SENSORIZED BEEHIVE HEALTH MONITORING USING WIRELESS SENSOR NETWORKS

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ABSTRACT:

Honey bees are one of the most important parts of the food web as a pollinator. They are estimated to perform more than 60% of the total pollination. Hence, it is evident that sheltering the bees’ population and maximizing their productivity is the concern of the hour. This topic is nowadays gaining momentum due to the increasing pollution levels and fear of extinction of certain bee species. There are various factors on which the health of honey bees depends, namely, temperature and humidity of the beehive, weight of the hive and certain gas levels inside the hive. Hence, in order to help the beekeepers monitor the health of the beehive, this paper proposes a system that will help them to check the parameters periodically without even visiting the apiaries. The system will also visualize the data collected from the sensors on a web based portal and the data collected will also be used for data analysis using classification algorithm. The system implements Internet of Things by using physical objects consisting of sensors, software and connectivity through network to exchange data.

KEYWORDS: Health Monitoring, Wireless Sensor Networks (WSN),Swarming of Bees’, Data Visualization, Internet of Things (IoT) and Sensors and Network.

INTRODUCTION:

Honeybees are considered very economical and important insects because of the fact that they carry out pollination of plants and cropsthat in turn bears the flowers and the fruits but also for the precious products that are produced by them in the beehive. They collect nectar from the trees, plants and flowers. A part of the collected nectar is used by them to maintain their own life but the remaining nectar is used by them to produce various bee products such as propolis, wax, royal jelly, honey, and queen milk and bee venom. These products are sometimes directly consumed or eaten by human beings and sometimes they are processed to some commercial cosmetic or medicinal products.

The branch of study that deals with rearing of honey bees in the apiary is known as Apiculture. Nowadays, PrecisionApicultureorPrecisionBeekeepingis practiced as a management plan or strategy to monitor the bees inside the beehives and produce the maximum benefit out of them. The main objective is to minimize the resource consumption and maximize the productivity.But there are some problems that they face in day to day life that threatens the bee’s population inside the beehives which of a great concern now. Environmental pollution, biological artificial products and other activities that are biological in nature leads to certain diseases that can badly affect the bee’s population. During summerseason, the major threat is swarmingofbeeswhere the queen bee leaves the beehive and in turn the worker bees and other bees also leaves the beehive slowly and slowly leaving the drones behind that eventually dies because of raised temperature.Hence, we have considered temperature and humidity as one of the important feature to measure to monitor the beehives because that can be easily monitored and is feasible economically. Apart from humidity and temperature, we are also measuring carbon monoxide gas level inside the beehive and weight of the beehive to monitor honey bees health inside the beehive.The purpose of the proposed work is to build a Honey Bees Health Monitoring System which will in turn monitor the beehives where bees are kept regularly by measuring the temperature, humidity, weight of the hive and carbon monoxide level inside the beehive and sending the sensed data to the beekeepers through messaging services so that they don’t have to visit the apiary regularly and can monitor the beehives more effectively than usual. Also, the data will be used for analysis so that data interpretation in the form of classification using decision tree as they bypass the approximation theme and have numerous advantages can be performed on the data received and general pattern can be observed which will help in improved beekeeping. [1-2]Currently, the existing system monitors either the temperature – humidity or weight or sound inside the beehive or images. But our proposed system considers all (temperature, humidity, weight and gas levels) aspects as important one and together they determine the health of the beehive inside the apiary. Our solution will be a hardware system which will be present in the apiary all the time sensing the parameters and notifying the beekeeper at regular intervals through an interface in the form of charts and graphs.

The overall idea of the work can be summarized in the following way: First of all, installing the above said sensors inside the beehive so that the environmental conditions in and around the beehive can be sensed though respective sensors. The sensed data will be sent to the beekeepers so that they can check the conditions of the beehive without visiting the apiary. In case of any abnormality, the beekeepers can personally visit the apiary and perform necessary actions required to get the conditions in control. The data will be visualized in a web interface in the form of graphs so that historical data can be compared with the current data. The data will also be used to perform classification algorithm to get the hidden patterns and identify the root causes of the problem. These algorithms produces results in such a way that it improves interpretability of human for the raw data available. [3]

The organization of this paper is as follows: section 2 deals with the literature survey and motivation for the work. Section 3 highlights the system design and architecture of the system. Section 4 deals with the modules description and analysis of the results obtained. Section 5 emphasizes on building a classification model using decision tree and how to interpret it. Section 6 winds up the paper and it also tells the future improvements that can be carried out.

RELATED WORK AND MOTIVATION:

Dunham made a practical experiment using eight thermocouples. He places these eight thermocouples into one hive in different places. He observed that the temperature fluctuation in empty places in the hive was higher than that in the ball of the beehive. Also, the temperature in the ball of the beehive is increases up to +30 Degree Celsius during the active brood rearing stage. Hence, he concluded that temperature has the highest effect on bees than any other environmental parameter.[4]A practical experiment that was complicated was carried out in Riga, Latvia by Stalidzans et al. They observed changes in temperature in individual bee hives during a complete year. The aim of the measurements was to observe the changes in the bee colony temperature and to define the bee colony activity states in the Latvian climate conditions. Small digital sensors were used for the temperature measurements. These sensors were placed under the pillow above the bee nest. The readings were made at 15 minutes interval. As a result, six bee activity states were defined. [5]In Rumania, a research was performed by Vornicu and Olah aiming to find a monitoring system achieved with the most recent software products and hardware products which can be attached to a bee family. This system is having the continuous denoting the climate conditions such that temperature, humidity and dew point, respectively their influence on the conditions in the beehive. The main motive of this monitoring was to find some undesirable effects as well as to achieve exact developing conditions for the bee families, by exact intervention. Sensors are used to measure temperature, relative humidity around a beehive. Three movable sensors were used. [6]The methodology adapted by Meitalovs et al. deals with three basic areas: Temperature Control, Humidity Control and Video Monitoring of hive as well as environment of the hive. The computer receives data from the measuring subsystem to store it in memory and analyze it. [7]Zacepins et al.developed a web system for easy access to all bee colony temperature measures. The idea for this web system is that a beekeeper can connect to the system with the help of Internet access from anywhere and examine the hive temperature. The interface should be simple for beekeepers as they are not that experienced with using computers. One module was developed for actual information about bee colony temperature which is measured using sensors. The second module was developed as an option for detailed analysis of temperature data. The third module was for administrative work configuration.[8]The journal written by Aleksejst al. reviews various practical implementations of temperature measurement systems in the beekeeping. It gives the details of manual temperature measurements, measurements by different loggers and remote monitoring of bee colony temperature changes.[9] One of the articles written by Murphy et al. mentions the monitoring of the beehive using the sounds produced inside it is a salient action for beekeepers to make sure that the bee colonies maximize productivity and remain healthy.[10] The system proposed by Sandra Kordić Evans shows how beehive data is being used to highlight the effects that different endogenous and exogenous factors have on honey bee colonies. Each hive is fitted with a monitor who sends the information to the monitor gateway via low power radio network.[11] Fitzgerald et al. mentioned in his paper that one of the key metrics is weight as it is the power and strength for the bee colonies. To accurately contemplate the productivity of the bee colonies, its condition as well as its health, measuring the changes in weight is important. [12] Popovici, et al. in his proposed system elucidates that Wireless Solutions such as WSN technology can be used to monitor a beehive colony. To monitor the behavior within a beehive this work deploys cloud computing with multi radio communications and WSN technologies energy neutral operation with low power. [13] The work described in the paper, written by Edwards et al. utilized heterogeneous wireless sensor networks technologies in order to describe the activities and conditions of the bee colony which collects data from a beehive inconspicuously. [14]Some of the other beehive health monitoring arrangements that are available in the market commercially, uses separate sensors for each parameter on a single chip, most of them are powered by secondary batteries and some of them utilizes solar power cells and for deployments that are done remotely, they do not use GSM modules. [15-17].The crucial parameters that this paper presents for monitoring the conditions inside the beehive are summarized as: Humidity inside the hive, Temperature inside the hive, Weight of the hive and Carbon Monoxide Gas Level inside the hive. [18]

The motivation behind taking up this research work has been highlighted below:

- Honey Bees are responsible for more than half of the pollination across the world. Thus, we can say that they have an important role in Agriculture.
- Due to pollution and climatic changes in recent years, the population of honey bees has been reduced.
- United Nation’s reports in recent years have emphasized on the food supply growing constraint for growing population.
- 153 billion Euros per year is the estimated worth of cropsdependent on pollination. [19]

PROPOSED FRAMEWORK FOR BEEHIVE HEALTH MONITORING SYSTEM:

The system presented in the work is inspired from the work done in the last few years in concern of the honey bees’ health. The hardware consists mainly of the microcontroller-based kit equipped with different types of sensors and a module that sends data from the hive to the network. The software part of the system helps to collect information, store it and finally send it to the required person. There is also a provision for visualizing the data collected. The sensors will be fitted into the roof of the beehive except for the weight sensor which will be fitted on the bottom of the beehive so that they can easily and effectively sense the conditions of the hive. The battery power supply will be kept outside the hive. The final system will help the beekeeper to maintain its hives effectively and easily. The description and process flow is explained below.The architecture diagram for the proposed system is given in Figure 1.

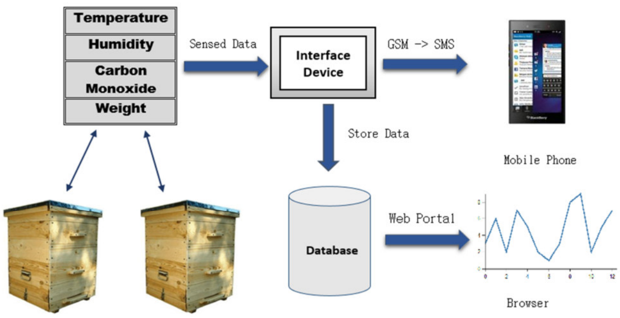

Figure 1 The architecture diagram for Honey Bee Health Monitoring System

The sensors will be fitted inside the beehive, namely, temperature, humidity, load cell and carbon monoxide gas sensor. They will sense and record the respective data at regular intervals. The sensor used for temperature and humidity is a single unit that measures both parameters i.e. DHT22 which uses a polymer capacitor operates on a power supply of 3.3 to 6V DC and current supply of 1mA to 1.5mA. The carbon monoxide sensor is a MQ-7 Gas Sensor which uses an aluminum oxide tube and tin dioxide layer and operates on 5V DC power supply. The load cell used for weighing has a capacity of measuring up to 40Kg which is a transducer that is used to get an electrical signal from a force. In order to amplify and enhance the result produced by the load cell, HX711 Analog-to-Digital converter is used which operates on a 2.6 to 5.5V power supply.

After sensing the data, they will forward the data to an interface device; in this case it will be the Arduino Uno R3 ATmega328P development board. Using a software called Parallax Data Acquisition tool PLX-

DAQ the interface will store the data in a tabular format in a database or spreadsheet.The data stored in the database or spreadsheet will then be used in two ways: using the Arduino GSM module, the data will be sent through SMS to the beekeeper which will contain all the data recorded for that time frame. The module used for this purpose is SIM900A RS232 engine which operates on 12V DC power supply and 1 to 1.5A current supply. Using visualization tools, the data will be presented in the form of graphs on the web browser for easy interpretation. The web interface used allows the beekeeper to enter the login credentials and access his/her personal portal. In the portal, the beekeeper can see and check the line graphs for all the parameters measured. The line graphs are made using C3.js, a JavaScript library that uses D3.js based charts. It fetches the data from the database or spreadsheet to draw the line charts.

SYSTEM ANALYSIS & COMPUTATIONAL RESULTS:

The work described in this paper has been decomposed into six modules. The module-wise description stating what the module contains and what are the functionalities of the module has been tabulated in Table I.

Table 1Module Description

SR. No.	Module Name	Content of the Module	Functions of the Module
1.	Beehive Unit	Box-like wooden or metal structure embedded with the proposed systemhardware	Contains the data (here honey bees for monitoring)
2.	Sensors Unit	Temperature, Humidity, Carbon Monoxide and Weight sensors	Senses the correspondingenvironment data inside the beehive
3.	Main Controller Unit	Processer and other devices that act as an interfacing device and power devices	Control the communication between the sensors and the environment and provide power to function all the time
4.	GSM Module Unit	GSM Shield over the processor or GSM module	To send the log reports in the form of an SMS to the beekeeper.
5.	Visualization Unit	Web Browser and Data Visualization Tools	To present the data in a meaningful format like charts and figures for interpretation.

The primary user interface will be a screen of the mobile phone that will receive the sensed information from the GSM module in the form of a SMS and another one is the browser window which will display the line charts using the visualization tools. There are three stakeholders for the system, namely, Admin who will be responsible for creating credentials for the beekeepers and also for authentication purpose. The second one is the Beekeeper who can access his personalized account with the credentials and see the health report of the beehives. The third one is the Analyst who will perform classification algorithm on the data available in the database for future predictions and better understanding of the factors leading to good health of the honey bees inside the beehives.The data for safe conditions of the bees' in the beehive has been collected from what the sensors have sensed in the days after the deployment of the system. The data for unsafe conditions has been generated randomly which does not satisfy the ideal conditions for all the parameters or as set of parameters used to monitor the beehive health. Each record in the dataset has four values: temperature value in degree Celsius, humidity percentage, weight of the hive in kilograms and carbon monoxide gas level in parts per million.

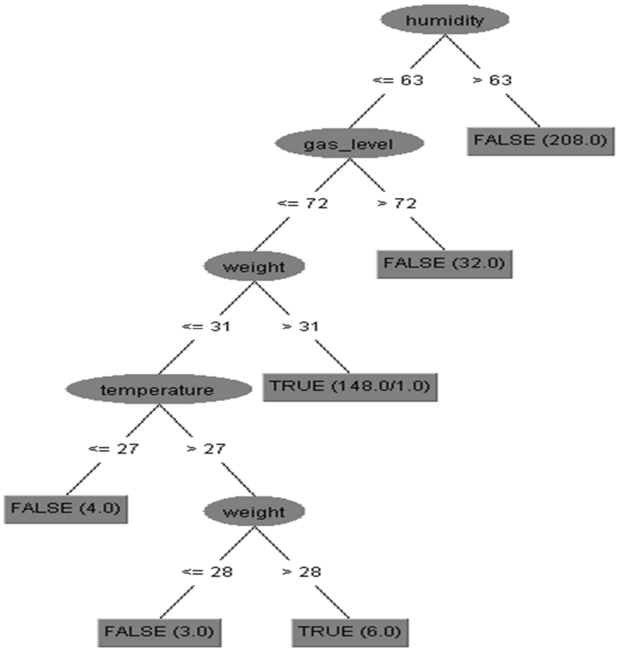

Figure 2 Decision Tree to predict whether bees' are safe or unsafe

To perform the desired classification using decision tree, C4.5 algorithm has been used which is derived from ID3 algorithm. [20] The decision trees that are produced by this algorithm are commonly used for classification and hence, for the same reason it is also called as statistical classifier. This algorithm uses information gain or entropy to build the decision tree just like ID3 algorithm. The data was also preprocessed first to remove any ambiguous entries, void entries and entries that does not satisfy the lower and upper threshold like humidity and weight cannot be less than zero. The two labels that are used to classify the records are: 'TRUE' to represent the safe conditions inside the hive and 'FALSE' to represent the unsafe conditions inside the hive. The objective of the classification using decision tree is to predict whether for the given environmental conditions inside the beehive, the bees' are safe or unsafe. There are several advantages of representing the classification rules in the form of a tree like the presentation in tree form is simpler to understand and interpret and also they can perform classification faster compared to other ways for different types of attributes although the attributes used here are all numerical. The decision tree generated is given in Figure 2.According to the decision tree, the most important parameter to monitor the health of honey bees is humidity because its informational gain provides more information that other parameters. The dataset contains 401 instances, out of which 153 instances have class label 'TRUE' and 248 instances have class label 'FALSE'.

To report the result whether the bees' are safe or not inside the hive, the decision tree can be used to compose classification rules. The rules that says the bees' are safe are as follows:

IF humidity <= 63 and gas_level <= 72 and weight > 31 THEN safe = TRUE
IF humidity <= 63 and gas_level <= 72 and weight <=31 and temperature > 27 and weight > 28 THEN safe = TRUE

Similarly, the rules that predicts that the bees' are not safe and an immediate action is required are as follows:

IF humidity > 63 THEN safe = FALSE
IF humidity <= 63 and gas_level > 72 THEN safe = FALSE
IF humidity <= 63 and gas_level <= 72 and weight <= 31 and temperature <= 27 THEN safe = FALSE
IF humidity <= 63 and gas_level <= 72 and weight <= 31 and temperature > 27 and weight <= 28 THEN safe = FALSE

The results observed for two days after deploying the system where all the sensors are working accordingly can be seen in Figure 3.

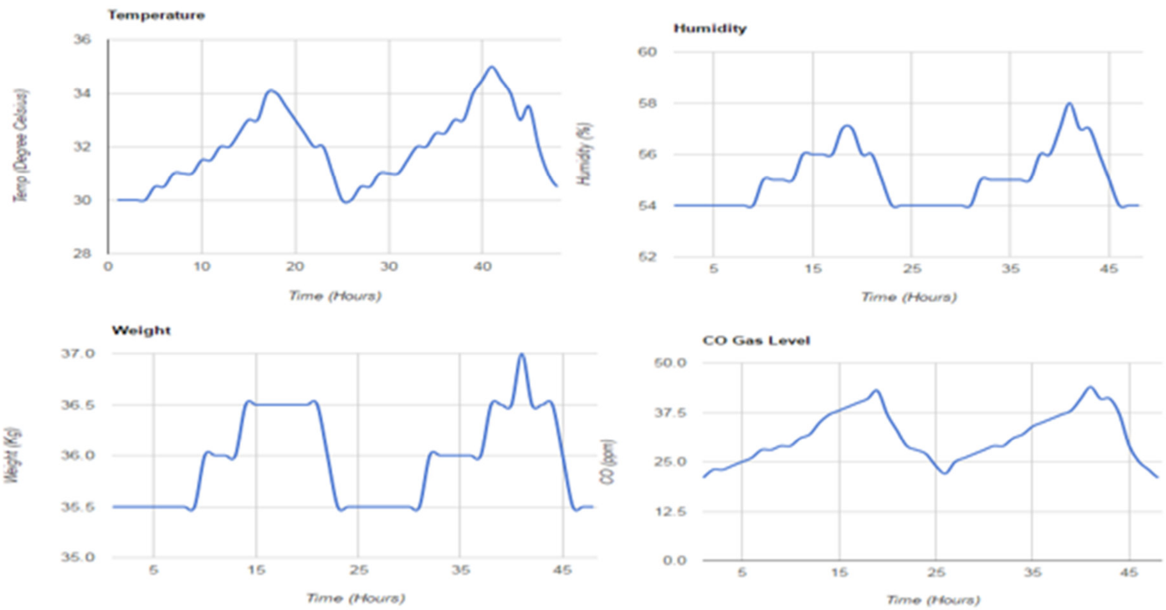

Figure 3. Observations in the form of the graph for different parameters used for the first two days

The results for temperature, humidity, weight of the hive and carbon monoxide gas level inside the hive is shown in the form of line charts. The time in hours is on the X-axis, 1 to 24 is for the day one and from 25 to 48 is for the second day, whereas the Y-axis represents the corresponding sensor unit, like Degree Celsius for temperature, %age for Humidity, Kg for weight and ppm (parts per million) for carbon monoxide gas levels.The SMS received on the beekeeper’s mobile phone contains all the data sensed by the sensors. The messages are sent at a regular interval of 30 minutes. Figure 4 shows how the messages were received in the mobile phone.

Figure 4 SMS Received on the mobile phone

CONCLUSION:

Honey Bee Health Monitoring System has been developed with all the listed functionalities and components in the system design part of the paper. The system helps the beekeeper to keep an eye on its apiary all the time without any personal intervention or visit to the apiary. Hence, the time consumption in regularly checking the beehives is minimized and now the analysis or the results are more accurate, efficient and consistent. The visualization is required to look into the system because it is easy to understand and interpret. The data analysis helps the beekeepers and data analysts to predict the future conditions and identify other hidden patterns available in the dataset and also the major parameters responsible for health of the honey bees.This system has an edge over other existing models to carry out the same task because this system considers more parameters in a single unit whereas other deploys only one or two parameters in a single unit. Hence, more proper and efficient monitoring can be performed with this model.Considering the future scope for the current system to improvise the model, solar power cells can be installed to provide power and energy to the system regularly and without any problems. The current framework can be extended to include oxygen, carbon dioxide and other harmful gases sensors. Also, including a bee counter system, sound recording and sound analysis system and a camera module inside the hive can improve the efficiency of the system.

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