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Change Detection for SAR Imagery Using Connected Components Analysis

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Abstract—**Objective of the described analysis is to provide consistent change detection method based on image processing techniques applied to the Synthetic Aperture Radar (SAR) images acquired over the same geographical area, but at two different time instances. The approach adopted in our work requires incorporation of results with the additional information derived from analysis based on mathematical morphology (MM) techniques and visual interpretation of multitemporal VHR optical satellite images.**

Keywords—**change detection, TSX, SAR image analysis, remote sensing.**

I. Introduction

CHANGE detection is the process of identifying differences that have occurred in the terrain situation at different times. One of the main problems related to Land Border Monitoring and detection of changes lies in the terrain accessibility. The Earth Observation (EO) data could allow us to obtain the rapid and reliable change detection information and thus be the particular asset to rational decision-making [1] by quantification of temporal effects using multitemporal data sets. Following the requirement of G-MOSAIC project (Service for Management of Operations, Situation Awareness and Intelligence for regional Crises) [2] to provide Border Guard with clear in-the-field situation and thus to provide a support emergency planning an approach to change detection has been tested. In particular, an approach based on Connected Components Analysis is presented. The proposed technique requires the application of image pre-processing scheme to the synthetic aperture radar (SAR) images acquired from the same geographical area, but at different time instances.

II. Dataset Characteristics

The data set under consideration is composed of synthesized data imagery nearby Polish-Ukrainian border area, which is simultaneously sensitive eastern border of European Union and external border of The Schengen Area. The study area covers ca. 90 km2 and is located around 49°48'N (latitude) and 22°55'E (longitude). A satellite radar based remote sensing is a promising data source for the land border monitoring because of its capability of imaging with high spatial resolution, despite differences of sun angles and atmospheric conditions, in comparison to optical sensors. However, the change detection, as one of automatic techniques for land monitoring (through analyzing a set of images captured over various terrain condition), is a very complicated problem. The indicated changes themselves, without the interpretation of the nature and significance have only a partial value. The changes have to be separated from the effects such as sensor noise or soil moisture. For the sake of reliable interpretation of the detected changes, the results of developed algorithm have been confirmed with the interpretation of optical satellite images. The tested set consists of two high resolution TerraSar-X satellite images captured in May and July 2010. The assessment of the results and rough validation of developed procedures were conducted based on the satellite earth maps.

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III. Radar Imagery Change Analysis

The reliability of the change detection analysis depends on various factors, starting from sensor settings and ending at environmental factors (in particular periodic) which all may lead to misjudgment and higher false alarm rate. In order to minimize possible processing failures related to instrumentation miscalibration, data set being processed should be acquired by the same sensor (or sensors), so that the crucial settings like viewing geometry, radiometric resolution and spatial resolution remain unchanged [3]. On the other hand, based on the types of land cover changes we want to follow, analyzed data set has to be chosen wisely. All of those factors have to be taken into account prior to data recording and/or choosing, so that the undesirable influences could be marginalized. Basic concept is to perform change detection analysis by making a comparison of the respective (pair of) SAR images. Due to large size of delivered SAR data (~100Mpx) a collection of regions of interest were defined for the experiment. For clarification we incorporate additional land cover information derived from optical satellite earth maps (Fig. 1). Since the nature of radiometric information in radar imagery is complicated, the final change detection results might contain errors. For the elimination of the radiometric noise impact on the final results, the pair of analyzed images are first preprocessed (sec. III-A). In order to discriminate all structures within the image domain which are characterized by difference in radiometric value in respect to date of acquisition, image arithmetic operations i.e. a pixel-by-pixel comparison, was performed (sec. III-B). The size of detectable change depends on application. The type of changes that might be of interest can range from short-term terrain modification such as snow cover, erection or disappearance of camps to long-term terrain modification like urban area development, building of new routes or deforestation. This method allows an automatic selection of the decision based on threshold selection for maximizing/minimizing the overall change detection volume. The supervised thresholding process can be established to determine whether it involves a change or no change at each pixel location (sec. III-C). The final map of change detection can be formed by merging pre-image with appearance results or respectively post-image with disappearance results (Fig. 3).

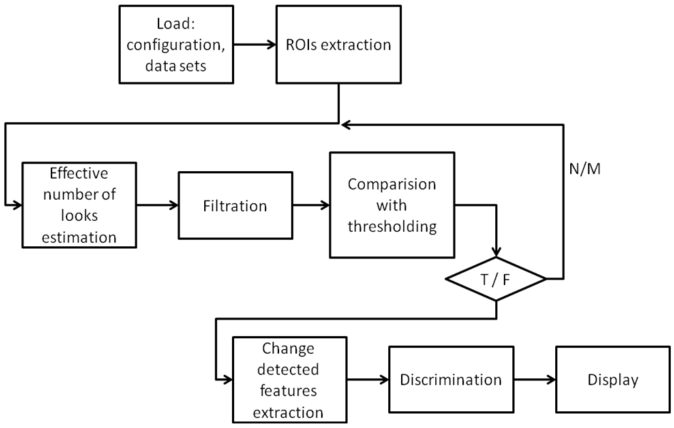


Fig. 1. Change detection algorithm block diagram.

A. SAR Image Preprocessing

The nature of information in SAR images is that the observed signal is used to derive physical properties of the scene, such as distributed complex reflectivity of the scene in the electromagnetic band of interest. Due to the physical nature of electromagnetic wave reflection radar imagery is characterized by strong noise (hereafter referred to as speckle), in comparison to optical images. Consequently, pre-filtering of SAR images has to be applied. Commonly, a multi-looking procedure (which consists in reducing speckle noise during image formation at the expense of spatial resolution) is applied to most of the SAR images. However, based on provided SAR dataset, a further filtering step needs to be performed to make the images useful for the analysis. In our case we applied a set of despeckling filters such as Lee filter, Kuan filter, Frost filter and (Gamma) MAP filter (each filtration can be performed in iterative/nested manner) [4],[5],[6].

B. Comparison of Corresponding SAR Images

The second step of the presented change-detection algorithm consists of a pixel based comparison of both images X_1 and X_2. According to the literature [7],[8], the comparison is performed by using ratio operator in order to further reduce the effects of speckle in the resulting image and to make the measured signal independent of the absolute intensity value of the considered pixel in the multitemporal images. To make the ratio distribution symmetrical and to transform the residual multiplicative speckle noise in an additive noise component, the ratio image is usually expressed in a logarithmic scale, resulting in the log-ratio image X_{LR}.

C. Change Detection

The next step involves several operations including adaptive thresholding, connected components labeling and analysis. The innovation of the proposed algorithm, in comparison to the algorithms known from the literature is extraction of objects from change-detection map, by using connected components analysis. Each object has assigned a list of attributes, such as size [m^2], (minimum, maximum, mean and deviation) reflectivity change [dB], shape coefficient, log-spiral transform prominent points which are used as features vector for further object discrimination (quasi-classification). Based on those properties, higher level processing is performed. However, it has to be emphasized that for full robust automation some sort of signature database is needed.

IV. Experimental Results

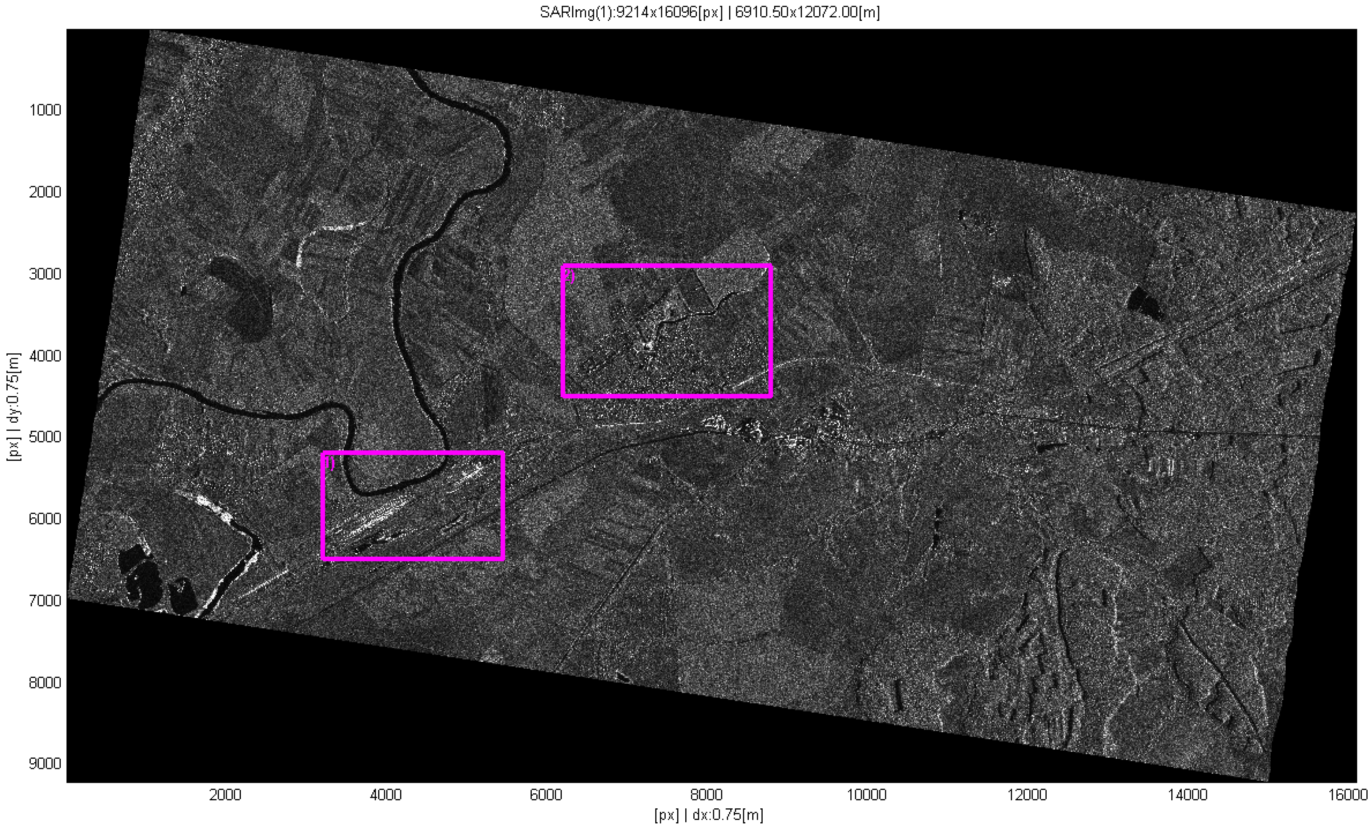
In this paper, we focused on SAR image change detection which is a challenging application of remote sensing. Input multitemporal dataset Fig. 2(a),(b) are composed of two high resolution SAR images recorded by the TerraSar-X satellite (X-band, HH-polarization) over the Medyka district (Poland) in May and July 2010. Detected changes are highlighted in red on the presented images. In the Fig. 3(a) the train movement on railway siding (in the middle from left to the right) and lorry movement on nearby discharge area (at the bottom left) are indicated. In the Fig. 3(b) water level change in the pond (in the center) and another train movement (bottom right) is detected. Fig. 3(c) and 3(d) depict corresponding optical images for the analyzed areas. Additionally, in Tab. I (sorted by area) summarized parameters of first ten largest objects measured during detection process were presented.

TABLE I
Detected Object List and Their Parameters Subset

#	Area[m^2]	$\tilde{x}$[m]	$\tilde{y}$[m]	min[dB]	max[dB]	u[dB]	σ^2[dB]
region of interest #1							
1	1481.06	120.99	73.48	-34.00	-5.50	-11.76	19.50
2	1406.25	69.65	43.00	5.50	15.72	7.34	1.83
3	1276.87	39.07	33.95	5.50	16.95	7.33	2.12
4	1076.62	24.63	29.65	5.50	13.46	7.07	1.56
5	1022.06	55.99	29.01	5.50	41.89	12.58	34.24
6	1020.37	28.44	30.66	5.50	17.59	7.24	1.79
7	864.56	28.42	22.42	5.50	12.81	7.52	2.35
8	834.75	26.91	30.58	5.50	14.85	7.36	2.08
9	695.81	32.66	18.47	5.50	13.84	7.74	2.72
10	668.25	60.65	28.30	5.50	30.33	10.97	18.95
region of interest #2							
1	2331.01	36.91	26.03	-19.42	-5.50	-9.05	4.91
2	1563.19	36.38	42.59	5.50	12.63	7.10	1.29
3	723.94	31.40	26.95	5.50	14.16	7.18	1.71
4	713.81	27.61	13.59	-19.47	-5.50	-8.01	3.73
5	688.50	21.34	26.58	5.50	21.17	7.23	2.92
6	546.75	29.69	16.42	5.50	11.77	6.69	0.76
7	529.87	26.88	19.25	5.50	16.69	7.06	1.90
8	502.31	23.21	18.29	5.50	12.44	7.17	1.61
9	487.12	26.36	21.81	-11.59	-5.50	-7.25	1.69
10	442.69	17.78	20.80	5.50	13.14	7.77	2.63

area – of continuous change; $\tilde{x}$, $\tilde{y}$ – center of mass coordinates; min – minimum reflectivity change ratio; max – miximum reflectivity change ratio; mean – average reflectivity change ratio; var – variance of reflectivity change ratio

(a)



(b)

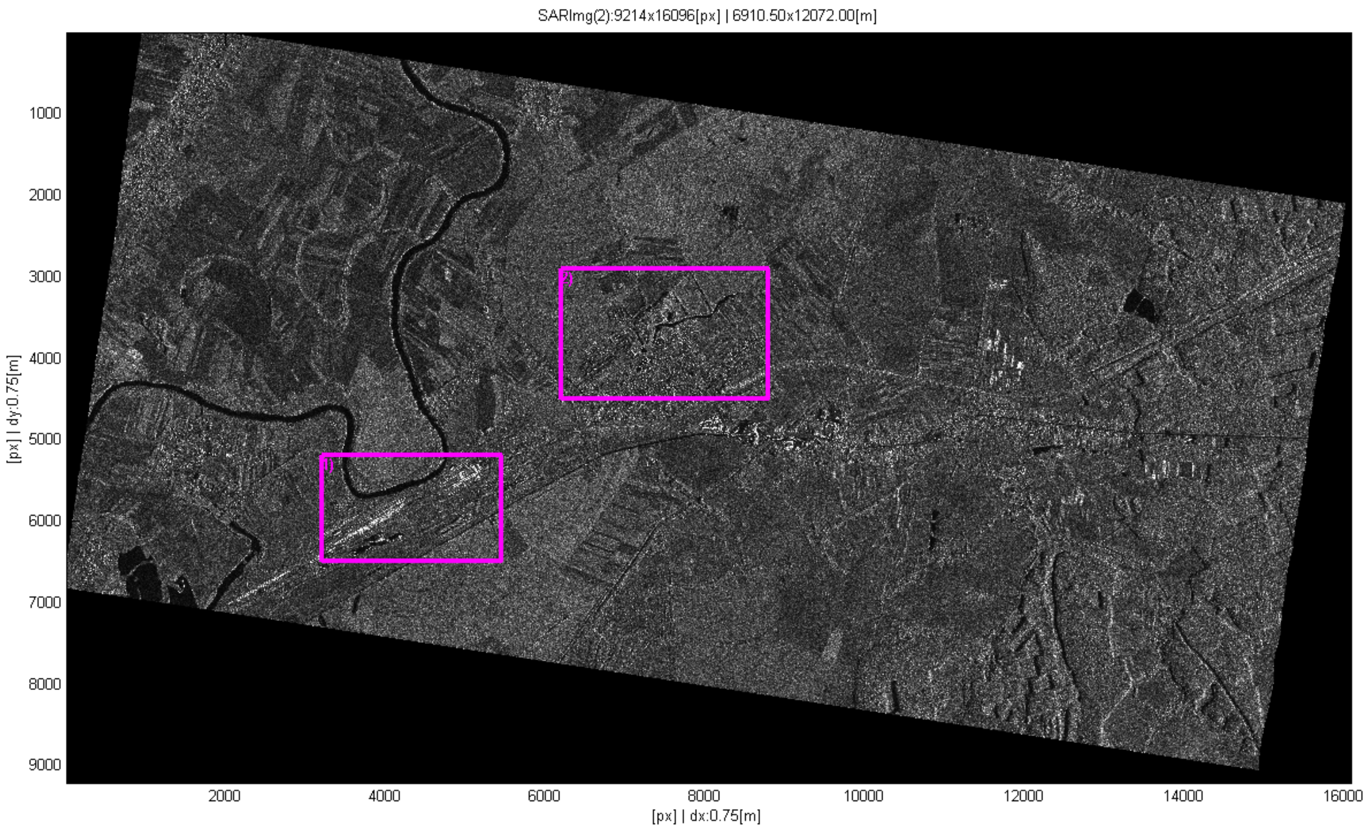
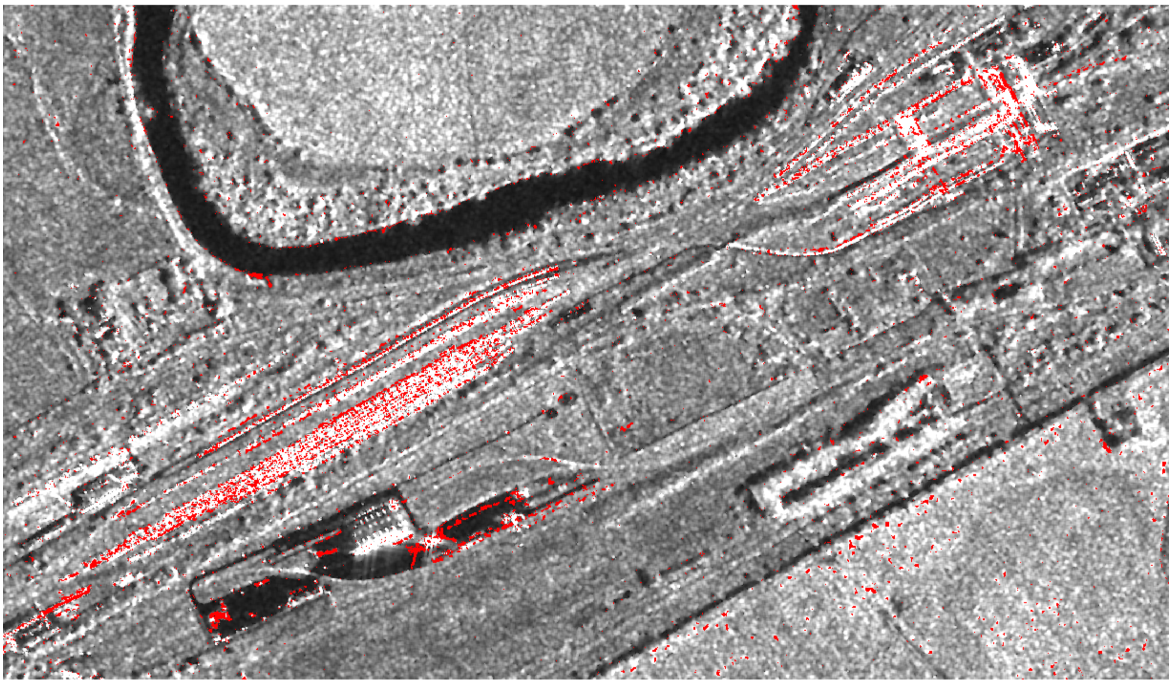
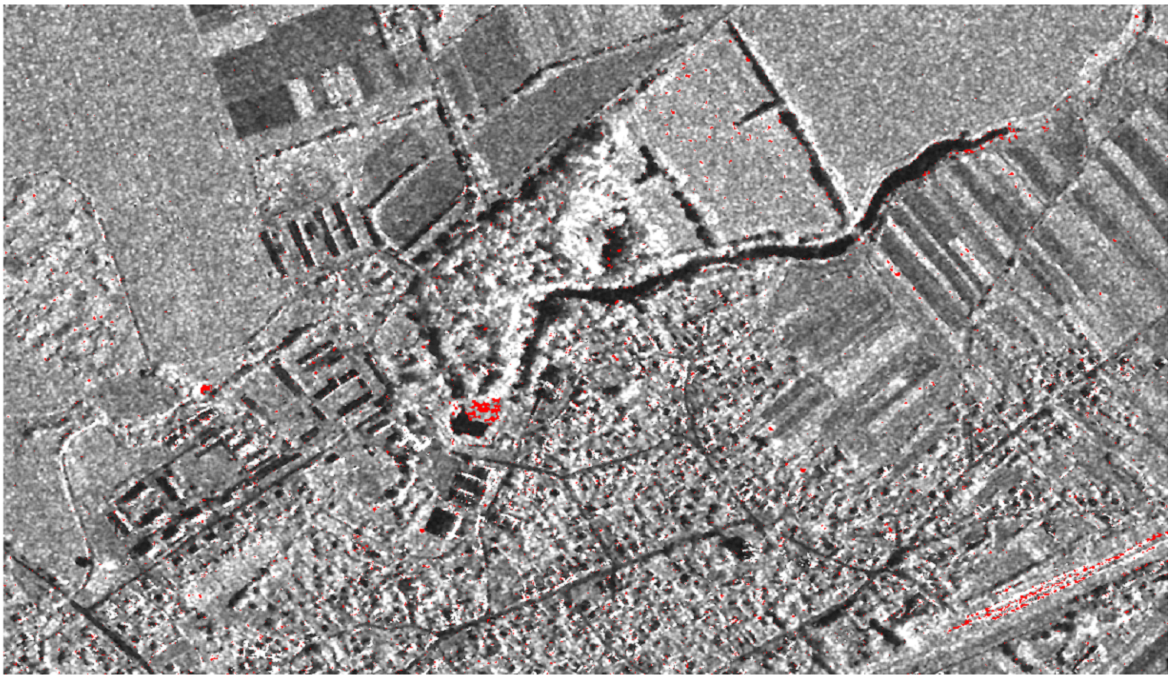


Fig. 2. TerraSAR-X satellite imagery acquired in May and July 2010 accordingly. 1), 2) regions of interest.

(a)



(b)



(c)

(d)

Fig. 3. Detection map: (a), (b) detected changes presented in red color over an original SAR image background; (c), (d) corresponding optical images.

V. Conclusion

Experimental results obtained on single-channel (single-polarization) of two different multitemporal SAR images captured by the TerraSar-X satellite have been presented. The results confirm the effectiveness of the proposed approach. However, it is clear that in order to achieve sufficient reliability, multitemporal SAR data has to be chosen properly. Further improvement could be probably achieved by developing and exploiting additional features (other polarization channels, interferometry). Finally, assessment of our approach has to be further verified.

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