Quantification and mapping of forest structure from Pléiades image texture

PLEIADES DAYS, TOULOUSE, 2014
The ORFEO Accompaniment Program:
preparation, accompaniment and promoting the use and the exploitation Pléiades images.

Group GT6-Forêt

B. Beguet thesis:
« Caracterisation, quantification and mapping of forest structure from Very High Resolution satellite imagery »

ENSEGID / INRA: collaboration since 2009
Introduction: general overview

...Very High Resolution satellite imagery...

- Which thematic innovation could we expect?

- Which methodological innovation is needed?

- Our priorities:
  - Forest management
    - Forest variable estimation
    - Forest inventory mapping
  - Forest changes
    - Strong damages: windfall, massive dieback
    - Anthropogenic activities: deforestation, reforestation...
the contribution of Pléiades images for forestry:

**Spatial resolution:**
- defines the dimension of the observed (or perceptible) objects
the contribution of Pléiades images for forestry:

**Spatial resolution:**

- defines the dimension of the observed (or perceptible) objects

- **HR** (Spot5, Formosat): useful for many applications but:
  
  pixel size > tree crown size

→ resolution is too low (5-10m) to describe forest stand complexity and diversity
the contribution of Pléiades images for forestry:

Spatial resolution:
- defines the dimension of the observed (or perceptible) objects
  - **HR** (Spot5, Formosat): useful for many applications but:
    - pixel size > tree crown size
      - resolution is too low (5-10m) to describe forest stand complexity and diversity
  - **VHR** (QuickBird, World-View, Pléiades):
    - pixel size and tree crown size
      - (0.5-2.5m) and (0-8m)
      - forest is no longer a « green carpet »: TEXTURE (tree spatial organization)

How to? → Optimize existing methods by an appropriate use of VHR imagery textural information at the stand level
Outlines

- Material
- Method
- Retrieving forest structure variables
- Forest structure mapping
- Conclusion
- Perspectives
Material: Study site

Maritime pine forest
Material

- Pléiades images:
  Pléiades 2012-2013
  (June, August, February)
  0.5m Pan + 2m MS (resampled)

- Forest information:
  - *in-field measurements*:
    - *Summer 2012, ~ 111 forest stands (>2 years)*
    - *Measured forest variables*: Crown diameter (Cd), Tree height (Ht), Diameter at breast high (Dbh), Density (Nah), Tree Spacing (Sp)

  - *Photo interpretation*:
    - *200 forest stands* labelized, covering the area forest variability
Forest structure classes definition

Classes are representative of the tree crowns dimension, the density of trees and their spatial distributions:

- **C1**: No visible trees - clearcuts - recent reforestation (stand age <3years)
- **C2**: visible trees - rows - Cd < 1m
- **C3**: visible trees - rows - 1.5m < Cd < 2.5m
- **C4**: visible trees - few rows - 3m < Cd < 4.5m
- **C5**: visible trees - no rows - Cd > 5m

*Pléiades © 2012, Distribution Astrium Services / SPOT Image S.A, France, tous droits réservés. Usage commercial interdit*
Method

- **Forest variable estimation:**
  
  **111 forest stands (measured in field)**
  - feature selection
  - multilinear regression
  - MS-PAN dataset

- **Forest mapping (hierarchical):**
  
  - MS-PAN dataset
  
  - Changing forest Vs. Forest (C1 Vs others)
    - Feature selection: 40 stands
    - Learning: 100 stands
    - Validation: 100 stands

  - Forest classes (C2 to C5)
    - Feature selection: 40 stands
    - Learning: 80 stands
    - Validation: 80 stands
Method

- **Texture feature calculation**:
  - 8 features derived from GLMC (Grey-Level Cooccurence Matrix)
  - wide range of parameter values (~2000 calculated variables)

- **Random forest classifier**:
  - used for feature selection (feature importance ranking), Ntree = 100
  - used for classification, Ntree = 100
  - provides margin information (classification confidence index)

- **Modelling-based feature selection (forest variable estimation)**:
  - based on multi-linear regressions
  - a new feature selection method: Random PRiF

- **Regularization**:
  - Neighbourhood Majority voting
  - Ball radius fixed by expert knowledge (radius = 8m = 4 MS pixels)
Results: Retrieving forest structure variables

- Tagon site, June Pléiades image
- Modelling using 5 texture feature subset

<table>
<thead>
<tr>
<th>Forest variable</th>
<th>$R^2$ multiple</th>
<th>RMSE (m)</th>
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<tbody>
<tr>
<td>Cd</td>
<td>0.807</td>
<td>1.097</td>
</tr>
<tr>
<td>Ht</td>
<td>0.831</td>
<td>3.126</td>
</tr>
<tr>
<td>Sp</td>
<td>0.819</td>
<td>0.837</td>
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</table>
Results: Forest structure mapping

- Random forest classifier, 40 texture feature subset

   → Changing forest Vs Forest:

<table>
<thead>
<tr>
<th></th>
<th>C1</th>
<th>C2</th>
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<tbody>
<tr>
<td>C1</td>
<td>13313</td>
<td>3787</td>
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<tr>
<td>C2</td>
<td>1984</td>
<td>70916</td>
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</table>

   Overall Accuracy: 93.59%
   Kappa: 0.78

→ Forest classes:

<table>
<thead>
<tr>
<th></th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>C5</th>
</tr>
</thead>
<tbody>
<tr>
<td>C2</td>
<td>14508</td>
<td>1115</td>
<td>474</td>
<td>103</td>
</tr>
<tr>
<td>C3</td>
<td>2260</td>
<td>14701</td>
<td>2742</td>
<td>97</td>
</tr>
<tr>
<td>C4</td>
<td>0</td>
<td>774</td>
<td>16919</td>
<td>1207</td>
</tr>
<tr>
<td>C5</td>
<td>0</td>
<td>969</td>
<td>1026</td>
<td>15105</td>
</tr>
</tbody>
</table>

   Overall Accuracy: 85.04%
   Kappa: 0.80
Results: Forest structure mapping

Reference Map
Results: Forest structure mapping

Changing Forest (Brown) Vs Forest (Green): Reference Map
Results: Forest structure mapping

Changing Forest (Brown) Vs Forest (Green): Classification

Overall Accuracy: 93.59%
Results: Forest structure mapping

Forest structure classification: Reference Map
Results: Forest structure mapping

Forest structure classification: Classification

Overall Accuracy: 85.04%
Results: Forest structure mapping

An example of margin information interest:

-1: strong confidence, wrong label
0: weak confidence, class boundaries
1: strong confidence, good label
Results: Forest structure mapping

An example of margin information interest: Reference labelling error detection
Results: Forest structure mapping

Forest structure classification (C1 to C5): Reference Map
Results: Forest structure mapping

Forest structure classification (C1 to C5): Classifications Union

Overall Accuracy (hierarchical strategy): 81.77%
Overall Accuracy (direct classification): 71.2%
Results: Forest structure mapping

Forest structure classification: ZOOM

Reference map

Panchromatic Pléiades image

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Results: Forest structure mapping

Forest structure classification: ZOOM

Reference map

Classification

Class 1
Class 2
Class 3
Class 4
Class 5
Conclusions and perspectives

- Pléiades images = powerful data for forest structure mapping.
- The proposed strategies provide good results for:
  - automatic GLCM parameters optimization
  - automatic forest structure variable retrieval
  - forest mapping at pixel level (and thus at stand level)
    improved by hierarchical strategy
  - detecting labelling errors / classification interpretation

- The method robustness will be tested on the two other dates (different acquisition parameters, different seasons)
- A forest change detection scheme could be processed on this basis by using bi-temporal images