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Research Article

Damage Detection from SAR Imagery: A
to the 2003 Algeria and 2007 Peru Eartl

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Abstract

This paper is focused on the improvement and further validation c
radar satellite imagery of an area affected by a major disaster
different sites on imagery of two different earthquakes occurred
21st, 2003, which severely affected the city of Boumerdes, and
2007. The combination of different radar-extracted features re
patterns, far less detailed than what available using optical im
mentioned ancillary data provide enough detail and precision to
damage level at the block level is achieved at enough detail using
idea.

1. Introduction

One of the most important issues in disaster damage detectior
precision. As a consequence of that, every kind of data available is
operators [1]. To this aim, remotely sensed imagery can be instru
(GIS) layers, printed maps, and historical datasets. However,

constantly growing in the past few years, image interpretation t accurate, are still not used in many applications.

Damage assessment is actually a big challenge, being impossible reason, the organizations such as the International Charter on "S wide range of sources. The need of rapid damage pattern estima using quick and possibly efficient approaches suited to the decided at which the analysis can be carried out is determined by the sp while SAR data can be useful to extract damage information only the single collapsed buildings from HR images.

The aim of this work is to understand the viability of radar sate many different disasters all around the world, looking also at diffe available with more and more fine spatial resolution, and thus wit improvement actually allows a better match between the growing the concentration of population) with the enhanced availability of in urban areas using SAR data are very limited, due to the problem or semiautomated tools.

2. Damage Pattern Estimate FROM Sar Data

In recent technical literature, some works have already suggeste proper temporal and spatial scale, interesting information about d works concerning earthquakes need data coming from ground sur information extraction. For this reason, these strategies are very ground displacements and soil properties [2, 3], or to provide pr very poor results in terms of damage assessment and rapid dar important to say that classification and change detection metho usable results to the final user. Instead, these methods integrate more precise and understandable results. Moreover, damage anal human settlements in general, where it is often easily feasible t (GIS) data.

In this work, we apply a technique recently proposed in [5] for th Golcük (Turkey) earthquakes. The first aim of this work is indeed t situations and produces useful results fro damage assessment in d this paper reports the results of an investigations about the robu features originally used in the cited papers.

The overall methodology of the data analysis is proposed in Figu here all the details of the algorithm. The procedure involves first o the original multitemporal dataset comprising pre- and postevent S is then input to a multiband supervised classifier, whose output is postclassification fusion step is performed at the end of the pro ancillary data.

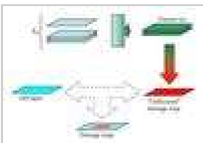

Figure 1: Overall structure of the damage map

The set of feature extracted from the multitemporal SAR imag
assumption that radar returns in damaged areas are quite differer
of the buildings. There are studies showing that urban areas show
values and correlation in amplitude/intensity values during time. I
the change in the complex coherence and in the intensity correl
tested in technical literature for the Hyogoken-nambu (Japan) a
where this was originally proposed [2], each (complex) SAR imag
prefiltered with a Lee filter, and intensity correlation r_i between t
sequence is computed according to the formula

$$r_i = \frac{\Sigma_W x_i x_{i-1} - N\bar{x}_i\bar{x}}{\sqrt{\left(\Sigma_W x_i^2 - N\bar{x}_i^2\right)\left(\Sigma_W x_{i-}^2\right.}}$$

where $x_i = \| X_i \|$ (recall that SAR data are complex values), the $\sum$
each image element in a window $W = N \times X$ around it, and finally the

Along with intensity correlation, another valuable input feature is
mean prefiltered data intensity $d_i = 10\log_{10}(\overline{x_i}) - 10\log_{10}(\overline{x_{i-1}})$, a
and postevent pointwise intensities.

Of course, according to the dimension of the window *W* and thus t
features, multiple scales of analysis of the data can be enhanced.
to our past experience, depends on the ground spatial resolution o
block of buildings in the human settlement under test. In all the c
equally valuable, when the SAR images have spatial resolution in t

The second step of the approach, as shown in Figure 1, is a
comparing two different approaches: a neuro-fuzzy per-pixel Fu
classifier based on the assumption of a Markov random field (MRF
fuzzy classifier has been chosen because of its proven capability to
per pixel classification, while the MRF approach allows a spatially
as such a minimal knowledge about the damages on the ground, t

After classification, and due to the complex interactions betwee
damaged or undamaged, it is very likely that the damage c
appearance. To improve the results, and to meaningfully focus th
final user, a fusion step between the map results and ancillary G
between the two classification methods are used to make a decis
each of the areas detailed by the GIS ancillary information. This
which has been detailed in [5] and in this work will be degraded
This basically means that the most voted damage class in each b
representative of the whole block.

Following this procedure, in next section two different test cas
countries in different parts of the world. Moreover, different SAR
analysis and data availability. With the results of the following
procedure presented here can be helpful in real situations, and co
the input feature set can highlight the damage patterns in the
comparing with the originally studied Bam (Iran) and Golcük (T
combination (if any) for all of them.

3. Applicative Test Cases

In order to test the proposed methodology, the aim of our tests w sensors on board of different satellites. The combination of differ information, availability or not of phase information was meant t approach and find where it has to be adapted. Moreover, the very spatial urban patterns and the effect of the earthquake, make the to the 2003 Bam test case in [5] and the 1999 Turkey case in [6] a

3.1. First Test Site: Boumerdes (2003 Algeria Earthquake)

The first results refer to the magnitude 6.8 earthquake occurred in the Boumerdes province (Figure 2) some 50 km east of Algiers, t Boumerdes, Zemmouri, Thenia, Belouizdad, Rouiba, and Reghaia data are available; in this work the analysis will be concentrated in have been acquired, one pre-event acquired on July 27th, 2002, ar

Figure 2: Location of the urban area of Boume

3.2. Second Test Site: Pisco (2007 Peru Earthquake)

The second example refers to the test case of Peru, whose central on August 15th, 2007. Among the affected cities, the city of Pisc ALOS/PALSAR fine beam double polarization (HH/HV) Precision meters posting. The two images were acquired before (on August, earthquake. Ancillary data consist of a GIS layer depicting the b obtained by manual digitalization of the information in [9], and event image used in that paper. From the same paper, also the in situ measurements was extracted (see Figure 5).

Since the data have been provided as amplitude images, no ph prevents us from using the bands which were considered as th detection, that is, pre- and postevent intensity, pre-post cohere coherence. Instead, from the available images only some intensi intensity correlation *r* and the backscattering coefficient *d* and tal the ALOS/PALSAR scene than the ERS and JERS data used in considered features are the pre- and postevent intensities, comput × 5 Gamma filter. As in the first test case the first classificati classifier or the context-aware MRF classifier is followed by a fusio is assigned to the class to which the majority of mapped pixels bel

For this test case, a wider range of classification maps is proposed combinations of features and classifiers, as well as to appreciate using the data fusion final step. The need for this extended re resolution of ALOS/PALSAR with respect to the ERS/JERS data us precise at the per-pixel level and allows defining spatial units smal (b) with 3(b)). Moreover, the lack of original complex data does no most important bands for the multiband/multitemporal damage a thus intend to analyze which, among the computed features, are t this situation.

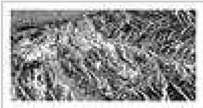

Figure 3: Postevent SAR image (left) and ava
highly damaged areas, orange to medium dam

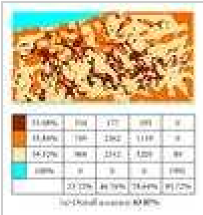

Figure 4: Damage maps for the Boumerdes a
detection algorithm; (b) introducing the GIS in

Figure 5: Postevent pan-sharpened image o
about the blocks in the town and (c) dam
(untouched), yellow (light damage), and orang

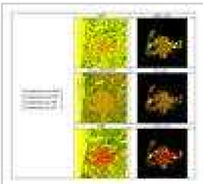

Figure 6: Per-pixel damage maps and focusec
the MRF and FA case. The input multiband/mul

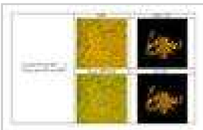

Figure 7: Per-pixel damage maps and focusec
the MRF and FA case. The input multiband/mul

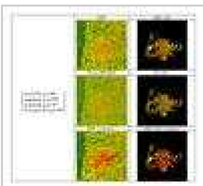

Figure 8: Per-pixel damage maps and focusec
the MRF and FA case. The input multiband/mul

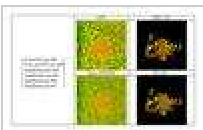

Figure 9: Per-pixel damage maps and focusec
the MRF and FA case. The input multiband/mul

Finally, Table 1 reports the overall accuracy for the maps in the
improve the visual comparison with a quantitative assessment.

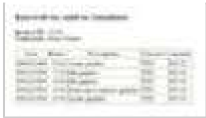

Table 1: Overall accuracy for maps in Figures

A first comment to the results is that the information fusion step is
decent mapping accuracy, but also understandable to anyone lo
accuracy values are in the same range as the one reported for th
the ground truth in the present case is more detailed, the higher s
accuracy values obtained from Boumerdes' images.

According to the maps and the accuracy values, the best result is
pre-event image (both polarizations HH and HV) and the amplituc
and the second best approach is the use of the backscattering an
image (HH polarization) and the postevent image (HV polarization)

Since the ALOS/PALSAR image pre- and postevent image pairs a
possible to compare the effect of polarization with respect to da
However, it was found that no particular choice can be made, anc
extent in some portion of the area are equally in place suing on
combination of both.

A last comment is driven by the fact that the damage maps in [9
our validation. In Figure 9, in fact, medium and high damages
reason is that previous trials attempting to obtain maps with high
accuracy values, as reported in Table 1 for sake of completeness,
maps, where a high level of damage is depicted in red, are repor
there are limits inherent to the structure of the artificial elements
the spatial resolution that prevent the 7 m ALOS/PALSAR to be er

4. Conclusions

In this paper, a rapid damage mapping approach is proposed, bas
SAR data. The approach proves to be robust and useful to detect
respect to accuracy and needs improvements.

More specifically, although semiautomatic SAR data interpretation
shows that a combination (fusion) of remotely sensed data a
improvement in this interpretation, making the data more useful
procedure, together with its affordability, were proved by the ana
many different parts of the world.

There are some commonalities among the choices of input feature
combination of the pre- and postevent intensity data with the
logarithmic means achieves always better results. The possibility t
coherence, not exploited in this work but proposed in the original p
multiple possible choices.

Very interesting and still open issues are those connected to t
correlation between the maps and the features itself to the actual,

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image was instead provided by INDECI, Instituto Nacional de Defe
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References

1. B. Allenbach, R. Andreoli, S. Battiston, et al., "Rapid EO dis perspectives after 4 years of charter actions," in *Proceeding Sensing Symposium (IGARSS '05)*, vol. 6, pp. 4373–4378,

2. M. Matsuoka and F. Yamazaki, "Building damage mapping Envisat/ASAR intensity imagery," *Earthquake Spectra*, vol.

3. C. Yonezawa and S. Takeuchi, "Decorrelation of SAR data b nanbu earthquake," *International Journal of Remote Sensin*

4. S. Stramondo, M. Moro, C. Tolomei, F. R. Cinti, and F. Doum modelling for the 2003 Bam earthquake (southeastern Iran) 347–353, 2005.

5. P. Gamba, F. Dell'Acqua, and G. Trianni, "Rapid damage de and exploiting ancillary data," *IEEE Transactions on Geosci* 1582–1589, 2007.

6. P. Gamba, F. Dell'Acqua, G. Trianni, and M. Stasolla, "GIS a urban areas," in *Proceedings of the Urban Remote Sensing*

7. P. Gamba and F. Dell'Acqua, "Increased accuracy multiband classifier," *International Journal of Remote Sensing*, vol. 24

8. G. Trianni and P. Gamba, "A novel Markov random field mo *Proceedings of 28th General Assembly of International Unior*

9. A. R. Zambrano, G. C. Henriquez, and K. Gonzales, "Contril informacion geografica en la evaluacio de los danos producio de agosto del 2007," (in Spanish), Direccion de Sismologia,