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SMART HIVES FOR SUSTAINABLE BEEKEEPING

Manuel Benedetti, Luca Ioriatti, Mauro Martinelli, Andrea Rosani, and Michele Sava, *Melixa Srl*

Gino Angeli, Paolo Fontana, *Edmund Mach Foundation*

Trento, Italy

Abstract: *Diseases and the use of pesticides in industrial agricultures are seriously affecting bees' ecosystem, causing the death of wild bees and increasing the complexity of beekeeping activity. Beekeepers experience and ability appears to be not enough to overcome these hurdles and hence a demand of remote monitoring has arisen. In such a framework, we propose a device that can be added to almost whatever beehive to enable remote monitoring. Starting from the measurement of the activity of the bees and a set of environmental parameters, the proposed add-on could significantly help beekeepers to infer the health status of their colonies, at the same time optimizing their inspections and hence reducing costs. The device has been designed to be as much user-friendly as possible: its autonomy is assured by a battery charged by means of solar panels and the data transmission occurs automatically through GPRS/2G network.*

I. Introduction

Becoming a beekeeper nowadays is probably much more complex than it was even in the relatively recent past. As a matter of fact beekeeping is facing today many problems that can be mostly attributed to the effect of human activities. It is well known in the entomologists' community that climate change and the practice of industrial agriculture have significantly changed the habitat of honeybees, on one hand causing probably the worst decline of the wild bees in the history and on the other hand creating the condition for the arise of diseases and the attack of parasites [1]. Bees represent a fundamental tile on the Earth, since they are responsible for the survival for more than the 80% of the vegetal species [2]-[3] thanks to pollination. Without bees, the world would be dramatically different and hence they have to be protected. Toward this end, researchers and beekeepers play a key role in saving bees all over the world.

In such a complex framework, we are addressing the problem of bees' monitoring by means of a system that can be profitably exploited to increase the efficiency and the effectiveness of the beekeeping processes. Data collection and observation of the bees' ecosystem represents an essential step in order to understand the behavior of a colony and provide beekeepers with useful information and indications. Thanks to the increased knowledge arising from the monitoring system, beekeepers can hence improve their ability, optimizing their visits in the apiaries with more effective and less invasive interventions as well as improving the quality of the final products (i.e., honey to a greater extent). Similarly, researchers can improve their analysis thanks to more accurate observation and correlations with environmental data.

Fig. 1. Smart beehives at Laimburg, South Tyrol

II. The Proposed Solution

Our solution consists of a technological add-on that transforms almost whatever existing beehive in a smart beehive. The device has been developed in cooperation with the entomologists of the Edmund Mach Foundation (www.fmach.it) within a research project started in 2011. After 2 years of experimental trials, the re-engineering of the current version has been launched and since the beginning of 2015 the product is on the market.

The device is characterized by a main unit that needs to be applied at the entrance of the hive, and a wire-connected scale, to be placed under the hive itself. The main unit comprises the master controller

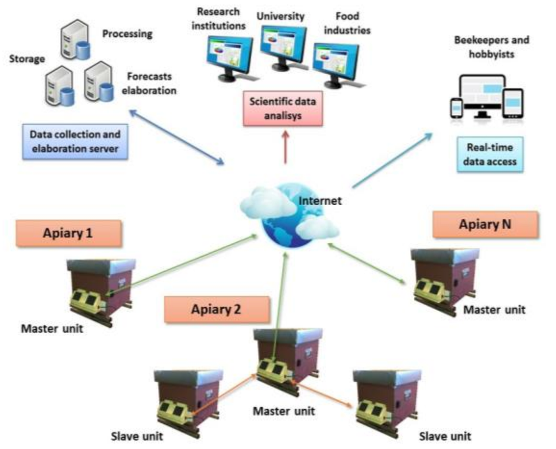


Fig. 2. System architecture

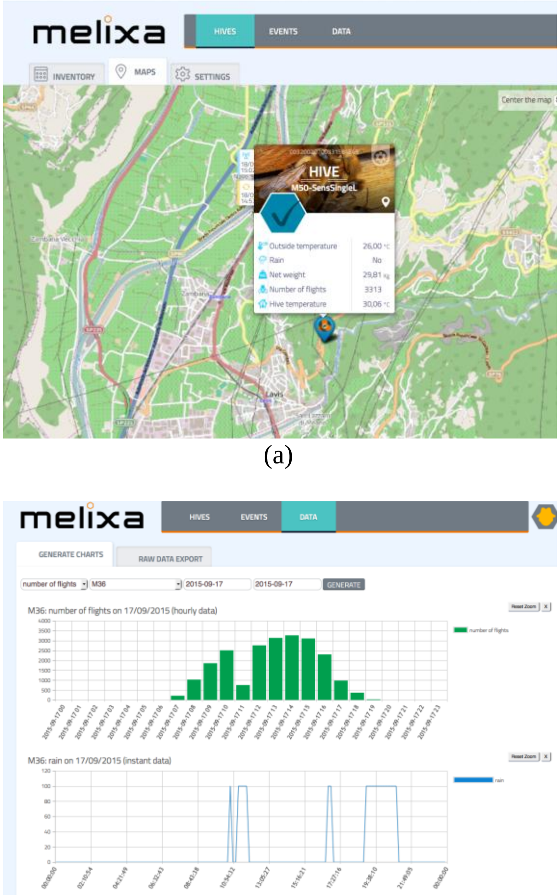
and the main board, enclosed by a conveniently designed plastic case. The scale is composed by a steel framework and a load cell in its fulcrum, connected to a slave controller, where a set of environmental sensors are also connected. The device measures the external temperature, rain/humidity as well as the internal temperature with a probe that can be inserted into the hive where needed. Moreover, thanks to an innovative sensor and a set of channels in the lower part of the case, the main unit is able to count the bees entering into the hive and going out. The bee-counter and the design of the case are currently patent pending.

In order to allow the remote monitoring, the main board is also equipped with an accelerometer and a communication module. The communication module is provided with a GPRS/2G module to allow the transmission of data. A GPS receiver is used for alarm purpose and product traceability. Collected data are sent to a cloud server where storage and analysis are performed. The information are then provided to the end user by means of a web platform accessible through smartphone/tablets and/or personal computers.

From an energetic perspective, the proposed device is autonomous. It is equipped with a NiMH 3,6V 3600mAh battery that is charged by two mono-crystalline 90 x 79 mm solar panels mounted with a 50° tilt angle.

Several examples of smart beehive have been already developed in the past [4]-[8], most of them at prototype level and/or characterized by a limited number of sensors and/or reduced data collection capabilities. The solution proposed in [4] is also equipped with a bee-counter based on optical technology, which unfortunately does not cope with nectar and dust.

The advantages of our implementation with respect to competing technologies can be summarized as follows: a) dust-proof/nectar-proof bee counter; b) plug-and-play wireless device, compatible with almost most of the existing hives; c) energy scavenging; d) cloud platform with big data analysis.



(a)

(b)

Fig. 3. User interface with (a) map view and (b) data view.

III. End User Interface

The cloud platform disposes of a back-office web interface for maintenance and a user interface protected by password and activated after the purchase of a system. Thanks to the user interface, beekeepers can supervise the system-equipped hives by means of different views, such as the inventory view, the map view shown in Fig. 3(a), and the data view shown in Fig. 3(b).

In the inventory view, a rectangular box is shown for each hive monitored. In the box a selection of the most important data is shown: external and internal temperature, rain, weight of the hive, and number of flights. Except from temperatures, a qualitative representation is employed for all the parameters in order to summarize the status of the hive. The last parameter is very important in order to understand the activities of the bees during the period of observation and it is computed starting from data provided by the bee-counter.

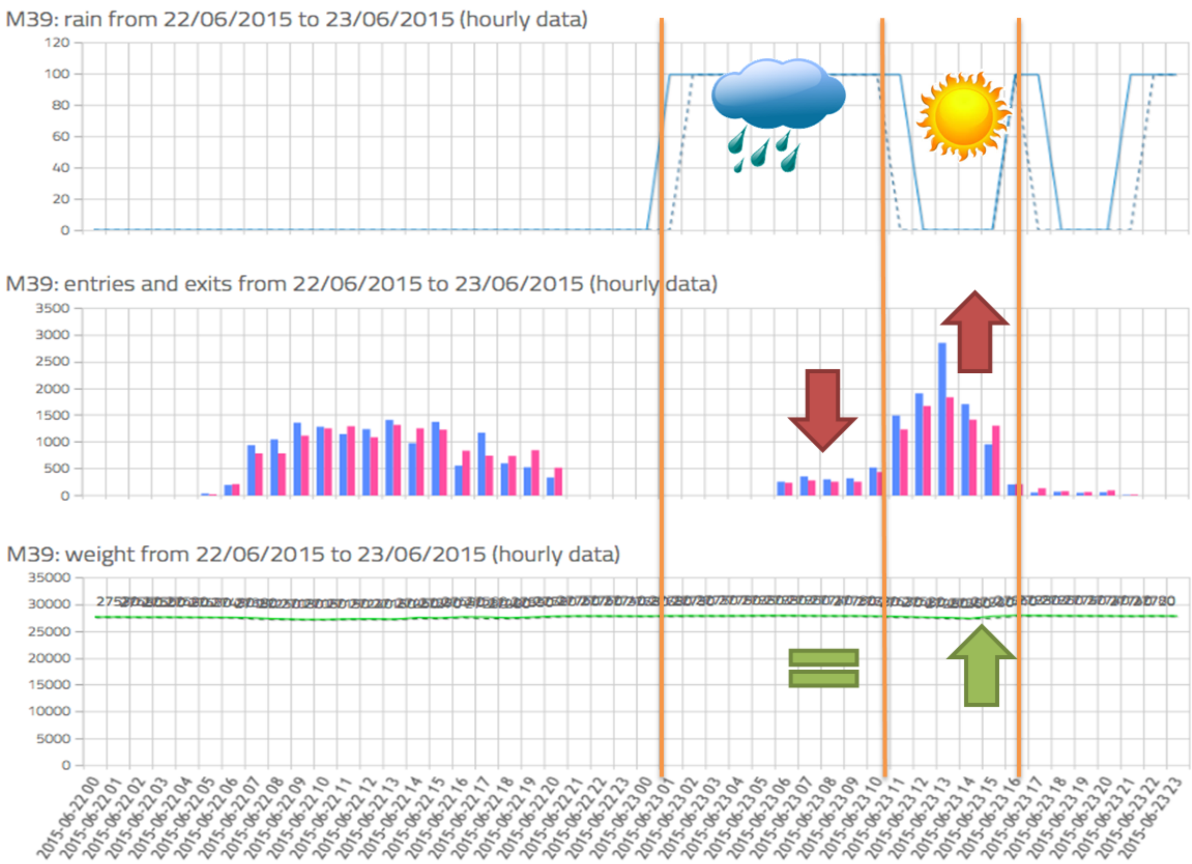


Fig. 4. Example of charts generated by the user interface.

An hexagonal button placed on the rectangular box summarizes the actual status of the system, reporting the last occurred alarm (rain, theft, activity issues, etc.).

In the map view, the rectangular boxes are distributed on a map in order to help beekeepers in the localization of their hives. The system makes use of OpenStreetMap [9], the open platform updated and maintained by a large community of contributors, notoriously more precise than other digital map solutions in the description of rural areas where most of the hives are supposed to be located.

Through a button located on the rectangular box, beekeepers can access data view, where the whole amount of collected information can be analyzed by means of a plot generation tool. Each user can decide which parameter has to be printed and the time period of interest (hours, days, months). More charts can be also generated in order to make comparisons among different physical quantities.

Data shown by means of the graphical representation can be also exported in CSV format for further analysis.

IV. Results

Fig. 4 shows an example of charts generated by the user interface. Some details have been added manually to the image for the sake of understanding.

The first plot (blue color) reports a "rain" event, identified by the value "100" from 2 AM of June 23 until 11 AM of June 6. Then it follows a "sun" event until 23 PM of the same day. Concerning the second graph, the bars reports the activities of the bees (blue bars describe exits, magenta bar describe entries). Compared to what happens on June 22, bees are less active as expected during the "rain" event, whereas the flights increase when the sun comes back, with a peak of exits approximately at 1 PM of June 23. Similarly the third graph (green plots) shows that the weight of the hive remains unchanged during the "rain" event, whereas it starts increasing between 3 PM and 4 PM due to the return of the forage bees. On the day before, the weight has a more regular increase in the afternoon thanks to the absence of the "rain" event.

It is worth noting that in the morning hours a small decrease of the weight occurs because of two factors: firstly, a certain amount of forage bees exit from the hive and start their flights; secondly, honey in the hive is also consumed to feed bees at larval stage. Concerning entries and exists from the hive, their sum is usually different from zero because of bees dying during the foraging activities. Such a difference could be in the order of 10% and in a healthy colony it is normally compensated by the number of eggs deposed by the queen bee.

V. Conclusion and Developments

Data concerning the activity of the bees and the hive weight allow inferring the health status of the colonies and the amount of honey produced/consumed. By correlating such an information with environmental condition (air temperature and humidity, light, rain, etc) we can provide indication about the behavior of colonies and forecasts about future trends. This feature is twofold important: on one hand, monitoring can help keeping the colony healthy, on the other hand data can be exploited to further optimize and improve the activity of the beekeeper, thus reducing costs and improving the quantity and quality of the products.

Despite beekeeping is based on centuries-old practices, the employment of technology appears to be mandatory nowadays, since the experience of beekeepers is not enough to interpret the signals coming from the colonies and the environment. Therefore the proposed solution could represent an effective response to novel needs of beekeepers.

Accordingly, the company is planning to extend the current version of the product to the control of apiaries by means of a master-slave architecture. Slave devices will communicate with the master unit, which will be responsible for the transmission of data to the main server through the GPRS/2G communication module.

The company is also working on an anti-theft version of the system, characterized by small wireless sensors equipped with accelerometers and weather probes that could be distributed into the apiary to extend the monitoring without increasing the cost of the system.

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