POLTimeSAR: Benefits of polarimetry on change detection in time-series

Elise Colin Koeniguer
ONERA / DTIS
A new dimension: time

Temporal SAR series

Is polarimetric information useful for change detection?

Change detection
In N images
N >> 2
Change detection: our framework

Input: temporal SAR series

Product: visualization

Product: detection

2 levels of product

Input: temporal SAR series

Level 1 « soft » decision

Level 2 « hard » decision (threshold)

Our change detection criterions

A « generic » criterion

High change detection performance for artificial or natural objects

Point-event detection

Step signal transition

Our change detection criterions

\[ CV = \frac{\sigma}{\mu} \]

\[ f_1(CV) \]

« Specific » criterions

\[ f_2(CV) \]
Outline

Activity Visualization

Construction site detection

Point-event detection

What can polarimetry do for…
Rapid and EAsy Change detection in radar Time-series by Variation coefficient
Synoptic

Coefficient of variation

\[ CV = \frac{\sigma}{\mu} \]

Permanent scatterer
Change

Hue H
Saturation S

Date 1
Date 2
Date N

Amplitude

maximum

Value V

Colored Representation

POLINSAR 2019 – Elise Colin-KOENIGUER
ESRIN Center since last PolInSAR
Maritime traffic

Sentinel 1, Google Earth Engine

2015-02-01  ASCENDING  VH  2018-05-10
What about High resolution?

TerraSAR-X (DLR)

- (1m)
- (25 cm)
If we use only one polarimetric channel:

**Sentinel 1 VV/VH**

**Finsch Petra Diamond Mine, South Africa**

Trains

Trucks
Most of the time, coefficient of variation (saturation) is maximum in VH on crops
Fusion of polarimetry in REACTIV

Date 1
Date 2

... Date N

Amplitude

Hue H

Saturation \( S = \max (CV_{pq}) \)

Value V

Maximum associated with maximum CV

Date 1
Date N
POLARIMETRIC TIME-SERIES OVER BUILDINGS
Parameters to analyze a specific event

Amplitude profile

$$CV_1 = \frac{\sigma_1}{\mu_1}$$

$$CV_2 = \frac{\sigma_2}{\mu_2}$$

$$\min\left(\frac{CV_1}{CV_2}, \frac{CV_2}{CV_1}\right)$$

$$CV = \frac{\sigma}{\mu}$$

$$R = 1 - \sum_s \min\left(\frac{CV_1}{CV_2}, \frac{CV_2}{CV_1}\right)$$

highlights any kind of changes from « stable » speckle

highlights constant piecewise signals
Results

- Radar intensity,
- Deep learning on Sentinel 2 images
Detection performance

For construction test sites > 20 pixels

Sentinel 1 VV/VH

![Detection performance graph](image)

Legend:
- Deep Learning on Sentinel 2
- Coefficient of Variation
- Ratio Coefficient of Variation
- Mean Ratio of Intensity
- Ratio of Intensity by dichotomy

Construction Site >20px

Probability of detection vs False Alarm rate

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VH VV and fusion

\[ R = \max(R_{VH}, R_{VV}) \]
\[ CV = \max(C_{VH}, C_{VV}) \]

- \( C_{VH} \) more sensitive to agricultural fields that are considered here as false alarms.
POLARIMETRIC TIME-SERIES FOR POINT-EVENTS
Detection of one-point event

\[ R = 1 - \min \left( \frac{CV_1}{CV_2}, \frac{CV_2}{CV_1} \right) \]

\( CV_1 \) computed without max value
\( CV_2 \) computed without min value

Amplitude profile EXAMPLE 1

\( R \approx 1 \)

CV\(_1\) low
CV\(_2\) high

Amplitude profile EXAMPLE 2

\( R \approx 0 \)

CV\(_1\) high
CV\(_2\) high
Sentinel 1 – VH and VV analysis

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<tr>
<td>VV and HV</td>
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Finsch Petra Diamond Mine, South Africa
Trains and Trucks: mainly VV only
### Application to urban

#### San Francisco: 13 images

#### San Andrea, 68 images

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<th>Mixed Area 2</th>
<th>Boats</th>
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High resolution Images of boats

UAVSAR (NASA/JPL)
60 quad pol Images
Visualization

Extension to the REACTIV method to polarimetric case

Polarimetry fusion enables to see all kinds of change

Construction site detection

VV better than HV for detecting construction test sites

Gain of fusion of polarimetric channels

Point-event detection

all polarizations are requested for good detection

On sea: HV better
Available code sources
https://github.com/elisekoeniguer/REACTIV

Google Earth Engine

Python

MATLAB

https://code.earthengine.google.com/f78083077aa1bfe9a089f69ac0946ddb

TERRASAR-X images have been provided by DLR
UAVSAR images – NASA-JPL

Ground Truth : / Software Metrics for ROC curves
Fabrice Janez (Onera)
Statistical analysis – Jean-Marie Nicolas (TelecomParis Tech)