Buildings extraction from very high resolution SAR images using Pulse Coupled Neural Network

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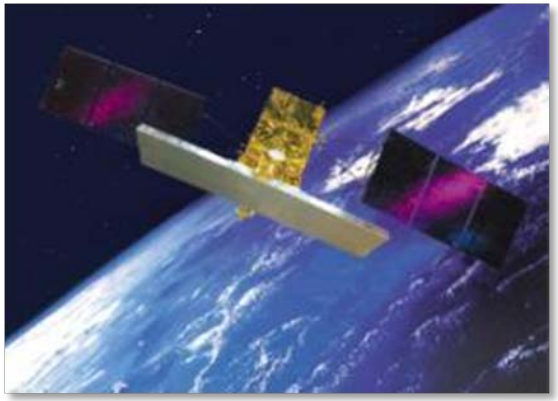
Image Information Mining: automation of geospatial intelligence from Earth Observation

Purpose of the study

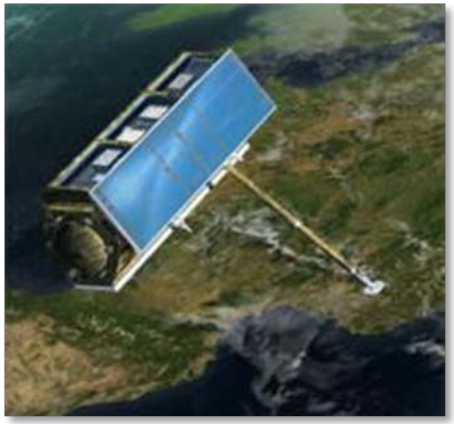
Buildings detection in images of low density urban areas, acquired by COSMO-Skymed and TerraSAR-X satellites.

COSMO-Skymed - COstellation of Small Satellites for the Mediterranean basin Observation

- Italian Space Agency (ASI) mission
- Constellation of four satellites COSMO (1-4) equipped with X-band SAR sensors with global coverage of the planet
- Observations of an area of interest can be repeated several times a day in all-weather conditions (revisit time of about 140 min)



TerraSAR-X

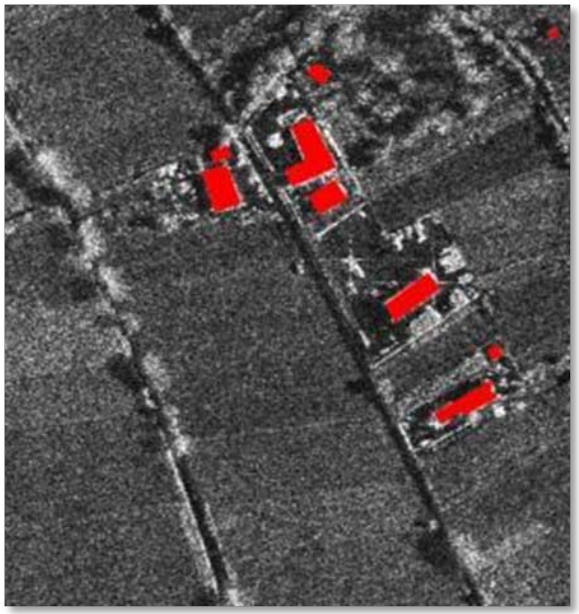


- German Aerospace Centre (DLR) mission
- The spacecraft acquires X-band radar images of the entire planet whilst circling Earth in a polar orbit at 514 km altitude
- Designed to carry out its task for five years
- Spatial resolution up to 1 m

DATA SET

COSMO-Skymed - COstellation of Small Satellites for the Mediterranean basin Observation

Fucino region (Italy), 22-11-2008



Spotlight mode
spatial resolution: 1 m

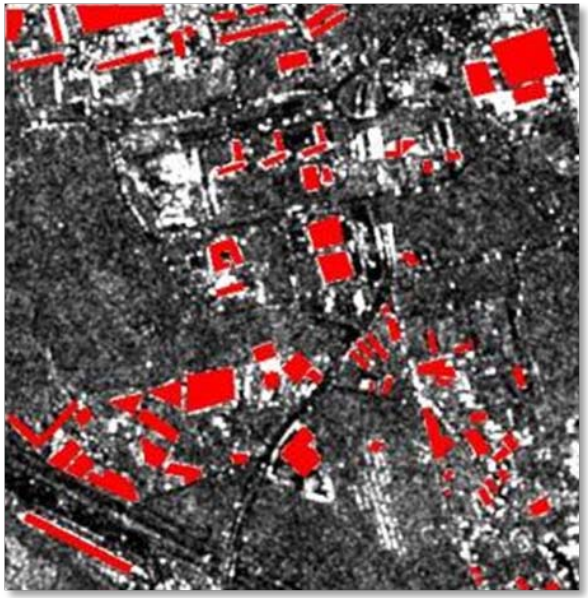
Ground truth from
Google Earth

DATA SET

TerraSAR-X

Tor Vergata University-Rome (Italy) , 24-11-2007

Stripmap mode
spatial resolution: ~3 m



Ground truth from
Google Earth

Pulse Coupled Neural Network (PCNN)

Neural Networks algorithms have been shown to represent a rather effective approach for the classification of satellite images.

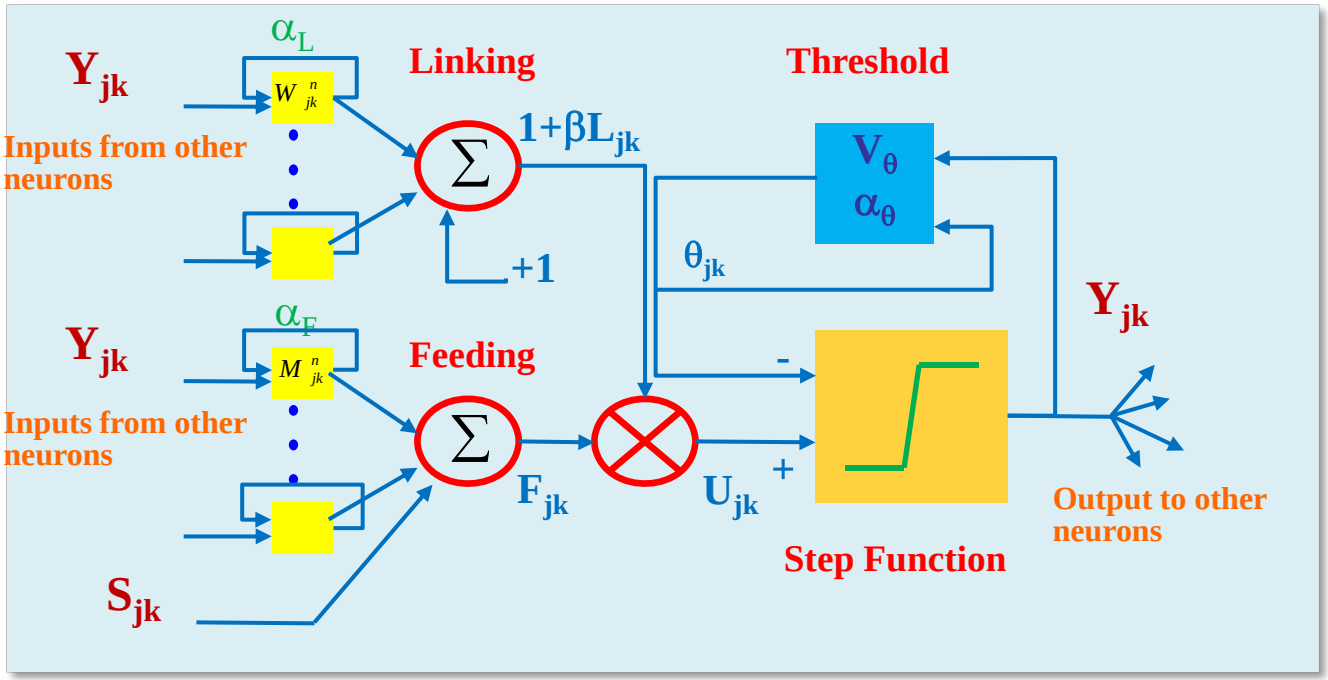
PCNN is a relatively novel unsupervised neural network based on the implementation of the mechanism underlying the visual cortex of small mammals.

Interesting results have been already shown by several authors in the application of these models in image segmentation, classification and thinning (G. Kuntimad et al. 1999; X. Gu et al., 2004), including, in few cases, the use of satellite data (J.A. Karvonen, 2004; K. Waldemark et al., 2000; F. Pacifici, in press).

The architecture of a PCNN is rather simpler than most other neural network implementations.

The network consists of multiple nodes coupled together with their neighbors within a definite distance, forming a grid (2D-vector).

Pulse Coupled Neural Network (PCNN)



Feeding: $F_{ij}[n]=e^{\alpha_F\delta_n}F_{ij}[n-1]+S_{ij}+V_F\sum_{kl}M_{ijkl}Y_{kl}[n-1]$

Internal activity: $U_{ij}[n]=F_{ij}[n]\{1+\beta L_{ij}[n]\}$

Linking: $L_{ij}[n]=e^{\alpha_L\delta_n}L_{ij}[n-1]+V_L\sum_{kl}W_{ijkl}Y_{kl}[n-1]$

Threshold: $\theta_{ij}[n]=e^{\alpha_\theta}\theta_{ij}[n-1]+V_\theta Y_{ij}[n]$

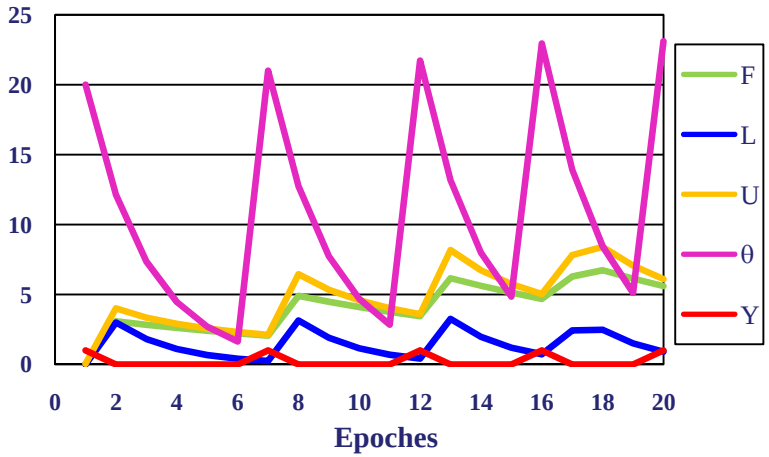
Output: $Y_{ij}[n]=\begin{cases}1, if\ U_{ij}[n]>\theta_{ij}[n]\\0, otherwise\end{cases}$

Pulse Coupled Neural Network (PCNN)

Pulsing nature of PCNN

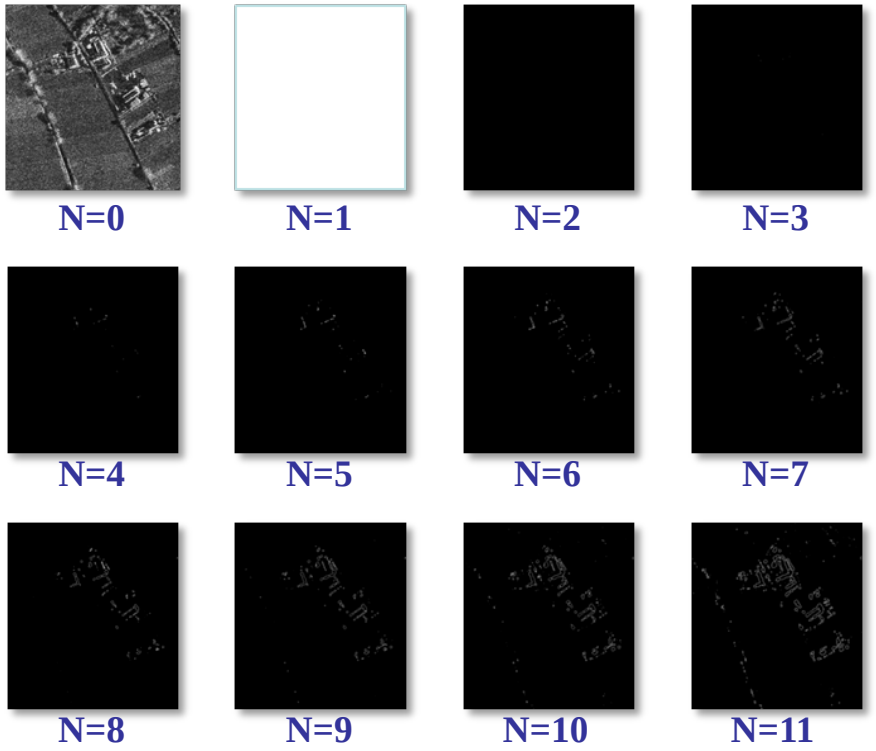
Wave signature is invariant to ROTATION, SCALE, SHIFT or SKEW of an object within the image

PCNN is a suitable approach for feature extraction in very-high resolution imagery, where the view angle of the sensor may play an important role.



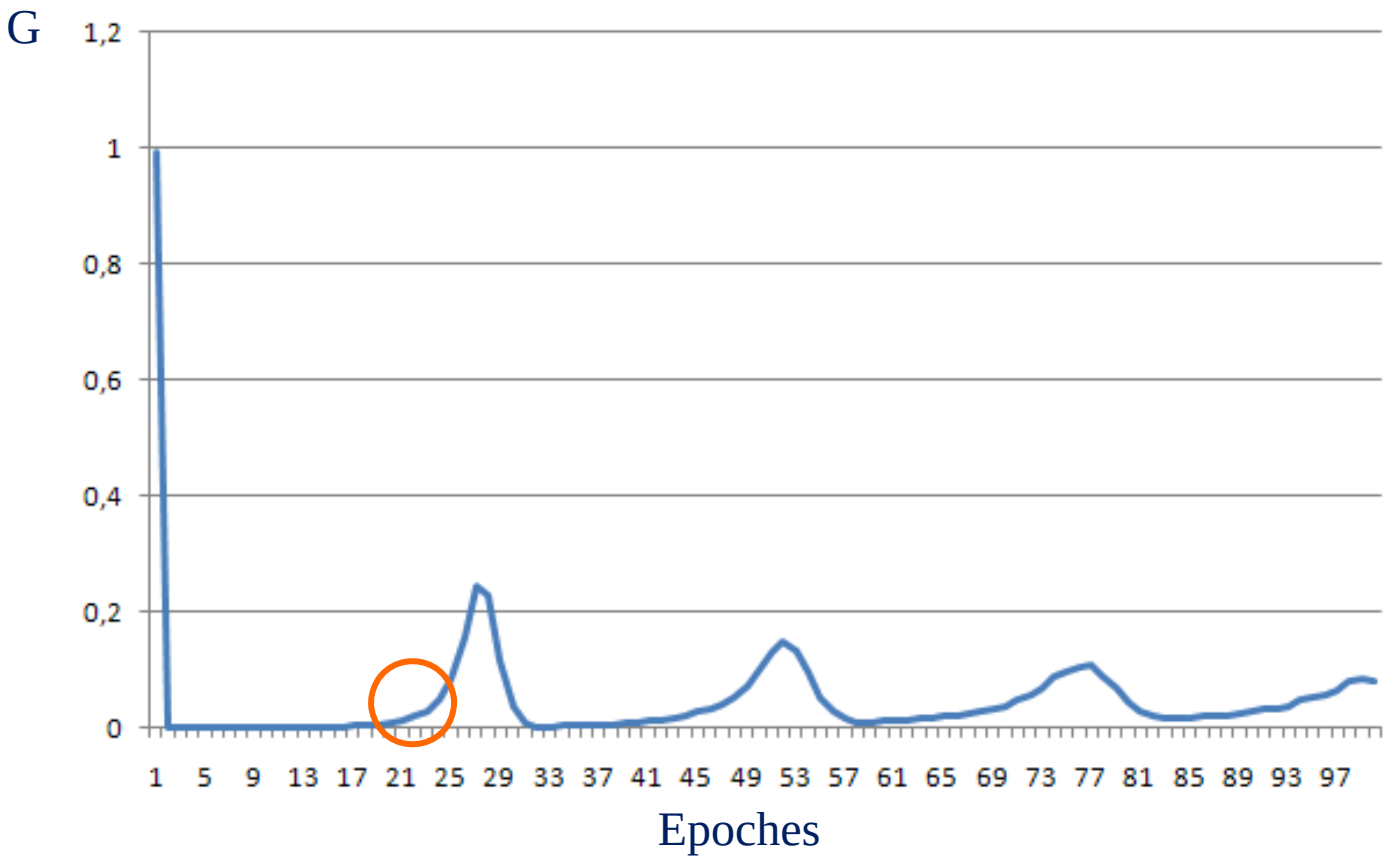
Pulsing Cosmo-Skymed image

As the iterations progress, the autowaves emanate from the original pulse regions and the shapes of the objects evolve through the epoches due to the pulsing nature of PCNN.



Pulse Coupled Neural Network (PCNN)

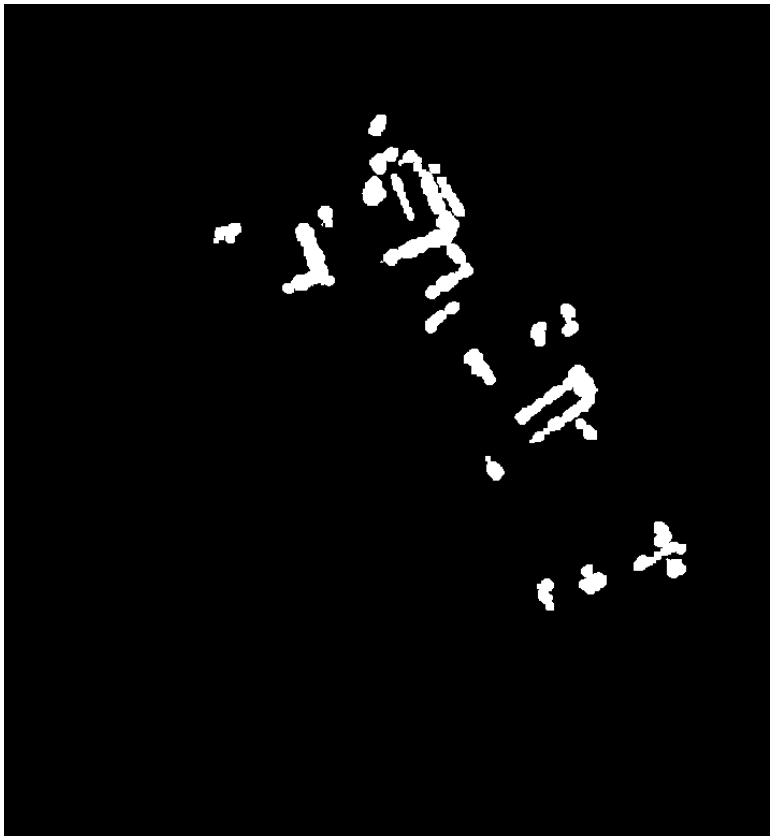
Time signal $G[n] = \frac{\sum_{ij} Y_{ij}}{N}$



Pulse Coupled Neural Network (PCNN)

PCNN result on Cosmo-Skymed image

n=21



Filtered result

Pulse Coupled Neural Network (PCNN)

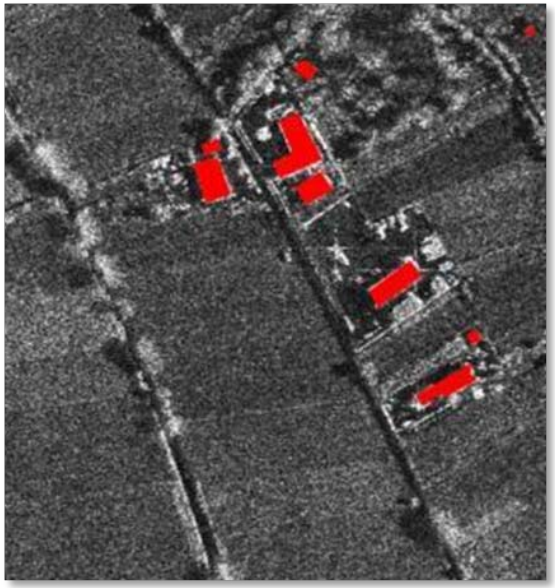
PCNN result on TerraSAR-X image

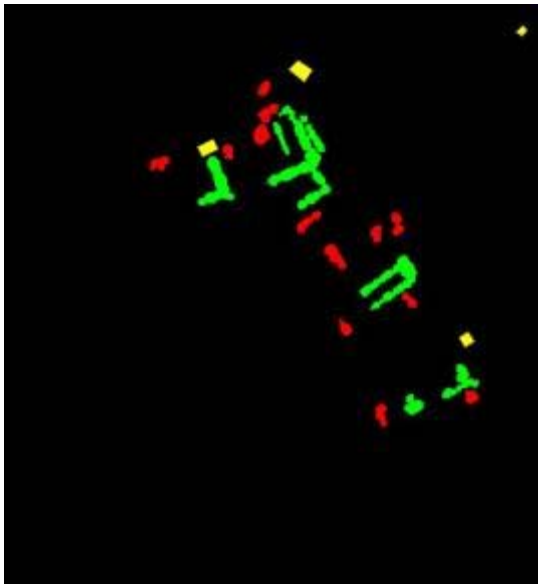
n=13

Filtered result

PCNN algorithm results

Buildings extraction from COSMO-Skymed image





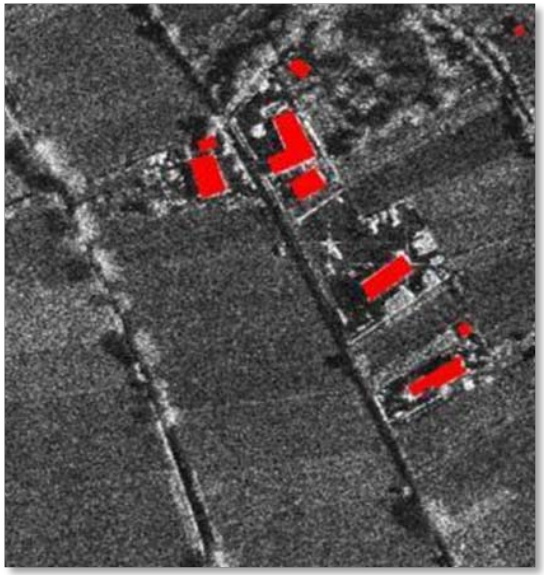
Object analysis

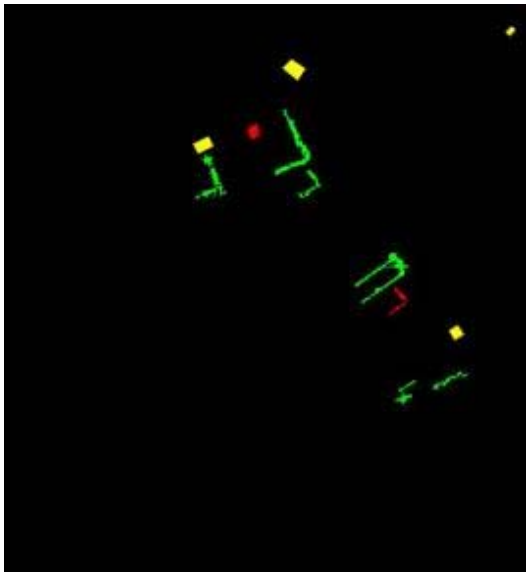
- False alarms
- Missed objects
- Detected objects

Alternative not automatic method results

Buildings extraction from COSMO-Skymed image

- Edge detection
- Objects extraction
- Filtering of the smaller objects





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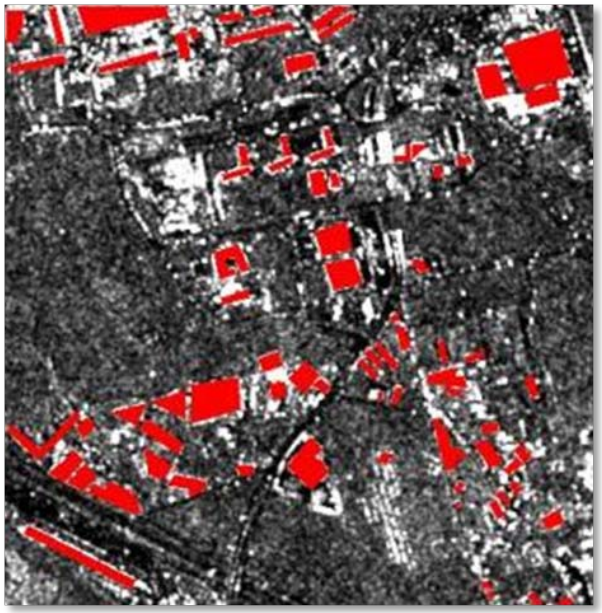
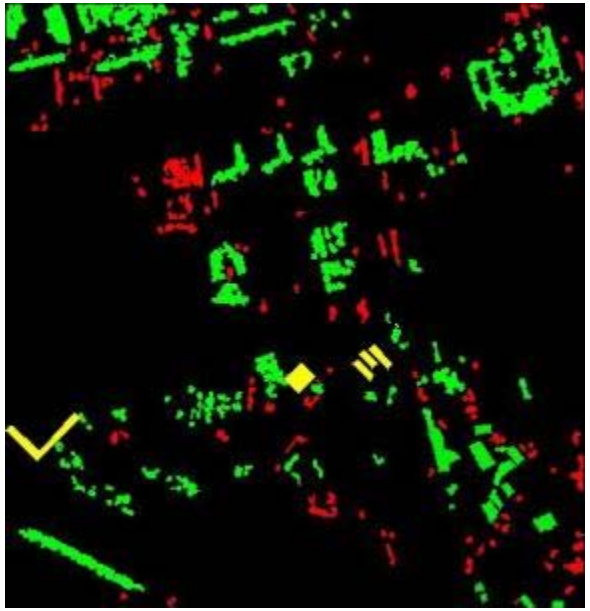
PCNN algorithm results

Buildings extraction from TerraSAR-X image





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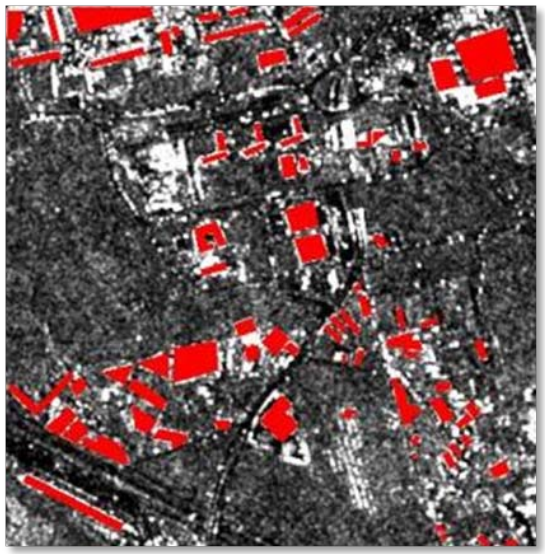

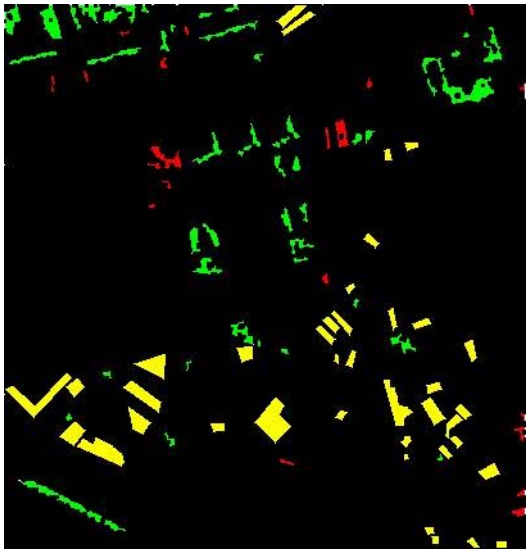

Object analysis

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- Missed objects
- Detected objects

Quantitative comparison of the results

PCNN

Cosmo-Skymed

	Unclassified	Buildings	Total
Unclassified	98.42	62.38	97.74
Buildings	1.58	**37.62**	2.26
Total	100.0	100.0	100.0

TerraSAR-X

	Unclassified	Buildings	Total
Unclassified	95.49	48.61	91.60
Buildings	4.51	**51.39**	8.40
Total	100.0	100.0	100.0

Alternative method

	Unclassified	Buildings	Total
Unclassified	99.75	83.13	99.44
Buildings	0.25	**16.87**	0.56
Total	100.0	100.0	100.0

	Unclassified	Buildings	Total
Unclassified	99.19	80.13	97.61
Buildings	0.81	**19.87**	2.39
Total	100.0	100.0	100.0

Conclusions

- In this work a relatively novel unsupervised neural network (Pulse Coupled Neural Network – PCNN) has been tested on very high resolution SAR images.
- Buildings' shapes are automatically extracted.
- The accuracy yielded by PCNN was quantitatively evaluated in comparison with commonly used features extraction techniques based on edge detection.
- PCNN algorithm achieved comparable results then alternative not automatic techniques based on edge detection.
- Improving algorithm and testing PCNN on other imagery are ongoing.

ACKNOWLEDGEMENTS

• Cosmo-Skymed image by e-GEOS S.p.A., Copyright of ASI

• TerraSAR-X image by © Infoterra GmbH