Pulse Coupled Neural Networks for Automatic Change Detection in Very High Resolution Images

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Introduction (1/2)

The commercial availability of very high resolution visible and near infrared satellite data has opened a wide range of new opportunities for the use satellite data.

New systems, such as the panchromatic WorldView-1, provide additional data along with very high resolution platforms, such as QuickBird or Ikonos, which have already been operating for a few years.

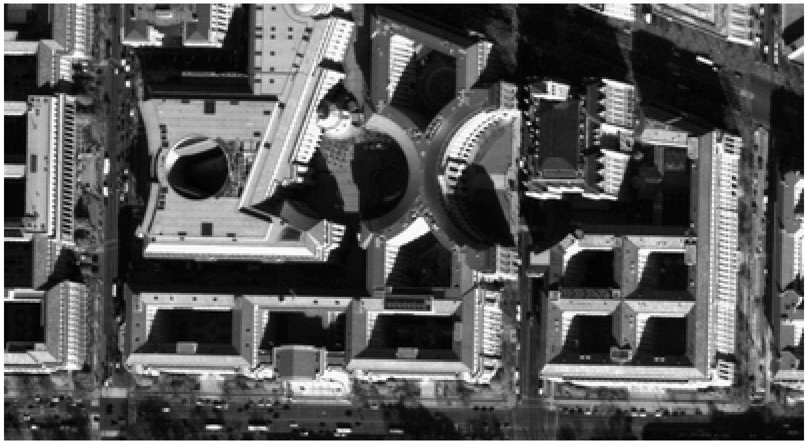
Although very high resolution data have great potentialities, several issues have to be considered.

Introduction (2/2)

The availability of a huge amount of information needs completely automatic techniques able to manage big data archives.

When changes must be detected, further problems become crucial, such as:

- the registration of two or more very high spatial resolution scenes
- the effects of changing solar elevations and view angles



Sensor noise, misregistration, seasonal and meteorological effects add up and combine to reduce the attainable accuracy in the change detection results.

Goal

We investigated an unsupervised neural network approach for the detection of changes in multi-temporal very high resolution images.

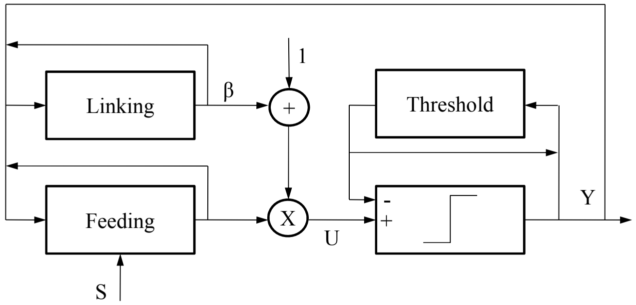
Pulse-Coupled Neural Network (PCNN) is a relatively novel technique based on the visual cortex of small mammals.

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 shown in the application of this model in image segmentation, including, in few cases, the use of satellite data.

Pulse-Coupled Neural Network (1/3)

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



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

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

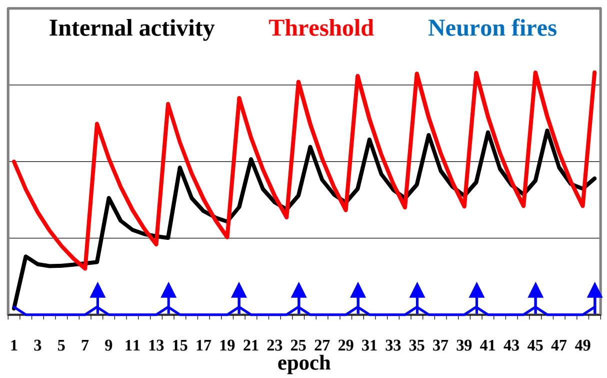
$$U_{ij}[n] = F_{ij}[n]\{1 + \beta L_{ij}[n]\}$$

$$Y_{ij}[n] = \begin{cases} 1 \; if \; U_{ij}[n] > \Theta_{ij}[n-1] \\ 0 \qquad Otherwise \end{cases}$$

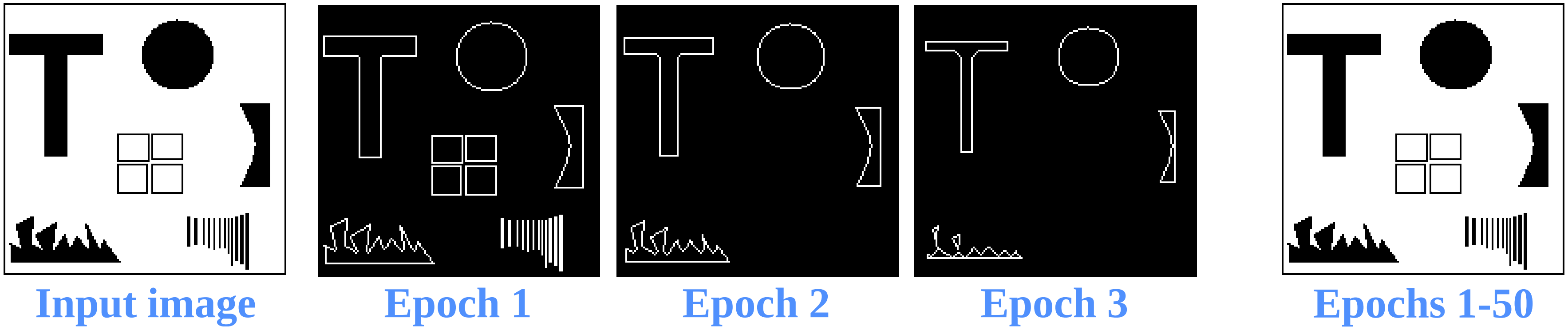
$$\Theta_{ij}[n] = e^{\alpha_\Theta \delta_n} \Theta_{ij}[n-1] + V_\Theta Y_{ij}[n]$$

When the internal activity becomes larger than the 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.



Pulse-Coupled Neural Network (2/3)



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

G[n] corresponds to the wave signature which is invariant to changes in rotation, scale or shift of an object within the scene.

This feature makes PCNN an attractive approach for change detection in very high resolution imagery, where the view angle of the sensor may play an important role.

Pulse-Coupled Neural Network (3/3)

Can PCNN be used to individuate, in a fully automatic manner, the hot spots of a satellite image where significant change occurred?

This can be obtained by measuring, in a moving window, the similarity between the signatures generated by the waves in each iteration associated to the images.

This approach aims at discovering changed subareas in the image rather than analyzing the single pixel.

This is more efficient when large data sets have to be automatically examined, as it should be the case in the very next years when new satellite missions (such as WorldView-2) will be providing additional data along with the ones already available.

Data Set

PCNNs were applied to multi-spectral and panchromatic very high resolution images taken over:

Rome, Italy:

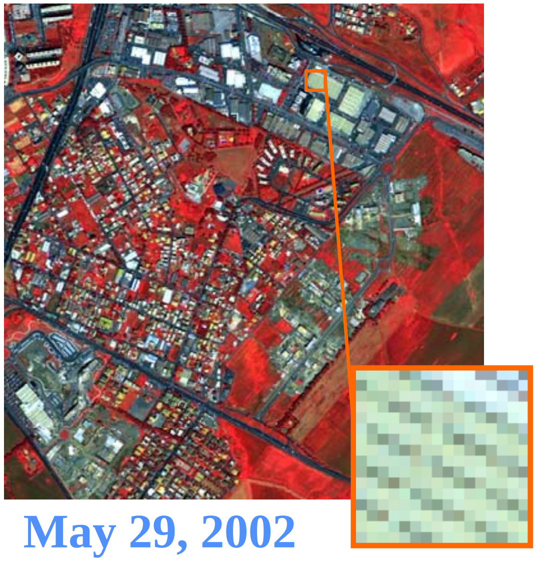
The images were acquired by QuickBird in May 29, 2002 and March 13, 2003 (about 2.4m)

Atlanta, Georgia (U.S.A.):

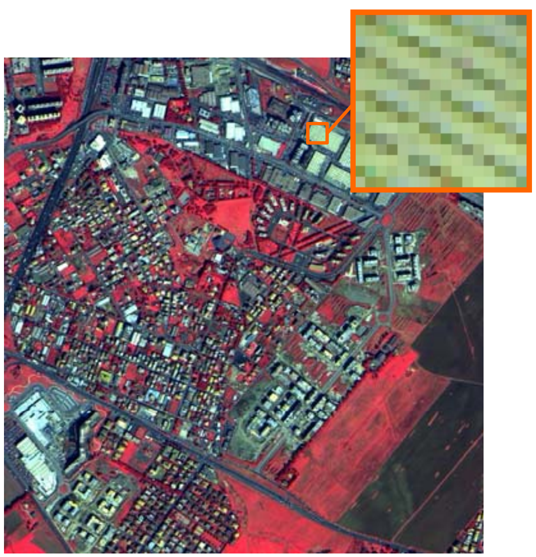
The images were acquired by QuickBird in February 26, 2007 and by WorldView-1 in October 21, 2007 (about 0.5m)

Washington D. C. (U.S.A.):

The images were acquired by QuickBird in September 23, 2007 and by WorldView-1 in December 18, 2007 (about 0.5m)



May 29, 2002

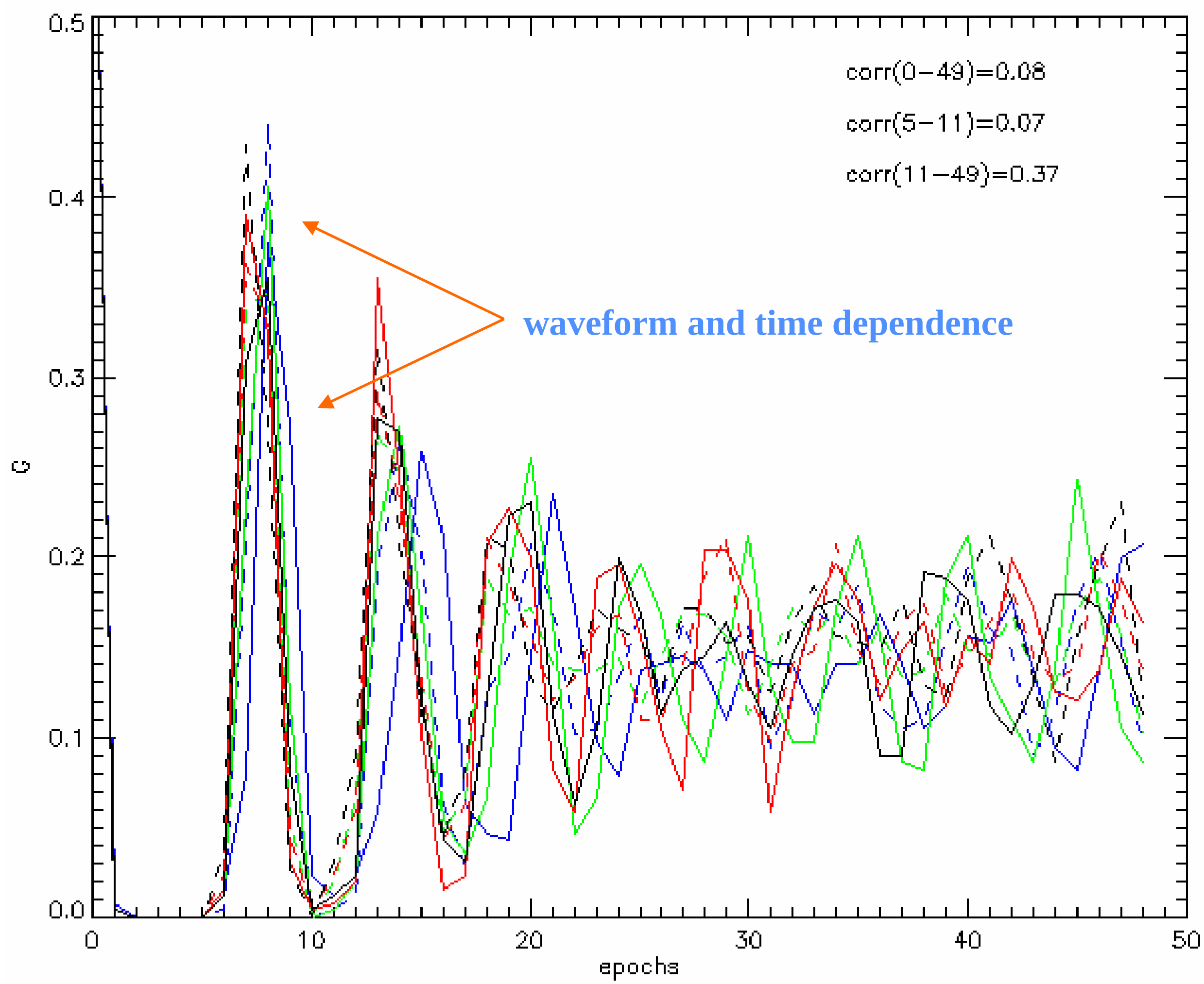


March 13, 2003

no-changes

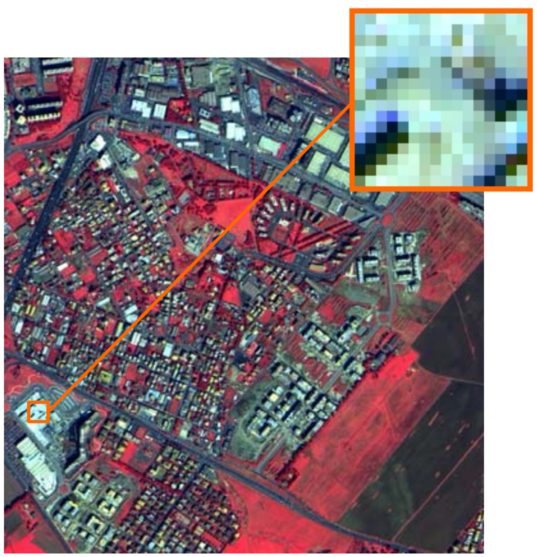
2002: dash line – 2003: solid line

R, G, B, NIR



Rome test case (2/5)

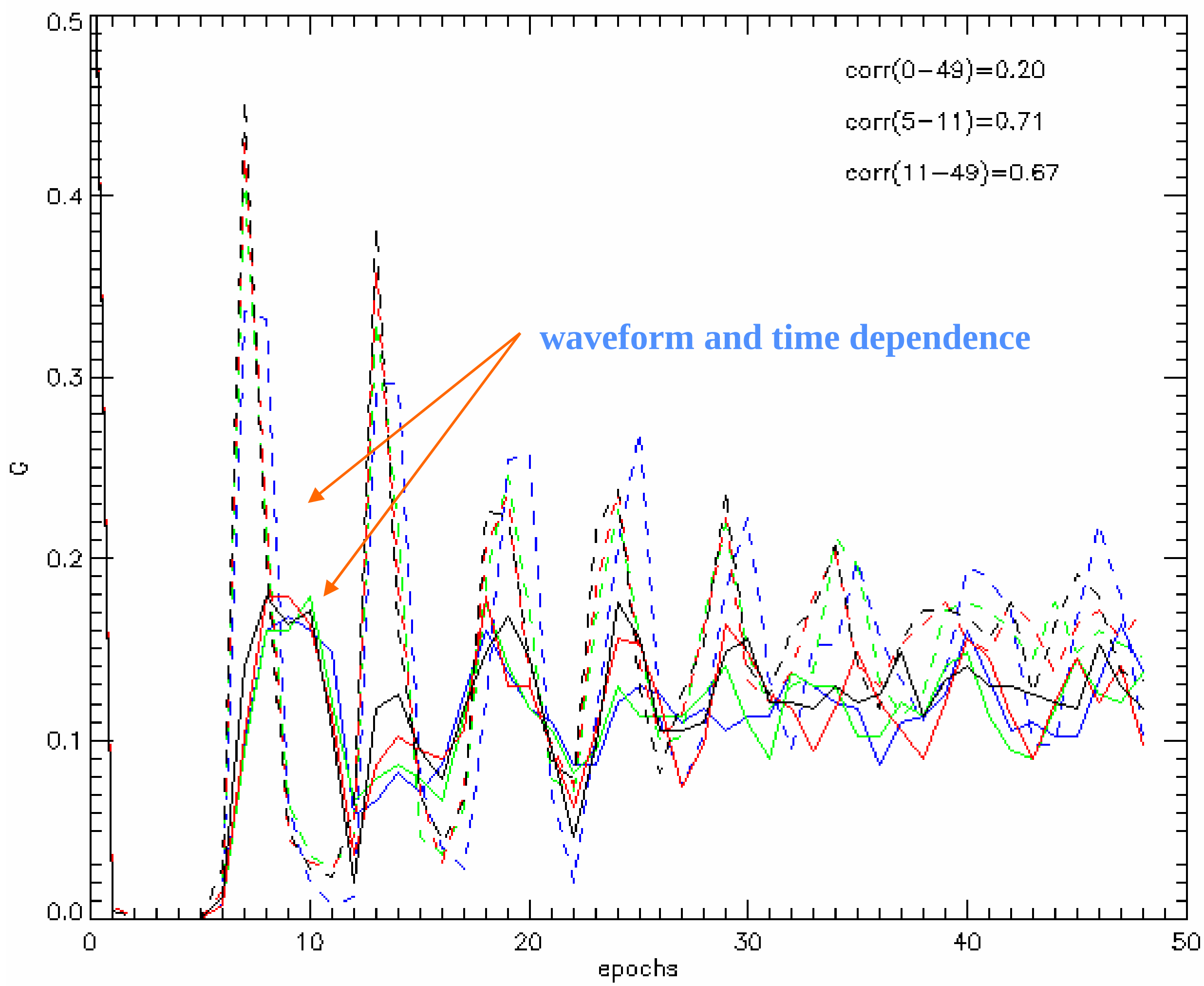
May 29, 2002



March 13, 2003

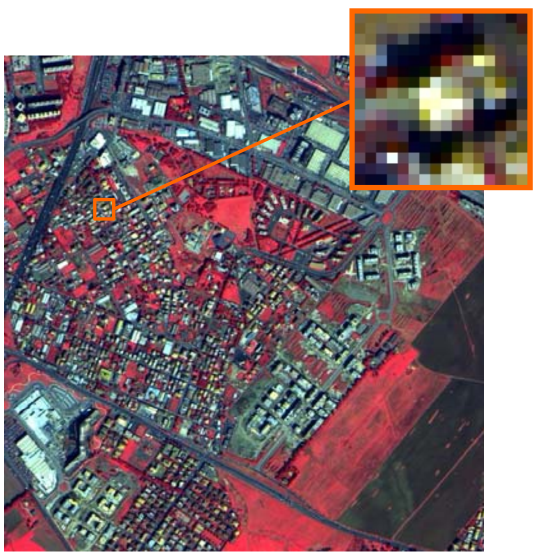
big changes

2002: dash line – 2003: solid line R, G, B, NIR



Rome test case (3/5)

May 29, 2002

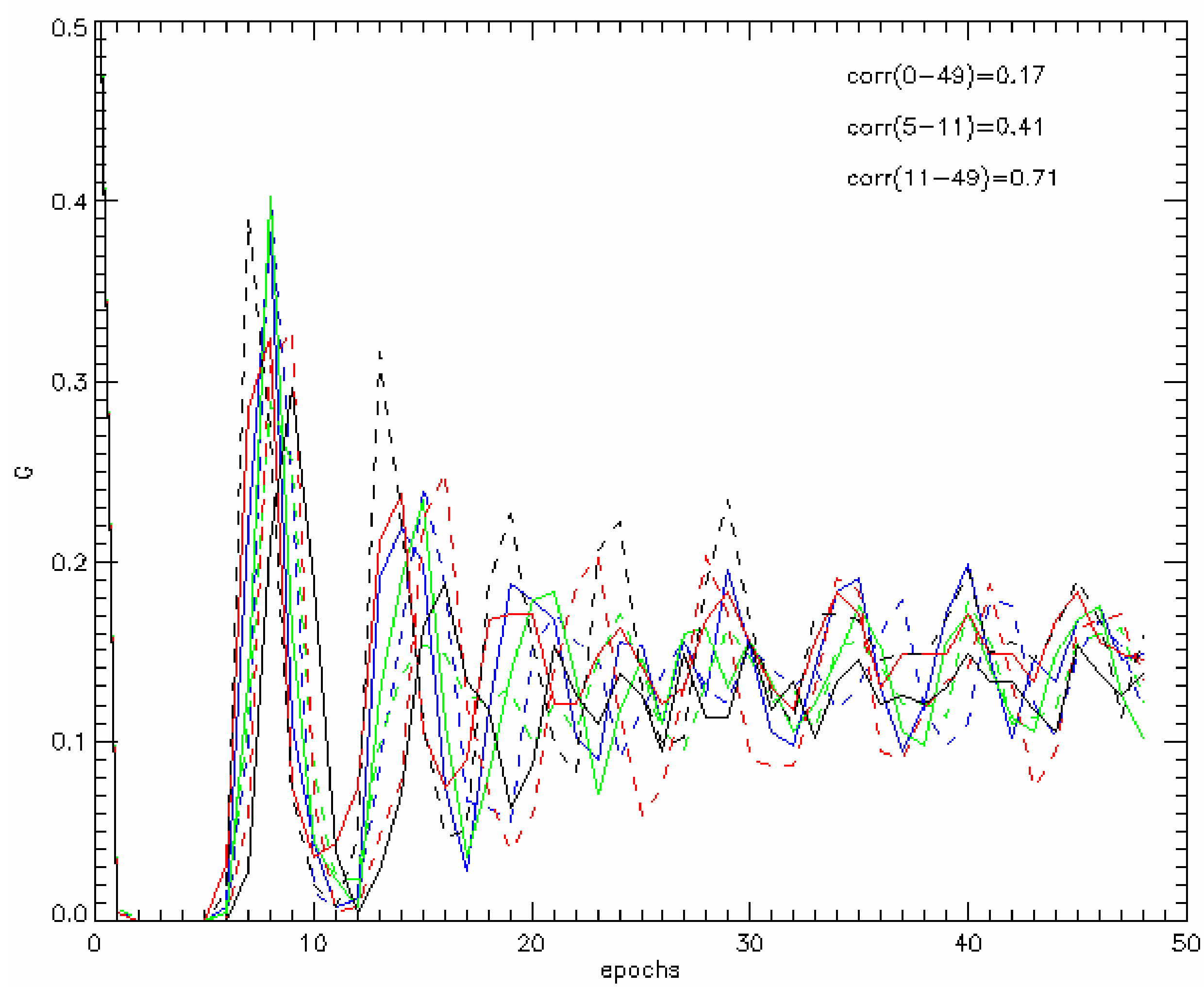


March 13, 2003

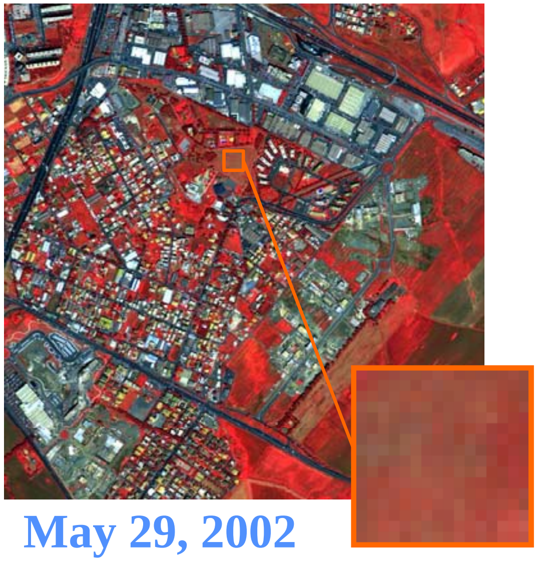
small changes

2002: dash line – 2003: solid line

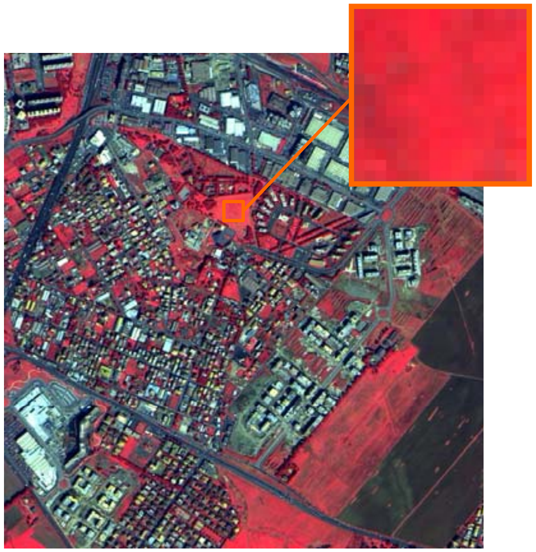
R, G, B, NIR



vegetation



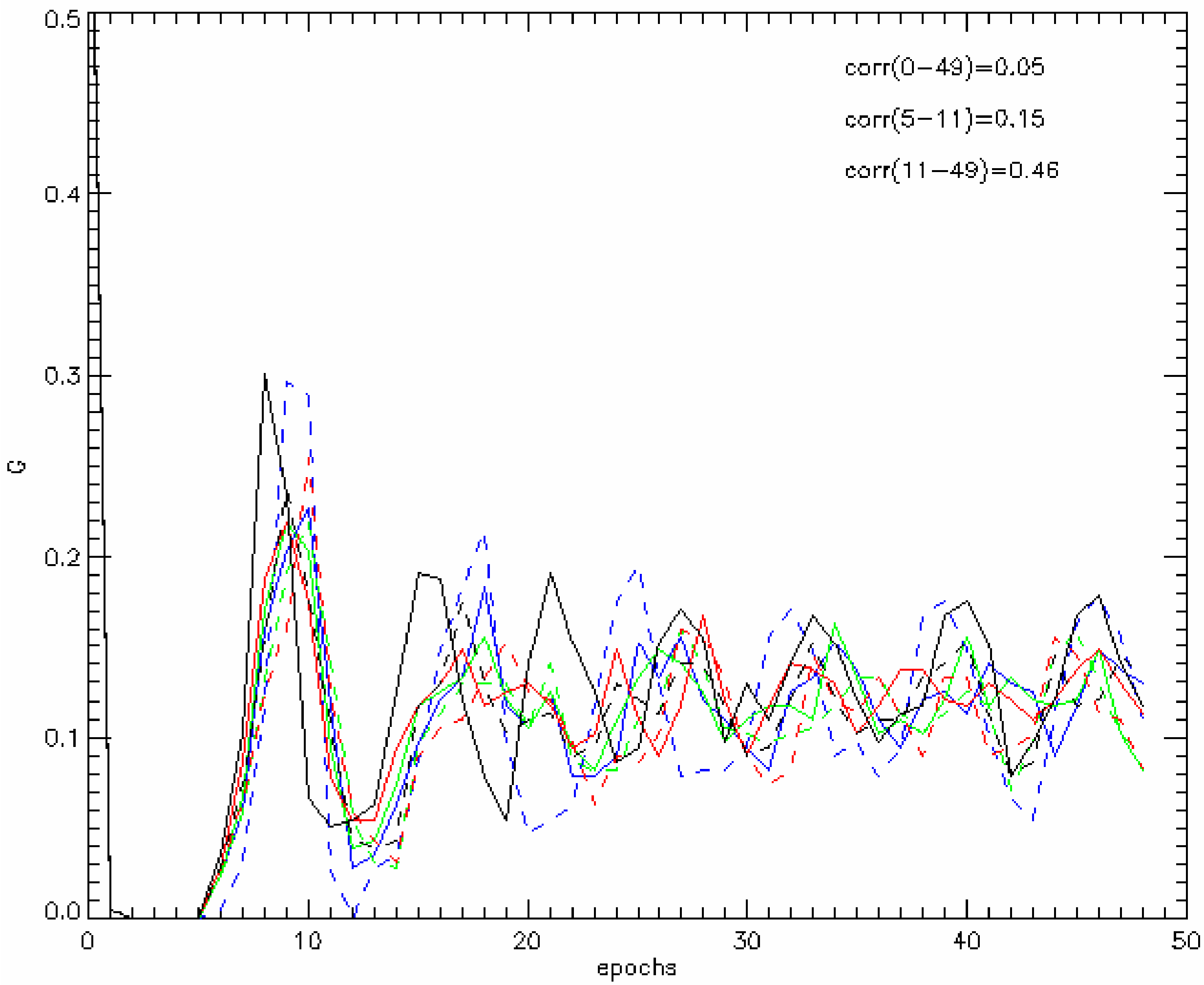
May 29, 2002



March 13, 2003

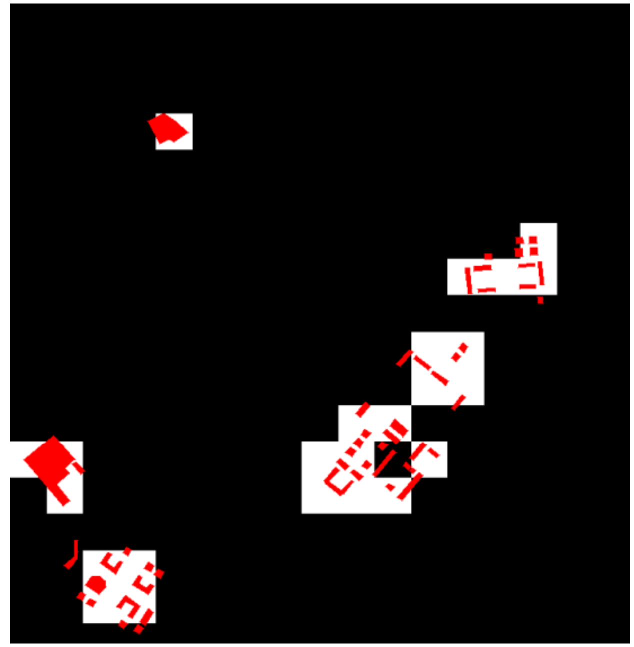
2002: dash line – 2003: solid line

R, G, B, NIR



Rome test case (5/5)

May 29, 2002

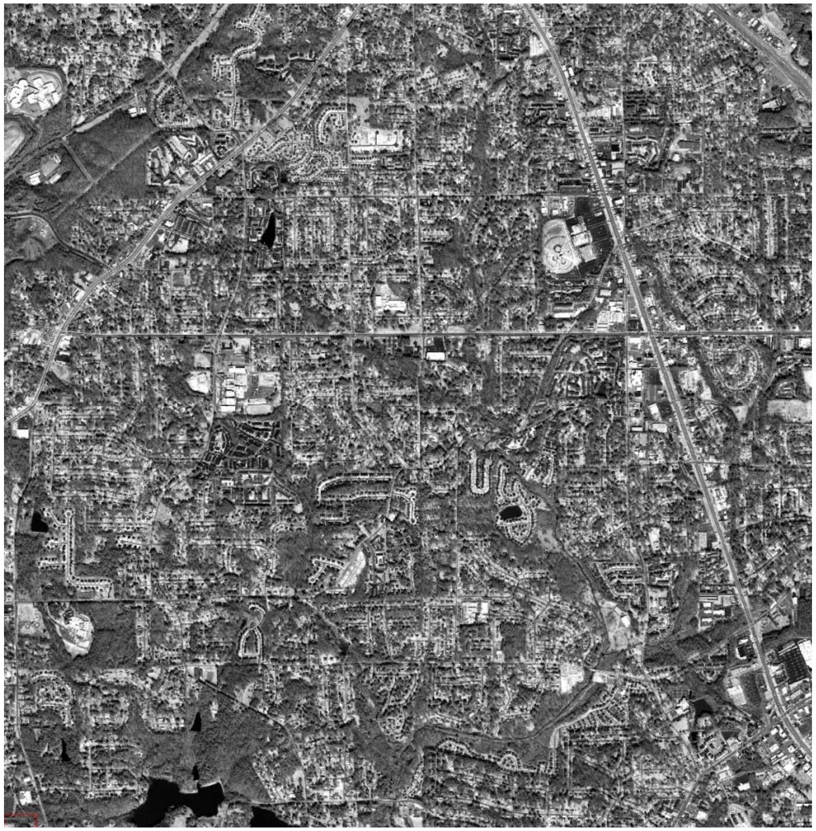


PCNN Change Detection

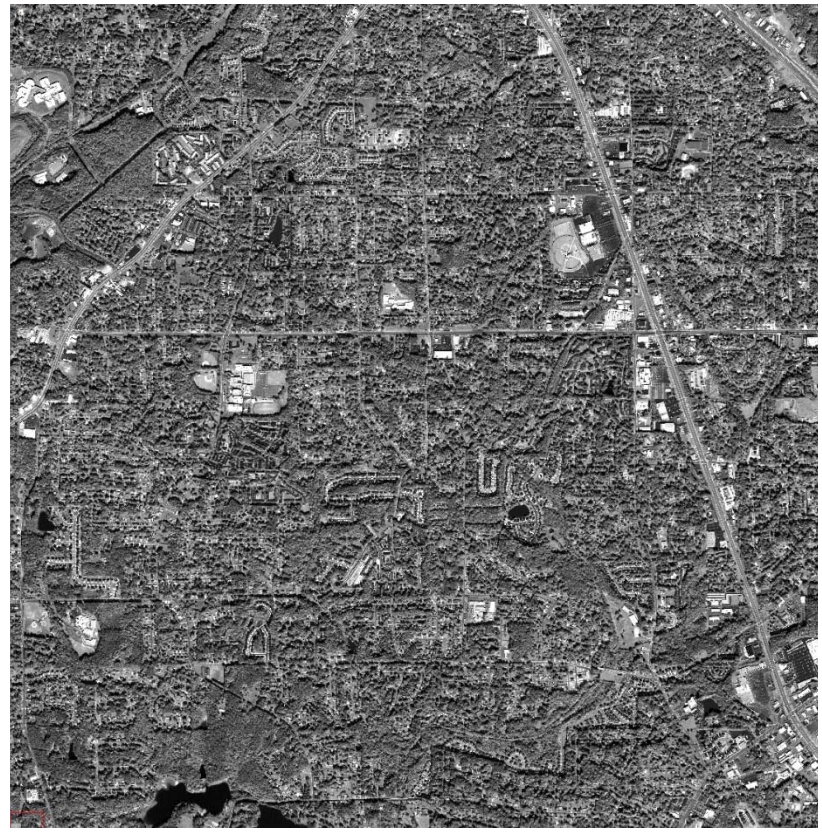
March 13, 2003

- 49 out of the 54 objects appearing on the ground reference were detected with no false alarms.
- missed objects are basically structures that were already present in the 2002 image (e.g., foundations or the first few floors of a building) but not completed yet.

Atlanta test case – full area (1/2)



QuickBird - February 26, 2007



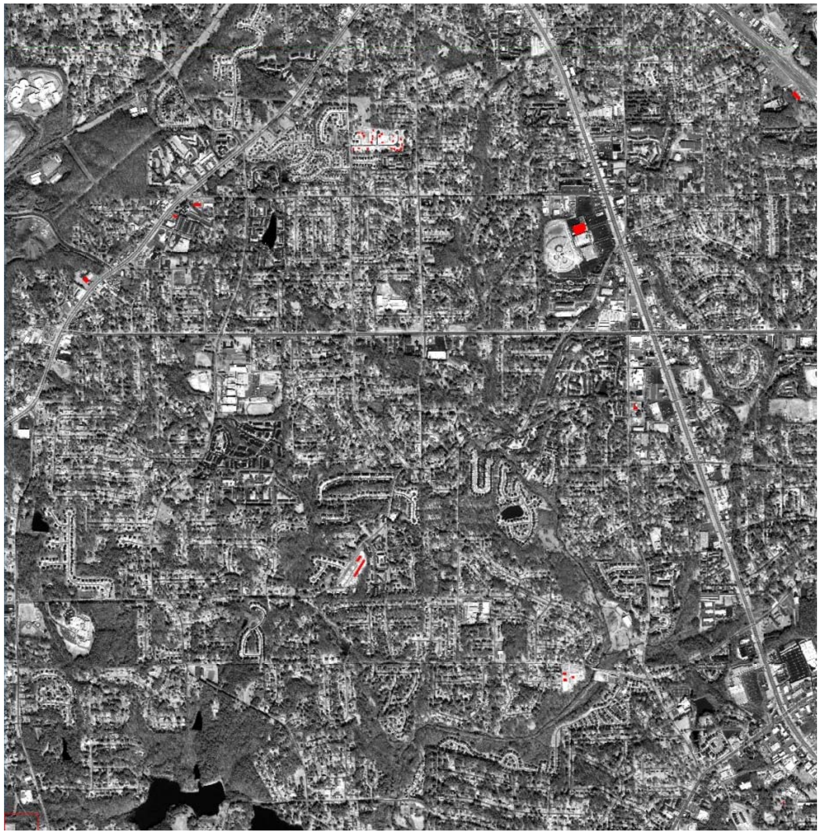
WorldView-1 - October 21, 2007

This test case represents an operative scenario where PCNNs give evidence of their potentialities in detecting hot spot areas in big data archives.

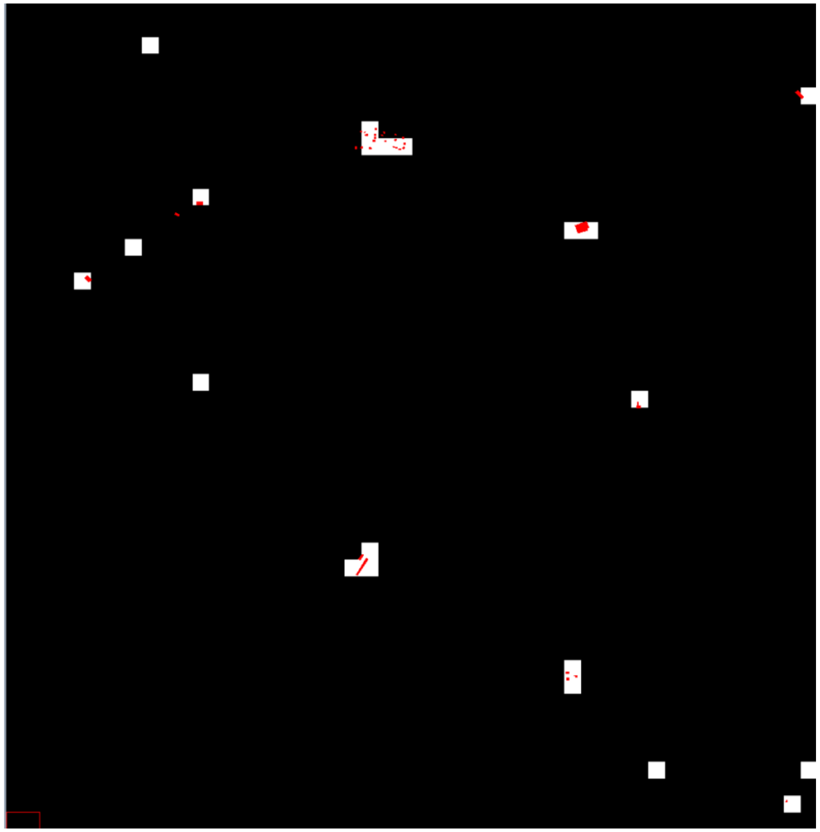
Approximately extension in area of 25 km^2 (10,000 x 10,000 pixels).

Atlanta test case – full area (2/2)

Many changes occurred although the small time window, mainly corresponding to the construction of new commercial and residential buildings.



Ground reference

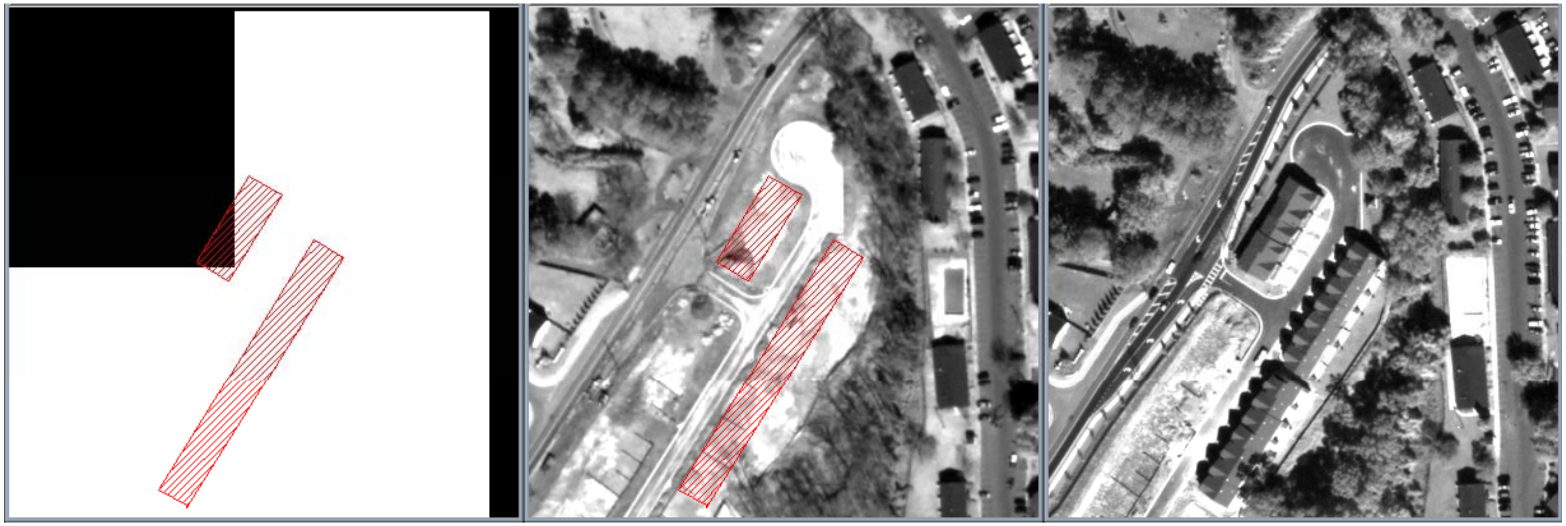


PCNN Change Detection

30 out of the 34 objects appearing on the ground reference were detected with 6 false alarms.

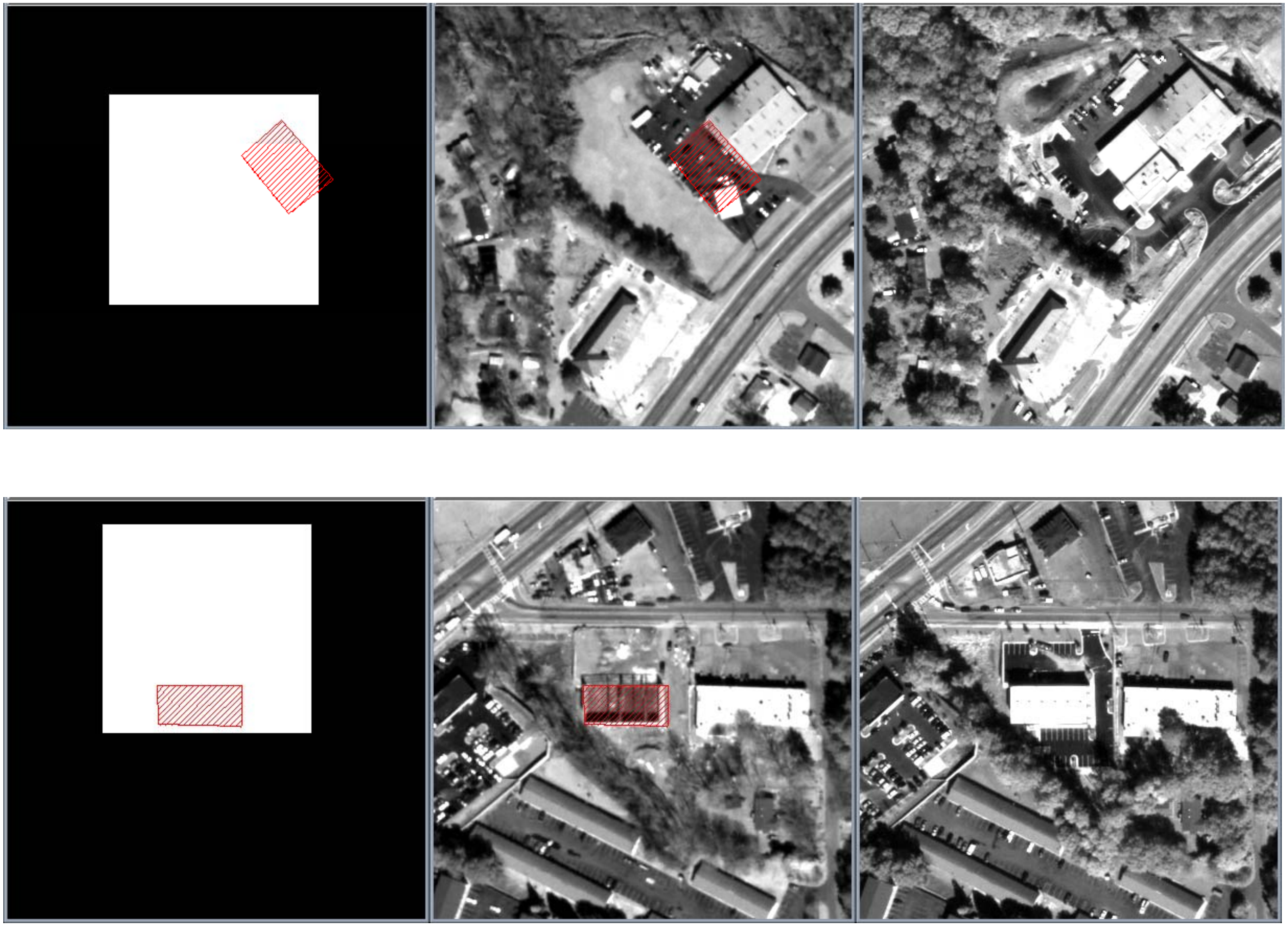
Atlanta test case – hot spot of real changes (1/2)

PCNN Change Detection | QuickBird – Feb. 2007 | WorldView-1 – Oct. 2007



Atlanta test case – hot spot of real change (2/2)

PCNN Change Detection | **QuickBird – Feb. 2007** | **WorldView-1 – Oct. 2007**



Atlanta test case – hot spot of false/missed alarms

PCNN Change Detection | **QuickBird – Feb. 2007** | **WorldView-1 – Oct. 2007**

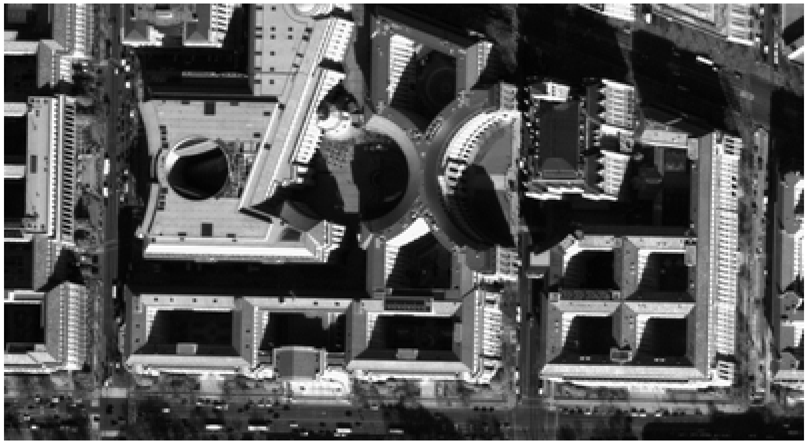
Example of false alarm due to the difference of season

Example of missed alarm

Washington D. C. test case (1/3)

The effects of different solar elevations, incidence angles, seasons and the residual misregistration of these images should not be neglected since they would cause several changes which are not significant to urban monitoring.

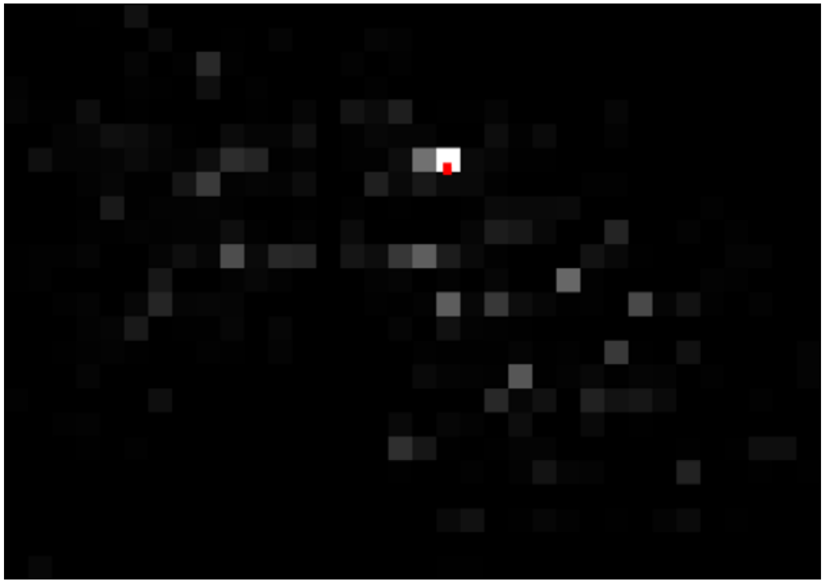
Differently from the previous case, the Washington D. C. images have been acquired with very different view angles and solar elevations to investigate the performance of PCNNs in this particularly condition.



The extension in area of this scene is about 9 km^2 (7,000 x 5,000 pixels).

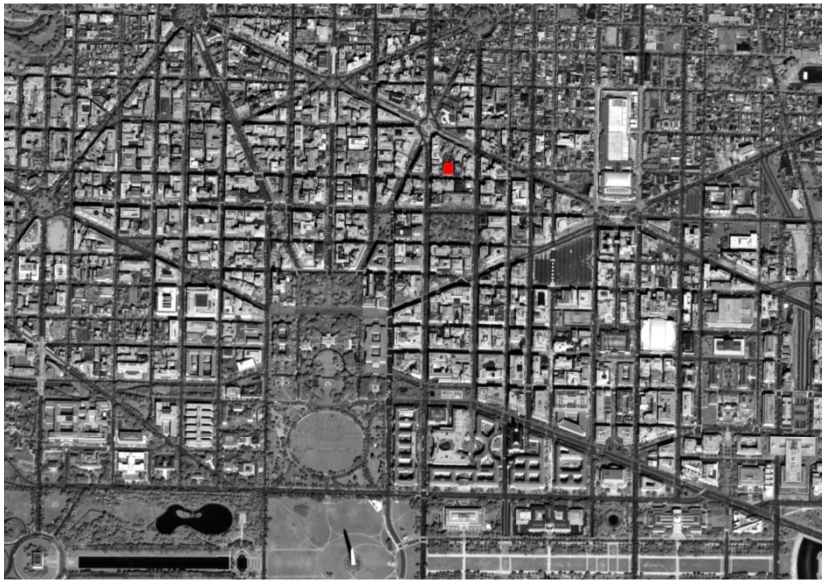
Washington D. C. test case (2/3)

QuickBird - September 23, 2007



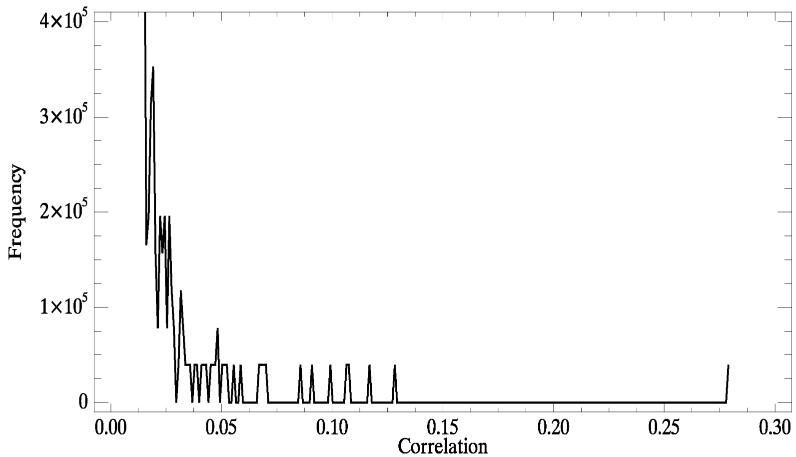
Pixel-based Image Difference

PCNN Change Detection

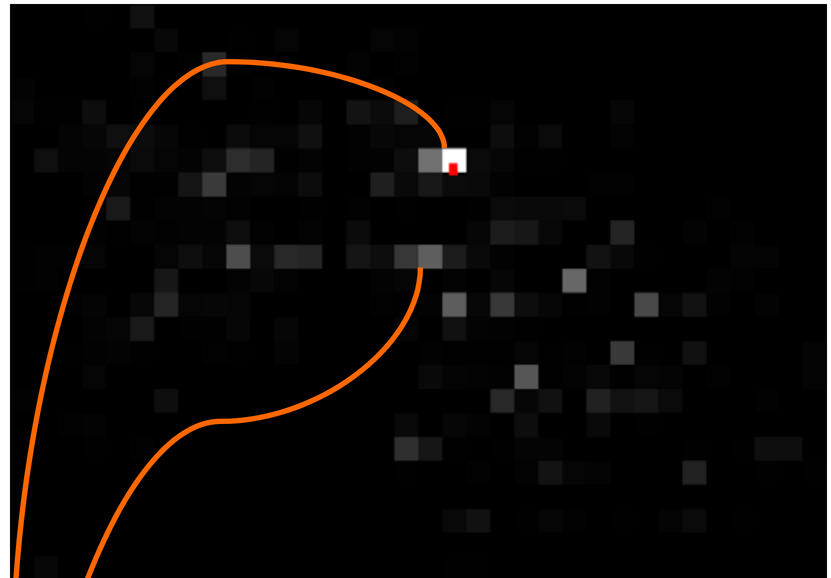


WorldView-1 - December 18, 2007

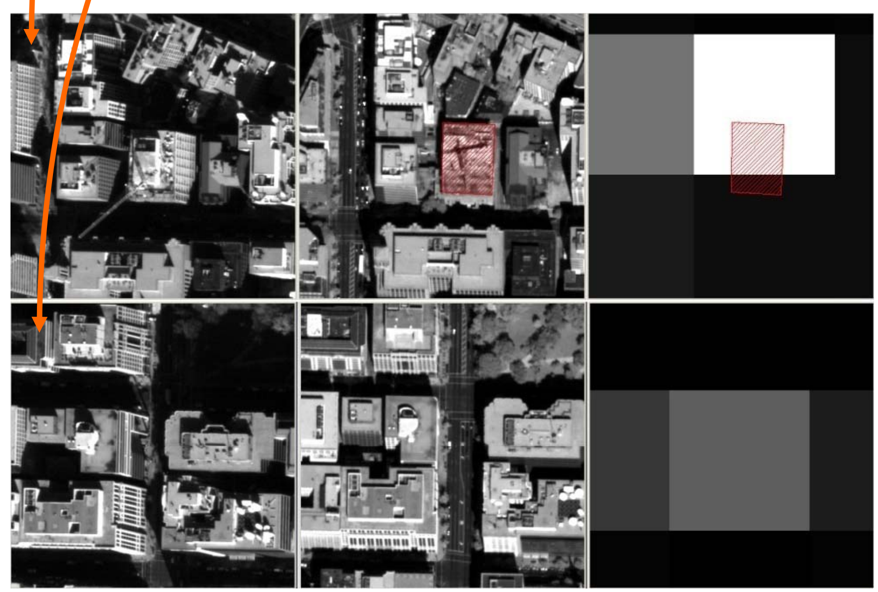
- PCNN detected correctly the only hot spot corresponding to changes.
- Differently from the previous case, where values were close to 0 or 1, non-changed areas show *corr* values slightly bigger than 0. This may be expected due to the very different view angles of the imagery used.



False alarms are characterized by *corr* values in the range (0.00; 0.12), while the *corr* value of the detected hot spot is more than two times higher, i.e. 0.27.



PCNN Change Detection



Details of the detected hot spots

Conclusions

The potential of a novel automatic change detection technique based on PCNNs was investigated. They are unsupervised, context sensitive, invariant to an object scale, shift or rotation.

The method is fast as it directly analyzes the correlation between the two signals associated to the images and no post-processing after the comparison is required to give the final response.

PCNNs were successfully applied to images with diverse spatial/spectral resolution and acquired with different view angles and solar elevations. No pre-processing, except for a raw image registration, was necessary.

Thank you for your attention!

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