Lecture 02. Introduction of Remote Sensing

- Concept of Remote Sensing
- Picture of Remote Sensing
- Content of Remote Sensing
- Classification of Remote Sensing
- Passive Remote Sensing
- Active Remote Sensing
- Comparison of Remote Sensing
- Summary
Concept of Remote Sensing

- Remote Sensing is the science and technology of obtaining information about an object without having the sensor in direct physical-contact with the object.

- Remote sensing is opposite to in situ methods that obtain information locally.
Concept of Remote Sensing

- The Nature of Remote Sensing is one kind of measurements.
- Measurements are to obtain or acquire information of an object using experimental methods.
- There must be some interaction between the object and the instruments in order to acquire the information of the object.
- The interaction can be direct (local) or remote.
Concept of Remote Sensing

- Without direct physical contact between the sensor and the object, some remote interaction must be introduced to carry away the object information so that the information can be acquired by the sensor remotely.

- The interaction between radiation and the object is the most common interaction used in modern remote sensing.

- The radiation includes electromagnetic radiation and acoustic waves.
Picture of Remote Sensing System

Interaction between radiation and objects

Radiation Propagation Through Medium

θ

Signal Propagation Through Medium

Radiation Source

Receiver & Detector

System Control & Data Acquisition

Data Analysis & Interpretation

*Angle θ is arbitrary
Concept of Remote Sensing

- During the interaction, radiation properties are modified by the object, therefore, containing the information of the object. Through recording and analyzing the modifications of the radiation, the object information can be retrieved.

An example: the wind measurements

\[ \Delta \omega = \omega_2 - \omega_1 = -(\vec{k}_1 \cdot \vec{v}_1 - \vec{k}_2 \cdot \vec{v}_2) \]
Content of Remote Sensing

- Remote Sensing contains many aspects, not only the instrumentation and data acquisition, but also the data processing, analysis, and interpretation.

1. Physical Science and Technology Development:
   physical interaction and principle study,
   instrument design, development, & test/calibration

2. Observational campaigns and missions:
   system deployment, data collection,

3. Data/signal Processing:
   data processing, information retrieval, error analysis

4. GeoScience Study:
   data analysis and interpretation.
Content of Remote Sensing

- Principle Investigation
  - Instrument Design
  - Instrument Development
  - Instrument Test/Calibration

- Data Acquisition
- Data Processing
- Data Interpretation
  - Information Product

- Measurements and/or Observations
Remote Sensing Applications

- Atmospheric Research
- Environmental Research and Industry
- Space Research and Industry
- Solid-Earth Research and Industry
- Ocean Research and Industry
- Space Exploration
- Astronomy Exploration
- Industry, Defense, Military
- and many more ...
Advantages of Remote Sensing

- Reaching inaccessible/difficult regions to make reliable measurements
- Avoiding hazardous to reach regions
- Fast and inexpensive probing of large volumes
- Minimal disturbance of measured processes
- ...
Classification of Remote Sensing

- **Passive Remote Sensing:** no self-generated radiation is used in the sensing, but using naturally occurring radiation, such as sunlight or nightglow emission.

- **Active Remote Sensing:** self-generated radiation sources are used, such as laser light, radio- and micro-wave, acoustic wave.

  Depending on whether a human-generated radiation source is used in the sensing process
Classification of Remote Sensing

- Optical Remote Sensing: probing and detecting in optical frequency range
- Radio Remote Sensing: probing and detecting in radio and microwave frequency
- Acoustic Remote Sensing: probing and detecting in acoustic frequency range

All include passive and active remote sensing

Depending on the frequency of radiation used in the probing and detection
Passive Remote Sensing (Scattering/Reflection)

- Photography
- Radiometer
- All-sky-imager
- Spectrometers
- Interferometer
- ...

Solar Radiation

Radiation Propagation Through Medium

Signal Propagation Through Medium

Receiver & Detector

System Control & Data Acquisition

Data Analysis & Interpretation
Space Imaging (Scattering/Reflection)
Passive Remote Sensing (Emission)

Emission from object

OH, Na, O

Receiver & Detector

System Control & Data Acquisition

Data Analysis & Interpretation
All-Sky-Camera (Emission)

Emissions from OH, Na, O, etc
Passive Remote Sensing (Extinction)

Solar Radiation

Receiver & Detector

System Control & Data Acquisition

Data Analysis & Interpretation

NOAA Dobson Spectrometer to measure ozone from the ground
Dobson Spectrometer (Extinction)

305 nm
Strong Absorption by ozone

325 nm
No Absorption by ozone

The ratio between the two light intensity is a measure of the total amount of ozone in the light path from the sun to the observing D.S.

\[ R = \frac{I_{325} - I_{305}}{I_{305}} \propto N_{O_3} \]
Active Remote Sensing

Interaction between radiation and objects

Radiation Propagation Through Medium

Transmitter (Radiation Source)

Receiver (Detector)

System Control & Data Acquisition

Data Analysis & Interpretation
Active Remote Sensing

From Biological Sonar
To SODAR, RADAR, LIDAR

SODAR: Sound Detection And Ranging
RADAR: Radiowave Detection And Ranging
LIDAR: Light Detection And Ranging

Based on the Same Principle
Radiation is transmitted into environment, backscattered by the objects, and then detected and analyzed by receivers.
How does sodar, radar & lidar work?

$$R = V \times \Delta t / 2$$

Where $$\Delta t = t_1 - t_0$$, i.e., the time of flight

For radar and lidar, $$V = c$$, i.e., the light speed

For sodar, $$V =$$ the sound speed
SODAR (Sound Detection and Ranging)

Desert Research Institute Doppler SODAR
http://www.dri.edu/Projects/Radar/SODAR/
SODAR (Sound Detection and Ranging)

Atmospheric Research LTD SODAR at Airfield

Three directions are measured with the SODAR so that the 3 components (u, v, w) of wind field can be derived
SODAR

- Sound wave or acoustic wave is used in the sensing. This is real mechanical sound wave, i.e., longitudinal wave, produced by compressing the atmosphere medium. It is not electromagnetic wave at the sound frequency.

- The speed used is the speed of sound (340 m/s).

- SODAR works better in the air with more moisture, rather than the dry air. Usually, it goes up to several hundred meters.
SONAR & SODAR

- SONAR is Sound Navigation Ranging, used under water, for the ocean detection, like submarine.

- SODAR is usually referred to the sound detection and ranging in the atmosphere. We use it for general description of SODAR and SONAR.

- SONAR works better under water.
RADAR (Radiowave Detection and Ranging)

- Electromagnetic waves in the radio frequency and microwave frequency range are used in the sensing.

- The speed used is the light speed ($3 \times 10^8$ m/s).

Recommend --
ASEN5245. Radar and Remote Sensing
Taught by Prof. Jeff Thayer
NEXRAD Weather Radar System
South Pole Meteor Scatter Radar
Arecibo Incoherent Scatter Radar
Millstone Incoherent Scatter Scatter Radar
Sondrestrom Incoherent Scatter Radar
AMISR - Advanced Modular Incoherent Scatter Radar

Resolute Bay, Canada and Poker Flat, Alaska
Incoherent Scatter RADAR Map
LIDAR (Light Detection and Ranging)

- Electromagnetic waves in the optical frequency range are used in the sensing.

- More commonly, we say light, especially laser light, is used in the sensing.

- The speed used is the light speed ($3 \times 10^8$ m/s).
Light Detection And Ranging (LIDAR)

Range Determined From Time-of-Flight: \( R = c \cdot \Delta t / 2 \)
# Hardware of SODAR, RADAR, LIDAR

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<thead>
<tr>
<th></th>
<th>SODAR</th>
<th>RADAR</th>
<th>LIDAR</th>
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<tbody>
<tr>
<td>Transmitter</td>
<td>Electric-acoustic converter</td>
<td>Electronic circuit + Antenna</td>
<td>Laser</td>
</tr>
<tr>
<td>Receiver</td>
<td>Headphone</td>
<td>Antenna</td>
<td>Optical telescope + Photon detector</td>
</tr>
<tr>
<td>Transmitted Energy</td>
<td>Acoustic Energy</td>
<td>Electromagnetic Waves</td>
<td>Light</td>
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## Comparison of Remote Sensing

<table>
<thead>
<tr>
<th>Passive</th>
<th>Active</th>
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<tbody>
<tr>
<td>Scattering</td>
<td>Scattering</td>
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<tr>
<td>Emission</td>
<td>Extinction</td>
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<tr>
<td>Extinction</td>
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### Optical

- Aerial / Space Photography
- UARS satellite
- TIMED/SABER satellite
- ABI satellite
- Airglow Imager
- Bomem Spectrometer
- Fabry-Perot Interferometer
- Dobson Spectrometer HALOE occultation

### Radio

- Passive Radiometer
- Passive Radiometer

### Sound

- SODAR

- LIDAR
- DIAL

- RADAR
- GPS Radio Occultation
Advantages of Active Remote Sensing

- independence of natural radiation sources and time of day;
- reduced sensitivity to background light;
- high intensity of stimulating signal;
- control of stimulating signal;
- knowledge of stimulating signal;
- capable of line integral, line average, line profile, 2-D coverage, 3-D coverage, 3-D spectrum – all as a function of time
- ...

Summary

- Remote Sensing concept & picture
- Nature of remote sensing & measurements
- Classifications of remote sensing
- Passive Remote Sensing
- Active remote sensing
- Comparison of Remote Sensing