AUTOMATIC DAMAGE DETECTION USING PULSECOUPLED NEURAL NETWORK FOR THE 2009 ITALIAN EARTHQUAKE

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1. INTRODUCTION

Timely and accurate damage detection caused by earthquakes is extremely important for supporting better decision making during the emergency. In general, damage detection involves the application of multi-temporal datasets to quantitatively analyze the temporal effects of the seismic event. Remote sensing data have been used extensively for mapping damages [1] due to their intrinsic advantages such as sequential data acquisition, synoptic view, and digital format suitable for computer processing.

For an operational use, it is crucial to produce damage maps as soon as the post-event images are available. This is key for civil protection departments who need a fast and preliminary overview of the epicentral area, quick information relative to the extension and distribution of damage, and the evaluation of infrastructure (roads, bridges) conditions.

In this paper, an unsupervised change detection algorithm based on Pulse Coupled Neural Network (PCNN) [2][3] is discussed. The proposed method has been applied to a multi-temporal, very high spatial resolution panchromatic dataset acquired over the City of L'Aquila (Italy) for mapping the damages caused by the earthquake. The resulting damage map has been compared with a ground truth derived by visual interpretation of optical images and ground survey.

2. TEST CASE: L'AQUILA EARTHQUAKE

The Mw 6.3 L'Aquila earthquake occurred during the night of the 6th of April 2009 (01:32 GMT). It hit a densely populated region of the Apennines and was felt all over Central Italy. About 300 people died and more than 60,000 people were evacuated from the City of L'Aquila and several nearby towns. The earthquake caused the partial or complete collapse of a significant number of highly vulnerable, historical buildings.

The dataset used is composed of two panchromatic QuickBird images taken before and after the earthquake (September 4th, 2006 and April 8th, 2009, respectively). The view angles of these images are -3.7° in-track and -

10.3° cross-track for pre-acquisition, and 2.8° in-track and 3.9° cross-track for post-acquisition. The same dataset, coupled with an Ikonos optical image and a pair of COSMO-SkyMed X-band SAR images, has already been exploited for mapping damages occurred in L'Aquila during the crisis [4].

3. METHODOLOGY: PULSE-COUPLED NEURAL NETWORKS DAMAGE DETECTION ALGHORITM

PCNN belongs to the class of unsupervised artificial neural networks in the sense that it does not need to be trained. The network consists of nodes with spiking behavior interacting with each other within a pre-defined grid. The architecture of the network is rather simpler than most other neural implementations: there are no multiple layers that pass information to each other. PCNNs only have one layer of neurons, which receives input directly from the original image, and forms the resulting pulse image.

The development of fully automatic damage detection procedures for very high spatial resolution images is not an easy task because several issues have to be considered. The crucial difficulties include possible different view angles, misregistrations, shadow and other seasonal and meteorological effects which add up and combine to reduce the attainable accuracy in the damage map. It is worth noting that these sensors can change the image acquisition angle in order to increase their revisit cycle, and this is particularly true in the case of earthquakes or other catastrophic events, where a matter of primary importance is to collect data as soon as possible.

PCNNs can be used to detect, in a fully automatic manner, the hot spot areas of an image where a significant change occurred [5]. They are not sensitive to changes in rotation, scale, shift, or skew of an object within the scene. These features make PCNN a suitable approach for change detection in very high spatial resolution imagery, where the view angle of the sensor, as already mentioned above, may change drastically. Moreover, PCNNs do need to be trained, which makes the proposed method a very interesting technique for classifying damage, since timeliness is an important issue.

4. RESULTS

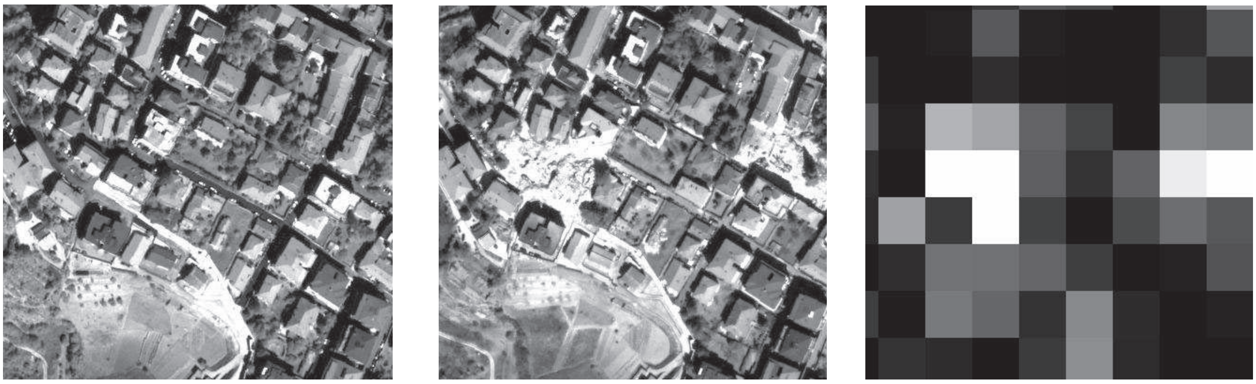
The panchromatic QuickBird images available for this event have very different look angles, which increases the number of false alarms in traditional pixel-based methods. However, the PCNN produced change map contains only a few errors due to its invariance to changes in rotation, scale, shift, or skew of an object in the PCNN's model.

The damage map produced is representative of the severely damaged buildings, which means that at least a part of the entire structure is collapsed. This map has been compared with a detailed ground truth obtained by visual inspection of the QuickBird images and a field survey from geologists of the Istituto Nazionale di Geofisica e Vulcanologia (INGV). The ground truth map reports the damage level in conformity with the

European Macrosesmic Scale 1998 (EMS-98) [6], where the damage level of each inspected building indicates a damage degree ranging between 1 (very light or no damage) to 5 (completely collapsed).

The comparison demonstrates a very good agreement between the two maps and, in particular, the heavily damaged buildings have been clearly detected and just few false alarms were present. The completely collapsed buildings class of the ground truth is composed of 17.327 pixels and 12.985 of them (about 75%) have been well classified by the PCNN algorithm. It is worth noting that the PCNN derived map is representative of the 4 and 5 degrees of EMS-98. In Fig. 1 is shown an example of the damage map.

Finally, the conformity of the PCNN damage map with the EMS-98 makes it very useful for an easy and quick interpretation by rescue teams and authorities involved in the reconstruction activities.



(a) (b) (c)

Fig. 1: QuickBird panchromatic image (a) before and (b) after the seismic even. The relative damage map is illustrated in (c), where in white are highlighted the macro-areas of the building collapsed.

5. REFERENCES

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