MULTITEMPORAL IMAGE ANALYSIS: PRACTICAL LECTURE

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Outline

1 Processing Chain for Change Detection

2 Change Vector Analysis (CVA)

- ✓ Effects of Radiometric Differences
- ✓ Effect of Residual Misregistration
- ✓ Detection of Multiple Changes

3 Compressed Change Vector Analysis (C^{2}VA)

- ✓ Effects of Radiometric Differences
- ✓ Effect of Residual Misregistration
- ✓ Detection of Multiple Changes
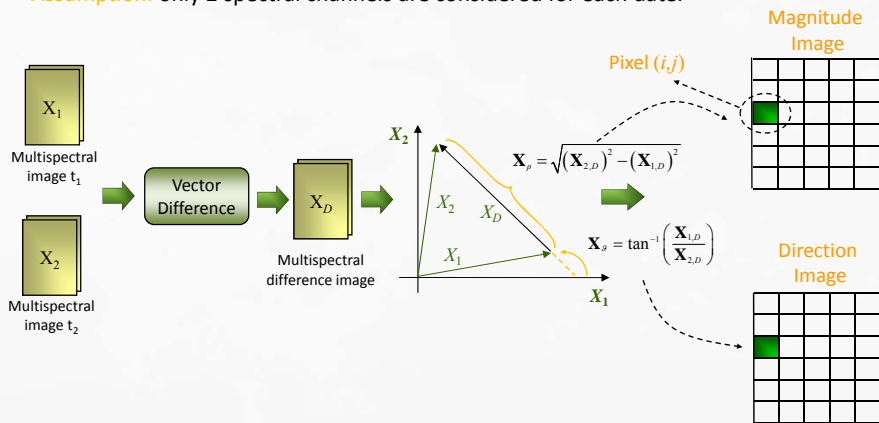- ✓ Analysis of Direction Ambiguity

Processing Chain for Change Detection
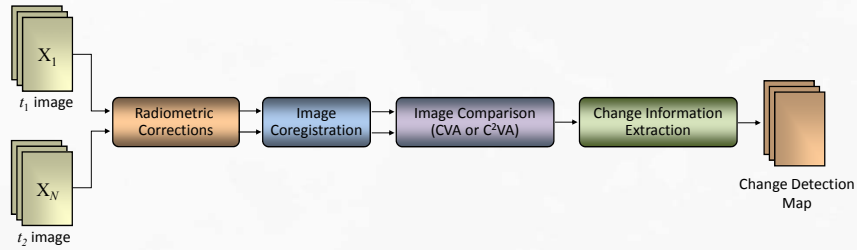
Change Vector Analysis (CVA)

CVA

Change Detection

Select Multitemporal Input Images
Image at Time t1 — Open...
Image at Time t2 — Open...

Pre-processing
☑ Radiometric Correction
☑ Coregistration

Change detection strategy
◉ CVA   ○ C2VA
First Band
Second Band
Calculate

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- ✓ Select image at time t_1;
- ✓ Select image at time t_2;
- ✓ Select the desired pre-processing steps;
- ✓ Select CVA option;
- ✓ Select the spectral channels to highlight the changes;

Press "Calculate" to :
- ✓ Perform pre-processing (if any);
- ✓ Compute magnitude and direction;
- ✓ Visualize polar representation.

CVA

Control Point Selection Tool 1
File Edit View Tools Window Help
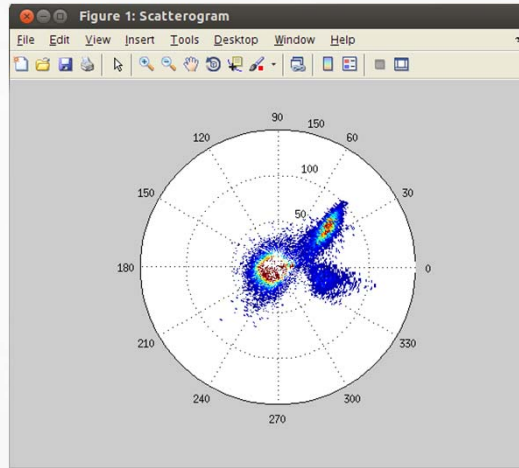
- ✓ If "Coregistration" check box is selected, coregistration form appears;
- ✓ Select Ground Control points (at least 4);
- ✓ Co-registration is performed by means of bilinear interpolation;
- ✓ Once finished select

```
File -> Close Control
Point Selection Tool
```

Control Point Selection Tool 1
File Edit View Tools Window Help
Close Control Point Selection Tool   Ctrl+W

Polar plot example

CVA
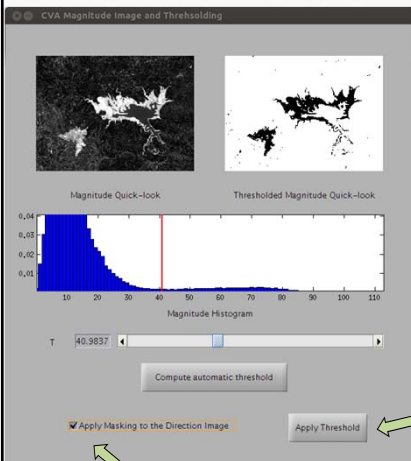
Select threshold for the magnitude variable:

- ✓ Perform automatic threshold selection (press **"Compute automatic threshold"** and wait some seconds);

- ✓ Manual threshold selection moving the red line on the histogram or cursor on the T scroll;

- ✓ Use zoom to better detect the threshold.

Press "Apply threshold" to :
- ✓ Threshold the magnitude;
- ✓ Move to direction analysis.

Select whether presence/absence of change information should be used in the analysis of direction information.

CVA
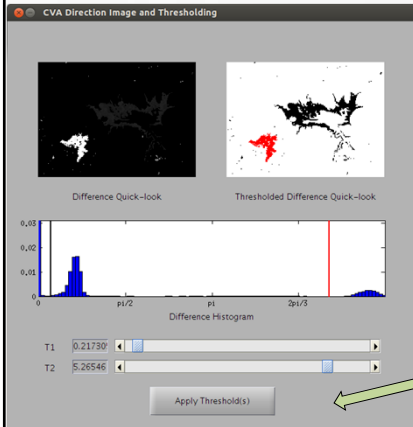
Select threshold(s) for the direction variable:

- ✓ Manual threshold selection moving the red and black lines on the histogram.

- ✓ Or moving the cursors on the T_1 and T_2 scrolls;

- ✓ Use zoom option to better detect the threshold(s).

Press "Apply threshold(s)" to :
- ✓ Threshold the direction;
- ✓ Visualize the final change detection map.

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CVA
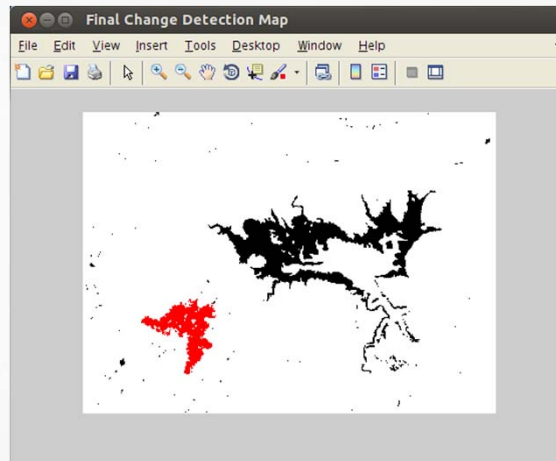
Change detection map example

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CVA: Outputs & Notes

Outputs:

- ✓ Multispectral difference image;
- ✓ Magnitude image;
- ✓ Direction image;
- ✓ Thresholded magnitude image;
- ✓ Thresholded direction image;
- ✓ Change detection map;
- ✓ Polar plot;

Notes:

- ✓ All outputs are saved in "Output" folder.
- ✓ Images are saved as a data file plus header format and can be loaded either in Matlab or ENVI environment.
- ✓ Each run overwrites output files, if you don't want to loose them rename the files.
- ✓ Polar plot is saved in Matlab .fig format.

CVA: Suggested Tests

Preform trials in order to analyze:

- ✓ The effect of using images with radiometric differences;

- ✓ The effect of using images with a significant amount of residual misregistration;

- ✓ The effect of using different combinations of spectral channels.

- ✓ The effect of the presence of multiple changes.

Tip: instead of thresholding, manually draw regions on the polar plot to isolate specific clusters of pixels.

CVA: Example and Discussion of Results

Study area: Lake Mulargia, Sardinia Island (Italy).

Multitemporal data set: a portion of 412×300 pixels of two images acquired by the TM sensor of Landsat-5 satellite in September 1995 and July 1996.

Before Change · After Change · Reference Map
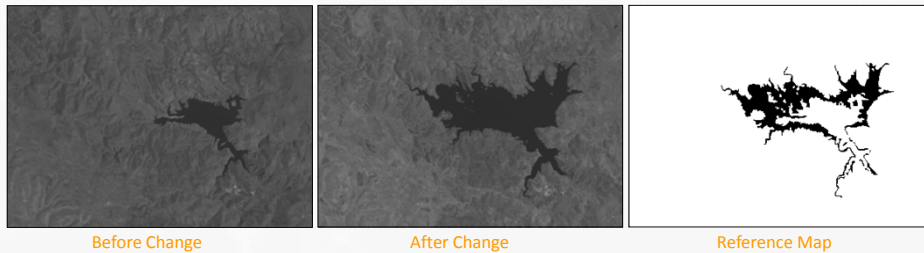
CVA: Example and Discussion of Results

Corrected Images (Ideal case) · Registration noise effects · Radiometric difference effects

Optimal threshold value on the magnitude variable: ideal case

Registration noise effects
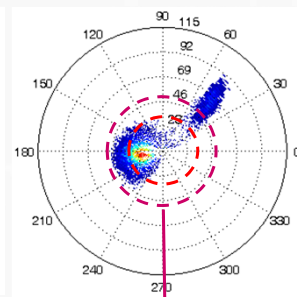
Threshold value on the magnitude variable: radiometric distortion case

F. Bovolo, L. Bruzzone, A Theoretical Framework for Unsupervised Change Detection Based on Change Vector Analysis in Polar Domain, *IEEE Transactions on Geoscience and Remote* Sensing, Vol. 45, No.1, 2007, pp.218-236.

Compressed Change Vector Analysis (C²VA)

✓ CVA in 2 dimensions permits to easily visualize the change information in polar coordinates, but may results in the loss of information due to spectral channel selection.

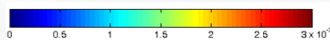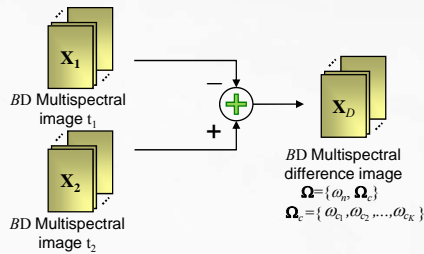✓ CVA may be applied on $B > 2$ spectral channels in hyperspherical coordinates. However, when B is greater than 3 it is impossible to visualize the data in the polar domain.

✓ Compressed CVA (C²VA) can overcome the abovementioned limit of polar CVA.

Compressed Change Vector Analysis (C²VA)

$\mathbf{X}_1$

BD Multispectral image t_1

$\mathbf{X}_2$

BD Multispectral image t_2

$\mathbf{X}_D$

BD Multispectral difference image
$\mathbf{\Omega} = \{\omega_n, \mathbf{\Omega}_c\}$
$\mathbf{\Omega}_c = \{\omega_{c_1}, \omega_{c_2}, ..., \omega_{c_K}\}$

Magnitude: the length of the multispectral difference vector ($\mathbf{X}_D$).

$$\mathbf{X}_\rho = \sqrt{\sum_{b=1}^{B} \mathbf{X}_{b,D}^2} = \sqrt{\sum_{b=1}^{B} (\mathbf{X}_{b,2} - \mathbf{X}_{b,1})^2}$$

bth spectral band of X_1

Direction: the angle between the multispectral difference vector ($\mathbf{X}_D$) and a reference vector ($\mathbf{X}_{ref}$) in a BD space.

$X_{2,D}$

$\mathbf{X}_D$

α

$X_{1,D}$

$\mathbf{X}_{ref}$

$X_{3,D}$
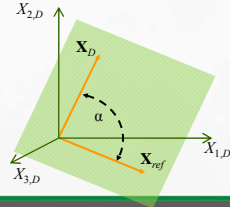
$$\mathbf{X}_\alpha = \arccos\left(\sum_{b=1}^{B} (\mathbf{X}_{b,D} \mathbf{X}_{b,ref}) \middle/ \sqrt{\sum_{b=1}^{B} \mathbf{X}_{b,D}^2 \sum_{b=1}^{B} \mathbf{X}_{b,ref}^2} \right)$$

$$\alpha \in [0, \pi]$$

BD unit vector

$$\mathbf{X}_{ref} = \left[\frac{\sqrt{B}}{B}, ..., \frac{\sqrt{B}}{B} \right]$$

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Compressed Change Vector Analysis (C²VA)

Definitions

1. *Compressed CVA (C²VA) Domain*

$$C^2VA = \{\rho, \alpha : 0 \le \rho < \rho_{max} \ \text{and} \ 0 \le \alpha < \pi\}$$

$$\rho_{max} = max\left\{\sqrt{\sum_{b=1}^{B} X_{b,D}^2}\right\}$$

α -> Random variable associate to direction image $\mathbf{X}_\alpha$

2. *Semi-Circle of unchanged pixels*

$$SC_n = \{\rho, \alpha : 0 \le \rho < T \ \text{and} \ 0 \le \alpha < \pi\}$$

3. *Semi-Annulus of changed pixels*

$$SA_c = \{\rho, \alpha : T \le \rho \le \rho_{max} \ \text{and} \ 0 \le \alpha < \pi\}$$

4. *Annular sector of the k-th kind of change*

$$S_k = \{\rho, \alpha : \rho \ge T \ \text{and} \ \alpha_{k_1} \le \alpha < \alpha_{k_2}, \ 0 \le \alpha_{k_1} < \alpha_{k_2} < \pi\}$$
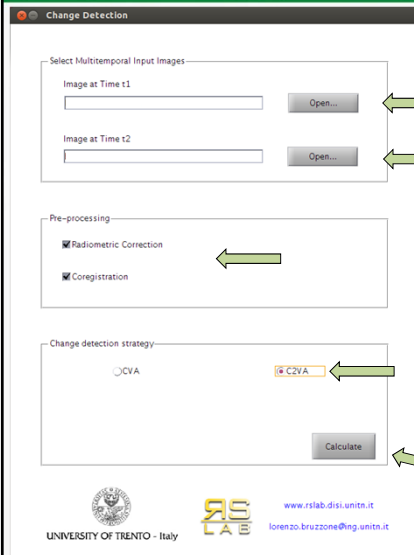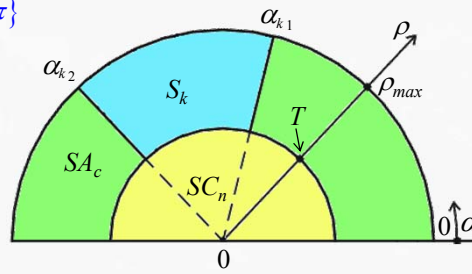
C²VA

✓ Select image at time t₁;

✓ Select image at time t₂;

✓ Select the desired pre-processing steps;

✓ Select C²VA option;

Press "Calculate"
and follow the similar steps described for CVA option.

C²VA: Suggested Tests

Preform trials in order to analyze:

✓ The effect of using images with radiometric differences;

✓ The effect of using images with a significant amount of residual misregistration;

✓ The effect of the presence of multiple changes;

✓ The effect of ambiguity in the direction information.

Tip: instead of thresholding, manually draw regions on the polar plot to isolate specific clusters of pixels.

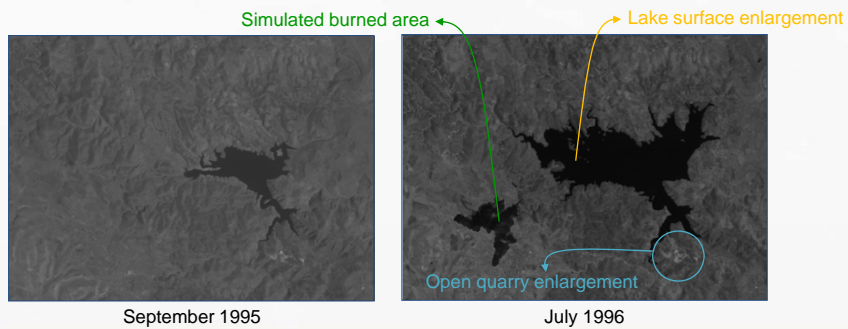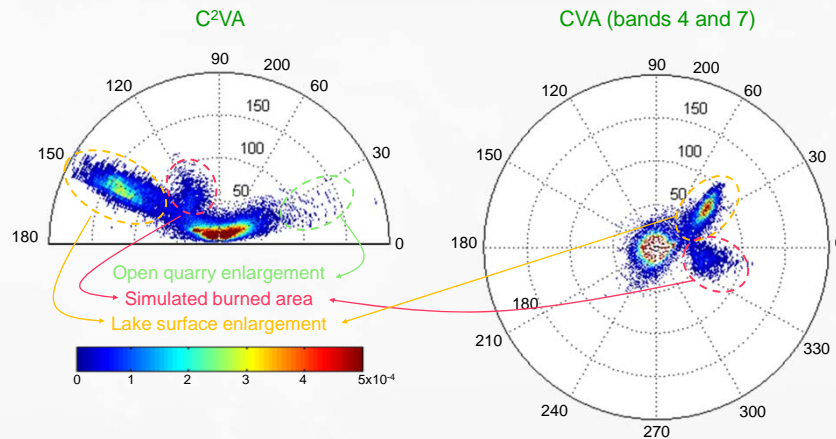# C²VA: Example and Discussion of Results

Study area: Lake Mulargia, Sardinia Island (Italy).

Multitemporal data set: a portion of 412×300 pixels of two images acquired by the TM sensor of Landsat-5 satellite in September 1995 and July 1996.

Changes: 2 natural changes, 1 simulated change

Simulated burned area

Lake surface enlargement

Open quarry enlargement

September 1995   July 1996

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C²VA: Example and Discussion of Results

C²VA

CVA (bands 4 and 7)

Open quarry enlargement
Simulated burned area
Lake surface enlargement

0　1　2　3　4　5×10^{-4}

C²VA: Example and Discussion of Results

Advantages:

✓ C²VA permits to easily visualize the change information in polar coordinates without the need of pre-selecting pairs of spectral channels (which is difficult when no prior information on the kinds of changes present in the images is available).

Disadvantages:

✓ Some ambiguity may rise from the dimension reduction process mainly for the simplified representation of the angle variable: this may result in similar direction values for different kind of changes.

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