Topic Series 04

Remote Sensing Systems Overview

I. What is Remote Sensing?

Remote Sensing: The characterization, description, and/or analysis of images without physical contact.

We often think of remote sensing as being spy-in-the-sky military technologies. Remote sensing actually covers a broad range of endeavors including aerial photography. In its simplest form, you are remote sensing me with your eyes.

Today we start to talk about remote sensing devices / technologies other than aerial cameras, that are playing a significant role in research and natural resource management applications.

We offer a course that covers much more detail on non-photographic sensors and digital image analysis: **FO-4452/6452, FO-4451/6451, Remote Sensing Applications**

II. Acquisition of Remote Sensing Data

Passive versus Active Sensors

All remote sensing systems collect some form of energy and convert it to **analog** or **digital** information.

Passive sensors rely on an energy source external to the system (e.g. light from the Sun, heat emitted from an object) to provide the return energy to sense the object.

> Examples of Passive Sensors: **Camera, Scanner, CCD's**. We'll concentrate on Scanners and CCD's.

Active sensors generate their own energy to bounce off of the target (e.g. radar: radio waves).

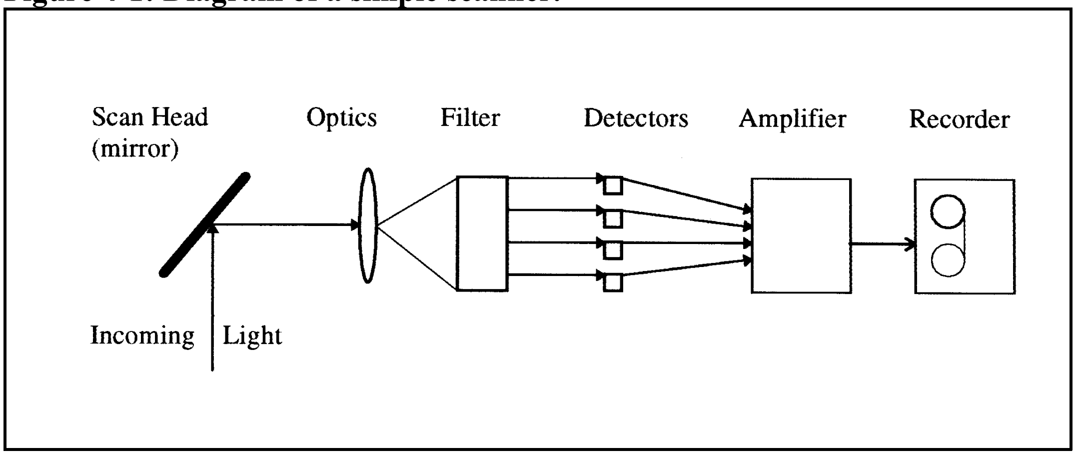
> Examples of Active Sensors: **radar** (radio detection and ranging), **lidar** (light detection and ranging), **sonar** (sound navigation and ranging). We'll talk a bit more about radar and lidar.

Passive Sensors

Scanners

A simple scanner takes incoming electromagnetic energy, focuses it through **optics** and a **filter** system (splits up wavelengths of light) onto electronic **detectors** that convert the energy to electrical signals that are **recorded**. The strength of the signals is related to amount of energy hitting the detector and thus tells us in a relative sense, how much energy was reflected or emitted from the target.

Figure 4-1: Diagram of a simple scanner.



Some scanners utilize a rotating or oscillating mirror to collect energy at right angles to the track of the airplane or spacecraft.

The smallest cross-track resolution element is usually called a picture element or **pixel** and is determined by the **instantaneous field of view (IFOV)** or angular field of view of the mirror at any point during the scan. Note that pixels are smallest directly beneath the instrument.

Thermal scanners present a special problem in that their internal components give off thermal energy. In order to be able to detect heat energy given off by a target away from the scanner (very little energy hitting the sensor), we **cool off** the thermal scanner either electronically or with liquid nitrogen.

Sources of Error/Distortion in Scanner Imagery

1) Cross-track distortion of pixels due to IFOV (bowtie)
2) Stair-step effect due to relative motion of platform and earth
3) Displacement due to terrain or earth curvature
4) Changes in radiometric calibration of detectors
5) Detector lag (blooming)
6) Electronic noise

Pushbroom Scanners utilize a wide angle optical system to focus incoming radiation on a linear array of detectors. Each detector samples light for one pixel. Multiple arrays are needed to look at more than one light wavelength at a time. These sensors are more stable than those with scanning mirrors (fewer moving parts, better geometric fidelity for the pixels).

CCD's

Charged Couple Devices (CCD's) are the basis for modern video and digital frame cameras. Like the pushbroom scanner, CCD's are made up of an **array** (in this case 2-dimensional) of light sensitive detectors that accumulate an electrical charge when hit by light. The stronger the light, the greater the charge. All detectors in the array are periodically sampled (every **1/30th second** for TV) to form a picture.

Digital frame cameras and some special purpose video cameras can include an **electronic shutter** that can be set to expose the CCD over a much shorter period of time (1/10,000 sec) to avoid blurring due to motion. These systems are the type most common in aerial applications. Digital frame cameras convert the information on the CCD directly to digital information that is stored either in **memory**, on a **disc**, or to a separate **computer**.

Most aerial CCD systems utilize special **filter combinations** with one or more cameras to capture different discrete parts of the spectrum like the near-infrared (good for vegetation monitoring).

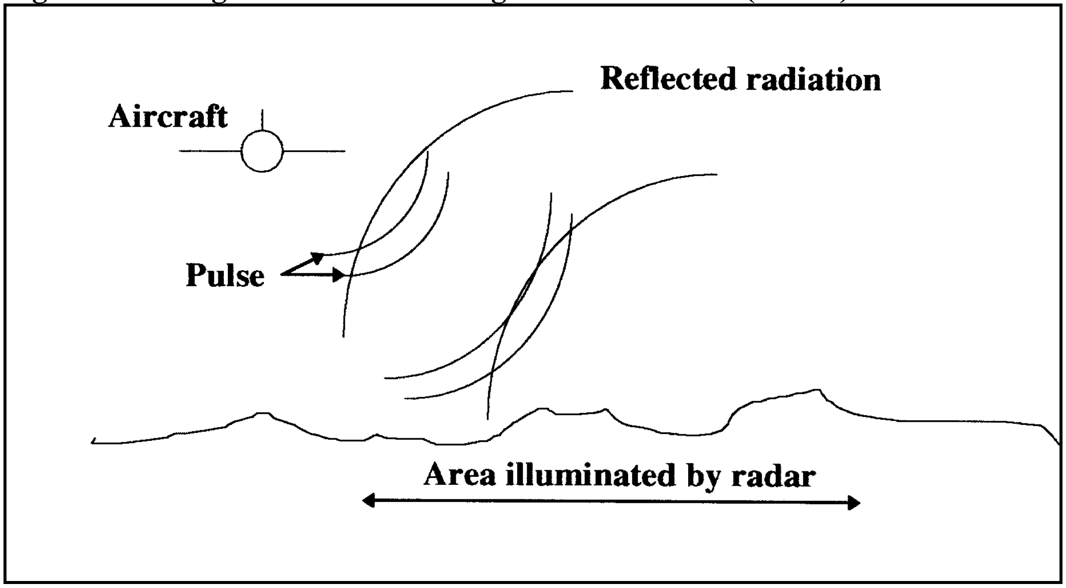
Digital Frame cameras and high-resolution video systems are becoming more commonplace and have been successfully put into commercial use.

Active Sensors

Radar

Radar is a product of WWII technology that was originally was intended for detection of targets in the air or on the sea. Radar systems used for remote sensing send out pulses of energy to the side of the platform hence the name **side-looking airborne radar (SLAR).** Information is recorded based on the amount of time it takes for the pulse to be reflected back to the radar receiver. This time delay and the strength of the return signal dictates where an object is in a radar image and how reflective the object is (brightness on the image). **Geometry and roughness** of the target are two attributes that dictate how much energy is reflected.

Figure 4-2: Diagram of Side Looking Airborne Radar (SLAR).



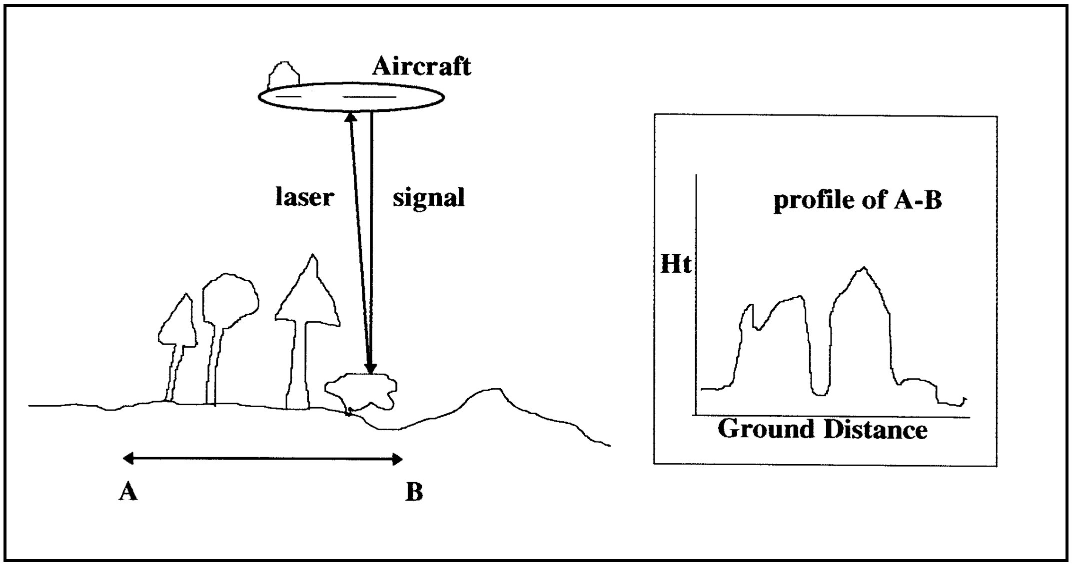
The **pulse duration** dictates the resolution of the system in the **cross-track** direction while the radar **beam width** gives the resolution in the **along-track** direction. The combination of these two features determines the size of a pixel.

Lidar

Lidar systems utilize a laser device to transmit a beam of light (usually **infrared**) to a target to determine the distance from the aircraft to the target. This is the same technology that is employed in **ground surveying instruments** and your friendly police department **speed detection equipment**.

A simple lidar system can be used to collect a terrain (or **canopy profile**) information along a line directly beneath the aircraft. More sophisticated systems employ a lidar with a scan head to collect a series of measurements along a line perpendicular to the flight path. A continuous series of lidar scan lines can be used to produce a 3-D **terrain map** of the area under the aircraft. When used with aerial photography, video, or digital frame camera imagery, this technology provides a lot of information about the terrain.

Figure 4-3: Concept of laser profiler (lidar) data collection.



III. Satellite Sensor Systems

Landsat

The first of **five Landsat satellites** was launched in 1972. Landsat 6 failed to reach orbit and Landsat 7 is scheduled for launch before 1998. All of the Landsat satellites were launched into near polar orbits.

The primary sensor that operated on Landsat 1-3 was the **multispectral scanner (MSS).** The MSS acquired data in 4 areas of the spectrum **(green, red, and two NIR).** Landsat 4 and 5 also had MSS sensors but these were secondary to the **Thematic Mapper (TM).** The IFOV for MSS data is **80m** as opposed to **30m** for the TM. MSS data are still used in natural resource surveys primarily for establishment of baseline conditions in change analysis studies. Images are about **115 miles (185km)** on a side. The orbital repeat cycle was about **18 days** for each satellite so with two operating, analysts could acquire data over the same site every 9 days. MSS data sets from historic archive can be obtained from the EROS Data Center in Sioux Falls, SD.

The TM has been in recent years the workhorse of data used for natural resource assessments. It images areas in 7 spectral regions **(blue, green, red, NIR, two mid-IR and thermal)** on an orbital repeat cycle of **16 days**. Images are **115 miles** on a side. Recent TM data is purchased from EOSAT Corp. Old data sets are archived at the EROS Data Center.

TM data are used for large-area general vegetation mapping and change monitoring.

SPOT (System Probatoire d'Observation de al Terre)

The first SPOT satellite was **launched in 1986.** Two additional satellites have been placed into orbit. These satellites also operate in near-polar orbits and have a repeat cycle of **26 days.** SPOT has a **steerable mirror** that allows it to look forward or back at adjacent orbit paths so the repeat cycle can be reduced. This also gives the satellite **stereo coverage capability**.

There are **two pushbroom sensors** that can operate in **panchromatic** and **multispectral** mode. The general configuration is for each mode to be supported so that both panchromatic and multispectral imagery are obtained on each orbit. The multispectral mode collects data in the **green, red and NIR** wavelengths at a **20m** spatial resolution. Panchromatic data are **10m** resolution. Image size is normally 60km.

These data are used in the same way TM are used. The panchromatic data have found some use in small-scale orthophoto map products.

NOAA AVHRR

The **Advanced Very High Resolution Radiometer (AVHRR)** was originally developed for use on polar-orbiting NOAA satellites for weather and ocean observations. This sensor images areas in the **visible, NIR and three thermal** channels at a resolution of 1.1km at nadir.

The AVHRR acquires data over any area on a daily basis so is very useful for time series analysis of gross changes in vegetation characteristics. The visible and NIR channels are used to produce a ratio referred to as the **normalized difference vegetation index (NDVI)** which is used as a relative measure of vegetation vigor.

These data are used primarily for continental to global studies of general vegetation cover and vigor.

ERS and RadarSat

These two satellites employ **radar** sensors. **ERS** was launched by the **European space Agency**. **RadarSat** was launched by **Canada** and has recently become operational. Space-borne radar systems are fairly new technologies and have not found their way into operational applications in natural resource assessments.

There is a lot of promise in the use of radar for general forest and land-cover surveys particularly in the tropics. Radar has all-weather, day-night capabilities so can be used in areas that have cloud-cover problems.

JERS and IRS

The **Japanese Earth Resources Satellite (JERS)** employs both a MSS similar to the SPOT satellite and a radar system. These data are not widely available but can be purchased from EOSAT.

The **Indian Remote Sensing (IRS)** satellite also employs MSS technology with resolutions similar to Landsat TM. These data are available through EOSAT.

Eyeglass

This is a satellite that is being developed by a group of companies to be the first system capable of generating 1m resolution data for commercial distribution. This satellite will be launched in about 1 year.

IV. Image Processing

Non-photographic sensor data are generally acquired in digital form so that each pixel is represented by one or more numbers that represent the reflected light from that area on the ground. These data can be used to generate photographic products for visual interpretation.

Because the imagery are in digital form, we can use computers to enhance the data for simple interpretation or to automatically divide the data into land-cover classes of interest. Products from such analysis are generally used in a GIS either as separate layers or to enhance the interpretation of other GIS layers. These procedures are covered in-depth in the remote sensing class.