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Design of an Automated Hive for Bee Proliferation and Crop Betterment

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***Abstract*—Apiculture has been a method for harvesting honey and helping crop proliferation, nonetheless late climate changes have affected bee population. Having an automated hive as a tool for beekeepers would help to increase and protect current bee population guaranteeing crop proliferation needed for human consumption. In this paper, we propose an electronic beehive that recollect honey automatically, regulate the temperature of the inner hive and distribute food for bees. Preliminary results showed the control and automation of the proposed system as well as the prototype implementation, concluding that the automated beehive might be able to improve bee proliferation and crop betterment in an automated way.**

***Keywords*-mechatronics; apiculture; control system; automation; bees; sustainability**

I. Introduction

Bees are one of the most important animals in the world. They are responsible to pollinate about 20% of the flowering plants species worldwide and almost 400 different agricultural crops [1], [2]. Honeybees, as well as other pollinators, are responsible for 19 billion worth of agricultural crops just in the United States during 2010 [3], representing around 10 billion dolars. Worldwide, there are around 25,000 different types of bee species. This huge number is divided into over 4,000 genres of bees, which are then further subdivided into nine families [2].

As known, pollination is essentially for plant reproduction, and it depends on bees and other species, e.g. bats. Pollination is the transfer of pollen from the male part of the flower, to the female part. Some plants rely on animals to assist with their pollination process, while others can pollinate themselves or rely on the wind to do so [4]. Thus, taking care of bees is an important task for their proliferation and crop betterment. Nonetheless, late climate changes have affected bee population.

Apiculture is related to the maintenance of honey bee colonies commonly in hives made by humans. The job of a beekeper is related to keep bees healthy and controlled in suitable conditions. As a result, the recollection of honey and the production of other honey-based products, including beeswax, pollen and royal jelly, can be done [1]. Typically, beekeepers employ apiaries, also called bee yards or hives, as place for bees. Apiculture has been a method for harvesting honey and helping crop proliferation [3].

Nowadays, bees are dying at a worrying pace. The increasing mortality rate of the species is due to several reasons [1], [4], [3]: the wrong use of chemical pesticides, bad distribution of hives in different growing areas, poor coordination between the cultivation and bee pollination cycles, and bad environmental condition. Studies proved that if apiaries or hives do not have the right environmental conditions, i.e. temperature, then bees tend to abandon them or bees die [4].

In that sense, this paper aims to propose an automated beehive. Particularly, this proposed device will automate the recollection of the honey, it will regulate the inner temperature to ensure better environmental conditions for bees, and an automated distribution of food will be included. The contribution of this work is to show a proof-of-concept of the design and development of the automated beehive, that to the best of authors' knowledge, it is the first time that an integrated system for automation beehives has done as a useful tool for beekeepers. Preliminary results on control and automation of the whole system as well as the prototype implementation are presented.

The rest of the paper is organized as follows. Section II describes related work of apiaries. Section III presents the proposed automated beehive in detail. Preliminary results are presented and discussed in Section IV, and Section V concludes this work.

II. Related Work

The integration of the automation in beehives lacks in the literature. However, different approaches have been proposed in order to determine the health of bees, their patterns and behaviors, or monitoring their climate conditions. In that sense, a brief review of two approaches around the technology of automated beehives is presented.

In [5], the authors explore and study the behavior of honeybees. It is revelant in the sense that they applied an image processing system for monitoring bees. Particularly, they pretended to observe and determine the patterns in the healthy of bees by analyzing videos recorded at the inside of hives. The main advatange of this work is the usage of vision-based systems to monitor and better understand patterns in bees.

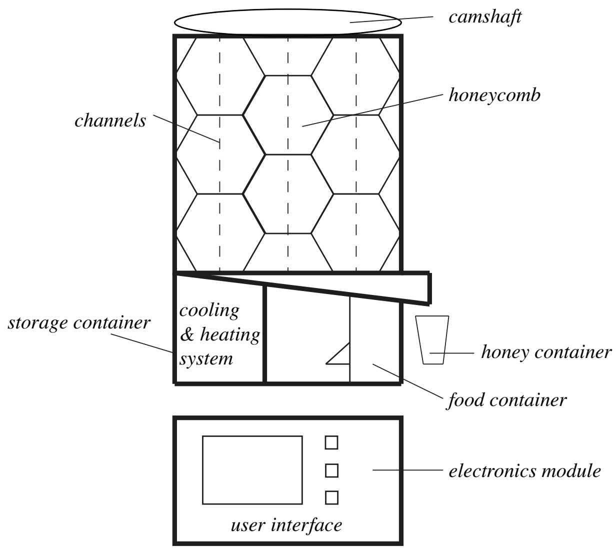

Figure 1. Schematic of the proposed automated beehive, i.e. smart hive.

The authors in [4] developed a wireless sensor network to monitor beehives inside and outside. They determined that migration of bees are due to changes in temperature inside the hives. Then, their sensor network monitored and sent alarms when there exist probability that changes in temperature might change the patterns of bees. In the same study, they surveyed different monitoring techniques previously done, such as: measuring temperature, humidity and gases, and audio, vibration and video. The key conclusion of the study determined that stable values of temperature maintain bees in normal conditions inside beehives.

Inventors Anderson and Anderson [6] claimed the design of an artificial honeycomb for use in a beehive enabling to remove honey without removing the honeycomb from the hive. This patent considered moveable cells that dephase the honeycomb, so honey flows down. This mechanism does not harm bees at all. However, this artificial honeycomb works manually, and not any electronics devices are attached to it.

III. Description of the Proposal

The proposed automated beehive, or smart hive, aims to be a support for beekeepers and as an alternative solution for protecting biodiversity and ensuring that crop cycles occur naturally. The smat hive is proposed to have three components: (i) the honeycomb, in which the bees produce honey, (ii) the storage container, designed for automation of food resources, and (iii) the electronics module, containing all electronics and computer devices. Figure 1 shows the schematic of the proposed automated beehive.

A. Honeycomb

The honeycomb is a grid inspired on the artificial honeycomb from [6]. In our proposal, the grid is made of channels that can move up and down to phase and dephase the cavities of the grid. These channels are automated by using a mechanism at the top of the grid (Fig. 1). Each channel is attached to a camshaft that rotates depending on the actuator. When the grid is dephased, the honey extraction occurs by gravity and also this procedure is harmless for bees. It is important to notice that once the honey enters at the bottom of the honeycomb, it is disposed within a single channel that goes directly to a honey container. This container is also automated with sensors. One sensor is attached at the top of the container that automatically detects if the container is full. When the latter condition occurs, the grid is closed, so the honey stops to flow down. An alarm is also set to inform to the beekeeper that the honey container is full and ready to be changed.

On the other hand, the honeycomb is provided with a temperature control system. It consists on a temperature sensor, a cooling system, a heating system and a microcontroller. The control system aims to regulate the inner temperature of the honeycomb between $25°$ C to $30°$ C, based on the studies related to temperature conditions reported in [4]. The controller is a simple on/off regulator that starts the heating system, and closes the cooling system, when the lower bound reference temperature is reached. Alternatively, the controller starts the cooling system, and stops the heating system, when the upper bound reference temperature is reached.

B. Storage Container

The storage container is a restricted access to bees, that is divided in two sections. The first section considers the hardware for the temperature system, and the second section is provided for food resources to bees when required.

First, to ensure that the cooling and heating systems do not affect the patterns of bees, these systems are located at one side of the storage container. The thermal effects by these systems are indirect, thus bees are never in contact with them. Second, if crop cycles are not regular (i.e. no food resources are available), then the storage container opens for bees. They can travel from the honeycomb to this container. At the food resources side of the container, an automated valve provides enough food to bees. This actions pretends to avoid swarming of bees (a peculiar pattern behavior that happens when there is no food [1]).

C. Prototype Implementation

A functional prototype was developed in order to validate the proposal, as shown in Fig. 2. This is a scalable prototype and, for animal policies, bees were not be considered at this stage of the project.

For the honeycomb, a single frame was manufactured (instead of usual 10 frames) in order to prove dephasing of the grid. For the temperature control system, the heating system was implemented with lights and the cooling system with a small fan, and the LM35 temperature sensor was used

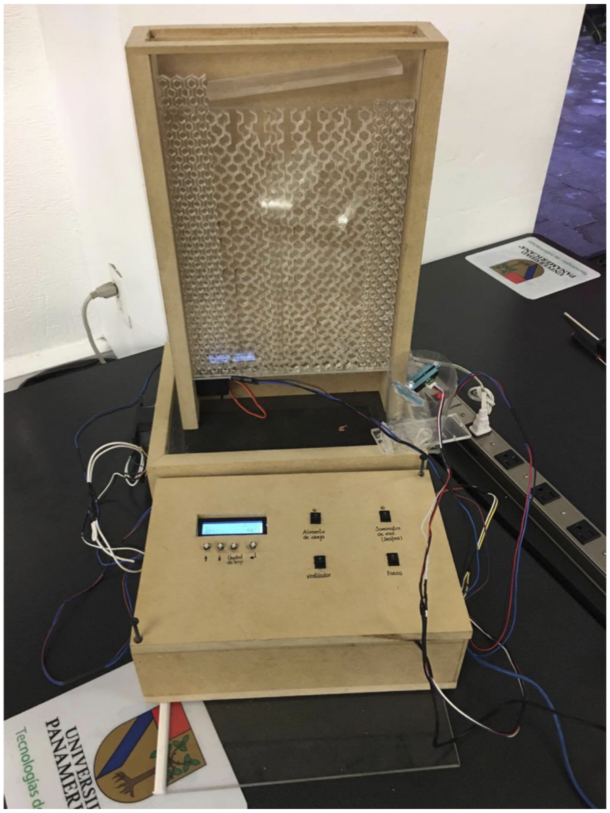

Figure 2. Prototype implementation of the automated beehive.

for monitoring purposes. An Arduino MEGA was employed as the microcontroller of the full system.

The electrical and electronics system of the automated beehive is shown in Figure 3. As noted, a user interface was implemented using an LCD display, a matrix of buttons, and switches. This interface aims to select the temperature reference and to manually turn on/off the lights and the fan. Additionally, two bulb lights where used for the heating system and a small fan for the cooling system. Two sensors were also connected: the LM35 temperature sensor, and a Sharp GP2D12 infrared proximity sensor to measure the level of honey in the container. Lastly, two servomotors were attached to the Arduino board in order to control the camshaft of the honeycomb, and the access for food resources at the storage container.

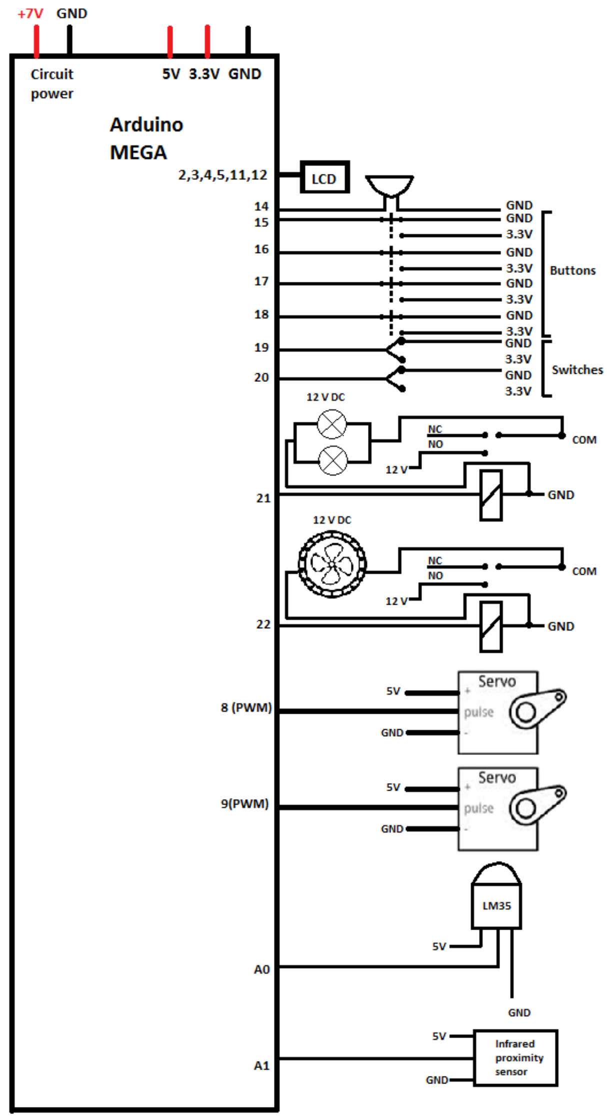

Figure 3. Schematic of the electric and electronics system of the automated beehive.

IV. Experimental Results

Three experiments were conducted for this system. One consisted on a qualitative experiment to determine if the grid of the honeycomb can be phased and dephased by using the servomotor and the camshaft located at the top of the structure. Then, another experiment considers to determine the time consuming of the temperature control system to increased/decreased 1° C. The last experiment consisted on the callibration procedure for the proximity sensor at the honey container.

A. Temperature Control System

To prove the performance of the temperature control system, we measure the time consuming of the temperature control system to increased and decreased 1° C. Twenty five samples were ran for each temperature event. Table I summarizes the results of this experiment. The average time to increase the temperature was 7.326 seconds per one degree Celsius, and 17.078 seconds to decrease the same degree Celsius.

B. Automated Honey Container

The next experiment consisted on callibrating the proximity sensor that detects if the honey container is full or not. An

Table I
TIME CONSUMING WHEN INCREASING/DECREASING 1° C IN THE HONEYCOMB

Increasing Temperature 1°C (Seconds)	Decreasing Temperature 1°C (Seconds)
7.21	16.20
6.52	18.46
7.29	17.57
7.11	18.14
7.24	18.27
6.89	18.42
5.94	18.22
7.73	18.20
7.40	17.89
7.73	17.05
7.64	18.65
7.83	15.02
7.03	16.25
6.31	17.02
7.94	17.07
7.61	18.38
6.70	16.11
7.26	15.74
7.52	15.29
7.92	18.28
7.73	17.71
7.40	15.06
7.73	16.16
7.64	15.31
7.83	16.47

Table II
MEASURES OF THE PROXIMITY SENSOR AT THE HONEY CONTAINER

Time (Seconds)	Distance (cm)
1	5.18
2	5.26
3	5.02
4	5.07
5	5.29
6	5.26
7	5.22
8	5.26
9	5.22
10	5.31
11	5.03
12	4.94
13	5.21
14	5.26
15	5.73
16	4.99
17	5.21
18	5.24
19	4.96
20	5.19
21	5.24
22	5.27
23	5.29
24	4.99
25	5.20

experiment was conducted by fully filling the container with a mix of honey syrup and water (5cm). Twenty five samples were collected during 25 seconds. Table II shows the results. As observed, the average measure from the sensor was 5.19cm, giving a relative error of 3.8%. Since the relative error was very small, it was decided to not implement any further pre-processing to the sensor signal.

C. Automated Honeycomb

Lastly, we tested subjectively the automation process of honey extraction, at the honeycomb, by pouring the honey over the honeycomb structure right in the gap created while dephased, and then close it to verify: if the honey could be retained, and then the easiness for the system to get empty. Visual inspection determined that this experiment successfully pass.

D. Discussion

According to the preliminary results, the temperature experiment determined that the controller needs at most 17.08 seconds to properly regulate the temperature. It is evident that the prototype is small, but this performance can be used to validate that the temperature controller works fine. It is important to say that for larger automatic beehives, the control system should be validated. In terms of the proximity sensor, the relative error of 3.8% showed that no enhancement to the sensor signals were required. Lastly, the automated honeycomb was tested by visual inspection. Other experiments should be done before a final validation of the system.

In this proof-of-concept, a simple on/off regulator was implemented. However, this prototype also allows to implement a more complex controller, such as a conventional PID or an adaptive controller. This should increase the accuracy in the output response of the temperature control system. If a bigger hive is required, both the fan and the light bulb can be substituted with more robust actuators, such as radiant heating and cooling by water-based systems.

To this end, this is the first time that an automated beehive is proposed for controlling temperature and automating honey extraction.

V. CONCLUSIONS AND FUTURE WORK

In this paper, we proposed an automated beehive for controlling the inner temperature of the honeycomb, for automatically extract honey without harming bees, and for controlling food supply. Particularly, the proposed system aims to be a useful tool for beekeepers in order to gain bee proliferation and crop betterment. In addition, a proof-of-concept of the fully system was implemented in a functional prototype.

Preliminary results concludes that the proposed automated beehive might be able to improve bee proliferation and crop betterment. Control the inner temperature and supply food during irregular crop cycles give right conditions to the bees to avoid swarming, i.e. migration. Additionally, automated honey extraction is included in the prototype.

Future work considers to analyze the full prototype with other tests. Then, a re-design of the proposed system is encourage in order to make it robust. Lastly, tests with bees will be also considered.

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