos by Alonso Sánchez Coello, 1558

Advanced robots

Kumotek: VisiON 4G Advanced Humanoid Robot:

Fully autonomous robot based on sensory information

Walking and movement control technology Robovie-Maker motion-editing software for movement.

Advanced brain (CPU board)

38cm 2.4kg

Most advanced bipedal robot' outperforming its rivals at the international RoboCup for design, vision, autonomy, and motion simulation.

Perceptional sense

(Vstone, by Ishiguro Laboratory in Osaka university)

Omnidirectional sensor 360^{o} visibility instantaneously. Excellent soccer performer.

Robots need to share the local information in order to recognize the relation of the partner robots in 3-on-3 soccer matches.

Communicates wirelessly with other robots in network Recognize the ball, approach to it, then shoot

Capable of Defense: Recognise opposition

Rescue Bots

2012: **Robonaut 2 (R2)** first humanoid robot in space

$2.5 million 330-llb, 38 PowerPC processors

Articulating fingers and thumbs.

Vision system: 4 stereo and an infrared camera: International Space Station, telemedicine: automated u/s scan and an injection, on a mannequin.

Cyberdyne Co: Robots cleaning up the damage of earthquake and tsunami

HAL: (evil supercomputer Kubrick's 2001: A Space Odyssey) Hybrid Assistive Limb – body suit allows wearing heavy radiation protection without feeling

Sensors monitor signals coming from the brain.

Activates robot's limbs in concert with the wearer's, taking weight off muscles.

1995: T-52 Enryu (*rescue dragon*): Kobe earthquake

5-ton, 10'-tall hydraulically operated robot,

Built to cut a path through debris for rescuers

Either be driven from a cockpit or remote control

Seven 6.8-megapixel CCD cameras mounted all over

Transmit to the remote operator: has no blind spots.

2007: **T-53**: lighter 9-ft machine on treads with a bulldozer attachment and giant arms to move debris

T-53 2007 earthquake hit Kashiwazaki City world's largest nuclear power plant by capacity.

Two iRobot PackBots, used by the U.S. military, have used to explore interior of reactor buildings.

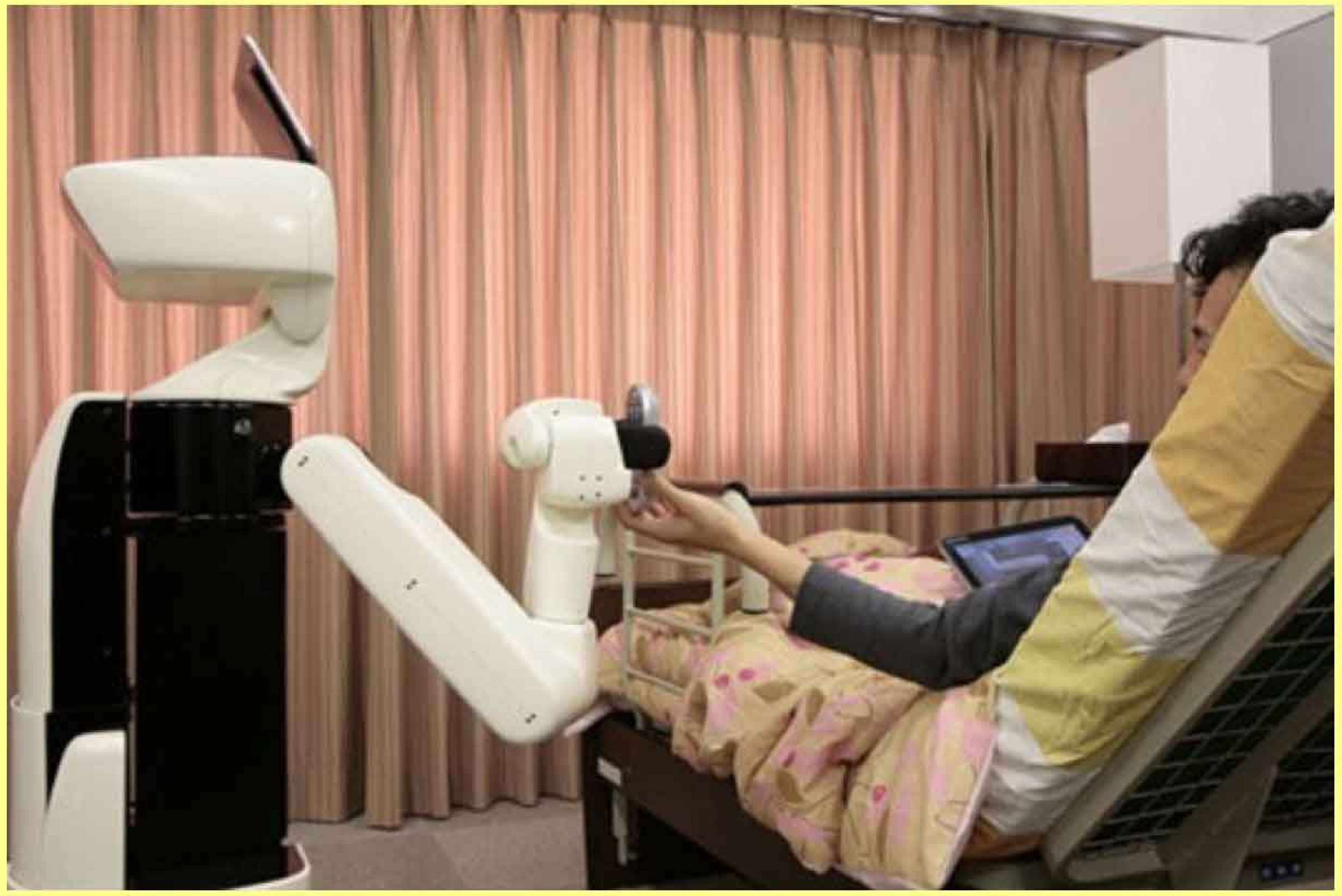
Radiation detector robot

Personal Robots

Toyota Human Support Robot (HSR) health care sector. Prototype being tested

No expensive legs of its predecessors for the simplicity of wheeled locomotion.

A bedridden patient controls the robot with a tablet PC to retrieve items in their room



ABI Research: personal robotics market will be worth $15 billion by 2015.

Toy robots; Sony's Aibo and iSobot, single-function "task" robots such as the Roomba vacuum cleaner and Looj gutter cleaning iRobot.

Evolution Robotics: **ER2** multi-purpose personal robot new technologies including robotic vision, enhanced navigation using a system vSLAM (visual Simultaneous Localization and Mapping), a new object recognition system that can be trained to recognize objects using a single camera and human-robot interaction technologies

Robi 13.4" tall (1 kg)

De Agostini, Italian publisher weekly basis, build own robot.

70 JPY¥1,990 issues ($25),

Key applications including security, video-conferencing and tele-presence, entertainment, child education, and training or personal assistance programs.

What should my robot look like?

Assistive robots in our homes elderly care doing laundry

Spare $400,000? Buy your own robot Willow Garage PR2 robot on general sale.

Two gripper-equipped arms, laser scanner and multiple cameras: fold towels, fetch a beer and plug itself into the mains when it needs to recharge.

Akanksha Prakash, Georgia Tech's Psychology.

Participants shown three images: Human or robotic face, or mixture, which most comfortable interacting with.

We assign ***emotional traits*** to a robot based on its face,.

"preferences for robot appearance varied across tasks."

For robotic investment advice: younger participants liked a mixed human-robot appearance, while older adults tended to prefer a more human face.

social tasks, both preferred a more human face.

associated robot with human-like care and trustworthy
Nothing like a human for toilet/washing

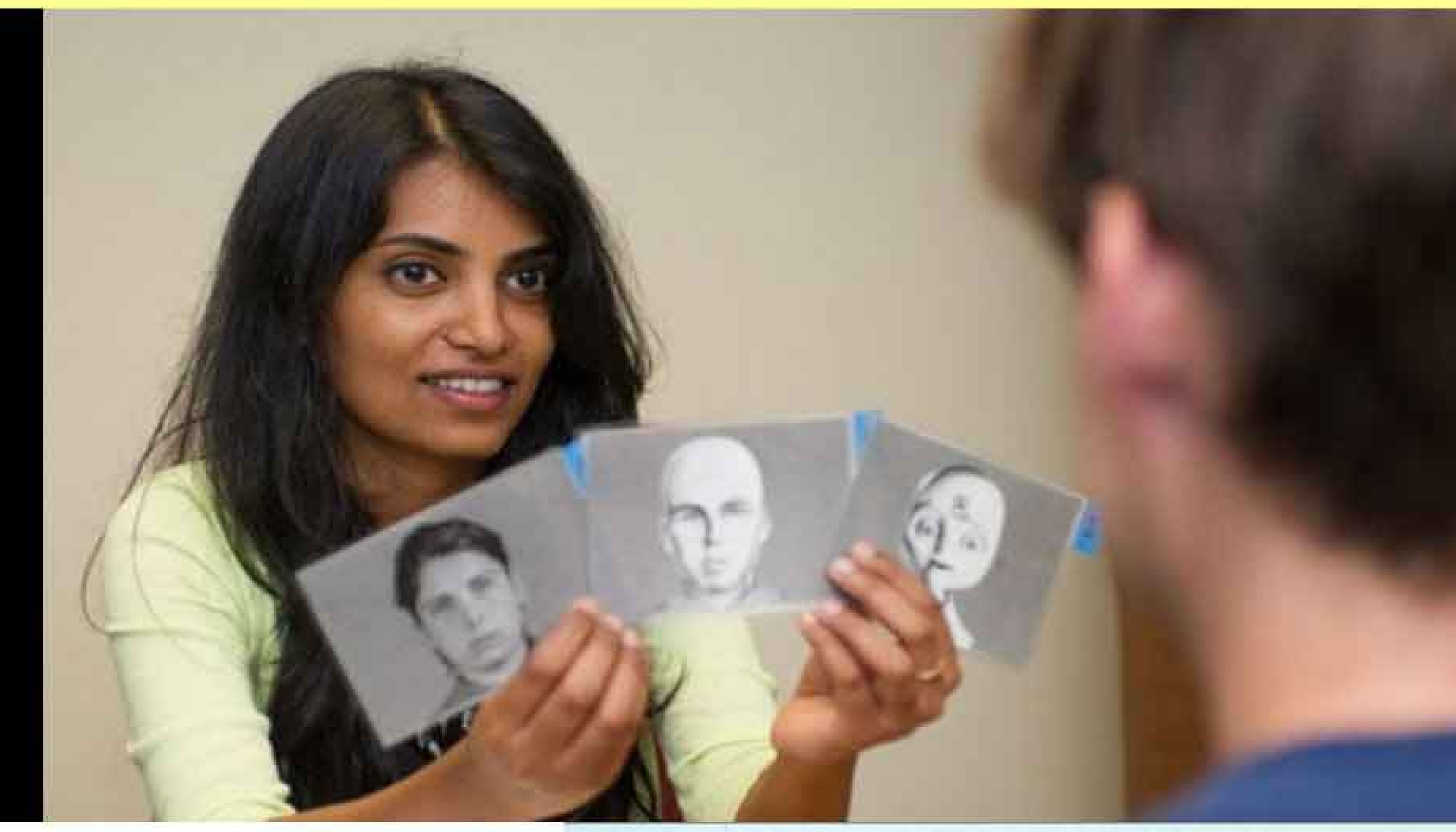
A human-like face, as opposed to just *human features*.

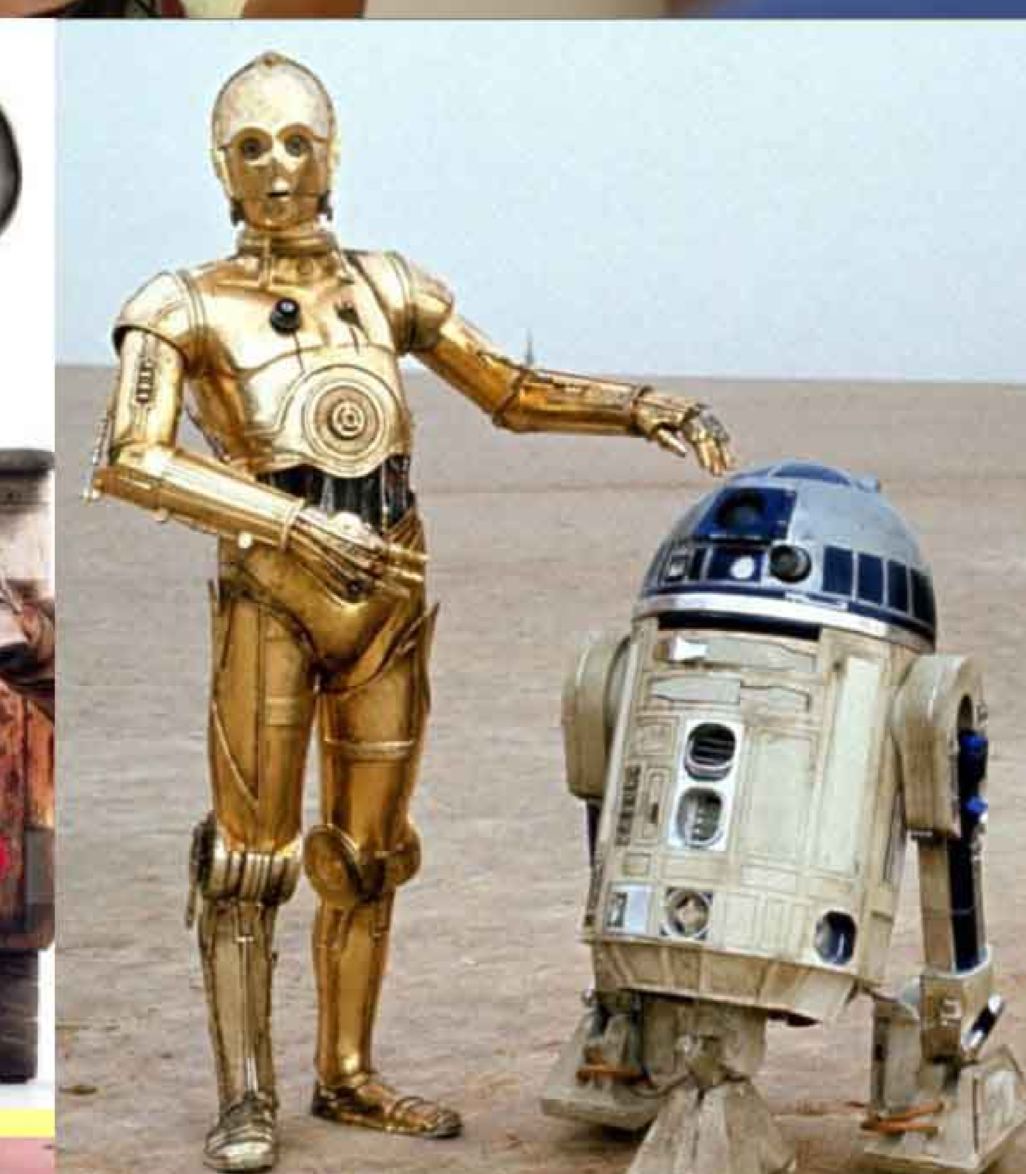
WALL-E had human features (eyes and eyebrows) that provided a huge range of expression

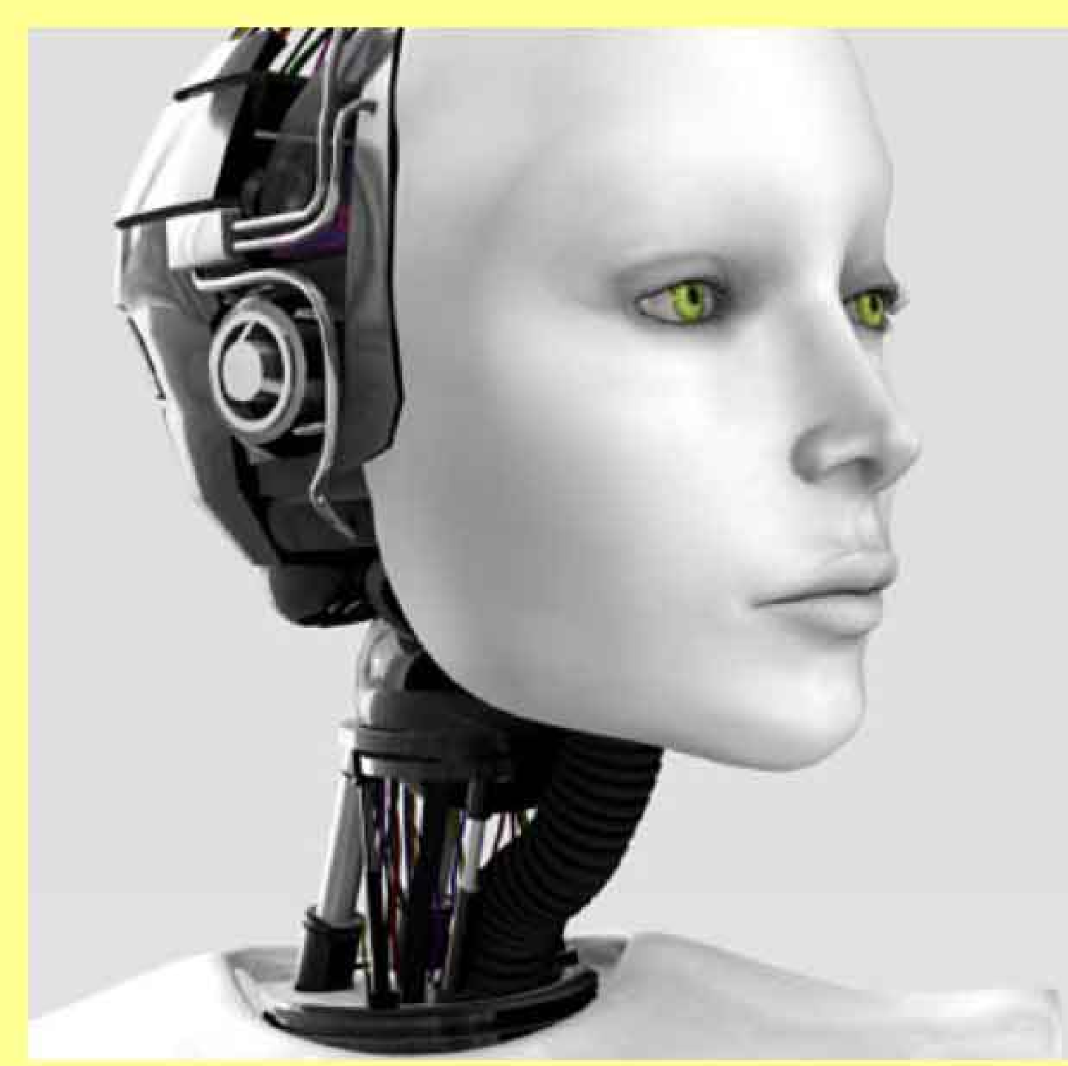
R2D2 & CP30

When robots enter our homes, they're **not** going to look much like us at all.

Brigit Helm anyone?







Drones

1849: Austrians attack Venice unmanned aerial vehicle UAV. Balloon bombs set on fire by electric charge long copper wire

2001: (UAV) in Afghanistan

British Army's minuscule "**Black Hornet**" surveillance devices, which fit into the palm of your hand,

Sentinels used by the US Air Force, "Beast of Kandahar"

Predator high-tech r/c plane though with some autonomous flying capabilities.

Designed for reconnaissance, variety of weapons, laser-guided AGM-114 Hellfire anti-armor missiles. 29 feet long with a 49 foot wingspan.

Since 1995 Iraq, Bosnia, Kosovo and Afghanistan.

US Air Force flew ~54 combat air patrols per day using drones, from bases in Saudi Arabia and Niger.

RAF: Five Reaper drones deployed in Afghanistan,

Civilian casualties is far higher

Battlefield 'killer robots' almost a reality.

Autonomous robots with the power to make decisions about killing human beings are under development, capable of selecting and killing targets autonomously.

"Lethal armed robots that could target and kill without any human intervention should never be built"

Steve Goose, Arms Division director at Human Rights Watch.

Vision gives robots autonomy
Ethics
Executioners
Soldiers
Surveillance

"watching over”

maintain social control, recognize and monitor threats, and prevent/investigate criminal activity.

TotalInformation Awareness program and ADVISE,

Technologies: high speed surveillance computers and biometrics software, laws: Communications Assistance For Law Enforcement Act,

Governments now possess an unprecedented ability to monitor the activities of their citizens

THANK YOU

C18th Automatons

1768-74: Pierre Jaquet-Droz Swiss: Machine Dolls advertising to sell watches. They are still working 6,000 moving pieces

programmable (change the message it wrote),

1773: “The artist” - 2000 parts.

Drew 3 pics: portrait of Louis XV and his dog Mon toutou, Marie Antoinette and Louis XVI, and Cupid’s chariot pulled by butterflies.

Mechanism: system of cams control hand movement in 2D, and lifting the pencil.

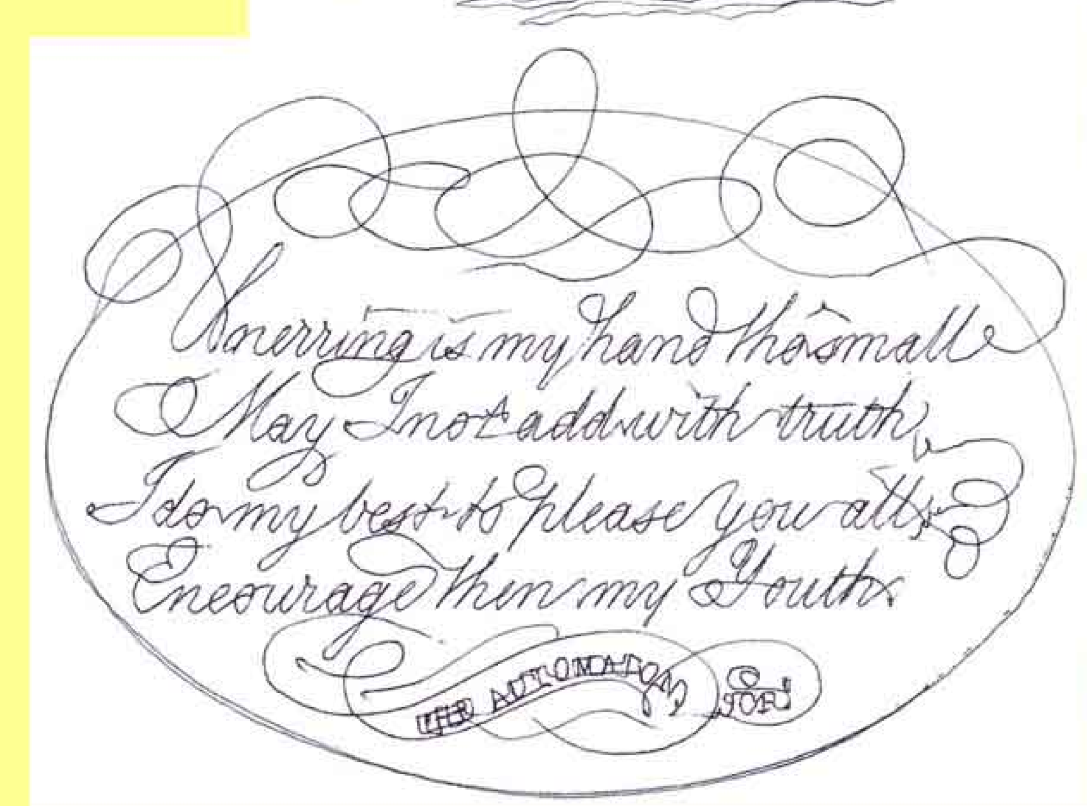
1772: **The Calligrapher** – complex 6000 parts. Writes a text of 40 letters encoded on the wheel selected one after the other.

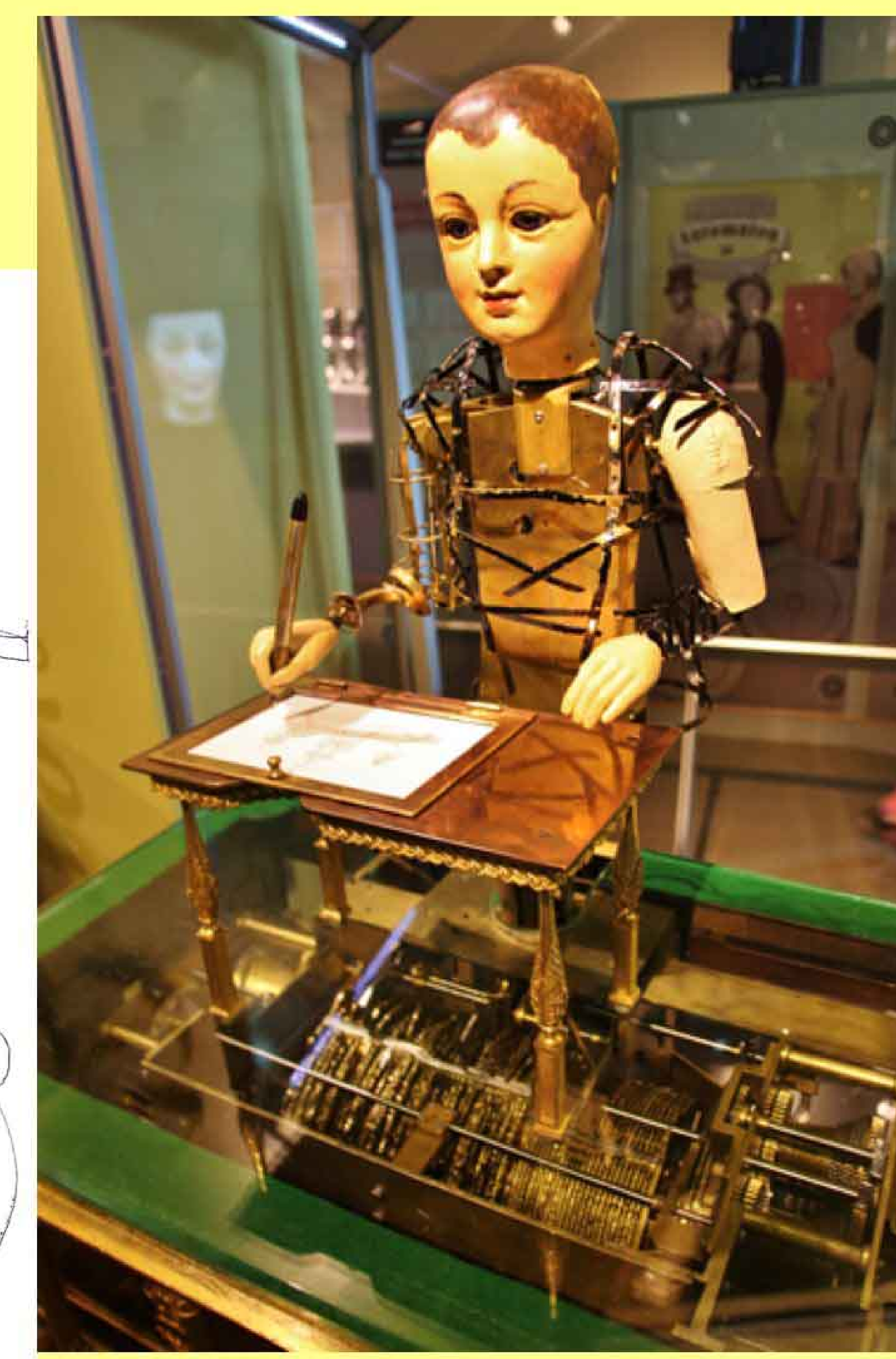
1800: **Henri Maillardet**, Swiss clockmaker worked in London

Draughtsman-Writer largest "memory" on brass discs; of any automaton—4 drawings and 3 poems (French and one in English).

Cams turned by clockwork; 3 steel brushes follow irregular edges translating the movements into side to side, front and back, and up and down movements of the doll's writing hand to produce the markings on paper.

Also made an automaton for Chinese characters given as a gift by George III to Emperor.





C18th Automatons

1737, **Vaucanson**: ***Flute Player***, life-size shepherd played tabor & pipe: 12 songs.

***Canard Digérateur*, Digesting Duck**

Mechanical duck ate grain, and defaecated Food collected in a container, pre-stored faeces was 'produced' from a second

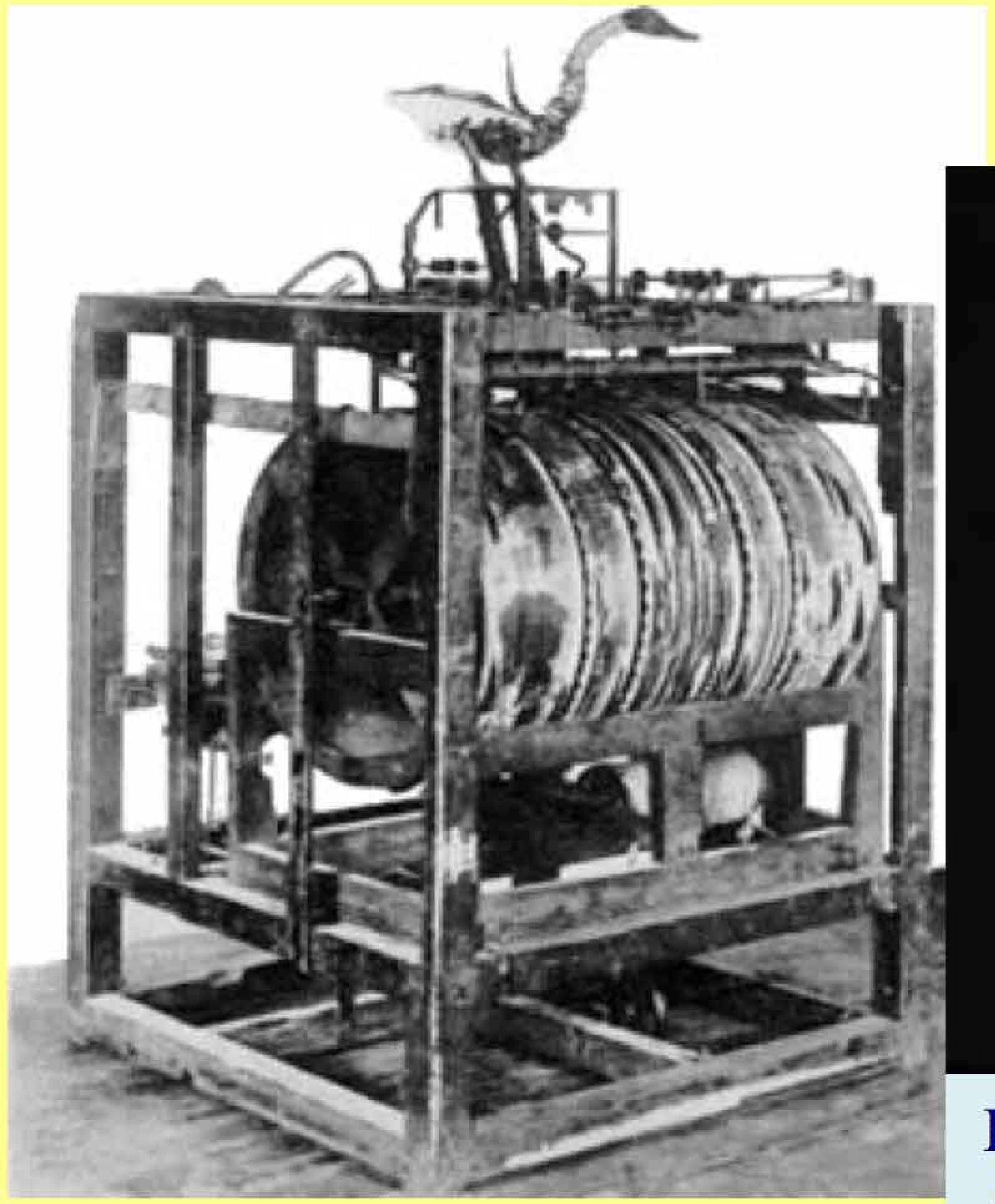
No actual digestion took place

Voltaire "without...the duck of Vaucanson, you will have nothing to remind you of the glory of France."

Tipu's Tiger: Death of Munro

Sultan of Mysore 1782-99. Locally painted wooden case; mechanism French artisans employed by Citizen Tipu's unofficial alliance with Revolutionary government.

1793: General Sir Hector Munro, victorious in second Mysore War. Only son eaten by 'an immense riyal tiger...four and a half feet high and nine long' when out shooting near Calcutta



Reproduction by Frédéric Vidoni Museum of the Automata: Grenoble

Pseudo automatons

1770 – “The Turk”– Wolfgang von Kempelen (Hungarian):
Clockwork : played chess against humans, Napoleon Franklin

An illusion,—hidden player in the cabinet and puppet.

Polish patriot, Worousky, lost both legs; artificial limbs in public,

1784: Racknitz saw performance in Dresden: built a series of models "The chess-player of Mr. Von Kempelen and an imitation of it".

1875: Psycho: The Egyptian Hall “England’s home of mystery”

John Nevil Maskelyne: Illusionist greatest brand name in *magic*. Invented illusions still performed today influenced Harry Houdini

John Algernon Clarke Agricultural inventor

mechanical man, appear to think, answer questions play cards.

Wore Chinese silk and turban (Oriental associated with mystery)

Box too small for a child & glass pillar so audience could see no hidden working

Rack of 13 cards play a game of whist

The exact workings of this mechanism are unclear.

Hidden backstage the operator, could see Psycho's cards

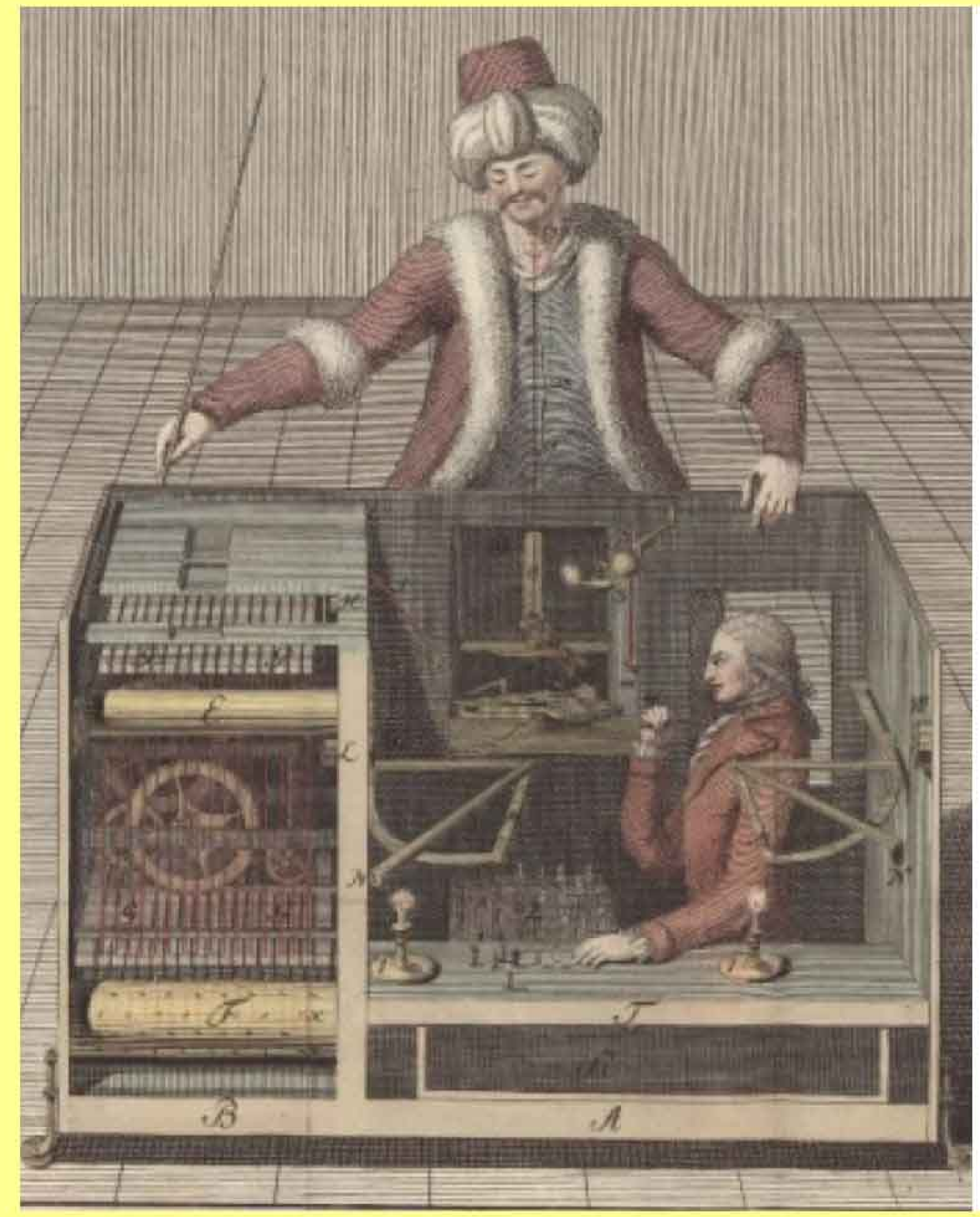
Inventors patented method of controlling clockwork compressed air.

Bellows to push compressed air through the glass cylinder.

Reciprocal bellows could have moved the internal mechanism

Offered £2000 to anyone who could emulate Psycho's act with automaton

Psycho not a real automaton: operated by a human being.



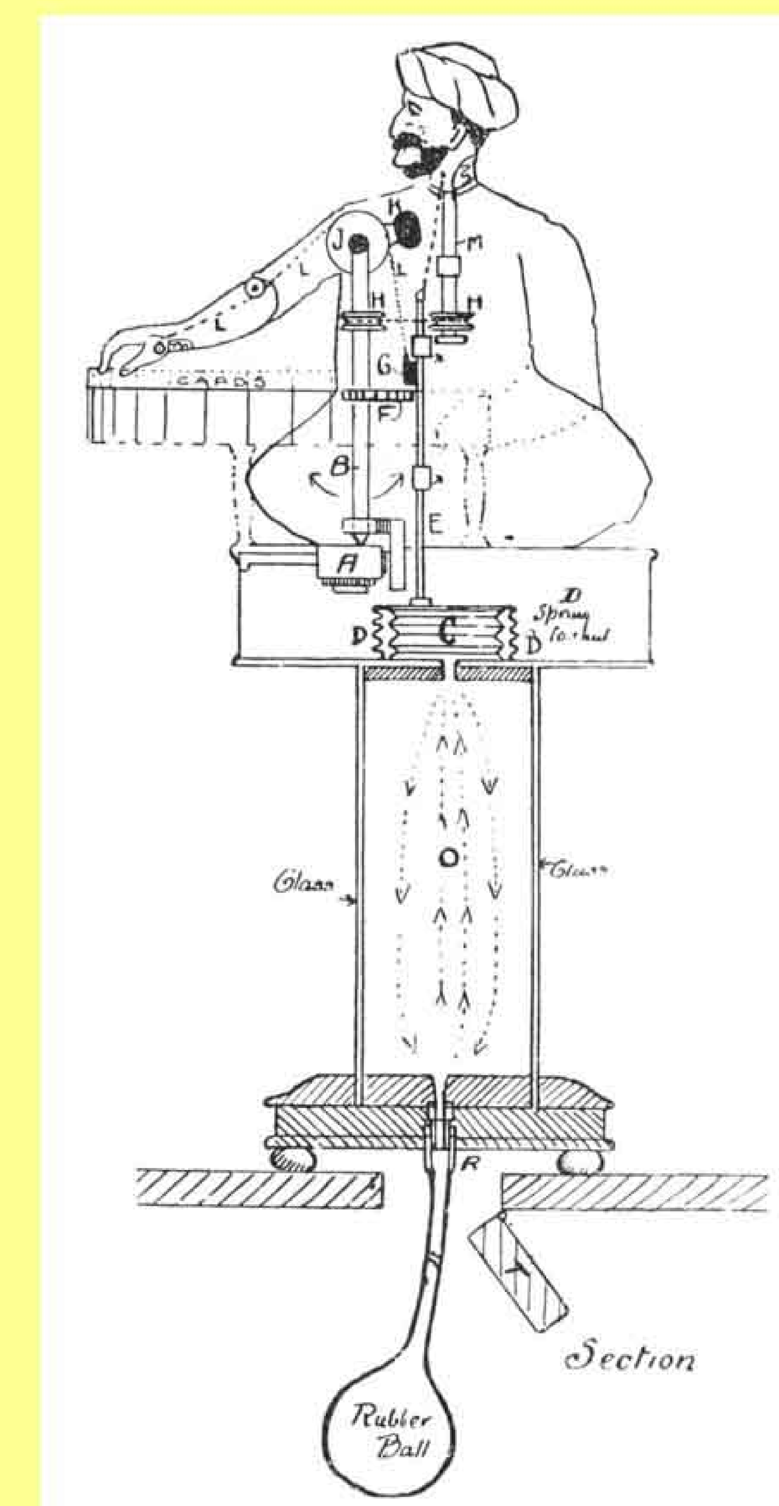


Fig. 473 Fortune-teller worked by compressed air (after A.-W. Gamage).