IMPROVING CHANGE DETECTION USING GEOMETRICAL FEATURES

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ABSTRACT

While pixel-based or object-based change detection approaches have been proposed in technical literature, change detection techniques based on feature extraction and comparison are less numerous, due to the reliability the extraction. This paper discusses how to exploit aggregated information obtained from geometrical features to obtain hints to changed areas and to unchanged areas as well. This approach not only allows to detect changes, but also to improve existing change detection results by reinforcing change areas and rejecting portions of the scene where geometrical features do not appear to have undergone any change. Results exploiting COSMO/Skymed data in Haiti show that the approach is valuable, and has great potential for improving change detection results obtained by more standard per-pixel approaches.

INTRODUCTION

Most of the change detection algorithms developed in technical literature are based on comparison of pre- and post-event features, either per-pixel backscatter or reflectance values (1,2,3) or more complex spatial features, such as textures and local spatial indexes (4,5). Change detection algorithms based on geometrical feature comparison are instead risky, as the comparison is highly dependent on the extraction results, and false positives/negatives may arise from poor performances of the extraction routines.

In this work we present therefore how to use geometrical features to improve change detection using rather trivial and pixel-based techniques as well as more sophisticated results. The focus is on earthquake damage extraction using SAR, and specifically COSMO/Skymed data. The idea is that geometrical features, as well as their spatial distribution in an image, may provide additional information uncorrelated to the results of pixel-based change detection approaches just because these geometrical feature are obtained using extraction algorithms based on totally different image processing techniques than those used for change detection. It is also very relevant how this additional geometrical information is used, and since false positives are more likely than false negatives, the idea is to use geometrical features to reinforce the results where they show that no damage/no change has occurred. By this way, the proposed approach is able to reduce the false positive without including more errors in the final change map.

In an alternative way to previous works by some of the authors, when the geometrical features were used to extract the pre-and post-event road networks and then to discard from change maps the potions of these networks that appear to be present in both the pre and post-event data set, in this work two other, different kind of geometrical feature information are considered. The first one is the density of geometrical features, computed as the percentage of pixels belonging to an extracted segment in a sliding window around the pixel under test. An alternative feature may be the direction (or better main direction) of the extracted geometrical feature within the same sliding window. Changes in these two quantities are likely to occur in change areas, while there is a very large likelihood that their vales is not going to change (at least significantly) in areas where no change occurred. By using sliding window estimate, the proposed approach averages the information over a set of geometrical feature extracted, thus reducing the likelihood of recognizing changes or no changes that are non-existent.

THE NOVEL PROPOSED FEATURES FOR CHANGE DETECTION

The very first step of the methodology is to extract “linear features” from both pre and post event data sets. For “linear features” we intend mainly road networks but even buildings edge, borders and all visible boundaries on the landscape. This step is performed by a specific routine for SAR data based on feature fusion and jointly considering many of the features associated with roads in SAR images (6). The routine is particular able to extract edges in areas where there is a strong contrast with the surround. Accordingly to that, the SAR sensor angle plays a relevant role. Following steps foreseen a refinement of the extracted edges: very short segments (e.g., smaller than 4-5 pixels) are deleted, and collinear or close segments fused together using perceptual grouping concepts (7).

The edge sets extracted for different dates are therefore compared by means of superimposing each other. Due to little misplacing of edges generated from the same features in SAR data due to georeferencing but also to the different SAR viewing angle, it is not possible to highlight changes just using a pixel to pixel difference. Instead, a buffer zone around each segment at one date is created (depending on the spatial posting of the data, and basically of 2-3 pixels) and superposition with the set at the other date(s) is performed to detect segment pairs that:

- are visible on both images (“common segments”, hints to unchanged areas);
- are visible only on one of the two images (“change segments”, hints to a possible change).

Common segments are likely to be located in areas whose appearance did not change significantly at the two or more considered dates and thus could be considered as hints to unchanged areas. These areas could be used to improve an existing change map by assuming that regions where segments match cannot be considered as changed, that is simply subtracting them from the map. Similarly, change segments are connected to change areas and could be considered as a means to extract a change map by themselves. Figure 1 represents the overall procedure, graphically displaying the processing steps introduced in this paragraph.

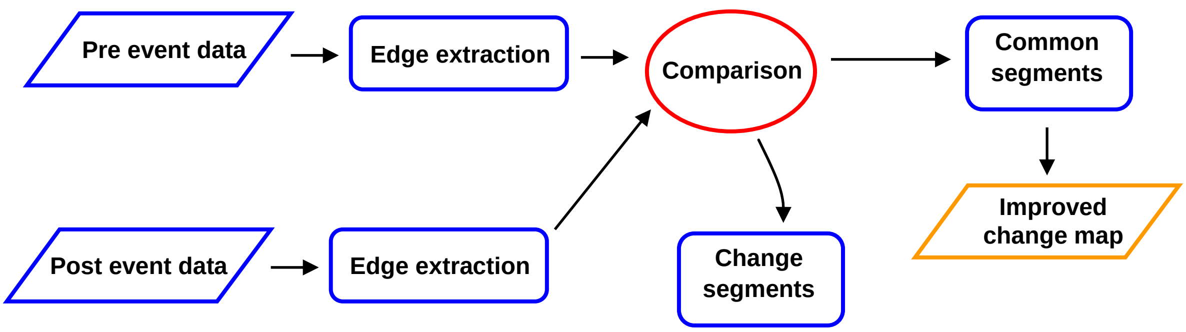


Figure 1: *Overall structure of the improved change detection procedure.*

Instead of using the segments to confirm changes obtained by other techniques, of course the matches can be used to extract changed directly. As the extraction of the single segment, however, cannot be considered reliable enough, especially for SAR images in urban areas, we rely on aggregated information, such as the local segment concentration or orientation. By comparing these values in two or more dates it is expected to be able to extract significant hints to changes.

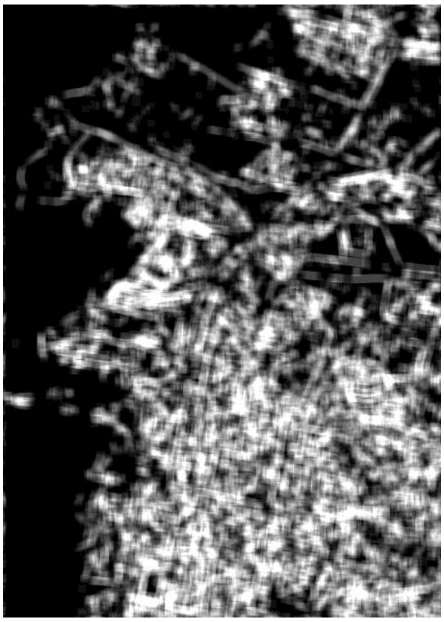
The first change indicator based on segment extraction that can be easily computed is the concentration of pixels belonging to a segment in the neighbourhood of the pixel under investigation, or “segment concentration”. Each “segment concentration” map is obtained using a moving window approach and eventually a map of the differences in segment concentration between two dates can be computed and significant areas of change (or no-changes, as before) extracted.

Another possibility is to take into consideration the mean local segment orientation, or “mean segment angle”. It is reasonable that areas where no significant changes occurred show similar edge orientation. Using the same moving window approach as before, local orientation maps can be computed and compared. Here again the resulting map could be considered as changing map by itself or the areas showing the same local orientation can be considered as hints to lack of any change and discarded from a pre-existing change map, with the final result to improve it.

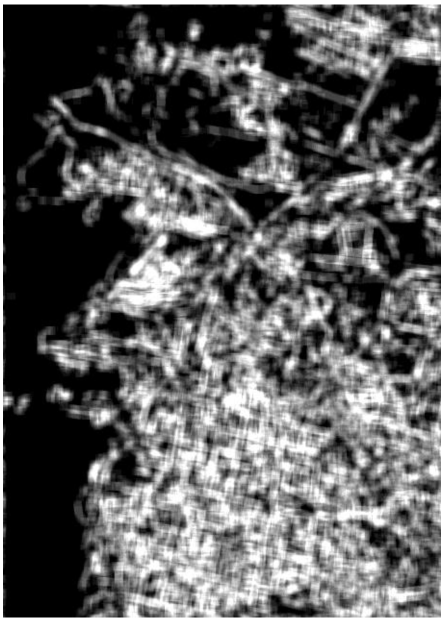
EXPERIMENTAL RESULTS

The approach was tested to extract change maps after the Haiti earthquake, occurred on January 12th, 2010. The SAR data used in this research were acquired by the COSMO/SkyMed constellation and are centred around the city of Port au Prince. The pre-event image was collected on 26 April 2009 and the post-event image on 15 January 2010. Both images were acquired in Spotlight mode.

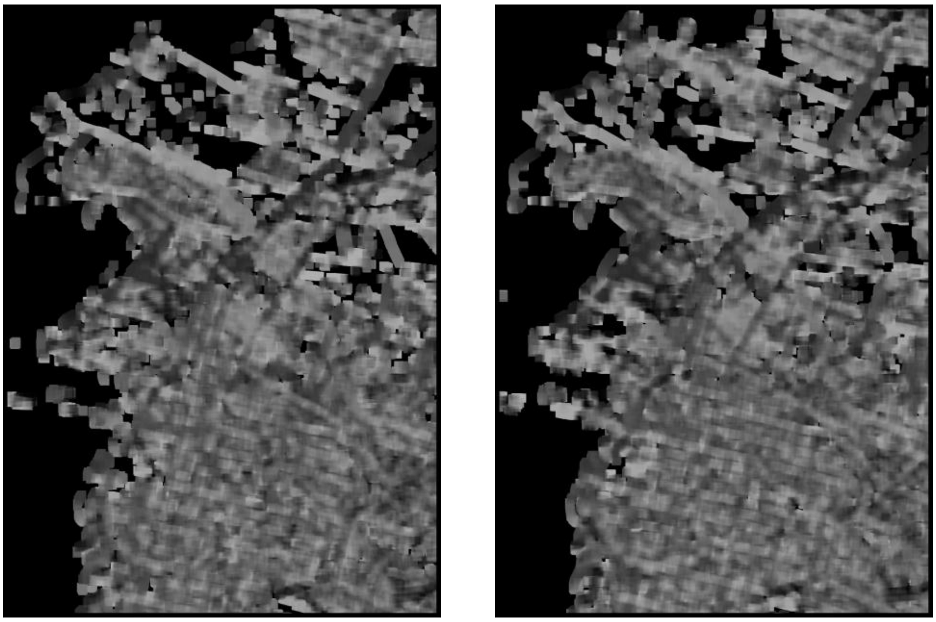
As mentioned above, a first possibility is to use directly the features extracted from geometrical elements of the scene to detect “change hotspots”, that is areas where a change is likely to have occurred. To prove the usefulness of this methodology, we extracted segments, limiting the minimum length size to 5 pixels, from the pre- and post-event Spotlight COSMO/Skymed images and used these sets to compute the “segment concentration” maps (Fig. 2 a,b) and the “mean segment angle” maps (Fig. 2 c,d). Of course, the computation did not take place in areas where no segments were extracted, which appear in black in the figure.



(a)



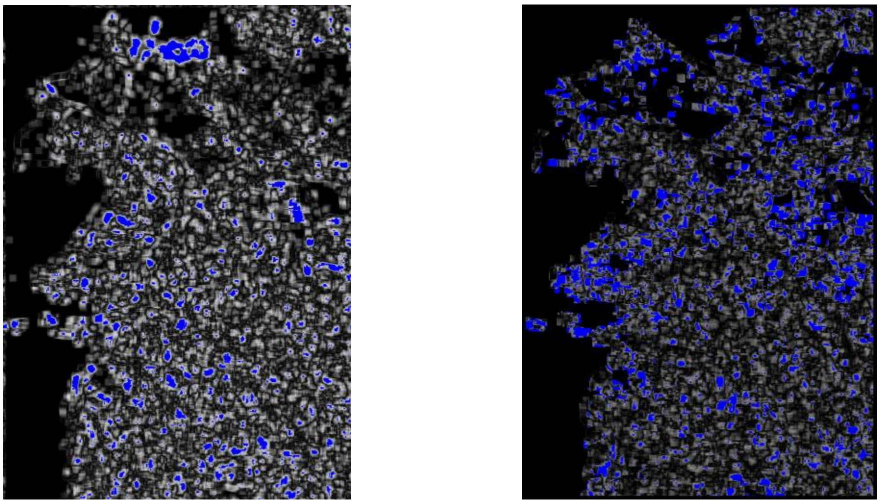
(b)



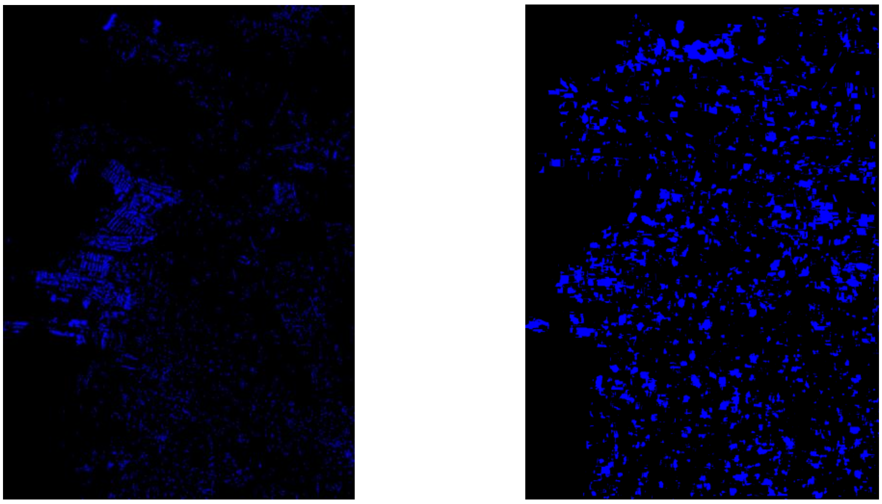
(c) (d)

Figure 2 – *Processing results on the pre- and post-event pair for Haiti: (a) pre-event segment concentration map; (b) post-event segment concentration map; (c) pre-event mean angle map; (d) post-event mean angle map.*

By exploiting the maps in fig. 2 two different change maps for the Haiti test site were obtained, shown in fig. 3 (a,b), to be compared with results obtained using a completely different approach by the University of Siena (8). The threshold used in this case was chosen empirically but it closely corresponds to the value identified by the upper point of the histogram. At the first glance the maps shown differences: concentration map emphasize areas where identifiable edges (normally represented by random oriented building edges) appear/disappear; orientation map underline areas where uniformly oriented edge were clearly in the pre-event image and disappeared in the post-event one, and this is usually the case for roads. In comparison to the change detection provided by the University of Siena we realize that a considerable part of changed areas are shown in all the maps, this is more clear if we consider a "sum" of changed areas highlighted in concentration and orientation maps (fig. 3d).



(a) (b)

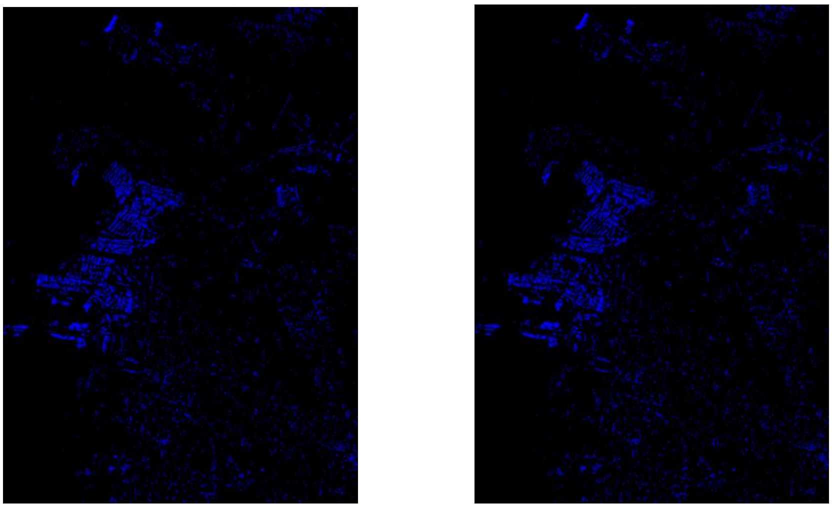


(c) (d)

Figure 3 – *Change maps obtained for the Haiti test case: (a) using segment concentration map; (b) using mean orientation angle map; (c) change map obtained by the University of Siena using the approach in* (*8*); (d) "Sum" of changed areas highlighted in concentration and orientation maps.

The visual inspection of the maps in fig. 3 confirms that the proposed methodologies, based on geometrical information, and pixel-based approaches considering the context as in (8) provide complementary information. Therefore, as designed in the previous section, these change maps can be combined to achieve more robust results. The idea is that the novel change maps can be exploited to confirm the existence of "change hotspots". Consequently, they can be used to actually remove the hotspots obtained by other means which do not appear to have generated a change on the concentration/orientation of the extracted segments. Indeed, the maps proposed in this work rely on segment extraction routines that may fail and are subject to errors. Although it is not possible to fully trust the change maps based on segments (see again fig. 3), it is instead more likely that change areas detected by pixel-based approaches, and that do not result into any real change in the segment concentration or orientation, are false positive.

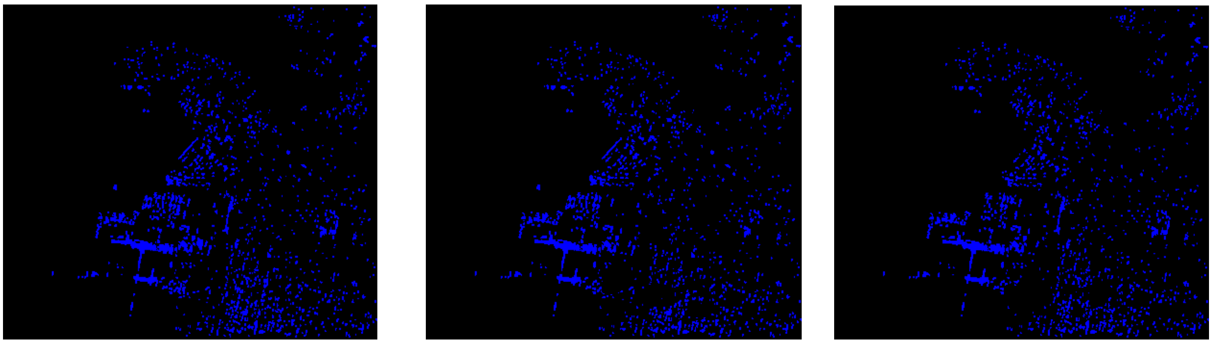
Using this criterion to discard possible false positive from fig. 3(c), the algorithm leads to the refined change maps in fig. 4.



(a) (b)

Figure 4 – *Improved change maps obtained for the Haiti test case: (a) using segment concentration maps; (b) using mean orientation angle maps (both should be compared with the initial change map fig. 3(c).*

The same approach has been applied to the same data but using a different initial change map provided by the university of Genoa (9) This map is proposed in fig. 5 (a), while the results of the proposed approaches are depicted in fig. 5 (b,c).



(a) (b) (c)

Figure 5 – *Improved change maps starting for Haiti starting from a change map provided by the University of Genoa: (a) initial change map, computed according to (9), (b) improved change map using segment concentration maps; (c) improved change map using mean orientation angle maps.*

Unfortunately, accuracy evaluation for the proposed maps is not a simple task, due to a lack of reliable ground truth. A visual inspection among the results and using ancillary information provided by the International Charter for Disasters gave however some positive feedback to perceive some improvement in comparison to the original change detection result. A closer to quantitative, although still very approximate, analysis can be performed considering the percentages of "change hotspots" deleted from the original change map. Values are reported in Table 1.

Table 1: Percentage of "change hotspots" removed from the initial change maps thanks to the analyses based on the segment concentration and mean orientation angle.

Test site	***Segment concentration***	***Mean orientation angle***
Haiti – University of Siena	10,1 %	4,1 %
Haiti – University of Genoa	4,1 %	2,7 %

CONCLUSIONS

This research proposes to include in the change detection procedures exploiting backscatter and spatial information in VHR SAR the possibility to evaluate aggregated measures coming from geometrical features in the scene. To this aim, we showed that hints to changed areas can be obtained by comparing at two or more dates the information about "segment concentration" and "mean segment angle". The same maps can be also considered as a way to find reliable hits to areas where no changes occurred, reducing the false positive percentage that is usually high in current change detection techniques' results, especially for SAR images.

Although quite rough, the approach proposed here open many possibilities worth exploring in future works, like for instance the possibility to detect "strong" or "smooth" changes in sequences of remotely sensed images by considering the temporal evolution of geometrical features' concentration and/or orientation maps.

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