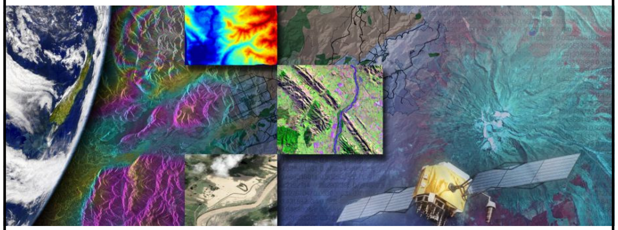
Lecture 6 – Digital Image Processing P2



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Lecture Outline

- Revision
- Image enhancements
  - Contrast stretching
  - Spatial filters
  - Spectral indices
- Information extraction
  - Supervised classification
  - Unsupervised classification
  - Modeling continuous variables – biophysical modeling

Revision

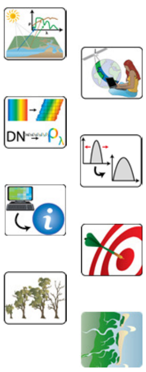
- Group 1
  - The year before last, the eruption of the volcano under the Eyjafjallajökull glacier in Iceland caused disruption and chaos in the aviation industry. How could remote sensing be used to monitor the event?
- Group 2
  - Coral bleaching events have been linked to prolonged periods of above average water temperatures. How could remote sensing be used in a coral monitoring program? Consider both the water temperature monitoring, as well as the health / status of the corals themselves.
- Group 3
  - Gamba grass is an introduced plant pest in the NT, causing widespread environmental problems. How can remote sensing be used to map and monitor its spread?

- Think specifically about the first stage in the image processing sequence and go through the process of defining the required spatial, spectral, temporal, and radiometric dimensions of an ideal data set, and then suggest an appropriate sensor/s system for the role

Resources

- Lillesand, T. M. et al (2008). Remote Sensing and Image Interpretation. New York, John Wiley & Sons, Inc. Chapter 7
- Jensen, J.R. (1996) Introductory digital image processing: a remote sensing perspective. 2nd Ed. Prentice Hall.RSCAL Digital image processing module
- Introductory Image Processing – The Remote Sensing Core Curriculum http://www.cas.sc.edu/geog/rslab/Rscc/index.html
- Canadian Centre for Remote Sensing Outreach materials http://ccrs.nrcan.gc.ca/resource/index_e.php#tutor
- Toolkit for mapping and monitoring coastal ecosystems with remote sensing http://www.gpem.uq.edu.au/cser-rstoolkit
- Image Processing Systems (some with free-ware or trials)
  - www.ermapper.com ER-Mapper
  - www.erdas.com Erdas Imagine
  - www.ittvis.com ENVI / IDL
  - www.definiens.com Definiens

Image Processing Sequence



Problem Definition
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Data Acquisition
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Image Pre-processing
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Image Enhancement
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Information Extraction
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Error Assessment
↓
Multi-temporal Analysis
↓
Information communication for problem solving

Image Enhancement

- Visual interpretation (general/feature specific)
- Increase (enhance) apparent visual distinction (contrast) between features in a scene
- Human interpretation suited to spatial patterns and associations
- Human interpretation not suited to discriminating grey levels
- Types of enhancements:
  - Contrast stretching by altering displayed pixel values
  - Spatial feature manipulation by enhancing/suppressing patterns
  - Multi-spectral manipulation by combining different bands to highlight certain features

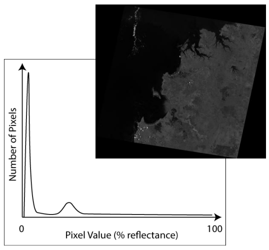
Source: S.Phinn

Types of spectral enhancements

- Contrast enhancements
  - Dynamic (histogram/LUT)
  - Permanent (write LUT values to image)
- Indices
  - Mathematical combination of DN or radiance values for each pixel to provide a synthetic image
  - High correlations are observed between image based indices and biophysical/chemical properties of interest.
- Data reduction
  - Compress multi- or hyper-spectral data sets into one synthetic band
  - Synthetic band correlated to a biophysical feature.
- Data Fusion
  - Pan sharpening

Image Enhancement: Contrast Stretching

- Contrast stretching example using look-up tables:
  - Look-up table or graph maps the image pixel values (x-axis) to displayed values (y-axis)
  - Actual pixel values do not change, only the display changes



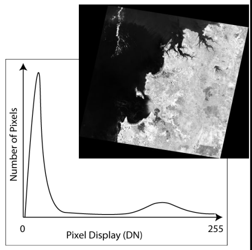
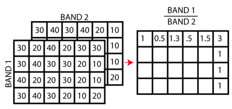


Image Enhancement: Spectral Indices

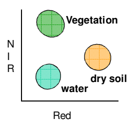
- Multispectral manipulation
  - Combination of selected bands using mathematical transforms
  - Transforms using +, -, * and /
  - Transformation equations are referred to as "Spectral indices"



Normalised Difference Vegetation Index (NDVI) =

$$\frac{NIR - RED}{NIR + RED}$$

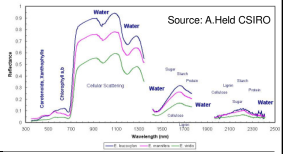
Original SPOT5 image



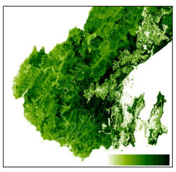
NDVI image derived from the red and NIR bands

Vegetation Indices

- Ratios emphasise difference between:
  - red (chlorophyll) absorption
  - NIR reflectance (leaf/canopy structure)
  - MIR absorption (canopy water content)
- Historical development of vegetation indices from red and NIR measurements
- Biophysical properties of plants highly correlated with SVI's:
  - absorbed photosynthetically active radiation (APAR)
  - % ground cover
  - canopy characteristics
  - biomass
  - leaf area index
  - productivity



Vegetation Indices

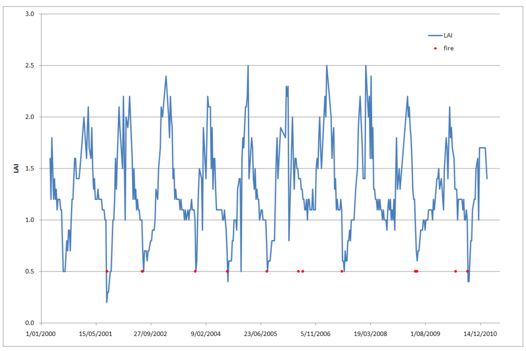


- Simple ratio (SR) = NIR / Red
- Normalized Difference Vegetation Index (NDVI)

$$NDVI = \frac{NIR - R}{NIR + R}$$

- The NDVI is the most widely (and often inappropriately) used SVI
- Problems of NDVI:
  - Terrain effects
  - Additive path radiance
  - Saturation at high biomass levels (due to red light absorption)
  - Soil background influences in areas of low cover
- Broad-band versus narrow band indices

Leaf Area Index (LAI)



SVI limitations

- Sensitivity to non-vegetation factors
- Illumination/topographic effects
- Redundancy of bands?
- Ensure they work in environment being analysed
- Indices suitable for Hyperspectral data?
- Examine slopes, inflection points of spectral signature curves

Spatial Enhancement

- Enhance specific patterns within the image
- High or low spatial frequencies and features with directional orientation
- Enhancement is achieved by using spatial filtering techniques
- Spatial filters = matrix of numbers used to modify image values

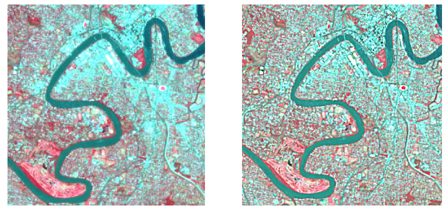
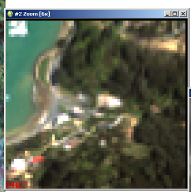


Image Enhancement: Pansharpening



Ikonos Multispectral 4m

Ikonos Panchromatic 1m

Ikonos Pansharpened 1m

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Information Extraction

- Image classification to produce thematic maps
  - Apply statistical decision rules to assign pixels with similar DN's to a thematic or categorical image class
- Biophysical modelling
  - Quantitatively estimate biophysical parameter(s) and processes based in each pixel by using DN's, radiance or reflectance values in empirical or deterministic models
- Spatial Modelling / GIS Integration
  - Combine original and classified image data with other spatially referenced data sets in spatially explicit models

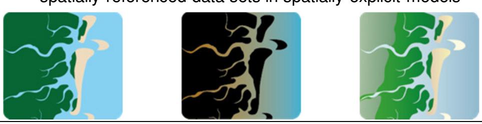


Image Based Analysis for Mapping

- Pixel based "image classification"
  - Main assumption: pixel is smaller than targets
  - Pixel are homogeneous in target
- Image object based "image segmentation"
  - Main assumption: pixel is smaller than targets
  - Objects/classes are not homogeneous – characteristic texture
- Sub-pixel classification
  - Main assumption: pixel is larger than targets
  - Pixel value is an area weighted combination of targets

Source: S.Phinn

Feature Extraction

- Image classification – what is it and why bother using it?
- Main output from image classification is a thematic map
- Processing technique is based on multivariate clustering and the assumption that pixels of a the same land-cover have the same spectral signature
- Implement the classification process by applying statistical decision rules to assign pixels with similar DN's to image classes
- Forms of classification:
  - Spectral pattern recognition
  - Spatial pattern recognition

Source: S.Phinn

The Basis of Image Classification

- Classification
  - Assigning each image pixel to a category based on (spectral) statistical pattern recognition techniques
  - i.e., pixels within the same cover type have similar magnitude DN's
- Goal of image classification
  - To produce a thematic map of surface cover types (e.g. land cover, vegetation type, soil type) by grouping image pixels with similar reflectance characteristics using statistical decision rules.

Image Classification

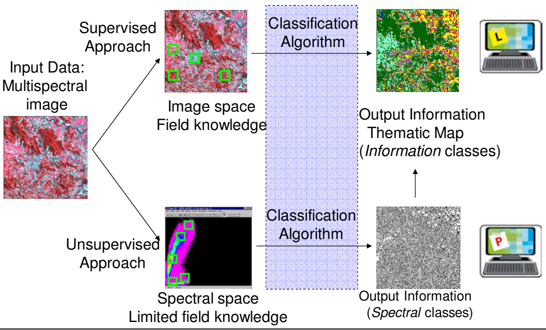
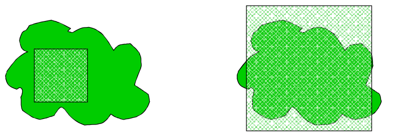


Image Classification Assumptions

- Several major assumptions
  - A high (H) resolution application i.e. each pixel is made up entirely of one surface cover type
  - The pixels making up one surface cover type are assumed to have similar spectral signatures
  - Different surface cover types have significantly different spectral signatures



H resolution – i.e. pixel is smaller than cover type

L resolution – i.e. pixel is larger than cover type

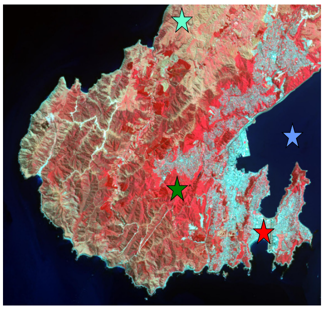
Training Sites – Define Categories / Classes to Map

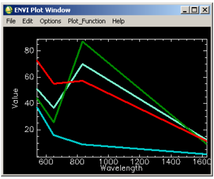
- What is the purpose of the map?
- Identify the variable to be mapped
- Consider the imprecise nature of geographic boundaries and data
- Scale of data suited to mapping requirements
- Application of existing classification schemes pertinent to task (e.g. Anderson et al. 1976, National Wetland Inventory)

Supervised Classification

- Analyst selects training sites for the required information classes
- Analyst specified training sites input into classification algorithm
- Each image pixel is assigned to an information category based on its statistical similarity to the training site for that information class
- Output map of information classes

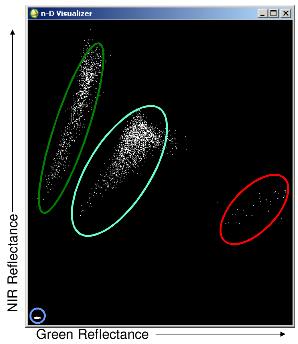
Supervised Image Classification

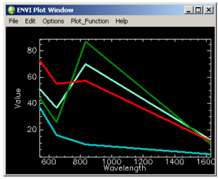




- Water
- Grasses etc
- Dense Veg
- Artificial Surfaces

Spectra Evaluation





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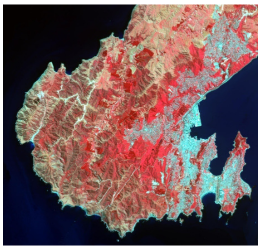
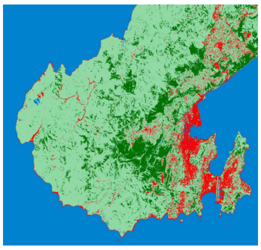
Classification Mapping





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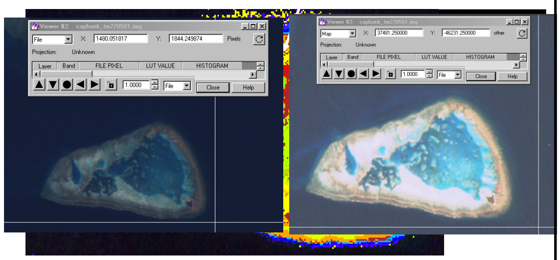
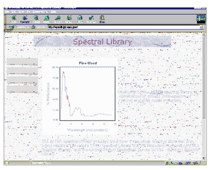
Classification Mapping



One Tree Reef, Landsat ETM B,G,R
27th May 2001

Spectral Signatures and Libraries

- Use of laboratory derived hand-held spectrometer measurements for individual materials (minerals, soils, leaves, water)
- Spectra derived from land cover types in images (field and air-photo references)
- Limitations of existing spectral libraries?
- Spectral libraries range in complexity and accessibility from Excel spreadsheets to interactive web-pages



Source: S.Phinn

Classification – Unsupervised

- Apply algorithm to define clusters of pixels in spectral space (spectral classes)
- Spectral class values are algorithm-defined training sites
- Each image pixel is assigned to a spectral class based on its statistical similarity to the training site for that spectral class
- Output map consists of spectral classes
- Analyst assigns information type labels to each spectral class to produce an information class thematic map

Classification – Spectral and Information Classes

- Spectral Class
  - Defined in spectral space and not associated with any cover type
  - Output from an unsupervised classification
- Information Class
  - Defined from land-cover type
  - Output from a supervised classification

Classification – Contextual Editing

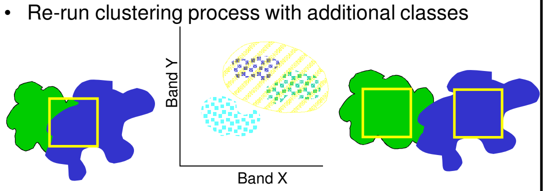
- Information derived from image or non image sources (eg. Elevation, slope, aspect, bathymetry, geology, soils…)
- Improves classification accuracy
- Prior to classification – Geographical stratification
  - Incorporating ancillary data prior to classification
- During classification – contextual logical channel
  - Incorporate additional layers into classification algorithm
- Post classification
  - Rule based
  - Reduces confusion between spectrally similar classes

Classification – Merging Training Sites

- Ultimate goal is to produce training statistics that are statistically separable and will maximise the success of image classification algorithms
- Merge multiple training sites if they are similar
- Group all observations into a single sample and re-calculate summary statistics

Cluster Busting

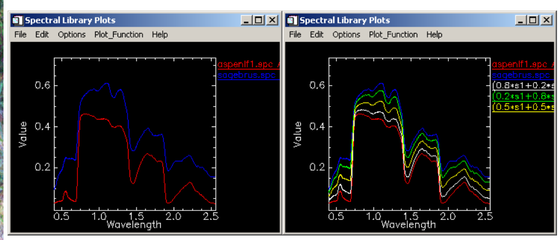
- Initial classification produces classes unable to be named
  - Pixel represents at least 2 feature classes so the pixel doesn't 'look' spectrally like either
  - Statistics did not separate important portions of feature space
- Create new image of 'confused classes'
- Re-run clustering process with additional classes



Subpixel Mapping – Linear Spectral Unmixing

- Determines the relative abundances of materials that are depicted in multi- or hyper-spectral imagery based on the materials' spectral characteristics.
- The reflectance at each pixel of the image is assumed to be a linear combination of the reflectance of each material (or endmember) present within the pixel.
- For example, if 25% of a pixel contains material A, 25% of the pixel contains material B, and 50% of the pixel contains material C, the spectrum for that pixel is a weighted average of 0.25 times the spectrum of material A plus 0.25 times the spectrum of material B plus 0.5 times the spectrum of material C.

Sub-pixel Mapping – Linear Spectral Unmixing



Alternative Classification Methods

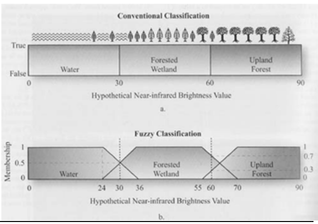
- Hybrid approaches to classification
  - Supervised approach for areas of known cover type
  - Unsupervised approach to cover those areas unable to be classified in the supervised approach
  - Inclusion of non-remotely sensed data sets (e.g. terrain, soils etc)
- Fuzzy or probabilistic classification approaches
- Object oriented image segmentation
- Decision trees
- Other image classification/target identification from
  - Hyperspectral data (curve matching)
  - SAR data (backscatter mechanisms)

Alternative Classifications – Hybrid

- Aim to improve accuracy of pure supervised or unsupervised classifications
- Useful where there is complex variability in spectral response patterns for individual cover types
- Use the unsupervised routine to identify the number of spectral subclasses within the image
- Use the supervised routine in more homogeneous areas of the image
- Combine both supervised and unsupervised for statistics evaluation and overall classification

Alternative Classification – Fuzzy

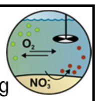
- Recognition that pixels are not all composed of a single feature class
- Takes into account heterogeneous nature of environments
- Each pixel has a number of membership grades according to the proportion of cover types found within the pixel
- Account for gradual transition between cover types rather than precise distinct boundaries



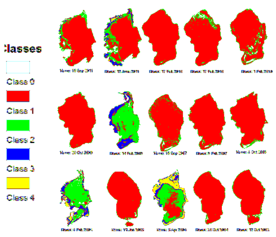
Alternative Classification – Object Oriented Image Segmentation

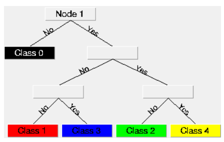
- Incorporate spectral and spatial information
- Useful in h-resolution data (i.e. pixel size is smaller than classes of interest)
- Uses spatial information to identify homogenous areas of pixels
- Can incorporate non-image spatial data
- Alternative to per-pixel classification
- Assigns 'image objects' (polygons) rather than pixels to classes – i.e. more efficient processing
- Covered in more detail later in the semester

Knowledge or Rule Based



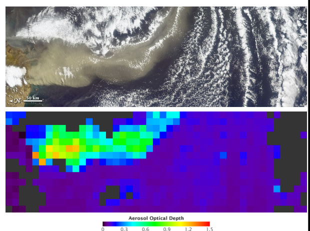
Monitoring water quality of Lake Woods using Landsat 5 TM band ratios (E. Westerhuis, 2012)





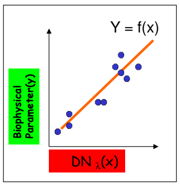
Biophysical Modeling

- Quantitatively relate image DN's to biophysical parameter(s) measured on the ground
- Requires understanding of EMR interactions
- Spatially explicit estimation of physical or biological parameters related to the absorption, transmission or scattering of EMR
  - Crop yield estimation
  - Defoliation measurement
  - Leaf Area Index (LAI)
  - Biomass prediction
  - Fire fuel loads
  - Water depth
  - Pollution concentration
  - Volcanic Ash / gases
  - Soil moisture
  - Aerosols

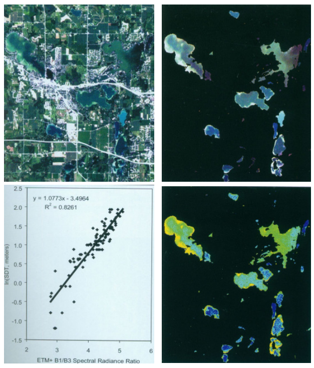


Empirical Models

- Most commonly applied approach for estimating biophysical properties
- Based on the assumption that variations in reflected, absorbed and scattered EMR recorded in image are DIRECTLY controlled by biophysical property of interest



Lake Water Clarity



True Colour Landsat ETM+ image

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Create water only mask image

↓

Plot B1/B3 ratio vs. natural log of water clarity (measured secchi depth)

↓

Determine equation of trendline

↓

Apply equation to ratio image

Source: Plate 36 – Lillesand et al.

Coming Up

- No Practical this week
- Lecture next week – Digital image processing III
- 2nd assessment due next Friday