PRINCIPLES OF REMOTE SENSING


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"It is the science of deriving information about an object without actually coming in contact with it."
Remote sensing as a technology can be said to have started with the appearance of the first photographs.

The so-called aerial photo - emerged in the 1840s with pictures taken from balloons.

By the First World War, cameras mounted on airplanes provided aerial views of fairly large surface areas that proved invaluable in military reconnaissance.

From then until the early 1960s, the aerial photograph remained the single standard tool for depicting the earth surface.
The mission to the Moon needed maps of the lunar surface, especially of the proposed landing sites. These were prepared using remote sensing techniques.

The first multispectral photography done from space was on the famous 1968 Apollo 9 manned mission. Four Hasselblad cameras were mounted in a holder such that they all aimed at the same target point when their shutters were triggered simultaneously.

Images from the Apollo 9 multispectral four-lens camera were digitized and used to develop techniques for processing Landsat data, which, in 1969, was still four years away.
In July 23, 1972 NASA launched the first Earth Resources Technology Satellite (ERTS-1). The multispectral data provided by the on-board sensors led to an improved understanding of crops, minerals, soils, urban growth, and many other Earth features and processes. The name of the satellite, and those that followed, was soon changed to Landsat. Landsat has provided more data about the Earth than can ever be analyzed.

<table>
<thead>
<tr>
<th>Camera Type</th>
<th>Spectral Bands</th>
</tr>
</thead>
<tbody>
<tr>
<td>Return Beam Vidicon camera (RBV)</td>
<td>B,G,R</td>
</tr>
<tr>
<td>Multispectral Scanner (MSS)</td>
<td>G,R, 2 NIR</td>
</tr>
<tr>
<td>Thematic Mapper (TM)</td>
<td>B,G,R, NIR, 2 MIR, FIR</td>
</tr>
<tr>
<td>Enhanced Thematic Mapper (TM)</td>
<td>B,G,R, NIR, 2 MIR, FIR, PAN</td>
</tr>
<tr>
<td>Operational Land Imager (OLI)</td>
<td>2B,G,R, NIR, 3MIR, PAN</td>
</tr>
</tbody>
</table>
MILESTONE IN THE HISTORY OF REMOTE SENSING

Balloons  →  Pigeons  →  Airplanes  →  Satellites
OVERVIEW OF REMOTE SENSING PROCESS

PHYSICAL OBJECTS

SENSOR DATA

EXTRACTED INFORMATION

APPLICATIONS

LAND USE

HYDROLOGY

VEGETATION

GEOLOGY

SOILS
The quantity most frequently measured by current remote sensors is the electromagnetic energy emanating from the object of interest.
ELECTROMAGNETIC SPECTRUM

Wavelength (nm)

Gamma Ray  X-Ray  UV Visible  Infrared  Microwave (Radar)  Radio

0.03  300  400  700  $10^6$ (1 mm)  $3 \times 10^8$ (30 cm)

Blue  Green  Red

400  500  600  700
REFLECTION OF COLORS
RELECTION OF COLORS

Sun

Visible spectrum

White light

Reflected part

Eye
DETECTING THE REMOTE SIGNAL
SPECTRAL DIFFERENTIATION - Remote sensing depends upon observed differences in the energy reflected or emitted from features of interest.

Spectral Resolution: This refers to the number of bands in the spectrum in which the instrument can take measurements.

- Human Eye = 3 channels (RGB) + 1 Pan
- Landsat TM = 7 channels
- SeaWiFS = 8 channels
- AVIRIS = 224 channels
SPECTRAL DIFFERENTIATION

Green  Red  Near-infrared
Mid-infrared  True Color  False Color
RADIOMETRIC DIFFERENTIATION - Examination of any image acquired by remote sensing ultimately depends upon detection of differences in the brightness of objects and the features.

Radiometric Resolution: This is the sensitivity to small differences in the radiation of an observed object.

- Landsat TM = 8 bit
- MODIS = 12 bit
- ERS SAR = 16 bit
SAME SCENE WITH TWO DIFFERENT RADIOMETRIC RESOLUTIONS
SPATIAL DIFFERENTIATION - Every sensor is limited in respect to the size of the smallest area that can be separately recorded as an entity on an image.

Spatial Resolution: This represents the ability of the sensor to detect and distinguish small objects and fine detail in larger objects. Depends on the instrument's sensitivity and distance from the object, and defines the pixel size of a digital image.

- IKONOS = 1 m
- Landsat TM = 30 m
- AVHRR = 1 Km
- Meteosat = 7 Km
DIGITAL CAMERAS AND MEGAPIXELS (10^6=MILLION OF PIXELS)
# Digital Cameras and Megapixels

<table>
<thead>
<tr>
<th>Megapixels</th>
<th>Resolución</th>
<th>Tamaño Impreso</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 MP</td>
<td>1600x1200px</td>
<td>20x15 cm.</td>
</tr>
<tr>
<td>3.1 MP</td>
<td>2048x1536px</td>
<td>26x19 cm.</td>
</tr>
<tr>
<td>4.1 MP</td>
<td>2272x1704px</td>
<td>28x21 cm.</td>
</tr>
<tr>
<td>5 MP</td>
<td>2592x1944px</td>
<td>32x24 cm.</td>
</tr>
<tr>
<td>6.3 MP</td>
<td>3072x2048px</td>
<td>39x26 cm.</td>
</tr>
<tr>
<td>7.1 MP</td>
<td>3072x2304px</td>
<td>39x29 cm.</td>
</tr>
<tr>
<td>8.2 MP</td>
<td>3264x2248px</td>
<td>41x28 cm.</td>
</tr>
<tr>
<td>9.1 MP</td>
<td>3456x2592px</td>
<td>43x32 cm.</td>
</tr>
<tr>
<td>10.1 MP</td>
<td>3648x2736px</td>
<td>46x34 cm.</td>
</tr>
<tr>
<td>11.1 MP</td>
<td>4080x2720px</td>
<td>51x34 cm.</td>
</tr>
<tr>
<td>12.1 MP</td>
<td>4000x3000px</td>
<td>50x38 cm.</td>
</tr>
</tbody>
</table>

- Resolución 200ppi - apto para impresión de fotografías.
- Para impresiones profesionales para imprenta (tipografía, serigrafía), se necesitan 300 ppp.
SAME SCENE-DIFFERENT PIXEL SIZE

Satellite
Pour l'Oberservation de la Terre

SPOT
20 m

Compact Airborne Spectrographic Imager

CASl
5 m
SAME SCENE-DIFFERENT PIXEL SIZE

Compact Airborne Spectrographic Imager

CASI
5 m

IKONOS
1 m
TEMPORAL RESOLUTION (TR) – it refers to the precision of a measurement with respect to time. Represents the frequency with which a sensor can re-visit an area of interest and acquire a new image. Depends on the instrument's field of vision, and the platform (ex. Satellite) movement.

- IKONOS = 3-5 days off-nadir / 144 days for true-nadir
- Landsat TM = 16 days
- AVHRR = ascending+descending coverage = ~6 hours
- GOES = ~15 minutes
GEOMETRIC TRANSFORMATION - Every remotely sensed image represents a landscape in a specific geometric relationship determined by the design of the remote sensing instrument, specific operating conditions, terrain relief, and other factors.

Each image includes positional errors caused by the perspective of the sensor optics, the motion of scanning optics, terrain relief, and Earth curvature.
INTERCHANGEABILITY OF PICTORIAL AND DIGITAL FORMATS - Most remote sensing systems generate photograph-like images of the Earth's surface. Any such image can be represented in digital form by systematically subdividing the image into tiny areas of equal size and shape, then representing the brightness of these areas by discrete values.
Image formation

U.V.  Visible  Infrared

\begin{align*}
\text{\textmu m} & \quad 0.4 & 0.45 & 0.5 & 0.55 & 0.6 & 0.65 & 0.7 & 3 & 6 & 20 \\
\text{Bands} & \quad 1 & 2 & 3 & 4 & 5 & 7 & 6 \\
\text{LANDSAT} & & & & & & & & \text{near} & \text{mid} & \text{thermal} \\
\text{TM} & & & & & & & & & & & \\
\end{align*}

\text{Display channels} \\
\text{Colour composite}

\begin{align*}
\text{B, G, R} & \quad 1, 2, 3 \\
& \text{Natural colours} \\
\text{B, G, R} & \quad 2, 3, 4 \\
& \text{Conventional false-colour} \\
\text{B, G, R} & \quad 1, 4, 7 \\
& \text{Optimised false-colour} \\
\end{align*}
The image analyst must always be conscious of the fact that the many components of the remote sensing process cannot be isolated from one another. This means that the interpreter must know the remote sensing system and the subject of the interpretation.
Acquisition and reproduction of remotely sensed images

Element of an image
pixel
(x, y, value)

Where?
Pixel coordinates

What?
Grey shades or colour

How much?
Sensitivity

Direction of motion
Satellite
Transmission to ground-station
Sensor
Scanning
Scene
Resolution cell

\[ R(\lambda) \]

E.L.
Orbiting eye

Remote Sensing techniques

Vision + Experience

Digital camera
Scanners
Radar

Global view
Detailed view
Data base
Archive

Computer + Expert

monitoring
real-time analysis

analysis of archived
data, change detection

thematic maps tables

decisions
ROLE OF THE ATMOSPHERE - All energy reaching the remote sensing instrument must pass through a portion of the Earth's atmosphere. The Sun's energy is altered in intensity and wavelength by particles and gases in the Earth's atmosphere. These changes appear on the image in ways that degrade image quality or influence the accuracy of interpretation.

90% of the signal in a satellite image is coming from the atmosphere.
IN SUMMARY...

THE KEY CONCEPTS OF REMOTE SENSING ARE:

1. Spectral Differentiation
2. Radiometric Differentiation
3. Spatial Differentiation
4. Geometric Transformation
5. Interchangeability of Pictorial to Digital Formats
7. Role of the Atmosphere
1. SPECTRAL RESOLUTION: This refers to the number of bands in the spectrum in which the instrument can take measurements.
   
   Landsat TM = 7 channels

2. RADIOMETRIC RESOLUTION: This is the sensitivity to small differences in the radiation of an observed object.

   Landsat TM = 8 bit

3. SPATIAL RESOLUTION: This represents the ability of the sensor to detect and distinguish small objects and fine detail in larger objects. Depends on the instrument's sensitivity and distance from the object, and defines the pixel size of a digital image.

   Landsat TM = 30m

4. TEMPORAL RESOLUTION: Represents the frequency with which a sensor can re-visit an area of interest and acquire a new image. Depends on the instrument's field of vision, and the platform (ex. Satellite) movement.

   Landsat TM 16 days
Watch the YouTube video called “What is Remote Sensing”