TIME-FREQUENCY ANALYSIS OF SAR IMAGES FOR CHANGE DETECTION

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1. INTRODUCTION: TIME-FREQUENCY ANALYSIS

Time-frequency analysis (TFA) has been pastly applied on SAR images in various ways: detection of points of interest based on backscattering criteria (through sub-band decomposition) [1, 2], characterization of the dominant backscattering mechanisms [3, 4] (through spectrogram analysis) or advanced interpretation [5, 6, 7] (polarimetry, moving target identification). TFA actually enables to isolate physical properties. During SAR image acquisition, each target is illuminated with different azimuth angles and different range frequencies. The targets are assumed to get stable response throughout the acquisition; yet some have particular behaviours, i.e. either very stable (for instance trihedrals) or directive (for instance dihedrals, resonance). Note that the higher the resolution is, the larger the ranging of azimuth angles and range frequencies are and the higher is the probability of observing scattering variations. Once SAR synthesis is performed, these variations are averaged inside SLC (Single Look Complex) images which are integrated signals; TFA is one way of retrieving this spectral variation again and thus characterizing the target backscattering. In previous work [3, 4], it was shown that a TFA method based on continuous Fourier transform analysis enables us to characterize four different backscattering mechanisms (stable, unstable, azimuth variant, range variant). This TFA method relies on the computation of so-called "spectrograms", which, for each pixel in the image, provide a 2D information giving the backscattered energy for every frequency (range, azimuth) positions. Spectrogram computation is thoroughly explained in [4, 3]. The idea is to compute, for every pixel, the energy embedded in varying sub-bands. Each sub-band, i.e. a spatial image with a degraded spatial resolution linked to a spectral band-pass filtering of the initial SLC spectrum, is characterized by a position of the band-pass filter central frequency. For each frequency pair (f_x, f_y), the spectrogram $\tilde{a}$ of the pixel (x, y) is thus a 2D image defined by:

$$\widetilde{a}(x, y, f_x, f_y) = FFT^{-1}[w_B(f_x, f_y) \times FFT(s)](x, y) \tag{1}$$

where x and y are the pixel coordinates (in slant range geometry), $w_B(f_x, f_y)$ is the band-pass filter centred on (f_x, f_y) (typically an Hamming function) and s is an extract of the SLC image centred on (x, y). FFT^{-1} stands for the inverse Fourier transform.

2. CHANGE DETECTION

We use here the backscattering properties obtained through spectrogram analyses to identify changes in image series. Change detection has been extensively studied with an amplitude point of view (comparison of amplitude values or statistics), for instance see [8, 9]. With TFA, it becomes possible to track the backscattering mechanisms involved in the pixel amplitude and thus to select pixels with similar properties. This should ensure that the pixels are associated to the very same structure of the scene or to very different objects. This change detection will be performed on a small analysis scale.

The change detection methods is made of several steps:

- computation of spectrograms for each pixel in every images,
- computation of the correlation coefficient between all the spectrograms of each pixel,

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- selection of very stable pixels (with respect to their physical properties) by a high thresholding on the correlation coefficient,
- selection of low correlation pixels: in this case, two possible cases arise. Either the pixel is very similar in each image but with a directive backscattering pattern inducing translations of geometrical pattern in the spectrogram (because of geometrical changes in the acquisition), or the pixel has changed in one image to another. In order to discard these two cases, extractions of features are performed on the spectrograms and a change criterion is computed on these features.

3. APPLICATIONS AND RESULTS OBTAINED ON TERRASAR-X IMAGES

A possible application of such a change detection approach is the selection of "Persistent Scatterers" (PS) in stack of interferograms. Interferometry is used to build Digital Terrain Models (DTM) or to estimate ground movements from the combination of the phases of several SAR images acquired under slightly different geometrical configurations. One of the major issues is to select reliable points present in every image of the stack, in order to further extract movement information. Such points are called "persistent scatterers" (PS) [10] and they should correspond to the very same structures of the scene in each image to assure that the phase differences are only linked to a movement and not to a surface change. Our change detection method should provide a reliable PS network.

As a consequence, we propose a method to combine TFA (based on spectrograms) with analyses of multi-temporal series (including interferograms). A special emphasis is put on the selection of PS with first comparisons based on the analysis of interferometric coherence. The algorithms described in this paper are assessed on real data (TerraSAR-X Spotlight images over Toulouse, France). Extensive analysis regarding ground truth is performed to understand TFA differences and validate our change detection. This study is a required step for further work on comparison of change detection methods.

4. REFERENCES

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