PULSE COUPLED NEURAL NETWORKS FOR AUTOMATIC FEATURES EXTRACTION FROM COSMO-SKYMED AND TERRASAR-X IMAGERY

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ABSTRACT

With the recent launches of COSMO-Skymed and TerraSAR-X satellites, a growing amount of very-high resolution images will be available. COSMO-SkyMed (COnstellation of small Satellites for the Mediterranean basin Observation) is an Earth observation satellite system funded by the Italian Government and conducted by the Italian Space Agency (ASI). It is made up of four satellites, equipped with X-band synthetic aperture radar (SAR) sensors with global coverage of the planet, called COSMO 1 - 4 and related ground infrastructures. Observations of an area of interest can be repeated several times a day in all-weather conditions. The first satellite of the constellation was launched on 7th June 2007, the second on 8th December 2007 and the third on 24th October 2008 [1]. The new German radar satellite TerraSAR-X was successfully launched on June 15th, 2007. With its active antenna, the spacecraft acquires X-band radar images of the entire planet whilst circling Earth in a polar orbit at 514 km altitude. TerraSAR-X is designed to carry out its task for five years and provides radar images with a resolution of up to 1m [2].

The data provided by these missions might be exploitable for several applications such as urban planning, civil protection, risk management, agriculture, coastal zone monitoring. However, these applications need filtering, detection, segmentation, classification, or pattern recognition, hence suitable models and techniques should be worked out for SAR high-resolution data to effectively design the needed algorithms. In fact, while many studies have appeared on feature extraction from medium-high resolution SAR images, less investigation, mainly due to the lack of public data, has been devoted to feature extraction in high-resolution, especially satellite, SAR imagery.

In this paper we investigate an unsupervised neural network approach for extracting features from very high resolution X-band SAR images. The Pulse-Coupled Neural Network (PCNN) is a relatively novel technique based on models of the visual cortex of small mammals [3],[4]. When applied to image processing, it yields a series of binary pulsed signals, each associated to one pixel or to a cluster. In literature, interesting results have been already reported by several authors in applications of this model to image segmentation, including, in few cases, the use of satellite data [5].

The architecture of PCNN is rather simpler than most other neural network implementations. PCNN do not have multiple layers and receive input directly from the original image, forming a resulting “pulse” image. The network consists of multiple nodes coupled together with their neighbors within a definite distance, forming a grid (2D-vector). The PCNN neuron has two input compartments: linking and feeding. The feeding compartment receives both an external and a local stimulus, whereas the linking compartment only receives a local stimulus. When the internal activity becomes larger than an internal threshold, the neuron fires and the threshold sharply increases. Afterward, it begins to decay until once again the internal activity becomes larger. This process gives rise to the pulsing nature of PCNN, forming a wave signature which is invariant to rotation, scale, shift or skew of an object within the image. This last feature makes PCNN a suitable approach for feature extraction in very-high resolution imagery, where the view angle of the sensor may play an important role.

This study discusses the PCNN technique in automatic SAR image feature extraction and applies it to a set of experimental data consisting of pre-processed COSMO-Skymed and TerraSAR-X images taken over test sites containing both natural and man-made features. Sub-areas of the images are considered and the PCNN signal features (waveform and epoch dependence) are employed to identify roads and buildings within selected regions of interest. Issues on the processing of

PCNN waveforms, on the optimization of the size of the two-dimensional net and on the setting of its parameters are considered, also with reference to spatial resolution and computational burden. The possibility of applying multi-scale procedures is also discussed. The features retrieved from the geo-referenced SAR images are compared against the ground truth provided by corresponding optical images. The accuracy yielded by PCNN is quantitatively evaluated and critically discussed, also in comparison with commonly used feature extraction techniques.

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