REMOTE SENSING
SENSORS

Lecture 6
RS Sensors

- **RS sensors** are instruments that measure the properties of EM radiation leaving a surface/medium due to scattering or emission.

- Generally, radiance is the property measured as a function of wavelength but could also include other parameters such as polarization.
Active and Passive sensors

The technology of developing sensors throughout the EM spectrum is not the same.

Technology for developing microwave sensors is quite different from that of optical-Infrared (OIR) sensors.
Figure 2.1.1 Classification of Sensor
RS Sensors

- Understand the basic design characteristics of the sensors and the various trade-offs that determine whether a sensor will be suitable for a given application.

- U.S. Landsat and French SPOT satellite systems were the first and most robust global monitoring systems to acquire moderate resolution data systematically.
Classification of sensors is evaluated based on its classification as well as its mapping accuracy requirements.

Reasonable assumption:
- Instruments ability to detect small differences in the emittance/reflectance of the earth’s surface in number of spectral bands for as small an object as possible and as often as possible.
What is the optimum set of specifications for remote sensing sensors?

Even if we identify an ideal set of parameters, the realization of a combination of these parametric values (i.e., Spatial resolution, Number of spectral bands, spectral bandwidth, signal-to-noise ration, etc.) is a complex problem due to strong correlation among these parameters.
RS Sensors Characteristics

- Sensors parameter under 4 domains:
  - 1. Spatial
  - 2. Spectral
  - 3. Radiometric
  - 4. Temporal
**Spatial Resolution**

- Measure of the sensor ability to image closely spaced objects so that they are distinguishable as separate objects.

- The theoretical limit of resolving two objects by an imaging system (Lens) is due to diffraction of the EM wave.

- Without any lens aberration (not possible!) one expects the lens to image a point object as a point in the image plane.
The image of a point will consist of a bright disc surrounded by concentric bright and dark rings called Airy patterns.

\[ D = \text{Aperture of the lens} \]
\[ f = \text{Focal length} \]
\[ \lambda = \text{Wavelength} \]

The distribution of energy in the Airy pattern due to circular aperture.

The diameter of the first minima is \( 2.44(\lambda/D)f \).
Two objects can be just resolved if the peak of the Airy pattern of one object falls on the first minima of the other separated by: (theoretical limit)

\[ 1.22(\lambda / D) \] OR Angular resolution : \( 1.22(\lambda/D) \)
Spatial Resolution

- When electronic sensors using discrete detectors are used for generating imagery (Landsat MSS, IRS LISS, etc.) → Spatial resolution is used to denote the projection of the detector element on the ground

- An Landsat ETM+ scene has an Instantaneous Field Of View (IFOV) of 30 meters in bands 1-5 and 7 while band 6 has an IFOV of 60 meters on the ground and the band 8 an IFOV of 15 meters
Spatial Resolution

- **IFOV in radians**: \( \frac{d}{f} \)
  - \( d \) is the dimension of the detector
  - \( f \) is the focal length

- The advantage of using IFOV is that, it characterizes a sensor irrespective of the altitude of the sensor.

- The information in the IFOV is represented by a pixel.

- The field of view (FOV) is the total view of the camera which defines the swath.
Spectral Resolution

- In multi-spectral RS, the variation in reflected/emitted spectral radiation is used to distinguish various features.

- It is rather difficult (nor essential in most cases) to get continuous spectral information.

- We sample the reflected/emitted spectrum by making measurements at few selected bands.

- The wavelength region of observation: Spectral bands is defined in terms of:
  - Central wavelength $\lambda_c$
  - Band width $\Delta \lambda$
Spectral Resolution

3 Aspects of spectral band selection

- Location of the central wavelength
- The bandwidth
- The total number of bands

Bandwidth is defined by:

\[ \lambda_1 \text{ (lower)} \text{ and } \lambda_2 \text{ (cut-off wavelength)} \]

The spectral resolution

\[ \Delta \lambda = \lambda_2 - \lambda_1 \]

The wavelength interval in which the observation is made. Smaller the \( \Delta \lambda \), higher the spectral resolution.

Full width at half maximum (FWHM)
Spectral Resolution

IRS LISS, Band 1 is 0.45µm - 0.52µm?

- In an ideal system the response should be 1 between the wavelength 0.45µm - 0.52µm and 0 for wavelengths outside
- Not practicable!
- Bandwidth is defined in terms of 50% of the peak value on either side (holds for Gaussian system)
- In practice, the pass band response has number of ‘ringings’ and assigning the peak value is not a straightforward process
- Techniques: method of moments to compute $\lambda_c$ and $\Delta \lambda$ (computationally involved)
Spectral Resolution

GNR401    Dr. A. Bhattacharya
Location of spectral bands

- Important criteria for location of spectral bands:
  - In the atmospheric window and away from the absorption bands
  - Certain spectral bands are best suited for specific themes
  - The bands selected should be un-correlated to the extent possible (statistical methods to evaluate correlation between bands)
  - Minimum set of optimal bands
  - Study showed that addition of middle IR band with any other band combination gives improved separability in agriculture classification
Radiometric Resolution

- **Constant ratio:**
  - The difference in the radiance of the objects in a scene plays an important role in their detection.
  - The contrast is usually defined usually w.r.t to 2 adjacent areas.

\[
C_R = \frac{L_{\text{max}}}{L_{\text{min}}}
\]

- **Contrast modulation:**

\[
C_M = \frac{(L_{\text{max}} - L_{\text{min}})}{(L_{\text{max}} + L_{\text{min}})}
\]
The contrast in the image is different from that of the scene (object plane) \( \Rightarrow \) The degradation of the contrast by imaging system is represented by the Modulation Transfer Function (MTF)

\[
\text{MTF} = \frac{\text{Contrast modulation in the image plane}}{\text{Contrast modulation in the object plane}}
\]
Radiometric Resolution

- In computer classification of the features from RS data
  - Statistical difference in the reflected value measured by the instrument
  - The absolute value of the reflectance (or radiance) is not important since one compares the relative reflectance value between pixels
  - However, if one needs two date data for classification or information fusion, then it is mandatory to have the absolute radiance value
MTF effect on radiometry: The ‘square’ wave pattern gives the actual radiance from three targets- barley, mildewed barley (MB) and sand. Two fields of mildewed barley- (a) one amongst barley and (b) one among sand. The ‘sine curve’ gives the radiance when measured with a radiometer. The MTF of the radiometer modifies the radiance value. Mildewed barley (MB) both (a) and (b) have same radiance (3.85). But due to radiometer MTF, the MB at (a) shows a lower value (3.6), while MB at (b) shows a higher value of (4.02). In case (b) the higher radiance of sand spills over to MB and reverse in (a).