Remote Sensing

2. Sensors and Platforms

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Rangnath R Navalgund, after working for more than two decades at the Space Applications Centre (ISRO), Ahmedabad has moved over to the National Remote Sensing Agency, Department of Space, Hyderabad, as its Director since May 2001. Definition of Indian spaceborne remote sensing missions and formulation of remote sensing applications programme in the country are his areas of work.

In the first part we defined remote sensing, its physical basis and major applications. In this part we describe various types of sensors used in remote sensing and suitable observation platforms for placing sensors. We then discuss how to extract information from remote sense images. We conclude the article with a look at the future.

Sensors

Sensors can be classified as passive or active. Sensors, which sense natural radiations, either emitted or reflected from the Earth, are called passive sensors. It is also possible to produce electromagnetic radiation of a specific wavelength or band of wavelengths and illuminate a terrain on the Earth's surface. The interaction of this radiation with the target could then be studied by sensing the scattered radiation from the targets. Such sensors, which produce their own electromagnetic radiation are called active sensors. A photographic camera, which uses only sunlight, is a passive sensor; whereas the one, which uses a flash bulb, is an active sensor. Again, sensors (active or passive) could be either imaging, like the camera, or non-imaging, like the nonscanning radiometer. Sensors are also classified on the basis of range of electromagnetic region in which they operate such as optical or microwave (*Figure* 1).

Part 1. Basics and applications, *Resonance*, Vol.6, No.12, pp.51-60, 2001.

The major sensor parameters which have bearing on optimum utilization of data include: (i) spatial resolution – the capability of the sensor to discriminate the smallest object on the ground; (ii) spectral resolution – the spectral bandwidth with which the imagery is taken; (iii) radiometric sensitivity – the capability to differentiate the spectral reflectance/emittance between various targets; and (iv) dynamic range – the minimum to maximum

Keywords.
Remote sensing, sensors, platforms in remote sensing.

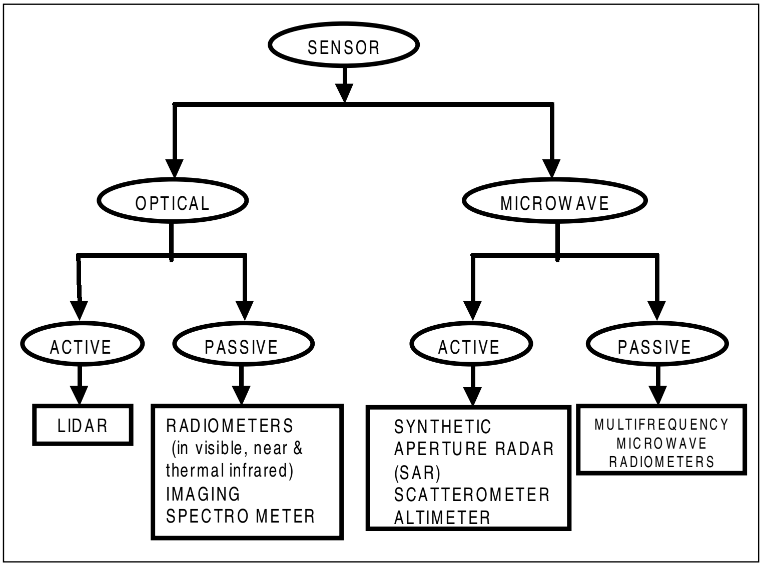

Figure 1. Classification of sensors.

reflectance that can be faithfully measured. In addition, the sensor should produce imagery with geometric fidelity. Repetitivity, or at what time interval same area gets imaged by the sensor is another important parameter of the sensor-orbit system. It is not possible to simultaneously get the best of all parameters. Hence trade-off between various parameters is required to realise a sensor system. Various types of sensors generally used in Earth observation are described briefly.

Photographic and Television Cameras

Photographic cameras are the oldest and probably the most widely used imaging systems. They have been successfully used from aircraft, balloons, manned and unmanned spacecraft. A multiband camera enables simultaneous photography of a ground scene in more than one spectral band. Some of the limitations of photographic cameras are their limited spectral response (only up to ~ 0.9 μm) and dynamic range, non-amenability to digital processing and problems associated with reproducibility of the quality of the imagery. Television cameras were the first imaging systems used in space to get the imagery of the Earth telemetered down as electrical signals.

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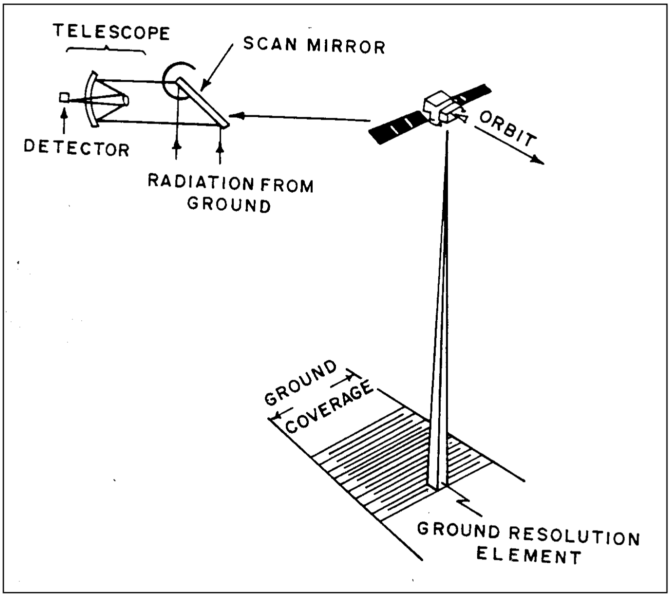

Figure 2. Principle of operation of a line scanner.

Optical Mechanical Scanners

In case of an optical mechanical scanner, the radiation emitted (or reflected) from the scene is intercepted by a scan mirror, which diverts the radiation to a collecting telescope (*Figure* 2). The telescope focuses the radiation to a detector. The detector receives radiation from an area on the ground (picture elements or pixel), defined by the detector size and focal length of the telescope. By rotating the scan mirror which is normally inclined at 45° to the optical axis, the detector starts looking at the adjacent pixels on the ground. Thus, by the scan mirror rotation/oscillation, radiation is received and measured from a continuous line of length corresponding to the total scan angle. If such an instrument is mounted on a moving platform (aircraft or spacecraft) with the optical axis parallel to the platform motion, the motion of the platform produces successive scan lines, giving a contiguous imagery. In case of a multispectral scanner (MSS), the energy collected by the telescope is channeled to a spectral dispersing system (spectrometer) to be registered in different spectral bands. Typical instruments using this principle include LANDSAT MSS and TM and the very high resolution radiometer onboard INSAT.

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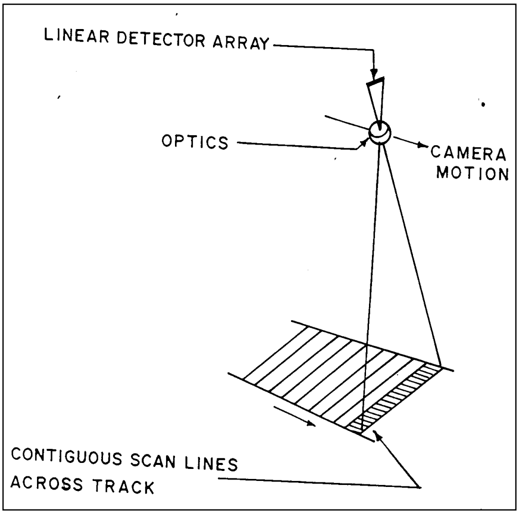

Figure 3. Principle of operation of a LISS camera.

Linear Imaging Self Scanning Sensors (LISS)

In this system, the basic sensor is a linear array of solid-state detectors. The optics focuses a strip of terrain in the cross track direction on to the sensor array. The image from each detector is stored and shifted out sequentially to get a video signal. The motion of the platform produces successive scan lines, thereby producing a two-dimensional picture (*Figure* 3). The spatial resolution primarily depends on the number of photo detectors available in a linear array and the required swath. Such sensors are expected to give a resolution of a few tens of metres even from geostationary altitudes. Currently a number of aircraft and spacecraft imaging systems including Indian remote sensing satellites are operating using CCDs. Sensors are also being developed to make spectroscopic measurement with very fine spectral resolution (< 0.001 μm) giving continuous coverage of the spectral region of interest to provide additional information on vegetative stress, mineral composition, etc.

LIDAR

With advancement of high power laser technology in the optical and IR region, active laser remote sensing is promising new means of obtaining useful information on Earth and its environment, especially related to atmospheric constituents and phenomenon. The laser system used for remote sensing is referred to as LIDAR (acronym for light detection and ranging, similar to RADAR).

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Passive Microwave Radiometer

Microwave radiometers are passive sensors used to measure the emitted energy. The emitted energy is collected by a suitable antenna. The signal is represented as an equivalent temperature, that is, the temperature of a black body source which would produce the same amount of signal in bandwidth of the system.

The power received by the radiometer is proportional to the product of the absolute physical temperature (T) and emissivity (e). eT is referred to as brightness temperature. If the microwave radiometer is used in a scanning mode similar to the optical scanner, passive microwave imaging is possible. Scanning may be done either by a mechanical drive of the antenna or by electronically scanning a phased array. IRS-P4 (Oceansat–1) carried such a multifrequency microwave scanning radiometer. Generally spatial resolutions obtained are coarse (kms).

Microwave Active Sensors

Side looking airborne radar (SLAR) was the first active sensor used to produce imagery of the terrain from the backscattered microwave radiation. The antenna mounted sideways on an aircraft transmits a pulsed microwave energy which illuminates the ground. The return signal is received by the same antenna and is processed either on board or on ground. The radar returns scattered rays back from different points in the field of view and are separated in phase at the radar receiver. Scattered energy depends on the radar cross-section of the target, the wavelength, the slant range and the radiation pattern. The spatial resolution of a SLAR at a certain height and look angle is controlled by two independent system parameters, namely, pulse duration for range resolution (R), and antenna length for azimuth resolution. SLAR cannot produce fine resolution radar imagery from satellite altitudes. Synthetic aperture radar (SAR) overcomes this problem.

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Platforms

The sensor systems need to be placed on suitable observation platforms. They can be stationary or mobile depending upon the needs of observation and constraints. For an imaging system, in general, the spatial resolution becomes poorer as the platform height increases, but the area coverage increases. Thus a trade off between the resolution and synoptic view is necessary in choosing the platform altitude. Further the platform's ability

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to support the sensor, in terms of weight, volume, power, etc., and its stability have to be considered. Though aircraft, balloons, rockets and satellites have been used as platforms, the most extensively used are aircrafts and satellites.

Aircrafts are mainly useful for surveys of local or limited regional interest. One of the major advantages is their ability to be available at a particular location at a specified time. They can be used at low altitudes (~ 1 km) to few tens of kilometres depending on aircraft. Currently there are aircrafts fitted with multiple sensors, capable of observations covering the whole range of the electromagnetic spectrum. The major limitation is the high cost for global coverage and even for regional coverage on repetitive basis.

Earth observation from a satellite platform provides a synoptic view of a large area, which is very useful for understanding interrelationships between various features; further it can be made under known solar zenith angle, providing similar illumination conditions. Another major advantage of satellite is its ability to provide repetitive observations of the same area with intervals of a few minutes to a few weeks, depending on the sensor and orbit. This capability is very useful to monitor dynamic phenomena such as cloud evolution, vegetation cover, snow cover etc. Spacecraft consists mainframe, power, thermal, altitude and orbit control, telemetry, tracking and command systems, etc. besides the payload (sensor).

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Orbits

Two types of spacecraft orbits are possible: (i) geostationary and (ii) near earth orbit (*Figure* 4). For a satellite orbiting in the equatorial plane of Earth from west to east at about 36000 km above the Earth, the period of revolution of satellite exactly coincides with that of the rotation of the Earth about its own axis. Thus the satellite appears stationary with respect to the Earth. Such an orbit is called geostationary. Geostationary satellites are extensively used for communication and meteorological observations. Due to the large distance from Earth, high resolution imaging from geostationary satellites is difficult. Resolution of about a kilometre has been successfully obtained from a number of geostationary satellites, including INSAT-2E.

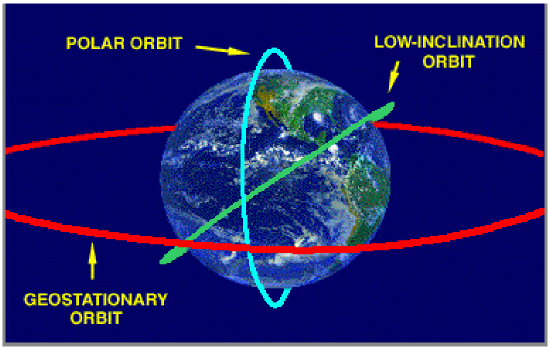

Figure 4. Near-earth polar and geosynchronous orbits.

Near-Earth orbit height varies from a few hundred kilometres to several thousand kilometres. Most useful orbit in this category for remote sensing is the circular, near polar, sun-synchronous orbit. In a sun-synchronous orbit, all points at a given latitude (say on a descending pass) will have the same local mean solar time. Further, the ground trace of the sun-synchronous satellite can be made to recur over a scene exactly at intervals of fixed number of days by maintaining the height of the orbit to a close tolerance, thus ensuring repetitive observations of a scene at the same local time. However, it should be noted that the solar zenith angle changes due to seasonal variations cannot be eliminated. Polar orbits facilitate global coverage and circularity ensures that spatial resolution is maintained.

Data Reception and Preprocessing of Satellite Data

When the satellite passes over the required area the sensors/ cameras mounted on the spacecraft acquire data of the area and convert them in to digital data. The digital data thus collected are then beamed to the ground. The ground stations consisting of antennae and reception systems receive these signals beamed by the satellites and are recorded on to magnetic media using computers. The data thus received is preprocessed using special software to produce computer compatible tapes and visual products for further analysis and interpretation.

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How does one Extract Information from Spaceborne Images?

The Earth surface as seen by the camera in different wavelengths, (reflected, scattered and or emitted) is provided either

False colour composite is a visual data product generated by assigning red, green and blue colour to images taken in near infrared, red and green spectral bands and composited.

in the form of a digital tape or a photographic product. Such a product is radiometrically corrected, geometrically, registered to a reference scheme and properly annotated. Interpretation of such a product for deriving information on the Earth surface requires, understanding of spectral signatures of different Earth surface features, apriori knowledge of the ground and subject experience. On many occasions, it is necessary to study images taken at two different times/seasons to discriminate objects. Interpretation also makes use of texture, association, shape and size characteristics of the objects for identification. Digital image processing techniques predominantly use magnitude of reflected/emitted radiation of objects at different spectral bands to identify and classify objects. Let us illustrate this process taking examples of land and water resources.

Land Resources

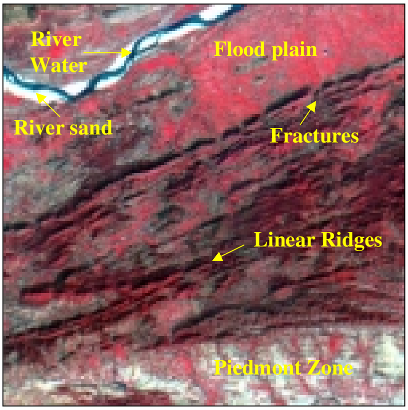
Agricultural area having standing crops appears in red tone in view of the high infrared reflectance of vegetation in the false colour composite (FCC). False colour composite is a visual data product generated by assigning red, green and blue colour to images taken in near infrared, red and green spectral bands and composited. Hence, vegetation is seen in red tone in view of its high NIR reflectance. Different shades within this tone may indicate different growth stages, density of crop, its variety, cultural practices, percent of soil cover, etc. Dense forest areas appear in dark red tone at all times of the year, if it is evergreen type. Fallow lands, bereft of any vegetation would give cyan tone. One could also distinguish long fallow from the current fallow by studying images of different seasons/years.

Wasteland categories are distinctly identifiable on the satellite images due to their characteristic pattern, association and signatures. Land with or without scrub appears like crop land in kharif season image and like 'fallows' in rabi season image. Sandy areas due to their high reflectivity would appear in white tone. Gullied/ravinous lands are identified by their pattern and association with river/stream systems. Barren rocky areas and stony pavements are discriminated because of their characteristic spectral response.

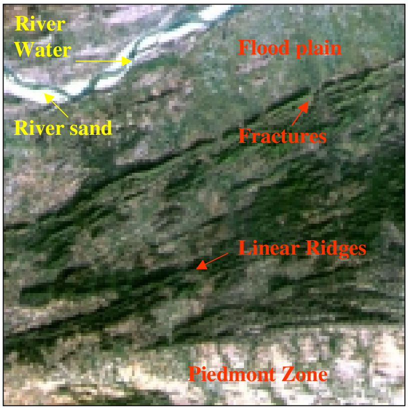
Water Resources

Surface waterbodies are easily identifiable on RS images through their dark blue tone resulting from absorption of infrared radiation by water. Geometrically registered images of different dates/season provide information on the spread of a surface waterbody, be it a village pond, lake or a reservoir. Volume of available water can be inferred by studying area-capacity curves. Presence of suspended sediment (turbidity) and aquatic vegetation in the waterbody can also be inferred from the images. Occurrence of ground water at any place is a consequence of the interaction of climatic, geologic, hydrologic and topographic factors. Search for ground water depends on locating the most promising zones having good porosity and permeability. Some of the indicators of ground water occurrence such as intersection of lineaments, fractures, faults, dykes, valley fills, abandoned and paleo channels, flood plains, areas of anomalous vegetation growth can be identified on the images (*Figure* 5). Images also facilitate delineation of watershed/subwatershed boundaries, and provide information on drainage pattern, landforms and land use information pertaining to the watersheds.

Figure 5. FCC and true colour images showing fractures, flood plain and linear ridges.



FALSE COLOUR



TRUE COLOUR

Future Perspectives

Brief scenario of space technology development and applications discussed so far gives an idea of the tremendous role played by remote sensing in national development in the country today. Of course, there are several improvements required in the quality of details/information provided by space technology. Some of the data needs felt acutely by the user community are: i) improved spatial resolution (2-3m) of RS data to provide terrain details on cadastral level

(1:10,000), ii) stereo capability (2-3 m height resolution) to help planning/execution of development plans, iii) high resolution (5–10m) multi-spectral data to facilitate identification of crops grown in small fields (~ 0.1 ha), iv) high repetivity data (-3 days) to monitor dynamic phenomena such as flood, changes in snow line, crop growth, etc. and v) data pertaining to physical and biological parameters of the ocean. Considering these, in the next 6-7 years, a host of spacecraft systems carrying different sensors have been planned in India. Cartographic satellites Cartosat 1 and 2 carrying panchromatic cameras providing data at 2.5 and 1m resolution and stereo capability are planned for launch in a couple of years. This should help large-scale mapping and terrain evaluation.

Resources at carrying a LISS-IV camera providing 5.8 m multi-spectral data, LISS-III camera and a 4-band wide field sensor providing data at 60 m spatial resolution at 5-day repetivity is also planned. Oceansat carrying a scatterometer, an altimeter and a radiometer and an independent SAR mission are also be in the offing. All these missions providing data at higher spatial and temporal resolutions, and in different parts of electromagnetic spectrum, along with the technical advances made in processing and modelling techniques including GIS should be revolutionizing the field of remote sensing applications in the country. Several new application experiments and demonstrations using interactive satellite based communication system for development training and continuing education using INSAT satellites are also playing a crucial role in national development.

Acknowledgement

The author wishes to thank his various colleagues for useful discussions and in particular K Mruthyunjaya Reddy for his assistance in preparing the manuscript.

Suggested Reading

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