Forest Discrimination Analysis of Combined Landsat and ALOS-PALSAR Data

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Presentation Outline

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  • motivation

• Data and Study Area
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  • PALSAR and Landsat TM datasets
  • data pre-processing

• Combined SAR–Optical Forest Classification
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  • maximum-likelihood classification (MLC)
  • band information (variable selection)
  • classification results

• Conclusion
  • summary of main outcomes
  • strategies for non-coincident data processing
Background

Assess and take advantage of the **complementarity** and **inter-operability** of radar and optical sensors for forest mapping and monitoring

Motivation

- technological advances in Synthetic Aperture Radar (not cloud-affected) complement the existing optical datasets
- **GEO-FCT**: Forest Carbon Tracking task of the Group on Earth Observations (in support of global forest carbon estimation)
- Australia’s response to GEO-FCT: International Forest Carbon Initiative (**IFCI**) to increase forest monitoring capacity
- further development of the National Carbon Accounting System (**NCAS**) developed by CSIRO: continental Landsat-based forest monitoring system
Data and Study Area

Pilot study area

- north-eastern Tasmania
- calibration site defined as part of Australia’s GEO-FCT demonstrator under IFCI
- 66km x 50km area
- main land covers:
  - dry & wet eucalypt forest
  - non-eucalypt forest
  - rainforest
  - plantations / deforestation
  - agriculture & urban areas
- significant topographic variations (elevation: 80m to 1500m)
Datasets

**ALOS-PALSAR**
- fine-beam dual polarisation (HH and HV), L-band (~24cm)
- ascending orbit (34.3 off-nadir)
- pre-processed to 25m pixel size

**Landsat TM**
- 6 spectral bands (thermal band omitted), 25m pixel size
- from the NCAS archive of MSS/TM/ETM+ imagery
- acquired Jan./Feb. 2008
SAR terrain illumination correction
Correct for illumination differences on forward/backward facing slopes

[Zhou et al., “Terrain slope correction and precise registration of SAR data for forest mapping and monitoring”, ISRSE 2011, Sydney]
Data Pre-Processing

Assessment of SAR–Landsat co-registration

- feature cross-correlation using 299 GCPs
- ~0.6 pixel combined RMS error (25m pixel size)
- 98% of residuals below 1.5 pixels

(HH,HV,Landsat Band 5)
SAR–Optical F/NF Classification

**Step 1**: definition of spectral classes using Canonical Variate Analysis (CVA)

230 training sites selected for the classification, representing a broad range of landcover types over the study area

Analyses are carried out for:
1. Landsat data only (6 bands)
2. PALSAR data only (2 bands)
3. combined SAR–Landsat data (8 bands, concatenated)

**Canonical roots** (measure of separability):
1. Landsat only: **18.9 8.6 3.2**  1.7 1.1 0.5
2. PALSAR only:  24.0  2.9
3. combined SAR–optical data: **28.9 12.6 7.7 3.3**  1.8 1.3 1.1 0.4

Plot of training sites in CV1-CV2 space for combined PALSAR–Landsat data (4 out of 6 sub-classes shown). Colour legend: forest sites, non-forest sites, cleared/growing plantations.
**Step 2: Maximum-Likelihood Classification (MLC)**

... using the spectral classes defined by CVA

**MLC example** in the Ben Lomond region: alpine heathland (shrubs)

PALSAR (HH/HV/HH-HV) | Landsat (bands 5/4/2) | TASVEG reference
---|---|---
SAR F/NF classification | Landsat F/NF classification | SAR–Landsat classification
**SAR–Optical F/NF Classification**

**Band information**

- **variable selection**: percentage of total F/NF information provided by the Landsat and PALSAR bands (and their combinations)
- contrasts between various subclasses (clusters) of forest and non-forest sites

<table>
<thead>
<tr>
<th>Bands</th>
<th>F vs. NF</th>
<th>Contrast 1</th>
<th>Contrast 2</th>
<th>Contrast 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>HH</td>
<td>16.3%</td>
<td>23.7%</td>
<td>31.7%</td>
<td>3.9%</td>
</tr>
<tr>
<td>HV</td>
<td>67.8%</td>
<td>50.8%</td>
<td>24.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>HH+HV</td>
<td>68.0%</td>
<td>54.7%</td>
<td>39.1%</td>
<td>4.3%</td>
</tr>
<tr>
<td>TM (6 bands)</td>
<td>59.2%</td>
<td>73.6%</td>
<td>41.0%</td>
<td>98.6%</td>
</tr>
<tr>
<td>TM + HH</td>
<td>68.1%</td>
<td>82.2%</td>
<td>84.5%</td>
<td>100.0%</td>
</tr>
<tr>
<td>TM + HV</td>
<td>99.8%</td>
<td>98.9%</td>
<td>79.9%</td>
<td>98.9%</td>
</tr>
<tr>
<td>TM+HH+HV</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

Plot of training sites in CV1-CV2 space (excluding sites from the ‘water’ class) for SAR–optical data. **Colour legend**: forest sites, non-forest sites, cleared/growing plantations.
Multi-Temporal SAR–Optical Processing

- assume that the datasets are **not** coincident temporally
- separate forest probability maps from each dataset
- refinement of the single-date forest classifications using a Bayesian Conditional Probability Network (CPN): spatial-temporal model
Conclusion

Summary

• SAR and optical sensors are inter-operable and provide complementary information for forest mapping and monitoring
• jointly considering PALSAR and Landsat data improves the forest/non-forest classification significantly:
  ◦ adding SAR bands (HH+HV) to the optical data provides one additional dimension for classification
  ◦ in PALSAR, the HV polarisation provides most of the discrimination information
  ◦ significant variation in the respective contribution of the PALSAR and Landsat bands towards the separation of specific sub-classes of forest and non-forest sites
• strategies for dealing with non-coincident datasets:
  ◦ use of a multi-temporal approach (e.g. conditional probability network)
  ◦ check for atypical spectral signatures in the maximum-likelihood classification
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Thank you...