HONEY BEE (APIS MELLIFERA) COLONY MONITORING METHODS WITH A POTENTIAL APPLICATION OF THE MACHINE INTELLIGENCE METHODS

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Abstract: This article brings an overview of the bee monitoring methods and is divided into two parts. The first part, which covers the general monitoring methods, describes the methods based on the sensor fusion data and acoustic measurements and the second part focuses on computer vision methods based applications for the Varroa Destructor mite detection. The conclusion drafts possible extension of those methods with the use of the deep learning methods and also the future direction of the author's research.

Keywords: Honey bee monitoring, Varroa Destructor, Machine intelligence

1 INTRODUCTION

The honey bee is not only a producer of honey, but also the most important pollinator worldwide, which covers more than 90% of the pollination service in the commercial production. [1] From this fact follows, that the good health state of the bee colonies has a great environmental and economic impact. The colonies health state can be damaged by various bee illnesses, or swarming – the bee keeper has to perform periodical checks to monitor this state, which could be very time consuming in the case of a great number of hives. From those reasons, several automated monitoring methods were developed and their selection is summarized in this article.

This article is divided into two sections, which describes the general monitoring methods and the methods for the Varroa Destructor mite detection with the use of the machine vision. The Varroa mite is one of the greatest threads for the bee colony and the problematics will be described further in the article. The intention of this article was to create an overview of the methods with the possible application of the deep learning and the anomaly detection techniques, which could be used for the author's future research.

2 GENERAL MONITORING METHODS

This section of the article focuses on the overview of the monitoring methods, which are not based on the computer vision techniques, but which can be extended using the machine intelligence methods. The first part brings an example of the sensor fusion methods and the second brings an example of the acoustic measurements. Those methods are not suitable for the single bee monitoring, but they can give a good overview about the bee colony health and honey supplies.

2.1 SENSOR FUSION MEASUREMENTS

There is a big variety of the bee monitoring methods, which use the general data as the temperature and humidity in the bee hive, bee dance recognition, fusion of the weather data, information about the crop resources in the hive surroundings, or even the single bee monitoring.

An example of the approach, which uses a variety of the sensors placed inside the bee hive, is the article [2]. This article describes a complex system based on the data collection from a group of hives and from the meteorological weather stations.

The parameters, which were considered as the indicators of the bee colony health, number of bees and the external weather and which were monitored with the in-hive sensors are the temperature, humidity, carbon dioxide level and oxygen level. Those sensors were later extended with the accelerometer and two pollutant sensors. All those sensors were integrated in the bee hive roof and they were equipped with the solar panels to charge the batteries and with the wireless transmission module to communicate with the server. This approach allows the daily data collection from plenty of hives without the disturbance of the bees or the limitation of the beekeeper. Those data are then connected with the information from the weather stations in the surrounding. [2]

Figure 1: Bee hive with the attached sensors and the communication module [2]

A similar example is shown in the article [3], which focuses on the bee colony monitoring in the area with an intensive agriculture activity in the western France.

This article uses a larger amount of recorded variables, as the colony life history, size, food reserves and the resource use, but also the environmental variables as the land use, floral resources and the weather conditions. The study covers the area of approximately 450 km^2 and around 250 bee hives. The amount and the potential of the data is bigger then in the previous study, but on the other hand it doesn't include any automated measurement or data collection. [3]

A similar problem is in the article [4], where the authors decode the bee waggle dances to determine how far and where is the bee forage, but again without the mention of any automated methods. This method could be extended and automated with the computer vision and machine intelligence method, because the manual detection performed in the article has to be very time consuming.[4]

Another approach brings the article [5], which uses small RFID tags directly placed on the bees to monitor their foraging area. A great advantage of this system is that the single bee motion can be monitored and used for the colony behavior understanding or for the certain area visit checking. On the other hand, this approach is highly disturbing to the bees, because they have to be tagged manually and it makes them more vulnerable against the predators. Another disadvantage is that only limited number of bees and areas can be monitored in this way and that only a limited number of the receiver antennas can be placed around the observed location. This method can be interesting for the entomologist research, or for the detection of the cropped areas. [5]

2.2 Acoustic measurements

An interesting field of the bee monitoring approaches are the acoustic measurements, which are based on the bee colony in-hive sound measurements.

Figure 2: Placement of the microphone and the data logger in the bee hive [6]

Both articles [6] and [7] describe the acoustic measurement combined with the external and internal temperature and humidity measurement for the bee swarming detection. Methods described in both articles are very similar to each other and they prove a correlation between the sound spectrum frequencies increase, in-hive temperature and humidity decline and the bee swarm. The measurement itself is done in short periodical intervals during the day with the data transferred to the PC for the analysis. Unlike the method in the article [2], both methods don't use a wireless communication between the hive and the control PC. [6] [7]

3 VARROA DESTRUCTOR MONITORING WITH THE USE OF THE MACHINE VISION

This part of the overview focuses on the applications of the computer vision methods on the Varroa Destructor mite monitoring. As mentioned in the introduction, this mite is a serious problem for the bee colony and its outbreak can lead to the colony collapse. From the article [1], which describes the results of the four-year long study with 1200 bee colonies in Germany, it follows that the V. Destructor was the main cause of the monitored colonies collapse. This mite is around 1mm big and catches the bee's body, which could be seen by the camera. It can also transmit secondary viral infections, which were the second most common case of the bee colony collapse described in [1].

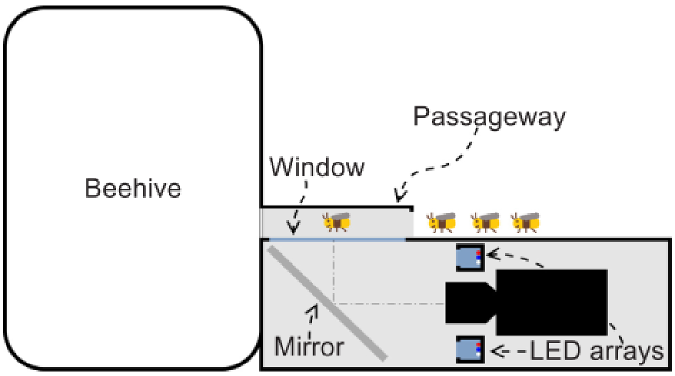

Figure 3: Experiment layout [9]

This topic is covered by the articles [8] and [9]. The first article describes a method, how to obtain an information about the mite occurrence on the single bee from the video. This method records the bees in a special tunnel, which allow only a single bee to pass in one moment. From this video, the bees are detected and the images of the single bees are obtained. Those images are further processed and classified using the non-machine vision classifiers. The output is the binary information about the mite occurrence. According to the authors, the accuracy of this method was around 80% and the method was considered as adequate. [8]

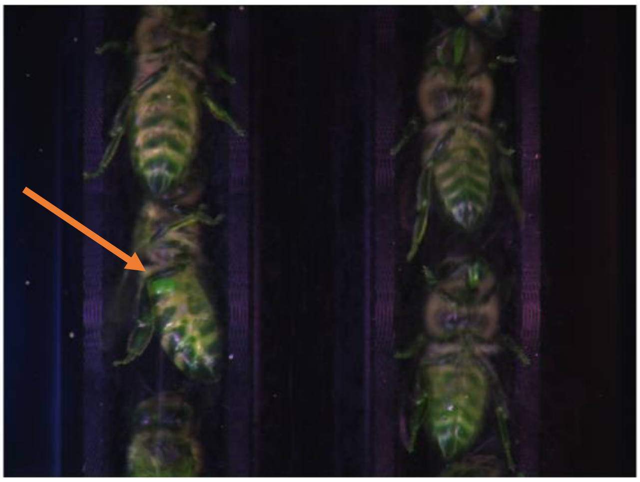

Figure 4: Camera view on the bees with the detected V. Destructor mite on the lower bee left [9]

The article [9] is based on the article mentioned previously and extends it with the use of the machine learning methods for the mite classification and the use of the multispectral illumination. Authors of this article created a video monitoring unit, which can be placed in front of the bee hive and which creates an entry tunnels to the bee hive. Under this unit is placed a camera with the illumination and mirror, as shown on the **Figure 3**. The major improvement, in comparison with the article [8], is the application of the convolutional neural networks, better illumination setup and the mite detection accuracy of 99%. [9]

4 CONCLUSION

This article brings a short overview of the bee monitoring methods, which can be easily extended with the machine vision application. From the non-computer vision methods, the method described in [2] has a good potential and it could be combined with the acoustic and weight measurements and which could be used for example for the detection of the swarm danger, number of bees, potential illnesses or the readiness of honey harvesting. Machine intelligence could be used for the highly reliable analysis of those phenomena and the sensor fusion data.

Computer vision methods described in [8] and especially in [9] are highly perspective for the real time V. Destructor detection. The place for my future research will be in the replacement of the convolutional neural network based classification with the anomaly detection and also with the development of the detection hardware, which would decrease the false negative detections caused by capturing bees only from the bottom side, which was mentioned in [9]. The aim of the my research will be to develop a fully functional computer vision based inspection system for the general bee illness and disorder detection with V. Destructor detection and removal as a first step.

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