Intro to Remote Sensing

Lecture 1
August 24, 2005
NASA Research Spacecraft
Applications of National Priority

- Carbon Management
- Public Health
- Energy Management
- Aviation
- Water Management
- Homeland Security
- Coastal Management
- Disaster Management
- Agricultural Efficiency
- Invasive Species
- Ecological Forecasting
- Air Quality
What is remote sensing

- **Remote Sensing:** remote sensing is science of
  - acquiring,
  - processing, and
  - interpreting
  images and related data that are obtained from ground-based, air-or space-borne instruments that record the interaction between matter (target) and electromagnetic radiation.

- **Remote Sensing:** using electromagnetic spectrum to image the land, ocean, and atmosphere.

- **In this class,** we will mostly focus on the
  - the principles and techniques for data collection and the interaction of electromagnetic energy with the Earth's surface (2/3 of the time)
  - some application examples (1/3 of the time)
  - also you will get familiar with ENVI, an image processing software.
Electromagnetic Spectrum

Source: http://oea.larc.nasa.gov/PAIS/DIAL.html

Fig. 1: The electromagnetic spectrum categorizes solar radiation from the longest to the shortest wavelengths.
Remote sensing platforms

Ground-based  Airplane-based  Satellite-based
Satellite Based

- **Sun-synchronous polar orbits**
  - Most earth imaging satellites is polar-orbiting, meaning that they circle the planet in a roughly north-south ellipse while the earth revolves beneath them. Therefore, unless the satellite has some sort of "pointing" capability, there are only certain times when a particular place on the ground will be imaged.
  - Global coverage, fixed crossing, repeat sampling
  - Typical altitude 500-1,500 km
  - Example: MODIS, Landsat

- **Non-Sun-synchronous orbits**
  - Tropics and mid-latitudes coverage, varying sampling
  - Typical altitude 200-2,000 km
  - Example: TRMM

- **Geostationary orbits**
  - Regional coverage, continuous sampling
  - Over equator only, altitude 35,000 km
  - Example: GOES
Types of remote sensing

- **Passive:** source of energy is either the Sun or Earth/atmosphere
  - Sun
    - wavelengths: 0.4-5 µm
  - Earth or its atmosphere
    - wavelengths: 3 µm - 30 cm

- **Active:** source of energy is part of the remote sensor system
  - Radar
    - wavelengths: mm-m
  - Lidar
    - wavelengths: UV, Visible, and near infrared

Camera takes photo as example, **no flash and flash**
Four types of resolution

- Spatial resolution
- Spectral resolution
- Radiometric resolution
- Temporal resolution
Spatial resolution and coverage

- **Spatial resolution**
  - Instantaneous field-of-view (IFOV)
  - Pixel: smallest unit of an image
  - Pixel size

- **Spatial coverage**
  - Field of view (FOV), or
  - Area of coverage, such as MODIS: global coverage, weather radar (NEXRAD): a circle with 230 km as radius
30 meter, spatial resolution
Northwest San Antonio

1 meter, spatial resolution
UTSA campus,
red polygon is the Science Building
Spatial Resolution

Jensen, 2000
Spectral resolution ($\Delta\lambda$) and coverage ($\lambda_{\text{min}}$ to $\lambda_{\text{max}}$)

- 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.
Radiometric resolution and coverage

- Sensor’s sensitivity to the magnitude of the electromagnetic energy,
- Sensor’s ability to discriminate very slight differences in (reflected or emitted) energy,
- The finer the radiometric resolution of a sensor, the more sensitive it is to detecting small differences in energy
Comparing a 2-bit image with an 8-bit image
## Basics of Bit

- **Computer store everything in 0 or 1**

### 8 bits as an example

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<th>256</th>
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<td>1</td>
</tr>
<tr>
<td>6</td>
<td>0</td>
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</tr>
<tr>
<td>5</td>
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<td>4</td>
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<td>3</td>
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</tr>
<tr>
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**Resolution:** 12 bits  
**Coverage:** 0 - 4095

### Maximum Number

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<td>12</td>
<td>4096</td>
</tr>
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</table>
Figure 4.19  IKONOS 11-bit data enables detail to be captured in areas within the cloud shadow. In the 8-bit image (a), there is no detail in the black cloud shadow area. Image (b) shows improved shadow detail after enhancement using the full 11 bits of data.

Source: Image courtesy of Space Imaging Corporation.
Temporal resolution and coverage

- Temporal resolution is the revisit period, and is the length of time for a satellite to complete one entire orbit cycle, i.e. start and back to the exact same area at the same viewing angle. For example, Landsat needs 16 days, MODIS needs one day, NEXRAD needs 6 minutes.

- Temporal coverage is the time period of sensor from starting to ending.
  - MODIS/Terra: 2/24/2000 through present
  - Landsat 5: 1/3/1984 through present
163 NEXRADs in the USA

First deployed in 1988

Spectrum
Microwave (centered at 10cm)

Spatial Resolution (km)
1, 2, 4

Spatial coverage (km)
Radius of 230km

Temporal Resolution
6-10 minutes
NEXRAD has very good coverage (maximum 230 km in radius) in the SA area.

Click here: http://weather.noaa.gov/radar/national.html for real time precipitation
NASA Landsat-7 (ETM+)
laided 4/15/1999

Spectrum coverage (8 bands)
Visible
Near Infrared
Thermal Infrared

Spectrum resolution
50-200 nm

Spatial resolution (m)
15, 30, 60

Spatial coverage
185 km (swath) or global

Temporal resolution and coverage
16 days, 4/15/1999 through present

Radiometric resolution and coverage
8 bits, 0 to 255
Terra satellite launched on 12/18/1999

**Spectrum coverage (36 bands)**
- Visible
- Near Infrared
- Thermal Infrared

**Spectral resolution**
10-500 nm

**Spatial resolution (m)**
250, 500, 1000

**Spatial coverage**
2400 km (swath), global

**Radiometric resolution and CVG**
12 bits, 0 - 4095

http://terra.nasa.gov/About/MODIS/modis_swath.html
IKONOS launched on 9/24/1999

Spectrum coverage (4 +1 bands)
Visible
Near Infrared
Panchromatic

Spectral resolution
65-95 nm, 403 nm

Spatial resolution (m)
4 and 1

Spatial coverage
11 km (swath), global

Radiometric resolution
11 bits

http://www.spaceimaging.com/
Tropical Rainfall Measuring Mission

"Hurricane Bonnie 08/22/98"

- first satellite rain radar to measure the 3-D of precipitation over the tropics between 35º latitude, since 1997

Wavelength 2.2 cm (13.8 GHz), 4 km resolution and swath of 220 km and tropical coverage, Temporal: daily

NASA Scientific Visualization Studio (Shirah)
Global Geostationary Environmental Satellites

Earth radius 6,370 km
Satellite altitude 35,800 km

3.9 µm and 10.7 µm
4 km, 30 minutes
Airborne Visible Infrared Imaging Spectrometer (AVIRIS)

- 400 – 2500 nm at 10 nm resolution
- 224 spectral bands
- 20 m spatial resolution when flying at 11 km
The size of a cell we call image resolution, depending on…
Such as 1 m, 30 m, 1 km, or 4 km
History of Remote Sensing

- Aerial photography is the original form of remote sensing (using visible spectrum) started in 1909.
- Aerial photographic reconnaissance was widely used after 1915 in WWI.
- *Photogrammetric Engineering*, the official monthly publication of the *American* Society of Photogrammetry, was first published in 1934.
- Color infrared photography began 1931, then was widely used in agriculture and forestry.
- Development of radar (1930-1940).
- During WWII, non-visible spectrum (infrared and radar) were used as tools in remote sensing.
- After the first man-made satellite (*Sputnik 1*) was launched on 4 October 1957, remote sensing moved to outer space.
- The United States' *Explorer 6* transmitted the first space photograph of the Earth in August 1959.
- The first systematic meteorological satellite observation came with the launch of the United States' *TIROS 1* in 1960.
- *Landsat 1* (originally called the Earth Resources Technology Satellite or *ERTS*) was the first satellite to collect data on the Earth's natural resources. It was launched on 23 July 1972.
- Hyperspectral remote sensing emerged (1980s), widely used in mineral, oil, etc. exploration.
- Since then, a large number and advanced types of remote sensing systems have been developed.
Heritage in Research to Operations
Research Systems to Operational Systems

Observation

- Imaging and Sounding
  - SeaWiFS
  - Terra
  - Aqua
  - NPP
  - NPOESS

- Solar Irradiance, Ozone, and Aerosols
  - ACRIMsat
  - SORCE
  - Glory
  - NPOESS

- SAGE III
  - AURA
  - NPP
  - NPOESS

- Atmospheric Composition
  - UARS
  - AURA
  - TBD

- Ocean Surface Topography
  - Jason
  - OSTM
  - NOAA/EUMETSAT

- Land Cover/Land Use Change
  - Landsat 7
  - LDCM
  - Operational NPOESS

- Tech
  - GIFTS*
  - GOES

- Tropo Winds
  - TBD

Data Assim

- Joint Center for Satellite Data Assimilation
  - NCEP

- Short-term Prediction Research and Transition Center
  - NWS

In operation

Under Development

In Formulation

Tech Development

* Canceled flight mission; gleaning technology for GOES-R
From Terra, Aqua to NPP to NPOESS

Use of Advanced Sounder Data for Improved Weather Forecasting & Numerical Weather Prediction

Aqua (2002) AIRS, AMSU & MODIS
Coriolis (2003) WindSat
METOP (2005) IASI/AMSU/MHS & AVHRR
NPP (2006) CrIS/ATMS VIIRS OMPS
NPOESS (2009) CrIS/ATMS, VIIRS, CMIS, OMPS & ERBS

NOAA Real-Time Data Delivery Timeline
Ground Station Scenario

NOAA Real-time User

C3S → IDPS → NOAA Real-time User

Joint Center for Satellite Data Assimilation

NWS/NCEP GSFC/DAO ECMWF UKMO FNMOC Meteo-France BMRC-Australia Met Serv Canada

NWP Forecasts
Whole Planet System Simulators for Policy, Management, & Exploration

Earth Ocean

Earth Land

Earth Ozone

Earth Surface

Earth El Nino

Earth Vegetation

Sun

Moon

Mars
The Advance of Science at NASA
Trend and Future of Remote Sensing (1)

- **High spatial resolution**
  - IKONOS launched in 1999 by Space Imaging
    (4 m multi-spectral and 1 m panchromatic)
  - QuickBird launched in 2001 by DIGITALGLOBE
    (2.44 m multi-spectral and 61 cm panchromatic)

- **High spectral resolution**
  - AVIRIS, 10nm and 20 m, 224 bands
  - Hyperion launched in 2000, 10nm and 30 m, 220 bands

- **High radiometric resolution**
  - 8 bits to 12 bits

- **High temporal resolution**
  - GOES 15-30 minutes
  - NEXRAD 6 or 10 minutes
Trend and Future of Remote Sensing (2)

- **Globe coverage, high repeatability (or improved temporal resolution)**
  - AVHRR, 1100m, morning or afternoon
  - MODIS, 250-1000m, morning or afternoon
  - NPOESS (will be launched in 2009), 370-740m, 4 hours

- **Real-time or near real-time availability**
  - MODIS available online in the second day?
  - NEXRAD available online in 6 minutes
  - NPOESS available online in 15 minutes

- **Cost free or affordable**
  - Most of the federal collected images are free available or lower cost, while commercial high resolution images are affordable.

- **Integrated remote sensing and GIS**
  - Remote sensing applications with the support of GIS
  - Remote sensing data as a major GIS data source
Major image processing software

- ENVI/IDL: http://www.rsinc.com/
- ERDAS Imagine: http://www.gis.leica-geosystems.com/Products/Imagine/
- PCI Geomatics: http://www.pci.on.ca/
- ER Mapper: http://www.ermapper.com/
- INTEGRAPH: http://imgs.intergraph.com/gimage/
- IDRIS:
- Ecognition: http://www.definiens-imaging.com/ecognition/pro/40.htm
- See5 and decision tree