Beyond Spectral and Spatial data: Exploring other domains of information

GEOG3010 Remote Sensing and Image Processing

Lewis
RSU
Domains of Information

- spectral
- spatial
- angular
- distance–resolved
- multi–temporal
Domains of Information

- recap on spectral / spatial
- consider physical basis for information
Spectral – Physical Basis

- **Optical**
  - reflectance varies with wavelength
  - spectral reflectance of different cover types / properties vary
Spectral reflectance

Related to:
- how much (illuminated) material (seen) reflectsance / absorptance characteristics of materials (+ multiple scattered effects)
Leaves

- Absorbtance by leaf pigments, water etc
- Acting in different parts of the spectrum
Leaves

Factors affecting reflectance/transmittance of plant elements

pigment type/concentration
  e.g. Chlorophyll a,b – absorb visible radiation

surface features:
  hairs, spines, veins, cuticular wax – scattering (e.g. specular)

cell morphology and content
  NIR – high refl. due to scattering at refractive index discontinuities ($n_{\text{air}} = 0; n_{\text{cell}} = 1.47$)

MIR – water absorption features
· So attempt to take RS measurement and relate to
  – cover type
    • different spectral properties)
  – amount of material (eg vegetation)
    • eg leaf
      – high NIR, low visible (basis of VIs
Interpretation complicated by:

- variations in Sun/view angle
Interpretation complicated by:

- projection of objects
  - orientation (leaf angle distribution)
Interpretation complicated by:

- projection of objects
Interpretation complicated

- So relationship between eg VI and canopy variables depends on cover type
  - (different canopy structure)
Microwave

- Similar `spectral´ concepts
  - (frequency $c = f$)
- again related to amount of material
- but very much driven by:
  - water content
  - size of objects (relative to wavelength)
  - orientation
    - effect dept. on polarisation
Spatial Information

- `texture` / spatial dependency / context
- typically use measures of texture
  - size of objects
  - orientation
  - spacing and arrangements
Spatial Information

Directional texture
Spatial Information

- Use:
  - calculate texture measures
    - use to discriminate / classify
    - relate to physical properties (tree spacing etc.)
Baringo, Kenya

`Textures` from tree density – dense to spars
Measure texture using statistical measure of spatial dependency

semivariance
Spatial Dependency

Geostatistics

- points at a small distance apart (A–B; B–C; C–D)
- are more likely to lie on the same object (have the same properties)
- than points further apart (A–C; B–D; A–D).
Spatial Dependency

Geostatistics

- geostatistics – measure/model spatial dependencies using semivariogram
Spatial Dependency

Geostatistics semivariance $\gamma(h)$

- at some `lag distance´ $(h)$ (spacing between points)
  the semivariance is:
  - half of the average (mean) squared difference between the property values at the sample points.

$$
\gamma(h) = \frac{1}{2} \sum (z(x) - z(x + h))^2
$$
Spatial Dependency

Geostatistics – $h = 1$

$\gamma(h) = \frac{1}{2} \sum (z(x) - z(x+h))^2$

θ 1 mean
Spatial Dependency

Geostatistics – \( h = 2 \)

\[
\gamma(h) = \frac{1}{2} \sum \left( z(x) - z(x + h) \right)^2
\]
Geostatistics – $h = 3$

$$\gamma(h) = \frac{1}{2} \sum (z(x) - z(x+h))^2$$
Spatial Dependency

Geostatistics – \( h \)

= 14

\[
\gamma(h) = \frac{1}{2} \sum (z(x) - z(x+h))^2
\]
Features of the semivariogram

- **Range**
  - range of spatial dependency in data

- **Sill**
  - semivariance at and beyond range (half the scene variance)

- **Nugget variance**
  - extrapolated semivariance at lag 0
  - variation at sub-measurement unit
Baringo, Kenya

`Textures` from tree density – dense to spars
Directional Information

- spectral depends on illuminated/viewed amounts of material
- As change view / illumination angles, change these proportions
  - so change reflectance


Directional Information

- Describe directional reflectance by **BRDF**
  - **Bidirectional Reflectance Distribution Function**
- e.g. plot as function of view zenith angle:
Hemispherical-Directional Reflectance Factor (HDFR)
(Near-Infrared Wavelengths)

Solar Zenith Angle = 30°
Canopy LAI = 2.0

Backscattering  Forward Scattering

View Zenith Angle (degrees)
Features of BRDF

- General upwards bowl shape for most biomes
- Retro–reflectance peak (‘hot spot’)
Features of BRDF

- Bowl shape
  - increased scattering due to increased path length through canopy
Features of BRDF

- Bowl shape
  - increased scattering due to increased path length through canopy
  -
Features of BRDF

- Hot Spot
  - mainly shadowing minimum
  - so reflectance higher
Features of BRDF

- Also
- orientation of leaves etc.
  - projection
  - quantify through eg leaf angle distribution
Use of directional information

- Discrimination / classification

Green, red, nir, swir
Use of directional information

Parameterisation of surface conditions

build model of physics of effect of surface properties on reflectence

invert model against RS BRDF measurements
Distance–resolved

- Can determine distance from satellites:
  - based on time–delay of signal
Distance–resolved

- Can determine distance from satellites:
  - based on time–delay of signal
Distance–resolved

- eg GPS
Distance–resolved

- EO example:
  - radar interferometry
Distance–resolved

• EO example:
  – radar interferometry:
    • assume know satellite position

\[2 \times d_1 = (N_1 + (\frac{3}{4} + \frac{1}{2})) \times 5.6\]

\[\frac{3}{4} \text{ way through half cycle}\]
\[
\left(\frac{3}{4} + \frac{1}{2}\right) \times 360 = 315 \text{ degrees}
\]

1 cycle (5.6 cm for C band)

\[\frac{3}{4} \text{ way through 270 degrees}\]

(360 degrees, 2 radians)
Distance–resolved

- EO example:
  - radar interferometry:

\[ 2 \times (d_2 - d_1) = (N_2 - N_1) \times 5.6 + ((\frac{3}{4} + \frac{1}{2}) - 0) \times 5.6 \]

\[ 2 \times d_2 = (N_2) \times 5.6 \]
Distance-resolved

- EO example:
  - position 1:
    \[ 2 \times (d_2 - d_1) = (N_2 - N_1) \times 5.6 + ((\frac{3}{4} + \frac{1}{2}) - 0) \times 5.6 \]
  - position 2:
    point on ground next to current point will have different phase change
    if its within the same cycle (height change less than 5.6cm)
    - can tell relative height change between these points
    - very precise (mm)
Shuttle Radar Topography Mission
Shuttle Radar Topography Mission

11 Feb 2000 (Endeavour) – 11 days
30m DEM of +/- 60 degrees latitude
Distance-resolved

Measure small change – subsidence
Distance-resolved

Measure small change – earthquake
Distance–resolved

RADAR
RADio Detection And Ranging

LIDAR
LIght Detection And Ranging
Distance–resolved LIDAR

- Send laser pulse from sensor
- measure round trip time
- \( = 2 \times \text{distance} \)
- 
  - use NIR mostly
    - atmospheric effects minimised
Distance–resolved LIDAR

- Examples – EA
- fly airborne LIDAR regularly for high resolution DEM
- use first/last return
- ground height / tree height
Distance–resolved – LIDAR
Distance–resolved LIDAR

- Examples – VCL
- Vegetation Canopy LIDAR
- NASA mission to fly 2000
- waveform LIDAR
Distance-resolved VCL

- waveform LIDAR
Distance–resolved waveform LIDAR

SCANNING LIDAR IMAGER OF CANOPIES BY ECHO RECOVERY (SLICER)

RETURN PULSE WAVEFORM

RETURN ENERGY

CROSS-TRACK LASER PULSES

GROUND RETURN

CANOPY TOP RETURN

height = 15 m

height = \frac{\text{travel time} \times \text{light speed}}{2}

NASA/GSFC Codes 924 and 921
Figure 2. Volumetric renderings of the LVIS data from La Selva depicting vertical (a & b) and horizontal (c) cross-sections and canopy rugosity (d). The z-axis was exaggerated to emphasize the vertical resolution (0.2997 m) of the sensor. Footprints from the non-rectilinear flightline (Fig. 1) were repositioned into a regular grid.
LIDAR

- `Simple´ form of measurement
- easy to use (? Simply)
- doesn´t work (well) on high slopes
- requires highly–sensitive instrumentation
- potentials for new forms of information
  - waveform LIDA
Interferometry

- Used for number of years
  - operational (SRTM)
- different `scales´ for different SAR frequencies
- doesn´t work well (for height) if change between images
  - wind in forests
- doesn´t work on high slope