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ANALYSIS OF THE POSSIBILITY OF UTALIZATION OF HONEY BEES IN EXPLOSIVE DETECTION

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Tehničko veleučilište u Zagrebu

Sažetak

Činjenica da pčele mogu otkriti eksploziv nadaleko je poznata još od kraja 90-tih, osobito od kada je Američka agencija za istraživačke projekte (DARPA) 1999. prikupila prijedloge na temu kontroliranih bioloških i biomimetričkih sustava. Pčelinji med je u Republici Hrvatskoj još od 1994., 1997., 1999., 2002., poznat i odobren kao osjetljiv pokazatelj nuklearnog zagađenja (nakon Černobila). Primjena pčela za otkrivanje eksploziva i nagaznih mina korištena je u nekoliko znanstveno-istraživačkih i razvojnih projekata. Postoje dva glavna aspekta primjene pčela: bioloških i tehničkih. Biološki aspekti su, između ostalih, obuka pčela, procjena njihove osjetljivosti na različite eksplozive i metode njihove primjene te ih u ovom članku nećemo razmatrati. U ovom članku ćemo razmatrati tehničke aspekte primjene pčela za otkrivanje eksplozivnih naprava i nagaznih mina, posebne metode, tehniku i tehnologiju prikupljanja podataka i informacija od pčela koje njuše eksploziv.Za otkrivanje pčela iznad eksplozivnih uzoraka korišteno je nekoliko metoda i tehnika: lociranje pčela pomoću lidara, lociranje pčela koje nose mikrovalni dipol i otkrivaju harmoničnost radarskih valova, otkrivanje pčela pomoću spektralnih značajki. Ova tehnika je vrlo komplicirana te je u Hrvatskoj istražen i odobren alternativni pristup za procjenu šire distribucije pčela: detekcija pčela iz zraka pomoću elektro optičkih senzora, korištenjem termalne kamere i digitalne obrade fotografije. Treći smjer istraživanja i razvoja namijenjen je ručnom senzoru za detekciju eksploziva i jedan takav sustav je dostupan (VASOR136).

Ključne riječi: *pčele, detekcija eksploziva, nagazne mine, obuka pčela, otkrivanje eksploziva i mina*

Abstract

The fact that honey bees can detect explosive is widely known since late ’90, particularly when US Defense Advanced Research Projects Agency (DARPA) solicited in 1999 proposals on Controlled Biological and Biomimetic Systems. The honey of honey bees was known and approved in Croatia in 1994, 1997, 1999, 2002, as the sensitive indicator of the nuclear pollution (after Chernobyl). The application of the honey bees for the detection of the explosive and the land mines was treated in several scientific research and development projects. There are two main aspects of the application of the honey bees: biological and technical. The biological aspects are among others, the conditioning, training of honey bees, and assessment of their sensitivity for the various explosives and methods of their application and will not be considered. In this paper we consider technical aspects regarding the application of the honey bees for explosive and landmine detection, particularly methods, techniques and technologies of gathering data and information from honey bees smelling the explosive. For the detection of the honey bees over explosive samples were used several methods and techniques: locating the honey bees by lidar, locating the honey bee caring the microwave dipole and detecting the third harmonic of the radar waves, detecting honey bees by spectral features. This technique is very complicated and alternative approach was researched and approved in Croatia for assessment of the bees’ distribution over wide area: detecting the honey bees from air by electro optical sensors, using long wave thermal camera and digital image processing. Third direction of research and development is aimed for the handheld sensor for detection of the explosive and one system is available (VASOR136).

Key words: *honey bees, detect explosive, land mines, training of honey bees, explosive and landmine detection*

1. INTRODUCTION

The honey bees are like the dogs the best friends to the humankind. It is not embarrassing that their role is not limited only to the honey production and the pollination. A very interesting analysis of the military application of the honey bees [20] provides a novel view on bees and has strong anchorage in programs of the US Defense Advanced Research Projects Agency (DARPA) [23,27] since 2000 (SRI 2000). The (hy)story of the honey bees and the detection of the explosive, unexploded ordnance (UXO) and the landmines has several phases and milestones. The basic research of the transport of chemical signatures from buried landmines, UXO, models and prediction started in late '90 by support of DARPA [15, 16, 17, 23, 27] and is crucial for understanding the application of the honey bees for the considered purpose. The application of the honey bees for the estimating the impact on the environment by chemicals and other agents of harm are presented in [11,22,19,12]. The very important application of the honey bees is assessment of the impact of the nuclear contamination after the nuclear plant's accident. It was example of Chernobil [5], of course the application for Japanese nuclear plant Fukushima is possible too.

2. SIDEWARD DETECTION OF THE HONEY BEES

The training and conditioning the honey bees to find trace level of explosives was successful and romising. [6,22] Due to former references about nuclear contamination assessment by honey [5] and new achievement regarding explosive detection by honey bees [6], the Scientific Committee of Croatian Mine Action Centre (CROMAC) supported Prof. N. Kezic proposal to start own research about land mine detection with the honey bees. Despite several attempts to get grant for this research [2,3], it was finally recognized in 2011 and supported in FP7 project (TIRAMISU 2011). In 2003 DARPA organized a dedicated brainstorming meeting (Rudolph 2003) and invited and supported N. Kezic and M. Bajic to participate [9,10,3]. At this brainstorming M. Bajic and N. Kezic for the first time presented new concept of the assessment the space-time distribution of honey bees over the area of interest by aerial nadir imaging by electro optical sensors and digital processing, Fig. 1. In Bromenshenk's team approach bees were detected by video cameras, visually and by Lidar [5,6] while the search and/or scanning was done sideward in the horizontal plane. The sideward detection of the honey bees by Lidar in the horizontal plane has significant disadvantage and forces to increase the technical complexity [18,19]. The crucial limitation is that the considered terrain has to be flat and the honey bees cannot be detected on the ground surface. The lower height of the detection in vegetation free space is 60 cm above the ground.

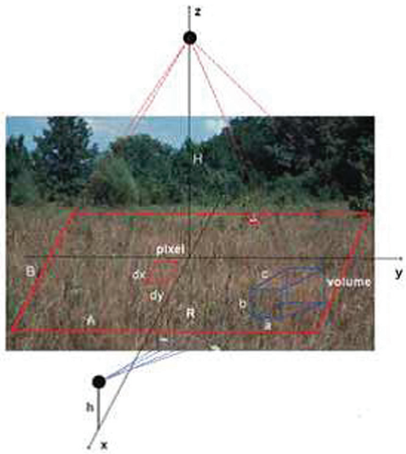

Figure 1. The aerial nadir imaging by electro optical sensors and digital processing enables imaging of bees on and above the surface, [3]. The sideward detection of the honey bees by Lidar requires flat terrain; bees cannot be detected on the surface.

3. AERIAL ELECTRO OPTICAL NADIR IMAGING OF THE HONEY BEES

The aerial nadir imaging of the honey bees on and above the terrain, announced at DARPA brainstorming [3], is competitive to sideward detection of the honey bees in rather all aspects. The detection of the honey bees on and above the ground surface is possible by digital cameras in the visible and near infrared wavelengths, although the greatest potential has long wave infrared remote sensing, while the honey bees have generally large thermal contrast in comparison to the terrain, Fig.2.

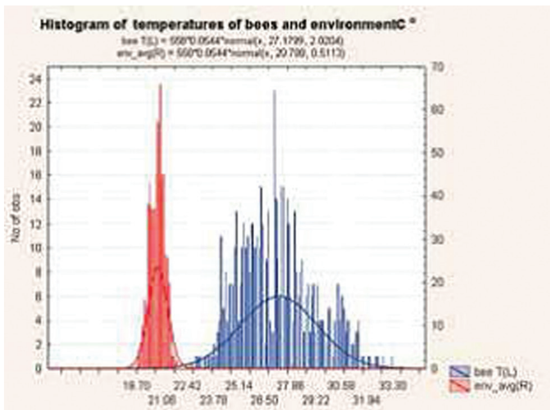

Figure 2. Histograms of the temperatures of honey bees (blue) and the environment (red) [10].

Probability of the detection, recognition and identification of the honey bees is defined by Johnson's criteria (Johnson 1958) and can serve as guidance for the selection of the operational parameters of the electro optical sensor. But the more serious problem is the clutter produced by the vegetation on the ground surface and the brute -force detection is rarely satisfactory. The solution was derived by use of the principal components analysis [8] and was developed to the applicable level [9]. Method starts with aerial image acquisition in visible, or in near infrared, or in long wave (thermal) in frared wavelengths, Fig. 1, whereas thermal infrared provides better detection in clutter, Fig. 2. The processing of images, the Principal Component Analysis, enables detection of movement of bees even if the spatial resolution and signal to clutter ratio are low and direct detection of bees is not possible, Fig. 3. Output of the method is map that defines the spatial temporal distribution of honeybees over the target area, Fig. 4. Although the suitable method was developed in 2006. the main obstacle for its deployment was the lack of availability of the suitable aerial platform. In this domain happened changes in several last years and now are available several options for aerial platforms that are suitable for application over the area where honey bees travel and search the targets. The unmanned radio controlled helicopter, hexacopters and blimp are cheap and their application is no longer obstacle for the deployment of the considered technology, Fig. 5.

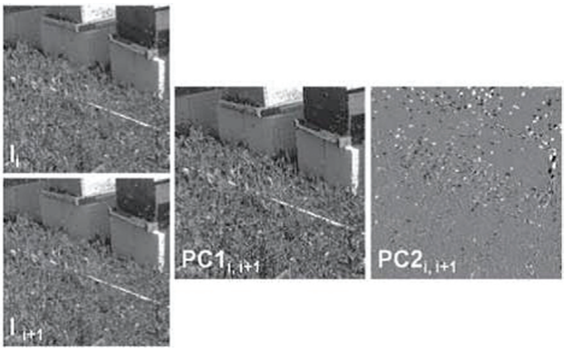

Figure 3. Processing the Images Ii and I i+1 into the principal components PC1i, i+1 & PC2i, i+1 [9]

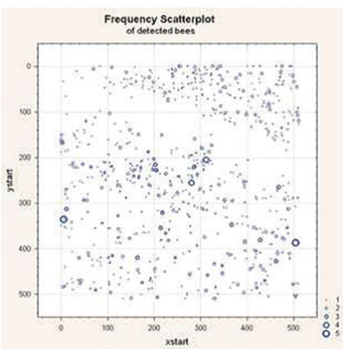

Figure 4. The temporal - spatial density of the honeybees, assessed by all (N-1) processed PC2. [9]

4. HANDHELD SENSOR WITH HONEY BEES

The honey bees can be used as the sensors in the handheld detector for the security checks. The first example is VASOR 136 [13], Fig. 6. The information about this new system is not available, but it should be considered as a tool for quality control after the clearing operations on the mine field.

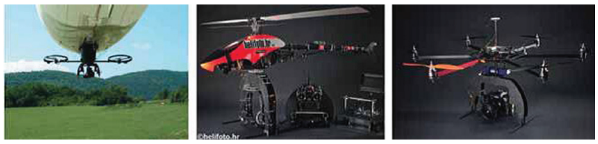

Figure 5. The unmanned aerial vehicles (UAV) with electric engines, available in Croatia for the considered purpose. All are radio controlled and provide route on the digital moving map. a) Blimp, payload 1 kg, endurance 1 h. b) UAV helicopter, endurance 10 min. c) Hexacopter, endurance 20 min.

Figure 6. a) The VASOR136 contains b) 36 cartridges each containing one bee. [26]: "Filtered in by a standard gas mask cartridge is a constant supply of clean air. When an operator presses a button on the VASOR, an air sample is taken from the environment that exposes the bees to ambient, unfiltered air. If the bees have been trained to respond to a vapor in that air, the bees will exhibit a proboscis extension reflex response and the response will be translated by the VASOR into a simple result shown on the screen display".

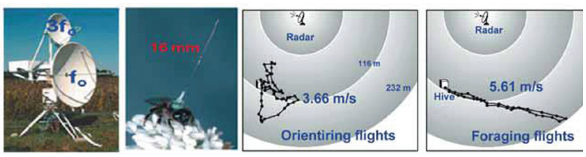

Figure 7. a) The flights of the honey bees were investigated by the harmonic radar. b) The honey bee carries the small antenna. c) Route in the orientiring flight. d) Route in the foraging flight. [7]

5. THE BASIC TECHNICAL CHARACTERISTICS AND THE PARAMETERS OF THE HONEY BEES

The basic characteristics of the honey bees that are important from technical point of view are following:

- one hive has from 20,000 to 40,000 bees, 50% of them are foraging,
- the radius of the foraging is from 1 to 3 km,
- the speed of the bees is 3.66 m/s in the orientiring flights, and 5,61 m/s in the foraging flights, Fig. 7,
- bee detect drop of scent at area 100 m2 in 15 minutes.
- density of bees above the target terrain is controlable by changing number and positions of hives.

The research of the honey bees is continuing, there are several very interesting examples. In “Balch et al. 2001” was applied automatic tracking and the dancing of bees was analysed [4]. A study [1] shows that it is possible for honeybees to both learn to discriminate between similar human faces and to subsequently recognize a target face when it is presented in conjunction with novel distracters faces. DARPA again focuses resources towards insects in a new program Hybrid Insect Micro Electromechanical Systems (MEMS) [15]. Program is aimed at developing tightly coupled machine-insect interfaces by attaching electronic payloads to the muscle or neural systems during the early stages of metamorphosis. The purpose of the MEMS payload will be to guide the insect’s locomotion, determine its position, and extract power to operate the electronic systems.

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