BEESMART
KAREL ELECTRONICS

PROJECT TEAM

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Abstract. This project aims to create a virtual environment for beekeepers so that they can monitor the hive conditions and also try to predict the bee amount present in the hive and the medical conditions of the bees by processing their sounds. The solution uses hardware components such as temperature, moisture, tilt, accelerometer, GPS, GSM and microphones for monitoring the hive conditions in addition to recording and processing sounds present in the hive and transferring them over GSM to a cloud server. After the processing of sound, relevant information was sent to beekeepers and other third-party users via a phone or web application. Hardware design, embedded module software design, machine learning algorithm & design, Android Application design, Web Application design and Cloud-Application connection design were the milestones constructed in order to logically divide the project. Furthermore, a fully functional hardware that is in connection with applications that notifies beekeepers and assist them in order to correctly classify and monitor hive conditions was acquired. Terminally, beekeepers can be more efficient during their honey production and collection process.

Key Words: Sound Processing, Hives, Machine Learning, Cloud Servers, Embedded Modules

PROJECT DESCRIPTION

Motivation: Even though, technological and industrial revolutions have been affecting different sectors, their overall impact over the beekeeping sector can be denoted as weak compared to their impact over many other sectors. Beekeepers still have to manually visit hives and check regularly for both internal and external conditions to optimize honey production. This project aims to apply state of the art algorithms and designed to integrate technology to beekeeping sector so that beekeepers can not only monitor the external and internal conditions of the hives, but also use the predictive aspect of the design to ease their timetable planning and optimize honey production. This project serves as a pioneer in terms of sound processing and applying machine learning techniques to hives for Turkey and such a comprehensive design has not been investigated or modelled in literature so far [1]. The sounds collected in the hives were processed on a run-time fashion. Besides that, the design would help beekeepers by sending real-time data of external conditions that also affect honey production. As a result of the project, the bee health could optimized utilizing the instant monitoring of the hive environment which varies according to the climate, natural life and environmental conditions. In other words, inter-operating with our company, KAREL, a novel product for hive monitoring was designed.

Novelty: To discuss the novelty of the project, similar products and projects should be observed. According to the literature research, five different products or projects were found: BeeHive Lab Project [1], Intelligent BeeHive [2], EDA Hives [2], BigbrotherBees [3] and BeeState [4] monitor. The main differences and combinations of systems of our project compared with the current researches conducted is given via table below.

Projects / Systems	Tilt & Accelerometer	Microphone& Sound Analysis	Temperature & Moisture	GPS & GSM	Android & Web Application	IoT & Machine Learning
BeeSmart	Included	Included	Included	Included	Included	Included
BeeHive Lab Project [1]	Included	Included	Included	Not Included	Not Included	Partially Included
Intelligent BeeHive [2]	Partially Included	Not Included	Included	Not Included	Included	Not Included
EDA Hives [2]	Included	Included	Included	Not Included	Not Included	Not Included
Big Brother Bees [3]	Not Included	Included	Not Included	Not Included	Included	Included
BeeState Monitor [4]	Partially Included	Not Included	Partially Included	Partially Included	Included	Not Included

TABLE 1. Comparison between Several up-to-date Projects

Design and Performance Specifications: This network contains hardware implementation of power supply and all of the sensor configurations as the fundamental subsections. It consists of YL-38 tilt sensor, HR-202L Moisture Sensor, DS18B29 temperature sensor, ARD-MDL 12-29 weight sensor, MEMS microphone, GPS module and finally GSM module. In addition to these sensors, additional RAM was placed for memory considerations. All of the components mentioned are connected to the printed board which has connection to power supply. The building stone of the project, was sound processing using edge computing. Further improvements made in efficient edge computing processes, which the specifications can be seen in the above picture. Utilizing from the 3G and LTE properties of the device, the data obtained from several sensors and modules can be transmitted to the cloud of Karel. Any significant change in the condition of the hives can be detected by the alarm generated by sensors. In the final section, utilizing from the server-web protocol, the server was used to inform the users by providing them the web and android applications.

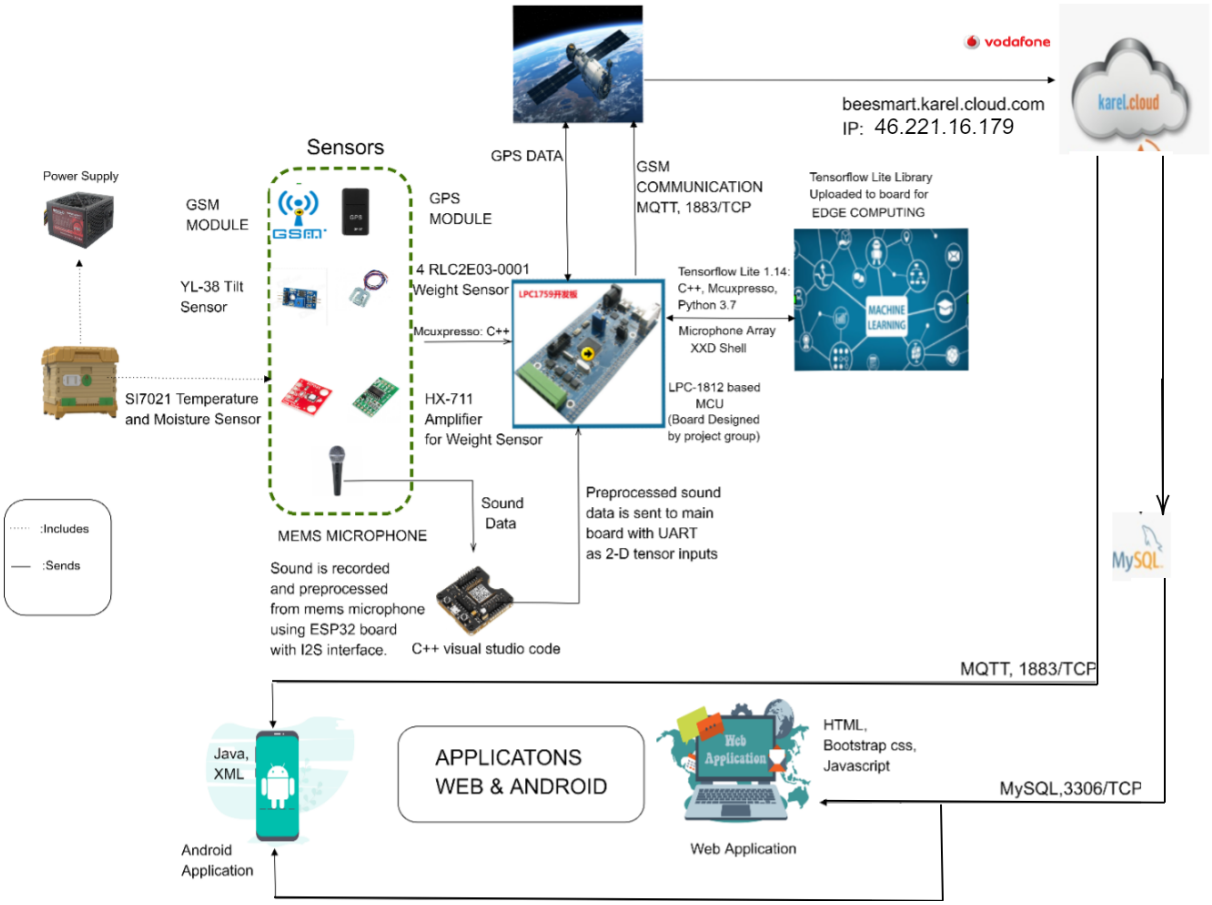


FIGURE 1. Big picture of the Project

MILESTONES

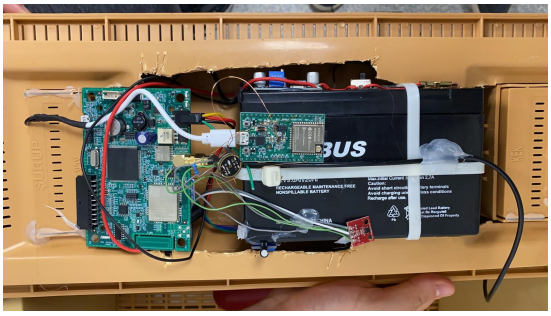
One of the primary milestone of the project was finalizing the Printed Circuit Board (PCB) design, check its compatibility with the overall software implementation and integrate to the hives as the last step. On the embedded software design part, our main aim was to combine all the sensory modules on a board, then send and process the data received from the board via GSM connections and show these accurate implementations on the designed board respectively. As the core of the project, an essential milestone in Machine Learning and design stage was to classify the conditions of the hive with a high accuracy, in an effective manner with using the bee sounds. Another performance expectation is to implement this in a timely manner without using a major storage. Since the project aims is to present a user-friendly web and android applications to monitor the health conditions of the hive without the necessity of visiting the hives, several turning points were specified in that regard. For android and web applications, primary milestone was to obtain notifications from the application implemented in case of sudden changes in the hive, without the need of accessing to the system manually. Finally, the milestone for server implemented was to successfully cluster the data regarding the conditions in the hive and transmit to the android and web applications when necessary.

DESIGN DESCRIPTION

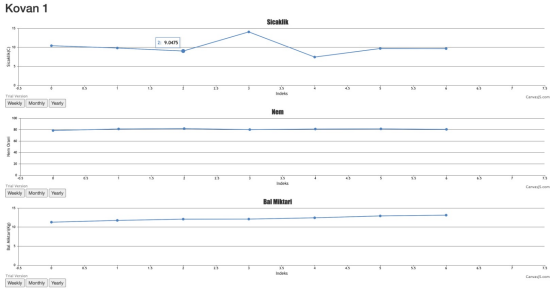
Hardware Design: PCB design was completed by using the OrCAD software program. After revisions, PCB was printed and relevant components soldering process was completed utilizing Karel Electronics' automatic soldering machine.
Embedded Software Design: Temperature, humidity, tilt, GPS and GSM sensors and their working protocols were implemented in the MCUXpresso IDE and uploaded to the designed board via ULINK 2 debugger. On the other hand, microphone code was implemented in Arduino IDE and uploaded to ESP32 board. Communication between two boards were established by UART protocol.
Machine Learning Algorithms Design: Raw data obtained from microphone was preprocessed on ESP32 board in order to obtain mel-spectrogram. Serially transferred mel-spectrogram data used as an input for machine learning model and prediction obtained. Model consists of several CNN and fully connected layers that were implemented in our board with TFLite library created by Tensor Flow. Model trained on PC with Python and converted to FlatBuffer and stored in flash memory.
Application to Cloud Connection: With agreement of our company, our designated data transfer protocol was decided to be MQTT, which provides reliable data transfer using the transport layer protocol. We implemented MySQL server that automatically saves the data listened. For general usage and possible extensions as a product, we implemented an Auto Subscriber at the backend of our server through Ubuntu.
Android Application Design: We have implemented the main UI & UX design requirements primarily. The initial screen where the user displays the current hive conditions also utilize the latest data entry for that specific hive to display them immediately, if the user decides not to display the past data, and this was relatively useful, since we already derive the database upon user selection for a hive using the Maps.
Web Application Design: The solution strategy for the web application is to use well-established standards in the field of we development and use open source libraries. Hence, we implemented HTML based website. We used JavaScript for the visualization type of application purposes and PHP for the cloud server connection purposes. Google Maps API is used for the location services and MySQL is used for the backend part of the web application.

RESULTS AND PERFORMANCE EVALUATION

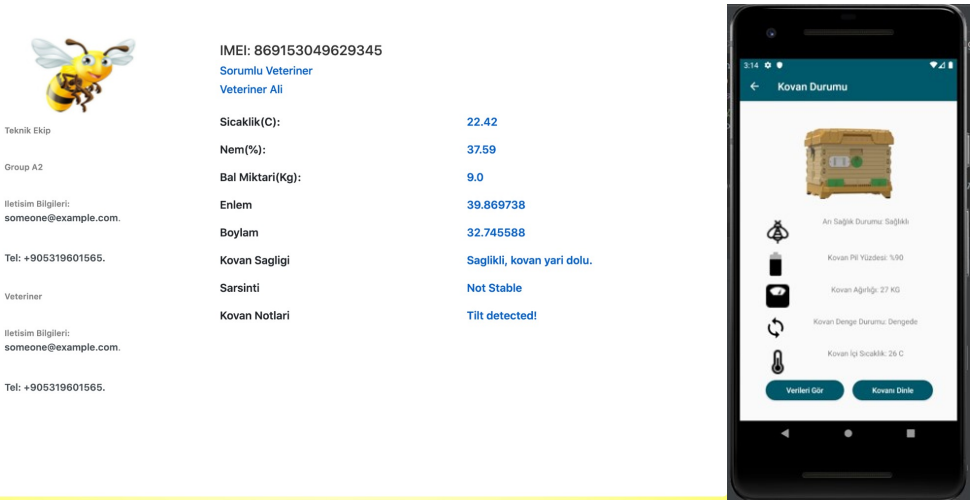
With the connection of individual parts, board can send MQTT packages, which include the ML Predictions, Sensory Readings, Location information via GSM to server successfully. Both sensor measurements and results of processing of sound observed from Android and Web applications after testing the performance of the Hardware-Cloud-App connection. Considering the previous work done described above, our team was able to successfully implement a novel smart bee-hive project which predicts health conditions using edge computing, without compromising the memory. Other sensory components operates properly, which completes our implementation and are accurate with calculations and expectations.



(A) Completed Hive Lid



(B) Web Analytics



(C) Web Application Screenshot (D) Android Application Screenshot

FIGURE 2. Results achieved

CONCLUSIONS AND FUTURE DIRECTIONS

Although all of our group members have profound knowledge in the area of Machine Learning and Artificial Intelligence, with unlimited hardware and cloud computing resources available in the industry at the moment with powerful CPU's and online GPU's, during our experience in course projects, efficiency was never the initial goal for us, it was all about performance. During the implementation of the edge learning aspect, both efficiency and performance became our primary concerns, and conducting complex operations with such a simple MCU was also one of the greatest achievements and challenges faced in this project.

Even though we can get accurate results through playing the test sounds we received that were recorded and labelled by a vet in the first semester, these results are theoretically accurate. To build a completely robust prediction system, saving and labelling the sound data through our own custom board after going to Köyceğiz would idealize the results. In addition, when starting this project, one of our main tasks was to regressively label the data and also predict the honey amount through sounds. Because of COVID-19, our trip to Köyceğiz was cancelled, so this subtask was neglected for completing the project, a future direction would also be to implement this task, as we couldn't receive the self-labelled data, it was impossible for us to complete this task.

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[4] Arnia *Better Knowledge for Bee Health, BeeState Monitor* `https://www.arnia.co.uk`

BEHIND THE SCENES

(A) Board-Hive Placement

(B) An Ordinary evening at Karel

(C) Our Hive Arrived!

(D) Fully Focused

FIGURE 3. Behind the Scenes