Remote Sensing 4113
Spring 2018
Midterm Exam Review Outline

The following is a general outline of topics which may be covered on the midterm exam. This is a list of the topics, not the material itself. For that material you'll need to review the text by Sabins, your lecture notes, the "PowerPoint" presentations, and for the recent EOS satellite systems, the official NASA web sites listed below.

While you do need to know facts, the emphasis will not be on memorizing details about the multiple types of remote sensing systems described in the text. It is more important that you treat those systems as examples of basic principles which determine the capabilities of remote sensing systems, and as examples of the basic techniques which we use to interpret the remotely sensed surfaces. Understand those basic principles and techniques. The one system we will cover in considerable detail, both as an important example, and as an important on-going source of data, is the Landsat Thematic Mapper.

Besides material from the lecture, material covered in the labs may also appear on the midterm exam. I haven't listed that material explicitly in this outline. Review your lab reports.

We'll spend most of Fri. Mar 2 or Mon. Mar 5 reviewing the material. Come with questions.

The exam will be closed book and closed notes but you should bring a calculator. I'll provide a list of equations and constants, but you will need to know how to use them.

Chapter 1: Introduction

Properties of light
- Electromagnetic wave nature of light.
- Relationship between frequency, wavelength, speed
- Polarization
- Spectral regions
  - Names of regions (UV, Visible, Near-IR, etc.) and relative size of λ
  - Approximate λ ranges for UV through Radio regions
  - Approximate λ for primary visible colors
- Interaction of light with matter
  - transmission, absorption, emission, scattering, reflection
  - index of refraction and speed of light in matter
- Atmospheric effects
  - scattering, absorption

Image characteristics
- Scale, brightness, contrast ratio, spatial resolution, spectral resolution
  - Definition of contrast ratio
  - Relationship of spatial resolution to range and resolving power

Human Vision
- General structure of eye and approximate resolution

General properties of scanning and imaging systems

You should understand what determines the fundamental characteristics of different systems such as:
- general scanning modes
- relationship between total field of view (FOV),
- instantaneous FOV (IFOV), scan parameters, focal length, range, etc.

Also you should have a general understanding of how multispectral, hyperspectral, and other sensors are built. However I don't expect you to memorize the characteristics of the many different types of sensors listed in the text. The one you should be familiar with is the Thematic Mapper (and ETM) on Landsat. If I give you the characteristics of others, such as the ASTER sensor on EOS, you should understand what those characteristics mean and how they impact the type of measurements those systems can make.

General properties of spectral curves (Fig 1-17)
- Reflective properties of vegetation, water, "typical" rock, soil, and clay

Chapter 2: Photographs from aircraft and satellites

I view this chapter as a general introduction to image analysis and color properties, whether obtained with photographic or other more modern digital techniques.

- Atmospheric scattering – which wavelengths are most affected
  - Equations for how scattering effects contrast ratio (CR).
- Relationship of angular and ground resolution and range
- Photographic scale and its relationship to focal length and range
- Geometry of aerial images
  - Relief displacement
  - Orthophotographs
  - Stereo imaging, principal points, vertical exaggeration, and application to dip and strike
  - Effect of sun angle
- Panchromatic black-and-white photographs
- Color and color-infrared photographs
  - nature of human color vision
  - additive and subtractive colors
  - (Note – I don't care about the detailed structure of color films as shown on pg. 54-55, but you should understand the principles by which these films work, since those are applicable to all color imaging, and to how you will perceive computer generated false color images.)
  - Signatures of typical materials in color and color-infrared images:
    - vegetation, red soils, water, etc.
- General types and properties of aerial and satellite images available – for example typical resolutions, field-of-view – but not specific properties of the many systems listed in the text.

Chapter 3: Landsat images

Unlike the many other instruments, you should have a more detailed knowledge of the characteristics of the Landsat system. That doesn't mean memorizing all the bands and λ ranges, but you should know number of bands, general colors or wavelength regions of the bands, their different spatial resolutions, and their general uses for interpreting different types of terrain. You should also know the general properties of the Landsat orbit. Concentrate on the TM instrument from Landsat 4 and 5, and know the enhancements added to the ETM instrument on Landsat 7. Also understand how the Operational Land Imager (OLI) on the new Landsat 8 (=LCDM) mission differs from the TM instruments on previous Landsats.

TM Information:

Band information: Bands 1-4 = B,G,R, Near-IR 30 meter resolution
Bands 5, 7 two SWIR channels at ~1.6 and 2.2 μm 30 meter
Band 6 TIR channel at ~11 μm. 120 meter

ETM: Improve TIR resolution to 60 meters, add 15 meter visible panchromatic channel

Landsat 8:

OLI: (Operational Land Imager) Pushbroom sensor.
Bands similar to TM but with subtle changes
(and bands renumbered, but you don't need to know those new numbers)

TIRS: Thermal InfraRed Sensor) Pushbroom sensor.
Two thermal bands in 10-12 μm region

Orbit characteristics:

(don't memorize values – but know what they mean and what they imply for the observations)
Altitude and swath width
Repeat cycle, sun synchronous, time of overflight
Path and Row coordinate system

Interpretation of images

Using different bands for recognizing different surface types: (Tables 3-4 and 3-5)
Appearance of dip slopes and anti-dip scarps
Appearance of folds, synclines, anticlines, faults, lineaments

Chapter 4: Other Satellites, plus (from lectures) newer satellite systems (EOS) and hyperspectral instruments

Don't try to memorize all the satellite systems. Do know the different classes, for example the advantages and disadvantages of data from the polar vs. geosynchronous "weather" satellites. Be familiar with the general properties of NASA's EOS (Earth observing system) satellites Terra and Aqua, in particular the general characteristics of the Aster and Modis instruments on them. Also, understand the different designs needed for and the advantages of hyperspectral (as opposed to multispectral) systems.

Existence of higher resolution systems such as SPOT's 10m resolution PAN camera – and what applications need that high resolution.

The National Oceanic and Atmospheric Administration (NOAA)'s two main satellite systems:

GOES (Geostationary Operational Environmental Satellites) for near-continuous monitoring of the whole earth.

POES (Polar Operational Environmental Satellites) for frequent (~1/day) repeat cycles across the earth.

AVHRR Advanced Very High Resolution Radiometer on board POES
- Its use for climate, forest fire, and volcanism warning systems.

The NASA EOS system (from the lectures – or the NASA web sites)

TERRA and AQUA – in Landsat like orbits with AM (TERRA) and PM (AQUA) sun synchronous orbits

The ASTER instrument on Terra
- Higher spatial resolution than Landsat TM, but smaller swath widths.
- Targeted rather than automatic "survey" mode data.
- Still "multi-spectral", but with the SWIR and NIR channels broken up into several bands to provide more spectral information.
- Info at http://asterweb.jpl.nasa.gov/

The MODIS instrument on both Terra and Aqua
- Lower spatial resolution but wider swath widths for ~1 or 2 day repeat cycles
- A few general purpose plus many (few dozen) special purpose bands
- Use in ocean, forest fire, etc. monitoring programs.
- Info at http://modis.gsfc.nasa.gov/

Hyperspectral instruments

AVIRIS: **A**irborne **V**isible / **I**nfra**r**ed **I**maging **S**pectrometer
Hyperion: On board EO-1 (NASA 2001 experimental satellite)
both with >200 bands in 0.4 – 2.5 μm region
Detailed mineral (or vegetation) composition from higher resolution spectra

You are also responsible for the following topics covered in lecture, but not in Sabins.

- Causes of mineral bands which can be examined with hyperspectral resolution
  - Electronic and "Charge Transfer" bands in UV and visible
  - Vibration bands
    - Infrared active gasses such as H_2O and CO_2
      - Reason these are IR active while O_2, N_2 are not
    - Vibration bands of minerals
      - OH (in clays, etc) at ~3 μm
      - SiO (in silicate rocks) at ~10 μm
  - "Crystal field" bands due to Fe (in many minerals) at 0.9 – 2.0 μm
    - How composition of mineral causes shift in wavelengths of bands

- Effects of mineral physical state on reflection spectra
  - Macroscopic mix = "checkerboard" or "linear mixing" on large scale
  - Microscopic mix = "intimate mix" on small scale
    - In microscopic mix darkest material at each wavelength dominates
  - Effects of particle size and moisture on strengths of absorption

Chapter 5: Thermal infrared images

- Heat and the Kelvin and Celsius temperature scales
- Heat transfer: Conduction, Convection, Radiation
- Difference between "reflected" and "thermal" regions of IR region
- Greenhouse gasses and atmospheric absorption
- Thermal radiation laws
  - Know how to use them
  - Know form of the temperature dependence for the first two:
    - Wien's Displacement law for λ_{max} = 2900 μm K / T
    - Stephan-Boltzmann law $F = \varepsilon \sigma T^4$ with $\varepsilon = 1$ for blackbody
  - Planck law for $I(\lambda) = \varepsilon B(\lambda,T)$ – don't memorize B but know how to use it to find I if λ,T is given, or find T if I,λ is given.
  - Understand general shape of the Planck curve vs. λ as T changes as shown in Fig. 5-2.

- Conductivity rules and related properties
  - Definition of and implications of:
    - Conductivity K
    - Heat capacity c
    - Density ρ
    - Thermal inertia $\gamma = P = (K \rho c)^{1/2}$
    - Thermal diffusivity $\kappa = K/(\rho c)$ (also called k in Sabins)
    - Albedo A

    - Apparent thermal inertia $ATI = (1-A)/(\Delta T)$

  - Shape of diurnal variation curves (Fig. 5-7) and how that changes with thermal inertia

- Interpretation of IR images
  - Characteristics of day and night images, and changes between them
  - General characteristics of different surfaces: rock, water, vegetation, wet vs. dry soil, clay

- Thermal emission spectra
  - Definition of "emissivity" spectra
  - Uses in determining mineral composition
  - Shifting ~10 μm band center for different silicate composition

Chapter 6 and Chapter 7 will be on the final, but not on the midterm

Chapter 8 – Digital image processing

- Understand how we represent images using digital systems:
  - Relationship betweein number of bits and number of data levels
  - Meaning of the DN (Data Number) histogram plots
- Image enhancement involving Linear, Linear 2%,
  - and other contrast and brightness stretching techniques