

Remote Sensing-An Introduction

What is Remote Sensing?

- Remote sensing is the science and art of obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area, or phenomenon under investigation (Lillesand and Kiefer, 2000)
- Photogrammetry and remote sensing are the art, science, and technology of obtaining reliable information about physical objects and the environment, through the process of recording, measuring, and interpreting imagery and digital representations of energy pattern derived from non-contact sensor systems (Colwell, 1997, ASPRS combined definition)
- A Maximal (Broad) definition: Remote sensing is the acquiring of data about an object without touching it
- A minimal definition: the noncontact recording of information from the ultraviolet, visible, infrared, and microwave regions of the electromagnetic spectrum by means of instruments such as camera, scanners, lasers, linear arrays, and/or area arrays located on platforms such as aircraft or spacecraft, and the analysis of acquired information by means of visual and digital image processing.

Characteristics and Components of A Remote Sensing System

- Measurements or observations are taken without making direct physical contact with the object in question. In contrast to in situ or in-place data collection.
- The electromagnetic spectrum is the energy that carries information through the atmosphere from the Earth's surface to the sensing device.
- The remote sensing instrument used to record the EM signals are often to be referred to a sensor: camera, scanner, altimeters, etc;
- Remote: at a distance from the object or area of interest. Remote sensing platforms: aircraft, satellite, and space shuttles.
- Telemetry communication: A network of satellite receiving stations
- Analysis and interpretation: visual and/or digital image processing techniques.

Science or Art or Both?

- Scientific aspects
- Art aspects

Types of Remote Sensing

Passive vs Active Remote Sensing

- Passive methods: photography and multispectral scanner, recording naturally occurring EM radiation that is reflected or emitted from the terrain.
- Active systems, microwave (radar), solar, laser sensors supply their own energy to illuminate the scene, and then record the amount of radiant flux scattered back toward the sensor system.

Aerial vs Spaceborne Remote Sensing

Airborne

- High-spatial, high-spectral resolution aerial photographs offer detailed view of the Earth's surface;

- Ground coverage is relatively small, and expensive to acquire;
- Severe geometric distortion may occur due to atmospheric turbulence and difficult to correct.
- On less regular temporal basis.

Satellite-based

- Satellite photographs and images provide synoptic, less detailed view;
- Ground coverage is large, and relatively cheap;
- On regular and consistent temporal basis;
- Stable orbit, and better geometric integrity;

Resolution/Resolving Power/Scale of Remote Sensing Data

- Spatial resolution
 - 1) A measure of the smallest angular or linear separation between two objects that can be resolved by the sensor.
 - 2) satellite sensors with fixed orbit and fixed optical systems have a constant instantaneous-field-of-view (IFOV).
 - 3) Sensor's nominal spatial resolution is the dimension in meters of the ground projected IFOV.
 - 4) the greater the resolving power of the sensor system, the smaller the spatial resolution, hence the more detailed information.
 - 5) In order to detect a feature, the spatial resolution of the sensor should be less than one-half the size of the feature measured in its smallest dimension.
- Spectral Resolution
 - 1) The number and dimension of specific wavelength intervals in the EM spectrum to which a remote sensing instrument is sensitive.
 - 2) Difficult to create a sensor that has extremely sharp bandpass boundaries. Nominal spectral resolution only shows the primary rang.
 - 3) Multi-spectral: multiple bands; Hyper-spectral: hundreds of spectral bands, the Airborne Visible and Infrared Imaging Spectrometer (AVIRIS) 224 bands.
 - 4) Bands are selected to maximize the contrast between object of interest and its background. Careful selection of the spectral bands may improve the opportunity of separating different geographical features.
- Radiometric:
 - 1) The sensitivity of remote sensing sensor to differences in signal strength as it records the radiant flux reflected or emitted from the terrain.
 - 2) the number of discriminable signal levels, 6-bits (64 levels) for Landsat-1 MSS, 8-bits (1-byte) for most, 10-bits for AVHRR.
- Temporal:
 - 1) How often a sensor visits a particular area. It is determined by the repeat cycle of satellite or the off-nadir pointable ability;
 - 2) Analysis of multiple date imagery provides information on how the environmental variables are changing through time.

Remote Sensing Process

- The process involves an interaction between incident radiation and the targets of interest.

- This is exemplified by the use of imaging systems where the following seven elements are involved.

- 1) **Energy Source or Illumination (A)**
- 2) **Radiation and the Atmosphere (B)**
- 3) **Interaction with the Target (C)**
- 4) **Recording of Energy by the Sensor (D)**
- 5) **Transmission, Reception, and Processing (E)**
- 6) **Interpretation and Analysis (F)**
- 7) **Application (G)**

Ideal Conditions for Remote Sensing

- **Uniform energy source:** Constant energy over all wavelengths at known output, irrespective of time and place.
- **Neutral atmosphere:** Noninterfering atmosphere that would neither absorb nor scatter electromagnetic energy.
- **Unique spectral signatures:** Each object would have a unique and known spectral response everywhere on Earth's surface.
- **Super sensor:** Sensing system that would be highly sensitive through all wavelengths of interest and would be economical and practical to operate.
- **Real-time data handling:** System that allowed instant processing of data and presentation of images.
- **Multiple data users:** Remotely sensed data would be useful to scientists and managers from all disciplines; one data set could supply needs of all potential users.

Actual Conditions for Remote Sensing

- **Energy source:** Varies with time, place, and objects in ways that cannot be fully predicted. Calibration is sometimes possible, but the exact nature of available electromagnetic energy is usually not known.
- **Atmosphere:** Varies according to latitude, season, time of day, local weather, etc. Strong absorption and scattering are the rule at most times and places.
- **Spectral signatures:** All objects have theoretically unique signatures, but in practice these may change and cannot always be distinguished; many objects appear the same.
- **Real sensors:** No existing sensing system can operate in all wavelengths of interest. Each system is limited by its optical or electronic nature to certain wavelengths. Likewise certain systems are limited by their high cost of operation.
- **Data handling:** Many systems now generate far more data than can be handled by either visual inspection or computer analysis. Few systems operate with real-time imagery.
- **Multiple users:** No single combination of remote sensing data and analysis will satisfy all users. Many users are not knowledgeable about subjects outside their immediate disciplines and thus cannot appreciate the full potential or limitations of remotely sensed data and images.

Image Processing Tasks and Scenario

- Digital images are the major types of today's remotely sensed data;

- Image processing techniques are employed to model, geocode, enhance and extract geo-spatial information
- Analog (visual image processing), Elements of image interpretation, digital image processing

Advantages of Remote Sensing Observation of Earth's Surface

- Recording and measuring EM radiation from the target
- This recording and measurement can be taken by airborne or satellite-borne sensors;
- Remotely sensed images are rectified and enhanced to show information better;
- Provide accurate, cheap, and frequently updated information about the Earth's surface

Information from Remote Sensing

- The images are interpreted to extract both metric and thematic information about earth's surface and near-surface for various applications.
- Thematic information: Derive bio-physical variables, vegetation abundance, water quality parameters, or soil moisture, the types of minerals present at the earth's surface.
- Metric information: Determination of the precise x, y location and height z of an object, stereoscopic aerial photography.
- The most important outcome of development of spaceborne remote sensing has been the role this science and technology has played in conceiving the earth as a system.
- Satellite remote sensing has brought a new dimension of understanding of the processes that govern our earth atmosphere system and also the impacts of human activities.

Application Areas

- land use/land cover mapping and change detection
- agricultural assessment and monitoring
- coastal and marine resource management
- mineral exploration
- oil & gas exploration
- forest resource management
- urban planning and change detection
- telecommunications siting and planning
- physical oceanography
- geology and topographic mapping
- sea ice detection and mapping

A Brief History

Origin of the term "Remote Sensing"

- The term "remote sensing" was coined by Evelyn L. Pruitt in an unpublished paper in the early 1960s by geographers in the Office of Naval Research (ONR) Geography Branch of USA to apply to the information derived from photographic and non-photographic instruments.

- The term remote sensing was promoted in a series of symposia sponsored ONR at the Willow RUN Lab of the University of Michigan.

Prior to 1960s

- 1859-first known balloon photograph
- At the beginning of 20th century, a passenger in an airplane piloted by Wilbur Wright made the first photographs from an airplane over Centocelli, Italy.
- By the late 1940s, rockets carrying cameras were being launched into sub-orbital flights. The photographs that they returned gave rise by the early 1950s to serious scientific discussion of the possibility of observing the weather from space. Several groups pursued the idea of launching a weather satellite
- First U2 flight over the FSU on July 5, 1956;
- Launch of first Earth Satellites by the Soviet Union on Oct 4, 1957, Sputnik 1. Provided first space views of our planet's surface and atmosphere.
- First successful U.S. satellite, Explorer 1, was launched on Jan 31, 1958 (123 days later).
- The formation of the National Aeronautics and Space Administration (NASA) on Oct 1, 1958. For more than 30 yrs, NASA has lead the development of all types of scientific satellites used for civilian purposes.
- The US launched the first of the Corona orbital satellites on February 28, 1959. The first successful mission occurred on August 18, 1960.

Since 1960s

- 1960-TIROS-1 (Television and Infrared Observation Satellite) the first meteorological satellite with low resolution
- 1966: A new era in meteorological observations opened with the launch of the first geostationary spacecraft, Applications Technology Satellite-1 (ATS-1) by NASA. The ATS provided the first continuous observations of cloud and severe weather tracking from a stationary platform
- 1972: U.S. launched the first Earth Resources Technology Satellite (ERTS-1), which provided the first multispectral map of the surface of the Earth. In 1975, satellite was renamed to Landsat-1, the first in an ongoing series that now totals 7.
- 1975: The first truly operational geostationary meteorological satellite, the Geostationary Operational Satellite 1 (GOES 1), was launched on Oct 16, 1975. U.S. has generally maintained 2 geostationary satellites in orbit, 1 at 75 degrees W and another at 135 degrees W longitude
- 1976: U.S. launched the 1st satellite in its Defense Meteorological Satellite Program (DMSP).
- 1978: Seasat, a satellite devoted to measurements of the oceans, which provided global measurements of winds at the ocean surface, sea surface topography, surface and internal waves and bathymetry in shallow regions
- 1981: the U.S. Space Shuttle program provided many opportunities for orbiting cameras and imaging instruments over the next 5 years. The first Shuttle Imaging Radar (SIR-A) was flown on the Space Shuttle. NOAA AVHRR
- 1982: U.S. Landsat-4 Thematic Mapper (TM) on Landsat provided the 1st high-resolution multi-wavelength images of Earth.

- 1986: France successfully launched the Satellite Pour l'Observation de al Terra (SPOT-1) satellite, PAN and XS.
- Since the late 1980s, more earth observation satellites, Landsat, SPOT, ERS-1, ERS-2, Radarsat-1, radarsat-2, JERS-1, IKONOS,

Academic Journals

International Journal of Remote Sensing
Photogrammetric Engineering and Remote Sensing
Remote Sensing of Environment
IEEE Transactions on Geoscience and Remote Sensing
ISPRS Journal of Photogrammetry and Remote Sensing
Geocarto International

Remote Sensing Software

Erdas Imagine
PCI EASY/PACE
ENVI/IDL
ER Mapper
ARC/INFO Grid
ArcView Image Analyst

Reading Assignment:

Chapter 1 in Jensen, J.R. 2007. **Remote Sensing of the Environment: An Earth Resource Perspective**. Second Edition, Upper Saddle River, NJ, Prentice Hall. 592 pp.