CROPLAND DETECTION WITH SAR INTERFEROMETRY: A SEGMENTATION MODEL

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ABSTRACT

Repeat-pass SAR interferometric data are multitemporal and display changes occuring between two acquisitions. As a consequence, phase and correlation images contains meaningful informations usable for cropland monitoring. This paper proposes a statistical model to segment high phasimetric structures. It is expressed in a Markov random field framework by using cooperatively phase and correlation information.

1. INTRODUCTION

Repeat pass interferometry analysis has demonstrated the capability of phase information to determine topographic elevation [9, 14] and small ground deformation [3, 8]. The interferometric correlation measures the variance of interferometric phase estimation. It contains significant information on temporal change used for thematic monitoring of the ground [1, 13], but phase image, presenting characteristics which could be useful, are rarely used for this scope. Actually, important “phase effects” can be observed on the evolution of vegetation fields submitted to rainy periods [2, 10]. To draw the potentialities of phase images, it is necessary to detect and characterize these meaningful effects.

In this work, we present a statistical model to segment these so-called “phasimetric effects” [7]. It is expressed in a Markovian Random Field framework well adapted to multiple source information (phase and correlation) and noisy images.

This paper is organized as follows: first we briefly describe interferometric data and define phasimetric effects properties, secondly the segmentation model is detailed and some results are commented, finally we propose some perspectives to begin the next step of this work: the classification of these effects.

2. CHANGE DETECTION WITH REPEAT-PASS INTERFEROMETRY

SAR interferometric data processing combines two complex valued SAR images acquired with slightly different sensor positions [5, 14]. Each interferogram pixel s is computed through the complex coefficient γ depending on the two radar signals E backscattered by the same area:

$$\gamma(s) = \frac{\displaystyle\sum_{s\in F} E_1(s).\overline{E_2(s)}}{\sqrt{\displaystyle\sum_{s\in F} |E_1(s)|^2 \times \sum_{s\in F} |E_2(s)|^2}}$$

γ depends on radar system, data processing parameters, geometric parameters, parameters related to the land surface and its temporal evolution between the two acquisitions.

The interferometric phase ($\arg\gamma$) is a measure of the difference in path lengths to the sensors, and this property is used to derive the three dimensional position of the image resolution elements, allowing the computation of Digital Evolution Maps. In knowing the terrain geometry and if the ground is stable, the phase only depends on land surface evolution. The interferometric correlation ($|\gamma|$) measures the variance of the interferometric phase, it strongly depends on temporal changes.

A random dislocation of the individual scatterers between the two acquisitions of an interferometric image, modifies the SAR image phase, resulting in a decrease of the interferometric correlation. If this dislocation is uniform in an area of identical properties, the coherence is conserved inside that region, only its borders correspond to a correlation decreasing. These kind of effects appearing in phase and correlation images have been defined by D. Massonnet and *al.* in [7] as “phasimetric effects”. They usually are strongly observable when the two acquisitions are separated by an important rainy activity. These structures, as they corresponds to fields, are sensitive to hydrometric variations.

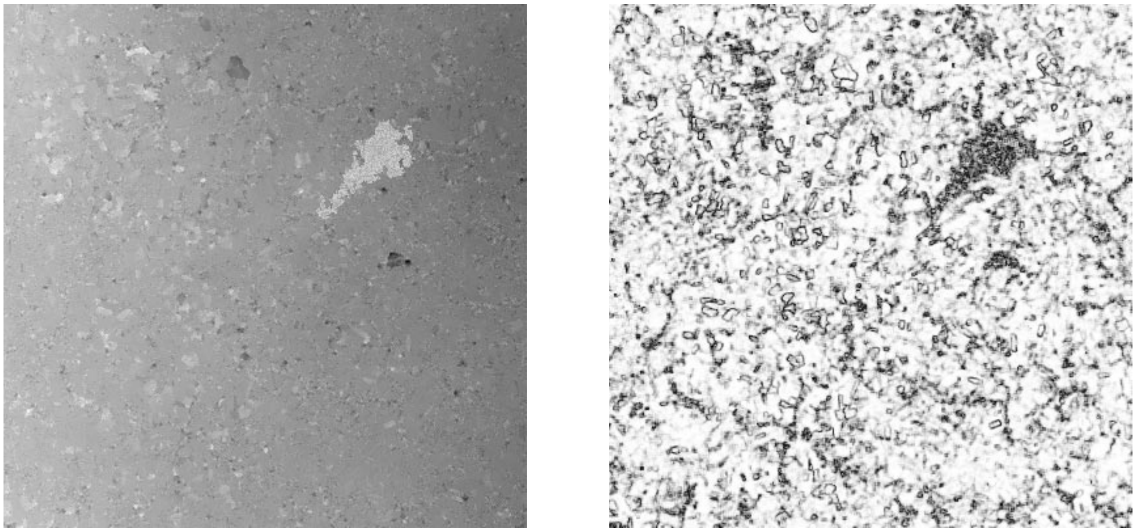

Figure 1: *Interferometric phase image and its corresponding correlation; the big low correlation area corresponds to a forest.*

As a consequence these data contain thematic informations which can be used to support land use classification. In order to discuss the potentialities of interferometric phase for thematic land study, the phasimetric effects have to be detected, this is the aim of the model presented in next section.

3. SEGMENTATION MODEL FOR PHASIMETRIC EFFECTS

Phase images to be segmented are corrected from all geometric effects: a topographic correction has been done with a digital elevation model [6] and orbital fringes suppressed by using an unwrapping method [4].

The objective is now to devise a method for characterizing each small region region staying out of its environment. Such regions are either brighter or darker. Instead on individually trying to localize each of these small regions we are going to perform a global segmentation of the background area than surrounds them.

The model makes uses of properties that grow out of phase and correlation image:

1. **homogeneous variation of the phase** outside regions displaying a phasimetric effect;
2. **correlation** is lower at boundaries between the background and phasimetric effect;
3. **regularity** of the segmented region.

These properties are translated in a MRF framework: let,

- S the set of pixel sites;
- $P = (P_s)_{s \in S} \in \{-1, +1\}^{|S|}$ is the random variable corresponding to the segmentation process, +1: background, -1: phasimetric effects;
- $Q = (Pha_s, Coh_s)_{s \in S} \in [0, 255]^{|S|} \times [0, 1]^{|S|}$ is the random variable describing image data *ie.* interferometric phase and coherence;
- $\mathcal{C}(p)$ denotes the set of background pixels;
- p and q are the respective realizations of P and Q.

We are given a Markov Random Field on these pixel sites, defined by a neighborhood system $\mathcal{V} = \{\mathcal{V}_s, s \in S\}$, where $\mathcal{V}_s$ is the set of neighbors of the pixel s, and by clique potentials.

The energy of the model can be written as:

$$U = U_1 + \beta U_2$$

where U_1 expresses the two image properties:

$$U_1(p|q) = \sum_{s \in \mathcal{C}(p)} \left[\left(\frac{Pha_s - \mu_s}{\sigma_s} \right)^2 - f(Coh_s) \right] \quad (1)$$

with

$$\forall s \in \mathcal{C}(p), Pha_s \sim \mathcal{N}(\mu_s, \sigma^2)$$

where $\mu_s = ax_s + by_s + c$, is used to express the variation of homogeneity;

$f(Coh_s)$, a threshold obtained from T, the gaussian acceptation, biased by the coherence, in such a way that the segmented region is stopped by points of low coherence.

The second energy term U_2 is used to express the regularity property, in order to merge noisy pixels to the background. It is based on the Ising model:

$$U_2 = \sum_{<s,t>} p_s p_t \tag{2}$$

Parameters a, b, c and σ are estimated during a pre-segmentation process, where are only used contours obtained by a Canny-Deriche filter performed on the phase image are used. T and β are fixed by the user.

The T parameter is used to determine the accepted grey level difference between a pixel which is considered as the background and one of its neighbors corresponding to a phasimetric effect. As we can see on figure 2, if T is too low, many of the expected high phasimetric regions are merged to the background. T also determines the importance of the correlation image.

β is linked to the influence of the regularity parameter. It allows to evaluate as background, small regions corresponding to noisy isolated pixels (see figure 3). But if it grows too much, we loose the precision of phasimetric effect localization.

4. CONCLUSION

This work is a first step in more ambitious project aiming at evaluate potentialities of interferometric phase data for thematic monitoring. We have proposed this segmentation method to detect phasimetric effects.

The choice of a statistical model gives some good results even for very noisy images. A method based on level set active contours as introduced by Sethian [11] could be used in a multi-source context. But they are less usable when noise is important and moreover, the resolution of associated differential partial equations is challenging numerically. To give a comparison, we use a deterministic relaxation method, an ICM (Iterated Conditional Mode), which gives a solution in less than 200 iterations (about 20 seconds on a DEC Alpha 233) for a 400×400 image.

The second step of this work will be a classification of the phasimetric effects in different comportment classes. And finally a global land classification using this information.

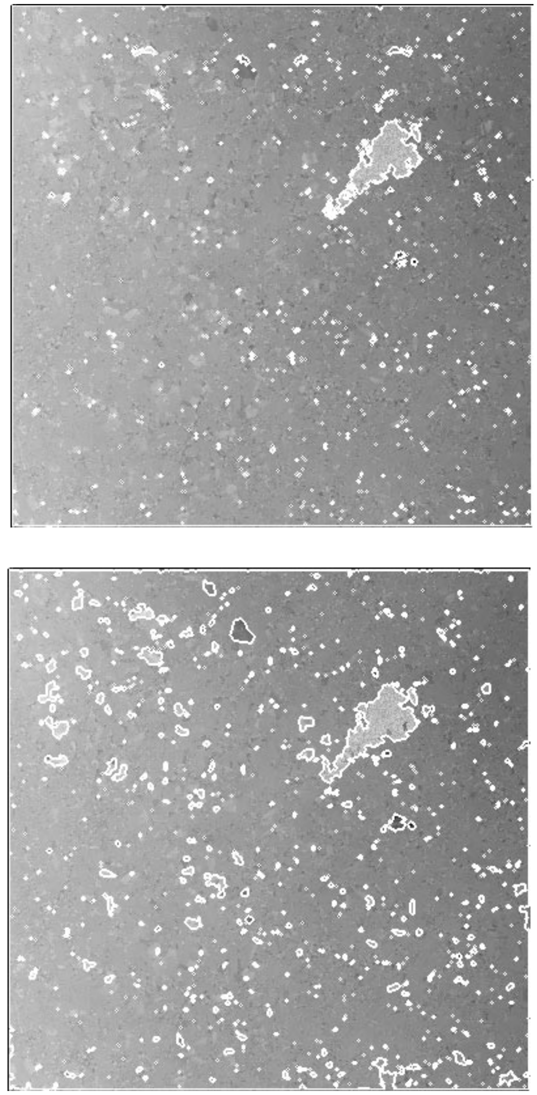

Figure 2: *Result of the segmentation using T = 45 (Up) and then T = 60 (bottom).*

Some studies of land use monitoring using interferometric correlation and/or the intensity of the backscattered signal have already been presented [1, 12]. Tacking into account phase information will improve their results.

5. ACKNOWLEDGMENTS

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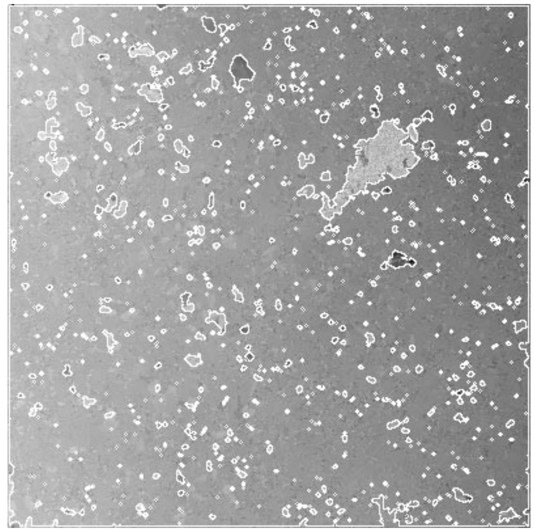

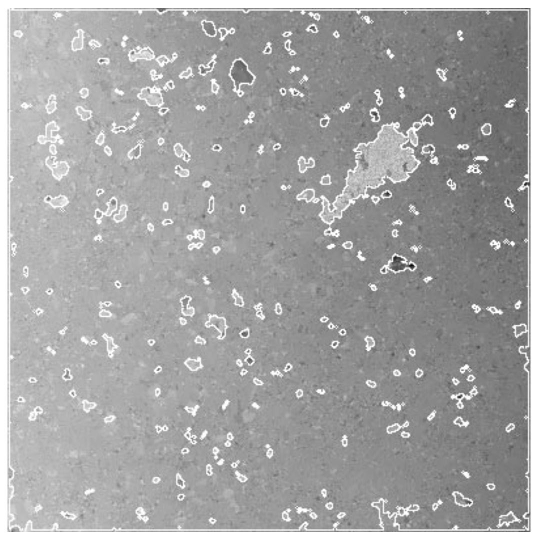

Figure 3: *Result of the segmentation using β = 5 and then β = 11, small regions corresponding to noisy pixels have disappeared.*