Digital Image Processing

COSC 6380/4393

Lecture – 1

Aug 22nd, 2023

Slides from Dr. Shishir K Shah and Frank (Qingzhong) Liu

Digital Image Processing

COSC 6380/4393

- Instructor
  - Pranav Mantini
  - Email: pmantini@uh.edu
  - Office: PGH 524
  - Office Hours: Th 10:30 AM – 11:30 AM (In-person, Room: PGH 524)

- TA

1. Nguyen, Vuong (Dustin)
   - dnguyen170@uh.edu
   - Office Hours: Wed 4:30 – 6: 30 PM
2. Mirza, Samiha
   - samiha.mirza1234@gmail.com
   - Office Hours: Mon 9 – 11 AM
3. Aloui, Rahma
   - raloui@cougarnet.uh.edu
   - Office Hours: Tue 10 – 12 AM

Introduction to the course

- Class Time & Location
  - Face-to-face:
    - Location: MH 150
    - TTh: 08:30 AM – 10:00 AM

- Grading
  - Assignments: 60%
  - Exam: 20%
  - Quizzes: 20%

- Individual Assignments (Coding)
  - **~4** to 5 Assignments - 60%
  - Implementation: Python
- Mid-term Exam – 20%
- Quizzes - 20%
  - Biweekly (once every 2 weeks)
  - Includes content from past two weeks
  - No quiz during midterm week

Logistics

- Late policy for Assignments:
  - Late by 1 day - 25% off the grade
  - Late by 2 days - 50% off the grade
  - Late by more than 2 days – No Credit
- Late policy for quizzes/midterm:
  - Late submission – No Credit
- Collaboration policy:
  - No collaboration allowed for **assignments; coding must be done individually.**
  - Discussing **Quizzes and midterm** is **not allowed**
  - Coding policy: using online code or other students/researchers' code is not allowed.
  - Posting questions on online forums (Chegg.com, etc.) is **not allowed**

Plagiarism

- The entire assignment/project will **not be graded**, **zero score** will be awarded, and **reported** to the department.
- Tips:
  - Do not share code/report
  - Do not share snippets of code
  - Do not share algorithms
  - Do not copy from online sources
  - Ideally, your code should not leave your computer/repo except for submission

TEXTBOOK

- **Digital Image Processing, 2nd Edition/3rd Edition, R. C. Gonzales and R. E. Woods, Prentice Hall.**

Course Expectations

1. Lectures (Required)
    1. Attend Lecture meeting (face-to-face)
    2. Ask questions
2. Submit quizzes (Required)
3. Submit midterm Exam (Required)
4. Submit assignments (Required)
5. Attend Office hours (Optional)

Attending Meetings

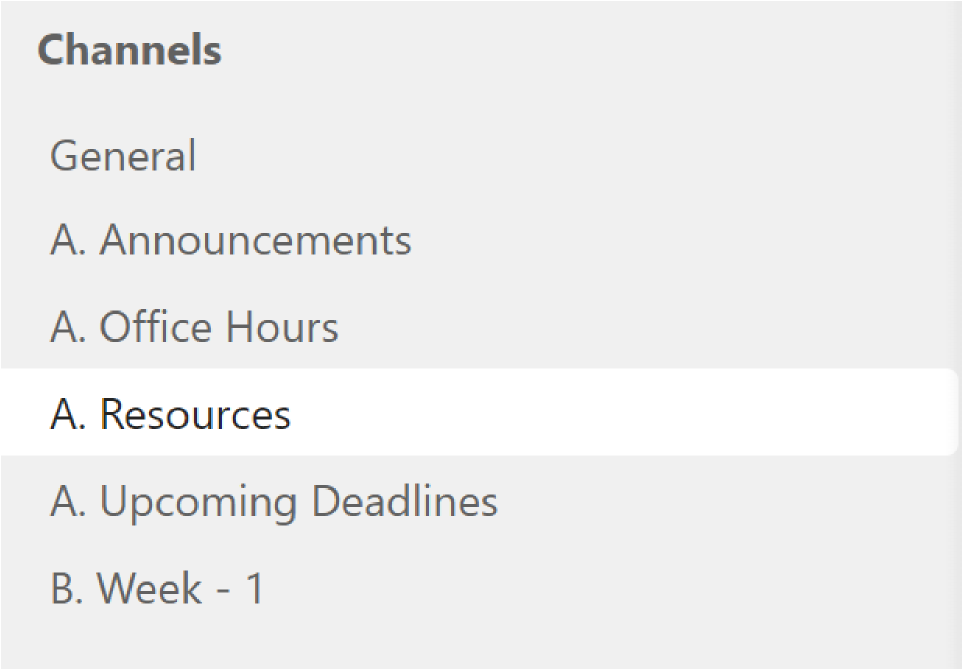
1. Two types of meetings:
    1. Lecture meeting (In-Person): Discuss course topics, address any questions from videos, and answer other questions if time permits.
    2. Office hours (In-Person/Online): Answer questions, help with assignments, etc. Please remember these meetings may not completely be one to one sessions. Please communicate with the TA and setup separate meeting with TA if you need to discuss something alone. (For example, grades etc.)

Microsoft Teams

1. View lecture recordings
2. Submit Homework
3. Submit Quizzes
4. Follow Announcements
5. Access Resources
6. View grades (homework, quiz, and exam)

TA and Instructor: Channels

- **Announcements and Deadlines**:
  - Post HW, Quiz releases along with deadlines
  - Announce upcoming Exams
- **Office Hours**:
  - Post regarding upcoming instructor and TA office hours
- **Resources**:
  - Share additions resource such as files, instructions, homework/quiz solutions, and auxiliary study material
- **Week – X**:
  - 1 channel for each week.
  - Includes video lectures and lab recordings
  - PDF of the lecture slides
  - For example, lecture and material pertaining week 5 can be found in channel Week-5



Student Channels

- General:
  - Students can post messages and discussion here
- Additional channels can be created if needed

Digital Image Processing

Introduction

- Example: Measure depth of the water in meters at a certain pier
- Take measurements randomly over time

H	18	22	4	9	17	7	21	3	19	1	12	13	15	11	6	16	23	10	8	2	20	0	14	5
D	2	1.5	2.4	1.5	2.2	1.75	1.5	2.5	1.75	2.25	2	2.25	2.5	1.75	2	2.4	1.75	1.5	1.5	2.4	1.5	2	2.4	2.25

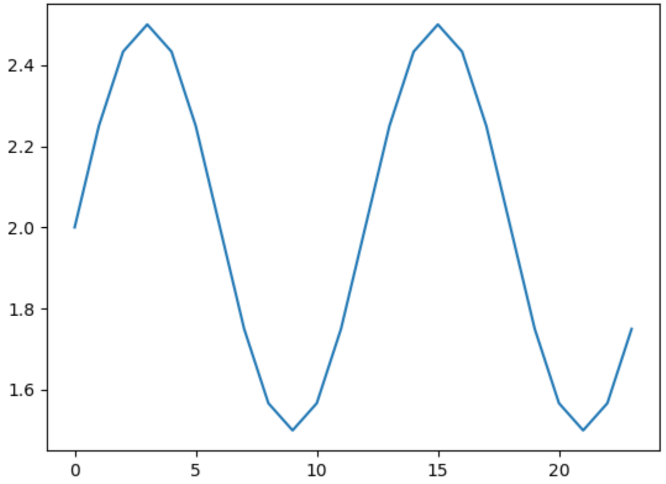
Introduction

- Example: Measure depth of the water in meters at a certain pier
- Another representation

H	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
D	2	2.2	2.4	2.5	2.4	2.25	2	1.75	1.5	1.5	1.5	1.7	2	2.25	2.4	2.5	2.4	2.25	2	1.75	1.5	1.5	1.5	1.75

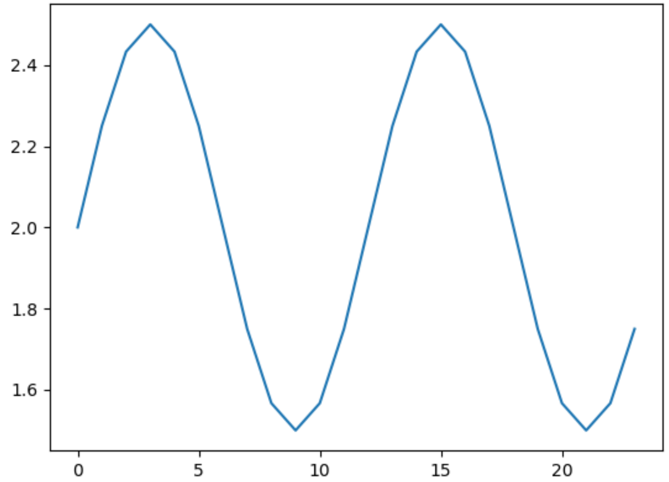
Introduction

- Example: Measure depth of the water in meters at a certain pier
- Yet another representation (chart: a graphical representation of data)



Introduction

- Example: Measure depth of the water in meters at a certain pier
- Yet another representation
- **Image** as a mode/format to convey information; for human consumption, for further processing, and etc.



Why an Image?

Why an Image?

- Psychology
  - Vision is how we experience the world
  - ~ 50% of cerebral cortex is for vision

Image Processing

- How do I acquire images that capture information?
  - Image Acquisition
- How do I process and present the acquired image?
  - Filtering and image enhancement
  - Image restoration
  - Color image processing
- How do we store and transfer images efficiently?
  - Compression
- Can we understand what is the information/content in the image?
  - Computer vision

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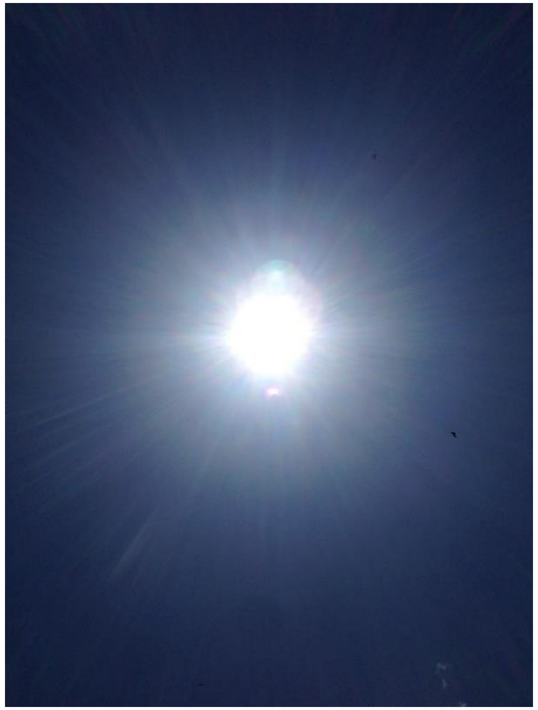
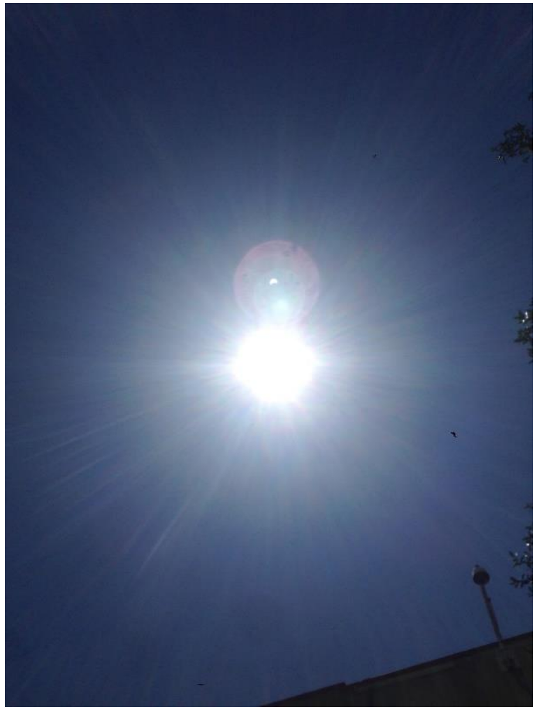
Example: Image Acquisition

- Solar Eclipse: August 21st, 2017
- Objective: Determine the progression of the eclipse

Example: Image Acquisition

- Image Acquisition device: IPhone 5 camera



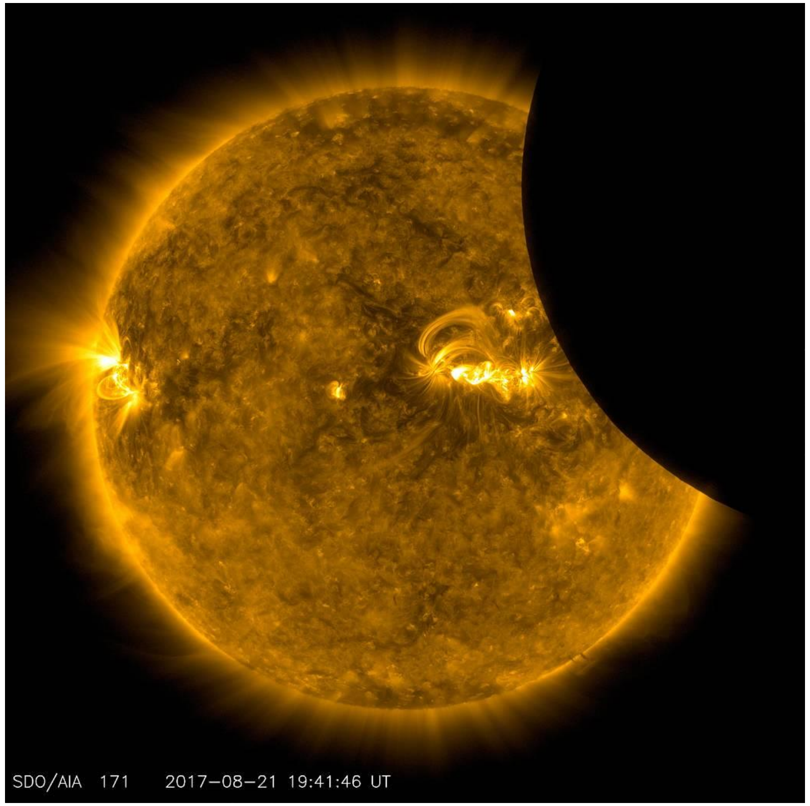


Example: Image Acquisition

- Image Acquisition device: Cardboard box with holes

Example: Image Acquisition

- Nasa: Solar Dynamics Observatory



Source: https://www.nasa.gov/image-feature/goddard/2017/sdo-views-2017-solar-eclipse-171-angstrom

Example: Image Processing

Long-exposure photography: Involves using a long-duration shutter speed to sharply capture the stationary elements of images

Origins of Digital Image Processing

FIGURE 1.1 A digital picture produced in 1921 from a coded tape by a telegraph printer with special type faces. (McFarlane.†)

Sent by submarine cable between London and New York, the transportation time was reduced to less than three hours from more than a week

Origins of Digital Image Processing

- Need for Image processing at Jet Propulsions Lab (JPL)
- Ranger 7 was built to take **high-resolution photographs of the moon** before impacting the lunar surface.
- Ranger 7 lunar lander was the first true success in the United States' early quest to explore the moon
- Ranger 7 approached the moon precisely on target and transmitted 4,308 images in the 15 minutes before it impacted the lunar surface

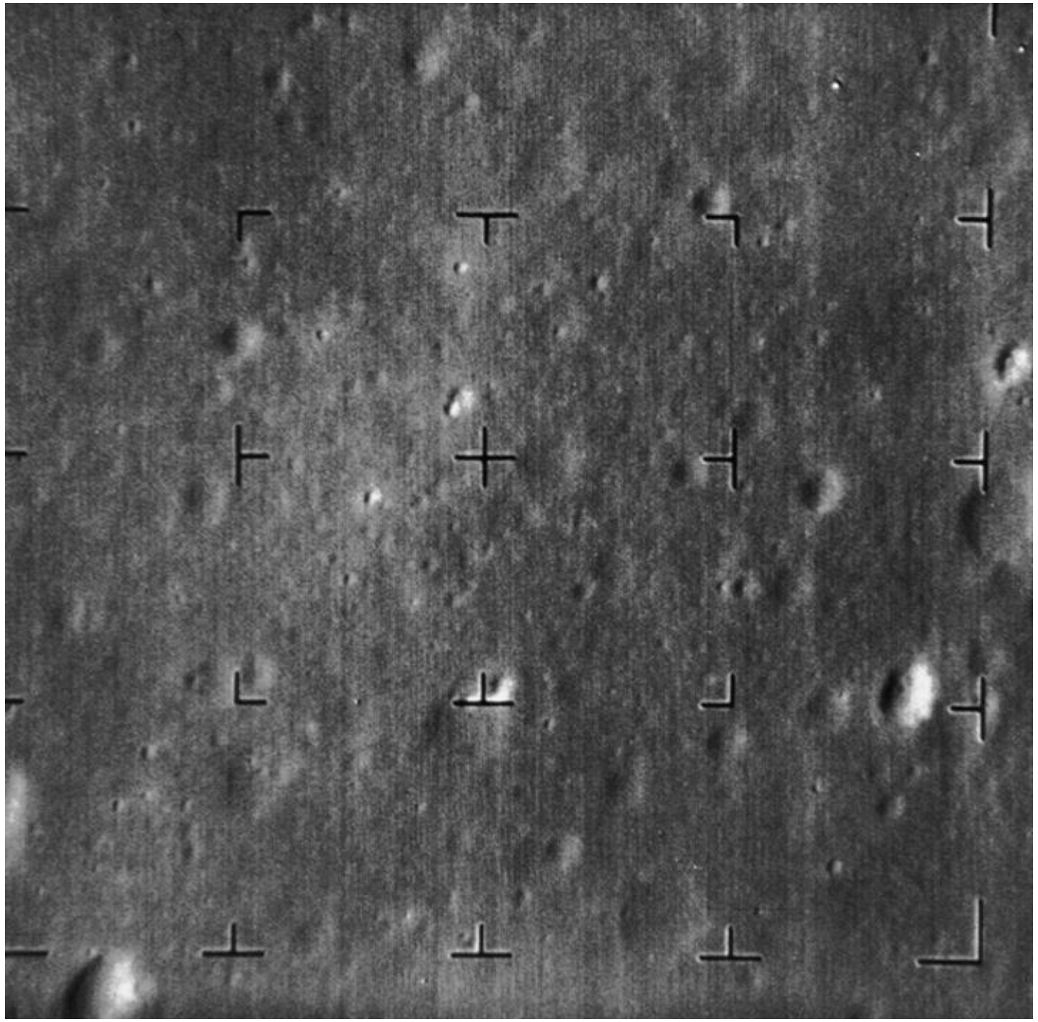
 https://www.jpl.nasa.gov/missions/ranger-7

First Image
2445.97 km

Second Image
2158 km

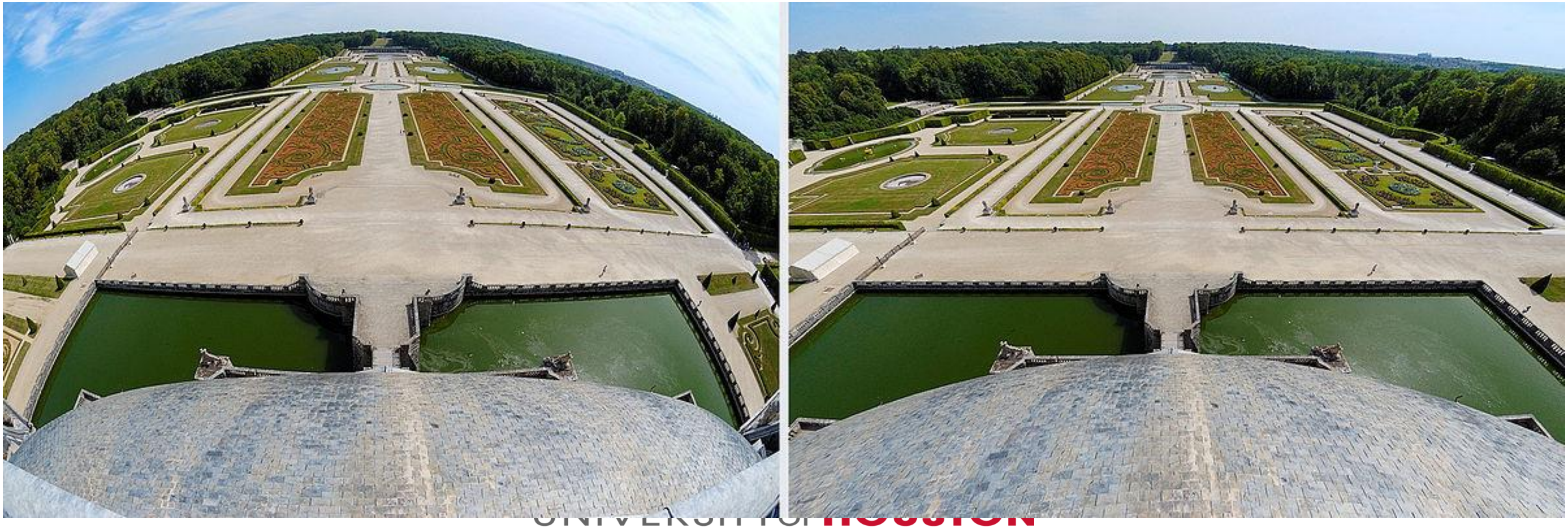
Final Image (2.5s before impact)

6.5 Km



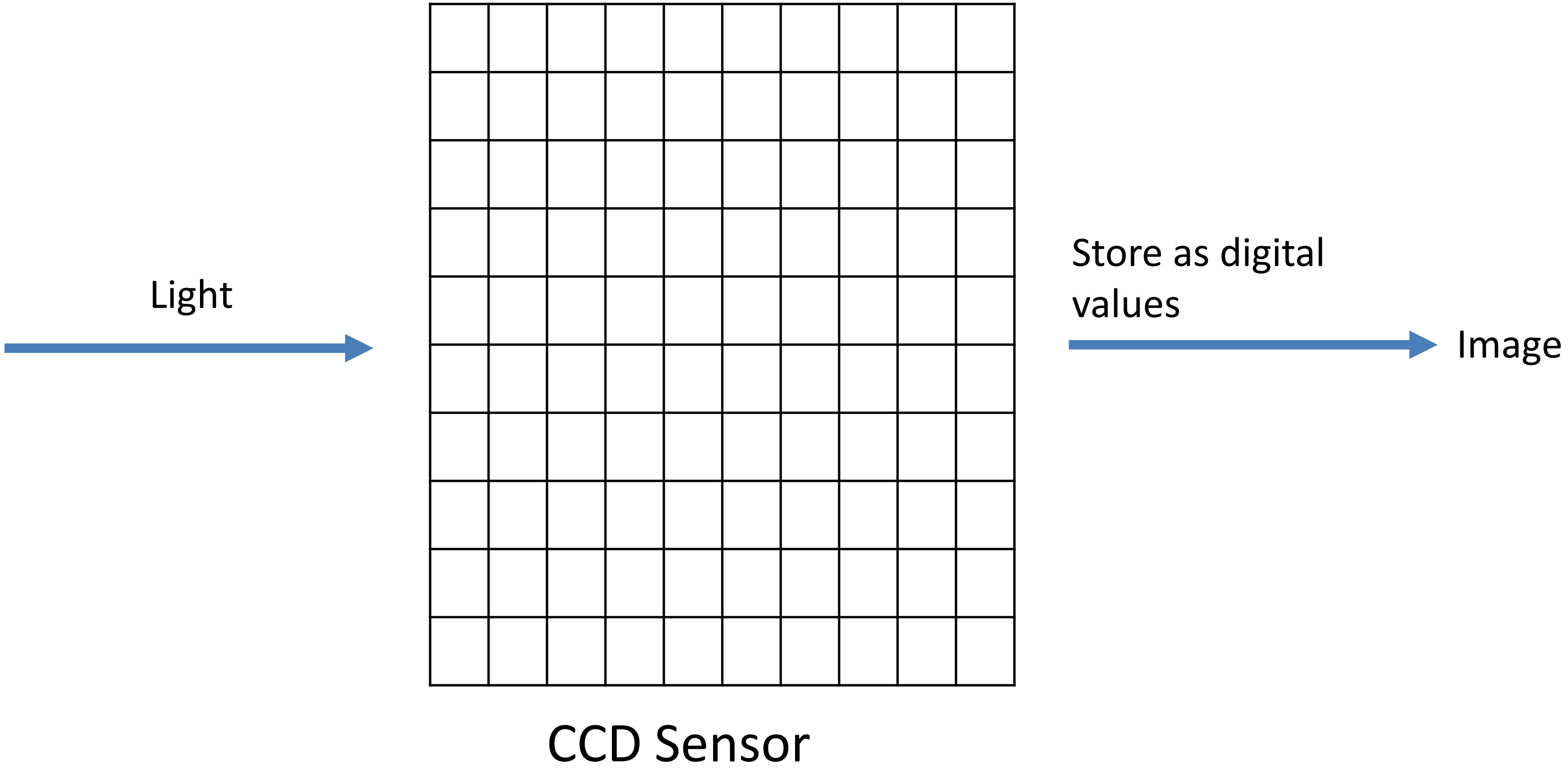
Need for Image processing

- Range 7 carried six television vidicon cameras.
- Lens Distortion



What are digital images?

Example: Camera



Electromagnetic (EM) energy spectrum

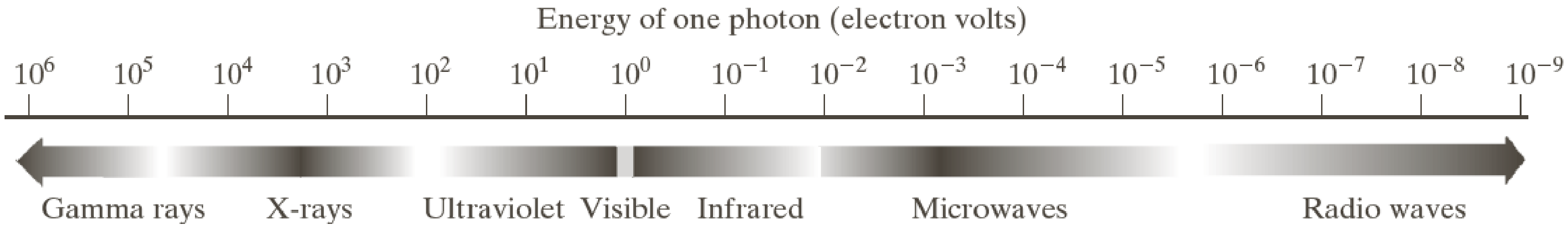


FIGURE 1.5 The electromagnetic spectrum arranged according to energy per photon.

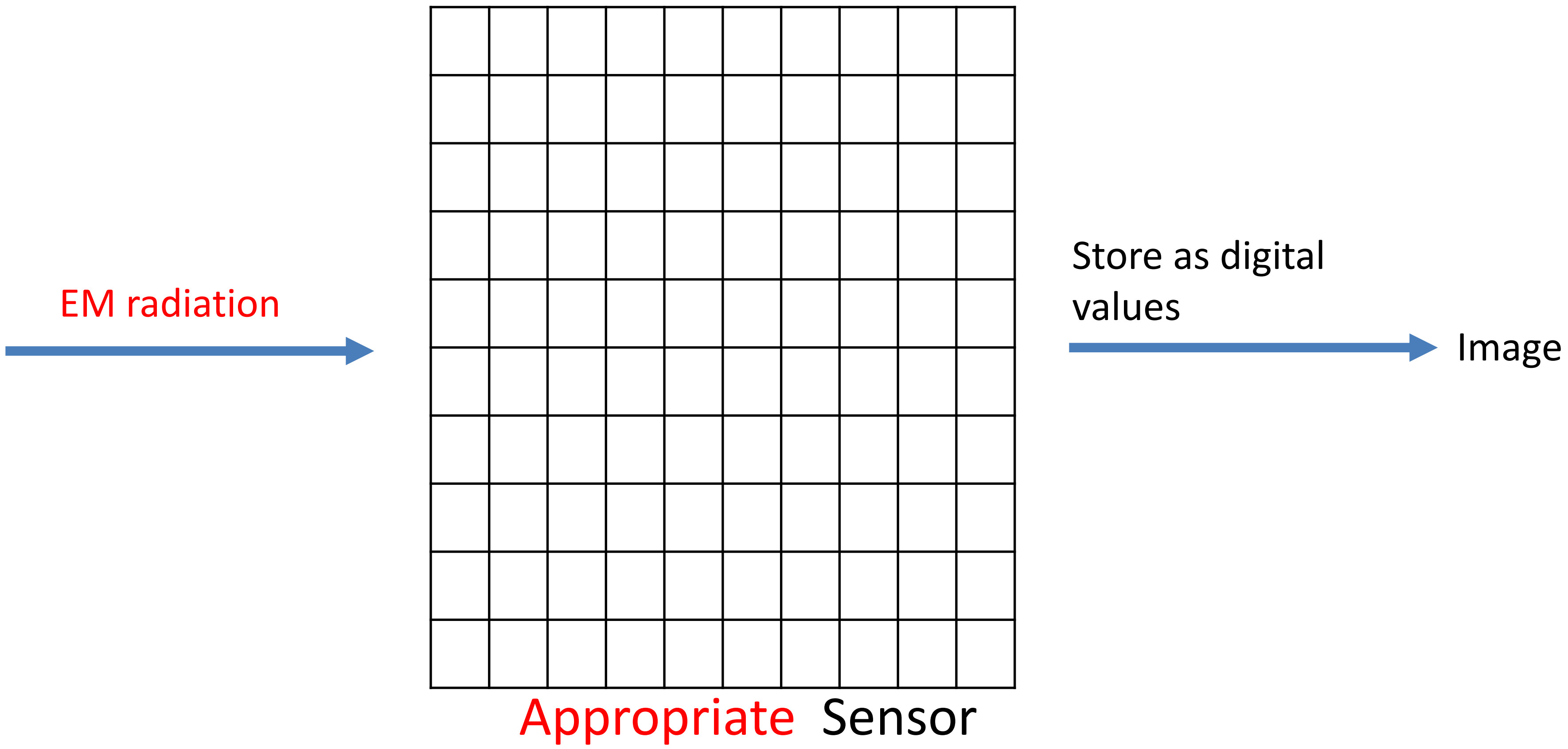
Light, an electromagnetic (EM) wave.

EM waves:

1. Propagating sine wave of varying wavelengths
2. Stream of massless particles travelling in a wave like pattern
3. Each particle has a certain amount of energy (photon)

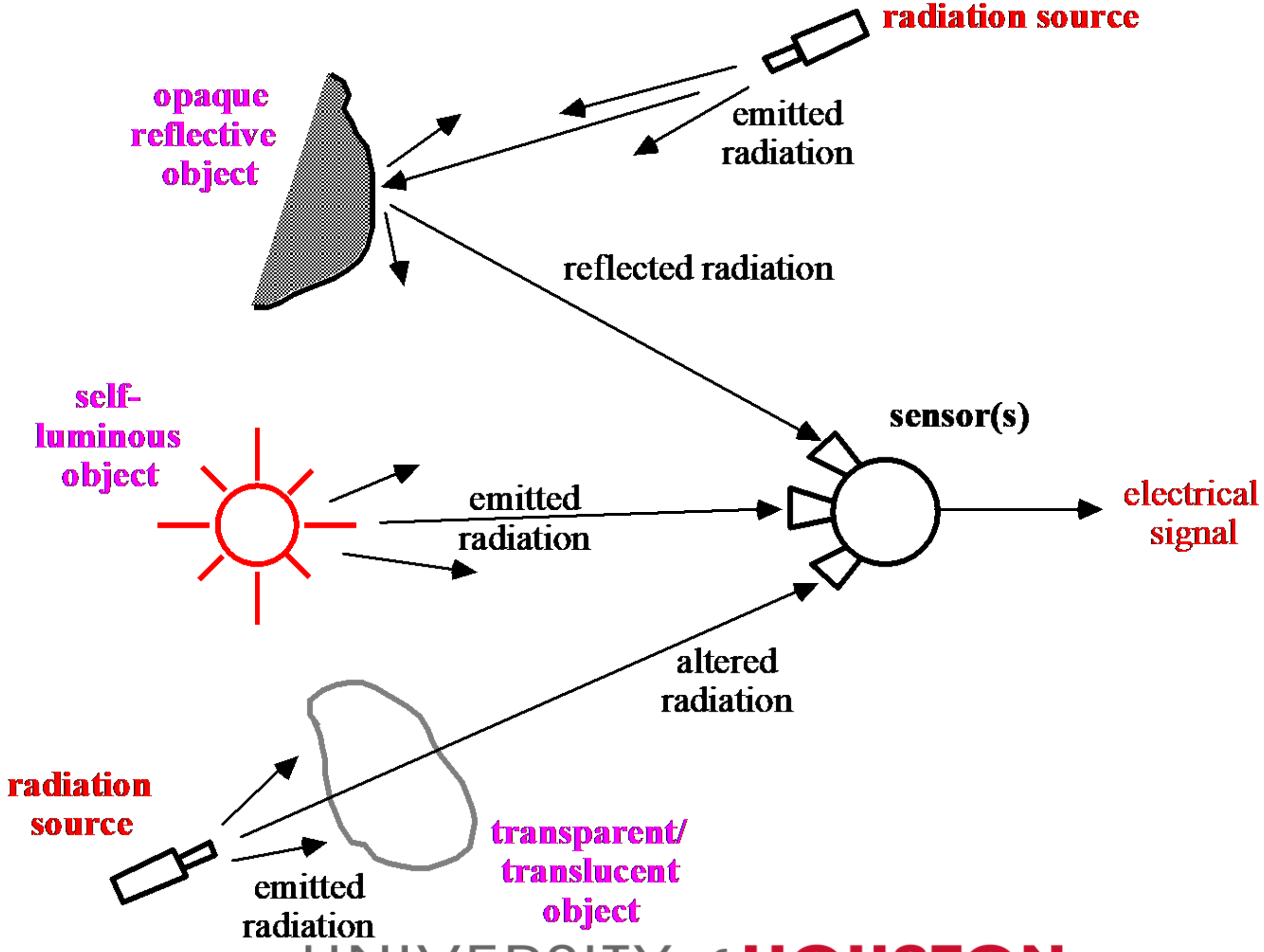
Grouped according to energy per photon

What are digital images?



Types of Radiation

- **Images** are as variable as the **types of radiation** that exist and the ways in which radiation **interacts** with **matter**:



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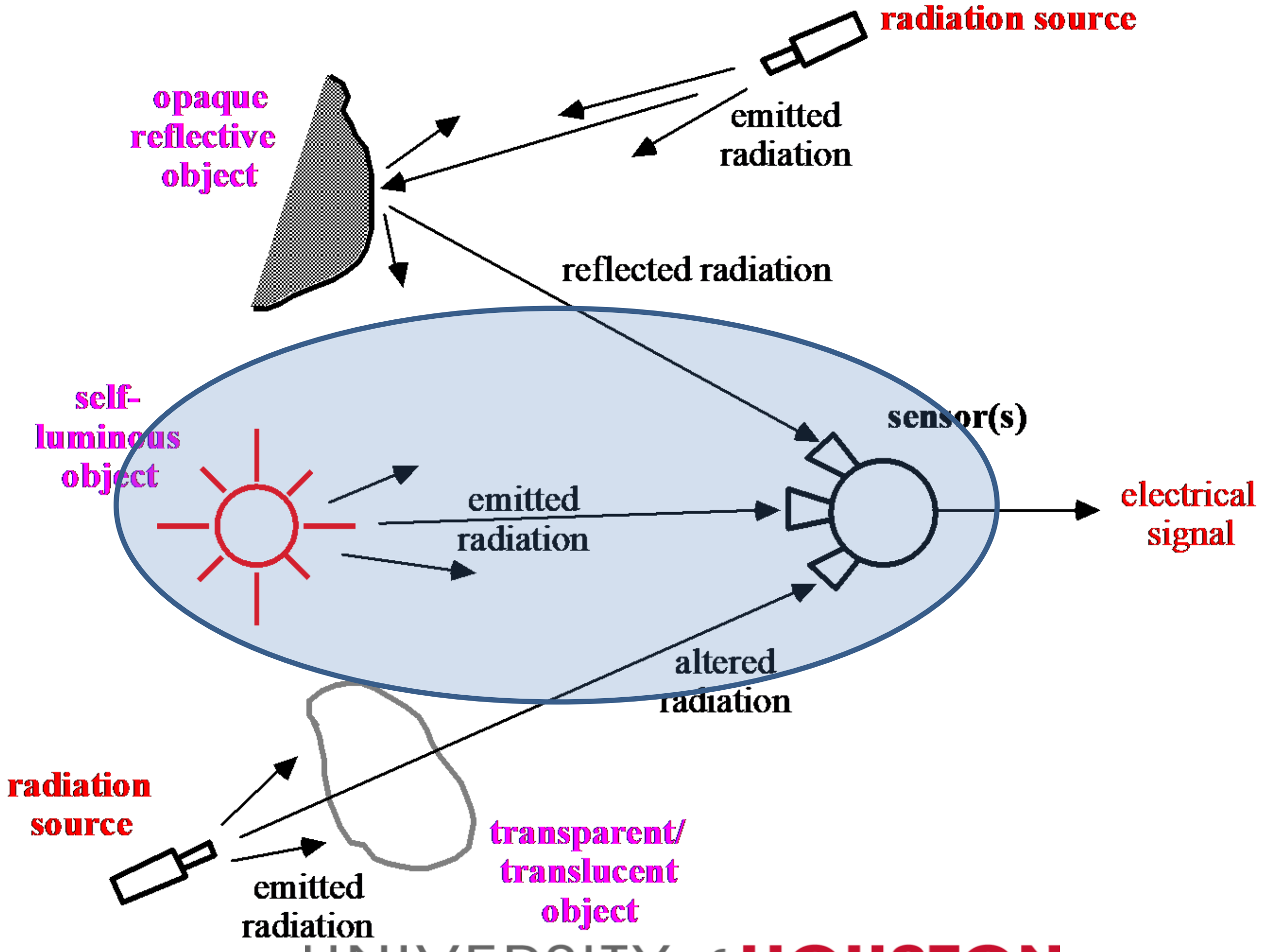

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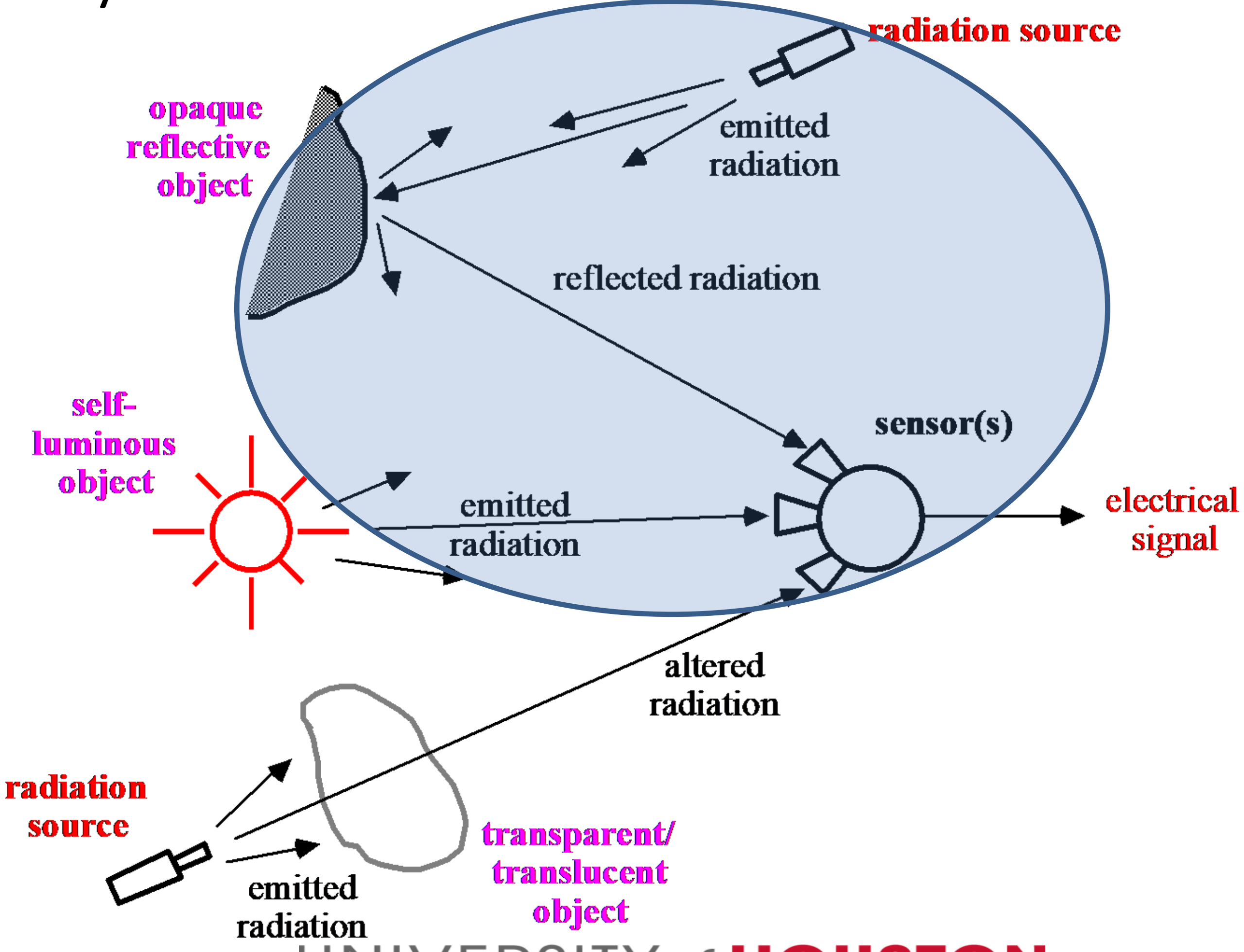

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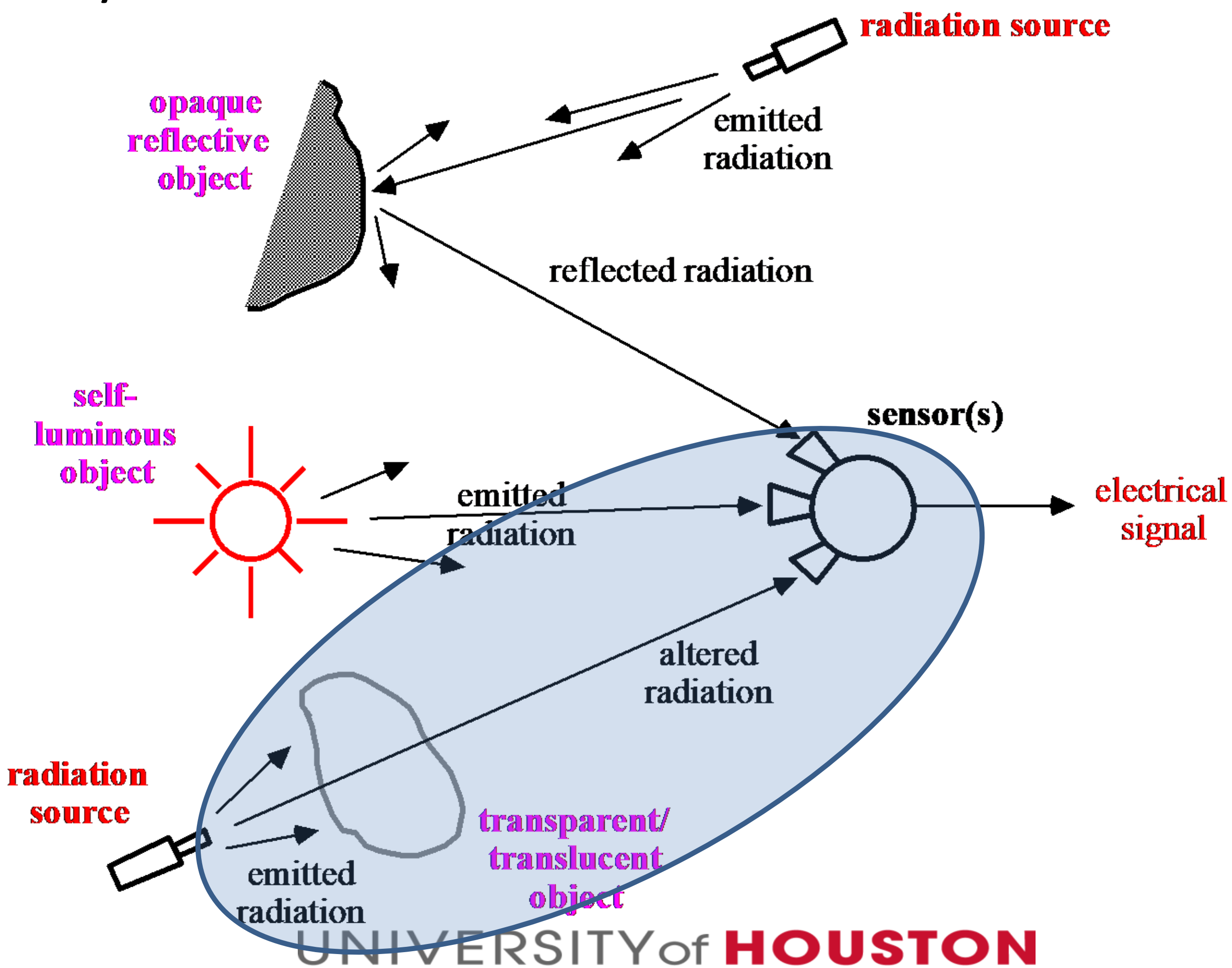


Electromagnetic (EM) energy spectrum

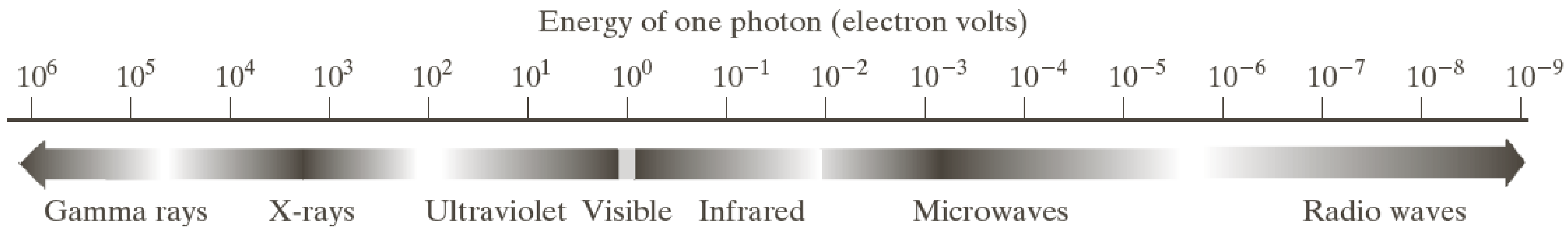


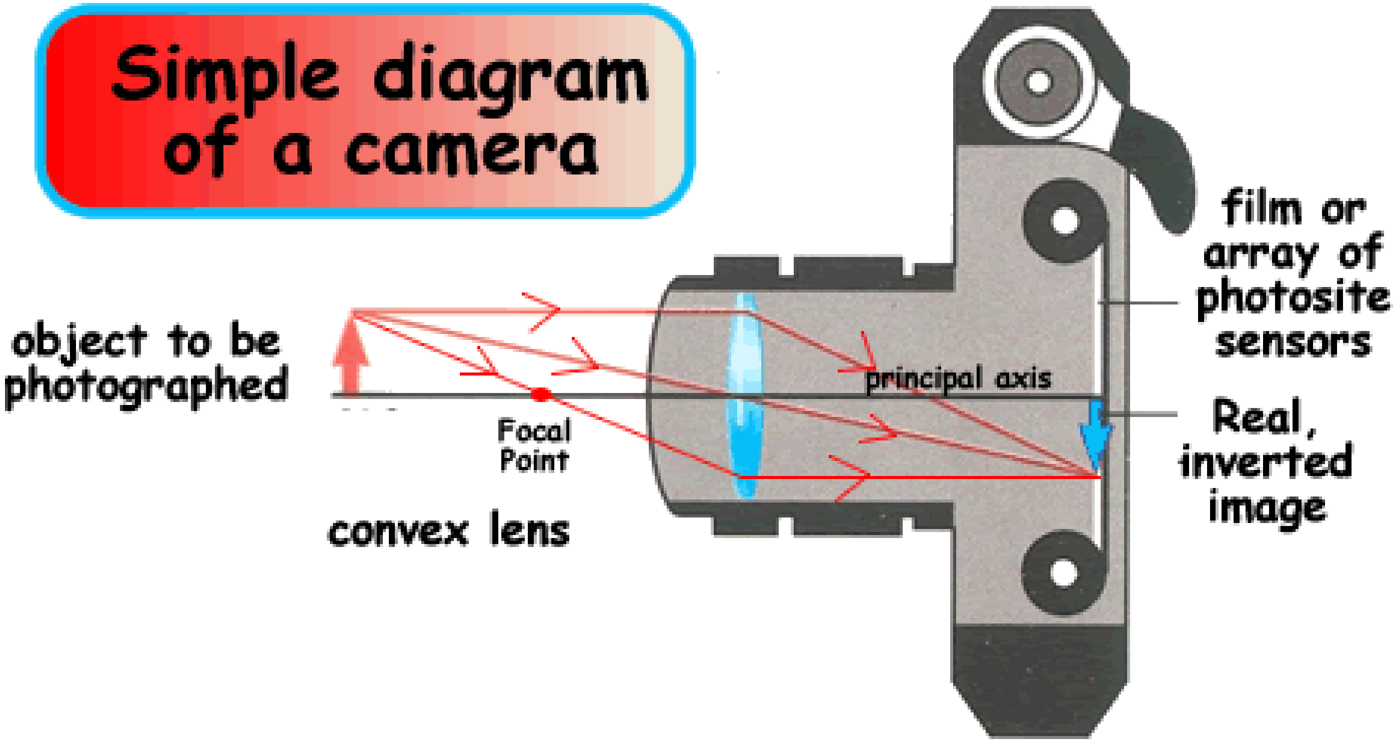
FIGURE 1.5 The electromagnetic spectrum arranged according to energy per photon.

Major uses

Gamma-ray imaging
X-rays
Ultraviolet
Visible and infrared bands
Microwave band:
Radio band

Imaging in visible spectrum

- Camera



https://www.cyberphysics.co.uk/topics/light/camera.htm

Examples: Automated Visual Inspection

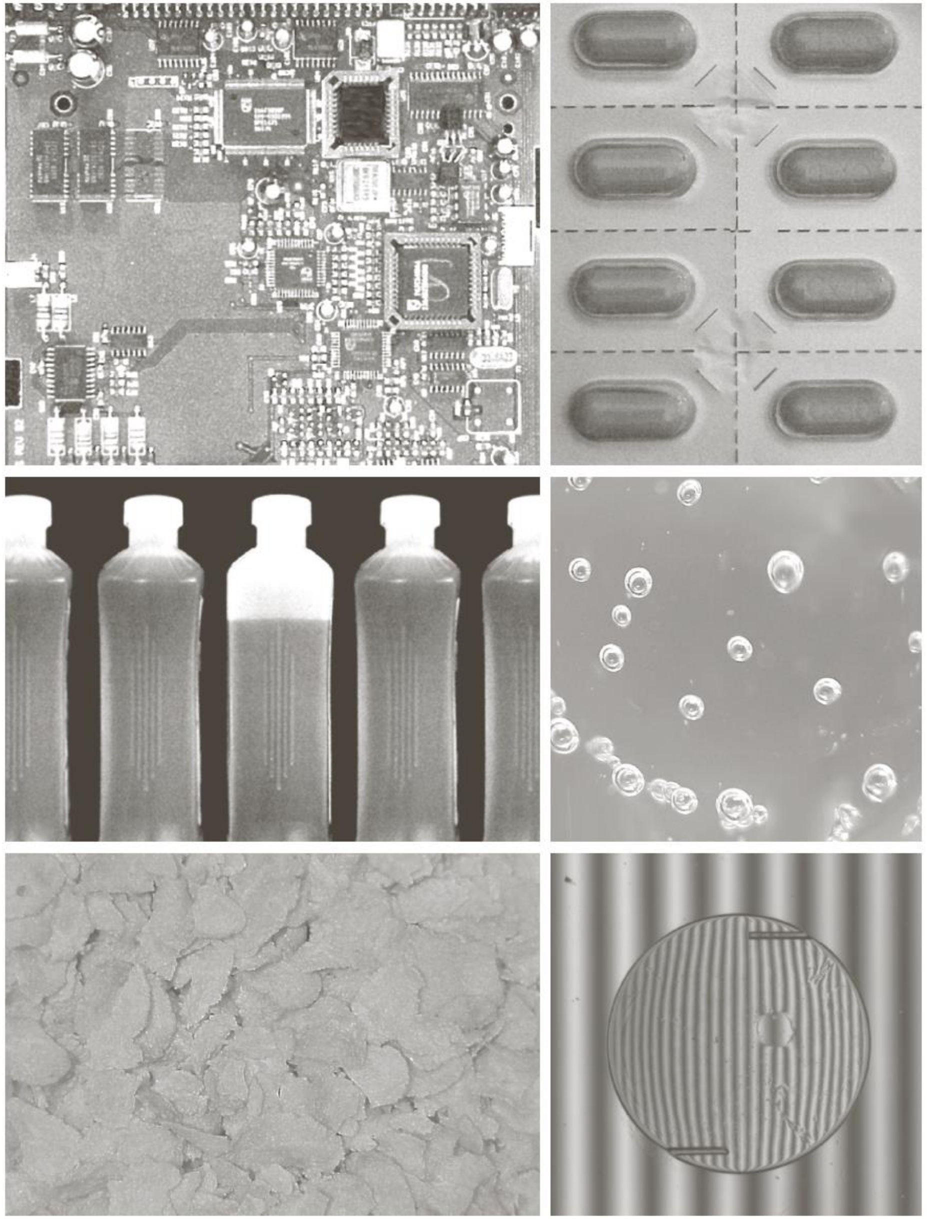
a b
c
d

FIGURE 1.15 Some additional examples of imaging in the visual spectrum. (a) Thumb print. (b) Paper currency. (c) and (d) Automated license plate reading. (Figure (a) courtesy of the National Institute of Standards and Technology. Figures (c) and (d) courtesy of Dr. Juan Herrera, Perceptics Corporation.)

Results of automated reading of the plate content by the system

The area in which the imaging system detected the plate

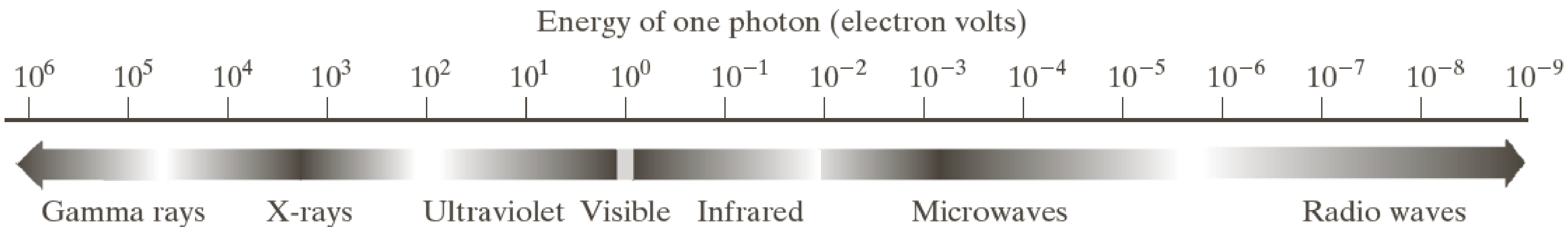
Examples: Automated Visual Inspection



a	b
c	d
e	f

FIGURE 1.14 Some examples of manufactured goods often checked using digital image processing. (a) A circuit board controller. (b) Packaged pills. (c) Bottles. (d) Air bubbles in a clear-plastic product. (e) Cereal. (f) Image of intraocular implant. (Fig. (f) courtesy of Mr. Pete Sites, Perceptics Corporation.)

Electromagnetic (EM) energy spectrum



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Major uses

Gamma-ray imaging

X-rays

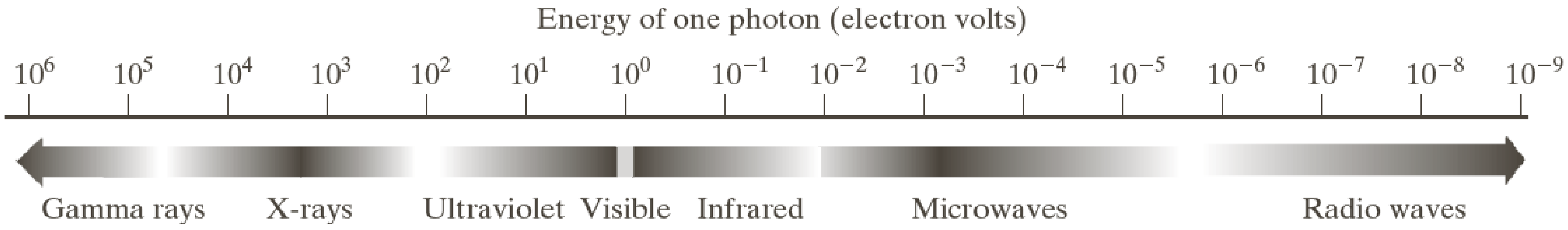
Ultraviolet

Visible and infrared bands: light microscopy, astronomy, remote sensing, industry, and law enforcement

Microwave band:

Radio band

Electromagnetic (EM) energy spectrum



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Microwave band:
Radio band

Bone Disorders

1. Fractures
2. Arthritis
3. Cancer originating in bone
4. Infection of the joints

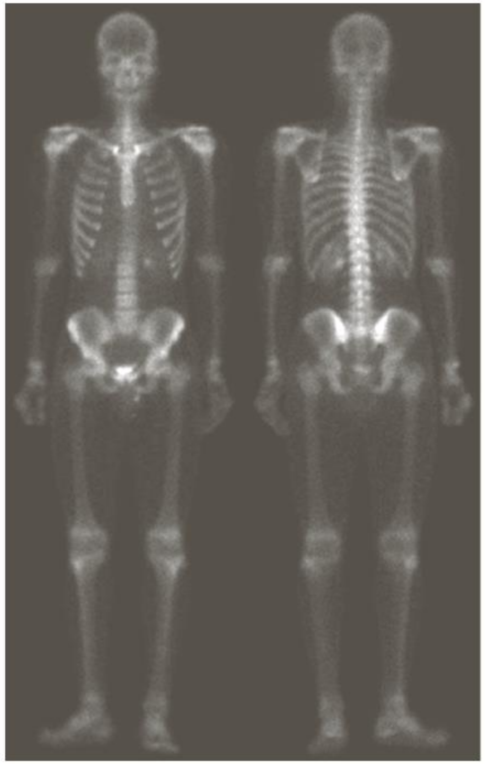
…

Understanding bone density is vital to diagnosis

Nuclear Medicine

- Application of radioactive substances in the diagnosis and treatment of disease.
- Radio active substance is taken internally, intravenously, or orally.
- The emitted radiation is captured by a Gamma Camera

Examples: Gama-Ray Imaging



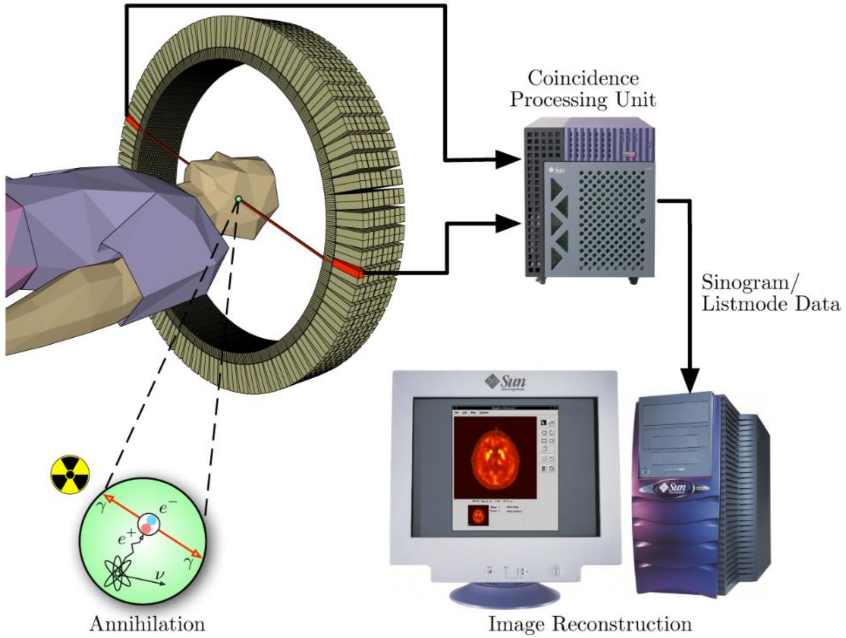
Bone Scan

PET Scan

- Detect early signs of cancer, heart disease and brain conditions
- Diseased cells that absorb large amounts of the radiotracer

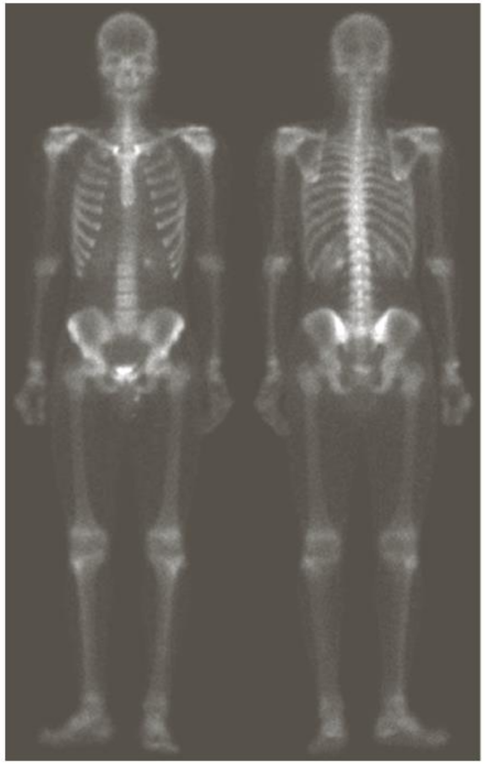
PET Scan

- **Positron emission tomography**
- Patient is given a radioactive isotope, it emits positron as it decays
- Positron meets electron, are annihilated and two gamma rays are given off.



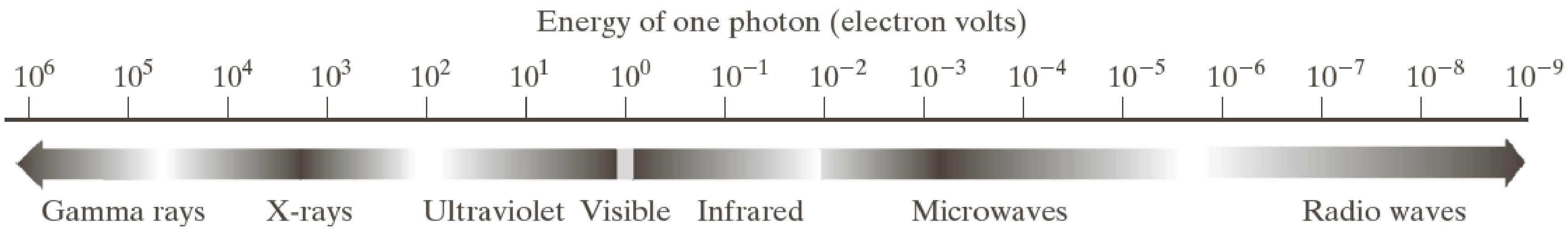
https://en.wikipedia.org/wiki/Positron_emission_tomography

Examples: Gama-Ray Imaging



PET Scan

Electromagnetic (EM) energy spectrum



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Major uses

Gamma-ray imaging: nuclear medicine and astronomical observations

X-rays

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Visible and infrared bands: light microscopy, astronomy, remote sensing, industry, and law enforcement

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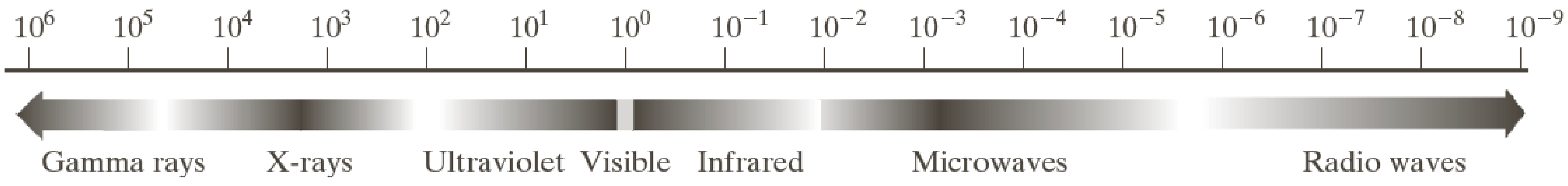
Radio band

Electromagnetic (EM) energy spectrum



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Microwave band:

Radio band

Dental X-Ray

- Images of teeth and jaws
  - Tooth decay
  - Gum diseases
  - Infections
  - Cavities
  - Fractures
  - …

Examples: X-Ray Imaging

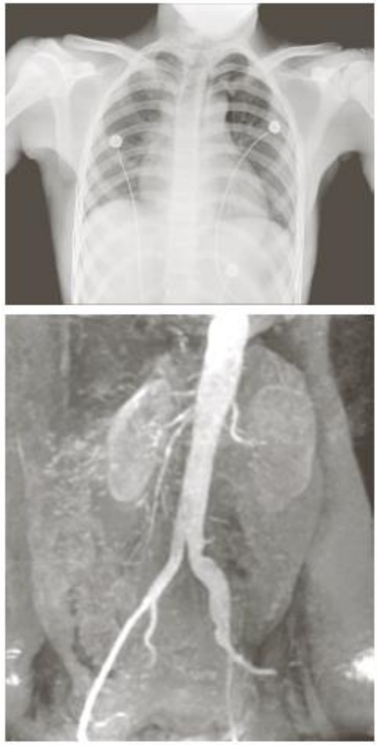
Diagnose Heart and Brain Disorders

- Visualize blood flow (blood vessels) in the body using imaging techniques
- Identify
  - Blockage in blood vessels
  - Internal bleeding
  - Aneursyms
  - ...

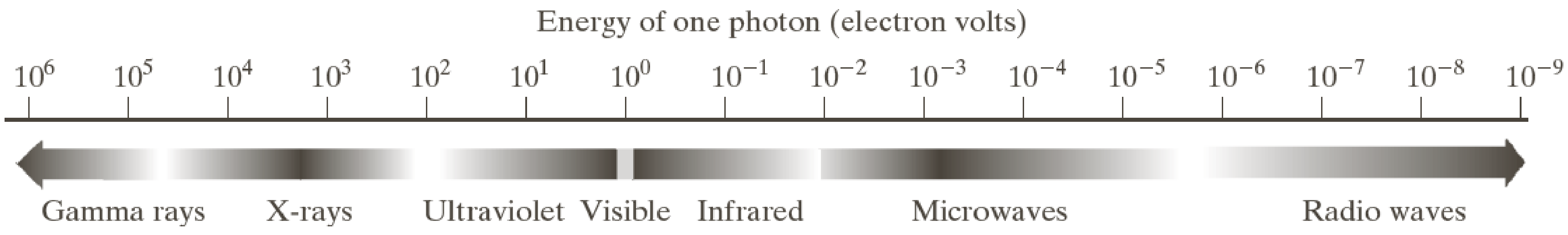
X-Ray

- Contrast enhanced radiography: **Angiography**
- Obtain images of blood vessels (angiograms)
- An X-ray contrast medium is injected, before taking an X-ray.
- This enhances the contrast of the blood vessel.

Examples: X-Ray Imaging



Electromagnetic (EM) energy spectrum



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X-rays: medical diagnostics, industry, and astronomy, etc.

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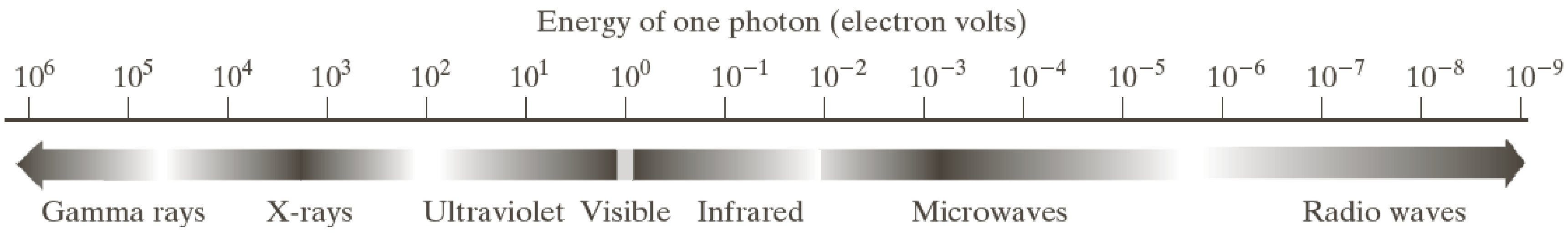

FIGURE 1.5 The electromagnetic spectrum arranged according to energy per photon.

Major uses

Gamma-ray imaging: nuclear medicine and astronomical observations

X-rays: medical diagnostics, industry, and astronomy, etc.

Ultraviolet: lithography, industrial inspection, microscopy, lasers, biological imaging, and astronomical observations

Visible and infrared bands: light microscopy, astronomy, remote sensing, industry, and law enforcement

Microwave band: radar

Radio band: medicine (such as MRI) and astronomy

GENERAL IMAGE TYPES

- We can distinguish between **three types** of imaging, which create different types of image information:
- **Reflection Imaging**
  - Image information is **surface** information; how an object **reflects/absorbs** incident radiation
    - - **Optical** (visual, photographic, laser-based)
    - - **Radar**
    - - Sonar, **ultrasound** (non-EM)
    - - **Electron microscopy**
- **Emission Imaging**
  - Image information is **internal** information; how an object **creates** radiation
    - - Thermal, infrared (**FLIR**) (geophysical, medical, military)
    - - Astronomy (stars, **nebulae**, etc.)
    - - Nuclear (particle emission, e.g., **MRI**)
- **Absorption Imaging**
  - Image information is **internal** information; how an object **modifies/absorbs** radiation passing through it
    - - **X-Rays** in many applications
    - - **Optical microscopy** in laboratory applications
    - - Tomography (**CAT**, PET) in medicine
    - - "Vibro-Seis" in geophysical prospecting

Fundamental Steps in DIP