SAR image change detection
using distance between distribution of classes

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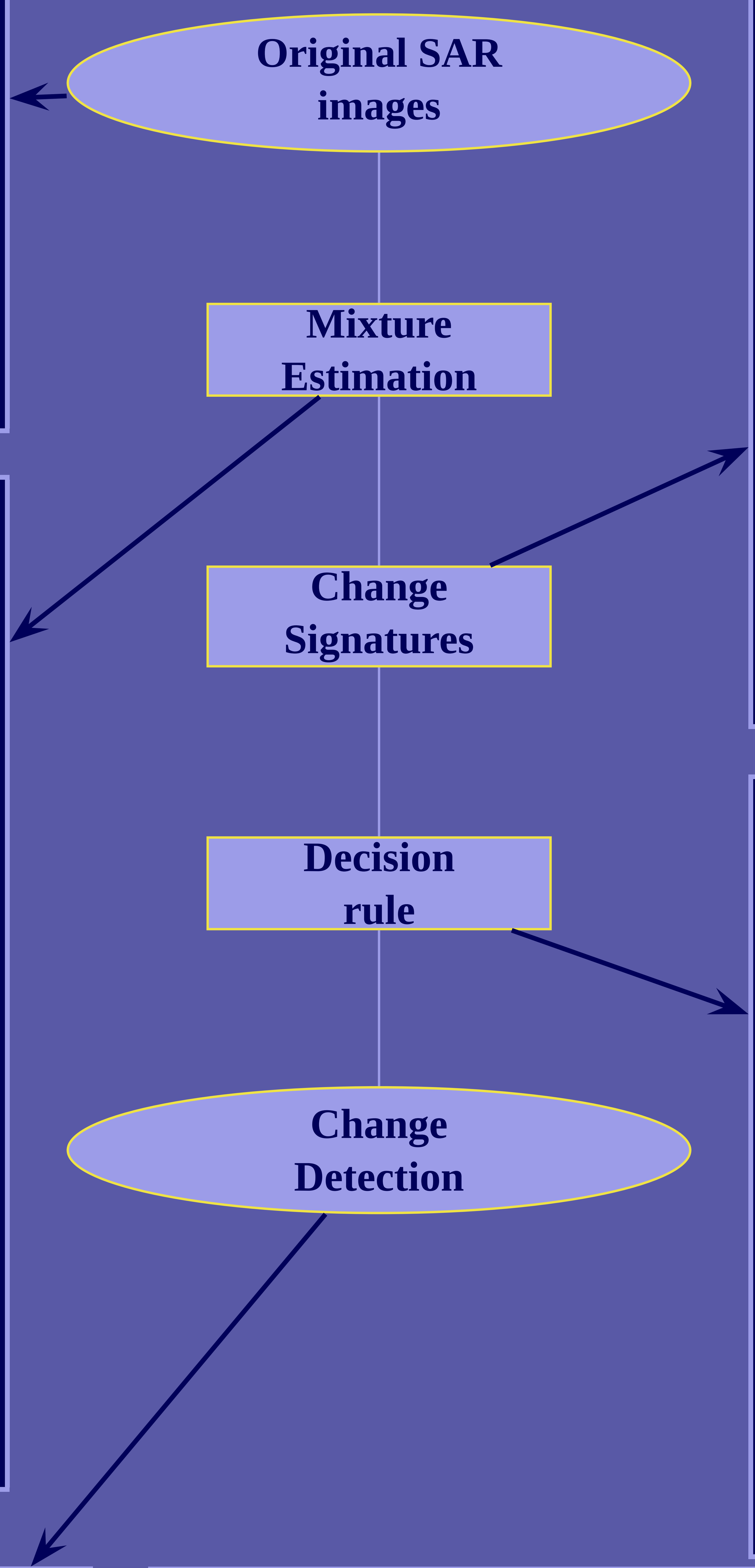
SAR image change detection process



Original Images

SAR images acquired at t_0 and t_1, before and after an eruption of the Nyragongo volcano (RD Congo) that occurred in January 2002.

SAR image at t_0: I_{t_0}

RADARSAT mode F5

SAR image at t_1: I_{t_1}

RADARSAT mode F2

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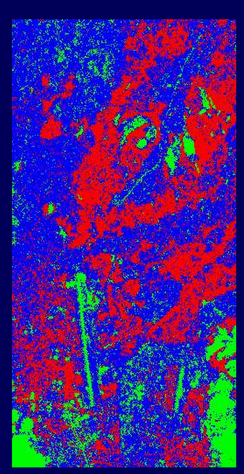
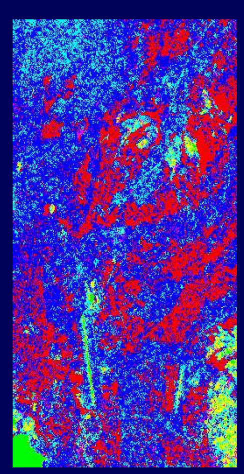
Image mapping through Mixture Estimation

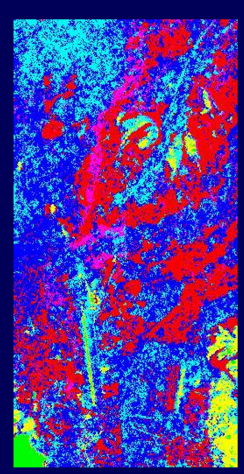
SEM mixture estimation is applied on I_{t_0}, I_{t_1} and (I_{t_0}, I_{t_1})



SEM on image I_{t_0} with $K = 3$ classes



SEM on image I_{t_1} with $K' = 6$ classes



Joint SEM on images (I_{t_0}, I_{t_1}) with K' classes

SEM yield the set of gaussian pdf:

- SEM on I_{t_0}: $\left\{ f^{t_0}(I_{t_0}|\omega_k),\ k = 1, 2, \dots, K \right\}$
- SEM on I_{t_1}: $\left\{ f^{t_1}(I_{t_1}|\omega'_k),\ k = 1, 2, \dots, K, \dots, K' \right\}$
- SEM on (I_{t_0}, I_{t_1}): $\left\{ f^{t_0,t_1}(I_{t_0}, I_{t_1}|\omega''_k),\ k = 1, 2, \dots, K' \right\}$

Number of class: The number of class K is given to process image I_{t_0}. But extra classes are created for processing image I_{t_1} since SEM is initialized with the result of SEM on I_{t_0} with K classes $\{\omega_1, \omega_2, \dots, \omega_K\}$ and some new classes are created when initial histogram of I_{t_1} restricted to classes ω_k becomes multimodal.

Change Signatures

Distance between distributions $\mathcal{D}(f, g)$

We consider Battacharyya distance between two pdf f and g in the change detection point of view:

$$\mathcal{D}(f, g) = 1 - \int \sqrt{f(x)\, g(x)}\, dx.$$

Significance measurement of a pixel between two pdf $\mathcal{S}_{(f,g)}(i, j)$

We caracterize the behavior of a pixel of position (i, j) within its class on image I_{t_0} and I_{t_1}:

$$\mathcal{S}_{(f_{I_{t_0}}, g_{I_{t_1}})}(i, j) = f_{I_{t_0}}\left(I_{t_0}(i, j)\right) \times g_{I_{t_1}}\left(I_{t_1}(i, j)\right).$$

Contrast measure between pdf on each image $\rho_{(f,g)}(i, j)$

We characterize the evolution of the membership of a pixel (i, j) between the two images I_{t_0} and I_{t_1} and its class on I_{t_0} and on I_{t_1}:

$$\rho_{(f_{I_{t_0}}, g_{I_{t_1}})}(i, j) = 1 - \min \left(\frac{f_{I_{t_0}}\left(I_{t_0}(i, j)\right)}{g_{I_{t_1}}\left(I_{t_1}(i, j)\right)}, \frac{g_{I_{t_1}}\left(I_{t_1}(i, j)\right)}{f_{I_{t_0}}\left(I_{t_0}(i, j)\right)} \right).$$

For all those criteria, 0 means 'no change',
1 means 'potential change'.

Paradoxical Reasonning

Fusion of Change Signature with the Dezert-Smarandache Theory

DSm Theory is an extent of Dempster-Shafer.
The hyper-power set D^Θ is defined as:

$$D^\Theta = \{\emptyset, \theta_{\text{ch}} \cap \theta_{\text{no ch}}, \theta_{\text{ch}}, \theta_{\text{no ch}}, \theta_{\text{ch}} \cup \theta_{\text{no ch}}\}.$$

The new basic belief assignments $m(\cdot) \in [0, 1]$ has to obey:

$$m(\theta_{\text{ch}}) + m(\theta_{\text{no ch}}) + m(\theta_{\text{ch}} \cup \theta_{\text{no ch}}) + m(\theta_{\text{ch}} \cap \theta_{\text{no ch}}) = 1. \quad (1)$$

The generalized belief and plausibility functions are defined as:

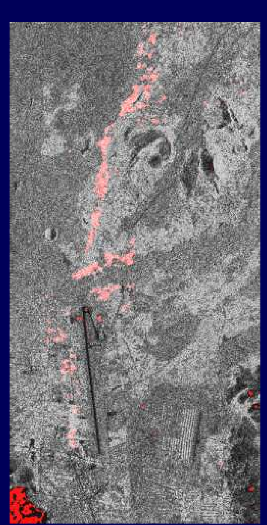
$$\text{Bel}(A) = \sum_{\substack{B \subseteq A \\ B \in D^\Theta}} m(B) \quad \text{and} \quad \text{Pl}(A) = \sum_{\substack{B \cap A \neq \emptyset \\ B \in D^\Theta}} m(B),$$

while the rule of combination between two sources of evidence follows:

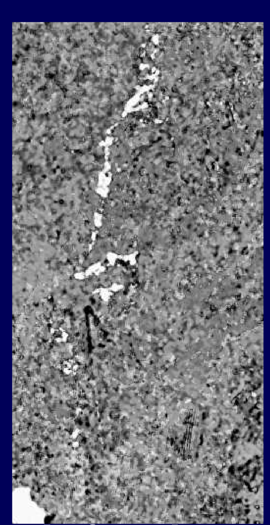
$$\forall C \in D^\Theta, \quad m(C) = [m_1 \oplus m_2](C) = \sum_{\substack{A, B \in D^\Theta \\ A \cap B = C}} m_1(A)\, m_2(B).$$

Results on Change detection

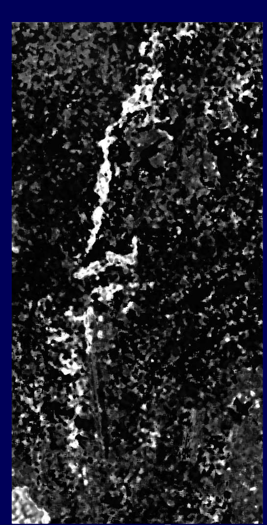
Detection of lava flow and mud slide due to the Nyragongo eruption



Decision: $\text{Bel}(\theta_{\text{ch}}) > \text{Bel}(\theta_{\text{no ch}})$



Belief on change: $\text{Bel}(\theta_{\text{ch}})$



Mass on change: $m(\theta_{\text{ch}})$

Advantages on the use of class statistics evolution over time

- First step based on multidate statistical segmentation improves robustness from speckle noise, image modality, indicence...
- Joint statistical segmentation improves robustness from natural ground evolution.
- Paradoxical reasoning improves the level of confidence in the decision process.
- The technique may be generalized, as it stands, to multidate (more the 2 dates) change detection.

Mass belief assignment

Mass assignment for comparing I_{t_0} and I_{t_1}

Hypothesis	mass
$\emptyset$	0 (by definition)
θ_{ch}	$\left(1 - \rho\left(f^{t_0}(I_{t_0}(i,j)\|\omega), f^{t_1}(I_{t_1}(i,j)\|\omega')\right)\right) \times \mathcal{D}\left(f^{t_0}(I_{t_0}(i,j)\|\omega), f^{t_1}(I_{t_1}(i,j)\|\omega')\right)$
$\theta_{\text{no ch}}$	$\rho\left(f^{t_0}(I_{t_0}(i,j)\|\omega), f^{t_1}(I_{t_1}(i,j)\|\omega')\right) \times \left(1 - \mathcal{D}\left(f^{t_0}(I_{t_0}(i,j)\|\omega), f^{t_1}(I_{t_1}(i,j)\|\omega')\right)\right)$
$\theta_{\text{ch}\cap\text{no ch}}$	$\rho\left(f^{t_0}(I_{t_0}(i,j)\|\omega), f^{t_1}(I_{t_1}(i,j)\|\omega')\right) \times \mathcal{D}\left(f^{t_0}(I_{t_0}(i,j)\|\omega), f^{t_1}(I_{t_1}(i,j)\|\omega')\right)$
$\theta_{\text{ch}\cup\text{no ch}}$	$\left(1 - \rho\left(f^{t_0}(I_{t_0}(i,j)\|\omega), f^{t_1}(I_{t_1}(i,j)\|\omega')\right)\right) \times \left(1 - \mathcal{D}\left(f^{t_0}(I_{t_0}(i,j)\|\omega), f^{t_1}(I_{t_1}(i,j)\|\omega')\right)\right)$

Mass assignment for comparing I_{t_0} and I_{t_1} into the joint segmentation

Hypothesis	mass
$\emptyset$	0 (by definition)
θ_{ch}	$\rho\left(f^{t_0,t_1}_{t_0}(I_{t_0}(i,j)\|\omega''), f^{t_0,t_1}_{t_1}(I_{t_1}(i,j)\|\omega'')\right) \times \mathcal{D}\left(f^{t_0,t_1}_{t_0}(I_{t_0}(i,j)\|\omega''), f^{t_0,t_1}_{t_1}(I_{t_1}(i,j)\|\omega'')\right) \times \mathcal{S}\left(f^{t_0,t_1}_{t_0}(I_{t_0}(i,j)\|\omega''), f^{t_0,t_1}_{t_1}(I_{t_1}(i,j)\|\omega'')\right)$
$\theta_{\text{no ch}}$	$\left(1 - \rho\left(f^{t_0,t_1}_{t_0}(I_{t_0}(i,j)\|\omega''), f^{t_0,t_1}_{t_1}(I_{t_1}(i,j)\|\omega'')\right)\right) \times \left(1 - \mathcal{D}\left(f^{t_0,t_1}_{t_0}(I_{t_0}(i,j)\|\omega''), f^{t_0,t_1}_{t_1}(I_{t_1}(i,j)\|\omega'')\right)\right) \times \left(1 - \mathcal{S}\left(f^{t_0,t_1}_{t_0}(I_{t_0}(i,j)\|\omega''), f^{t_0,t_1}_{t_1}(I_{t_1}(i,j)\|\omega'')\right)\right)$
$\theta_{\text{ch}\cap\text{no ch}}$	$m\left(\theta_{\text{ch}\cap\text{no ch}}\right)$ is adjusted in order to respect eq. (1).
$\theta_{\text{ch}\cup\text{no ch}}$	$\rho\left(f^{t_0,t_1}_{t_0}(I_{t_0}(i,j)\|\omega''), f^{t_0,t_1}_{t_1}(I_{t_1}(i,j)\|\omega'')\right) \times \left(1 - \mathcal{D}\left(f^{t_0,t_1}_{t_0}(I_{t_0}(i,j)\|\omega''), f^{t_0,t_1}_{t_1}(I_{t_1}(i,j)\|\omega'')\right)\right) \times \mathcal{S}\left(f^{t_0,t_1}_{t_0}(I_{t_0}(i,j)\|\omega''), f^{t_0,t_1}_{t_1}(I_{t_1}(i,j)\|\omega'')\right)$

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