LECTURE NOTES ON
REMOTE SENSING & GIS
IV B. Tech II semester (JNTU (A)-R13)

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CIVIL ENGINEERING

OBJECTIVES:

1. *To introduce the students to the basic concepts and principles of various components of remote sensing.*

OUTCOMES:

On completion of the course the students will have knowledge on

1. *Principles of Remote Sensing and GIS*

UNIT – II

REMOTE SENSING:

Basic concepts and foundation of remote sensing – elements involved in remote sensing, electromagnetic spectrum, remote sensing terminology and units. Energy resources, energy interactions with earth surface features and atmosphere, resolution, sensors and satellite visual interpretation techniques, basic elements, converging evidence, interpretation for terrain evaluation, spectral properties of water bodies, introduction to digital data analysis.

TEXT BOOKS:

1 Remote Sensing and GIS by B.Bhatta, Oxford University Press,New Delhi.
2 Fundamentals of remote sensing by gorge Joseph , Universities press, Hyderabad

REFERENCES:

1. Advanced surveying : Total station GIS and remote sensing – Satheesh Gopi – Pearson publication.
2. Remote Sensing and its applications by LRA Narayana University Press 1999.
3. Basics of Remote sensing & GIS by S.Kumar, Laxmi Publications.
4. Remote sensing and GIS by M.Anji Reddy ,B.S.Pubiliications,New Delhi.
5. GIS by Kang – tsung chang, TMH Publications & Co.,

UNIT-2

Concept of Remote Sensing

Remote Sensing is defined as the science and technology by which the characteristics of objects of interest can be identified, measured or analyzed the characteristics without direct contact.

Electro-magnetic radiation which is **reflected** or **emitted** from an object is the usual source of remote sensing data. However any media such as gravity or magnetic fields can be utilized in remote sensing.

A device to detect the electro-magnetic radiation reflected or emitted from an object is called a "remote sensor" or "**sensor**". Cameras or scanners are examples of remote sensors.

A vehicle to carry the sensor is called a "**platform**". Aircraft or satellites are used as platforms.The technical term "remote sensing" was first used in the United States in the 1960's, and encompassed photogrammetry, photo-interpretation, photo-geology etc. Since Landsat-1, the first earth observation satellite was launched in 1972, remote sensing has become widely used.

The characteristics of an object can be determined, using reflected or emitted electro-magnetic radiation, from the object. That is, "each object has a unique and different characteristics of reflection or emission if the type of deject or the environmental condition is different."Remote sensing is a technology to identify and understand the object or the environmental condition through the uniqueness of the reflection or emission.

This concept is illustrated in figure 1.1.1 while figure 1.1.2 shows the flow of remote sensing, where three different objects are measured by a sensor in a limited number of bands with respect to their, electro-magnetic characteristics after various factors have affected the signal. The remote sensing data will be processed automatically by computer and/or manually interpreted by humans, and finally utilized in agriculture, land use, forestry, geology, hydrology, oceanography, meteorology, environment etc.

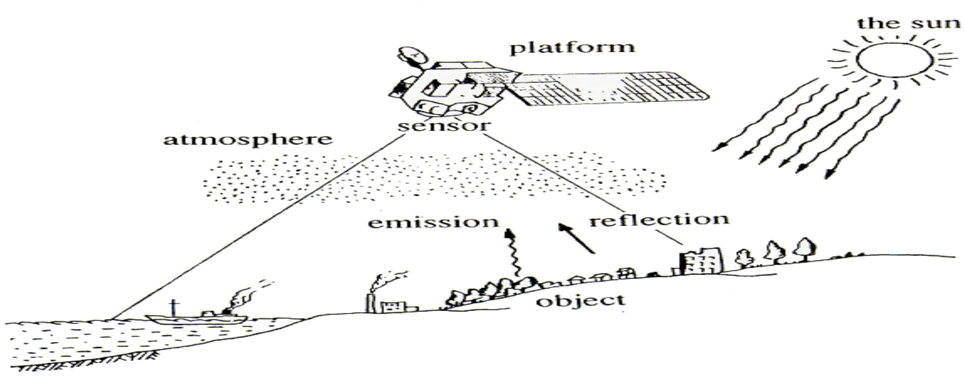

Figure1.1.1 Data collection by remote sensing

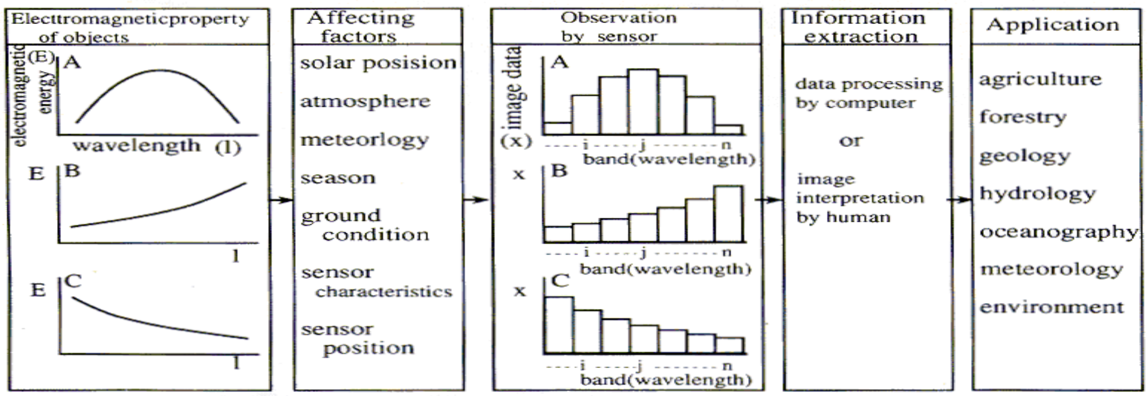

Figure1.1.2 Flow of remote sensing

1.2 Characteristics of Electro-Magnetic Radiation

Electro-magnetic radiation is a carrier of electro-magnetic energy by transmitting the oscillation of the electro-magnetic field through space or matter. The transmission of electro-magnetic radiation is derived from the Maxwell equations. Electro-magnetic radiation has the characteristics of both wave motion and particle motion.

(1) **Characteristics as wave motion**

Electro-magnetic radiation can be considered as a transverse wave with an electric field and a magnetic field. A plane wave for an example as shown in Figure 1.2.1 has its electric field and magnetic field in the perpendicular plane to the transmission direction. The two fields are located at right angles to each other. The wavelength λ, frequency ν and the velocity υ have the following relation.

$$\lambda = \upsilon / \nu$$

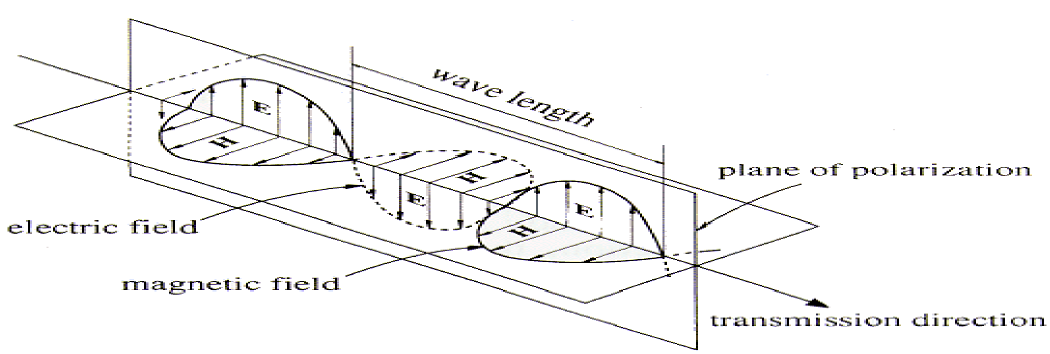

Figure 1.2.1 Electromagnetic radiation

Electro-magnetic radiation is transmitted in a vacuum of free space with the velocity of light c,

(= 2.998 x 108 m/sec) and in the atmosphere with a reduced but similar velocity to that in a vacuum. The frequency n is expressed as a unit of hertz (Hz), that is the number of waves which are transmitted in a second.

(2) Characteristics as particle motion

Electro-magnetic can be treated as a photon or a light quantum. The energy E is expressed as follow.

$$E = h^{\nu}$$

where h : Plank's constant

ν : frequency

The photoelectric effect can be explained by considering the electro-magnetic radiation as composed of particles. Electro-magnetic radiation has four elements of frequency (or wavelength), transmission direction, amplitude and plane of polarization. The amplitude is the magnitude of oscillating electric field. The square of the amplitude is proportional to the energy transmitted by electro-magnetic radiation. The energy radiated from an object is called radiant energy. A plane including electric field is called a plane of polarization. When the plane of polarization forms a uniform plane, it is called linear polarization.

The four elements of electro-magnetic radiation are related to different information content as shown in Figure 1.2.2. Frequency (or wavelength) corresponds to the color of an object in the visible region which is given by a unique characteristic curve relating the wavelength and the radiant energy. In the microwave region, information about objects is obtained using the Doppler shift effect in frequency that is generated by a relative motion between an object and a platform. The spatial location and shape of objects are given by the linearity of the transmission direction, as well as by the amplitude. The plane of polarization is influenced by the geometric shape of objects in the case of reflection or scattering in the microwave region. In the case of radar, horizontal polarization and vertical polarization have different responses on a radar image.

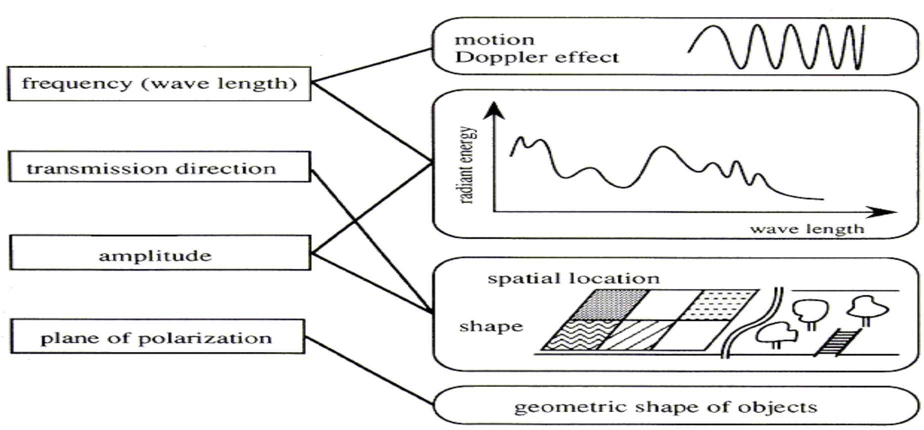

Figure 1.2.2 Information derived from elements of electromagnetic radiation

1.3 Interactions between Matter and Electro-magnetic Radiation

All matter reflects, absorbs, penetrates and emits electro-magnetic radiation in a unique way. For example, the reason why a leaf looks green is that the chlorophyll absorbs blue and red spectra and reflects the green spectrum The unique characteristics of matter are called spectral characteristics .Why does an object have a peculiar characteristic of reflection, absorption or emission? In order to answer the question, one has to study the relation between molecular, atomic and electro-magnetic radiation. In this section, the interaction between hydrogen atom and absorption of electro-magnetic radiation is explained for simplification.

A hydrogen atom has a nucleus and an electron as shown in Figure 1.3.1. The inner state of an atom depends on the inherent and discrete energy level. The electron's orbit is determined by the energy level. If electro-magnetic radiation is incident on an atom of H with a lower energy level (E1), a part of the energy is absorbed, and an electron is induced by excitation to rise to the energy level (E2) resulting in the upper orbit.

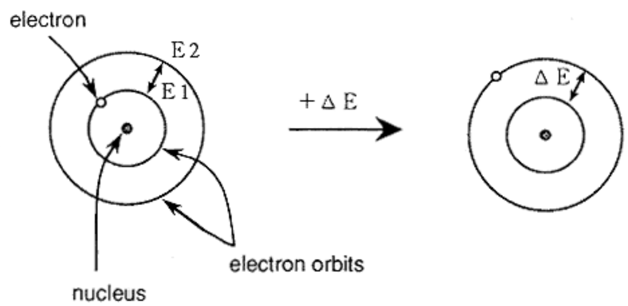

Figure 1.3.1 Change in energy level of the electron of a H atom according to absorption of electromagnetic radiation wavelength λ H

The electro-magnetic energy E is given as follow.

$$E = hc / \lambda$$

where h : Plank's constant

c : velocity of light

λ : wavelength

The difference of energy level

$$\Delta E = E2 - E1 = hc / \lambda H$$ is absorbed.

In other words, the change of the inner state in an H-atom is only realized when electro-magnetic radiation at the peculiar wavelength lH is absorbed in an H-atom. Conversely electro-magnetic radiation at the wavelength λ H is radiated from an H-atom when the energy level changes from E2 to E1.

All matter is composed of atoms and molecules with a particular composition. Therefore, matter will emit or absorb electro-magnetic radiation at a particular wavelength with respect to the inner state.

The types of inner state are classified into several classes, such as ionization, excitation, molecular vibration, molecular rotation etc. as shown in Figure 1.3.2 and Table 1.3.1, which will radiate the associated electro-magnetic radiation. For example, visible light is radiated by excitation of valence electrons, while infrared is radiated by molecular vibration or lattice vibration.

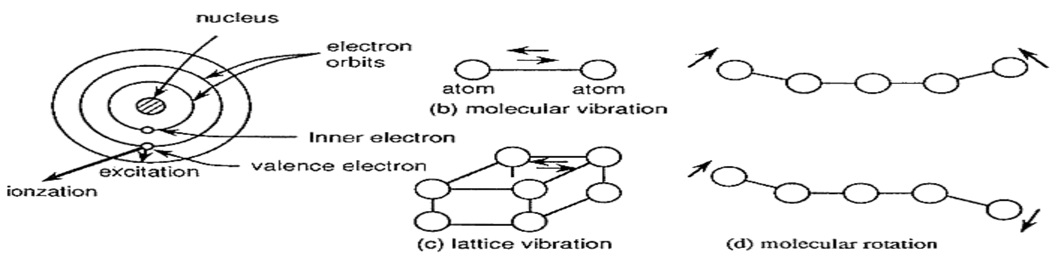

Figure 1.3.2 Schematics of characteristic states associated with electromagnetic radiation

Table.1.3.1 Relation between characteristic state and electromagnetic radiation

Characteristic state	energy (eV)	associated electromagnetic wave
Nuclear transmission and disintegrations	$10^7 \sim 10^5$	γ - ray
Ionization by inner electron removal	$10^4 \sim 10^2$	X - ray
Ionization by outer electron removal	$10^2 \sim 4$	Ultra - violet
Excitation of valence electrons	$4 \sim 1$	Visible
Molecular vibration, Lattice vibration	$10 \sim 10^{-5}$	Infrared
Molecular rotations, electron spin resonance	$10^{-4} \sim 10^{-5}$	Microwave
Nuclear spin resonance	10^{-7}	Meter wave

[unit] energy of 1eV = 1.60219×10^{-19} Joule   wavelength of 1eV light = 1.23985 μm

1.4 Wavelength Regions of Electro-magnetic Radiation

Wavelength regions of electro-magnetic radiation have different names ranging from γ ray, Xray, ultraviolet (UV), visible light, infrared (IR) to radio wave, in order from the shorter wavelengths. The shorter the wavelength is, the more the electro-magnetic radiation is characterized as particle motion with more linearity and directivity. (see 1.2).

Table 1.4.1 shows the names and wavelength region of electro-magnetic radiation. One has to note that classification of infrared and radio radiation may vary according to the scientific discipline. The table shows an example which is generally used in remote sensing.

Table 1.4.1 Classification of electromagnetic radiations

class				wavelength	frequency
ultraviolet				100A ~ 0.4 μm	750 ~ 3,000 THz
visible				0.4 ~ 0.7 μm	430 ~ 750 THz
infrared	near infrared			0.7 ~ 1.3 μm	230 ~ 430 THz
	short wave infrared			1.3 ~ 3 μm	100 ~ 230 THz
	intermediate infrared			3 ~ 8 μm	38 ~ 100 THz
	thermal infrared			8 ~ 14 μm	22 ~ 38 THz
	far infrared			14 μm ~ 1 mm	0.3 ~ 22 THz
radio wave	submillimeter			0.1 ~ 1 mm	3 ~ 3 THz
	micro wave	millimeter	(EHF)	1 ~ 10 mm	30 ~ 300 GHz
		centimeter	(SHF)	1 ~ 10 cm	3 ~ 30 GHz
		decimeter	(UHF)	0.1 ~ 1 m	0.3 ~ 3 GHz
	very short wave		(VHF)	1 ~ 10 m	30 ~ 300 MHz
	short wave		(HF)	10 ~ 100 m	3 ~ 30 MHz
	medium wave		(MF)	0.1 ~ 1 km	0.3 ~ 3 MHz
	long wave		(LF)	1 ~ 10 km	30 ~ 300 KHz
	very long wave		(VLF)	10 ~ 100 km	3 ~ 30 KHz

The electro-magnetic radiation regions used in remote sensing are near UV(ultra-violet) (0.3-0.4 μm), visible light(0.4-0.7 μm), near shortwave and thermal infrared (0.7-14 μm) and micro wave (1 mm - 1 m).

Figure 1.4.1 shows the spectral bands used in remote sensing. The spectral range of near IR and short wave infrared is sometimes called the reflective infrared (0.7-3 μm) because the range is more influenced by solar reflection rather than the emission from the ground surface In the thermal infrared region, emission from the ground's surface dominates the radiant energy with little influence from solar reflection.

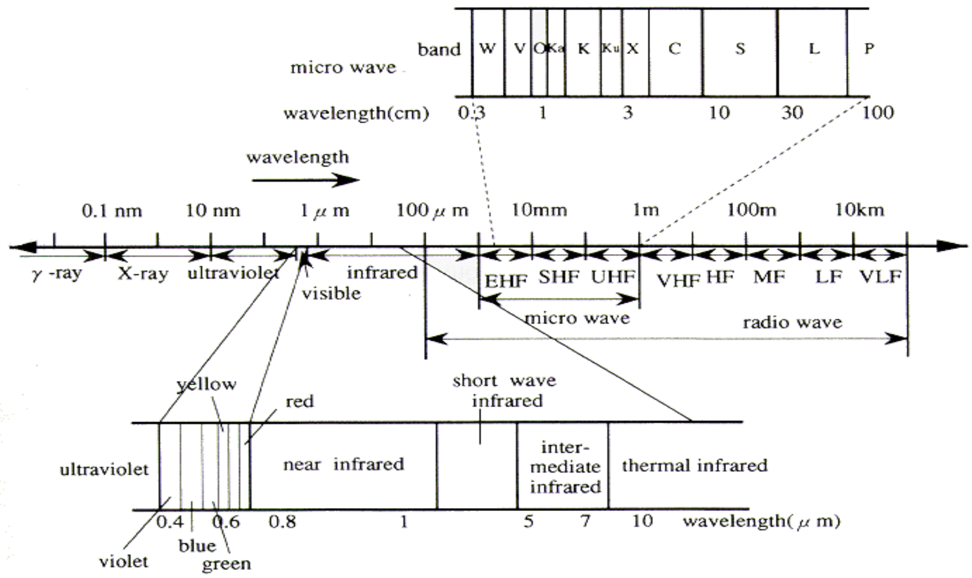

Figure 1.4.1 The bands used in remote sensing

Visible light corresponds to the spectral colors. They are, in order from the longer wavelengths in the visible region, the so called rainbow colors; red, orange, yellow, green, blue, indigo and violet are located with respect to the wavelength.

Short wave infrared has more recently been used for geological classification of rock types. Thermal infrared is primarily used for temperature measurement,while micro wave is utilized for radar and micro wave radiometry. A special naming of k band, X band, C band, L band etc. is given to the micro wave region as shown in Figure 1.4.1.

1.5 Types of Remote Sensing with Respect to Wavelength Regions

Remote sensing is classified into three types with respect to the wavelength regions; (1)Visible and Reflective Infrared Remote Sensing, (2)Thermal Infrared Remote Sensing and (3)Microwave Remote Sensing, as shown in Figure 1.5.1.

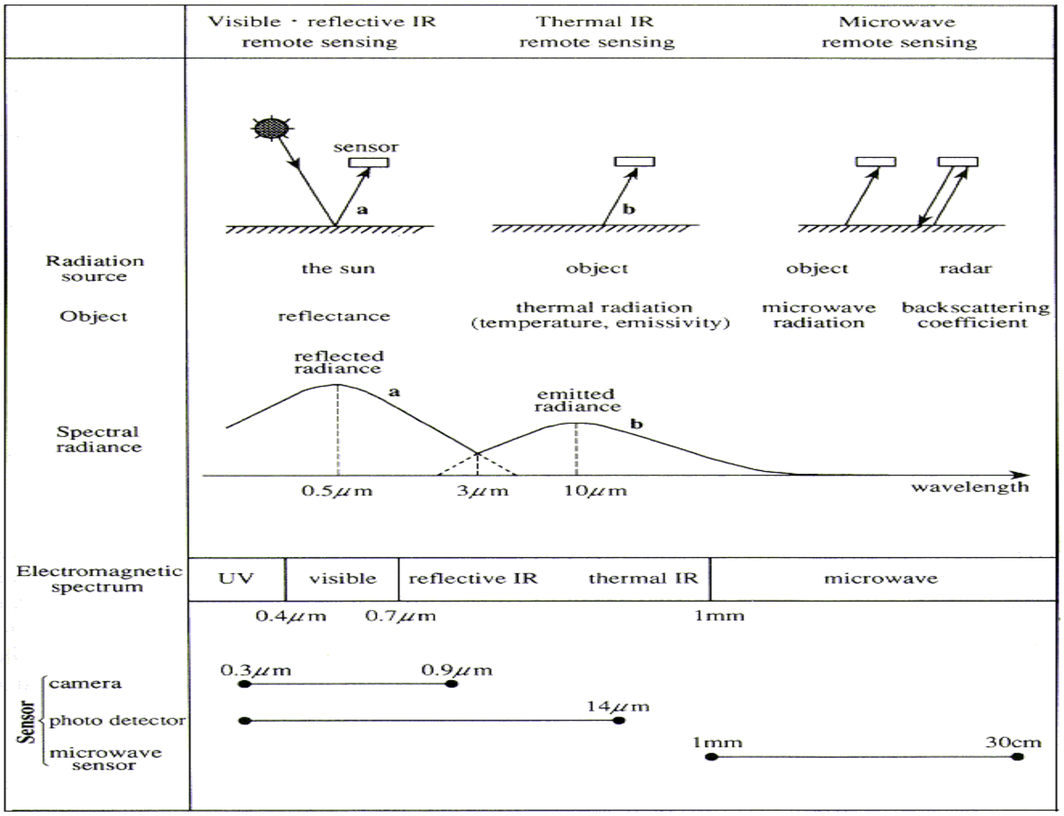

Figure 1.5.1 Three types of remote sensing with respect to wavelength regions

The energy source used in the visible and reflective infrared remote sensing is the sun. The sun radiates electro-magnetic energy with a peak wavelength of 0.5 µm. Remote sensing data obtained in the visible and reflective infrared regions mainly depends on the reflectance of objects on the ground surface .Therefore, information about objects can be obtained from the spectral reflectance. However laser radar is exceptional because it does not use the solar energy but the laser energy of the sensor.

The source of radiant energy used in thermal infrared remote sensing is the object itself, because any object with a normal temperature will emit electro-magnetic radiation with a peak at about 10 µm as illustrated in Figure 1.5.1.

One can compare the difference of spectral radiance between the sun (a) and an object with normal earth temperature (about 300 °K), as shown in Figure 1.5.1. However it should be noted that the figure neglects atmospheric absorption for simplification, though the spectral curve varies with respect to the reflectance, emittance and temperature of the object.

The curves of (a) and (b) cross at about 3.0 μm. Therefore in the wavelength region shorter than 3.0 μm, spectral reflectance is mainly observed, while in the region longer than 3.0 μm, thermal radiation is measured.

In the microwave region, there are two types of micro wave remote sensing, passive microwave remote sensing and active remote sensing. In passive microwave remote sensing, the microwave radiation emitted from an object is detected, while the back scattering coefficient is detected in active micro wave remote sensing.

Remarks: the two curves (a) and (b) in Figure 1.5.1 show the black body's spectral radiances of the sun at a temperature of 6,000 °K and an object with a temperature of 300 °K, without atmospheric absorption.

Digital Data

Images with a continuous gray tone or color, like a photograph are called analog images. On the other hand, a group of divided small cells, with integer values of average intensity, the center representing the cell's value, is called a digital image. The spatial division into a group of cells is called sampling as illustrated in Figure 6.1.1, while conversion of analog images into integer image data is called quantization as illustrated in Figure 6.1.2 and 6.1.3.

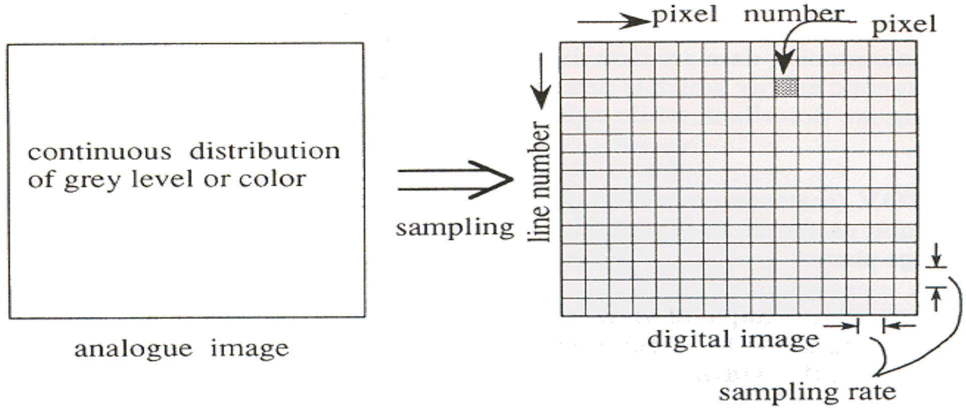

Figure 6.1.1 Concept of sampling

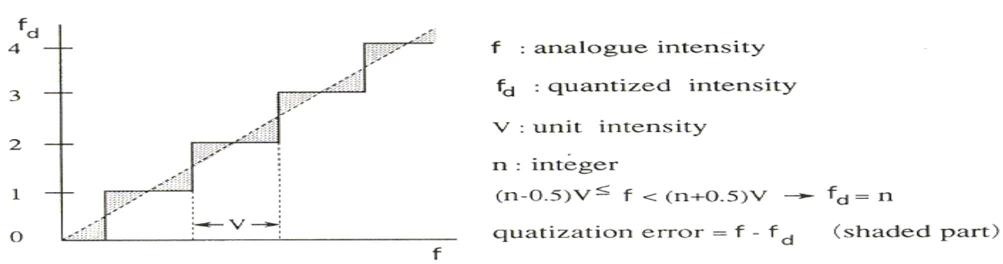

Figure 6.1.2 Concept of quantization

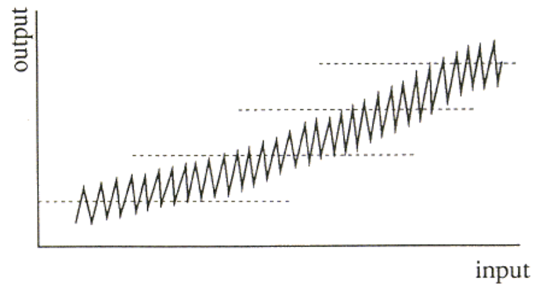

Figure 6.1.3 Quantization in the case of a signal containing a noise

An individual divided cell is called a pixel (picture cell). The shape of the cell is usually square for easy use in a computer, though triangular or hexagonal can also be considered.

A digital image has coordinates of pixel number, normally counted from left to right, and line number, normally counted from top to bottom.

The most important factor in sampling is pixel size or sampling frequency. If the pixel size is large or the sampling frequency is long, the appearance of the image becomes worse, while in the reverse case the data volume becomes very large. Therefore the optimum sampling should be carefully considered.

Shannon's sampling theorem, for specifying the optimum sampling, is given as follows.

"There will be no loss of information if sampling is taken with a half frequency of the maximum frequency involved in the original analog frequency wave."

Let the analog intensity be f and the unit intensity v(>0) as divider in quantization. Let the quantized intensity be fd, fd is given by n as illustrated in Figure 6.1.2. The difference between f and fd is called quantization error.

The question is how to determine the number of quantization levels or the unit intensity as divider. If the number of levels is too small, the quantization error will increase. In the reverse, the data volume increases with informationless data because of the noise level, as shown in Figure 6.1.3.

For example in Figure 6.1.3, the quantization should be divided by a level larger than that of the noise. In this example, four levels would be an appropriate quantization.

Information Extraction in Remote Sensing

Information extraction in remote sensing can be categorized into five types as shown in Table 7.1.1. Classification is a type of categorization of image data using spectral, spatial and temporal information. Change detection is the extraction of change between multi-date images. Extraction of physical quantities corresponds to the measurement of temperature, atmospheric constitutients, elevation and so on, from spectral or stereo information. Extraction of indices is the computation of a newly defined index, for example, the vegetation index from satellite data. Identification of specific features is the identification, for example, of disaster, lineament, archaeological and other features, etc.

Table 7.1.1 Types of information extraction by remote sensing

Types	Example
Classification	Land cover, Vegetation
Change detection	Land cover change
Extraction of physical quality	Temperature, Atmospheric component, Elevation
Extraction of indices	Vegetation index, Turbidity index
Identification of specific features	Identification of disasters like forest fire or flood, Extraction of linearment Detection of archaeological feature

Table 7.1.2 provides a comparison between human and computer information extraction. As seen in the table, human and computer methods supplement each other, so that they both may offer better results when combined. For example in geology, computers will produce an enhanced image, from which humans can interpret the geological features.

Table 7.1.2 Comparison between human and computer information extraction

Method	Merit	Demerit
Human (Image interpretation)	*Interpreter's knowledge are available *Excellent in spatial information extraction	*Time consuming *Individual difference
Computer (Image processing)	*Short processing time Reproductivity *Extraction of physical quantities or indices is possible	*Human knowledge is unavailable *Spatial information extraction is poor

A computer system with an interactive graphic display through which humans and computers can interactively work together is called "a man-machine interactive system".

Because human interpretation is time consuming, as well as expensive, a special computer technique, with the ability of human interpretation, is being developed. For example, an expert system is a computer software system with a training ability to use the interpreter's knowledge for information extraction.

Image Interpretation

Image interpretation is defined as the extraction of qualitative and quantitative information in the form of a map, about the shape, location, structure, function, quality, condition, relationship of and between objects, etc. by using human knowledge or experience. As a narrow definition, " photo-interpretation " is sometimes used as a synonym of image interpretation.

Image interpretation in satellite remote sensing can be made using a single scene of a satellite image, while usually a pair of stereoscopic aerial photographs is used in photo-interpretation to

provide stereoscopic vision using, for example, a mirror stereoscope. Such a single photo-interpretation is discriminated from stereo photo-interpretation.
Figure 7.2.1 shows a typical flow of the image interpretation process.

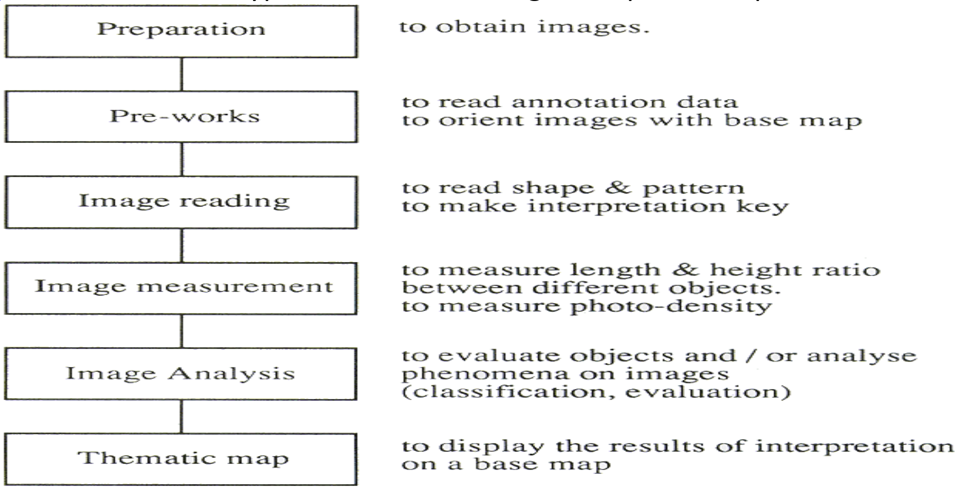

Figure 7.2.1 The image interpretation processing

Image reading is an elemental form of image interpretation. It corresponds to simple identification of objects using such elements as shape, size, pattern, tone, texture, color, shadow and other associated relationships. Image reading is usually implemented with interpretation keys with respect to each object.
Image measurement is the extraction of physical quantities, such as length, location, height, density, temperature and so on, by using reference data or calibration data deductively or inductively.
Image analysis is the understanding of the relationship between interpreted information and the actual status or phenomenon, and to evaluate the situation.
Extracted information will be finally represented in a map form called an interpretation map or a thematic map.
Generally the accuracy of image interpretation is not adequate without some ground investigation. Ground investigations are necessary, first when the keys are established and then when the preliminary map is checked.

Interpretation Elements

The following eight elements are mostly used in image interpretation; size, shape, shadow, tone, color, texture, pattern and associated relationship or context.(see Figure 7.4.1[Size, Shape, Shadow, Tone], Figure 7.4.2

(1) Size:
A proper photo-scale should be selected depending on the purpose of the interpretation. Approximate size of an object can be measured by multiplying the length on the image by the inverse of the photo-scale.

(2) Shape:
The specific shape of an object as it is viewed from above will be imaged on a vertical photograph. Therefore the shape looking from a vertical view should be known. For example,

the crown of a conifer tree looks like a circle, while that of a deciduous tree has an irregular shape. Airports, harbors, factories and so on, can also be identified by their shape.

(3) Shadow:

Shadow is usually a visual obstacle for image interpretation. However, shadow can also give height information about towers, tall buildings etc., as well as shape information from the non-vertical perspective-such as the shape of a bridge.

(4) Tone:

The continuous gray scale varying from white to black is called tone. In panchromatic photographs, any object will reflect its unique tone according to the reflectance. For example dry sand reflects white, while wet sand reflects black.In black and white near infrared infrared photographs, water is black and healthy vegetation white to light gray.

(5) Color:

Color is more convenient for the identification of object details. For example, vegetation types and species can be more easily interpreted by less experienced interpreters using color information. Sometimes color infrared photographs or false color images will give more specific information, depending on the emulsion of the film or the filter used and the object being imaged.

(6) Texture:

Texture is a group of repeated small patterns. For example homogeneous grassland exhibits a smooth texture, coniferous forests usually show a coarse texture. However this will depend on the scale of the photograph or image.

(**7) Pattern:**

Pattern is a regular usually repeated shape with respect to an object. For example, rows of houses or apartments, regularly spaced rice fields, interchanges of highways, orchards etc., can provide information from their unique patterns.

(8) Associated relationships or context:

A specific combination of elements, geographic characteristics, configuration of the surroundings or the context of an object can provide the user with specific information for image interpretation.

Figure 7.4.1 A sample of aerial photograph at Naha-city in Okinawa pref. (scale about 1/13,000)

[Size] Small fishery boats &large working ships
[Shape] square apartment houses & irregular low old houses
[Shadow] high buildings along the main street
[Tone] dark forest & light cultivated field, lighter coral reef & darker deep sea

Figure 7.4.2 A sample of aerial photograph at a part of Ibaragi Pref. (scale about 1/10,000)
[Texture] coarse forest area & fine young re-forest area
[Pattern] shaped housing vegetation, linearly road, meandering river and quadrangulation cultivated fields

Satellite Sensor Resolutions

Spatial resolution

Spatial resolution is the measure of smallest object that can be detected by a satellite sensor. It represents area covered by a pixel on the ground. Mostly, it is measured in meters. For example, CARTOSAT-1 sensor has a spatial resolution of 2.5x2.5 m , IRS P6 LISS IV sensor has a spatial resolution of 5.6x5.6 m for its multispectral bands and LISS III has spatial resolution of 23.5x23.5 m in its first three bands. The smaller the spatial resolution, the greater the resolving power of the sensor system.
That's why one can detect even a car in the satellite image acquired by IKONOS (spatial resolution 1x1 m) but can see hardly even a village in a satellite image acquired by AVHRR (spatial resolution 1.1x1.1 km).

SPECTRAL RESOLUTION:

Spectral resolution refers to the specific wavelength intervals in the electromagnetic spectrum for which a satellite sensor can record the data. It can also be defined as the number and dimension of specific wavelength intervals in the electromagnetic spectrum to which a remote sensing instrument is sensitive. For example, band 1 of the Landsat TM sensor records energy between 0.45 and 0.52 µm in the visible part of the spectrum.The spectral channels containing wide intervals in the electromagnetic spectrum are referred to as coarse spectral resolution and narrow intervals are referred to as fine spectral resolution. For instance the SPOT panchromatic sensor is considered to have coarse spectral resolution because it records EMR between 0.51 and 0.73 µm. on the other hand; band 2 of the ASTER sensor has fine spectral resolution because it records EMR between 0.63 and 0.69 µm.

Radiometric resolution

Radiometric resolution defined as the sensitivity of a remote sensing detector to differentiate in signal strength as it records the radiant flux reflected or emitted from the terrain. It refers to the dynamic range, or number of possible data-file values in each band. This is referred to by the number of bits into which the recorded energy is divided. For instance, ASTER records data in 8-bit for its first nine bands, it means the data file values range from 0 to 255 for each pixel, while the radiometric resolution of LISS III is 7-bit, here the data file values for each pixel ranges from 0 to 128.

Temporal resolution

The temporal resolution of a satellite system refers to how frequently it records imagery of a particular area. For example, CARTOSAT-1 can acquire images of the same area of the globe every 5 days, while LISS III doest it every 24 days.

The temporal resolution of a satellite sensor is very much helpful in change detection. For instance, agricultural crops have unique crop calendars in each geographic region. To measure specific agricultural variables it is necessary to acquire remotely sensed data at critical dates in the phenological cycle. Analysis of multiple-date imagery provides information on how the variables are changing through time. Multi-date satellite images are also used to detect change in forest cover.

Satellite sensors:

LANDSAT

Landsat satellite sensors are one of the most popular remote sensing systems, the imagery acquired from these are widely used across the globe.

NASA's Landsat satellite programme was started in 1972. It was formerly known as ERTS (Earth Resource Technology Satellite) programme. The first satellite in the Landsat series Landsat-1 (formerly ERTS-1) was launched on July 23, 1972 .Since then five different types of sensors have been included in various combinations in Landsat mission from Landsat-1 through Landsat-7. These sensors are Return Beam Vidicon (RBV), the Multispectral Scanner (MSS), the Thematic Mapper (TM), the Enhanced Thematic Mapper (ETM) and the Enhanced Thematic Mapper plus (ETM+). Landsat ETM (or Landsat 6) was launched in 1993 but it could not achieve the orbit. Six year later in 1999 Landsat ETM+ (or Landsat 7) was launched and it is the recent one in the series.

Landsat ETM+ contains four bands in Near Infrared-visible (NIR-VIS) region with 30mx30m spatial resolution, two bands in Short Wave Infrared (SWIR) region with same resolution, one in Thermal Infrared (TIR) region with spatial resolution of 60mx60m and one panchromatic band with resolution. Its revisit period is16 days.

SPOT

SPOT (Systeme Pour l'Observation de la Terre) was developed by the French Centre National d' Etuded Spatiales with Belgium and Sweden. The first satellite of SPOT mission, SPOT-1 was launched in 1986. It was followed by SPOT-2 (in 1990), SPOT-3 (in 1993), SPOT-4 (in 1998) and SPOT-5(in2002).

There are two imaging systems in SPOT-5- HRVIR and Vegetation. The HRVIR records data in three bands in VIS-NIRregion with 10mx10m spatial resolution, one band in SWIR region with 20mx20m spatial resolution and one panchromatic band with 5mx5m resolution. The Vegetation instrument is primarily designed for vegetation monitoring and related studies. It acquires images in three bands in VIS-NIR region and in one band in SWIR region (all with 1000mx1000m) spatial resolution.

Advanced Very High Resolution Radiometer (AVHRR**)**

Several generations of satellites have been flown in the NOAA-AVHRR series. NOAA-15 is the recent in the series. The sensor AVHRR (Advanced Very High Resolution radiometer) contains five spectral channels two in VIS-NIR region and three in TIR. One thermal band is of the wavelength range 3.55-3.93 mm, meant for fire detection. Spatial resolution of AVHRRis 1100mx1100m. NOAA-AVHRR mainly serves for global vegetation mapping, monitoring land cover changes and agriculture related studies with daily coverage.

Indian Remote Sensing (IRS) Satellites

The Indian Remote Sensing programme began with the launch of IRS-1A in 1988. After **that IRS-1B (1999), IRS-1C (1995) and IRS-1D (1997)** was launched. IRS-1D carries three sensors: LISS III with three bands of 23.5mx23.5m spatial resolution in VIS-NIR range and one band in SWIR region with 70.5x70.5 m resolution, a panchromatic sensor, with 5.8mx5.8m resolution and a Wide Field Sensor (WiFs) with 188mx188m resolution. WiFS is extensively used for vegetation related studies.

ISRO's IRS-P6 (RESOURCESAT-1) is very advanced remote sensing system. It was launched in 2003. It carries high resolution LISS IV camera (three spectral bands in VIS-NIR region) with spectral resolution of 5.8mx5.8m which has capability to provide stereoscopic imagery. IRS-P6 LISS III camera acquires images in VIS-NIR (3 spectral bands) andSWIR (one spectral band) with spatial resolution of 23.5mx23.5m. IRS-P6 AWiFS (Advanced Wide Field Sensor) operates inVIS-NIR (3 spectral bands) and SWIR (one spectral band) with spatial resolution of 56mx56m.