

Imaging Spectroscopy

Definition

- “the simultaneous acquisition of images in many relatively narrow, contiguous and/or noncontiguous spectral bands throughout the ultraviolet, visible and infrared portions of the electromagnetic spectrum” (Jensen, 2005)

Spectroscopy

- capabilities extend remote sensing into fields of spectroscopy
- science devoted to detailed examination of very accurate spectral data
- spatial *vs.* spectral

Origins of Classical Spectroscopy

- Isaac Newton (1642-1727)
 - used glass prisms to separate visible light into spectrum of colors
- William Wollaston (1766-1828)
 - noted spectra displayed dark lines when light projected through a narrow slit
 - what's the meaning of this?

Origins of Classical Spectroscopy

- Joseph Fraunhofer (1787-1826)
 - German glassmaker who discovered distinctive lines in spectra of light from the sun & stars
 - dark lines (*absorption spectra*) are observed as radiation passes through gases at low temperature
 - bright lines (*emission spectra*) form as heated gases (i.e., sun's atmosphere) emit radiation
 - lines have origins in chemical elements present in the gasses
 - astronomers can investigate differences in chemical composition of stars and planets

Origins of Classical Spectroscopy

- Neils Bohr (1885-1962)
 - character of Fraunhofer lines determined by atomic structure of gases

Instruments in Spectroscopy

- Spectroscopes (visual examination of the spectrum)
- Spectrographs (arranged, so can be photographed)
- Spectrometers – instruments designed to collect radiation with a lens & divide it into spectral regions
 - use prisms or diffraction gratings
 - radiation then recorded on film or recorded electronically

Applications of spectra

- apply to problems in astronomy
- apply in laboratory analysis to characterize unidentified materials

Spectral signature

- High resolution – spectrally – radiometric measurement over a broad spectral region
- Surface units can be separated, classified & identified based upon some unique characteristics in their reflectivity spectrum
 - Diagnostic absorption band or combination of absorption bands
 - Diagnostic reflectivity change at a certain wavelength
 - Ratio of reflectivities in 2 separate spectral regions

Hyperspectral Remote Sensing

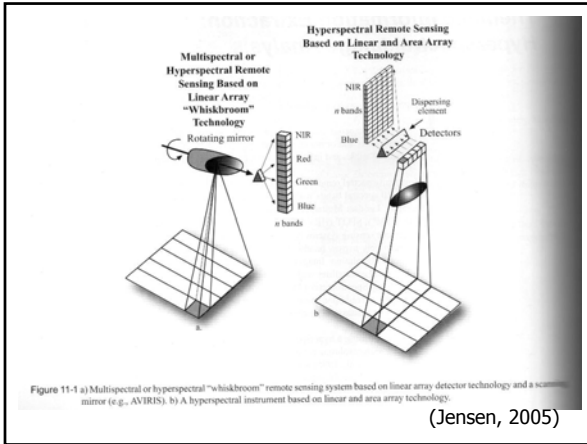
- applying the practice of spectroscopy to examine reflected solar radiation
- make precise, accurate & detailed spectral measurements (*imaging spectrometry*)
- match observed spectra to those in data bases (*spectral libraries*)
- instruments used for areas – not point targets (like stars or lab samples)
- fine spectral, spatial & radiometric resolutions

Hyperspectral Remote Sensing

- careful calibration of instrument
- 200+ channels at 10 to 12 bits
- examines very detailed spectra for images of the earth's surface
- applies corrections for atmospheric effects
- matches them to spectra of known features

Hyperspectral Scanners

- called imaging spectrometers
- acquire data in many, very narrow, contiguous spectral bands (visible, near IR and mid IR portions)
- 200 bands of data



Hyperspectral Scanners

- helps to discriminate features that have diagnostic absorption & reflection characteristics "lost" within coarse bandwidths of conventional MSS
- Example:
 - Landsat TM 7 – 2.08-2.35 μm – 0.27 μm wide
 - imaging spectrometer can acquire data over this range using bands 0.01 μm wide

Airborne Visible-Infrared Imaging Spectrometer (AVIRIS)

- developed by NASA & JPL – tested 1987, in service 1989 on
- 224 channels, 9.67 nm wide, 0.4-2.45 μm spectral range
 - 4 separate panels (0.4-0.7 μm , 0.7-1.3 μm , 1.3-1.9 μm , and 1.8-2.8 μm)
 - each panel calibrated separately
- operates 20 km above ground – NASA's ER-2 research aircraft
 - line of data is 614 pixels, pixel size of 20 m
 - produces 11 x 11 km scenes

Spectral curves

- Examples

Image Cube

- representation of hyperspectral data as a 3-D figure
- two dimensions formed by x & y axes of usual image display
- 3rd dimension z formed by accumulating spectral data as additional bands

Image Cube

- top of cube is data at shortest wavelength (ultraviolet)
- bottom formed by spectral channel at longest wavelength (2.5 μm)
- intermediate wavelengths are found as slices through the cube



Data Libraries

- *spectral libraries*
- maintained by gov't agencies (JPL, TEC, USGS)
- libraries assemble spectra that have been acquired at test sites
 - data acquired from various terrain & climate zones
 - under range of illumination conditions
- identification and cataloging of spectral data
- spectral matching process



Spectral mixing analysis

- linear mixing vs. nonlinear mixing
 - Mixed pixels
- spectral mixing analysis – spectral unmixing
 - more precise identification vs. broad classes of features (unsupervised classification)
 - separate pure from impure pixels
 - identify endmembers



Analysis Tools for Hyperspectral Sensing

- view as a "cube" - lines x columns x bands – front is a color composite, top & right edges are the information in the rest of the bands
- multi-temporal analysis – look at average pixel values at different times – sensitive to phenological stages of the plant
- expert system-based procedures to match spectrum for each pixel to libraries of laboratory spectra for various minerals



Analysis Tools for Hyperspectral Sensing

- assume unique absorption ("valleys") characteristics of various material types
- look for features such as number of low points in a curve, their wavelength location, width, depth & symmetry



Analysis Tools for Hyperspectral Sensing

- detection of "red shift" – slope of reflectance spectrum over 0.68-0.76 μm
- shifts to longer or shorter wavelengths document changes in chemical & morphological status – changes the chlorophyll reflectance
- detect & map previously hidden mineral deposits (biogeophysical mapping)



Applications

- Environmental site characterization
 - contaminant distribution and/or surface properties
- Natural resources management, exploration & extraction
 - identify or map specific minerals or rock types
 - petroleum exploration: map surface distribution of rocks with certain characteristics (organic content, porosity) & tie this info with subsurface data



Applications

- Forestry, agriculture & ecosystems analyses
 - differentiations between species & plant health within species
- Military & intelligence applications
 - adds confidence to interpretations of high spatial resolution data
 - military operations: can accurately assess target identity, attributes & defenses than with conventional remote sensing imagery
 - reduced decision risk, increases chances of making correct decisions – saves lives, achieve goals in military action



New Millennium Program Earth Observation (EO)-1

- EO-1 Hyperion – launched 21 Nov 2000
 - 30-m spatial resolution; 7.5 km swath
 - 242 channels (0.36-2.6 μm – 0.010 to 0.011 μm width)
 - 6 nm VNIR – 12 nm SWIR
 - S:N ratio
 - 100 VNIR – 130 SWIR
- formation flights with Landsat-7 & EOS-AM satellites
- <http://eo1.gsfc.nasa.gov/>



Summary

- vast amounts of data
- problems in collecting & analysis prevent routine use of hyperspectral data
- basis to discover & refine the knowledge needed to develop improved sensors
- develop analytical techniques that can be applied on a more routine basis



Summary

- monitor long-term research (LTR) sites (biophysical processes that change over time)
- provides detailed information for ecological monitoring
- understand patterns of lower-resolution data recorded at same sites



Web sites

- http://www.techexpo.com/WWW/opto-knowledge/IS_resources.html