Sensors

As sensor or ‘remote sensor’ is a device to detect the electro-magnetic radiation reflected or emitted from an object. Cameras or scanners are examples of remote sensing-sensors.

Classification of Sensors

Passive

Non-scanning

Non-imaging

- Microwave Radiometer
- Magnetic Sensor
- Gravimeter
- Fourier Spectrometer
- Other

Imaging

Camera

- Monochrome
- Natural color
- Infrared
- Other

Scanning

Imaging

Image Plane Scanning

- TV Camera
- Solid Scanner

Object Plane Scanning

- Optical Mechanical Scanner
- Microwave Radiometer

Continued ….. Classification of Sensors

Active

Non-scanning

- Non-imaging
  - **Microwave Radiometer**
  - **Laser Water Depth meter**
  - **Laser Distance meter**

Scanning

- **Imaging**
  - **Object Plane Scanning**
  - **Real Aperture Radar**
  - **Synthetic Aperture Radar**
  - **Image Plane Scanning**
  - **Passive Phased Array Radar**

Table 5: Wavelength Band of Principle Sensor

Wavelength (m)	UV	VISIBLE			INFRA-RED Near S.W. Interm. Thrm. Far							RADIO
SENSOR	0.4	0.5	0.6	0.7	0.9	1.5	5.5	8.0	14	1000	1000	100000
(CAMERAS:)												
monochrome film												
Color film												
IR film												
Color IR film												
SOLID SCANNER (SPORT HRV)												
(Thermal Video)												
TV CAMERA												
OPTICAL MECHANICAL SCANNER												
(Airborne MSS)												
(Landsat MSS)												
(Landsat TM)												
RADAR												
MICROWAVE RADIOMETER												

Definition of Optical Sensor's Characteristics

Items	Definition
band range of EMW	observation width of EMW (Electro-magnetic v
centre wavelength	centre wavelength on band
band responsibility at both ends of a band	characteristics' curve at both ends of a band
band sensitivity	sensitivity on a band
without band sensitivity	sensitivity on spectral ranges outside of the ba
sensitivity difference between different bands	ratio of sensitivity between different bands
S/N ratio	signal to noise ratio
dynamic range	range of sensor's sensitivity in terms of th maximum and minimum radiance ratio
sensitivity difference between pixels	ratio of maximum output level to minimum o
linearity of sensor's input-output characteristics	input level to output level in higher input pow
noise equivalent power	input signal power giving output equivalent w
field of view	area covered by a remote sensor, picture (an scanning width by scanner)
instantaneous field of view (IFOV)	field of angle detected by one detector
registration between different spectral bands	geometric distortion between one standard ba
MTF	modulation transfer function of a sensor, det IFOV
optical distortion	image distortion due to optical components aberration
angle of stereoscopic observation	difference of viewing angle of stereoscopic sen
imaging frequency	time taken for scanning one line

Resolution

In general, resolution is defined as the ability of an entire remote-sensing system, including lens, antennae, display, exposure, processing, and other factors, to render a sharply-defined image. Resolution of a remote-sensing system is of different types.

(1) Spectral Resolution

(2) Radiometric Resolution

(3) Spatial Resolution

(4) Temporal Resolution

The spectral resolution of a remote sensing instrument (sensor) is determined by the band-widths of the EMR of the channels used. High spectral resolution, thus, is achieved by narrow band widths which, collectively, are likely to provide a more accurate spectral signature for discrete objects than broad band width. However, narrow-band instruments tend to acquire data with a low signal-to-noise ratio (the ratio of effective input signal to the noise level), lowering the system's radiometric resolution. This problem may be alleviated if relatively long look (or dwell) times are used during imaging. In contrast, broad-band sensors usually have good spatial and radiometric resolution. In the broader usages of spectral resolution, there are also tradeoffs between application and spectral and radiometric resolution. In remote sensing, the data from a multiple number of channels or bands, which divide the electro-magnetic radiation range from ultra violet to radio waves are called multi-channel data, multi-band data, or multi-spectral data.

SATELLITE SYSTEM SOME OPTICAL SENSOR SYSTEM	LANDSAT 4/5 MSS	LANDSAT4/5 TM	SPOT XS	NOAA AVHRR	MOS MESSR	JERS OPS VINR and SWIR	ADEOS AVNIR	IRS-1C LISS-III	IRS-1C WiFS
Spectral Resolution (Number of Bands)	Four	Seven	Three	Five	Four	Seven	Four	Four	Two
Spectral ranges (wave-length portion of EMR) in µm (micrometers)									
Blue		0.45 - 0.52					0.40 - 0.50		
Green	0.50 - 0.60	0.53 - 0.61	0.50 - 0.59		0.51 - 0.59	0.52 - 0.60	0.52 - 0.62	0.52 - 0.59	
Red	0.60 - 0.70	0.62 - 0.69	0.62 - 0.68	0.58 - 0.68	0.61 - 0.69	0.63 - 0.69	0.62 - 0.72	0.62 - 0.68	0.62 - 0.68
NIR	0.70 - 0.80	0.78 - 0.90	0.78 - 0.88	0.73 - 1.10	0.72 - 0.82	0.76 - 0.86		0.77 - 0.86	0.77 - 0.86
NIR	0.80 - 1.10				0.80 - 1.10		0.82 - 0.92		
IIR		1.57 - 1.78				1.60 - 1.71		1.55 - 1.75	
IIR		2.10 - 2.35		3.55 - 3.93		2.01 - 2.12			
IIR (MIR)						2.13 - 2.15			
IIR (MIR)						2.27 - 2.40			
ThIR		10.45 - 11.66		10.3 - 11.2					
FIR				11.5-12.5					

Spectral Band Range (µm) used in Thematic Mapper (TM) onboard Landsat's 4 and 5 sensor system and their potential application

Band Number	Band Range (µm)	Potential applications
1	0.45 to 0.52	coastal water mapping; soil/vegetation differentiation; deciduous/coniferous differentiation (sensitive to chlorophyll concentration); etc.
2	0.52 to 0.62	green reflectance by healthy vegetation; etc.
3	0.63 to 0.69	chlorophyll absorption for plant species differentiation;
4	0.78 to 0.90	bio-mass surveys; water body delineation;
5	1.55 to 1.75	vegetation moisture measurement; snow/cloud differentiation;
6	10.4 to 12.5	plant heat stress management; other thermal mapping; soil moisture discrimination;
7	2.08 to 2.35	hydrothermal mapping; discrimination of mineral and rock types;

Spectral Band Range (µm) used in Advance Very High Resolution Radiometer (AVHRR) sensor onboard NOAA Satellite system and their potential application.

CHANNEL NUMBER	**WAVE LENGTH) (µm**	**USES**
CHANNEL 1	0.58 - 0.68	cloud delineation, weather snow and ice mapping and monitoring, etc.
CHANNEL 2	0.73 - 1.1	surface water delineation, vegetation and agriculture assessment, range surveys, etc.
CHANNEL 3	3.53- 3.93	land/water distinction, sea surface temperature, hot spot detection (forest fires and volcanic activity),etc.
CHANNEL 4	10.3 - 11.3	day/night cloud mapping, sea and land surface temperature, soil moisture, volcanic eruption, etc.
CHANNEL 5	11.5 12.5	sea surface temperature measurement, soil moisture, weather, etc.

Radiometric resolution is determined by the number of discrete levels into which signals may be divided. Considering the effects of varying illumination, the radiometric dynamic range of a sensor is determined by the maximum radiance value that the sensor system can experience for a given band.

For example, the initial analogue voltage signal of the Landsat (1,2,3) MSS detectors is converted to digital count output ranges from 0 to 63 for a total of 64 quantizing levels. However, the maximum number of quantizing levels possible from a sensor system depends on the signal-to-noise ratio and the confidence level that can be assigned when discriminating between levels. **Information contained in digital image data are expressed by bit (binary digit) per pixel, per channel**. A bit is a binary number, that is 0 or 1. Let the quantization level be n, then the information in terms of bits is given by $\log_2 n$ (bit). In remote sensing, the **quantization level** is normally 6, 8 or 10 bits. For computer processing, the byte unit (1 byte =8bits; integer value 0-255; 256 gray levels) is much more convenient. Therefore, remote-sensing data will be treated as one or two byte data.

The total data volume of multi-channel data per scene is computed as:

data volume (byte)=(line number)*(pixel number)*(channel number)*(bits)/8.

Quantization level of remote-sensing data

Sensor	Satellite	Level (bit)	Descriptions
MSS	LANDSAT	6	8 bits data after radiometric correction
TM	LANDSAT	8	
HRV (XS)	SPOT	8	
HRV (PA)	SPOT	6	
AVHRR	NOAA	10	both 10 and 16 bits' data are available at distribution
SAR	JERS-1	3	real 3 bits, imaginary 3 bits

Spatial resolution, in terms of the geometric properties of the imaging system, is usually described as the instantaneous field of view (IFOV). The IFOV is defined as the angle which corresponds to the sampling unit on the ground. The IFOV is a function of satellite orbital altitude, detector size, and the focal length of the optical system. Thus, the IFOV, when expressed in degrees or radians, is the smallest plane angle over which an instrument (e.g., a scanner) is sensitive to radiation; when expressed in linear or area units, such as metres or hectares, it is an altitude-dependent measure of the ground resolution of the scanner, in which case it is also called an 'instantaneous viewing area'. The field of view (FOV) is defined as the maximum angle of view in which a sensor can effectively detect electro-magnetic energy. Ground resolution is the minimum detectable area or distance on the ground. In some cases, the projected area on the ground corresponding to a pixel or IFOV is also called ground resolution. Swath width (also called the total field of view [TFOV]) is the width on the ground corresponding to the FOV.

Spatial Resolution

SATELLITE SYSTEM SOME OPTICAL SENSOR SYSTEM	LANDSAT 4/5 MSS	LANDSAT 4/5 TM	SPOT XS	NOAA AVHRR	MOS MESSR	JERS OPS VINR and SWIR	ADEOS AVNIR	IRS-1C LISS-III	IRS-1C WiFS
Spatial Resolution	80 m	30 m	20 m	1.1 km (LAC)	50 m	18 m X 24 m	16 m	24 m	188 m (200 m)
Off-nadir viewing (side-look) capability for the (PAN) Panchromatic mode for stereo image data acquisition)			SPOT PAN (10m resolution) 0.51- 0.73 µm 3 days revisit capability			JERS OPS VINR (18m X 24m) Bands 3 & 4 0.76 - 0.86 µm	ADEOS AVNIR PAN (8 m Resolution) 0.52 - 0.72 µm	IRS-1C PAN (6 m resolution) (70 km swath width) 0.50 - 0.70 µm (6-bit)	

Spatial Resolution

SATELLITE SYSTEM SOME OPTICAL SENSOR SYSTEM	**LANDSAT 4/5** **MSS**	**LANDSAT 4/5** **TM**	**SPOT** **XS**	**NOAA** **AVHRR**	**MOS** **MESSR**	**JERS** **OPS VINR and SWIR**	**ADEOS** **AVNIR**	**IRS-1C** **LISS-III**	**IRS-1C** **WiFS**
Spatial Resolution	80 m	30 m	20 m	1.1 km (LAC)	50 m	18 m X 24 m	16 m	24 m	188 m (200 m)
Off-nadir viewing (side-look) capability for the (PAN) Panchromatic mode for **stereo** image data acquisition)			**SPOT PAN** (10m resolution) 0.51- 0.73 µm 3 days revisit capability			**JERS OPS VINR** (18m X 24m) Bands 3 & 4 0.76 - 0.86 µm	**ADEOS AVNIR PAN** (8 m resolution) 0.52 - 0.72 µm	**IRS-1C PAN** (6 m resolution) (70 km swath width) 0.50 - 0.70 µm (6-bit)	

Temporal resolution is related to **the repetitive coverage of the ground coverage by the remote-sensing system**. The temporal resolution of Landsat 4/5 is sixteen days. There are very few objects and/or phenomena in nature that do not change in respect to one another throughout the course of time. For many of the physical and cultural features on the landscape, there are optimal time periods during which these features may best be observed. These optimal periods might be seasonal, or could last only for a few days or weeks. In the case of some applications, the time interval at which remotely-sensed data are acquired becomes an important factor. For example, to monitor crop growth, images should be obtained at a predetermined time interval within a year's period. However, to monitor urban growth patterns, imagery acquired at time intervals of a year or more may be appropriate. Thus, in remote sensing, a substantial number of dynamic events, such as crop growth, rangeland development, hydrologic processes, earth damage, urban change, and marine processes; may be used as key discriminants.

SATELLITE SYSTEM	LANDSAT 4/5	LANDSAT4/5	SPOT	NOAA	MOS MES	JERS	ADEOS	IRS-1C	IRS-1C
SOME OPTICAL SENSOR SYSTEM	MSS	TM	XS	AVHRR	SR	OPS VINR AND SWIR	AVNIR	LISS-III	WiFS
TEMPORAL (Revisit Cycle) (in days)	16	16	20 (nadir)	1 image/day	17	44	41 (nadir)	24 (nadir)	

SATELLITE SYSTEM SOME OPTICAL SENSOR SYSTEM	**LANDSAT** 4/5 **MSS**	**LANDSAT** 4/5 **TM**	**SPOT** **XS**	**NOAA** **AVHRR**	**MOS** **MES** **SR**	**JERS** **OPS VINR and SWIR**	**ADEOS** **AVNIR**	**IRS-1C** **LISS-III**	**IRS-1C** **WiFS**
Temporal resolution (Revisit Cycle) (in days)	16	16	20 (nadir)	1 image/day	17	44	41 (nadir)	24 (nadir)	24 (nadir)