ACTIVITY MONITORING IN A COMMERCIAL HARBOR USING MULTITEMPORAL REPEAT-PASS INTERFEROMETRIC SAR DATA

D. Borghys, C. Perneel

Royal Military Academy
Signal & Image Centre
Brussels, Belgium

A. Bouaraba *

Ecole Militaire Polytechnique
Laboratory of Microwaves and Radar
Algiers, Algeria

ABSTRACT

Since the launch of Terrasar-X, Radarsat 2 and the Cosmo-Skymed constellation, spaceborne SAR data with a high spatial resolution have become more readily available, allowing to monitor areas with a high level of human activity independent of weather circumstances. The current paper investigates the use of multi-temporal spaceborne SAR data for monitoring human activity within a commercial port. A large stack of spotlight images is available for this project, allowing a high level of temporal detail. In the current paper HiRes spotlight data from the Cosmo-Skymed constellation are used. For activity monitoring on land a method was developed that combines information from interferometric coherence and amplitude information into a semi-supervised change detection and classification scheme. The activity monitoring on water focusses on the detection of ships in the harbor. The ship detection is based on an image processing chain applied on the log-intensity data.

Index Terms— interferometric SAR, change detection, activity monitoring, harbor scene analysis, ship detection

1. INTRODUCTION

In the frame of a demo project, aiming amongst others at demonstrating the use of space-borne SAR for monitoring of human activity within a commercial harbor, a time series of CSK data was acquired over the area of Zeebrugge, Belgium. Zeebrugge is a maritime commercial port consisting of three parts: an outer port, an inner port and the seaport of Bruges. The area of interest in the presented work is focussed on the outer port which consists of a liquefied natural gas terminal, several container terminals, two roll-on/roll-off terminals for freight and passengers and berth for cruiseships and passenger ships. Activity monotoring on land is focussed on movements of containers and vehicles, while on water the focuss lies on the autonomous detection of ships.

*A. Bouaraba participated to the work during his stay at RMA, Brussels in the frame of his PhD study

2. DATA SET

For this demo project a set of over 50 SAR images from CSK, TSX and RS-2 was provided by the respective image providers. The dataset consists of spotlight data (HH polarised) acquired as sets of interferometric pairs, polarimetric data (from RS-2) and ScanSar data over a larger area for ship detection. All data were acquired between May and August 2011. AIS data was also acquired as ground truth data for ship detection. In the current paper a set of interferometric couples of CSK spotlight data are used. The images were acquired on 15, 16 and 19 june 2011 and have a ground grid size of 0.69m (Azimuth) $\times$ 0.66m(Range) and an incidence angle of 28°.

3. ACTIVITY MONITORING ON LAND

The used approach for activity monitoring on land is based on coherent change detection. In coherent change detection (CCD) the detection of changes is based on a combination of the interferometric coherence and the amplitudes of the two separate SAR images between which the coherence is estimated. Interferometric coherence γ is estimated as the sample complex cross correlation coefficient between two SAR images z_1 and z_2 over an N-pixel local area: $\gamma = \frac{\sum_{i=1}^{N} z_{1,i} z_{2,i}^*}{\sqrt{\sum_{i=1}^{N} |z_{1,i}|^2}\sqrt{\sum_{i=1}^{N} |z_{2,i}|^2}}$. In CCD usually the magnitude of the coherence $|\gamma|$ is used. Changes due to human activity should be characterised by a low $|\gamma|$ and a high amplitude in at least one of the two images. However, the expression above is biased estimator of the coherence [1]. The bias is more important for low values of γ. This leads to detection errors (mainly false alarms). The effect of the bias is inversely proportional to the size of the scanning window used for the coherence estimation [1]. Increasing N would thus reduce the bias. However, in our case, small changes are of interest and averaging using large windows will deteriorate the detection small changes. In [2] it is shown that applying a two-level coherence estimation and using the complex coherence instead of the coherence magnitude, significantly improves the detection of coherent changes. Figs. 1 and 2 show color composites (R: coherence, G: amplitude image 1, C: amplitude image 2) for various approaches of coherence bias reduction. Fig. 1(left) is the result obtained using N=9, i.e. a 3×3 scanning window for the coherence calculation. Fig. 1(right) shows the result with N=9 where the coherence magnitude $\mid \gamma \mid$ is averaged using a 3×3 scanning window (M=9). In Fig. 2(left) the result is shown using the average of the complex coherence γ. For the detection of human activity the coherence information needs to be combined with amplitude data. A speckle filtering reduces the false alarm rate [3]. Fig. 2(right) shows the result of applying a 3×3 local sigma filter [4] to the amplitude data. We suppose

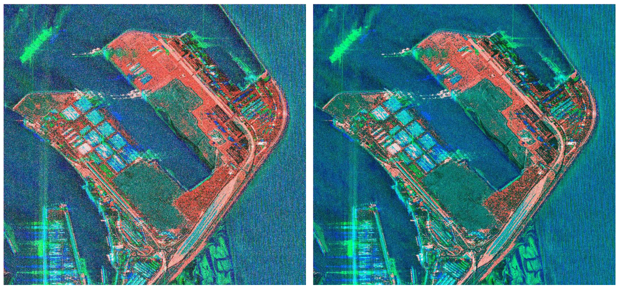

Fig. 1. Left: N=9,M=1 using $\mid \gamma \mid$, right: N=9,M=9 $\mid \gamma \mid$

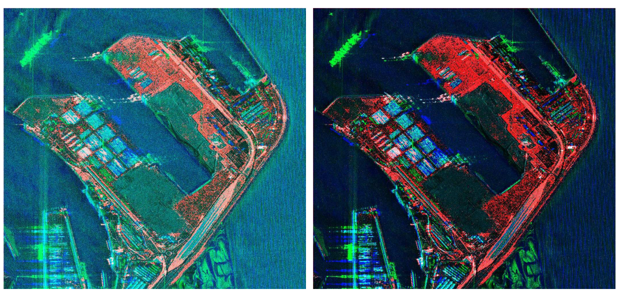

Fig. 2. Left: N=9,M=9 using γ , right: N=9,M=9 using γ and Locσ

that man-made objects present a high radar return. Human activity is thus characterised by a low coherence and a high amplitude in at least one of the two images (i.e. the areas that show a combination of green and blue in figs.1-1). After filtering coherence and amplitude, a semi-automatic change detection and classification method is applied [3]. The developed change detection and classification method is quite simple and is based on a combination of thresholds on the three features, i.e. the filtered coherence and log-intensity of the speckle-filtered images. The thresholds sub-divide each of the three features into a "low" and "high" value area. The method consists a rule-based set of decisions applied to the thresholded images. Dividing each of the three feature sets into two value regions leads to 8 possible combinations, thus 8 possible classes. Table 1 presents an overview of the properties of the different classes. Classes of interest for change detection and activity monitoring are C2-C4. Classes C1, C5 and C8 contribute to the overall scene understanding. C6 and C7 represent classes in which the coherence is high but the intensity changes between both images. If this situation occurs, it is due to the fact the coherence (or intensity) value supersedes the threshold in a region where it shouldn't (the tails of the histograms). This is mainly due to subsistence of coherence bias even after applying the filter. These two classes represent a very small portion of the image and pixels could be easily re-assigned to valid classes. Fig. 3 shows the results of the semi-automatic detection and characterization of changes between 15 and 19th of June. More details on the developed method can be found in [3].

Class	Features			Interpretation
	Coherence	LogInt(I1)	LogInt(I2)	
C1	L	L	L	Low backscatter: specular surfaces: water, roads, flat roofs, shadows
C2	L	L	H	Change: man-made objects present in I2, not in I1
C3	L	H	L	Change: man-made objects present in I1, not in I2
C4	L	H	H	Change: man-made object present in both images but it changed from I1 to I2
C5	H	L	L	No change and low backscatter: bare soil or low vegetation
C6	H	L	H	Invalid class (mainly due to high coherence bias)
C7	H	H	L	Invalid class (mainly due to high coherence bias)
C8	H	H	H	Strong scatterers present in both scenes: fixed structures (e.g.parts of buildings, railways)

Table 1. Overview of the eight classes resulting from the semi-supervised change detection and classification

4. SHIP DETECTION

Ships present a high contrast with respect to the water. Because a port like Zeebrugge is characterised by fast loading/unloading, ships that appear in an image of one date will not be present in the images of other dates. Therefore, representing the images of different dates in different colors, allows to visualise the ships movements to a human operator. Fig. 4 shows a color composite of intensity data from three dates. The ships are clearly seen as colored objects on the

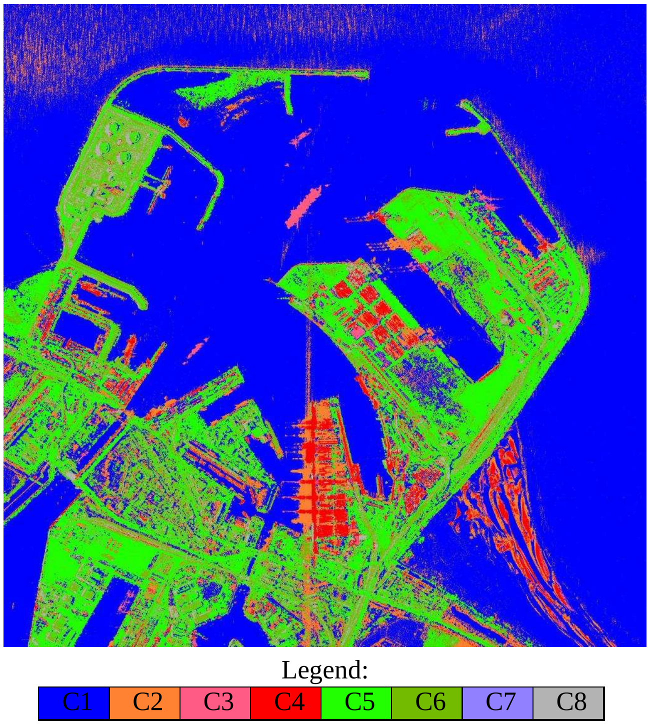

Fig. 3. Result of classification of changes (changes are represented in red, dark pink and orange);

water.

However, in order to automatically monitor ship traffic, a method needed to be developed that allows automatic detection of the ships. First speckle reduction is applied. Because the ships are much larger objects than the containers or vehicles on land, a Lee filter [5] with a larger window size (5×5) is applied. The land surface is then masked out from the image. Image processing methods are applied in order to find the ships on the individual images. Fig. 5 illustrates the processing chain on a small part of the scene containing two ships and a crane. The processing is applied to the log-intensity image after Lee filtering. The first processing step is a morphological closing, which fills gaps within the ships signature. In the second step a region growing is applied. The growing starts from pixels that are above a given threshold and applies a constraint on the minimal pixel value and on the size of the regions to be detected. Because the land surface is masked out, the region growing will not continue on land. The next step merges closeby regions in order to segment the ships as single objects. The resulting regions are then vectorized and their geometrical attributes are determined. A filter on the surface area and aspect ratio is applied to reduce false targets. Fig. 6 shows these parameters for the 18 initially found regions. The actual ships correspond to object numbers 1,2,3,4,5,10,11,16 and 17. It can be seen that the aspect ratio is a very discriminative feature. However, one of the ships (object 10) has a

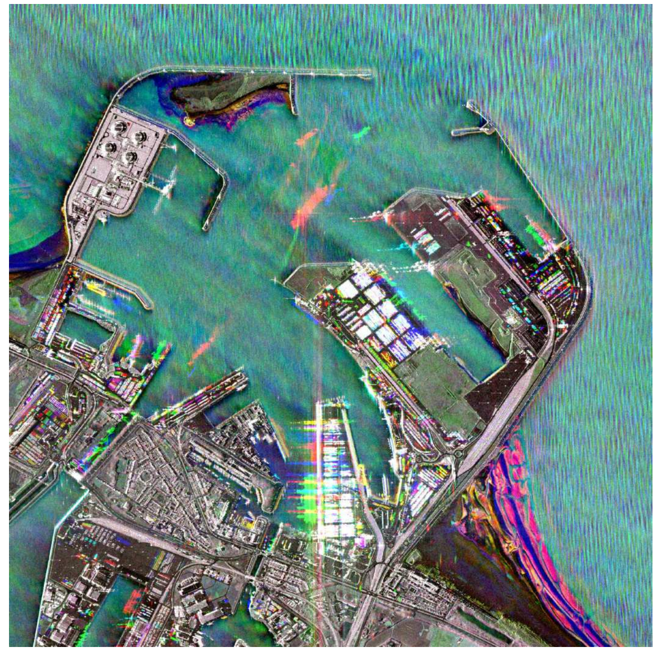

Fig. 4. Color composite of Lee-filtered intensity data from three different dates (R:15jun,G:16jun,B:19jun)

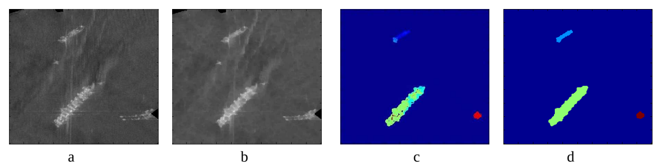

Fig. 5. Illustration of the processing steps for ship detection. a: original Lee-filtered log-int image, b: result of morphological closing, c: result of binary region growing, d: result of region merging

low aspect ratio because its segment includes the layover of a crane. The final ship detection result is shown as the green contours in fig. 4(right). The objects in red are objects initially found by the region merging and eliminated by the filter on surface area and aspect ratio. Comparing the detection result with AIS data acquired simultaneaously with the SAR acquisition, shows that all ships within the port have been correctly detected. One false alarm (1 object) remains that is due to the layover on the water surface of the large cranes in the container terminal. The developed method seems promising but still needs to be validated on other images.

5. CONCLUSIONS

This paper presents a method for monitoring activity in a harbor. The method relies on coherent change detection for monitoring of activity on land and on a specifically developed im-

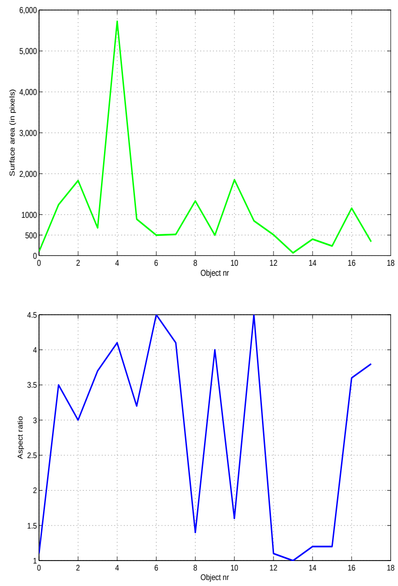

Fig. 6. Geometrical characteristics of segmented regions: left: surface area, right: aspect ratio

age processing scheme for ship detection on the water. For the detection of small changes on land it is important to reduce the bias in the interferometric coherence estimation. This is done using a two-level windowing method. The developed ship detection method allows to detect the ships in the harbor autonomously with a very limited number of false alarms and thus to count the number of ships in the harbor at the moment of SAR data acquisition. In future work the results will be further validated using more images from the acquired dataset.

6. ACKNOWLEDGEMENTS

The SAR data was obtained through a collaboration within NATO/SET145. The Cosmo-Skymed data were provided to the NATO/SET145 by e-GEOS (Italy) in the frame of a Demo project.

7. REFERENCES

[1] R. Touzi, A. Lopes, P. Bousquet, and P.W. Vachon, "Coherence estimation for SAR imagery," *IEEE-TGRS*, vol. 37, no. 1, pp. 135–149, January 1999.

[2] A. Bouaraba, D. Borghys, A. Belhadj-Aissa, M. Acheroy, N. Milisavljevic, and D. Closson, "Coherent change detection performance using high-resolution SAR images," *Progress in Electromagnetic Research*, Submitted 2012.

[3] D. Borghys, A. Bouaraba, and C. Perneel, "Combination of different SAR modalities for geospatial intelligence applications in a harbor environment," in *Proc. on Algorithms for Synthetic Aperture Radar Imagery XIX*, 4-8 April 2012, vol. 8394.

Fig. 7. Final ship detection results for 15th of June

[4] E.M. Eliason and A.S. McEwen, "Adaptive box filters for removal of random noise," *Photogrammetric Engineering and Remote Sensing*, vol. 56, no. 4, pp. 453, April 1990.

[5] J.S. Lee, "Digital image enhancement and noise filtering by use of local statistics," *IEEE-PAMI*, vol. 2, no. 2, pp. 165–168, Mar 1980.