Professional Development Short Course On:

Remote Sensing Information Extraction

Instructor:

Dr. Barry Haack

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Remote Sensing Satellites and Information Extraction

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Objectives and Outline

- Definitions\vocabulary\concepts of RS
- Current status of satellite RS
- Information extraction methods RS
- Remote sensing links with GIS
- Case studies
Case Studies

- Omo River Delta Growth – Kenya
- Agriculture and Change – Afghanistan
- Mapping and Monitoring Urban Growth – Nepal
- Land Use Mapping and Change – Mt. Everest
- Ratio Estimation for Rice – Bangladesh
- Radar and Optical Data Fusion – Sudan, Nepal
Remote Sensing

- Collection of information without direct contact
- Remote sensing primary source of spatial data
- Maintains a historical record of the Earth’s surface
- Provides current information
- Allows for change detection and predictive models
RS Information Extraction
Methods

- Visual/manual/photographic/optical from hard or soft copy products
- Digital/numerical/computer/quantitative
  - Image enhancement
  - Automated classification
- Some hybrid or combination techniques
- “Art and science of remote sensing information extraction”
Remote Sensing Roles

- Base maps
  photogrammetric considerations
  generally air photo based (hyperspatial - spaceborne)
  great spatial detail
  contours, transportation, buildings, utilities
- Thematic information
  single or multiple classes
  often spatially generalized
  focus of this workshop
Major Issues RS Integration to GIS

- Geometric rectification to coordinate system
- Cartographic generalization - scale compatibility
- Data structure (raster - vector)
- Error - accuracy
Resolution in Remote Sensing

- Spatial, degree of spatial detail, meters, pixel size
- Spectral, number and types of energy - wavelengths
- Temporal, frequency of acquisition, days or hours
- Radiometric, discrimination in energy recorded (bits)
- Concept of resolutions useful for remote sensing data evaluation
  data specifications for informational needs
Spatial Resolution
Remote Sensing Platform

- Height above surface
- Airborne or spaceborne
- Historically tradeoff - footprint and spatial resolution
  - low altitude, small footprint - large spatial detail
  - high altitude, synoptic view - low spatial detail
- Exceptions in national assets\intelligence data and recent spaceborne systems
Remote Sensing Platform Tradeoff; Spatial Resolution vs Footprint/Synoptic Coverage

Object, area or phenomenon within the field-of-view of the sensor system
Electromagnetic Spectrum

- Classified by wavelength and frequency
- Inverse relationship - wavelength and frequency
- Wavelengths in micrometers (one one-millionth meter)
- Reflected or emitted energy

<table>
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<th>Wavelengths</th>
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<th>Applications</th>
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<tr>
<td>1m</td>
<td>radar</td>
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</table>
Electromagnetic Spectrum

The Electromagnetic Spectrum includes:
- Gamma Ray
- X-Ray
- Ultraviolet
- Infrared
- Microwaves
- Radio Waves

The Visible Spectrum includes:
- Ultraviolet
- Violet
- Blue
- Green
- Yellow
- Red
- Infrared

Wavelength (nm): 400 - 700
Energy Flow Profile

- Energy source
- Source to surface
- Interaction at surface
- Surface to sensor
- Sensor to user
Components Of EFP; Wavelength, Time and Location Dependent
Selected Spectral Signatures - Reflectance Curves
Signature Extension Problem

- Signatures are highly variable
- Signatures may not be unique
- Signatures may be too unique
- Mixed pixel problem (mixel)
- Signatures cannot be extended over time or space
Operational Spaceborne Remote Sensing - Classes

- Medium spatial resolution multispectral (10 to 100m)
- Radar
- High spatial resolution (<10 m)
- Low spatial resolution multispectral (>100 m) includes meteorological
- Hyperspectral
Landsat Orbit Parameters

- 570 mile or 920 km height
- 16 to 18 day repeat coverage
- Near polar NE to SW orbit
- 81 north to 81 south
- Sun synchronous 9:30 am
- Archived by global path/row location
- All data free from USGS – EROS since January 2009 (~1,000,000 frames distributed)
Since 1982, Landsats 4 and 5
Seven spectral bands, VB, VG, VR, NIR, MIR, TIR, MIR
30 meter pixel, 120 m TIR
256, 8 bit radiometric resolution
Enhanced Thematic Mapper ETM+
Landsat 7  1999
Seven bands
Panchromatic band at 15m
System difficulties, May 2003, Landsat Data Continuity Mission LDCM (2011)/Data Gap?
SPOT

- French, Five since 1986, Linear array or push broom
- SPOTs 1 to 3
- 10 m panchromatic, 20 m three band multispectral
- 60 by 60 km format
- Pointable sensor, stereo - greater temporal resolution
- SPOT 4  1998
  Added fourth MSS band (Mid IR 1.5 to 1.75)
- SPOT 5, 2002
  2.5 and 5 m panchromatic at 60 km swath
  Vegetation mapper on 4 and 5 at 1km. Daily
ASTER

- US and Japan, 1999, research, Terra platform
- Advanced Spaceborne Thermal Emission and Reflection Radiometer
- 14 Bands, three visible/NIR, 15 m
- six SWIR/MIR, 30 m
- five TIR, 90 m
- 60 km swath
- 5 day temporal resolution in vis/NIR
- stereo possible, DEM
- Archive exists, on-demand instrument
Advantages of Radar

- Day and night
- Weather independent / cloud penetration
- Vegetation and surface penetration
- Determine distance IFSAR DEM
- SLAR  Side Looking Airborne Radar
- SAR  Synthetic Aperture Radar
RADARSAT

- Canadian
- 4 November 1995 launch RADARSAT 1
- C-band, 5.6 cm, HH polarization
- Programmable incident angle, spatial resolution, and swath/footprint
- Spatial resolution from 8 to 100 m
- Footprint from 50 x 50 km to 500 x 500 km
- RADARSAT 2, 2008, Quad Polarization
Fine Spatial Resolution (< 10 m) Hyperspatial

- **GeoEye**
  - IKONOS, 1999
    - .8 m panchromatic, 3.2 m three band MSS
    - 11 x 11 km footprint, 3-5 day temporal
  - GeoEye 1, September 2008
    - .41 m pan, 1.6 m MSS (3 bands), 15.2 km
- **Digital Globe - QuickBird, 2001**
  - 0.6 m pan and 2.6 m MSS, 1-3.5 days, 16.5 km
  - WorldView=1, 2007
    - 0.5 m pan, 11 bit, 1.7 day revisit, 17.6 km
- **SPOT 5, 2002**
  - 2.5 and 5 m panchromatic, 60 km
- **Variable costs, archive vs new acquisition, ~$25 sq km**
Statistical Nature of Digital Remote Sensing Data

One value per band per pixel
MSS scene – 30 MB
TM scene – 290 MB
File value vs look up table value
Band histograms and statistics
Spectral signature matching
Major Issues RS Information Extraction - Integration to GIS

- Geometric rectification to coordinate system
- Cartographic generalization - scale compatibility
- Data structure (raster - vector)
- Error - accuracy
Visual Image Interpretation

- Geometric correction
  before or after interpretation
  creation of mosaic/image maps
- Classification system (single or multiple classes)
- Class definitions
- Minimum mapping unit (MMU)
- Hardcopy or softcopy data sources
- Conversion to GIS - direct digital, digitizing, scanning
- Accuracy assessment
Land Use/Land Cover; Kathmandu, Nepal
Issues of Automated Classification

- Normally based only on pixel by pixel values
- No context/site/situation which is strength of visual
- Only use digital if visual inadequate
- Not necessarily more accurate or objective
Atmospheric Compensation

- Variations in Energy Flow Profile
- Within scene or between scenes
- Signature extension problem; spatial and temporal
- Match sensor data to known reflectance curves
- Match imagery over time and space
- Very difficult to do effectively
- Often not necessary and simply ignored
  (extract signature from scene)
Initial Statistical Evaluation

- Full study area for display, often sampling
- Digital Numbers (DN)
- Display is normally of stretched data (file vs look-up table)
- Assume normal distribution of data, often is not normal
- Histograms (often bi and multimodal)
- Count zeros or not in statistics?
- File (upper left origin) or Map (lower left origin) coordinates
- Basic statistics; mean, standard deviation, minimum, maximum
- Multivariate measures; Variance and co-variance, correlations
## Sample Scene Statistics

Landsat TM, Charleston South Carolina

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<th>Mean</th>
<th>Std.Dev</th>
<th>Min</th>
<th>Max</th>
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<td>7</td>
<td>111</td>
<td>4</td>
<td>90`</td>
<td>130</td>
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Geometric Rectification (1)

- Often can be vendor supplied
- Registration to other data (scene to scene, no coordinate base)
- Rectification to coordinate system
- Two or three dimensional (often two dimensional, ortho X, Y and Z)
- Select coordinate system (UTM, Lat/Long, State Plane)
- Select geoid datum; NAD27, NAD83, WGS84 etc.
- Use of Ground Control Points (GCPs)
  - Sources; base map, other image, GPS
- Select order of transformation (First, Second, Third, etc.)
  - First order adequate for Landsat
  - Second order for off-nadir such as SPOT
  - Third and higher, rubber sheeting for greater distortions
Geometric 2

- Evaluate transformation based on Root Mean Square (RMS) error
  - Overall and per point, measured in pixel resolution
  - RMS under 1 desirable and possible
- Options to reduce high RMS
  - Delete GGP's
  - Add GCP's
  - Increase order of transformation
- Balance order, GCPs and RMS
  - Fewer GCPs always better RMS
- Apply transformation, change pixel size, spatial resolution
  - Radiometric resampling
Automated Classification -1

- Signature matching process
- Pixel or object oriented
- Difficulties
  - signature not unique for given sensor
  - signature too unique (10 corn fields, 10 signatures)
  - mixed pixels (unmixing with simple covers)
  - atmospheric changes, signature extension issue
Automated Classification -2

- Signature extraction
  training sites or supervised clustering or unsupervised
- Application of a decision rule
- Accuracy assessment
- Spatial filtering for GIS compatibility
Signature Extraction

- Most important aspect, poor signatures always poor results (Garbage in – Garbage out)
- From analysis data set
- Possibly stratify study area
- Supervised or unsupervised
Supervised Signatures

- Training (Calibration) sites (Areas of Interest AOI)
- Prior knowledge of data
- Multiple sites per class
- Minimum size (10 x number of bands) normally much larger
- Use of seed pixel with spatial and spectral constraints
Unsupervised Signature Extraction or Clustering

- Locates pixels of similar spectral characteristics
- Analyst defined number of clusters
- Minimum three times number of expected cover types
- Sometimes hundreds (splitters or lumpers)
- Many clusters insignificant or mixed pixels
- Analyst must identify class for each cluster

- Hybrid (combination of supervised and unsupervised)
<table>
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<tr>
<th></th>
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<th>R</th>
<th>NIR</th>
<th>MIR</th>
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<td>1</td>
<td>1</td>
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Accuracy Assessment (1)

- Locational and thematic
- Extremely important - visual and digital extraction
- Spatial data without accuracy of questionable value
- Accuracy should be a component of metadata
- Very difficult and often avoided, embarrassing
- Expensive
Temporal differences often a constraint
Classification the most difficult to evaluate, definitional in part
Major difficulty is identification of ‘truth’ (Validation)
Best if validation at time of data acquisition
Truth must be different from training sites
Method of accuracy evaluation

- Points or polygons
- Sample size (minimum 50 per class?)
- Sample selection; random, systematic, stratified

Numerous statistical procedures for accuracy

- Contingency matrix *
- Errors of omission and commission
- Producers and users accuracies
- Kappa coefficient

Less concern statistical procedure, more with truth
## Contingency Table Sudan

<table>
<thead>
<tr>
<th></th>
<th>Urban</th>
<th>Veg</th>
<th>Other</th>
<th>Totals</th>
<th>Users %</th>
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<tbody>
<tr>
<td><strong>Urban</strong></td>
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<td>335</td>
<td>1,502</td>
<td>17,085</td>
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<td><strong>Agriculture</strong></td>
<td>2,012</td>
<td>3,015</td>
<td>1,159</td>
<td>6,186</td>
<td>48.7</td>
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<tr>
<td><strong>Other</strong></td>
<td>934</td>
<td>200</td>
<td>21,961</td>
<td>23,095</td>
<td>95.0</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td>18,194</td>
<td>3,551</td>
<td>24,622</td>
<td>46,367</td>
<td></td>
</tr>
<tr>
<td><strong>Producers %</strong></td>
<td>83.8%</td>
<td>84.9%</td>
<td>89.2%</td>
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</table>

Correctly Identified Pixels: $\frac{40,225}{46,367} = 86.8\%$
Methods to Improve Information Extraction 1

- Change data input
  - Different sensor
  - Different date
  - Multitemporal
  - Multisensor
  - Context, texture
  - Ancillary data, GIS
Methods to Improve Information Extraction 2

- Change processing strategies
  - Better signatures
  - Change decision rule, hierarchical
  - Neural networks, AI, expert systems,
    - fuzzy logic,
    - regression trees
  - CART
Conclusions

- Multiple RS platforms and sensors in future
- Importance of date of RS data and field work
- Visual information extraction before digital
- Accuracy assessments required
- RS and GIS integration is two directional
- Art and science of RS, visual and digital

- Thank you!
You have enjoyed ATI's preview of
Remote Sensing Information Extraction

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