AUTOMATIC MICROCLIMATE CONTROLLED BEEHIVE OBSERVATION SYSTEM

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Abstract. Swarming of honey bee colonies is one of the factors that reduces profitability of beekeeping. Therefore recognition of preswarming condition of a bee colony is of industrial importance. The developed beehive observation system consists of 1) control subsystem, 2) measuring (temperature and relative humidity) subsystem and 3) video recording subsystem. Video monitoring of the front of the beehive (video camera 1) as well as environment (video camera 2) is switched on when untypical changes of microclimate are detected. That allows to find out reasons of each particular case of microclimate changes (swarming, direct sunshine, rain, strong wind, noise or other reasons).

Keywords: bee, beehive, observation system.

Introduction

Swarming is a natural way of proliferation of bee colonies when a part of the bee colony leaves the living place to establish a new colony in a new place at least some kilometres away from the current place of living. This mechanism of proliferation harms industrial beekeeping where proliferation of colonies is done in a controlled way ensuring that the new colony remains reachable for the beekeeper.

There are no easy detectable indications of preswarming conditions that would be visible for a beekeeper without opening the hive as swarming is a highly stochastic process that depends on genetical and other peculiarities of a particular bee colony [1, 2]. Thus early detection of preswarming condition of a colony requires inspection of bee colonies that causes additional labour costs and disturbs bee colonies.

Another option would be monitoring of microclimate changes of the colony in order to detect automatically the changes inside the hive that are similar to the changes in the behaviour of bees inside the hive during preswarming stage. One of the reasons of microclimate changes could be warm-up before take-off. This kind of phenomena is observed when colonies start flying from the place outside the hive [3]. Also other changes in behaviour of the colony that are not clearly visible from outside could cause measurable changes in the microclimate (temperature, humidity, oxygen concentration and carbon dioxide concentration) of the bee colony. In that case continuous measurement and analysing of microclimate parameters could allow automatic detection of preswarming conditions.

The reasons of significant microclimate parameter changes can be different: internal – it can be preswarming, swarming, overheating or environmental – rain, wind, outside noise and other reasons, which influence behaviour of bees inside the hive. Thus, it would be necessary to observe the hives and environment to find out the reason of microclimate changes in any particular case. Continuous video recording of hives by video cameras request big volume of memory on the computer as well as time for video analysing. Activating of video recording just during some changes in activity of bees would be necessary. Thus, microclimate monitoring systems [4, 5] should be interconnected with the video recording system where significant changes in microclimate parameters initiate activation of video recording.

We aim to develop an automatic measurement and monitoring system in order to find out the features of microclimate changes that would allow to detect the preswarming condition of the colony from other microclimate influencing reasons.

Materials and methods

The beehive observation system consists of 1) control subsystem, 2) measuring (temperature and relative humidity) subsystem and 3) video recording subsystem. Video monitoring of the front of the beehive (video camera 1) as well as environment (video camera 2) is switched on when untypical changes of microclimate are detected. That allows to find out the reasons of each particular case of microclimate changes (swarming, direct sunshine, rain, strong wind, noise or other reasons). The structure of the observation system is demonstrated in Figure 1.

The system currently is installed to monitor two bee hives with colonies. It can be extended to a bigger number of observed hives increasing the number of sensors or reducing the number of sensors per hive.

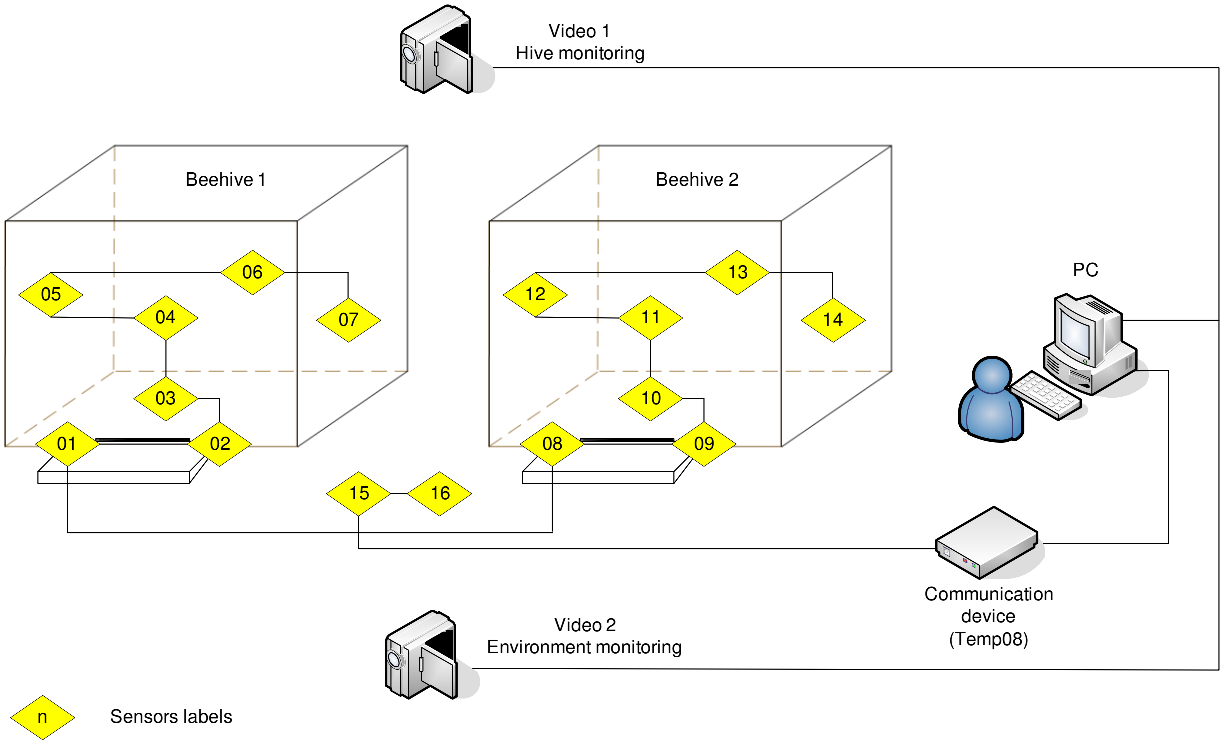

Fig. 1. **Overall structure of the system**

1. Control subsystem

The control subsystem consists of a computer and software.

The computer receives data from the measuring subsystem to store it in memory and analyse it. Accordingly to the analysis of microclimate data performed by software the video recording subsystem can be activated by the computer. Measurements as well as video capture files are stored in the computer on the hard drive.

The software that is developed for the monitoring system consists of two parts: 1) data management and 2) video recording control.

The data management software reads the data from sensors using HyperTerminal communication type between the computer and communication device (interface between sensors and the computer), which is connected to the computer through COM port. Frequency of data capturing can be set in the program. When software has read the data it prints them on the screen and saves in MS Access database. The current data are graphically presented on the screen. Also it allows seeing the previous data on the graphic and exporting it into MS Excel file.

The software was created by using MS Visual Studio 2005, C# programming language. Connections to the database were managed by help of ADO.NET technology [6].

In the main window of the program data of the current assignment are included; switch on and off video cameras and monitoring of the current data. By picking the needed sensors from the list, software allows to watch how the data were changing from the beginning of the experiment till the last reading (Fig. 2).

Microclimate measurements can be exported in the MS Excel file. By choosing the sensors from the list it is possible to monitor which data were saved and export them. After that in the MS Excel it is possible to create graphics and to work with them. It eases the use of the obtained data for analysis.

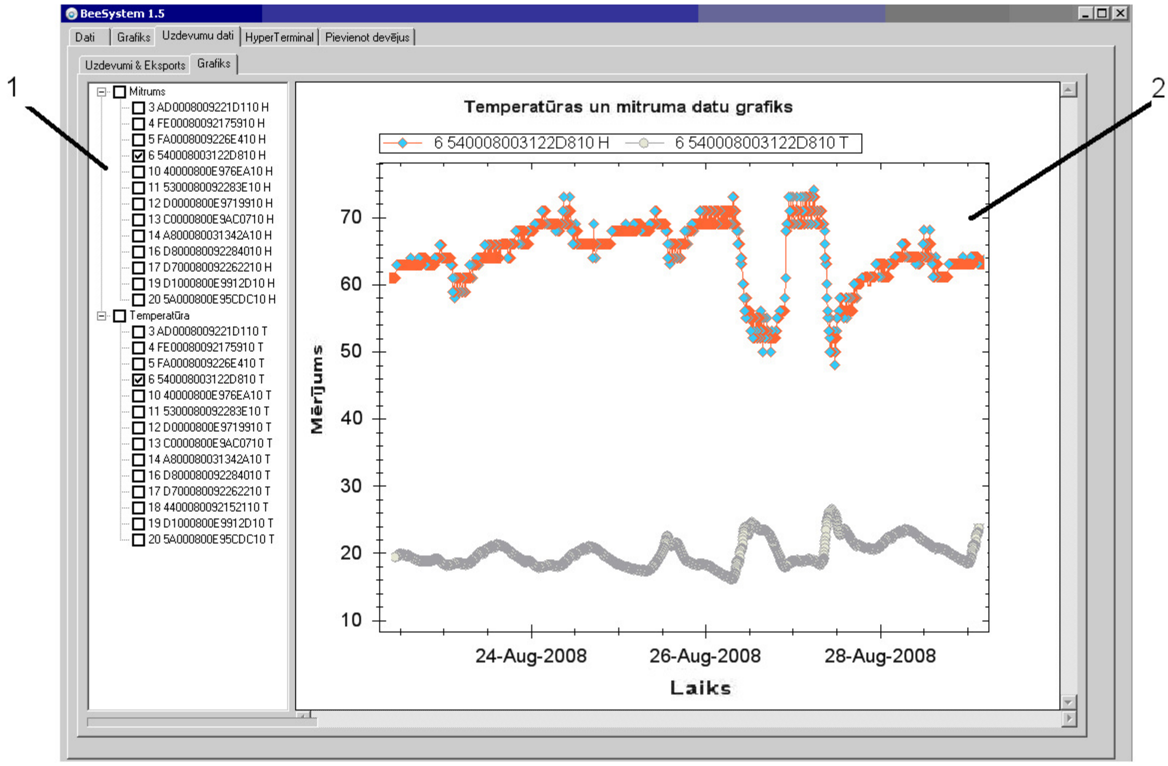

Fig. 2. **Screenshots of the program, functions of fields:** 1 – list of all the sensors that exist in the system; 2 – graphical visualization of the chosen sensors

Also the system allows real time monitoring of temperature and humidity changes in the hive. Every sensor is placed in the right position on graphic and shows what temperature and humidity in the current moment is at that place and how these parameters changed (Fig. 3).

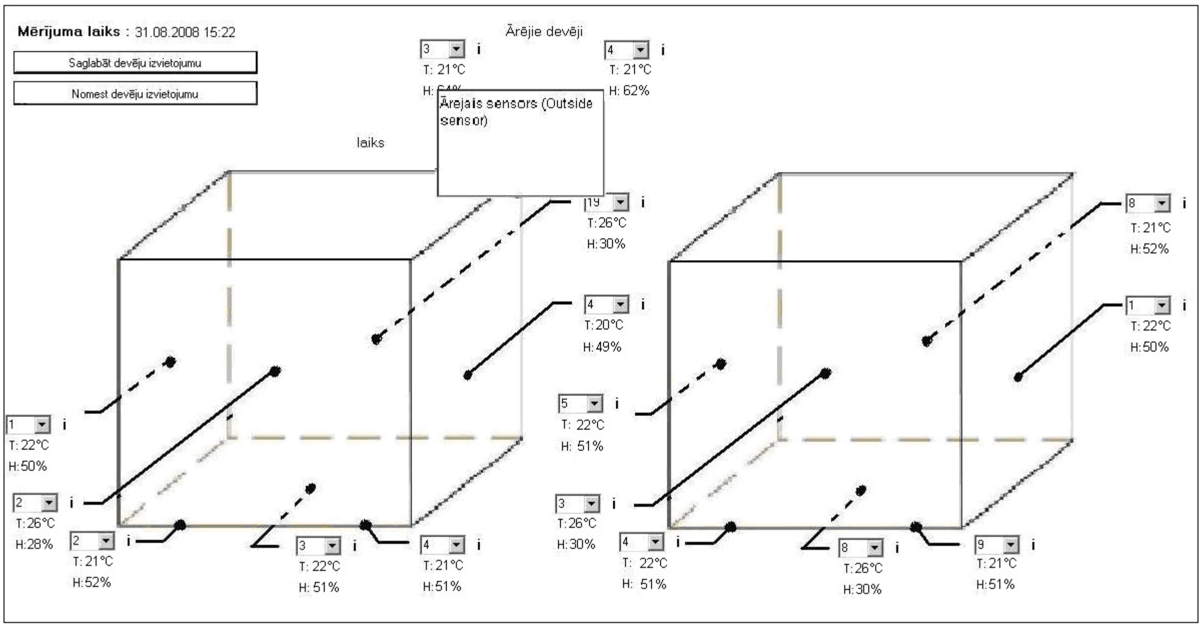

Fig. 3. **Visualization of data in real time**

The video recording control program receives the data and analyses them – if the values are out of borders for a period of time, the system switches on video cameras for some time, so that later it could be analysed why the system turned on – was it because of the bees preparing for swarming or was it some outside factors. The system has different parameters and based on them the system analyzes the data for one sensor when the system should switch on cameras (Fig. 4).

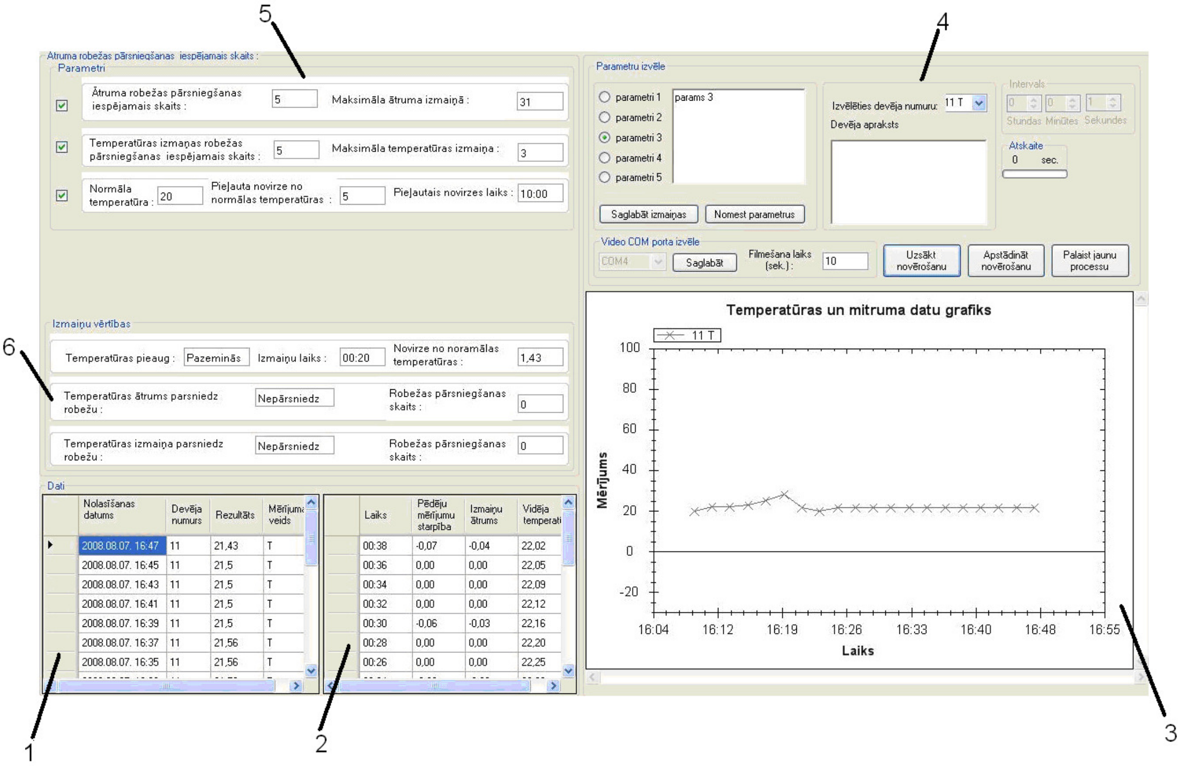

Fig. 4. **Video controlling system, functions of fields:** 1 – data readings; 2 – readings differentiation; 3 – graphical visualization of readings; 4 – parameters, 5 – readings criteria parameters; 6 – data changes values

The system traces temperature and humidity changes, change speed and time of these changes and based on these criteria decides the possible state of bees in the hive. For example, if the speed changes too fast or the change of the values is too big – lowers or drops, that means that something might affect the bees – an inside or outside factor. Afterwards video monitoring allows to determine what exactly happened. Also a possibility exists of creating different variants of those readings for sensors placed in different parts of the hive. That allows configuring the system for a concrete sensor, based on which normal parameters should be, for how much temperature can be changed and for how long these changes can last.

The system can trace the possible fault automatically, without the operator to be always near the computer. If for some reason the data are not getting read anymore, the system can turn on the sound signal to alarm about it, also it can send e-mail to the user or users that the system has some errors. That helps to eliminate errors and faults in the system and maintain continuous data reading.

All the data are saved in the database, also a list of all assignments, sensors and other classificatory which help to work with the system.

2. Measuring subsystem

Seven sensors of temperature and humidity are placed in each of two hives (middle of each wall, top and floor of the hive and entrance). Two additional sensors are placed under the hive to monitor the outside temperature and humidity being protected from direct sun or rain influence. Two sensors are used to have reliable data about ambient temperature and humidity. All sensors are combined in one net and are connected to commutative device, which sends data to the computer. The data from sensors are saved in the database on the hardware of the computer.

MD3020 microcircuit [7] with HIH3610 humidity sensor [8] and DS18S20 temperature sensor is used for temperature and relative humidity measurement inside and outside of the hive.

Sensor DS18S20 has digital output. HIH3610 has analogue output that is converted into digital by MD3020 microcircuit. Digital signals reading is done by Temp08 or Log08 devices [9] that are connected to the computer through COM port.

3. Video recording subsystem

For video monitoring Sony's B1700 cameras are used. The cameras are connected to the video adapter located in the computer. One camera is focused to the entrances of hives to be able to register swarming that can be recognized as intensive flying of bees around the hive mostly leaving it.

Another camera is oriented to detect the view and sounds of environment that surrounds the observed hives to detect environmental influence on the colonies located in the hives.

Results and discussion

The developed system was tested in a field experiment in August-October, 2008 in Jelgava, Latvia with two colonies of *apis mellifera* honey bees. The data about changes of temperature and humidity in the hive and under the hive were captured. The data of some sensors about dynamics of temperature (Fig. 5) and relative humidity (Fig. 6) of August 22, 2008 indicate that extremes both of temperature and relative humidity are registered by the ambient air sensor and the sensor in the bee nest (between frames in the middle of the nest, 5 cm from the top of the frame).

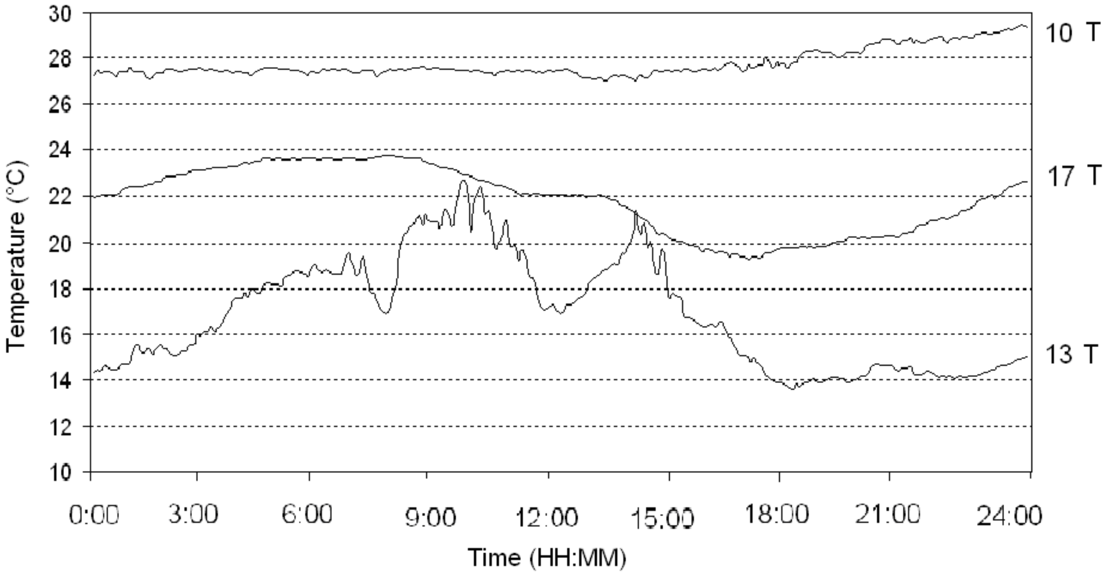

Fig. 5. **Temperature measurements of August 22, 2008:** ambient temperature under the hive (13T), side wall inside the hive (17T), in the bee nest (10T)

Ambient temperature changes during the day within a range of 9 ˚C (14-23 ˚C) and is relatively unstable. The bee nest temperature is higher and is very stable within a range of 2 ˚C (27-29 ˚C).The temperature on the wall changes within 5 ˚C (19-24 ˚C) being quite stable. Twice the wall temperature equals to the ambient temperature when ambient temperature has relatively high peaks. There is no strong instant influence of ambient temperature to both sensors inside the hive.

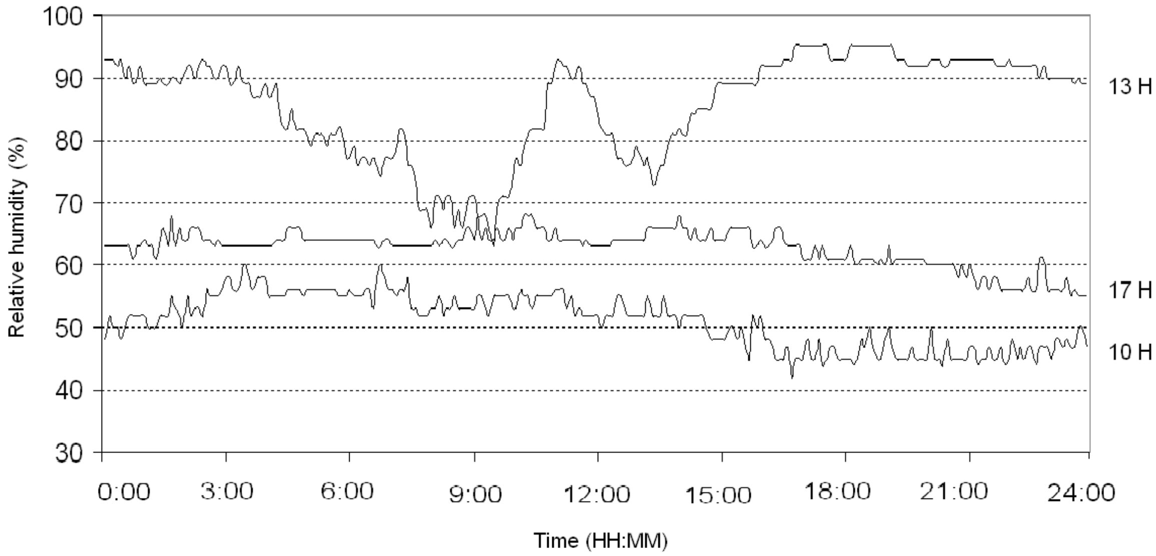

Fig. 6. **Relative humidity measurements of August 22, 2008:** ambient humidity under the hive (13T), side wall inside the hive (17T), in the bee nest (10T)

Ambient relative humidity changes during the day within range of 30 % (65-95 %). The bee nest relative humidity is lower and varies within a range of 17 % (43-60 %). The relative humidity on the wall changes within 12 % (55-67 %) being quite stable. Both sensors that are located inside demonstrate low influence of the ambient humidity. Still the "noise" of all sensors seems similar.

Relatively slow speed of changes of temperature and relative humidity in the hive is a good precondition to be able to register changes in the bee colony behaviour before swarming.

The results of the video monitoring demonstrate behaviour of bees over the day, at what time they are more active and how the outside weather influences their activity. Also we can see that, for example, loud noises can influence the activity of the bees and cause climate changes in the hive.

Unfortunately, the observed bee colonies did not swarm during our observations as observations were started after intensive swarming period.

It was found out that bees are not disturbing the readings of humidity sensors by coating their surface with wax or propolis.

Conclusions

1. Automatic measurement and monitoring system of microclimate changes in a bee colony and video monitoring of environment are developed using magistral structure of digitalized sensors network.
2. Relatively slow speed of changes of temperature and relative humidity in the hive during normal work of the colony is a good precondition to be able to detect swarming-related changes in the bee colony behavior.
3. Video recording activation depending on changes of temperature and humidity in the hive allows efficient long-time monitoring of swarming.
4. The system is adapted for bee colony observation specifics allowing convenient interpretation of data both working with real time data as well as with historical data stored in the data base.
5. Digital outputs of data from sensors are used to reduce data transmitting errors.
6. The developed observation system can be used in other similar projects, where it is needed to monitor the climates changes. The system can be easily edited and configured to adapt for particular needs of a project.

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