The multisensor and hyper spectral survey of the UXO around the exploded ammunition depot, of the land mines test site vegetation

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Abstract

The general survey of the unexploded ordnance (UXO) scattered around the ammunition depot after its unplanned explosion and the ground based measurements of the hyper spectral samples (end members) of UXO have been done in order to create initial spectral library of UXO. The methods, technique and collected data are presented and evaluated. The Johnson's criterion was used for detection, classification, recognition and identification of UXO in the airborne images (visible and near infrared wavelengths) of the surrounding of the ammunition depot. The test site near Benkovac contains 1000 landmines and 524 metal debris buried in the year 2001 in squares 1x1 m, at depths from 5 to 20 cm below the surface. The locations of 885 landmines and debris are not public and the blind tests are possible. The sparse vegetation covers some squares since the soil is meager. The hyper spectral data have been collected of the 1x1 m squares by the ground based mechanic scanner. The spectral samples of the vegetation inside and outside of the test site have been collected and total Nitrogen contents were measured.

INTRODUCTION

The research and the development of the methods and techniques of the multisensor and the hyper spectral survey of unexploded ordnance at/around the ammunition depot after its unplanned explosion are tasks in TIRAMISU, [1], [2], [3]. The example of the exploded ammunition depot Padjene (Croatia) and UXO scattered around it, was selected for the case study, Fig.1, Fig. 2. One another task is based on similar technique, this is the hyper spectral analysis of the stress of vegetation inside/around of the mine fields. The test site Benkovac, Fig. 3, (1000 landmines, since 2001) and the mine fields (Tromedja, Murgici, Siroke bare) have been selected for the case study of the vegetation stress. In the year 2012 has been done development and initial use of the ground based hyper spectral acquisition system, Fig 6a, Fig. 8b. The airborne multisensor system [4] was used for the multisensor images shooting mainly by team of FGUNIZ.

a b

Figure 1. a) The ammunition storage Padjene after the unplanned explosion 13/09/2011, shown on the oblique aerial photography one month later. b) Several types of UXO collected around the exploded depot Padjene. The spectral features of fifteen UXO types have been measured by the ground based hyper spectral imaging system, Fig.6a.

The airborne detection of the unexploded ordnance (UXO) is presented in the first chapter, the hyper spectral analysis of the UXO in the second chapter and the hyper spectral analysis of vegetation inside and outside of the test site benkovac and the minefields in the third chapters.

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Figure 2. Typical view of the terrain around the exploded ammunition depot Padjene. The vegetation was burned-out, and six UXO targets can be reliably percieved. Ground based photography 24/10/2011 (M. Bajić).

Figure 3. Test site near Benkovac, established 2001., contains 1000 landmines (800 for statistical blind tests). Dimensions 200 x 50 m. Digital ortho photo of the test site Benkovac, derived from airborne images shooting 15/06/2012 in TIRAMISU mission of CTDT and FGUNIZ.

I. Airborne survey of the Unexploded Ordnance

The research and developmnent of the airborne survey of the unexploded ordnance at/around exploded ammunition depot started by collecting the very high resolution images in the visible (VIS), near infra red (VNIR) and the long wave infrared (LW IR) wavelengths, Fig. 4. The LW IR images collected by old Agema THV-1000 hve very poor quality and are discarded. The colour images show potential for the survey of UXO, Fig. 5.

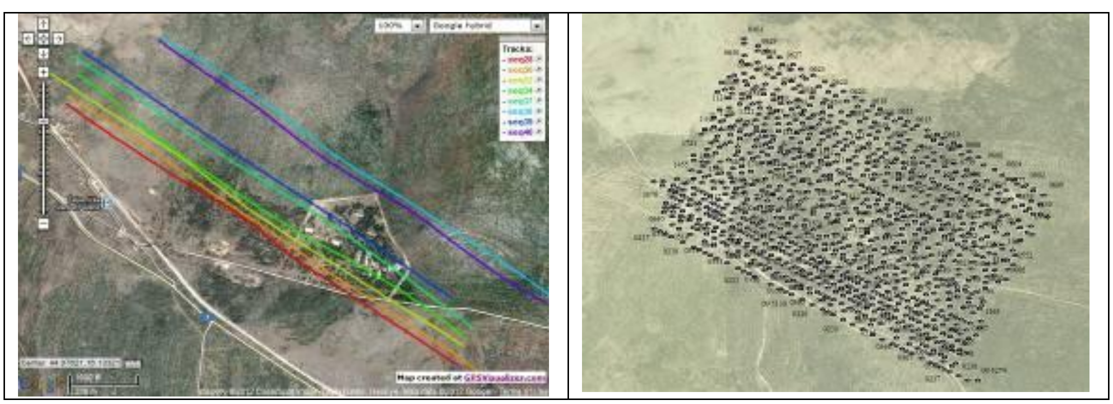

Figure 4. a) Flight routes over the ammunition depot and its vicinity (example). b) Geo tagged positions of the very high resolution airborne images collected by Nikon D90 color camera and MS-4100 multispectral camera. 11-15/06/2012, a TIRAMISU mission CTDT and FGUNIZ.

The survey of the UXO at/around the exploded ammunition depot can be described by the probabilities of following functions: *detection, classification, recognition and identifica*tion, related to the spatial resolution and the search time, in advanced [5] and historic Johnson's model [6]. The main goal of the our resesrch and development is to provide the trade-off between needed very high spatial resolution (linked to the critical dimensions of the smallest UXO) and desired coverage of a wide strip. The end user requested the detection of the UXO that has minimum diameter 40 mm and larger. The examples of UXO photography at Fig. 1b and examples of UXO at the aerial image at Fig. 5 determine the range of the requierd spatial resolution.

Figure 5. Example of the UXOs and calibration cross on the aerial color image acquired 13/06/2012 in TIRAMISU mission of CTDT and FGUNIZ.

The historic Johson's model [5] uses only the narowest dimension of the target, while the advanced model [4] is based on the geometric mean L_c of two ortogonal minimum dimensions, L_x and L_y,

$$Lc = (LxLy)^{1/2}. \quad (1)$$

If the time of the search is not limited (here we could think on the search of the interpreter on the image), the probability $P\infty$ is determined [4, p. 427, 432] by

$$P_\infty = (N/N_{50})^E/[1+(N/N_{50})^E] \quad (2)$$

where

$$E = 2.7+0.7(N/N_{50}), \quad (3)$$

N is the number of resolvable cycles (one cycle equals two resolution elements) across the target dimension, N50 is the number of cycles across the target for 50% probability of survey functions, given in Tab.1.

Table 1. N50 for detection, classification, recognition, identification

Function of the survey	N_{50}
50% detection probability	1.5 resolution elements (0.75 cycles) per critical dimension
50% classification probability	3.0 resolution elements (1.5 cycles) per critical dimension
50% recognition probability	6.0 resolution elements (3.0 cycles) per critical dimension
50% identification probability	12.0 resolution elements (6.0 cycles) per critical dimension

The advanced Johnson's model is applied in our research and development of the airborne survey of UXO as the means aimed to determine needed spatial resolution for the considered functions of the detection, classification, recognition and identification. The maximum distance (range) of the survey is not included in the development of the survey.

The concept of the airborne multisensor survey of UXO at/around exploded ammunition storage includes other approaches too: the use of multispectral images, which should enable discrimination of the vegetation, object oriented processing and interpretation, variety of enhancements, principal component analysis (PCA), independent component analysis (ICA), which should increase probability of the considered survey functions and the confidence of the mentioned tasks.

II. Hyper Spectral Analysis of the Unexploded Ordnance

The hyper spectral analysis of the unexploded ordnance (UXO) includes hyper spectral shooting from the mount by the hyper spectral scanner V9 (ImSpector, Specim), Fig. 6. The collected hyper spectral data have been processed, dark current was compensated, and the hyper spectral cubes have been derived. While the collected data are radiance, the atmospheric correction QUAC (QUick Atmospheric Correction, ENVI) converted it into reflectance. Fifteen kinds of UXO have been used and the hyper spectral cubes are produced.

a b c

Figure 6. a) Computer controlled mount carries the hyper spectral line scanner for ground based imaging the unexploded ordnance (UXO). Height of the sensor is 1.1 m above the ground level. On the left hand side is the reflectance etalon (LabSphere, Spectralon MS180-1967). b) Aerial bomb RBK, photography. c) Hyper spectral image of bomb RBK, visualized channels: 650 nm – red, 550 nm – green, 450 nm – blue. The full width of half maximum (FWHM) of channels is 4.5 nm. The photography and the hyper spectral image do not show the same bomb.

The UXO samples appear in the different conditions (intact, damaged, burned, covered by rust, original paint), orientation, but the types of soil have been similar. The set of fifteen hyper spectral cubes is the source for assessment of the spectral samples (end-members) needed for advanced hyper spectral interpretation. The example at Fig. 7, shows reflectance of the aerial bomb RBK, shown at Fig. 6b, Fig. 6c, of the soil and the small samples of green vegetation. Note that on the RBK in spectral domain dominate several different areas, in the example Fig. 7 they are named RBK grey and RBK light. Further research includes thorough analysis of the spectral characteristics of the considered fifteen UXOs.

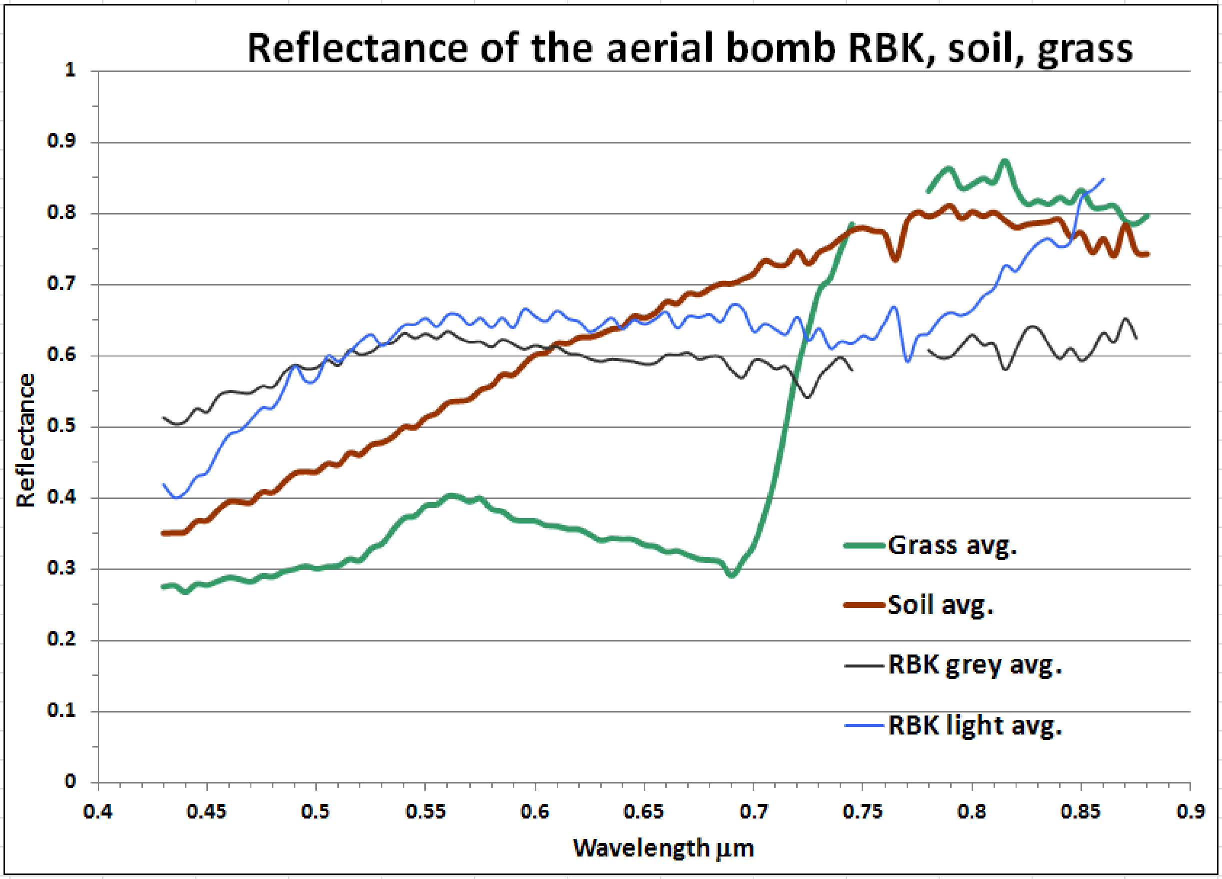

Figure 7. The average (avg.) reflectance of aerial bomb RBK grey, RBK light, soil and grass.

III. Hyper Spectral Analysis of the Vegetation Inside/around the Test Site Benkovac and the Minefields

The hyper spectral analysis of the vegetation has been done inside/around the test site Benkovac, Fig. 3, and in the minefields Tromedja, Murgici, Siroke bare, Fig. 9. The Benkovac test site has 800 land mines located at unknown positions in 1628 marked squares, each has dimension 1 x 1 m, they serve for statsistical blind tests. Additional 200 land mines are located at known positions and depths, they serve for training of the sensors. The goal of the research are spectral and bio – chemical features of the grass, therefore areas covered with bushes, small trees are excluded from the analysis. Due to this fact 1121 squares of 1x1 m are considered. The consequence is that real number of the land mines available for the analysis is smaller then 800. All 1121 areas 1x1 m have beed shooted by the ground based hyper spectral imaging system Fig. 8b, while 406 hyper spectral cubes have been derived. Each hyper spectral cube has 584 x 500 pixels, 16 bits, 95 channels, from 430 nm to 900 nm. Inside of test site Bekovac are collected 171 random grass samples, and around the test site are collected 143 grass samples, Fig.8a, for analysis of Nitrogen content. Around the test site have been measured hyper spectral features of grass at locations shown at Fig. 8a.

The hyper spectral measurement of grass radiance in the minefields Tromedja, Murgici, Siroke bare has been done by ground based system shown at Fig. 6a, while the whole process was more complex then in Benkovac test site. The first step was demining, deminer has to detect a landmine, remove and disarm it, take the gras which was atop of the mine and bring it to the measuring team, which was in safe area far from the mine field. At the safe location the samples of the grass from the mine field and a grass around the mine filed have been measured.

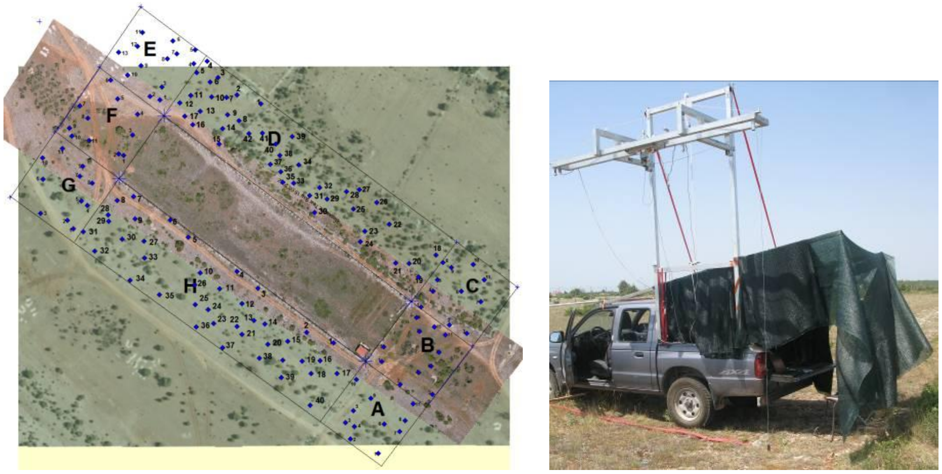

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Figure 8. Hyper spectral and bio-chemical sampling the vegetation at test site Benkovac. a) Locations of the random samples of vegetation around the test site Benkovac (July 2012). b) Height of the sensor above the ground level is 3.1 m, enables to cover two squares 1x1 m and the reflectance etalon (LabSphere, Spectralon MS180-1967). The air temperatures in July have been from 30 ^{o}C to 40 ^{o}C, this coused non smooth carriage movement.

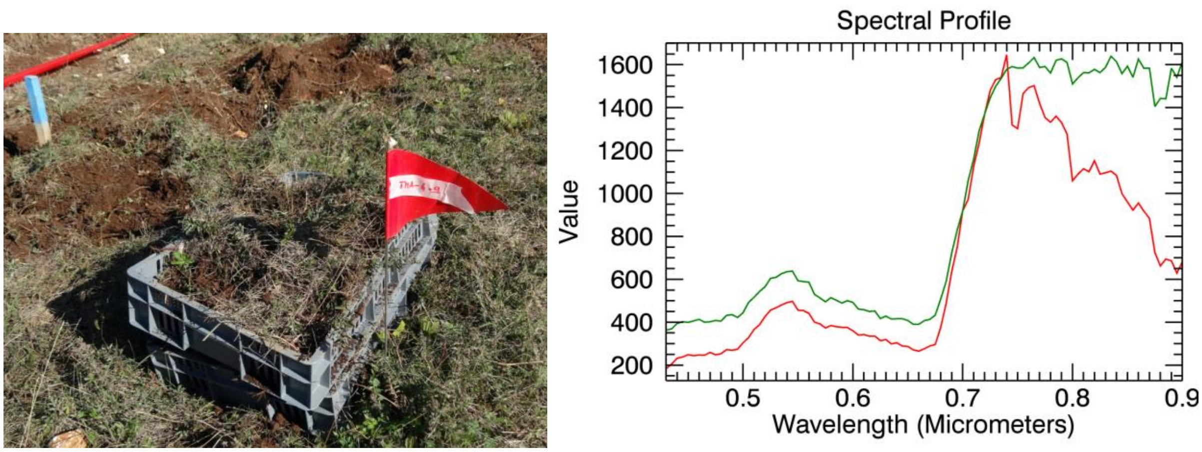

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Figure 9. a) Deminer detected, removed the land mine and collected sample of grass which was atop of the mine (TIRAMISU CTDT mission, September 2012). Hyper spectral data have been acquired by system shown at Fig. 6a, in a safe area far from the mine field. b) The typical reflectance (green) of the grass collected in the minefield, atop of the land mine, obtained after the atmospheric correction by QUAC (QUick Atmospheric Correction, software ENVI) of the measured radiance (red).

The hyper spectral measurements in 2012 of the grass of the test site Benkovac and around it, has been done in month July, when grass is dry, in its last vegetative phase. Therefore in 2013 we will do new hyper spectral measuring in the several phases of grass development, from 15/04/2013 to 15/06/2013. The ground based hyper spectral imaging is slow process and work intensive. Therefore CTDT and FGUNIZ develop a lightweight hyper spectral imaging system, controlled by WiFi, at distances larger than 1000 m, which can perform airborne mission by use of the blimp. The development has beed done, tests approved usability of the blimp based hyper spectral imaging with high spatial resolution, at low altitude (20 to 100 m), at low speed (1 m/s to 10 m/s), without interpolation of the hypere spectral image in the flight direction.

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