HYBRID POLINSAR: HIGH RESOLUTION & POLARIMETRY APPLIED TO URBAN
Outline

- **Quantify** the role of polarimetry on a specific application: **Urban classification**
  - Ground Truth for performances comparison
  - Various mode of TerraSAR-X

- **On the joint use of:**
  - Polarimetry, Interferometry, & Intensity
  - Data fusion

- High resolution versus polarimetry
Performances comparison

- How to make a **fair** comparison?

- Not in favor polarimetry in urban...
Hybrid PolInSAR: interferometric mode with two distinct polarization mode
Hybrid PolInSAR: information content

**Hybrid PolInSAR**:
- Coherence vector
- Phase
- Correlation matrix

**Polarimetric coherence matrix**:
- Statistical distance (Wishart & co)
- Polarimetric decompositions
- & All existing technics

**High resolution « power » image**:
- Improved SPAN
- HR polarimetry reconstruction (frequency transfer)

**TerraSAR-X Hybrid interference pattern**
(Full Pol 2010 & Single Pol 2011)
Corregistration by H. Oriot
## Available Data Set

<table>
<thead>
<tr>
<th>System</th>
<th>Resolution</th>
<th>Frequency</th>
<th>Interferometric mode</th>
<th>Polarimetric mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>TerraSAR-X</td>
<td>1 m x 1 m</td>
<td>X-band</td>
<td>repeat pass</td>
<td>HH Single</td>
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<td></td>
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<td>3 images (2007)</td>
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<td>3 images (2011)</td>
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<tr>
<td>TerraSAR-X</td>
<td>2 m x 2 m</td>
<td>X-band</td>
<td>repeat pass</td>
<td>HH/VV Dual</td>
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<td>2 images 11 days</td>
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<tr>
<td>TerraSAR-X</td>
<td>2 m x 6 m</td>
<td>X-band</td>
<td>repeat pass</td>
<td>HH/HV/VV Full</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3 images 11 days (2010)</td>
<td></td>
</tr>
</tbody>
</table>
San Francisco images

X-band, 1m x 1m  
*TerraSAR-X*

X-band, 2m x 6m  
*TerraSAR-X*

Ground truth (+/- 1m)
Asses performances

Sample 1 (no building):
• Hh, Hv, Vh, Vv (Quad) * 3
• HR Hh * 6
• Hh Vv (Dual)

Sample 2 (no building):
• Hh, Hv, Vh, Vv (Quad) * 3
• HR Hh * 6
• Hh Vv (Dual)

Sample 3 (building):
• Hh, Hv, Vh, Vv (Quad) * 3
• HR Hh * 6
• Hh Vv (Dual)

• Statistic distances
• Decomposition based distances
• Interferometric coherence

• H0 hypothesis:
  - False Alarm Probability/ Threshold

• H1 hypothesis:
  - Detection Probability/ Threshold

10^n runs
Criteria tested

- **Polarimetry**: Statistical Gaussian-based distance (GLRT)
  - From two pass for Full-PollnSAR (averaged matrices, polarimetric stability hypothesis)
  - From a single pass for Hybrid

- **Intensity**: 1D based distance (GLRT)
  - 4 sub-bands HH images from each pass are generated to match ground truth resolution
  - 8 intensity images for InSAR
  - 4 intensity images from a single pass for Hybrid

- **Phase**: Interferometric coherence
  - Optimized coherence for Full-PollnSAR
  - 1 HH coherence for Hybrid
  - 4 HH coherence for InSAR

*Scattering Vector stacking:*
Phase information overwhelmed by power information: need to process it independently at first
Separated ROC curves

- Interferometric Coherence:
  - Highest performances
  - Greatly improved by polarimetric optimization (low contribution of HV...)

- Intensity:
  - Second highest performances
  - Barely benefits from increased number of sample (Hybrid vs InSAR)

- Polarimetry
  - Barely benefits from increased number of sample (Hybrid vs Full-PollnSAR)
Data Fusion: And threshold example

\[ P_{FA} = f(\tau_1, \tau_2) \]

\[ P_{FA} = f(\tau_1, 0) \]

\[ P_{FA} = f(0, \tau_2) \]

Infinite amount of solution: Double threshold ambiguity

Equalized partial false alarm: as many false alarm from each Criterion

\[ P_{FA} = f(\tau_1, \tau_2) \quad f(0, \tau_2) = f(\tau_1, 0) \]

Unique solution

Criteria fusion:
- Polarimetry & Interferometry (Full PollInSAR)
- Power & Interferometry (InSAR)
- Polarimetry & Power & Interferometry (Hybrid) (3 criteria fusion)
All data type: fusion comparison

- All information combined:
  - InSAR and PolInSAR provide very close performances
  - Hybrid surpass both thanks to information diversity
Polarimetry and Intensity, fusion comparison

Without interferometric coherence (2 pass data):
- Polarimetry alone is far behind
- Hybrid still surpass intensity only due to information diversity.
High Resolution Polarimetric Reconstruction
High Resolution Polarimetric Reconstruction
Observations

In the very restricted field of the application of building vs all classification & the San Fransisco TerraSAR-X data set.

- If only a single pass is used: High resolution Single Pol yield the best performances.
- When two passes are used: Hybrid PolInSAR or Full PolInSAR yield the best results.
- When three passes can be considered, Hybrid Single+Full+Full will yield the best result thanks coherence optimization.
Conclusions

- Ground truth allows to **quantify** performances but in a very precise scope

- Know your information hierarchy: Coherence, Polarimetry, Intensity?

- Even "low" quality information improves performances over more already measured "high" quality information

- **Diversity > Quantity**

- Many hybrid couple to be investigated
An optic/vision parallel

- Do we need resolution for polarimetry as much as we need it for SPAN?
  - Human eye principle:
    - 4.5 M cone cells (color vision) only with bright lighting. Blue cone cells are not even in focus!
    - 90 M rod cells (intensity vision), much more sensitivity, higher SNR, works at night.
    - Highly use of the brain processing power.