DETECTING HUMAN-INDUCED SCENE CHANGES USING COHERENT CHANGE DETECTION IN SAR IMAGES

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ABSTRACT:

The technique of coherent change detection in repeat-pass Synthetic Aperture Radar imagery has the potential to detect very subtle scene changes such as changes in man-made targets or potential human activities. In this paper, we propose a simple method for detecting temporal changes in a scene possibly caused by human activities, such as building up areas of hard surface on a terrain that was previously a part of a desert. This method is based on comparison of coherence change detection results obtained in successive time frames. In order to cover a wide range of applications and situations, the proposed method is intentionally designed so that it does not need any specific knowledge source about the terrain. However, once coherent change detection results are obtained, various knowledge sources can be taken into account in order to improve the final interpretation. These knowledge sources can be related to the sensors, such as their operational principles, or to the situation at hand, referring to the context – terrain type, land-use, historical background etc. A way to include them in the reasoning process is discussed here too. In addition, in order to further improve the quality of the obtained output, usefulness of applying a spatial regularization technique is tested as well. The method is illustrated and validated using ALOS PALSAR multi-temporal data related to a real situation - works performed in building up additional runways of an airport. The results are in concordance with the ground-truth information, showing that the presented method is promising.

RÉSUMÉ:

La technique de détection de changements cohérents en imagerie radar à ouverture synthétique permet de détecter des changements fins dans la scène observe, comme les objets artificiels et les activités humaines, au cours de passages successifs. Dans cet article, nous proposons une méthode simple pour détecter les changements temporels dans une scène qui ont pu être causés par les activités humaines, telles que la construction de zones de surface dure sur un terrain qui était auparavant un désert. Cette méthode repose sur la détection des changements obtenus à partir d'images de cohérence successives. Afin de couvrir un large éventail d'applications et de situations, la méthode proposée est volontairement conçue de sorte qu'elle n'ait besoin d'aucune source de connaissances spécifiques sur le terrain. Cependant, une fois que des résultats de détection des changements cohérents sont obtenus, les sources de connaissances diverses peuvent être prises en compte, si elles sont disponibles, afin d'améliorer l'interprétation finale. Ces sources de connaissances peuvent concerner les capteurs et leurs principes de fonctionnement, ou la situation observée et son contexte - type de terrain, utilisation des terres, contexte historique ... Nous discutons de la manière d'inclure de telles informations dans le processus de raisonnement. Enfin la qualité du résultat peut être encore améliorée par une régularisation spatiale. La méthode est illustrée et validée à l'aide de données multi-temporelles ALOS PALSAR correspondant à une situation réelle - travaux effectués pour la construction de pistes supplémentaires d'un aéroport. Les résultats sont en accord avec la vérité terrain, et montrent que la méthode présentée est prometteuse.

1. INTRODUCTION

Change detection is an application for which Synthetic Aperture Radar (SAR) is particularly well suited as this type of sensors can consistently produce high-quality well-calibrated imagery with good geo-location accuracy (Price and Stacy, 2006). Two forms of change detection in repeat-pass SAR imagery may be considered, namely coherent and incoherent change detection (Price and Stacy, 2006). While incoherent methods compare the backscatter of two images acquired using the same imaging parameters, coherent methods exploit the coherence between such two images acquired at different times (Scheuchl, Ullmann and Koudogbo, 2009).

Detection of temporal changes in an area of interest using coherent change detection (CCD) in repeat-pass (SAR) imagery (Touzi et al., 1999) is presented in this paper, as a follow-up of the method introduced in (Milisavljević, Closson and Bloch, 2010). The CCD technique has the potential to detect subtle scene changes (Price and Stacy, 2006), e.g. changes in man-made targets (Wright et al., 2005) or potential human activities. Nevertheless, urban areas represent a potential problem (Fanelli et al., 2000; Matikainen, Hyyppä and Engdahl, 2006) for the

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interpretation of the decorrelation due to too many possible human activities.

The paper is organized as follows. Firstly, we point out main ideas of the CCD technique. Then we describe our study area together with the data, as well as our method for analysis of CCD results in order to obtain information about potential human-induced scene changes, such as building up areas of hard surface on a terrain that was previously a part of a desert. In order to cover a wide range of applications and situations, the proposed method is intentionally designed so that it does not need any specific knowledge source about the terrain. Still, once CCD results are obtained, various knowledge sources can be taken into account in order to improve the final interpretation. These knowledge sources can be related to the sensors (operational principles and experience) or to the situation at hand (context – terrain type, land-use, historical background etc.). A way to include them in the reasoning process is discussed here too. In addition, in order to further improve the quality of the obtained output, usefulness of applying a spatial regularization technique is tested as well. Finally, we validate the obtained results and propose ways to continue the work.

2. ON COHERENT CHANGE DETECTION

Starting points for CCD processing are the complex images of an interferometric SAR image pair (two images from approximately the same geometry collected at two different times). Namely, CCD uses the correlation between them and provides information on the stability of the target (Matikainen, Hyyppä and Engdahl, 2006; Price and Stacy, 2006). For instance, forests have a low coherence value, which means that such a type of target has changed much from one image to another (thus in time corresponding to the collection of these two images), while urban areas typically have high coherence values even between image pairs separated by several years (Luckman and Grey, 2003; Matikainen, Hyyppä and Engdahl, 2006).

The coherence can be expressed as the product of five dominant contributions, as shown in (Zebker and Villasenor, 1992; Preiss, Gray and Stacy, 2006):

1) the relative backscatter signal to radar receiver noise ratio in the interferometric image pair,
2) the volume decorrelation,
3) the baseline decorrelation,
4) the decorrelation related to mismatch between the coherent acquisition apertures and image-formation processing stages used to produce the primary and repeat-pass imagery, and
5) the decorrelation in the scene over the repeat-pass time interval (temporal decorrelation); this type of decorrelation is the one we are interested in, as it is determined by various sources of scene change, such as environmental effects (moisture changes, atmospheric effects) or man-made disturbances.

The value of the product of the first four contributions mentioned above is close to one if the repeat-pass imaging geometry is designed carefully and if interferometric processing steps are performed, such as compensation for aperture and processor mismatch as well as image registration (Preiss, Gray and Stacy, 2006). Therefore, under such conditions, the coherence of the scene image reflects the true scene coherence over the repeat-pass interval. For the data used in this paper, these conditions are fulfilled.

Therefore, a starting point in our analysis is the fact that in this type of scene/terrain, low coherence values can refer to the moving ground (sand), which is perturbed all the time, while high coherence values can be related to a hard surface (e.g., concrete).

3. STUDY AREA AND THE DATA USED

The study area is an airfield that is located in a desert part of Israel. This type of terrain is a good start for analysing the usefulness of the CCD method for detecting potential human activities due to low soil moisture as well as low vegetation.
As far as the data are concerned, four ALOS PALSAR (Phased Array type L-band SAR) images (Rosenqvist, Shimada and Watanabe, 2004) of the scene in the descending mode are processed, corresponding to four different dates of acquisition: 15 November 2007, 15 February 2008, 1 April 2008 and 17 May 2008. Starting from the Single Look Complex data, three CCD results are obtained using the following pairs: 15 November 2007 and 15 February 2008 (period 1), 15 February 2008 and 1 April 2008 (period 2), as well as 1 April 2008 and 17 May 2008 (period 3). As an example of the three obtained CCD results, Fig. 1 contains the CCD result for the images of period 1. The images of the other two periods can be found in (Milisavljević, Closson and Bloch, 2010). The coherence images are generated using the module Insar of Erdas Imagine 2010 platform.

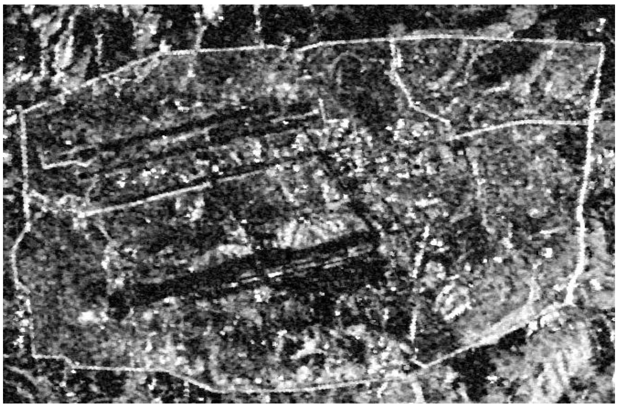

Figure 1. CCD result for the images acquired on 15 November 2007 and 15 February 2008 (period 1)

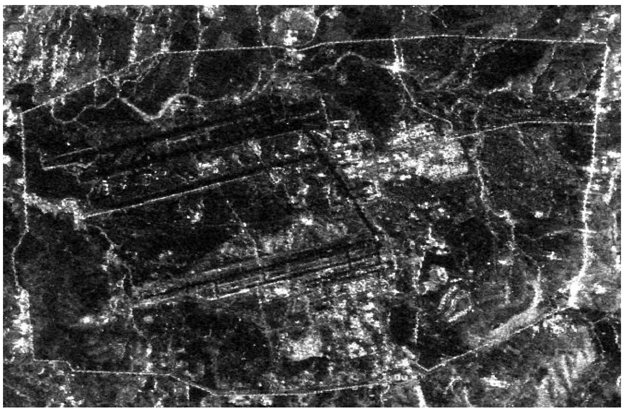

Figure 2. Amplitude of the SAR data acquired on 15 November 2007

In order to illustrate the usefulness of the SAR phase information used to obtain the CCD results, Figures 2 and 3 contain amplitude information of the SAR data pair corresponding to the two dates from Figure 1. Visually, there are no significant changes in amplitude values between two images. We have tested two amplitude change detection techniques, i.e., image differencing (Rosin, 1998) and image rationing (Lu et al., 2004), which confirm that no significant change in amplitude occurs between these two time intervals. However, the phase-based change detection result shown in Figure 1 demonstrates that changes occur in that period, which justifies the need for using this part of SAR information in this type of applications.

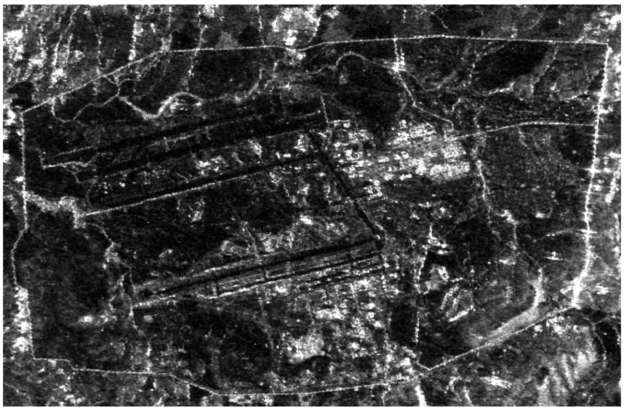

Figure 3. Amplitude of the SAR data acquired on 15 February 2008

4. OUR METHOD FOR DETECTION OF HUMAN ACTIVITIES

This method is introduced in (Milisavljević, Closson and Bloch, 2010) and we outline it here. Firstly, a noise removal method using median filtering is applied to each of the three CCD results. Then, each of the three CCD results is divided in three classes, based on coherence value:

- if a CCD pixel is dark (low coherence), it is labelled as 1;
- if it has a medium value, it is labelled as 2,
- if it has a high coherence value, it is labelled as 3.

As an illustration, Fig. 4 contains the obtained result in case of the CCD image from Fig. 1. Green colour corresponds to label 1 (so, low coherence), white colour is used for label 2 (medium coherence), and red is used for label 3.

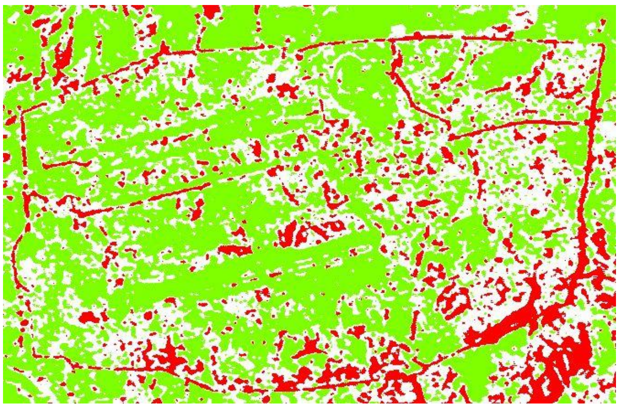

Figure 4. Classification result of Figure 1

In the following, results shown in Fig. 4 are referred to as A, the classification results obtained on the CCD pair from period 2 – B, and those obtained on the CCD pair from period 3 – C.
In a next step, we compare the results A and B, in order to see whether within the first periods of time the coherence values were similar (i.e., there was no change in the soil disturbance from one period to another) or not. The comparison of values A and B (AB) in each pixel can result in one of the following labels: 11 (low coherence in CCD results in period 1 and in period 2), 12 (low coherence in CCD results in period 1 and medium in period 2), 13 (change from low to high coherence, i.e., possible increased human activity), 21, 22, 23, 31, 32, 33.

Since the threshold between low and medium, on the one hand, and medium and high, on the other hand, is crisp and since these changes are not as radical as changes from very low to very high coherence (or the opposite), we regroup these AB values so that

- 11, 12 and 21 are grouped together, labelled as 1,
- 22 is labelled as 2,
- 23, 32 and 33 represent one group, labelled as 3,
- 13 remains 13,
- 31 remains 31.

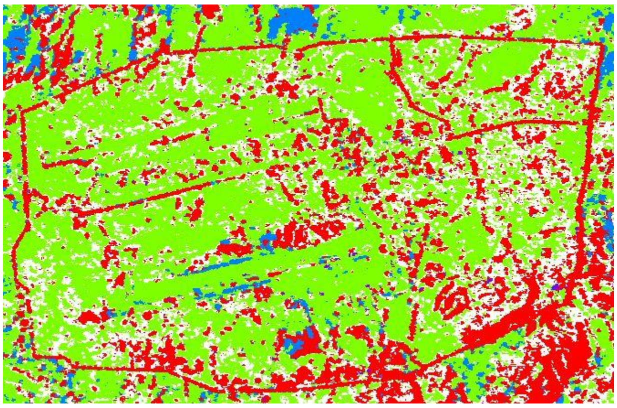

Figure 5. Comparison of values A and B: 1 – green, 2 – white, 3 – red, 13 – blue, 31 – purple

The obtained result is illustrated in Fig. 5. Similar reasoning is applied in comparing the results B and C.

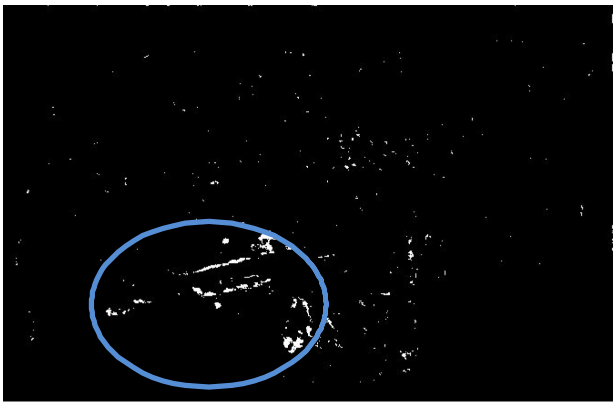

Figure 6. White pixels show where AB is 13 and BC is 3. Region within the blue ellipse is zoomed in Figure 7

Now, if AB value is 13, this means that the coherence was low in period 1 and high in period 2. If BC value is 3 at that same place, meaning that the coherence remained high from period 2 to period 3, this can mean that there were some works in that place (for instance, human activity such as creating built-up areas) which started in the first period (AB=13) and have been finished in the following periods (BC=3, referring to a built-up area, i.e. hard surface). The pixels where AB=13 and BC=33 are shown in white in Fig. 6 and zoomed in Fig. 7.

Figure 7. Zoom of the region within the blue ellipse in Fig. 6

5. INCLUSION OF KNOWLEDGE SOURCES

In (Milisavljević, Closson and Bloch, 2010), we mention the possibility of including knowledge sources. We develop this idea here. Namely, once CCD results are obtained, various knowledge sources can be taken into account in order to improve the final interpretation. These knowledge sources can be related to the sensors, such as their operational principles, or to the situation at hand, referring to the context – terrain type, land-use, historical background etc. We illustrate here the inclusion of three knowledge sources:

1. area of interest (airport), extracted manually from a very high resolution image and shown in Fig. 8 - it can be included in the obtained results in a straightforward way, by taking into account only pixels that are within the white region;

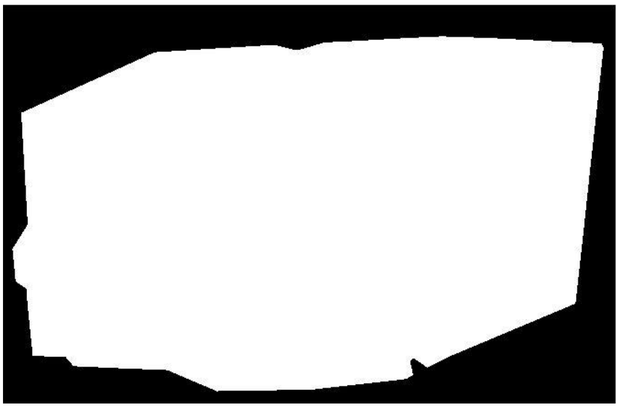

Figure 8. Area of interest (in white)

2. pedologically extracted robustness (i.e., soil hardness), presented in Fig. 9; while dark grey pixels represent areas with low robustness, high (white) values correspond to hard surface; it is difficult to perturb such a soil and detect human activities, so coherence is high in such an area and the reliability to detect human activities is low; therefore, regions with the highest robustness are superimposed to the classification results as areas with surely high coherence (label 3);

3. slope (extracted from the digital elevation model created from contours of topographical maps), presented in Fig. 10, where the lighter the pixel, the higher the slope, so the lower the possibility to have an airfield; again, regions with the highest slope can be superimposed to the classification results as being of low interest while looking for human activities in an airport (so, labelled as 3).

Figure 9. Pedologically extracted robustness. Black – no data; dark grey – low robustness; light grey – medium robustness; white – highest robustness

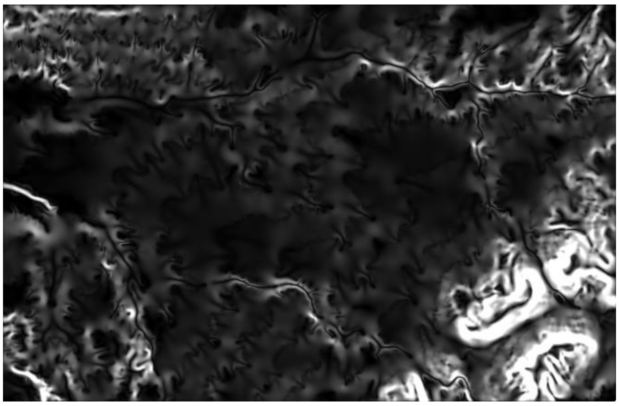

Figure 10. Slope (extracted from the digital elevation model)

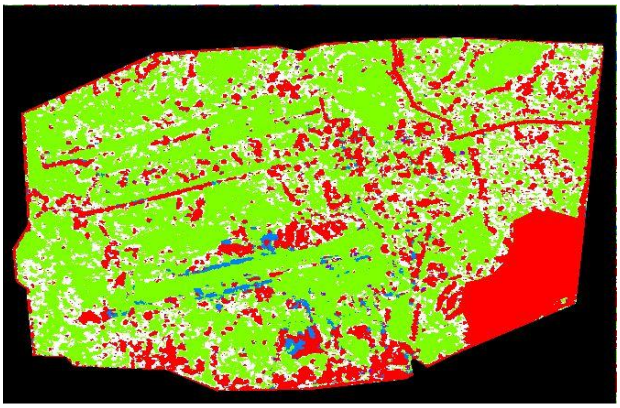

Figure 11. Result of the inclusion of three knowledge sources in results shown in Figure 5

As an illustration, Figure 11 contains the result of the inclusion of the three knowledge sources mentioned above to the result shown in Figure 5.

Based on the way the knowledge sources are included, it is certain that the method itself would not be affected if they were not present. In addition, as these sources, in this particular case, affect only areas that are outside of the region within the blue ellipse of Figure 6, even the results shown in Figures 6 and 7 would not be affected either.

6. SPATIAL REGULARIZATION

In order to improve the quality of the obtained output, we test here the usefulness of applying a spatial regularization technique as well. Again, in order to test the principle itself, we use a simple spatial regularization method: majority voting within a sliding window. Applying this method to the image shown in Figure 11, we obtain the result presented in Figure 12.

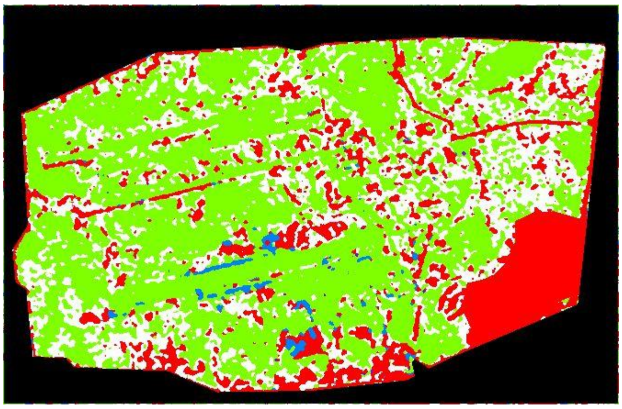

Figure 12. Result of spatial regularization applied to Figure 11

Although spatial regularisation does not affect the method itself either, it improves the quality of the final result by removing isolated points thus clearing the image and emphasizing the detected areas, as can be seen by comparing Figures 6 and 13, i.e., Figures 7 and 14.

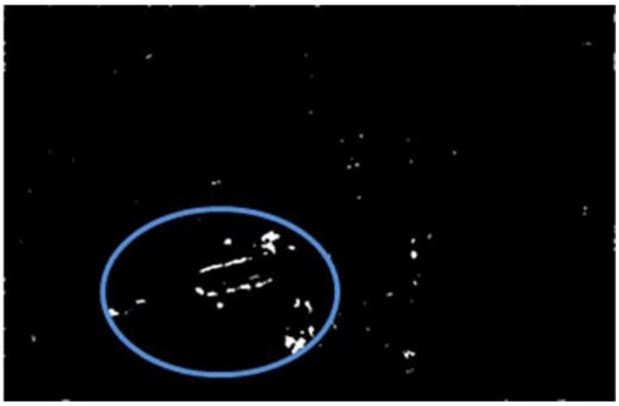

Figure 13. Same as Figure 6, but obtained after applying spatial regularization to the starting images. Region within the blue ellipse is zoomed in Figure 14

Figure 14. Zoom of the region within the blue ellipse in Fig. 13

7. VALIDATION

Results presented here indicate that there is a region where human activities might have been performed, with changes in coherence values corresponding to works in building a hard surface on a sand terrain, and that these activities appear mainly in two parallel stripes as well as around them.

A newspaper article from February 2008 (Greenberg, 2008) makes it possible to validate the obtained results. This article speaks about works at this same airfield, mentioning that a new runway is being built, together with other operational buildings around the runway, and that the works are about to be finished. The article also shows aerial photos which correspond to the region extracted by our analysis (Fig. 14). This means that our results are in a complete concordance with the reality, showing that the approach presented in this paper is promising for detecting human activities.

8. CONCLUSION AND FUTURE WORK

A simple method to detect potential human activities using CCD technique in repeat-pass SAR imagery is presented here. The results are validated, showing that the method is promising in extracting zones where a potential temporal change in the human activities occur, such as works in building-up areas of hard surface. As a good study case for a first research step, a desert type of soil is analyzed. Terrains which represent more difficult situations from the point of view of CCD technique will be studied in a next step.

The presented method does not need any specific knowledge sources. Nevertheless, we show in this paper that if knowledge sources exist, it is possible to include them in order to improve final results. These knowledge sources can be related to the sensors, such as their operational principles, or to the situation at hand, referring to the context – terrain type, land-use, historical background etc. Three types of knowledge sources (information on the area of interest, pedologically extracted robustness and slope extracted from the digital elevation model) are included in the obtained results as an illustration. In a next step, possibilities of including some other knowledge sources, such as geological maps or aerial photos will be studied.

In addition, in order to improve the aspect of the final result, the application of a spatial regularization method is tested, showing that it might be useful to further analyze ways to remove artefacts and preserve only the useful information.

Finally, in future work, fusion of the obtained results with data coming from other sensors in order to further improve the quality and the robustness of the results will be investigated.

REFERENCES

Fanelli, A. et al., 2000. Understanding ERS Coherence over Urban Areas. In: *ESA-SP-461 (Ed.), ERS-Envisat Symposium*, Gothenburg, Sweden.

Greenberg, H., 2008. “Longest landing field in Middle East to be constructed in Nevatim”. http://www.ynetnews.com/articles/0,7340,L-3508174,00.html (accessed 30 May 2010)

Lu, D. et al., 2004. Change detection techniques. *International Journal of Remote Sensing*, 25(12), pp. 2365-2407.

Luckman, A. and Grey, W., 2003. Urban Building Height Variance From Multibaseline ERS Coherence. *IEEE Transactions on Geoscience and Remote sensing*, 41(9), pp. 2022-2025.

Matikainen, L., Hyyppä J. and Engdahl, M. E., 2006. Mapping Built-Up Areas from Multitemporal Interferometric SAR Images – A Segment-based Approach. *Photogrametric Engineering & Remote Sensing*, 72(6), pp. 701-714.

Milisavljević, N., Closson, D. and Bloch, I., 2010. Detecting potential human activities using coherent change detection. In: *International Conference on Image Processing Theory, Tools and Applications (IPTTA10)*, Paris, France.

Preiss, M., Gray, D.A. and Stacy, N.J.S., 2006. Detecting Scene Changes Using Synthetic Aperture Radar Interferometry. *IEEE Transactions on Geoscience and Remote sensing*, 44(8), pp. 2041-2054.

Preiss, M. and Stacy, N.J.S., 2006. Coherent Change Detection: Theoretical Description and Experimental Results. Technical Report, DSTO–TR–1851, Defence Science and Technology Organisation, Edinburgh, Australia.

Rosenqvist, A., Shimada, M. and Watanabe, M., 2004. ALOS PALSAR: Technical outline and mission concepts. In: *4th International Symposium on Retrieval of Bio- and Geophysical Parameters from SAR Data for Land Applications*, Innsbruck, Austria.

Rosin, P.L., 1998. Thresholding for Change Detection. In: *IEEE International Conference on Computer Vision*, Bombay, India, pp. 274-279.

Scheuchl, B., Ullmann, T. and Koudogbo, F., 2009. „Change detection using high resolution Terrasar-X data: preliminary results”, HighRes09, Hannover, Germany. http://www.isprs.org/proceedings/XXXVIII/1_4_7-W5/paper/Scheuchl-185.pdf (accessed 30 May 2010)

Touzi, R. et al., 1999. Coherence Estimation for SAR Imagery. *IEEE Transactions on Geoscience and Remote sensing*, 37(1), pp. 135-149.

Wright, P. et al., 2005. Coherent Change Detection with SAR. In: *European Radar Conference (EURAD 2005)*, Paris, France, pp. 17-20.

Zebker, H.A. and Villasenor, J., 1992. Decorrelation in Interferometric Radar Echoes. *IEEE Transactions on Geoscience and Remote sensing*, 30(5), pp. 950-959.