# Chapter 1

Introduction



## Overview

- Remote sensing: definition.
- Remote sensing versus photogrammetry.
- Elements of remote sensing.
- Key concepts:
  - Spatial resolution.
  - Radiometric resolution.
  - Spectral resolution.
  - Temporal resolution.



## Overview

- Acquisition platforms:
  - Historical overview.
  - Terrestrial, aerial, and space borne platforms.
  - Passive versus active remote sensing sensors.
- Remote sensing: applications.
- Practical example:
  - What is needed to carry out remote sensing activities?



## Remote Sensing: Definition

- Remote sensing is the process of obtaining information about an object using a sensor which is physically separated from the object.
- Remote sensing rely on sensors, which detect emitted or reflected energy from objects.
- Human vision is the most popular example of a remote sensing system.

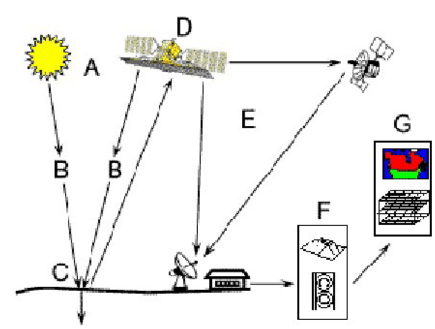


## Photogrammetry: Definition

- The art and science of determining the position and shape of objects from photography.
- The process of reconstructing objects without touching them.
- Non contact positioning method.
- Question: what is the difference between remote sensing and photogrammetry?
  - Photogrammetry deals with the measurements of geometric properties of objects.
  - Remote Sensing focuses on determining the material and condition of surfaces based on their radiometric properties.



## Elements of Remote Sensing



## Elements of Remote Sensing

- **Energy Source or Illumination (A):**
  - The energy source that illuminates or provides electromagnetic energy to the target of interest.
- **Radiation and the Atmosphere (B):**
  - As the energy travels from its source to the target, it will come in contact and interact with the atmosphere.
  - This interaction may take place a second time as the energy travels from the target to the sensor.



## Elements of Remote Sensing

- **Interaction with the Target (C):**
  - Once the energy makes its way to the target through the atmosphere, it interacts with the target.
  - The interaction outcome depends on the spectral properties of both the target and the radiation.
- **Recording of Energy by the Sensor (D):**
  - Scattered/emitted energy from the target is recorded by the implemented sensor.
- **Transmission, Reception, and Processing (E):**
  - Recorded energy is transmitted, often in electronic form, to a receiving and processing station where the data is converted into an image (hardcopy and/or digital).



## Elements of Remote Sensing

- **Interpretation and Analysis (F):**
  - Processed image is interpreted, visually and/or digitally, to extract information about the target which was illuminated.
- **Application (G):**
  - Apply extracted information about the target in order to:
    - Gain better understanding of that object,
    - Reveal some new information, or
    - Assist in solving a particular problem.



## Resolutions

- The characteristics of remote sensing systems can be described by the following types of resolutions:
  - Spatial resolution,
  - Radiometric resolution,
  - Spectral resolution, and
  - Temporal resolution.
- These resolutions control our ability to interpret remote sensing data.

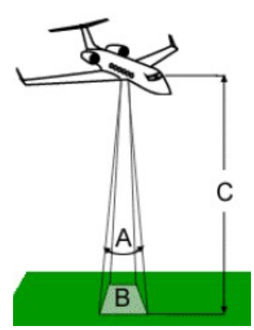


## Spatial Resolution

- Spatial resolution dictates the amount of discernible details in an image:
  - The size of the smallest possible feature that can be detected.
- In general the spatial resolution depends on the **Instantaneous Field of View (IFOV)**, A, of the implemented sensor.
- The IFOV is the angular cone of visibility of the sensor.
  - The projection of the IFOV into the surface of the earth is known as the **resolution cell** (B).
- The spatial resolution is mainly controlled by the separation between the sensor and the target (C).



## Spatial Resolution

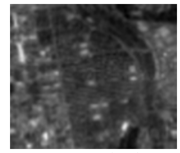


# Spatial Resolution

- For a homogeneous feature to be detected, its size has to be equal to or larger than the resolution cell.
  - If the feature is smaller than this, it may not be detectable as the average brightness of all features in that resolution cell will be recorded.
- However, smaller features may sometimes be detectable if their reflectance dominates within a particular resolution cell allowing sub-pixel or sub-resolution cell detection.



# Spatial Resolution


LANDSAT (30m)


LANDSAT (15m)

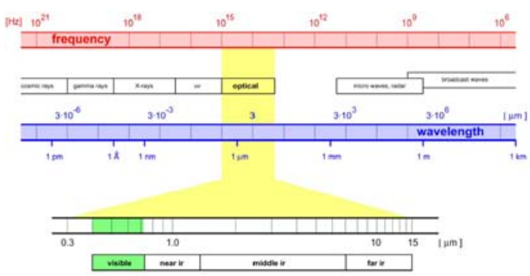

SPOT (10m)


KOMPSAT-1 (6m)


IKONOS (1m)



# Electromagnetic Radiation



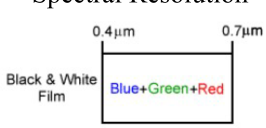



# Spectral Resolution

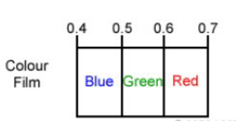
- Spectral resolution describes the ability of a sensor to define fine wavelength intervals.
- The finer the spectral resolution, the narrower the wavelength range for a particular channel or band.
  - Black and white film records wavelengths extending over much, or all of the visible portion of the electromagnetic spectrum.
  - Color film is individually sensitive to the reflected energy at the blue, green, and red wavelengths of the spectrum.
  - Color film has higher spectral resolution when compared to black and white film.



# Spectral Resolution




Spectral sensitivity of black and white films




Spectral sensitivity of color film



# Spectral Resolution

## Spectral Resolution

- **multi-spectral sensors** record energy over several separate wavelength ranges at various spectral resolutions.
- Advanced multi-spectral sensors called **hyper-spectral** sensors, detect hundreds of very narrow spectral bands throughout the visible, near-infrared, and mid-infrared portions of the electromagnetic spectrum.
- Such sensors facilitate fine discrimination between different targets based on their spectral response in each of the narrow bands.



## Radiometric Resolution

- Radiometric resolution of an imaging system describes its ability to discriminate very slight differences in the recorded energy.
- The finer the radiometric resolution of a sensor, the more sensitive it is to detecting small differences in reflected or emitted energy.
- For digital imagery, the radiometric resolution is defined by the number of bits used for coding the recorded grey values.
  - By **comparing a 2-bit image with an 8-bit image**, one can see that there is a large difference in the level of discernible details.



## Radiometric Resolution

8 bits per pixel

2 bits per pixel



## Temporal Resolution

- Temporal resolution of a remote sensing system refers to the frequency with which it images the same area.
- Frequent imaging is important for:
  - Disaster & environmental management.
    - For example, floods, oil slicks, spread of forest disease from one year to the next.
  - Change detection applications.



## Multi-Temporal Imagery

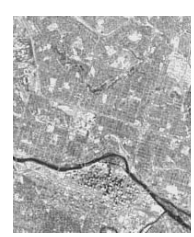
Calgary 56

Calgary 72



## Multi-Temporal Imagery

Calgary 1999



Calgary 2001

# Multi-Temporal Imagery

Calgary 2002

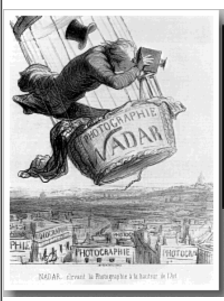


# Remote Sensing

Data Acquisition System
Historical Overview



# Historical Review: Balloons

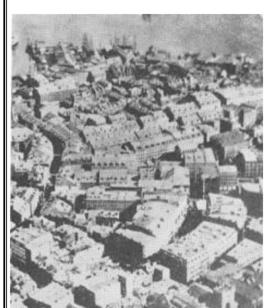




First image was captured in 1859



# Historical Overview: Balloons



Boston from a Balloon (1860)

St. Luis Island, Paris
Captured by Balloon, 1860



# Historical Overview: Kites

Aerial Photography from a Kite, 1880

Labrugauere, France from a kite (1889)



# Historical Overview: Kites

kite photos, San Francisco, California right after the infamous 1906 earthquake that, together with fire, destroyed most of the city

## Historical Overview: Pigeons



## Historical Overview: Planes (1908)


New York

Reims



## Historical Overview, Rockets

Historically, the first photos taken from a small rocket, from a height of about 100 meters, were imaged from a rocket designed by Alfred Nobel, launched in 1897 over a Swedish landscape

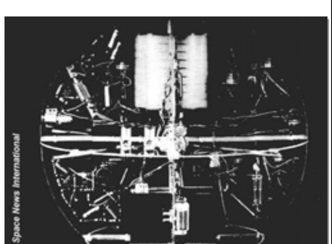


## Historical Overview: Rockets

A camera succeeded in photographing the landscape at a height of 600 meters by Alfred Maul's rocket during a 1904 launch.



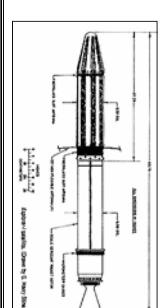
## Historical Overview: Satellites




Sputnik-1, 1957

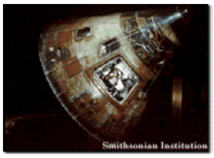


## Historical Overview: Satellites



First US satellite
Explorer-1, 1958

# Historical Overview: Satellites




Apollo-8, First photo of Earth from space, 1968

Africa, July 1972
Apollo 17



# Remote Sensing

Data Acquisition Systems



# Ground Based Sensors

- **Ground-based sensors** are often used to record detailed information about the surface.

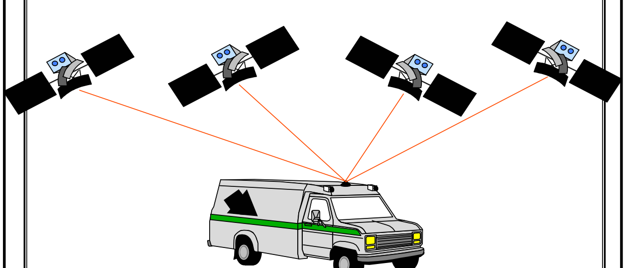


# Ground Based Sensors


Terrestrial Mobile Mapping System (TMMS)



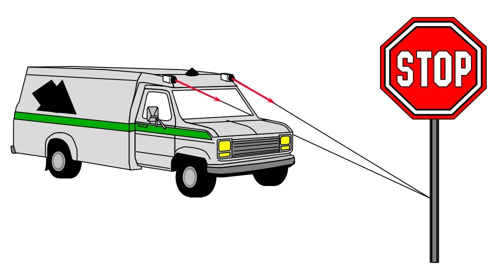
# Ground Based Sensors: TMMS



Absolute positioning using GPS



# Ground Based Sensors: TMMS




Stereo-Positioning

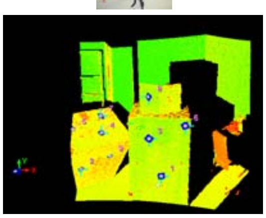
## Ground Based Sensors: TMMS




## Ground Based Sensors: TMMS




## Ground Based Sensors



Laser System

Digital Camera

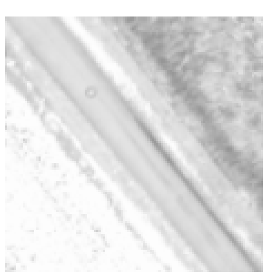


## Aerial Platforms

- Aerial platforms are primarily stable wing **aircraft**, although helicopters are occasionally used.
- Aircrafts are often used to collect very detailed imagery.
- They facilitate the collection of data over virtually any portion of the Earth's surface at any time.



## Terrestrial versus Aerial Platforms





## Space Borne Platforms

- Remote sensing data can be captured by satellites.
- Because of their orbits, satellites permit repetitive coverage of the Earth's surface on a continuing basis.

## Data Acquisition Systems: Remarks

- The choice of the remote sensing platform depends on:
  - The application under consideration.
  - Accessibility of the area under consideration.
  - Amount of required details.
  - The cost.

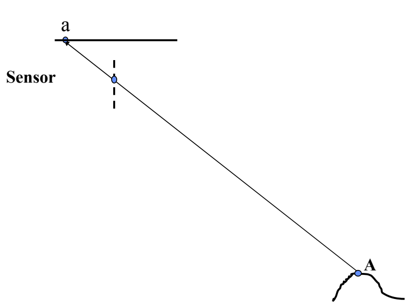


## Remote Sensing Systems

Passive versus Active Sensors



## Passive Sensors



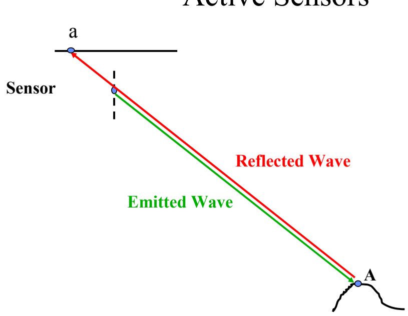



## Passive Sensors

- Remote sensing systems which measure energy that is naturally available are called **passive sensors**.
- Passive sensors can only be used to detect energy which is naturally available.
  - Optical imagery can be only captured during the time when the sun is illuminating the Earth.
- Thermal and infrared imagery can be detected day or night, as long as the amount of energy is large enough to be recorded.



## Active Sensors

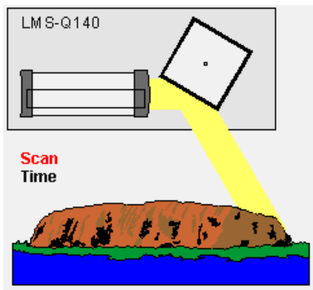





## Active Sensors

- **Active sensors** provide their own energy source for illumination.
- The sensor emits radiation which is directed toward the target to be investigated.
- The radiation reflected from that target is detected and measured by the sensor.
- Advantages for active sensors include the ability to obtain measurements anytime, regardless of the time of day or season.
- Problems: More power is needed.

# Active Sensor: LIDAR

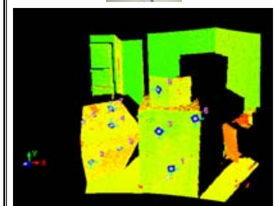



LIght Detection And Ranging



# Active & Passive Sensors





Active Sensor

Passive Sensor



# Active & Passive Sensors



# Remote Sensing

Applications



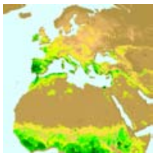
# Remote Sensing Applications

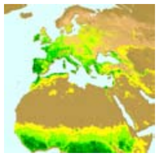
- Meteorology.
- Agriculture.
- Forestry.
- Environmental.
- Oceanography.
- Cartography.

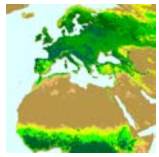


# Weather Monitoring

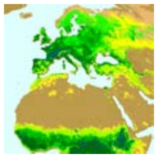
# Agriculture


Feb., 86


Apr., 86


Jun., 86

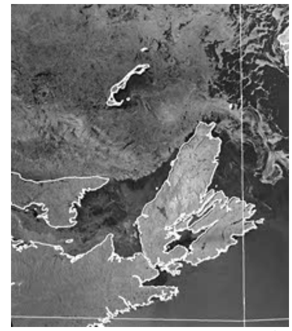

Aug., 86


Oct., 86


Dec., 86

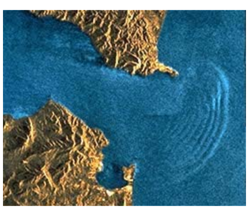


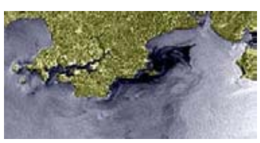
# Ice Detection and Mapping





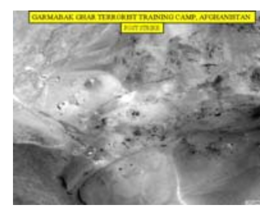
# Ocean & Costal Monitoring


**Ocean waves**


**Oil spill detection**



# Change Detection



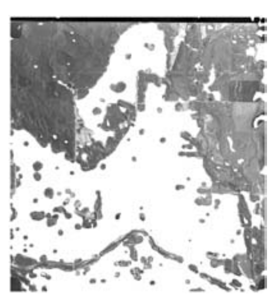

# Change Detection

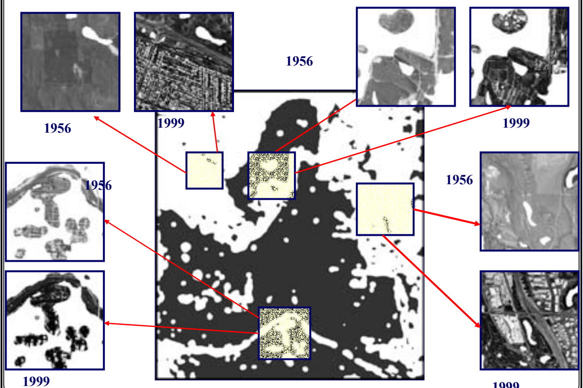

Calgary, 1956


Calgary, 1999



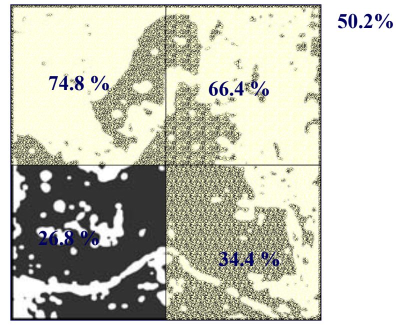
# Change Detection Analysis








## Change Detection: (Quantitative Measurements)





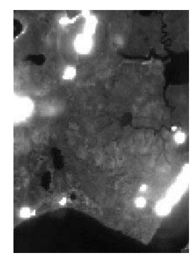

## Disaster Assessment

Devastation created by tornado



## Forest Fire Monitoring

True Color Image



Thermal Image



## Remote Sensing: Practical Example

Recognition of Road Signs in Terrestrial Color Imagery

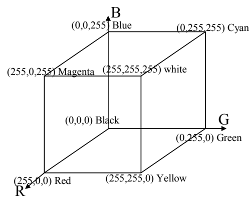


## Automatic Recognition of Road Signs from Color Terrestrial Imagery

- Analyze an image sequence to find out whether there are regions with interesting colors, i.e. most probably correspond to road signs.
- Generated Hypotheses are based on:
  - The radiometric, spectral, properties of the sought after objects.
  - The geometric properties of the sought after objects as well as the imaging system.

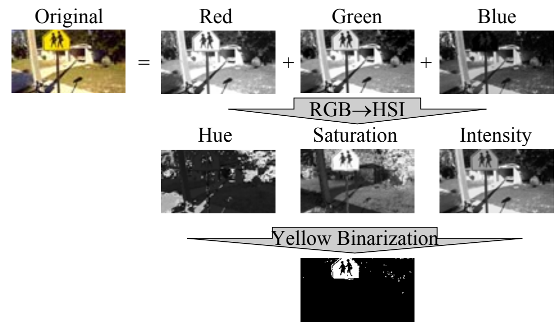
# RGB Color Model

- RGB model:
  - Based on additive color theory.
  - Represented by cube model.



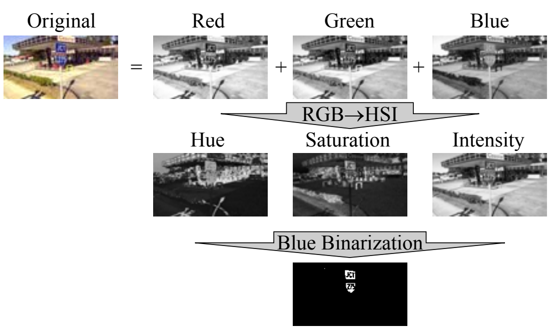



# Identification of Predefined Signatures



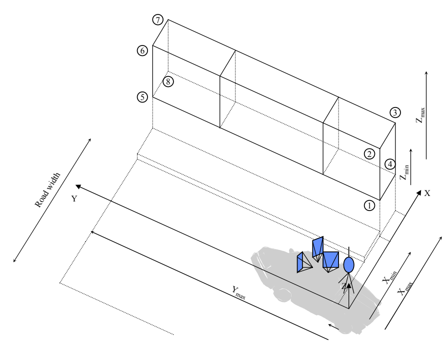



# Identification of Predefined Signatures



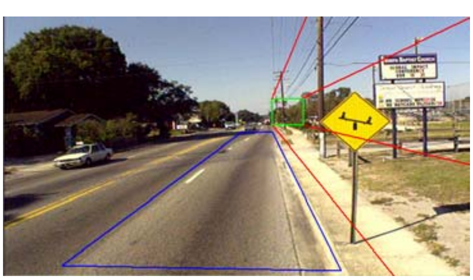



# Area of Interest



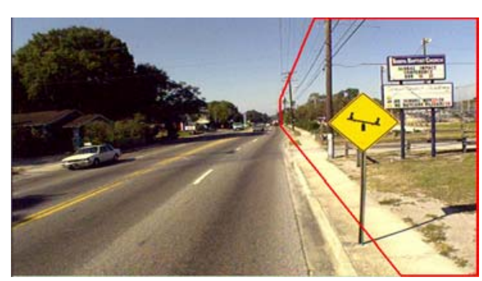



# Expected Sign & Road Locations

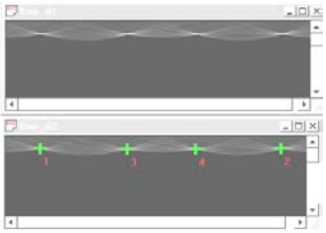




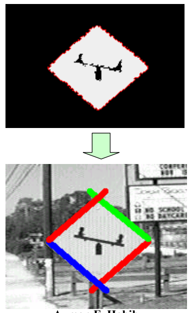
# Area of Interest



# Detect Straight Lines: Hough Transform



**Hough image & Detected Peaks**

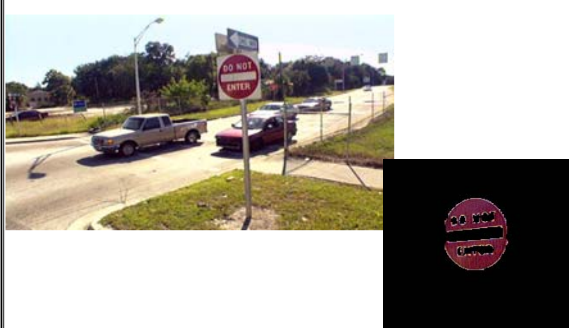




# Generated Hypotheses



# Generated Hypotheses






# Final Remarks

- For remote sensing, we need to:
  - Understand the characteristics of the energy, which will be recorded, and how it is interacting with the atmosphere and the target (chapter 2).
  - Understand the characteristics of the remote sensing system (chapter 3).
  - Understand the processing mechanism of the acquired remote sensing data.
    - Radiometric processing (Chapters 4, 6).
    - Geometric processing (Chapters 5, 6)