Topics

- *History of Digital Image Processing*
- *The purpose of Computer Vision*
- *Low level digital image processing*
- *Image Formation*
- *Electromagnetic Radiation*
- *Images acquired at different wavelenghts may have very different properties*
- *Image Processing - Examples*

History of Digital Image Processing

Early 1920s - Bartlane cable picture transmission system

- used to transmit newspaper images across the Atlantic.

- images were coded, sent by telegraph, printed by a special telegraph printer.

- took about three hours to send an image, first systems supported 5 gray levels

1964 – NASA's Jet Propulsion Laboratory began working on computer algorithms to improve images of the moon.

- images were transmitted by Ranger 7 probe.

- corrections were desired for distortions inherent in on-board camera

Evolving technology and algorithms => explosion of application areas

Why Image Processing?

- The future is multimedia information processing
- Images(and video) are everywhere !

  In the broadest possible sense, images are pictures: a way of recording and presenting information visually. We use photography in everyday life to create a permanent record of our visual experiences.

- Many and diverse applications

  There are two major areas of application of digital image processing techniques: 1) improvement of pictorial information for human interpretation and 2) processing of scene data for autonomous machine perception . In machine perception , interest focuses on procedures for extracting from an image information in a form suitable for computer processing.

Typical problems in machine perception that routinely utilise image processing techniques are:

automatic character recognition,

industrial machine vision for product assembly and inspection,

military recognition,

automatic processing of fingerprints,

screening of x-rays and blood samples,

and machine processing of aerial and satellite imagery for weather prediction.

digital archiving

The purpose of Computer Vision

•Vision allows humans to perceive and understand the world surrounding us.

•Computer vision aims to duplicate the effect of human vision by electronically perceiving and understanding an image.

•Giving computers the ability to see is not an easy task - we live in a three dimensional (3D) world, and when computers try to analyze objects in 3D space, available visual sensors (e.g., TV cameras) usually give two dimensional (2D) images, and this projection to a lower number of dimensions incurs an enormous loss of information.

The purpose of Computer Vision:

•In order to simplify the task of computer vision understanding, two levels are usually distinguished; **low level** image processing and **high level** image understanding.

•Low level methods usually use very little knowledge about the content of images.

•High level processing is based on knowledge, goals, and plans of how to achieve those goals. Artificial intelligence (AI) methods are used in many cases. High level computer vision tries to imitate human cognition and the ability to make decisions according to the information contained in the image.

•This course deals almost exclusively with low level image processing, high level image processing is discussed in the course **Image Analysis and Understanding**, which is a continuation of this course.

Low level digital image processing:

•Low level computer vision techniques overlap almost completely with digital image processing

•The following sequence of processing steps is commonly recognized:

•**Image Acquisition**:

- An image is captured by a sensor (such as a TV camera) and digitized;

•**Preprocessing**:

- computer suppresses noise (image pre-processing) and maybe enhances some object features which are relevant to understanding the image. Edge extraction is an example of processing carried out at this stage.

•**Image segmentation**:

- computer tries to separate objects from the image background.

•**Object description and classification** in a totally segmented image is also understood as part of low level image processing.

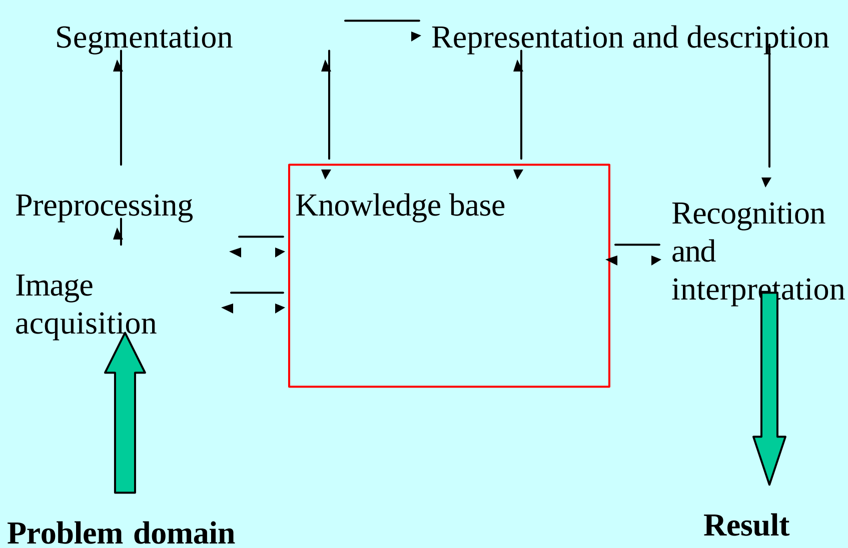


Figure shows the fundamental steps required to perform an image processing task.

A range of representations

- **Generalized images**
- **Segmented images** are formed from the generalized image by gathering its elements into sets likely to be associated with meaningful objects in the scene.
- **Geometric representations** are used to capture the all-important data of two-dimensional and three-dimensional shape.
- **Relational models** are complex assemblages of representations used to support sophisticated high-level processing.

Image Formation

Three dimensional world is projected onto a two dimensional image plane from which information about the 3D world is extracted . Two dimensional image is the representation that mediates between perception and the 3D world. The relationship between stages are described below.

3D World Þ 2D Image – is image synthesis (graphics)

3D World Ü 2D Image – is image analysis (geometry and radiometry)

2D Image Þ Perception – is the study of perception from images (perceptual psychology). This may or may not correct interpretation of the 3D world.

2D Image Ü Perception – Identical perceptions can arise from different images . Examples include colour, texture, and lightness/edge etc.

Image Formation

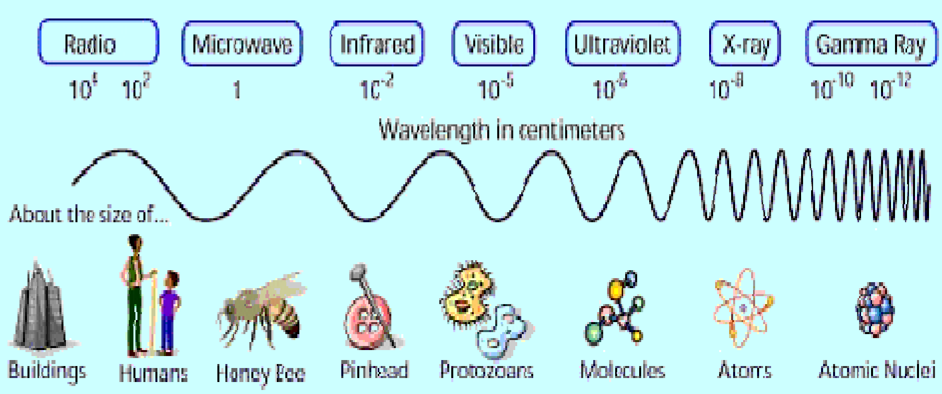
Image formation occurs when a sensor registers radiation that has interacted with physical objects.

Both human vision and photography require a light source to illuminate a scene. The light interacts with the objects in the scene and some of it reaches the observer, whereupon it is detected by the eyes or by a camera. Information about the objects in the scene is recorded as variations in the intensity and colour of the detected light.

Light is the visible portion of the electromagnetic (EM) spectrum.

The Electromagnetic Spectrum

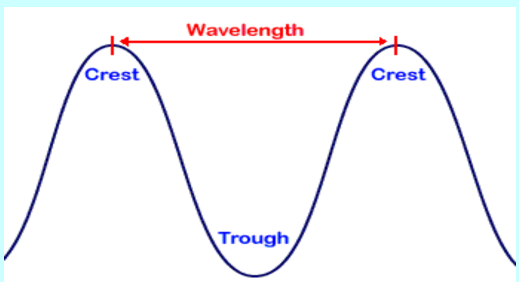
The electromagnetic (EM) spectrum is just a name that scientists give a bunch of types of radiation when they want to talk about them as a group.



Electromagnetic Radiation

EM radiation is produced by the oscillation of electrically charged material, and has wave-like properties .

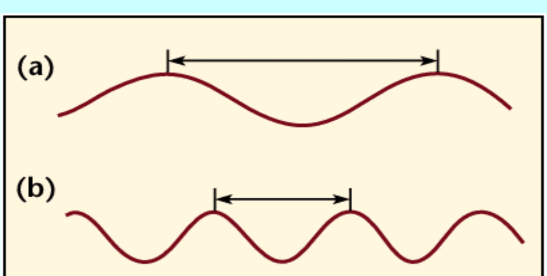
Do you listen to the radio, watch TV, or use a microwave oven? All these devices make use of electromagnetic waves. Radio waves, microwaves, visible light, and x rays are all examples of electromagnetic waves that differ from each other in wavelength.



Wavelength is the distance between one wave crest to the next.

Electromagnetic Radiation

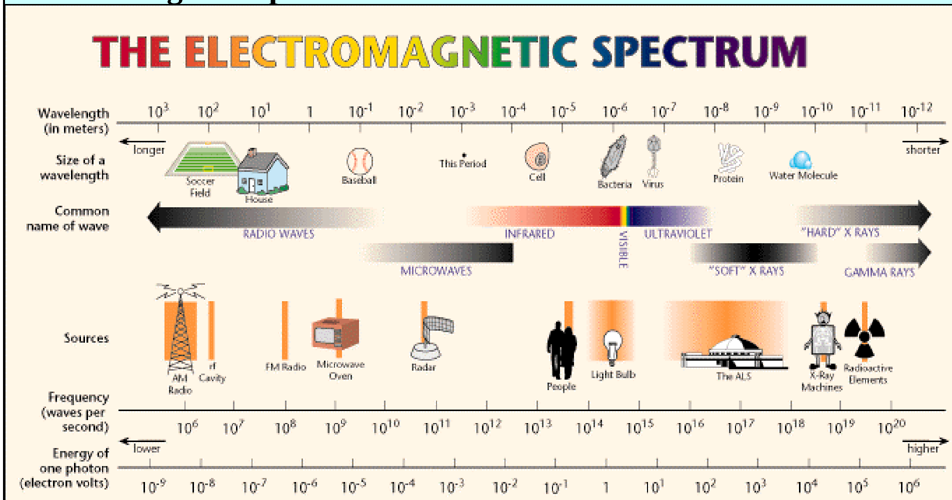
Waves in the electromagnetic spectrum vary in size from very long radio waves the size of buildings, to very short gamma-rays smaller than the size of the nucleus of an atom.



(a) Longer wavelength

(b) Shorter wavelength

The full range of wavelengths (and photon energies) is called the "electromagnetic spectrum."



The photons with the highest energy correspond to the shortest wavelengths

The electromagnetic spectrum covers a wide range of wavelengths and photon energies. **Light used to "see" an object must have a wavelength about the same size as or smaller than the object.** The ALS generates light in the far ultraviolet and soft x-ray regions, which span the wavelengths suited to studying molecules and atoms.

Look at the picture of the electromagnetic spectrum. See if you can find answers to these questions:

1. What kind of electromagnetic radiation has the shortest wavelength? The longest?
2. What kind of electromagnetic radiation could be used to "see" molecules? A cold virus?
3. Why can't you use visible light to "see" molecules?

Did you know that electromagnetic waves can not only be described by their wavelength, but also by their energy and frequency?

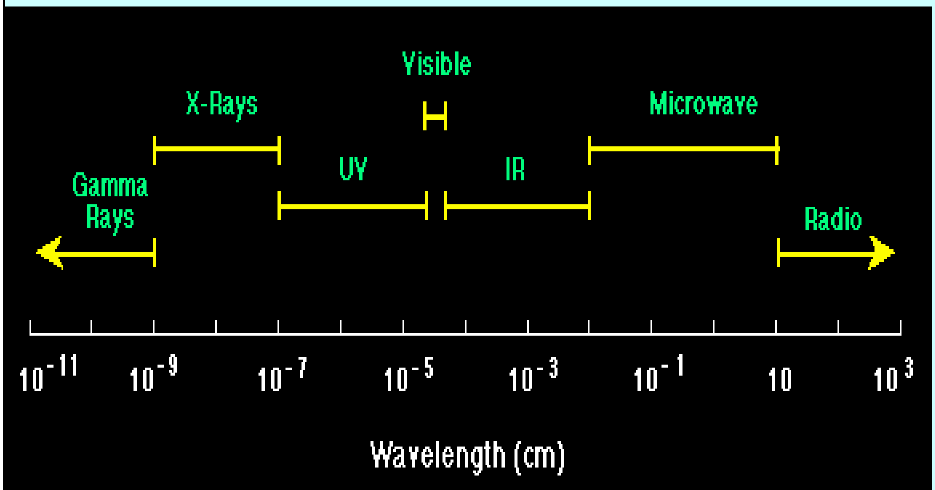
This means that it is correct to talk about the energy of an X-ray or the wavelength of a microwave or the frequency of a radio wave.

Regions of the Electromagnetic Spectrum

Spectrum of Electromagnetic Radiation

Region	Wavelength (Angstroms)	Wavelength (centimeters)	Frequency (Hz)	Energy (eV)
Radio	$> 10^9$	> 10	$< 3 \times 10^9$	$< 10^{-5}$
Microwave	$10^9 - 10^6$	10 - 0.01	$3 \times 10^9 – 3 \times 10^{12}$	10^{-5} - 0.01
Infrared	10^6 - 7000	$0.01 - 7 \times 10^{-5}$	$3 \times 10^{12} - 4.3 \times 10^{14}$	0.01 - 2
Visible	7000 - 4000	$7 \times 10^{-5} - 4 \times 10^{-5}$	$4.3 \times 10^{14} – 7.5 \times 10^{14}$	2 - 3
Ultraviolet	4000 - 10	$4 \times 10^{-5} - 10^{-7}$	$7.5 \times 10^{14} - 3 \times 10^{17}$	$3 - 10^3$
X-Rays	10 - 0.1	$10^{-7} - 10^{-9}$	$3 \times 10^{17} – 3 \times 10^{19}$	$10^3 - 10^5$
Gamma Rays	< 0.1	$< 10^{-9}$	$> 3 \times 10^{19}$	$> 10^5$

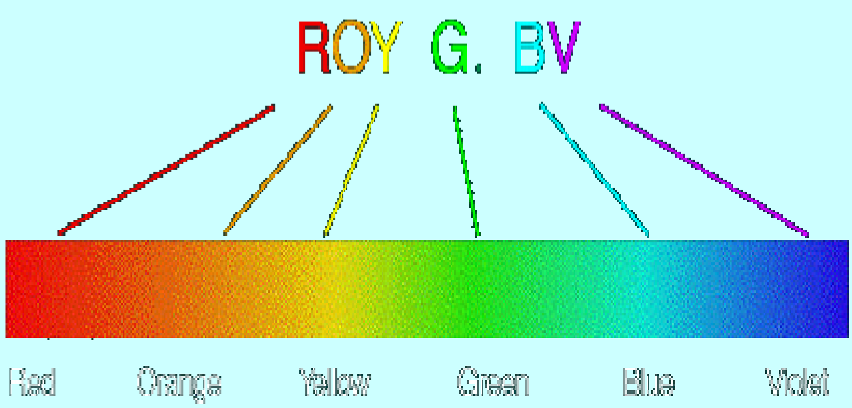
Regions of the Electromagnetic Spectrum



Thus we see that visible light and gamma rays and microwaves are really the same things. They are all electromagnetic radiation; they just differ in their wavelengths.

The Spectrum of Visible Light

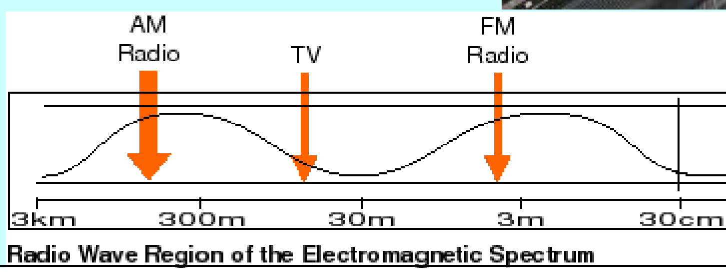
The visible part of the spectrum may be further subdivided according to color, with red at the long wavelength end and violet at the short wavelength end, as illustrated (schematically) in the following figure.



Images acquired at different wavelengths may have very different properties.

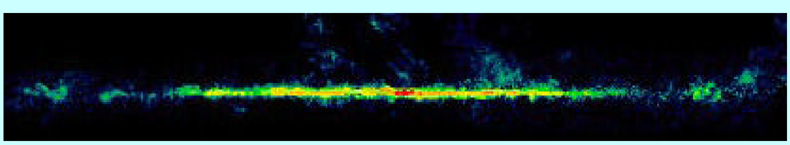
Radio Waves

Radio waves have the longest wavelengths in the electromagnetic spectrum



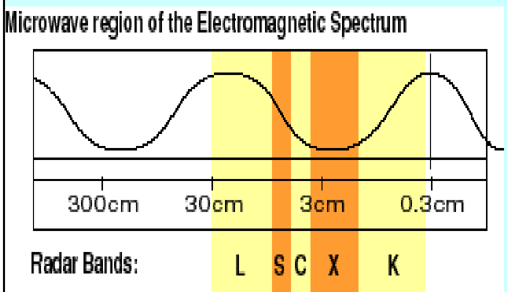
What do Radio Waves show us?

The above image shows the Carbon Monoxide (CO) gases in our Milky Way galaxy.



Many astronomical objects emit radio waves, but that fact wasn't discovered until 1932. Since then, astronomers have developed sophisticated systems that allow them to make pictures from the radio waves emitted by astronomical objects.

Microwaves

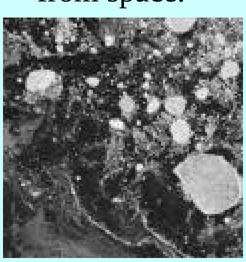


Microwaves have wavelengths that can be measured in centimeters! The longer microwaves, those closer to a foot in length, are the waves which heat our food in a microwave oven.

Microwaves are good for transmitting information from one place to another because microwave energy can penetrate haze, light rain and snow, clouds, and smoke.

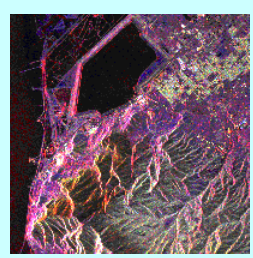
What do Microwaves show us?

Because microwaves can penetrate haze, light rain and snow, clouds and smoke, these waves are good for viewing the Earth from space.



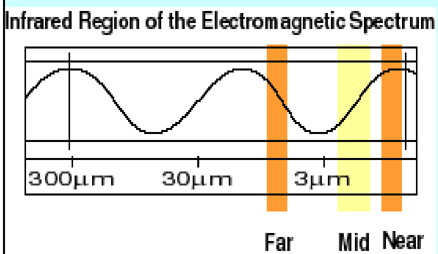
The ERS-1 satellite sends out wavelengths about 5.7 cm long (C-band). This image shows sea ice breaking off the shores of Alaska.

The JERS satellite uses wavelengths about 20 cm in length (L-band). This is an image of the Amazon River in Brazil.



This is a radar image acquired from the Space Shuttle.. Here we see a computer enhanced radar image of some mountains on the edge of Salt Lake City, Utah.

The Infrared



Infrared light lies between the visible and microwave portions of the electromagnetic spectrum. Infrared light has a range of wavelengths, just like visible light has wavelengths that range from red light to violet. "Near infrared" light is closest in wavelength to visible light and "far infrared" is closer to the microwave region of the electromagnetic spectrum. The longer, far infrared wavelengths are about the size of a pin head and the shorter, near infrared ones are the size of cells, or are microscopic.

Far infrared waves are thermal. In other words, we experience this type of infrared radiation every day in the form of heat! The heat that we feel from sunlight, a fire, a radiator or a warm sidewalk is infrared. The temperature-sensitive nerve endings in our skin can detect the difference between inside body temperature and outside skin temperature.

How can we "see" using the Infrared?

Even objects that we think of as being very cold, such as an ice cube, emit infrared. When an object is not quite hot enough to radiate visible light, it will emit most of its energy in the infrared. The warmer the object, the more infrared radiation it emits.

Humans, at normal body temperature, radiate most strongly in the infrared at a wavelength of about 10 microns. (A micron is the term commonly used in astronomy for a micrometer or one millionth of a meter.) This image (which is courtesy of the Infrared Processing and Analysis Center at CalTech), shows a man holding up a lighted match!

How can we "see" using the Infrared?

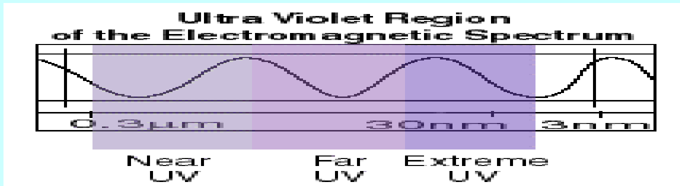
To make infrared pictures like the one above, we can use special cameras and film that detect differences in temperature, and then assign different brightnesses or false colors to them. This provides a picture that our eyes can interpret.

The image at the left (courtesy of SE-IR Corporation, Goleta, CA) shows a cat in the infrared. The orange areas are the warmest and the white-blue areas are the coldest. This image gives us a different view of a familiar animal as well as information that we could not get from a visible light picture.

What does the Infrared show us?

This is an infrared image of the Earth taken by the GOES 6 satellite in 1986. A scientist used temperatures to determine which parts of the image were from clouds and which were land and sea. Based on these temperature differences, he colored each separately using 256 colors, giving the image a realistic appearance.

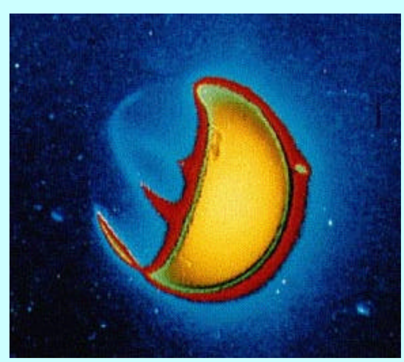
Ultraviolet Waves



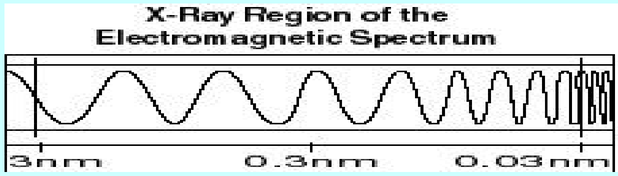
Ultraviolet (UV) light has shorter wavelengths than visible light. Though these waves are invisible to the human eye, some insects, like bumblebees, can see them!

What does Ultraviolet light show us?

The Far UV Camera/Spectrograph deployed and left on the Moon by the crew of Apollo 16 took this picture. The part of the Earth facing the Sun reflects much UV light. Even more interesting is the side facing away from the Sun. Here, bands of UV emission are also apparent. These bands are the result of aurora caused by charged particles given off by the Sun. They spiral towards the Earth along Earth's magnetic field lines.



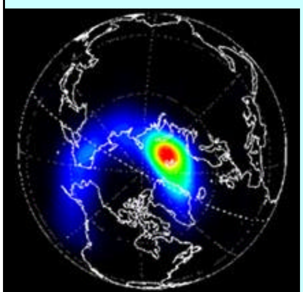
X-rays



As the wavelengths of light decrease, they increase in energy. X-rays have smaller wavelengths and therefore higher energy than ultraviolet waves. We usually talk about X-rays in terms of their energy rather than wavelength. This is partially because X-rays have very small wavelengths. It is also because X-ray light tends to act more like a particle than a wave. X-ray detectors collect actual photons of X-ray light - which is very different from the radio telescopes that have large dishes designed to focus radio waves!

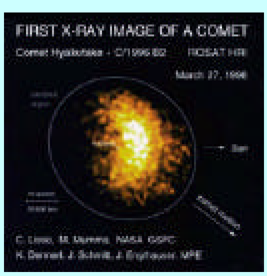
X-rays were first observed and documented in 1895 by Wilhelm Conrad Roentgen, a German scientist who found them quite by accident when experimenting with vacuum tubes. A week later, he took an X-ray photograph of his wife's hand which clearly revealed her wedding ring and her bones. The photograph electrified the general public and aroused great scientific interest in the new form of radiation. Roentgen called it "X" to indicate it was an unknown type of radiation. The name stuck, although (over Roentgen's objections), many of his colleagues suggested calling them Roentgen rays. They are still occasionally referred to as Roentgen rays in German-speaking countries.

What does X-ray light show us?

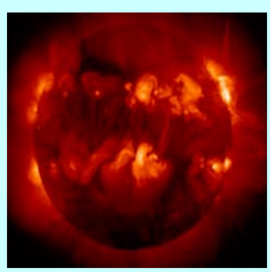


To the left is the first picture of the Earth in X-rays, taken in March, 1996 with the orbiting Polar satellite. The area of brightest X-ray emission is red. The energetic charged particles from the Sun that cause aurora also energize electrons in the Earth's magnetosphere. These electrons move along the Earth's magnetic field and eventually strike the Earth's ionosphere, causing the X-ray emission. These X-rays are not dangerous because they are absorbed by lower parts of the Earth's atmosphere. (The above caption and image are from the Astronomy Picture of the Day for December 30, 1996.)

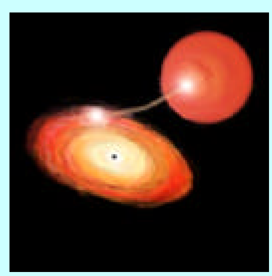
What does X-ray light show us?



Recently, we learned that even comets emit X-rays! This image of Comet Hyakutake was taken by an X-ray satellite called ROSAT, short for the Roentgen Satellite. (It was named after the discoverer of X-rays.)

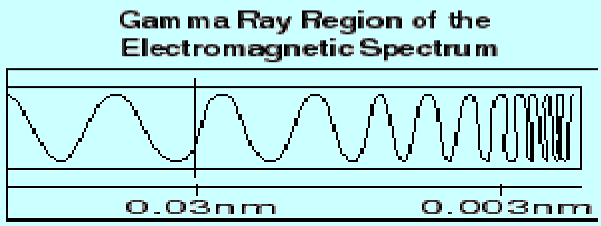


The Sun also emits X-rays - here is what the Sun looked like in X-rays on April 27th, 2000. This image was taken by the Yokoh satellite



Many things in deep space give off X-rays. Many stars are in binary star systems - which means that two stars orbit each other.

Gamma-rays



Gamma-rays have the smallest wavelengths and the most energy of any other wave in the electromagnetic spectrum. These waves are generated by radioactive atoms and in nuclear explosions. Gamma-rays can kill living cells, a fact which medicine uses to its advantage, using gamma-rays to kill cancerous cells.

What do gamma-rays show us?

Perhaps the most spectacular discovery in gamma-ray astronomy came in the late 1960s and early 1970s. Detectors on board the Vela satellite series, originally military satellites, began to record bursts of gamma-rays -- not from Earth, but from deep space

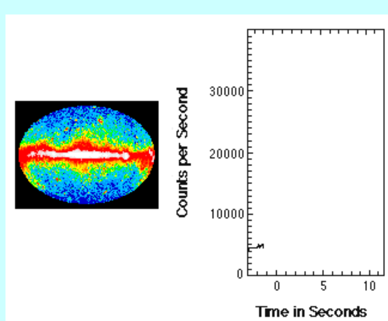


Image /Video Processing - Examples

Image processing is a general term for the wide range of techniques that exist for manipulating and modifying images in various ways.

- Image Enhancement
- Image Restoration
- Image Reconstruction
- Feature Extraction and Recognition
- Compression

Image Enhancement

Enhancement: Improve the visual quality of the image.

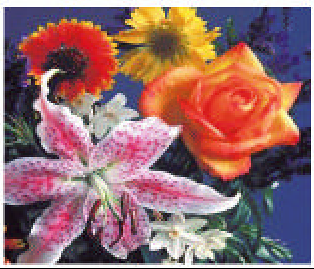
Example : Nose removal using median filtering

Image Restoration

Same as image enhancement, but you have additional information concerning the quality degradation.

Example: removing motion blur in a image of a fast moving object.

The technique known as deconvolution can be applied to remove the motion blur.



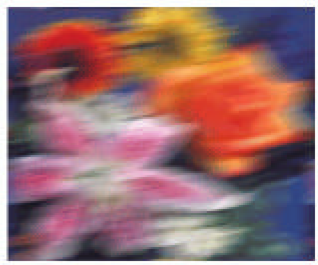
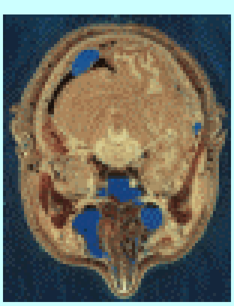


Image Reconstruction

Reconstruction from projections. Used in constructing 3D data from 2D projections in Computer Tomography



[545x700 24-bit color JPEG, 69069 bytes] Section through Visible Human Male - head, including cerebellum, cerebral cortex, brainstem, nasal passages (from Head subset)

Image Representation using Features

- Low level representations using color, texture, shape, motion, etc
- High level features for recognitions; e.g., facial features

Image Compression

Image "axial" – original

Image "axial" restored after compression 41.99, and speckle suppression

The mathematical model of imaging has several different components:

- An image function is the fundamental abstraction of an image.
- A geometrical model describes how three dimensions are projected into two
- A radiometrical model shows how the imaging geometry, light sources , and reflectance properties of objects affect the light measurement at the sensor.

The mathematical model of imaging has several different components:

- A spatial frequency model describes how spatial variations of the image may be characterised in a transform domain.
- A colour model describes how different spectral measurements are related to image colours
- A digitising model describes the process of obtaining discrete samples .