EMERGING TECH CONFERENCE – Edge Intelligence

Volume 02, 2023, Page 21 – 22

Proceedings of Emerging Tech Conference:
Edge Intelligence 2023

Implementation of a Beehive Health Monitoring System Based on Sound

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Abstract

A beehive monitoring system was implemented for monitoring the internal and external conditions of the hive, as well as detecting beekeeping phenomena, like swarming, queen bee's absence and arrhenotoky, based on the acquired sound.

1 Introduction

Given how vital the honeybees are for the stability of the ecosystem by being responsible for the reproductive process of several plant species and for maintaining biodiversity, a lot of scientific effort is given into developing methods and systems to monitor and protect bee populations. In this context, these approaches focus on developing acquisition systems equipped with sensors for measuring temperature, humidity, carbon dioxide, weight, as well as acoustic sensors. Acoustic methods are non invasive and are proven to be successful in detecting and, even, predicting various beekeeping phenomena like swarming, and the queen bee's absence [1]. Some of the proposed approaches involve the extraction of the Mel's Frequency Cepstral Coefficients (MFCC) which are employed for multiple sound-related applications, including in beehive health monitoring [2].

In this work, a sensor system was implemented, equipped with environmental, weight, motion sensors, microphones and more, in order to monitor the condition of different beehive populations under different phases. By monitoring the sound of multiple beehives for a prolonged period, it was possible to detect phenomena like the queen bee's absence, arrhenotoky, and swarming. The proposed system is able to detect the phenomena through a statistical analysis of the MFCCs extracted from the acquired audio data.

2 Method – Sound Processing

First, a large audio dataset was created from the recordings of multiple hives over a three-year experimental process, during which the beekeepers interfered at multiple occasions in order to force the different beekeeping phenomena. The MFCCs were extracted for the different phases of the experiment and their statistical distributions were analyzed. As a result, it was possible to make a clear distinction between the different phases of the experiment based on the values of these features.

The decision-making process is based on creating an initial reference of the beehive's sound and then comparing each subsequent measurement to that reference. The reference is eventually determined by the means and standard deviations of the MFCC. Each subsequent measurement's MFCC values are

compared to the reference distributions and a relative probability is calculated. The closer a feature value is to the mean the greater the probability. As a result, when a phenomenon takes place, certain mel bands exhibit drastically lower probability values, thus alarming for a possible occurring phenomenon. Depending on which mel bands are differentiated, it is possible to distinguish between the different phenomena and generate an estimated probability.

3 Implementation

The system is based on the SAMD21 microcontroller of Arduino Nano 33 IoT which is responsible for acquiring environmental data, performing digital sound recording, weight acquisition, bee traffic monitoring, lid status control and motion detection and on Arduino MKR NB1500 for narrowband IoT connectivity. It is equipped with an environmental sensor, a PDM MEMS microphone, weight load cells, infrared reflective object sensors, a magnetic reed switch and an accelerometer. For the sound processing, the MFCC extraction was optimized in terms of memory given only 32KB available in SAMD21 and a microSD card is used for local storage. The results of the analysis are transmitted to a webpage dashboard using the narrowband IoT connection. The system is also equipped with an RTC clock for accurate timestamps, as well as a photovoltaic cell. The harvested energy from the cell is used to charge a Li-ion battery, powering the system.

4 Conclusion

The proposed system is a low-power solution for beehive monitoring. The current implementation can be installed on a beehive and autonomously monitor its conditions and protect it.

5 Acknowledgement

This research has been co-financed by the European Regional Development Fund of the European Union and Greek national funds through the Operational Program Competitiveness, Entrepreneurship, and Innovation, under the call RESEARCH – CREATE – INNOVATE (project code: T2EDK 01681).

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