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APPLICATION OF A SPECTRAL ANGULAR MAPPER ON THE MULTISPECTRAL DAEDALUS IMAGES IMPROVED CLASSIFICATION QUALITY OF THE INDICATORS OF THE MINEFIELDS

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Abstract

In a frame of the project »Space and airborne Mined Area Reduction Tools – SMART" (European Commission, IST-2000-25044), was used set of multispectral images acquired by scanner Daedalus (DLR, Oberpfaffenhofen, Germany). These images were classified with different methods at the pixel level (RMA, ULB – Brussels, Belgium) and at the region level (ULB – Brussels, Belgium). The representative set of the training and validation patches containing the ground truth data was provided and used. The relevant classes in the project are related to the likelihood of the landmine presence (*indicators of mine presence* – IMP) and to the likelihood of the landmine absence (the *indicators of mine absence* IMA), and are not ordinary land cover and land use classes. These classes were defined by iterative research that finished by approved list of IMP and IMA, that depend on the context. The detection of several important IMP and IMA was not possible without use of the multi-band polarymetric synthetic aperture radar data (E-SAR, DLR). The goal of the current work was to improve classification quality of IMA if only multispectral (Daedalus) images are available. In the paper we report about improvement of the IMA detection by supervised classification methods (Mahalanobis, Maximum likelyhood, Minimum distance to mean) if the information obtained by the Spectral Angular Mapping (SAM) method and a priori knowledge about dimensions and shapes of ther fields were fuzed. The most important omission errors of IMA were significantly reduced, and the application of SAM method was approved as useful for the considered problem.

Keywords: *spectral angular mapper, classification, Daedalus, SMART, minefield indicators*

2. INTRODUCTION

There were acomplished several R&D projects regarding the airborne remote sensing application for the needs of the humanitarian demining (Acheroy *et al.* 2000), (Bajic *et al.* 2000), (Bishop & Partridge 2001), (Genderen & Maathuis 1999). Among them only (Yvinec *et al.* 2005), (Acheroy *et al.* 2000) achieved sucessful detection of the minefield indicators, although the significant gain to the understanding of the mined scene was provided by (Genderen & Maathuis 1999), (Bajic *et al.* 2000). The greatest difficulty of the humanitarian demining is the fact that the landmines (antipersonnel and antiarmor) were laid before many years (in Croatia even in 1991.) and are covered by thick layers of soil and the vegetation canopy. Therefore the direct detection of the landmines by the airborne survey is not possible, and other approaches were analysed. The only exception is in the very early phase of the landmine deployment, or in the case of the unexploded ordnance laid on the ground surface, as was in Kosovo (Bishop & Partridge 2001). This problem was identified in (Genderen & Maathuis 1999), further developed in (Yvinec *et al.* 2005), (Bajic *et al.* 2000) and the indirect indicators of the minefields were introduced and used for the reduction of the mine suspicious area (Yvinec *et al.* 2005; section 3.1): "From this collaboration and after a field campaign we made a list of the features to look for in the data, based on what could be seen in the data and what could be related to the absence or presence of mines or minefields. Very soon, it appeared that if we wanted to help area reduction, that is, to be able to help stating that

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2. INTRODUCTION

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The indicators of mine absence are generaly rare, in SMART (Yvinec *et al.* 2005) only two categories were approved: cultivated land and asphalt roads, we focus on the cultivated land only. The detection of the cultivated land in the area that is suspected as infected by landmines was achieved by use of synthetic antenna radar (E-SAR) data, multispectral scanner DAEDALUS data, expert knowledge, contextual information, mine information system data, war history, by use of fusion and production of the danger map and the map of the confidence (Yvinec *et al.* 2005). In the paper we consider the case if only the multispectral DAEDALUS images are available and the goal is to increase quality of the cultivated land detection. The detection of the cultivated land in the mine suspected area can be done by any of supervised classification methods (e.g. Mahalanobis, Maximum likelyhood, Minimum distance to mean), whereas the Mahalanobis method provided the best results. The main disadvantage of the (applied) supervised classification methods was high percentage of the commission errors (Congalton & Green 1999.) of the indicators of mine absence, this means that other classes were declared as classes of mine absence (even the classes of mine presence) whereas this was not a truth. This type of errors is not acceptable in the humanitarian demining (must be kept very low), while the omission erros for the indicators of mine absence are not critical and are allowed.

The key contribution of the work presented in the paper is the use of the information that can be derived by the spectral angle mapping (SAM) method applied on the DAEDALUS multispectral images, and a priory knowledge about the shape and the dimensions of the cultivated areas.

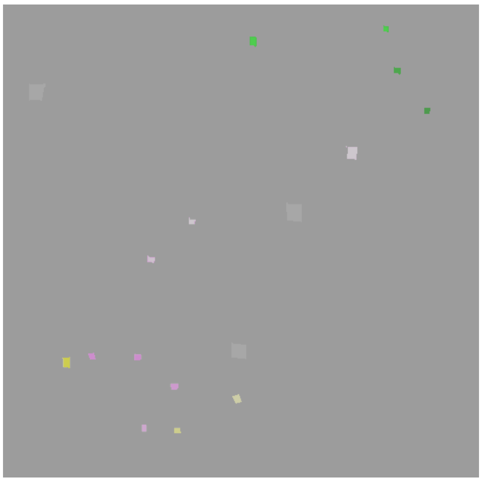
3. SUPERVISED CLASSIFICATION OF A MINE SUSPICIOUS AREA

An area (0.262144 km^2.) was selected, which is suspected as beeing contaminated by the landmines, Fig.1a (multispectral Daedalus, channels 6, 3, 1 shown, 1 m ground resolving distance), Fig.1b (aerial color infrared photography, scanned at 3 cm ground resolving distance). The complete area was officially defined by Mine Action Centre as the mine suspected area, Fig.1.f, in the time when aerial survey was made and the multispectral (DAEDALUS), the synthetic apperture radar (E-SAR) and the aerial color infrared photographies were acquired. The ground truth data were collected in the same time and the additionally refined by use of the color infrared photographies, Fig.1c.

a

b

c



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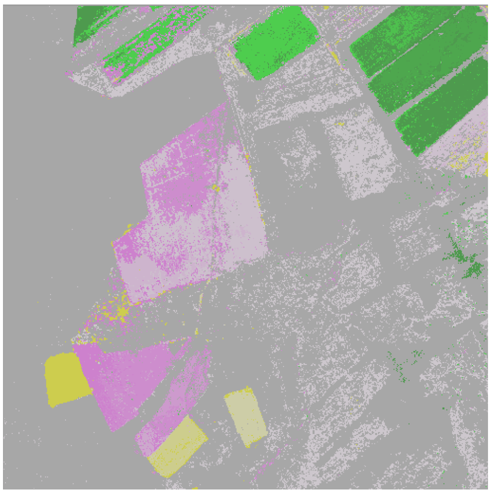
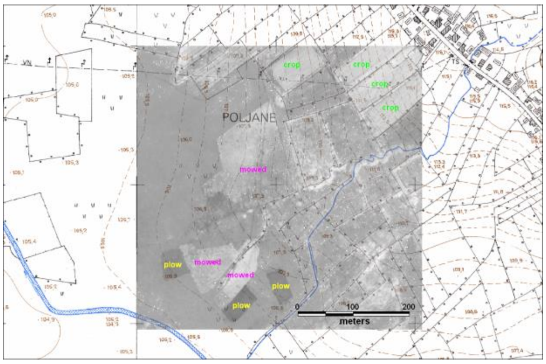


e



f

Figure 1. Supervised classification of the test area. a) Daedalus 6, 3 and 1 channels, ground resolving distance 1m. b) Aerial color infrared photography, ground resolving distance 3 cm, acquired in the same time on the same platform as Daedalus images, additional source of the ground truth. c) Ground truth classes. d) Training classes, IMA. e) The result of a best of applied classifications methods (Mahalanobis). f) Mine suspected test area shown on the map, scale 1:5000.

Note: Legend of the IMA ground truth, training samples and the classification results: green – crop, yellow – plow, pink – mowed, light gray – other, IMP.

In the current paper we consider the indicators of mine absence (IMA) only, while the goal of the analysis was to improve the quality of the IMA classification and to enable suspected area reduction. The IMA in SMART (Yvinec *et al.* 2005) are cultivated fields, infrastructure in use and asphalt roads in use, we will analyse cultivated fields only. There are far more IMP (20) than IMA (3), IMP enable suspicion reinforcement, but for the reduction of the suspected area is mandatory to improve quality of IMA classification. The most critical parameter of the IMA classification are the commission errors and the goal of the paper is to reduce them by fusion of the results obtained by the spectral angle method and the a priori information about the dimensions and the shapes of the fields that are IMA objects. The first step is the supervised classification of the suspected area, aiming to detect the IMA distribution in area. Three supervised classification methods were applied, Mahalanobis, Maximum likelyhood and Minimum distance to mean, using training set shown at Fig.1.d. The best results were obtained by the Mahalanobis method, see thematic map showing classification results, Fig.1.e and Fig.1.f. The full error (confusion) matrix (Congalton & Green 1999; pp.9) is not needed, while only the commission errors are critical. Following this oppinion, the comparison of the Mahalanobis classification and the reference ground truth data is shown in Tab. 1.The commission errors to IMA classes crop, plow and mowed areas are very large in percentage and in area values (e.g. crop 4020 m^2). The results that were obtained by the best of tested supervised classification method are entirely unacceptable for the humanitarian demining purposes. The addidtional pixels of the other classes to the IMA classes means that we declare an area that is IMA although it is IMP. The reduction of the suspicious area is not allowed with such high commission errors.

4. SPECTRAL ANGLE MAPPING METHOD

The spectral angle mapping method - SAM, (Kruse *et al.* 1993), is efficient when applied on the hyperspectral set of images. The hyperspectral images cover certain wavelength range in many neighboring channels and the spectral coverage is almost continuous. In the considered case the multispectral data (Acheroy *et al.* 2000), (Yvinec *et al.* 2005) are given at eleven wavelengths and the spactral coverage is neither continuous nor given in the neighboring narrow channels. Our hypothesis is that SAM can contribute to the improvement of the quality of IMA classification, by decreasing the commission errors. The spectral dependence of the IMA classes crop, mowed and plow supports this assumption. Part of the reflection spectra for crop and plow is shown at Fig. 2. The pattern of the spectral dependence of a crop, Fig.2.a, is typical for vegetation. The pattern of the plow, Fig.2.b. has different distribution of the extrema in comparison to the pattern of the crop.
For each of three IMA classes were selected samples of the spectra and the SAM was made (MicroImages 2004). The result of the SAM classification provides results for each of the

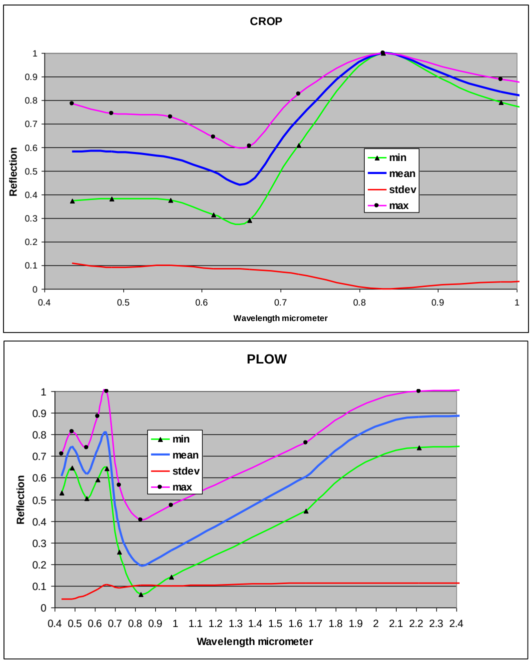


Figure 2. The dependence of the reflection coefficient on the wavelength of the 36 samples, each covers 11 m^2. a) Crop (green on the Fig. 1c). b) Plow (yellow on Fig1c).

Note that data are available only at eleven wavelengths (ten was shown) signed by marks and not continuously as lines show. The lines were drown with aim to help understanding of the reflection flow with wavelengths.

considered IMA class (corn, plow, mowed). The information obtained by SAM and the a priori information about the dimensions and the shapes of the considered fields of were fused and the Mahalanobis classification thematic maps were interactivelly cleaned, Fig.3. The Fig. 4 shows the effect of this procedure for the test area, while Tab. 1., shows measures of the benefits.

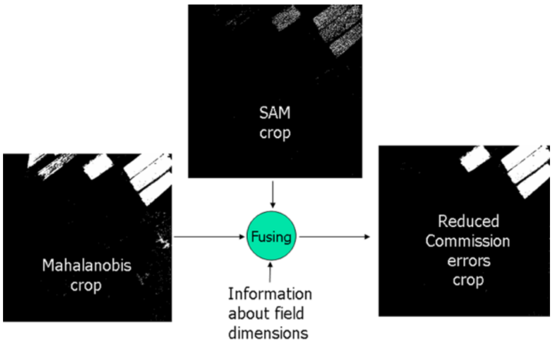


Figure 3. By the fusion of the results of the SAM classification (upper image), the Mahalanobis data are cleaned (left image) of the pixels that do not exist at SAM crop image and have smaler dimensions than fields in the considered mine suspected area (Fig. 1.a, Fig. 1.b.).

Table 1. Improvement of the IMA classification by the information obtained by SAM method

IMA classes	Reference ground truth area		Mahalanobis classification		Classification errors			Mahalanobis improved by SAM
					Comm-ission	Omiss-ion	errors	
name	m^2	%	m^2	%	m^2	m^2	%	m^2
plow	6055	2.310	7403	2.824	1348		**22.263**	6055
mowed	30761	11.734	33159	12.649	2398		**7.796**	30458
crop	18793	7.169	22813	8.702	4020		**21.391**	18879
IMP	206535	78.787	198769	75.824		-7766	-3.760	

a

b

Figure 4. a) Result of the supervised Mahalanobis classification. b) Pixels were interactively discarded if not agreed with SAM results or if the pattern that they form has not a shape that appears in the area (a priori information), Fig.1.f.

5. CONCLUSIONS

In SMART only three kinds of Indicators of Mine Absence (IMA) for the area reduction were identified and approved. IMA are a key for the reduction of the suspicious area. Commission errors of IMA classification are unacceptable for humanitarian demining criteria (in analysed example 7.7 to 22.%). Oppositely, there were >20 kinds of Indicators of Mine Presence (IMP), identified and approved, for the suspicion reinforcement. Fusing result of Spectral Angle Mapper method, knowledge about fields dimensions & shape, lowers IMA Commission errors to nearly zero!

Formalisation of the knowledge regarding the IMA, of the fusion, of the criteria for the selection of treshold angle of SAM should be further investigated.

6. ACKNOWLEDGEMENTS

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Slavica Ćosović Bajić rođena je u Zagrebu gdje je završila sve škole. Na fakultetu elektrotehnike i računarstva magistrirala je 1974, a doktorirala 1986. Od 1974. radi na Tehničkoj vojnoj akademiji, a od 1987. na Višoj Končarevoj školi, koja 1998. ulazi u sklop Tehničkog veleučilišta. Danas je dekanica Tehničkog veleučilišta u Zagrebu i Predsjednica Vijeća veleučilišta i visokih škola. Sretno je udana za Milana Bajića, profesora i pukovnika HV-a. Sin Milan, snaha Monika i unuka Zita svojom pažnjom čine joj život ljepšim i daju dodatnu energiju i motivaciju za posao. Bavi se rekreativno tenisom, skijanjem i planinarenjem.

Milan Bajić, Ph. D, Ret. Lt.C., former Professor of Remote Sensing at the Faculty of Geodesy University of Zagreb, Croatia. He leaded Croatian teams in FP6 R&D projects of European Commission about airborne remote sensing for mine action (SMART, ARC), was manager in Croatian technology project in which was developed and realized the aerial multisensor acquisition system. He was scientific leader in two operational projects of the application of the airborne and space borne remote sensing of the minefields, in Croatia and in Bosnia and Herzegovina, funded by US State Depertment. Since 2012 he participates four years in FP7 R&D project TIRAMISU. In TIRAMISU he researches the methods of hyperspectral survey of the mine fields and methodology of validation of the outcomes of TIRAMISU. He is author of more than 40 scientific papers, a book on Radar antennas. Married, one child. Hobbies: Nordic skiing, mountaineering.