Bees for Explosive Detection

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Abstract

NATO Science for Peace and Security Programme accepted to support Bees for Explosive detection at the end of 2017 year. Conditioning of a colony has been challenge and its use in a test mine field conditions was one of the research goals in TIRAMISU FP7 project. An aim of the programme is to develop innovative methods and technologies for the detection of legacy landmines. This will be achieved by the advancement and integration of current state-of-the-art techniques, namely, bee colonies in conjunction with organic semiconductor-based explosive vapour sensing films, and UAVs with high-definition and thermal imaging cameras and image processing and analysis software. The use of these methods together will allow both the passive sampling of an area to confirm the presence of explosive materials, and the active pinpointing of landmine locations. The major objective of Bees for Explosive is to work with end-users and experts to ensure a high-impact delivery of the project's results.

The problem of legacy landmines in post-conflict areas still carries a huge cost in terms of injury to civilians, unfarmed land, loss of trade and communication, and there is potential security threat of the availability of explosive materials being scavenged by terrorist organisations for homemade explosive devices.

Humanitarian demining is expensive, time consuming and presents high risks and threats. Besides well-developed techniques and procedures such as metal detectors and prodders, use of biological methods is recommended. Existing bio-systems, including bee colonies, can be trained and used efficiently as standalone detection tools. Bees orientate well in space and in their search for food, depend on a well-developed sense of smell [1]. As ideal pollinators, bees collect a particular food, and remain attracted to its odour as long as the pasture exists, even if a new source of food occurs in the vicinity. Knowing their behaviour and biology, it is possible to manage bees. We can direct bees to search the scent that we associate with the source of food, or to have flights in specific area directed by artificial sources of food. Duration of training is very short, i.e. after two to three days bees can link odour with the food source. Persistency to the trained-on odour is not long lasting - only one to three days - but it is possible to prolong interest using short morning re-conditioning. The experience in the training of bees for plant pollination is the basis for training bees to detect the odour of explosives. Since the odours of DNT and TNT are very discreet, training of bees is complex activity. Likewise, it is possible to train bees to recognise the other scents, but the most complex training is on raw military TNT.

Honeybees are widespread in almost all inhabited areas and they present inexpensive tool available at any location. Procedures and methods for honeybee training had been developed (in TIRAMISU FP7-project), and consequently bees can be used as the tool for control of target area on a target scent.

In this project, we propose two complementary methods for the detection of explosive devices. Both methods use honeybees trained to smell explosive. The first one (passive method) is based on development of new sensors that should enable detection of explosive particles collected by honeybees, and in that way determine if an area covered by the flight of a bee colony is suspected to contain explosives. The second one (active method) is designated for localisation of explosive devices in a suspected area. For this purpose, new methods for monitoring honeybees over the landmines will be proposed, and automatic (computer) analysis of high definition georeferenced video obtained by UAVs will be employed for honeybees detection and tracking. A space-time density map of trained honeybees should point to the location where an explosive device may be located.

Honeybees - passive method

The main task of the passive method is to detect the presence, or lack of explosives in a wide area of interest. Honeybees have been used to monitor heavy metals, volatile chemicals, and radioactive materials [2]. As honeybees collect water and forage for nectar and pollen, the electrostatic charge on their body hair attracts dust, pollen, soil, and other particles, including chemicals from their flight area. Thousands of honeybees from a single colony accumulate these particles in flight and bring back to the closed environment of the hive. Honeybees can be directed to fly in specific areas by placing artificial food sources in different positions. On their return, they bring back to their hives particles of chemicals as well as biological agents and other materials collected during flight. The particles of TNT collected in the beehive can be measured and analysed using equipment for the specific detection of nitro-aromatic vapours.

The high sensitivity of organic semiconductor films to nitro-aromatics has led to these materials being considered in recent years as a useful technology for explosive vapour detection [3,4]. The sensors work by a change in light emission (fluorescence or laser light) when minute quantities of TNT-like molecules come into contact with the polymer film. The sensors are promising for detection of collected particles of explosives in bee hives, but more work is required to integrate sampling and detection. Experience has shown that periodic sampling within the hive could allow a much more reliable method for vapour sensing, since several steps are eliminated from the previous procedure.

By combining the passive method of honeybee explosive vapour collection, and improved discrimination of the vapours, it is anticipated that a practical and reliable methodology for explosives detection can be achieved.

Honeybees - active method

The main task of the active method is to directly locate explosives in the field of interest. Honeybee colonies will be trained in a closed mesh tent for 4 – 5 days with sugar syrup in an environment of TNT odour. Flying bees in the tent will associate food with the smell of TNT. The conditioned honeybee colony will then be transferred onto the test minefield. Trained bees should search for the targeted odour and then hover over the area of odour presence, i.e. over the location of a buried landmine in a free-flight over an area. However, the main limiting factor in the use of bees for explosives' detection is the inability to track their movements in a free flight. In general beekeeping, many efforts have been investigated in bee monitoring in a hive and at a hive entrance. But monitoring of bees in nature is still an issue. Tracking systems that use video imaging, lidar, radar taggants and pigments have been extensively studied in order to find and track honeybees in a minefield, but an automatic system which allows the establishment of foraging patterns and bee densities is still missing. All the above mentioned technologies have some advantages and disadvantages regarding automatic bee detection, tracking and behaviour analysis. Video acquisition process, which is needed to be made in order to track movement of trained honeybees across a potential minefield, consists of many task- and equipment-related steps. In order to cover as much ground as possible in the short time, it is necessary to use more than one video camera and an algorithm for movement of unmanned aerial vehicles which carry cameras. The size of each individual honeybee is very small in comparison with the environment which may contain explosives and it is necessary to assure detection of honeybees so that suspicious areas can be isolated. Video acquisition will be achieved using 3 UAVs which fly in formation and provide slightly overlapping videos. This research has the goal of developing an automatic system to establish foraging patterns and space-time bee density map based on data captured in the minefield. We plan to leverage recent advances in the area of computer vision and machine learning in order to design a system for visual detection of bees which is robust to challenging imaging conditions and other sources of degradations. The approach will be based on modern methods for moving object detection and tracking, which are robust to variations in imaging conditions, such as lighting and camera movements. Although a considerable amount of work on these types of algorithms has been done, the algorithms for moving object detection have been focused mainly on larger objects. Therefore, an important challenge that will be addressed in this project is detection and tracking of small moving objects. In order to reduce the number of false positives in detection of honeybees, besides moving object detection, we also intend to use object classification, as bees or other objects, based on their appearance and features. The main ingredients of this approach are representation of images using visual features and their classification via machine learning approaches. In this project we will analyse the possibilities to apply deep neural networks (DNN) to the task of detection of honeybees. We will evaluate using both pre-trained networks and end-to-end training for the specific problem of this project. Furthermore, since it is of interest to move parts of the detection algorithm to an embedded system near the camera, we will investigate the possibilities of implementation of DNN on small embedded systems such as Raspberry Pi. Besides conventional imaging in the visible spectrum, we plan to investigate how using of thermal imaging can help in segmentation of honeybees, as objects of thermal footprints different from backgrounds.

Both honeybee passive and active methods can be used as standalone methods, however better results are expected if used simultaneously or sequentially. For instance, the passive method can be used to initially survey a particular area, followed by the active method then used to pinpoint landmine locations with accuracy. That way, using the active method, costly human and technical resources can be reduced and safety of deminers that are directly involved in the process can be increased. These methods can also be applied for suspected hazardous area reduction and/or to confirm the completion of the demining process in internal and external quality control.

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