Monitoring Beehive Sound Levels with Arduino-based System

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Abstract

An automated beekeeping is a promising approach to addressing various issues associated with a beekeeping. Among primary problems, a swarming procedure stands out as a major concern. An uncontrolled swarming can lead to significant financial losses. During a swarming period a potential for losing a bee swarm is high, therefore a noise monitoring at this period gains a significant importance. Our long term research aims at a development of an intelligent monitoring system for beehive conditions, based on a hive-generated noises analysis. This paper presents an experiment that collected data about acoustic characteristics of bee states using an Arduino microcontroller and a MAX9814 microphone module. The obtained data analysis is discussed.

Keywords: beehive condition monitoring, acoustic level analysis, Arduino microcontroller, microphone, anthropogenic disturbance

1. Introduction

Currently, beekeepers are increasingly facing an issue of a rising mortality among honeybees, attributed to various factors [1]. This problem carries significant ecological and economic consequences that may cause a heavy impact on a biodiversity of wild plants [2] and agricultural production [3], [4]. One of the most destructive phenomena in this field is Colony Collapse Disorder, in which honeybees abandon their hives [5], [6], [7]. This colony collapse or demise is a result of multiple negative factors that can act independently, combine, or amplify one another [8]. A mortality of honeybees can be attributed to various factors, which can be classified into two main groups: a natural factor and a anthropogenic factor. Natural factors include bee infestations by Varroa mites and a swarming. The former are major parasites of honeybees, leading to a reduced hive viability and a decreased honey production [9]. A swarming, on the other hand, is a natural process of dividing a bee colony into two parts [10]. During the swarming, some worker bees and one or several queens leave a current nest to establish a new colony elsewhere. However, this process can pose a challenge for beekeepers as it involves a loss of some bees and, consequently, a decline in honey production.

To deal with Varroa mite a number of methods were proposed including computer vision approaches [11], [12], [13] and real-time visualization systems [14] that allow monitoring of honeybee activity by counting their entry and exit from a beehive [15], [16]. Sensor fusion [17], [18] and fiducial markers [19] can also be incorporated into the monitoring process to provide more robust and accurate measurements. Researchers identified a correlation between the swarming and a hive weight, a sound, a temperature, and a humidity inside a hive [20]. Particularly noteworthy is an analysis of sounds produced by honeybees, which has proven to be one of the most effective methods for detecting the swarming [21]. Scientific studies in this field demonstrated a correlation between specific sound frequencies and the swarming process [22], [23], making an acoustic analysis of bee sounds a promising avenue for monitoring and studying a condition of bee colonies.

This article presents results of a pilot experiment that analyzed a hive noise under normal conditions and after bee disturbances. It is a part of our long term goal of constructing an IoT-based monitoring system that could improve a productivity of honeybees by a timely detection of various events inside beehives and reporting results of AI-based analysis to beekeepers.

2. Experimental Setup

The Arduino UNO microcontroller acts as a main processor, performing key monitoring functions of the experimental setup. The microcontroller receives data from MAX9814 microphone module. The microcontroller and the microphone were placed together into a cardboard box with a power and data wire connected to a notebook computer. The box was placed under a hive cover, above hive frames. The setup and the device placement within a beehive are depicted in Fig. 1.

a b

Fig. 1. Experimental setup: (a) the device; (b) the container placement inside a beehive

The device was programmed using the Arduino open-source software development platform. Arduino IDE was used for programming the microcontroller and reading data from the microphone. Upon powering up the microcontroller, the program initializes variables and opens a serial port at a baud rate of 115200. Data are transmitted through UART communication, and obtained by the microphone values are converted to decibels. A flow of the program is depicted in Fig. 2.

3. Results

A pilot experiment targeted to examine a state and a behavior of bees in terms of acoustic changes under artificial human-made disturbances. The pilot experiment was conducted on October 8, 2023, at 14:30:00 of the local time. By this time of the year, bees completed their main honey gathering season and started preparations for the upcoming winter season.

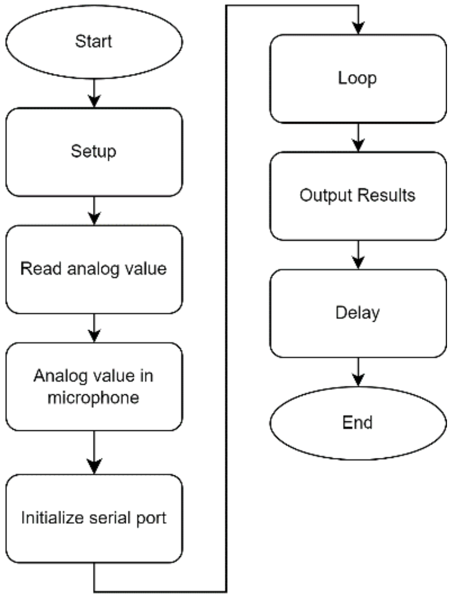

Fig. 2. Acoustic monitoring flowchart

The device was placed into a beehive and the microphone collected acoustic data from bees. The experiment was divided into two phases, 30 seconds each. The first phase corresponded to normal conditions of the beehive. In the second phase an anthropogenic disturbance was generated by knocking the hive for 3 seconds in order to provoke a response from the bees. The phase aimed to investigate changes in the bees' behavior.

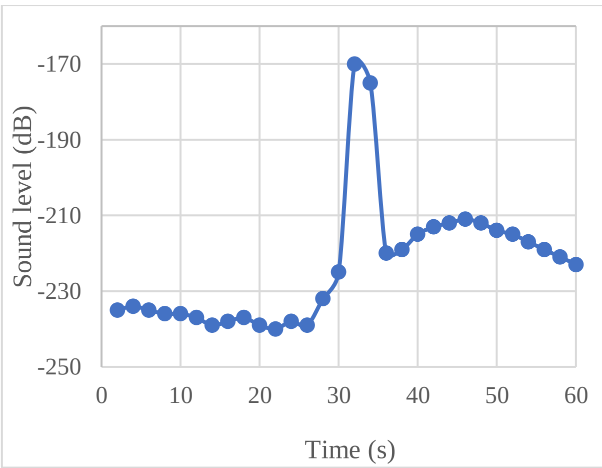

Fig. 3. An acoustic level at a human disturbance event

Fig. 3 presents experimental results of acoustic levels that were measured within the beehive for one minute. It is worth noting that the measurements were taken during a cool weather, which could have affected the acoustic level, making it lower compared to the main honey harvesting period. Initially, in a state of a rest, the measured acoustic level was -240 dB. The highest recorded acoustic level was -170 dB, which occurred at the beginning of the second phase (14:30:31) when the beehive was subjected to a 3-seconds knocking. At this moment, the bees transitioned to an alarmed state, that was reflected in the acoustic level of -210 dB, which gradually decreased over several seconds. Interestingly, when the device was removed from the beehive, there was a clustering of bees around its location. This behavior could be interpreted as an attempt of the bees to protect their colony. They formed a small cluster around the device, and as their stings proved ineffective against the potential threat, they attempted surrounding the "*intruder*" with their bodies, creating a defensive barrier. This behavior impacted the acoustic level, which increased by several decibels in the period from 14:30:27 to 14:30:29, prior to the anthropogenic disturbance.

Based on the experimental observations, it was concluded that while the device could collect valuable acoustic data, a safer placement of a microphone and the processing block should be selected (which could be done using a virtual environment [24]), e.g., on an outer surface of a back wall of a beehive that is opposite a bees' entrance. This would protect the device from overheating and other factors generated by the bees themselves and ensure a more reliable data acquisition.

4. Conclusions

In this study, a part of the bee monitoring system designed to collect data on an acoustic level within a beehive was successfully developed and tested. The experiment aimed to study a bees' behavior under conditions of an anthropogenic disturbance. This experiment represents a step towards a better understanding of bees behavior and their response to interventions. Based on the experimental observations, it was also concluded that a proper selection of the monitoring device and sensors' location is crucial.

Acknowledgement

This paper has been supported by the Kazan Federal University Strategic Academic Leadership Program ("PRIORITY-2030").

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Authors Introduction

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