Paper name: Principles and Applications of Remote Sensing, GIS and GPS

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Topic: Concept and Development of GIS

1.1 Introduction

> *"Remote sensing is the science (and to some extent, art) of acquiring information about the Earth's surface without actually being in contact with it. This is done by sensing and recording reflected or emitted energy and processing, analyzing, and applying that information".*
>
> *(Source: CCRS Tutorial "Fundamentals of remote sensing")*

Remote sensing (RS), also called earth observation, refers to obtaining information about objects or areas at the Earth's surface by using electromagnetic radiation (light) without being in direct contact with the object or area. So, remote sensing is day to day business for people. Reading the newspaper, watching cars driving in front of you, looking at a lecturer during a course are all remote sensing activities. The human eyes register the solar light reflected by these objects and your brains interpret the colours, the grey tones and intensity variations. Next, these data are translated into useful information. The human eye, however, is limited to a small part of the total electromagnetic spectrum i.e. approximately 400 to 700 nm. In remote sensing various kinds of tools and devices are used to make electromagnetic radiation outside this range from 400 to 700 nm visible to the human eye, especially the near-infrared, middle-infrared, thermal-infrared and microwaves. Increasingly, remote sensing is used to acquire information about environmental processes such as agricultural crop growth, land cover changes, deforestation, vegetation dynamics, water quality dynamics, urban growth, etc. In this chapter we provide a brief historic sketch and summarise the basic concepts of remote sensing.

1.2 Concepts of remote sensing

Remote sensing (RS) refers in a general sense to the instrumentation, techniques and methods used to observe (sense) the surface of the Earth, usually by the formation of an image in a position – stationary or mobile – at a distance remote from that surface (after Buiten & Clevers, 1993). In remote sensing electromagnetic (EM) radiation coming from an object (in case of earth observation: the Earth's surface) is being measured and translated into information about the object or information on processes related to the object. In the measurement phase the following components are relevant:

a. the source of the EM radiation;
b. the path through the atmosphere;
c. the interaction with the object;
d. the recording of the radiation by a sensor.

These comprise the remote sensing system as illustrated in Figure 1.1.

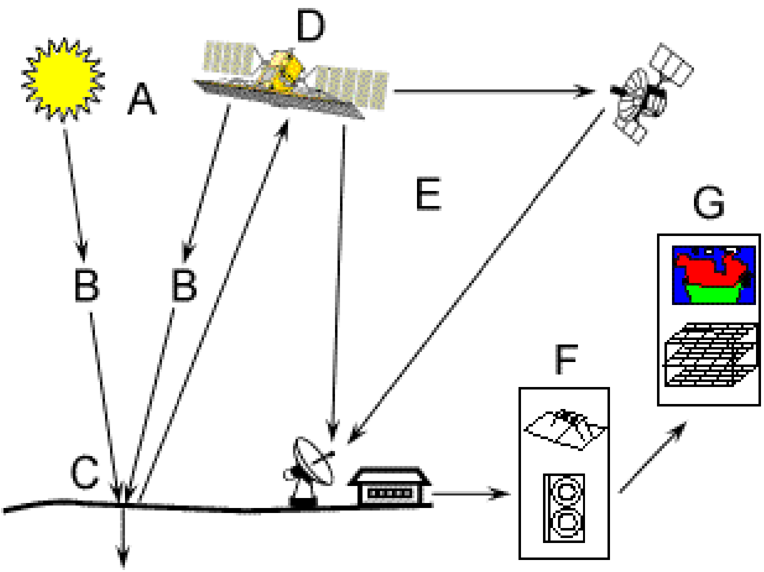

Figure 1.1: The remote sensing system (see text for explanation of letters).

The second phase can be considered to cover the following components:

e. transmission, reception end (pre)processing of the recorded radiation;
f. interpretation and analysis of the remote sensing data (mostly using a computer);
g. creation of the final product, which is mostly stored as a GIS layer.

1.3 Historic overview

In 1859 Gaspard Tournachon took an oblique photograph of a small village near Paris from a balloon. With this picture the era of earth observation and remote sensing had started. His example was soon followed by other people all over the world. During the Civil War in the United States aerial photography from balloons played an important role to reveal the defence positions in Virginia. Likewise other scientific and technical developments this Civil War time in the United States speeded up the development of photography, lenses and applied airborne use of this technology. Although the space era of remote sensing was still far away after the Civil War, already in 1891 patents were granted in Germany to successful designs of rockets with imaging systems under the title: 'new or improved apparatus for obtaining bird's eye photographic views of the Earth'. The design comprised a rocket propelled camera system that was recovered by a parachute. Table 1.1 shows a few important dates in the development of remote sensing.

The next period of fast development took place in Europe and not in the United States. It was during World War I that aeroplanes were used on a large scale for photo reconnaissance. Aircraft proved to be more reliable and more stable platforms for Earth observation than balloons. In the period between World War I and World War II a start was made with the civil use of aerial photos. Application fields of airborne photos included at that time geology, forestry, agriculture and cartography. These developments lead to much improved cameras, films and interpretation equipment. The most important developments of aerial photography and photo interpretation took place during World War II. During this time span the development of other imaging systems such as near-infrared photography, thermal sensing and radar took place. Near-infrared photography and thermal-infrared proved very valuable to separate real vegetation from camouflage. The first successful airborne imaging radar was not used for civilian purposes but proved valuable for nighttime bombing. As such the system was called by the military 'plan position indicator' and was developed in Great Britain in 1941.

Table 1.1: Milestones in the History of Remote Sensing

1800	Discovery of Infrared by Sir W. Herschel
1839	Beginning of Practice of Photography
1847	Infrared Spectrum Shown by J.B.L. Foucault
1859	Photography from balloons
1873	Theory of Electromagnetic Spectrum by J.C. Maxwell
1909	Photography from Airplanes
1916	World War I: Aerial Reconnaissance
1935	Development of Radar in Germany
1940	WW II: Applications of Non-Visible Part of the electromagnetic spectrum
1950-	Military Research and Development
1959	First Space Photograph of the Earth (Explorer-6)
1960	First TIROS Meteorological Satellite Launched
1970	Skylab Remote Sensing Observations from Space
1972La	nch Landsat-1 (ERTS-1): MSS sensor
1972-	Rapid Advances in Digital Image Processing
1982	Launch of Landsat-4: New Generation of Landsat Sensors: TM
1986	French Commercial Earth Observation Satellite SPOT
1986	Development Hyperspectral Sensors
1990-	Development High Resolution Spaceborne Systems First Commercial Developments in Remote Sensing
1991	Launch of the first radar satellite ERS-1 by ESA
1992	Launch of radar satellite JERS-1 by Japan
1995	Launch of Radarsat by Canada
1995	Launch of ERS-2 by ESA
1999	Launch EOS: NASA Earth Observing Mission ‘Terra’ with MODIS and ASTER
1999	Launch of IKONOS, very high spatial resolution sensor system
2001	Launch of QuickBird, very high spatial resolution sensor system
2002	Launch of ‘Aqua’ with MODIS by NASA
2002	Launch of Envisat-1 with optical and radar instruments by ESA
2008	Launch of GeoEye
2009	Launch of WorldView-2 by DigitalGlobe
2013	Launch of Landsat-8 by NASA/USGS
2015	Launch of Sentinel-1 by ESA
2016	Launch of Sentinel-2 by ESA
2016	Launch of Sentinel-3 by ESA

After the wars in the 1950s remote sensing systems continued to evolve from the systems developed for the war effort. Colour infrared photography (CIR) was found to be of great use for the plant sciences. In 1956 experiments were conducted by Colwell on the use of CIR for the classification and recognition of vegetation types and the detection of diseased and damaged or stressed vegetation. It was also in the 1950s that significant progress in radar technology was achieved. Two types of radar were developed at that time: SLAR: side-looking airborne radar, and SAR: Synthetic Aperture Radar. Either development aimed at the acquisition of images at the highest possible resolution. Crucial to the SAR development was the ability to finely resolve the Doppler frequencies using a frequency analyses algorithm on the returning radar signal by the US Air Force research centre.

1.4 The space era

In the early 1960s the US started placing remote sensors in space for earth observations.

TIROS (Television Infrared Observation Satellite) was the first meteorological satellite. A long series of meteorological satellites followed this one. 1960 was also the beginning of a famous US military space imaging reconnaissance program called Corona. Unfortunately, much of this programme remained classified until 1995. In 1970 the TIROS programme was financed by and renamed into NOAA (National Oceanic and Atmospheric Administration). Until today the NOAA Advanced Very High Resolution Radiometer (AVHRR) is orbiting the globe and collecting information on weather patterns in visible, near-infrared and thermal wavelengths. NOAA-19 was launched on 6 February 2009. It may also be used for other (monitoring) applications. The 1950s and 1960s were also important for the organisational development of remote sensing. Various civil research organisations and universities became highly interested in these new technologies. Today remote sensing is not only taught at the university level but also at high schools.

In the early 70s the first satellite specifically designed to collect data of the Earth's surface and its resources was developed and launched: ERTS-1 Earth Resources Technology Satellite (later in 1975 this programme was renamed into Landsat). This first earth resources satellite was in fact a modified Nimbus weather satellite carrying two types of sensors: a four waveband multi-spectral scanner (MSS) and three return beam vidicon television cameras (RBV). The sensors aboard this satellite proved to be able to collect high quality images with a reasonable detail. These images gave remote sensing a world-wide recognition as a valuable technology. The main advantages recognized at that time were: ready availability of images for most of the world, lack of political, security and copyright restrictions, low cost, repetitive multi-spectral coverage and minimal image distortion.

Landsat 2 and 3 were launched in 1975 and 1978, respectively, and carried the same payload as the first satellite of this series. The payload was changed in 1982 with Landsat 4. The RBV was replaced by the technically more advanced Thematic Mapper (TM) sensor. An improved design of the TM, the ETM+ (Enhanced Thematic Mapper) was mounted aboard Landsat 7 and launched in 1999. The Landsat series is a very successful programme, various MSS and TM sensors exceeded by far its design life time and its imagery is probably the most widely used data in the Earth sciences. One black spot on its history record is the 'failure upon launch' of Landsat 6 in 1993.

Finally, on 11 February 2013 the Landsat programme was continued with the launch of Landsat 8. Originally called the Landsat Data Continuity Mission, it has a two-sensor payload, the Operational Land Imager (OLI) and the Thermal InfraRed Sensor (TIRS). Respectively, these two instruments collect image data for nine shortwave bands and two longwave thermal bands.

The Landsat programme was followed by various other successful earth observation missions carried out by other countries. In 1978, the French government decided to develop their own earth observation programme. This programme resulted in the launch of the first SPOT satellite in 1986. To the original SPOT design of three spectral bands a new sensor called Vegetation was added aboard SPOT-4 in 1998. In 2002 SPOT-5 has been launched. Spatial resolution was increased to either 2.5 or 5 m panchromatic imagery, 10 m in the visible and near-infrared and 20 m in the middle-infrared. SPOT-6 (launched 9 September 2012) and SPOT-7 (launched 30 June 2014) have 4 multispectral bands at 6 m and a panchromatic band at 1.5 m.

Other earth observation missions are the Indian Remote Sensing Programme (IRS) that started in 1988, the Russian Resurs series, first launched in 1985, and the Japanese ADEOS (Advanced Earth Observing Satellite) put in orbit in 1996. The European Space Agency

(ESA) launched its first remote sensing satellite (ERS-1) in the year 1991. ERS carries various types of sensors aboard among which the AMI, a C-band (5 cm radar) active microwave instrument. The main focus of the ERS programme is oceanographic applications although it is also widely used for monitoring tropical forests. In 1995, ERS-2 was successfully launched. In March 2002, ESA launched Envisat-1, an earth observation satellite with an impressive payload of 10 instruments such as a synthetic aperture radar (ASAR) and a Medium Resolution Imaging Spectrometer (MERIS). More recently, ESA moved to more operational missions within the Copernicus programme, called the Sentinels. Sentinel-1A was launched on 3 April 2014 as a radar mission and is considered a continuation on the ASAR sensor on Envisat. Sentinel-2A is an optical mission launched on 23 June 2015 as a continuation of the Landsat programme. Its Multi Spectral Instrument (MSI) covers the VNIR/SWIR spectral region in 13 bands and incorporates two new spectral bands in the red-edge region. It carries 4 bands at 10 m, 6 bands at 20 m and 3 bands at 60 m (the latter for atmospheric corrections). Finally, Sentinel-3A, launched 16 February 2016, is a continuation of the MERIS sensor on Envisat.

An important development has been the launch of Ikonos in 1999. Ikonos has a multispectral system collecting information in 4 bands (blue, green, red and near-infrared) at a spatial resolution of 4 m. Ikonos has also a panchromatic mode (0.45-0.90 μm) with a spatial resolution of 1 m. In 2001, QuickBird was launched with similar bands as Ikonos, but with a spatial resolution of 2.44 m and 0.61 m, respectively. OrbView-3, launched in 2003, is very similar to Ikonos. GeoEye, launched in 2008, operates even at spatial resolutions of 1.64 m and 0.41 m, respectively. In 2009 WorldView-2 has been launched, having an increased number of spectral bands: 8 multispectral bands at 1.8 m and a panchromatic band at 0.46 m. WorldView-3 (launched on 13 August 2014) and WorldView-4 (launched on 11 November 2016) have multispectral bands at 1.24 m and a panchromatic band at 0.31 m. With these commercial systems, spaceborne remote sensing approaches the quality of airborne imaging.

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