Praveen Kumar
Dept. of Geography

Salient Characteristics of orbital platform

Platforms

Platforms refer to the structures or vehicles on which remote sensing instruments are mounted. The platform on which a particular sensor is housed determines a number of attributes, which may dictate the use of particular sensors. These attributes include: distance the sensor is from the object of interest, periodicity of image acquisition, timing of image acquisition, and location and extent of coverage. There are three broad categories of remote sensing platforms: ground based, airborne, and satellite.

Ground based -- A wide variety of ground based platforms are used in remote sensing. Some of the more common ones are hand held devices, tripods, towers and cranes. Instruments that are ground-based are often used to measure the quantity and quality of light coming from the sun or for close range characterization of objects. For example, to study properties of a single plant or a small patch of grass, it would make sense to use a ground based instrument.

Laboratory instruments are used almost exclusively for research, sensor calibration, and quality control. Much of what is learned from laboratory work is used to understand how remote sensing can be better utilized to identify different materials. This contributes to the development of new sensors that improve on existing technologies.

Field instruments are also largely used for research purposes. This type of remote sensing instrument is often hand-held or mounted on a tripod or other similar support. Permanent ground platforms are typically used for monitoring atmospheric phenomenon although they are also used for long-term monitoring of terrestrial features. Towers and cranes are often used to support research projects where a reasonably stable, long-term platform is necessary. Towers can be built on site and can be tall enough to project through a forest canopy so that a range of measurements can be taken from the forest floor, through the canopy and from above the canopy.

The BOREAS (BOReal Ecosystem-Atmosphere Study) field experiment was conducted to gain knowledge about relationships between the boreal forest and Earth's atmosphere. illustrates two towers that were used during BOREAS. For more information about BOREAS, see http://boreas.gsfc.nasa.gov/.

Airborne -- Airborne platforms were the sole non-ground-based platforms for early remote sensing work. The first aerial images were acquired with a camera carried aloft by a balloon in 1859. Balloons are rarely used today because they are not very stable and the course of flight is not always predictable, although small balloons carrying expendable probes are still used for some meteorological research.

At present, airplanes are the most common airborne platform. Nearly the whole spectrum of civilian and military aircraft is used for remote sensing applications. When altitude and stability requirements for a sensor are not too demanding, simple, low-cost aircraft can be used as platforms. However, as requirements for greater instrument stability or higher altitudes become necessary, more sophisticated aircraft must be used.

In this section, aircraft are divided into three categories (low, mid, and high) based on their altitude restrictions. In general, the higher an aircraft can fly, the more stable a platform it is, but correspondingly more costly to operate and maintain.

Low altitude aircraft typically fly below altitudes where supplemental oxygen or pressurization are needed (12,500 feet above sea level). They are good for acquiring high spatial resolution data limited to a relatively small area. Included in this class are the common fixed-wing, propeller driven planes used by private pilots, such as the Cessna 172 or 182, and Piper Cherokee. This class of aircraft is inexpensive to fly and can be found throughout the world. Some of these airplanes are specially outfitted for mounting remote sensing instruments in the underside of the plane; however, many times instruments are simply hung out the door using simple mounts.

Helicopters are usually used for low altitude applications where the ability to hover is required. Helicopters are quite expensive to operate and they are typically used only when needed. Ultralight aircraft are a class of aircraft that is gaining popularity. The Federal Aviation Authority (FAA) defines an ultralight as a single seat powered flying machine that weighs less than 254 pounds, has a top speed of 55 knots (63 mph), stalls at 24 knots (28 mph) or less and carries no more than 5 gal. of fuel. These small, often portable, aircraft are inexpensive and are able to take off and land where larger aircraft cannot. They are limited to flying at lower elevations and at slow speeds. If the demands of the remote sensing requirement are not too strict, ultralight aircraft may be a reasonable alternative to larger aircraft.

Midaltitude aircraft have an altitude limit under 30,000 feet above sea level. This includes a number of turbo-prop aircraft. Often at higher altitudes, there is less turbulence so stability is better. This class of airplane is used when stability is more important and when it is necessary or desired to acquire imagery from a greater distance than available from low altitude aircraft. These aircraft can obtain greater areal coverage more quickly than low altitude platforms.

High altitude aircraft can fly at altitudes greater than 30,000 feet above sea level. This class of airplane is usually powered by jet engines and is used for specialized tasks, such as atmospheric studies, research to simulate satellite platforms, and other applications where a high altitude platform is required. High altitude aircraft are good for acquiring large areal coverage with typically lower spatial resolutions.

Another class of aircraft that has been in use for many years is remote control aircraft, or drones. Remotely controlled aircraft are often used for conditions when it may be too hazardous to fly. They have been used extensively by the military.

Satellite -- The most stable platform aloft is a satellite, which is space borne. The first remote sensing satellite was launched in 1960 for meteorology purposes. Now, over a hundred remote sensing satellites have been launched and more are being launched every year. The Space Shuttle is a unique spacecraft that functions as a remote sensing satellite and can be reused for a number of missions.

Satellites can be classified by their orbital geometry and timing. Three orbits commonly used for remote sensing satellites are geostationary, equatorial and Sun synchronous. A geostationary satellite has a period of rotation equal to that of Earth (24 hours) so the satellite always stays over the same location on Earth. Communications and weather satellites often use geostationary orbits with many of them located over the equator. In an equatorial orbit, a satellite circles Earth at a low inclination (the angle between the orbital plane and the equatorial plane). The Space Shuttle uses an equatorial orbit with an inclination of 57 degrees.

Sun synchronous satellites have orbits with high inclination angles, passing nearly over the poles. Orbits are timed so that the satellite always passes over the equator at the same local sun time. In this way the satellites maintain the same relative position with the sun for all of its orbits. Many remote sensing satellites are Sun synchronous which ensures repeatable sun illumination conditions during specific seasons. Because a Sun synchronous orbit does not pass directly over the poles, it is not always possible to acquire data for the extreme Polar Regions. The frequency at which a satellite sensor can acquire data of the entire Earth depends on sensor and orbital characteristics. For most remote sensing satellites the total coverage frequency ranges from twice a day to once every 16 days.

Another orbital characteristic is altitude. The Space Shuttle has a low orbital altitude of 300 km whereas other common remote sensing satellites typically maintain higher orbits ranging from 600 to 1000 km.

Most remote sensing satellites have been designed to transmit data to ground receiving stations located throughout the world. To receive data directly from a satellite, the receiving station must have a line of sight to the satellite. If there are not sufficient designated receiving stations around the world, any given satellite may not readily get a direct view to a station, leading to potential problems of data discontinuity. To work around this problem, data can be temporarily stored onboard the satellite and then later downloaded upon acquiring contact with the receiving station. Another alternative is to relay data through TDRSS (Tracking and Data Relay Satellite System), a network of geosynchronous (geostationary) communications satellites deployed to relay data from satellites to ground stations.

The payload for remote sensing satellites can include photographic systems, electro-optical sensors, microwave or lidar systems. For applications benefiting from simultaneous coverage by different sensors, more than one sensing system can be mounted on a single satellite. In addition to sensor systems, there are often devices for recording, preprocessing and transmitting the data.

Fundamental Sensor Types

There are several broad categories of basic sensor system types such as passive vs. active, and imaging vs. nominating. Passive vs. active refers to the illumination source of the system; imaging vs. nominating refers to the form of the data. A variety of different sensors fit in these categories, which are not mutually exclusive.

Passive vs. active sensors -- Passive sensors measure light reflected or emitted naturally from surfaces and objects. Such instruments merely observe, and depend primarily on solar energy as the ultimate radiation source illuminating surfaces and objects. Active sensors (such as radar and lidar systems) first emit energy (supplied by their own energy source) and then measure the return of that energy after it has interacted with a surface. Use of data collected by passive sensors often requires accurate measurements of solar radiation reaching the surface at the time the observations were made. This information allows for the correction of "atmospheric effects" and results in data or images that are more representative of actual surface characteristics.

***Imaging vs. nominating sensors* --** Remote sensing data are the recorded representation of radiation reflected or emitted from an area or object. When measuring the reflected or emitted energy, either imaging or nominating sensors can be used. Data from imaging sensors can be processed to produce an image of an area, within which smaller parts of the sensor's whole view are resolved visually (see discussion of pixels below). Nonimaging sensors usually are hand held devices that register only a single response value, with no finer resolution than the whole area viewed by the sensor, and therefore no image can be made from the data. These single values can be referred to as a type of "point" data; however some small area is typically involved depending on the sensor's spatial resolution.

Image and nominate data each have particular uses. Nonimage data give information for one specific (usually small) area or surface cover type, and can be used to characterize the reflectance of various materials occurring in a larger scene and to learn more about the interactions of electromagnetic energy and objects. Image data provide an opportunity to look at spatial relationships, object shapes, and to estimate physical sizes based on the data's spatial resolution and sampling. Image data are desirable when spatial information (such as mapped output) is needed. This text refers primarily to imaging sensors and data.

Images produced from remote sensing data can be either analog (such as a photograph) or digital (a multidimensional array or grid of numbers). Digital data can be analyzed by studying the values using calculations performed on a computer, or processed to produce an image for visual interpretation. Image interpretation is used to decipher information in a scene. In the past, image interpretation was done largely using subjective visual techniques, but with the development and ongoing advancement of computer technology, numeric or digital processing has become a powerful and common interpretation tool.

In many cases, image interpretation involves the combination of both visual and digital techniques. These techniques utilize a number of image features including tone and color, texture, shape, size, patterns, and associations of objects. The human eye and brain are generally thought to more easily process the spatial characteristics of an image, such as shape, patterns and how objects are associated with one another. Computers usually are better suited for rapid analysis of the spectral elements of an image such as tone and color. Sophisticated computer software that can perform like the human eye and brain may be more commonly available in the future.

Passive Sensors

Passive sensors are the most common sensor type for vegetation related remote sensing. This is not only because passive sensor systems are generally simpler in design (built only to receive energy) but also because portions of the solar spectrum provide very useful information for monitoring plant and canopy properties.

A major limitation of passive systems is that in most cases they require sunlight in order for valid and useful data to be acquired. Consequently, deployment of or data acquisition by passive sensors is very dependent on lighting (time of day, time of year, latitude) and weather conditions, since cloud cover can interfere with the path of solar radiation from the sun to the surface and then to the sensor.

The signals detected by passive sensors can be greatly altered due to atmospheric effects, especially in the shorter wavelengths of the solar spectrum that are strongly scattered by the atmosphere. These effects can be minimized (but not eliminated) by collecting data only under very clear and dry atmospheric conditions. Sophisticated atmospheric correction routines now exist to remove atmospheric effects from data acquired by passive sensors.

Photographic -- The most common sensor system is the photographic camera -- a simple passive sensor. Many of the historic developments in remote sensing were directly related to the development of photographic systems. Camera systems are similar in design to the human eye. Both have a lens at one end of an enclosed chamber and a light-sensitive material (film for a camera and the retina for an eye) at the other. In both systems, an iris is used to control the amount of light that can strike the film/retina. In a camera, a shutter is placed between the lens and film to control how long the light can strike the film. Filters can be attached in front of a lens to restrict the wavelength of light permitted to strike the film.

There are three basic elements of photographic systems -- optics, film, and filters. Optics refer to lenses and the geometry of light retrieval in a camera. The lenses in a camera are responsible for focusing and zooming on an object. Before light reflected from an object strikes the film, it must pass through one or more lenses. As light passes through a lens, it is bent to focus the imaged object on the film. To minimize distortions associated with the use of single lenses, most camera lenses are actually composed of multiple lenses that work in concert to form an image onto the film.

The amount of image detail that can be recorded on film is directly related to the distance between the lens and the film, referred to as the focal length. As the focal length increases, the detail that can be seen on the film increases. Increasing the focal length is commonly called zooming in on an object.

Film in a camera is used to record the image that passes through the lens. Photographic film is composed of a durable base, which is coated with a light-sensitive layer know as the emulsion. During the short time that a shutter is open, light strikes the film and leaves a latent image on the emulsion. This image can be made visible by the process of developing and printing.

Emulsions are made of materials sensitive to particular regions of the electromagnetic spectrum. For example, some film is only sensitive to visible light, whereas other film is sensitive to near-infrared light. In color film, the emulsion is composed of three layers, with each being sensitive to different wavelengths of light, normally blue, green and red light. With black and white film, the emulsion is sensitive to a broad spectrum of light. Film emulsions are generally limited to recording wavelengths between 0.4 to 0.9 micrometers. one exposed using natural color film and the other using color infrared film (a different type of film). Black and white film sensitive to visible light and black and white film sensitive to infrared wavelengths can also be used for remote sensing purposes.

Film speed is another quality of emulsions that is important for aerial photography. Film speed refers to the quantity of light than is needed to expose the emulsion. Fast film requires less light than slow film to record the same image. If the camera platform is moving, one would want to use a high speed film to reduce the blurring effects of the moving camera. Unfortunately, there is a tradeoff between film speed and image quality -- the faster the film speed, the grainier the image. Because of this tradeoff, it is necessary to carefully choose a film speed that will meet the requirements of the end user. Some sophisticated camera mounts have an image motion compensator that reduces the blurring effect of the moving platform, which potentially allows the use of slower film.

In many remote sensing applications, it is important to restrict the light entering the camera by the use of filters. Color filters work by absorbing a range of wavelengths while allowing other wavelengths to pass through. Another filter type, known as neutral color filters, do not alter the spectral composition of light, but instead reduce the amount of light of all wavelengths that pass through.

Perhaps the most common color filter is an antihaze filter. These are clear or yellow filters, which absorb out the shorter ultraviolet and blue wavelengths that are substantially scattered by particulates in the atmosphere. Another filter used for monitoring vegetation is an infrared filter, which absorbs visible light and only allows infrared light to pass through.

Aerial photography is one of the oldest forms of remote sensing and it is still used extensively today. It is usually the choice if great spatial detail is needed. For example, photography can be used to identify individual tree species (based on the shape of individual trees) and measure tree heights using special photographic techniques. Because of the detail that can be discerned on a photograph, aerial photography is used extensively for mapping vegetation classes.

Aerial photography is also used as a reconnaissance tool to provide overview information for a particular area. For instance, if there has been an outbreak of a disease that is killing a certain tree or agricultural species, aerial photography using infrared film (to locate trees that are being stressed) can monitor areas for signs and extent of the disease.

Electro-optic radiometers -- A radiometer is an instrument designed to measure the intensity of electromagnetic radiation in a set of wavebands ranging from the ultraviolet to microwave wavelengths. Microwave radiometers are discussed in Section 3.3.3. The radiometers discussed here are called electro-optic sensors because they measure electromagnetic energy using optical techniques and electronic detectors. Though they are only capable of recording a single data value for their view area, if they are mounted in a scanner device images can be produced. Imaging systems are described in Section 3.3.4.

Radiometers are similar in design to a camera in that they have an opening for the light to enter, lenses and mirrors for the light to pass through, but instead of film, they have an electronic detector to record the intensity of electromagnetic energy. As energy hits the detector, a signal proportional to the incoming irradiance is processed to either a digital or analog output that can be recorded.

Detectors for radiometers have been devised to measure wavelengths from 0.4 to 14 micrometers. Although some radiometers can detect this entire range of wavelengths, most only measure selected wavebands in this range. Radiometers that measure more than one waveband are called multispectral radiometers. For this type of radiometer, the light must be separated into discrete wavebands so that multiple waveband or multichannel readings can be taken. This separation can be done using filters, prisms or other sophisticated techniques.

Nonimaging radiometers are commonly used as research tools to better understand how light interacts with objects, for spectral characterization of a variety of surfaces, and for atmospheric measurements. Another common use is to measure the quantity and quality of solar energy. These measurements can in turn be used to correct other imaging and nominating measurements for atmospheric effects.

Passive microwave systems -- Passive microwave systems are based on a type of radiometer that detects wavelengths in the microwave region of the spectrum. Because of the nature of microwave radiation, optical systems cannot be used for the detection of this range of wavelengths. As with optical systems though, both nominating and imaging systems are available. The components of a microwave radiometer are an antenna, receiver, and recording device. Microwave energy emitted from Earth's surface is collected by an antenna, converted by a receiver into a signal, and recorded.

The features of electromagnetic energy measured by microwave radiometers are polarity, wavelength, and intensity. These properties provide useful information about the structure and composition of an object. Most of the applications of passive microwave radiometers have been in the fields of atmospheric and oceanographic research. It has also proven to be an effective tool for the measurement of soil moisture, an important parameter in studying vegetation.

Visible, infrared, and thermal imaging systems -- By combining a number of detectors or radiometers into detector arrays, it is possible to create a sensor that can acquire a 2D image of an area. There are three basic designs for imaging sensors: frame, push broom, and mechanical scanner.

The first two designs are similar. The frame sensor is a 2D array of detectors that acquires an entire image in one exposure similar to the way a camera captures an image on film. A pushbroom sensor is a 1D array that obtains an image one line at a time. Each new data line is added as the platform moves forward, building up an image over time. In a mechanical scanner system the sensor acquires only one or several pixels in any given instant, but since the scanner physically sweeps or rotates the sensor (a radiometer) or a mirror back and forth, an image is produced.

This category of sensor (passive visible, infrared and thermal imaging systems) contains numerous instruments that have been deployed on a wide variety of platforms and used for many applications. Most modern imaging systems are multispectral (acquiring data for more than one limited spectral area). The recording of each discrete spectral sampling is referred to as an image band or channel. Using image processing techniques, multiple (usually three) bands selected from a multispectral image database can be combined to make a single color composite image.

Active Sensors

Active systems supply their own illumination energy which can be controlled. Some advantages active systems have over passive sensors are they do not require solar illumination of surfaces or perfect weather conditions to collect useful data. Consequently they can be deployed at night or in conditions of haze, clouds, or light rain (depending on the wavelength of the system).

Radar (active microwave) -- Radar (radio detection and ranging) systems use microwaves (wavelengths ranging from 1 millimeter to 1 meter). Microwave pulses are transmitted at a target or surface, and the timing and intensity of the return signal is recorded.

Transmission characteristics of radar depend on the wavelength and polarization of the energy pulse. Common wavelength bands used in pulse transmission are K-band (11-16.7 mm), X-band (24-37.5 mm), and L-band (150-300 mm). The use of letter codes to designate the wavelength range for various radar systems originated when radar was being developed during World War II. The random letter designations were assigned arbitrarily to ensure military security, however their use has persisted. Distinct from wavelength is the polarization of the transmitted energy. Pulses can be transmitted or received in either an H (horizontal) or V (vertical) plane of polarization.

Factors determining the strength of a radar return signal are complex and varied, however the most important are geometric and electrical properties of the surface or object that reflects the signal (see Chapter 4 Section 2.3.1 for more discussion about radar). Information about the structure and composition of objects and surfaces can be detected with radar. Radar has been used in a number of fields, including geology, snow and ice studies, oceanography, agriculture, and vegetation studies. Radar has been especially useful in areas with nearly constant cloud cover.

Lidar (active optical) -- Lidar (light detecting and ranging) systems use laser light as an illumination source. A short pulse of light is emitted from a laser and a detector receives the light energy (photons) after it has been reflected, or absorbed and remitted, by an object or surface. Lidar systems emit pulses at specific, narrow wavelengths that depend on the type of laser transmitter used. The possible wavelengths range from about 0.3 to 1.5 micrometers, which covers the ultraviolet through near-infrared spectral range. The simplest lidar systems measure the round trip travel time of a laser pulse, which is directly related to the distance between the sensor and the target. Basic distance measuring lidars are often referred to as rangefinders or as laser altimeters if deployed on an aircraft or spacecraft. These systems typically measure elevation, slope, and roughness of land, ice, or water surfaces.

More advanced lidars measure the received intensity of the backscattered light as a function of travel time. The intensity of the signal provides information about the material that reflected the photons. Such backscatter lidar systems are often used for atmospheric monitoring applications concerned with the detection and characterization of various gases, aerosols and particulates. Lidar methods have recently been adapted to measure tree heights and the vertical distribution of canopy layers with great accuracy and precision (See Figure 4.03 in Chapter 4, Section 2.4.1). Lidar instruments have flown on the Space Shuttle, and Vegetation Canopy Lidar (VCL) and Ice, Cloud, and land Elevation Satellite (ICESat) lidar missions are planned for the near future.

Lidar systems can also make fluorescence measurements. Fluorescence refers to the process where a material absorbs radiant energy at one wavelength and then emits it at a different wavelength without first converting the absorbed energy into thermal energy. The wavelengths at which absorption and emission occur are specific to particular molecules. Fluorescence data can identify and quantify the amount of plankton and pollutants in the marine environment. Leaf fluorescence can also help to identify plant species.