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 (C2VA)
   - Effects of Radiometric Differences
   - Effect of Residual Misregistration
   - Detection of Multiple Changes
   - Analysis of Direction Ambiguity
**Processing Chain for Change Detection**

- \( X_1 \) image at time \( t_1 \)
- \( X_2 \) image at time \( t_2 \)

1. **Radiometric Corrections**
2. **Image Coregistration**
3. **Image Comparison (CVA or C²VA)**
4. **Change Information Extraction**
5. **Change Detection Map**

**Change Vector Analysis (CVA)**

**Assumption:** only 2 spectral channels are considered for each date.

- \( X_1 \) Multispectral image at time \( t_1 \)
- \( X_2 \) Multispectral image at time \( t_2 \)

1. **Vector Difference**
2. **Change Image**
3. **Direction Image**
4. **Magnitude Image**

- \( X_i = \sqrt{(X_{1i} - X_{2i})^2} \)
- \( X_o = \tan^{-1}\left(\frac{X_{2i}}{X_{1i}}\right) \)
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.

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
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 T₁ and T₂ scrolls;
- Use zoom option to better detect the threshold(s).

Press “Apply threshold(s)” to:

- Threshold the direction;
- Visualize the final change detection map.
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.

Compressed Change Vector Analysis (C\(^2\)VA)

- CVA in 2 dimensions permits to easily visualize the change information in polar coordinates, but may result 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 (C\(^2\)VA) can overcome the abovementioned limit of polar CVA.

**Compressed Change Vector Analysis (C\(^2\)VA)**

Magnitude: the length of the multispectral difference vector \((\text{X}_d)\).

\[
\text{X}_d = \sqrt{\sum_{b=1}^{B} \text{X}_{d,b}^2} = \sqrt{\sum_{b=1}^{B} (\text{X}_{d,b} - \text{X}_{\text{ref},b})^2}
\]

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

\[
\alpha = \arccos \left( \frac{\sum_{b=1}^{B} (\text{X}_{d,b} \cdot \text{X}_{\text{ref},b})}{\sqrt{\sum_{b=1}^{B} \text{X}_{d,b}^2} \cdot \sqrt{\sum_{b=1}^{B} \text{X}_{\text{ref},b}^2}} \right)
\]

\(\alpha \in [0, \pi]\)

BD unit vector:

\[
\begin{pmatrix}
\text{B} \\
\text{B} \\
\text{B}
\end{pmatrix}
\]
Definitions

1. **Compressed CVA (C²VA) Domain**
   \[ C²VA = \{ \rho, \alpha : 0 \leq \alpha < \pi \} \]
   \[ \rho_{\text{max}} = \max \left\{ \sum_{n=0}^{N} x_{n}^{2} \right\} \]
   \[ \alpha \rightarrow \text{Random variable associated with direction image } X_{\alpha} \]

2. **Semi-Circle of unchanged pixels**
   \[ SC_{n} = \{ \rho, \alpha : 0 \leq \rho < T \text{ and } 0 \leq \alpha < \pi \} \]

3. **Semi-Annulus of changed pixels**
   \[ SA_{c} = \{ \rho, \alpha : T \leq \rho < \rho_{\text{max}} \text{ and } 0 \leq \alpha < \pi \} \]

4. **Annular sector of the k-th kind of change**
   \[ S_{k} = \{ \rho, \alpha : \rho \geq T \text{ and } \alpha_{n} \leq \alpha < \alpha_{n+1}, 0 \leq \alpha_{n} < \alpha_{n+1} < \pi \} \]
**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.

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**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

- Lake surface enlargement
- Simulated burned area
- Open quarry enlargement

September 1995  
July 1996
C\(^2\)VA: Example and Discussion of Results

Advantages:

- C\(^2\)VA 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.
References


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