PROCESSING AND SEGMENTATION OF COSMO-SKYMED IMAGES FOR FLOOD MONITORING

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1. INTRODUCTION

Floods monitoring and detection represent a relevant problem in risk management. In the case of flooding emergency a promptly overall view of the phenomenon reduces delays in the intervention planning.

When the emergency has ended and the flood have subsided, it is very important to have a detailed and accurate estimate of the flood affected area for assessing the hazard and to create hydrological models in order to plan further interventions that may reduce the risk of future flooding.

In this context, major aim of this paper is to present some applications of image processing and segmentation to SAR (Synthetic Aperture Radar) satellite observations for mapping flooded areas in small to medium-size catchment basins.

The proposed work has been developed in the framework of the project "OPERA – Civil protection from floods" funded by the Italian Space Agency, in collaboration with Civil Protection Department. The major aim of the authors' department tasks is to prove the added value of the Cosmo-Skymed (CSK) data in the analysis of flooded areas and the performances of image processing and segmentation methods as a tool that could help and fasten the interpretation process.

Two main products have been designed and realized within Opera project, dealing with fast-ready map display and detailed flood map generation, respectively

A fast-ready flooding map is generated starting from an image acquired before the flood event and an image after the event in the same area. It consists in a display able to focus the attention on flooded areas while enhancing the changes occurred as well as the steady water. For a better human interpretation, colours are used by combining the SAR images of the temporal sequence, after an appropriate, automatic pre-processing step.

Detailed maps are generated thanks to a multi-temporal image segmentation. After the user has manually localized a few points corresponding to water in one image, the classes of flood, steady-water and no-change areas are detected. The results is made of connected regions, so that the raster to vectorial format conversion becomes possible.

Both products rely on multi-temporal SAR acquisitions of the same area. No restriction to the acquisition mode or to the spatial resolution are made, given that the geometric registration problem has been faced. The methods can be applied when the same satellite configuration is selected for the image couple. However, they also perform when opposite parameters (as deals with look-angle and orbit direction) are used for image acquisitions (i.e., for instance, left-descending and right-ascending orbits).

Many classical methods for SAR processing and segmentation rely on the supervised approach or are based on precise statistical models. In the former case a major constraint is that a training set defined from one image does not assure good performances on a different test image. The model-based approach needs a precise calibration phase based on a complete and precise measurement of acquisition parameters such as a very accurate radar-backscatter model.

On the contrary, the methods here proposed take uncertainty into account, both in the data representation and in the processing steps.

When some a–priori knowledge is required, as for the fast-ready map generation, only a linguistic, qualitative model description is adopted, thus avoiding the need for precise calibration and measurements.

For the detailed map generation, the training process is reduced to a very simple user interaction. Starting from one of the satellite image of the temporal sequence, the manual definition of a few points (i.e., seeds) that surely belong to water allows the automatic detection of open water and flooded areas. No a-priori knowledge or calibration at all is here required, since the manual indication allows a local estimate of simple statistical descriptors. The processing required for the generation of the detailed map is adaptive to the statistics local to the seed, and is obviously adaptive with respect to the specific image acquisition, too.

We are here addressing SAR amplitude/intensity multi-temporal image sequences. We are not facing the problem of windy conditions that have to be solved by using additional information with respect to the only SAR backscatter intensity. A few papers have been proposed taking into account texture features or interferometric coherence extracted from InSAR (Interferometric-SAR) data [1,2].

2. FAST-READY FLOODING MAPS

To the end of maps generation a major role is played by the pre-processing step. Not only de-speckling is often required to achieve a correct and successful result, but also calibration is critical when dealing with multi-temporal analysis or with a model matching step. Since we are not interested in a quantitative model calibration and matching, we propose an Adaptive-Self -Similarity-Normalization step to allow a combination and a comparison of the punctual amplitude/intensity levels characterizing the pre-event and post-event images.

Some processing algorithms, like for instance segmentation methods, can be applied indifferently to 8-bpp (bit-per-pixel) or 16-bpp images. On the contrary, some other steps like, for instance, gray-level and false colour display, need a 1-Byte rescaling. Since SAR images are acquired with 2 Bytes per pixel it is then required a re-scaling step able to preserve the information content. To this end, the original image histogram is the key point to refer for a good result that reduces the risk of loosing significant information.

Because of the strong histogram asymmetry, due to the well- known non-gaussian model of radar backscatter, the classical equalization procedure, generally used to improve the visual perception, is here inapplicable.
Since we are dealing with the problem of water localization, all the image processing steps could be goal-driven, for instance by focusing on dark regions of interest. One can also consider that a loss of contrast in light areas is of limited relevance to the end of a display, does not affect the correct detection of dark regions, and, finally, is addressing a vey low-energy level range.
We have proved that, after clipping the original histograms at a same fiducial interval, the equalization step is able to cross-calibrate the pre- and post-images since it refers both to a common uniform model. After such a step a difference between the two images can be extracted and used as a third dimension in the color space.
It was empirically observed that the choice of the fiducial level is not affecting the result too much, thus proving the robustness of the method. At the same time, the contrast between the class of interest (water) and all other classes is improved, thus allowing a better visualization.

3. DETAILED FLOODING MAPS

For the generation of detailed flooding maps a multi-temporal "seed-growing" segmentation was applied independently to each image of the pair. By taking intensity and topological connectedness into account at a same time, as in [3], an adaptive growing mechanism is realized. The aggregation criterion is of the "centroid-linkage" type, as defined in [4]. It is based on a distance measure that takes the local seed statistics into account. In such a way, it is possible to avoid the use of any parameters during the processing.
One of the innovative aspects lies in the intelligent scanning mechanism that is not pre-determined but is adaptive to the image at hand.
Data fusion for the temporal analysis is here realized at the symbolic level, that is, the combination of the results obtained from the two images is made starting from the segmented images. This means that, in principle, the multi-temporal pair might also refer to two different acquisition settings, given the same geometric configuration and that registration problems have been solved. This might allow the future use of multi-polarimetric SAR images.

4. RESULTS

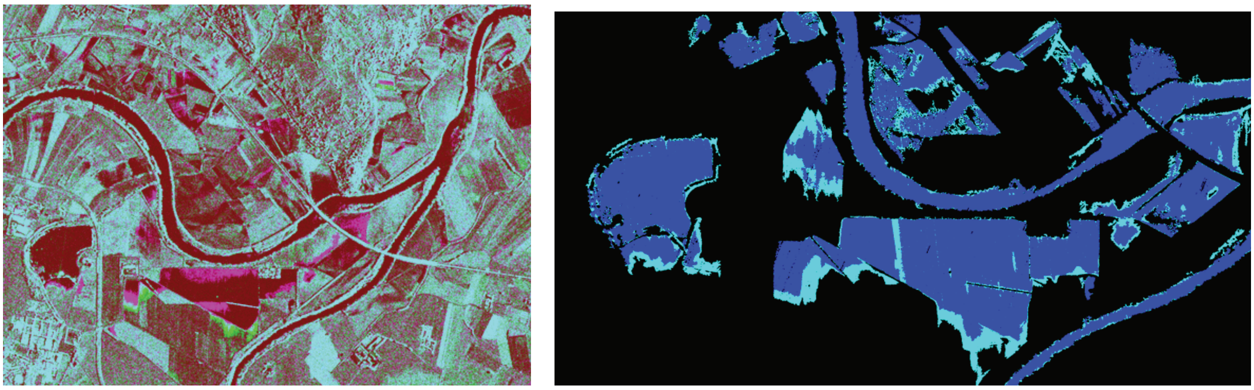
Experiments have been accomplished on various COSMO/SkyMed (CSK) multi-temporal sequences. We here present images related to a flood of the Tanaro River occurred on April 28, 2009, in an area close to Alessandria (Italy). Images have been acquired in different acquisition modes (Spotlight and Stripmap) and with different geometric acquisition parameters. The results are then evaluated by comparison with a test map containing the actually flooded areas.

The multitemporal data set consists of two pairs of coregistered Cosmo/Skymed Spotlight (1-meter resolution) images and Cosmo/Skymed Stripmap (2.5-meter resolution) images, acquired on April 29, April 30, and May 1, 2009.

In the following figure an example of fast-ready map is presented, in the left part, showing flooded areas, steady water and changes occurred between the dates of April 30 and May 1, when using Stripmap images.

Right part shows the detailed map pointing out the changes occurred between April the 29th and April the 30th as derived from a Spotlight image pair.

A more comprehensive experimental session will be reported in the final paper, showing how the two algorithms are independent from image resolution.



Case study: (left) Fast-ready map from {April 30, May 1} Stripmap image pair (color legend: reddish-purple = “steady water”; magenta = “flood areas”; cyan = “no-change”); (right) Detailed flood map from {April 29, April 30} Spotlight image pair (color legend: blue = “steady water”; cyan = “flood areas”; green=“other changes”; black = “no-change”).

From among the main advantages we might here recall that both methods are applicable to many types of images referring indifferently to intensity or amplitude images, any look angle, any polarization. In particular, even though fast-ready maps require homogeneous pair images, the detailed-map might be derived from images characterized by different acquisition settings.

5. REFERENCES

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