

Image Formation and Sensing

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Image Formation and Sensing

1 Image Formation and Sensing

- Introduction
- Visible light imaging
- Gamma-rays imaging
- X-rays imaging
- Imaging with ultraviolet (UV) light
- Imaging with Infrared (IR) light
- Microwaves imaging
- Radiowaves imaging
- Acoustic imaging
- Electron imaging
- Laser imaging

Image Formation and Sensing

Introduction

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Image Formation and Sensing

Introduction

Image Formation and Sensing

- Digital image is formed by **energy** interacting with a measuring devices or **sensors**
- The **sensors** can respond to stimuli from
 - various parts of the **electromagnetic spectrum (EM)**,
 - **acoustical** energy, as in ultrasound images,
 - the **distance** to the objects.
 - **temperature, pressure**, etc.

Image Formation and Sensing

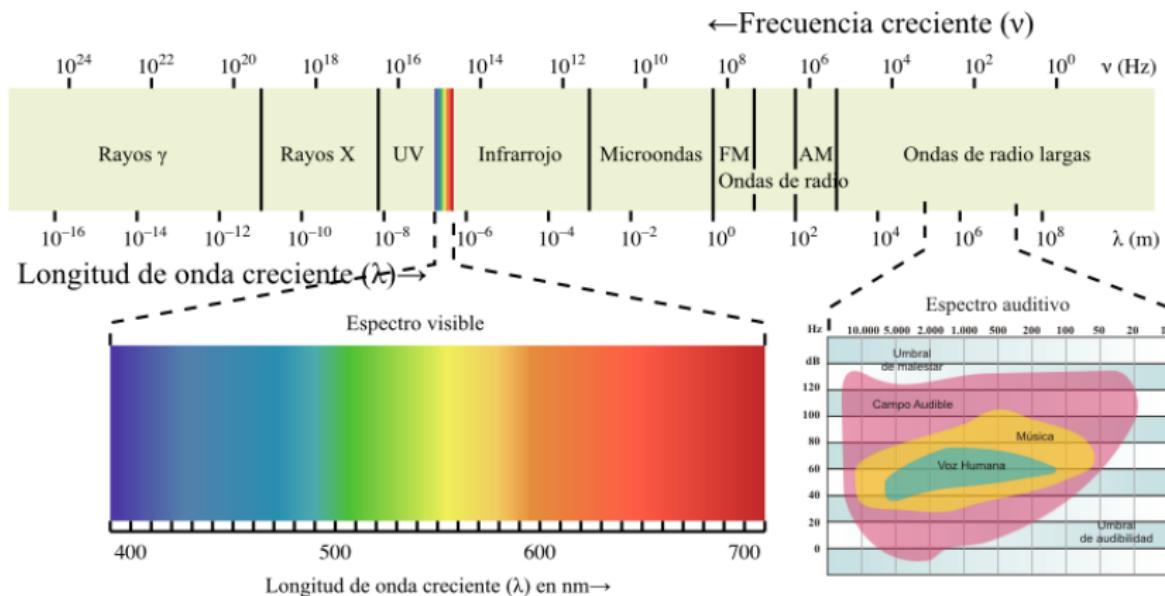
Introduction

Electromagnetic spectrum (EM)

- Gamma rays
- X-rays
- Ultraviolet (UV)
- Visible light
- Infrared (IR)
- Microwaves
- Radio waves

Image Formation and Sensing

Introduction



Electromagnetic spectrum

Image Formation and Sensing

Visible light imaging

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Image Formation and Sensing

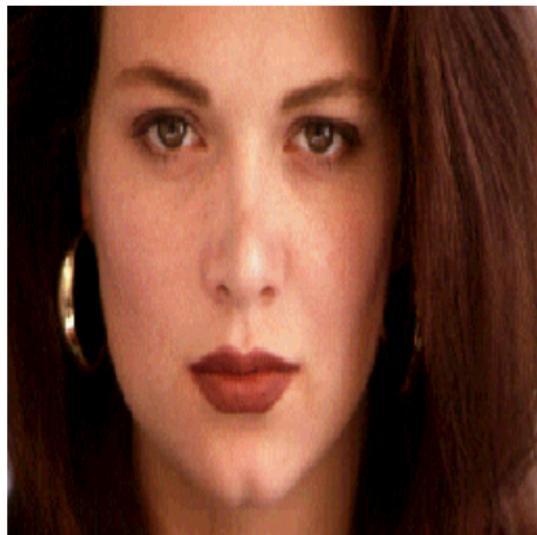
Visible light imaging



Digital images with visible light

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Visible light imaging



Color image

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Visible light imaging

Color channels of an image in the RGB color space



Red channel



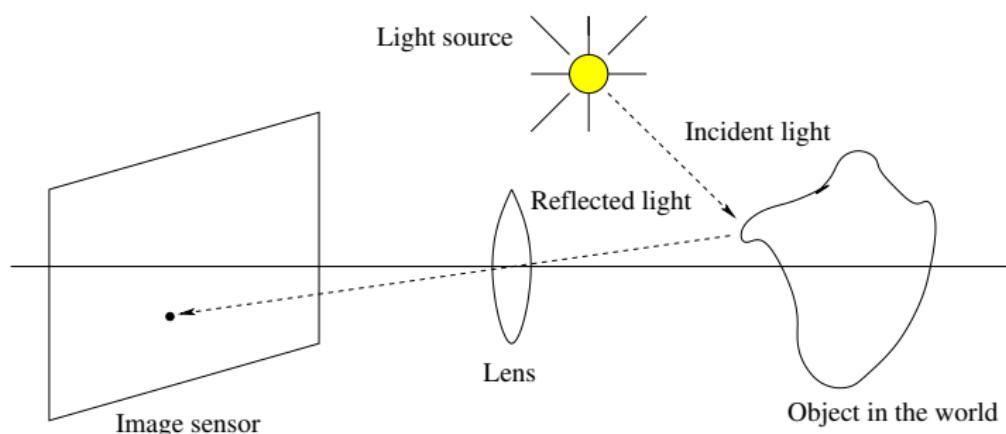
Green channel



Blue channel

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Visible light imaging



Model for vision light imaging

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Visible light imaging

Definition (Intensity light)

- $f(x, y)$ is a form of energy

$$0 < f(x, y) = i(x, y)r(x, y) < \infty$$

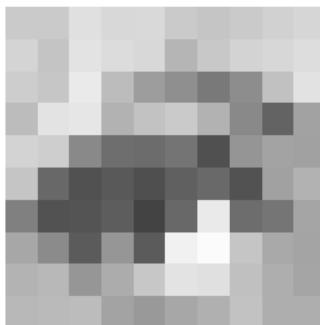
where

- $i(x, y)$: **illumination** or incident light on the object
 $0 < i(x, y) < \infty$
- $r(x, y)$: **radiance, reflectance** or proportion of the light reflected by the object
 $0 < r(x, y) < 1$
(0: total absorption; 1: total reflectance).

Image Formation and Sensing

Visible light imaging

Digital image



Gray scale levels

202	202	224	216	217	202	197	202	209	214
212	196	227	220	216	181	200	211	215	22
205	198	234	188	157	143	121	141	193	226
188	227	230	178	194	202	178	137	99	162
211	206	137	110	108	116	80	149	163	161
197	104	81	89	79	96	105	82	161	178
128	82	84	93	67	104	234	109	117	165
167	139	91	150	91	241	251	197	169	164
179	184	150	172	199	227	224	192	174	165
184	186	188	163	153	167	176	194	174	174

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Visible light imaging



Image from the Andromeda Galaxy using visible light (NASA)

Image Formation and Sensing

Gamma-rays imaging

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Gamma-rays imaging

Positron Emission Tomography (PET)

- Nuclear medicine uses a **radioactive material**,
 - called a **radiopharmaceutical** or **radiotracer**,
 - which is **injected** into the bloodstream, swallowed or inhaled as a gas.
- This **radioactive material**
 - accumulates in the organ or area of the body being examined,
 - where it **gives off** a small amount of energy in the form of **gamma rays**.
- **Special cameras**
 - **detect** this energy
 - and **create** pictures offering details on both the structure and function of **organs** and **tissues** in the body.

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Gamma-rays imaging



PET: Positron Emission Tomography

<http://cdn1.medicalnewstoday.com/>

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X-rays imaging

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X-rays imaging

X-rays imaging

- Radiography
- Computerized Tomography (CT)
- Radioscopy or fluoroscopy
- Angiography

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X-rays imaging

Radiography

- X-rays are used in medical diagnostics by using **film** which responds to X-ray energy.
- The X-rays are **passed through** the patient and **recorded** on the film.

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X-rays imaging



Radiography

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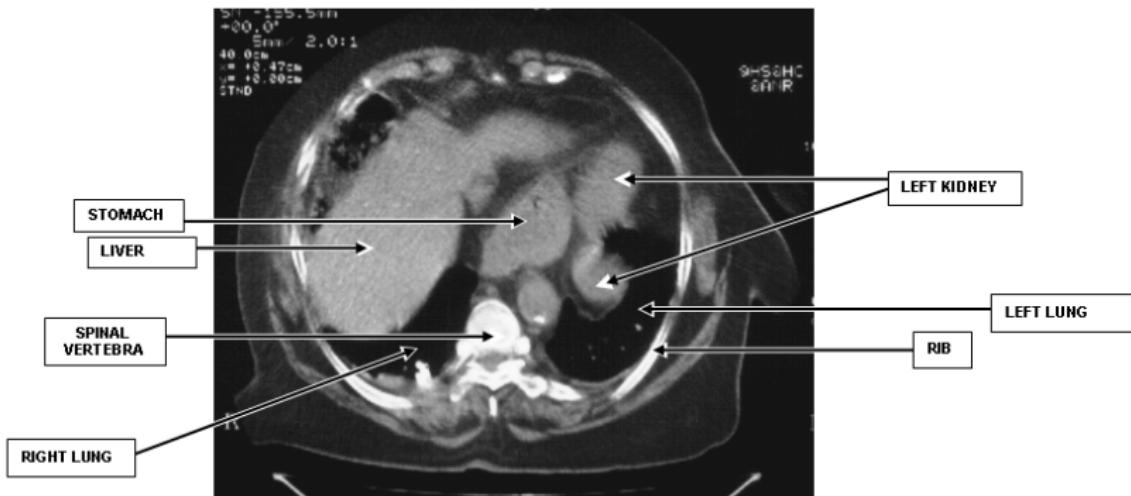
X-rays imaging

Computerized Tomography (CT)

- A **ring** of detectors encircles the patient
- and is **rotated** to obtain **2D-slices**,
- which can be **assembled** into a **3D-image**.

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X-rays imaging



Computerized Tomography (CT)
CVIP: S. E. Umbaugh (fig. 2.2.-10(e))

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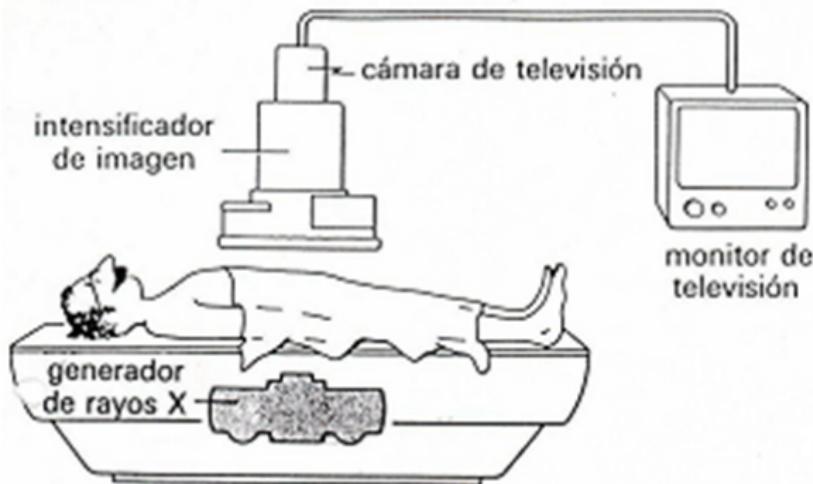
X-rays imaging

Radioscopy or fluoroscopy

- Imaging technique that uses X-rays to obtain real-time **moving** images of the interior of an object
- In **medicine**, this technique may show the **movement** of the heart and lungs, for instance.

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X-rays imaging



Radioscopy process

Image Formation and Sensing

X-rays imaging



Radioscopy

<http://www.fac.org.ar/>

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X-rays imaging

Angiography

- Examination by **X-ray** of blood or lymph vessels, carried out after **introduction** of a **radiopaque** substance.

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X-rays imaging



Angiography process

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X-rays imaging



Angiography

<http://sabia.tic.udc.es>

Image Formation and Sensing

Imaging with ultraviolet (UV) light

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Imaging with ultraviolet (UV) light

Imaging with ultraviolet (UV) light

- Applications
 - Industry applications
 - Law enforcement
 - Microscopy
 - Astronomy
- Objective: to find evidences that are **invisible** to the human vision system.
 - In **forensics**: fingerprints, body fluids, bite marks or even shoe prints on waxed floor have been found
It requires no powders or chemical on nonporous surfaces.
 - In **astronomy**: properties of a new detected galaxy

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Imaging with ultraviolet (UV) light



Image from the Andromeda Galaxy using ultraviolet light (NASA)

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Imaging with Infrared (IR) light

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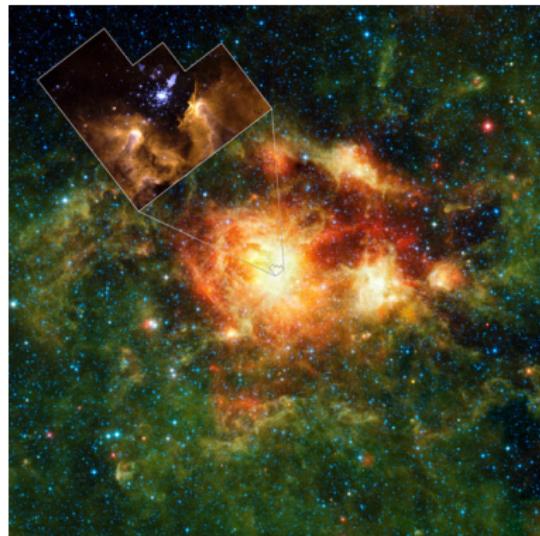
Imaging with Infrared (IR) light

Imaging with Infrared (IR) light

- **Satellite imaging** (remote sensing)
 - The features of interest (e.g. moisture content and mineral mapping) are found in the **IR spectrum**.
 - Multispectral Images, which include **IR bands**, are often used in **weather analysis**.
- **Law enforcement**
- **Fire detection**.
- **Thermographic** imaging to diagnose **pathologies** in both animals or humans.

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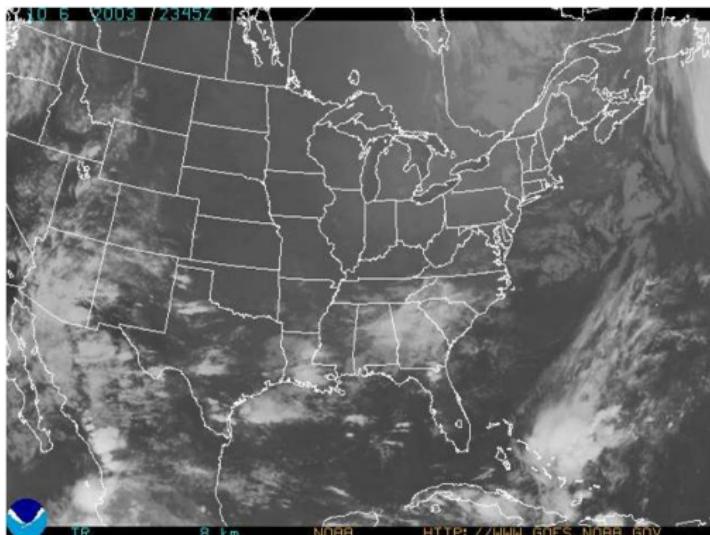
Imaging with Infrared (IR) light



Infrared image (NASA)

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Imaging with Infrared (IR) light



Infrared satellite image showing water vapor
CVIP: S. E. Umbaugh (fig. 2.2.-11(b))

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Imaging with Infrared (IR) light

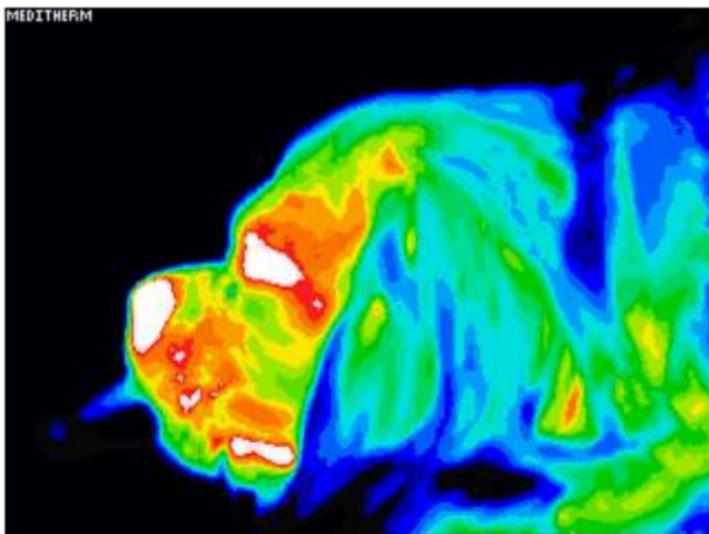


Infrared image in the near infrared band

CVIP: S. E. Umbaugh (fig. 2.2.-11(d))

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Imaging with Infrared (IR) light



Thermographic infrared image for diagnosis of brain diseases in animals
CVIP: S. E. Umbaugh (fig. 2.2.-10(e))

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Microwaves imaging

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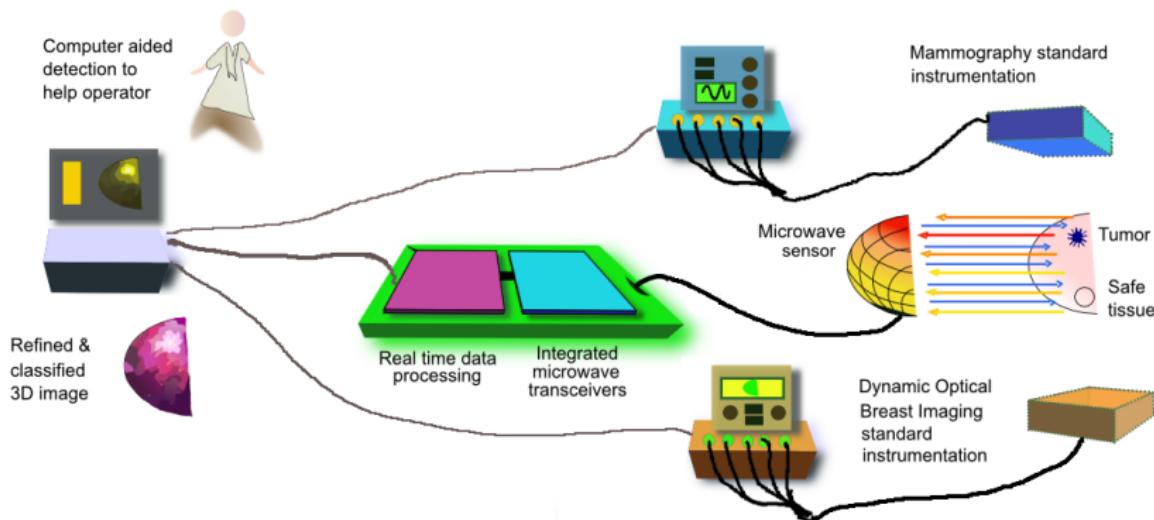
Microwaves imaging

Microwave imaging

- This technique is most often used to detect and evaluate **hidden** or **embedded** objects in a structure (or media).
- For instance
 - Medical imaging: detection of an early stage **breast cancer**
 - Security: **concealed** weapon detection at security check points or **through-the-wall** imaging.
 - Industry: **corrosion** detection in painted aluminum or steel surfaces.

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Microwaves imaging



Microwave imaging system for combined early diagnostics of breast cancer

<http://www.micenea.it>

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Radiowaves imaging

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Image Formation and Sensing

Radiowaves imaging

Radiowaves imaging

- Magnetic Resonance Imaging (**MRI**).
- Radio tomographic imaging (**RTI**).

Image Formation and Sensing

Radiowaves imaging

Radiowaves imaging

- Magnetic Resonance Imaging (**MRI**)
 - The system sends **radio waves** through a patient in short pulses in the presence of a powerful **magnetic field**.
 - The body responds by **emitting** **radio waves**, which are measured to **create** an image.
 - This has excellent **contrast resolution** to show subtle differences among the soft tissues and organs of the body that are not easily viewed on conventional X-ray or CT films.

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Radiowaves imaging



Magnetic resonance image (MRI) of a patient's shoulder.

CVIP: S. E. Umbaugh (fig. 2.2.-12(b))

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Radiowaves imaging



Magnetic resonance image

<http://hamiltonhealth.ca/cvs/mri-campaign/what-is-mri>

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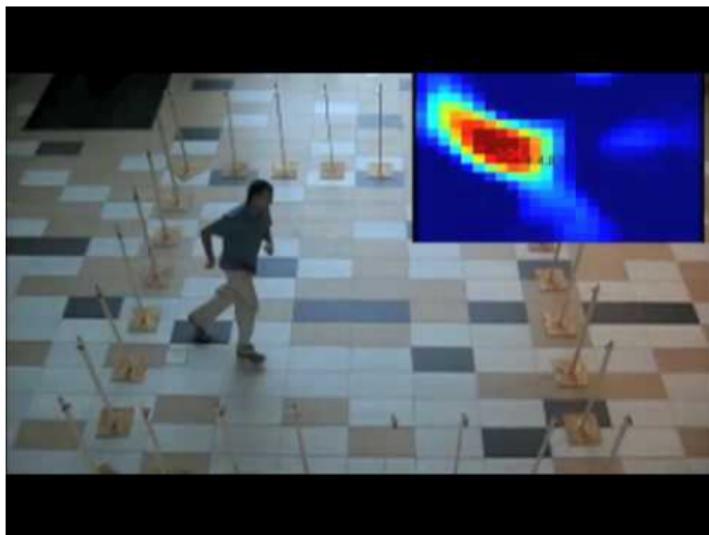
Radiowaves imaging

Radiowaves imaging

- Radio tomographic imaging (**RTI**)
 - to "see", locate and track people or objects in an area surrounded
 - by inexpensive **radio** transceivers that send and receive signals.

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Radiowaves imaging



Radio tomographic image

The University of Utah: College of Engineering

Image Formation and Sensing

Acoustic imaging

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Image Formation and Sensing

Acoustic imaging

Acoustic imaging

- **Pulses of sonic** energy (**sound**) are sent out at various frequencies and then the reflected waves are measured.
 - The **time** it takes for reflect signals to appear contains distance information,
 - and the **amount energy reflected** contains informations about the object's density and material.
- The measured information is used to **create** a 2D or 3D image.

Image Formation and Sensing

Acoustic imaging

Acoustic imaging

- Use in **biological systems**: the bat uses it to “see”
- Use in **man-made systems** such as sonar of the the submarines.

Image Formation and Sensing

Acoustic imaging

Acoustic imaging: applications

- **Geology:** oil and mineral explorations.
- **Industry:** defect detection
- **Medicine:** using ultrasound waves
 - **Sonogram:** to follow the development of the unborn baby inside the womb
 - **Echocardiogram:** to detect heart disease.

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Acoustic imaging



Sonogram 2D

<http://www.dexus.com/>

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Acoustic imaging

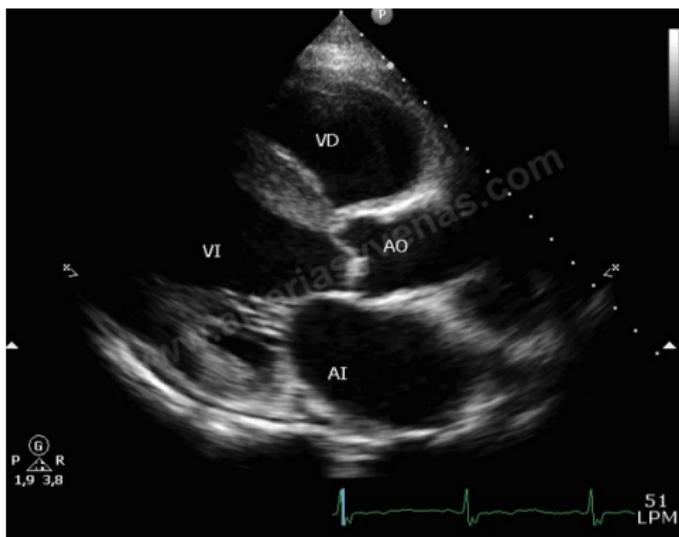


Sonogram 3D

<http://www.dexus.com/>

Image Formation and Sensing

Acoustic imaging



Echocardiogram

<http://www.arteriasyvenas.com/clinica/ecocardiograma>

Image Formation and Sensing

Electron imaging

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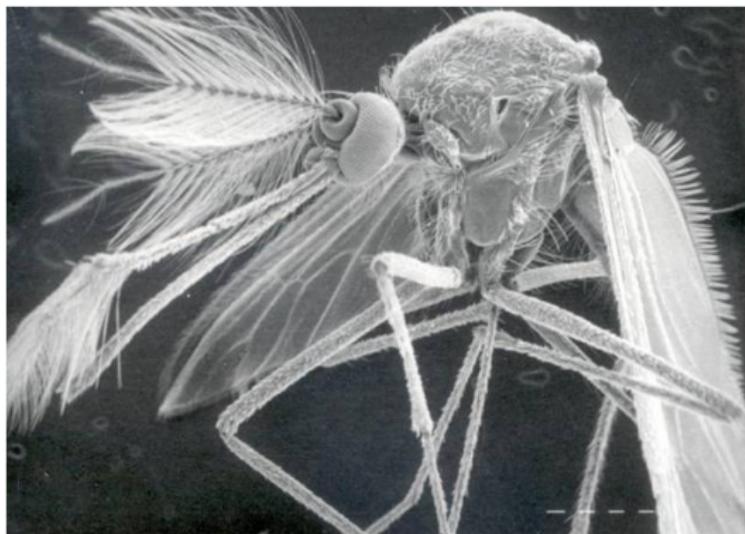
Electron imaging

Electron imaging

- Electron microscopes can **magnify** the image up two hundred thousand times
- These microscopes produce a **focused beam of electrons**
- **TEM:** Transmission Electron Microscope.
 - It transmits a beam of electrons **through** the specimen and then **projects** the results onto a screen for viewing.
- **SEM:** Scanning Electron Microscope.
 - It scans the electronic beams **across** the specimen and detects **various signals** generated by the electrons interacting with the specimen and uses these to produce an image.

Image Formation and Sensing

Electron imaging



SEM image of a mosquito

CVIP: S. E. Umbaugh (fig. 2.2.-14(b))

Image Formation and Sensing

Laser imaging

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- **Laser imaging**

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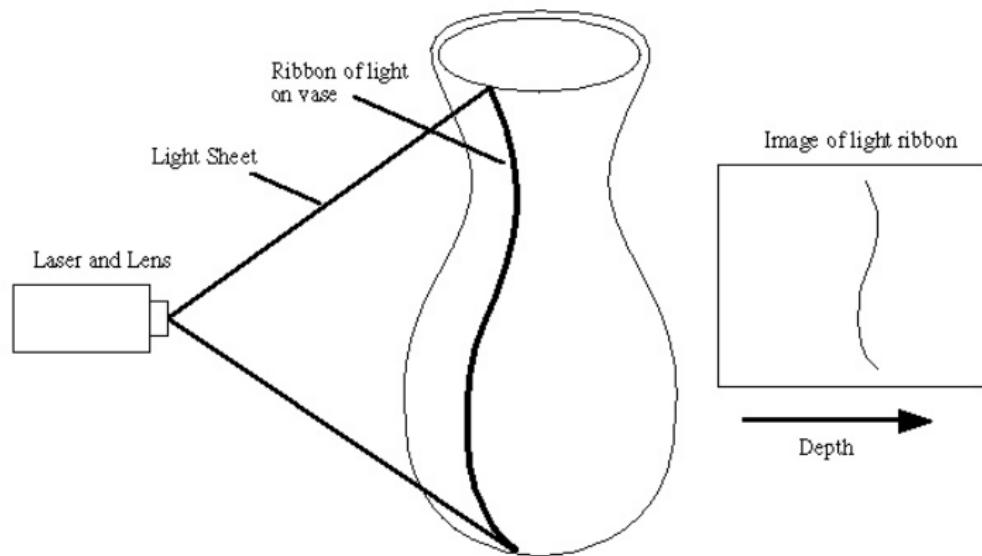
Laser imaging

Laser imaging

- **Lasers** (Light Amplification by Stimulated Emission of Radiation) are specialized light sources that produce a narrow light beam in the **visible**, **IR**, or **UV** range of the **EM spectrum**.
- Lasers are used to create **range image** (or depth maps) which contains information about the **distance** of a point in the world to the image sensor.

Image Formation and Sensing

Laser imaging



Forming a range image

www.cc.gatech.edu/~turk/bunny/bunny.html

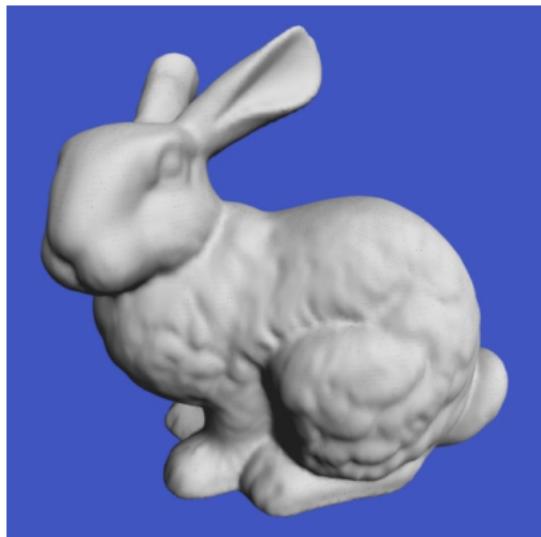
Image Formation and Sensing

Laser imaging



(a) Rabbit

www.cc.gatech.edu/~turk/bunny/bunny.html



(b) Range image

Image Formation and Sensing

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