Beekeeping in the future – smart apiary management

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Abstract— **Future of the traditional beekeeping is to implement smart apiary management and start to use automatic and remote tools for bee colony monitoring together with beehive control mechanisms to improve bee colony productivity. Within the ERA-NET ICT-Agri project "ITAPIC" different bee colony monitoring and control systems together with its combinations were introduced and analysed. This paper presents authors vision for implementation of Precision Beekeeping together with the smart apiary concept. Different parameters of the bee colony can be monitored: temperature, humidity, gas content, sound, vibration etc. Continuous monitoring of some bee colony parameters is very challenging and not user friendly, allowing using it only for research purposes, not for practical implementation by the beekeepers. Precision beekeeping idea is to introduce tools that can be easily implemented into beekeeping practice. This paper describes developed systems and its combinations for successful smart apiary management. Developed systems are based on temperature, sound and video monitoring. Both data transmission types: wired and wireless are applied and compared. As well discussion of automatic beehive heating or/and cooling system implementation into practice is opened. As apiaries usually are placed outside in rural areas, important part of the smart beekeeping is usage of alternative energy for powering all the devices. Most suitable alternative power supply to this moment is usage of solar power with solar panels, which can be mounted on the hive. Together with hardware part it is needed to develop software part for data observation. Software part should be developed as a web system or/and mobile application. Cloud system with decision support functionality and with additional option for informing the beekeepers about changes in the state of the bee colonies could be considered as well.**

Keywords—Precision Apiculture; Precision Beekeeping; bee colony monitoring; smart beekeeping, smart apiary.

I. INTRODUCTION

Precision Agriculture is well developed methodology for sustainable production of agricultural products [1]. Several sub-branches like, precision farming [2], precision livestock farming [3], precision viticulture [4], precision forestry are already defined and recently also precision beekeeping (PB or precision apiculture) joined the Precision Agriculture scope [5]. PB combines Information Technologies and beekeeping science and is defined as an apiary management strategy based on the monitoring of individual bee colonies to minimize resource consumption and maximize the productivity of bees [6].

Beekeeping is traditional and very old branch of agriculture. Beekeeping has huge impact on all agricultural field, as bees are the main insect pollinators and plays the important role in whole crop production and survival of wild plants [7]–[9]. That's why the health of honeybee populations has been a growing concern amongst scientists, ecologists, farmers and policy makers [10]. To evaluate bee colony state, health and development without usage of information and communication technologies, beekeepers have to open the hive and make visual observations. Such often intrusive inspections are time consuming and possible can lead to a stress of the colony. Thanks to the rapid development of sensor technologies honeybee colony states and status can be monitored remotely [6], [11]–[13]. So there is big interest in developing new non-invasive methods that can further contribute to assessing colony status.

Authors cannot imagine future of the beekeeping without implementation of information technologies tools for colony management. Within the ERA-NET ICT-Agri project "ITAPIC" (www.itapic.eu) different bee colony monitoring and control systems together with its combinations were introduced and analysed. This paper presents authors vision for implementation of Precision Beekeeping together with the smart apiary concept.

II. SMART APIARY MANAGEMENT

Different parameters, like temperature, humidity, gas content, weight, sound, vibration and different measurement or monitoring systems can be developed and introduced to the beekeepers for the bee colony online and real-time monitoring. Implementation of some measurement systems for bee colony continuous monitoring is very challenging and not user friendly, that's limits it's usage by the beekeepers. Precision beekeeping idea is to introduce tools that can be easily implemented, used and maintained by the beekeepers.

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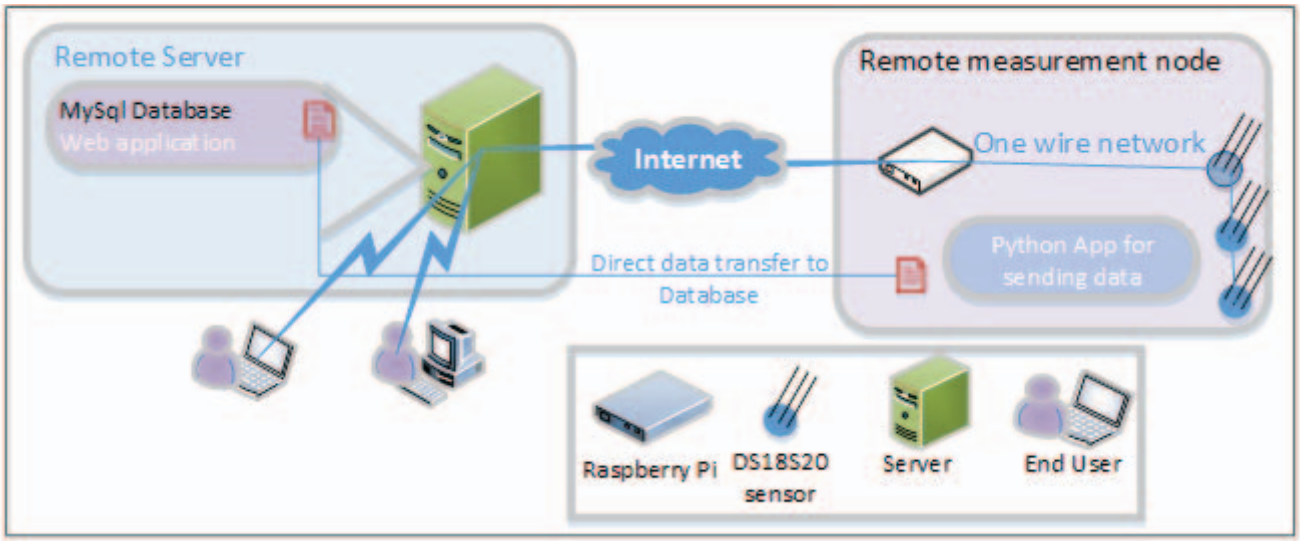

Figure 1. Architecture of wired temperature monitoring system

It is concluded that simplest, cheapest, but at that time also informative sensor to place into bee hive is temperature. Temperature monitoring of the bee colonies has the longest history. By monitoring of the bee colony temperature some important states of the honeybee colony can by identified and monitored, like death, brood rearing, queenless and swarming state [14]. Within the project wired (see Figure 1) and wireless temperature monitoring systems (see Figure 2) together with the web systems for data observations were developed and tested. Both systems have advantages and disadvantages. Usage of wireless sensors instead of wired leads to increase of system implementation costs, but grants ease installation and maintenance tasks. Developed multi-node wired temperature measurement system for bee colonies online monitoring, is based on Raspberry Pi microcomputer. Raspberry Pi is a small size computer, allowing connecting different types of external devices, including various sensors. Dallas DS18S20 temperature sensors were chosen to monitor temperatures in honeybee hives. Sensors were connected to Raspberry Pi via 1-Wire network. Software, written in Python programming language, was used to gather data from bee hives and store in MySQL database for further data analysis and comparison between hives [15]. Approximate cost of one Raspberry Pi based system for monitoring of 20 bee colonies is 120,- EUR (only components and materials, without labour costs).

Wireless monitoring system consists of three main components: measurement node, main unit and remote database server. Measurement node obtains data from sensors and it is formed from a low-power microcontroller, a wireless transceiver, on-board sensors and power source. Main unit is required for data transfer and consists of a low-power microcontroller, a wireless transceiver, peripheral extension connectors and a power source. Remote database server is required for data storage for further analysis and demonstration. Measurement nodes are attached outside the hive and only the sensors are installed into the hive [16]. In authors case price of wireless system was relatively high, because it was as prototype device. Approximate cost of one wireless system for monitoring of 20 bee colonies is 400,- EUR (only components and materials, without labour costs). Nowadays costs of wireless sensors and components are decreasing fast, so it can be predicted that cost of wireless system could be near to cost of wired temperature monitoring system.

As well there is still open question for a discussion – "Is there any harmful effect of wireless data transmission on bee health?" Almost simultaneously with the development and improvement of wireless technologies, there are a lot of discussions in the society about the wireless technology impact on living organism's health. Author U. Warnke in his paper looks at the effects of wireless technologies in a bigger picture: "Man-made technology created magnetic, electrical and electromagnetic transmitters which fundamentally changed the natural electromagnetic energies and forces on earth's surface – radically changing million-year-old pivotal controlling factors in biological evolution. U. Warnke also says, that the artificial magnetic, electric and electromagnetic fields are confusing animals, because they were depending on the natural fields, which helped them navigate to their home environment. These fields also affect bees [17].

Figure 2. Wireless system for bee colony monitoring

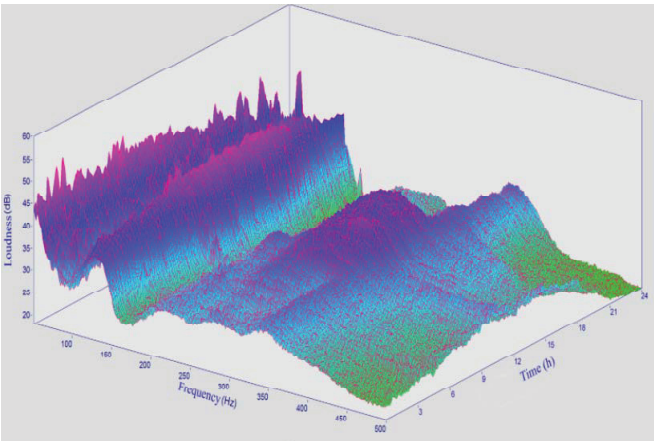

Figure 3. Example of bee colony sound analysis

Our environment of the century of technologies is polluted by electromagnetic, electric fields. It is considered, that some of the living beings, including bees are in danger, due to that. Particularly dangerous to bees are cell phones/cell phone towers as these devices communicate via strong electromagnetic radiation. Wi-Fi devices in respect to cell phones can be considered less harmful, as the Wi-Fi devices operate on power levels far lower than cell phone or Smartphones. While cellular tower may emit 50 Watts, a Wi-Fi router is restricted to 4 Watts or 1 Watt, depending on the frequency band in use.

For several years there has been observed a phenomenon that is called Colony Collapse Disorder (CCD). It is a mysterious disappearance of entire bee colony. Unusual colony losses are reported from many countries worldwide, including Switzerland, half of all US American States, Canada, Austria, Germany, South Tyrol, Spain, Poland and New Zealand. There can be many reasons what causes CCD. But one of the reasons stands out – artificially made electromagnetic fields.

Next colony monitoring system, which can be considered for the practical usage is audio monitoring of the bee colonies. The goal of the audio monitoring system is to analyze bee colonies sounds to identify normal (healthy) and abnormal activities of the hives (see Figure 3). Within the ITAPIC project hives are monitored continuously and every 5 minutes the spectrum curves of the emitted sounds are analyzed. In a healthy hive two main frequency ranges are clearly visible in the spectrum. These dominant frequency ranges represent the typical buzz sound of the hive (100-150 Hz), and the rise and decline in the proportions of the wing beat frequency (200-250 Hz) during the collection phase during the day. By combination with environmental data the acoustic data gives a good indicator for a healthy hive. In authors case applications of sound recording devices (microphones) were investigated. In other cases microphone can be substituted by accelerometers to measure vibrations in order to provide information on colony activity and development [10].

Within the ITAPIC project also video observation system for bee colony monitoring on the hive entrance was developed (see Figure 4). The purpose of video monitoring of a bee hive is to analyse bee activity at the hive entrance and observing the bee colony as naturally as possible, without disturbing the bees. By counting the number of bees entering and leaving the hive during the day, general activity patterns can be observed and analysed. The Video Monitoring Unit (VMU) is constructed as an external box positioned in front of the bee hive as an extension to the hive entrance. The bees are thus forced to pass through the monitoring unit whenever they enter or leave the hive. VMU consists of a closed box and a lid on top forcing the bees to walk into and out of the bee hive as opposed to flying. Automatic online video system is based on Raspberry Pi. The system succeeds in automatic counting honeybees, identifying their position and measuring their in-and-out activity [18]. Implementation of video monitoring system for all colonies is relatively expensive and author's proposal would be to use one such system for apiary. Approximate costs of one video monitoring system is up to 150,- EUR (only components and materials, without labour costs).

The last system which surely has to be in the smart apiary is weight monitoring of at least one control colony, because equipment of all colonies with automatic scales is too expensive. In the market there are huge amount of different scale systems and each has an option to choose the one suitable for theirs needs [11], [19]–[21].

In some cases different systems can be combined together using the one basic platform, for example video or audio system, which is based on Raspberry Pi can easily integrate temperature sensors. Weather station also is needed in the apiary to monitor the ambient environment and give input data for the hive heating/cooling system (if applicable).

Figure 4. Developed video monitoring system

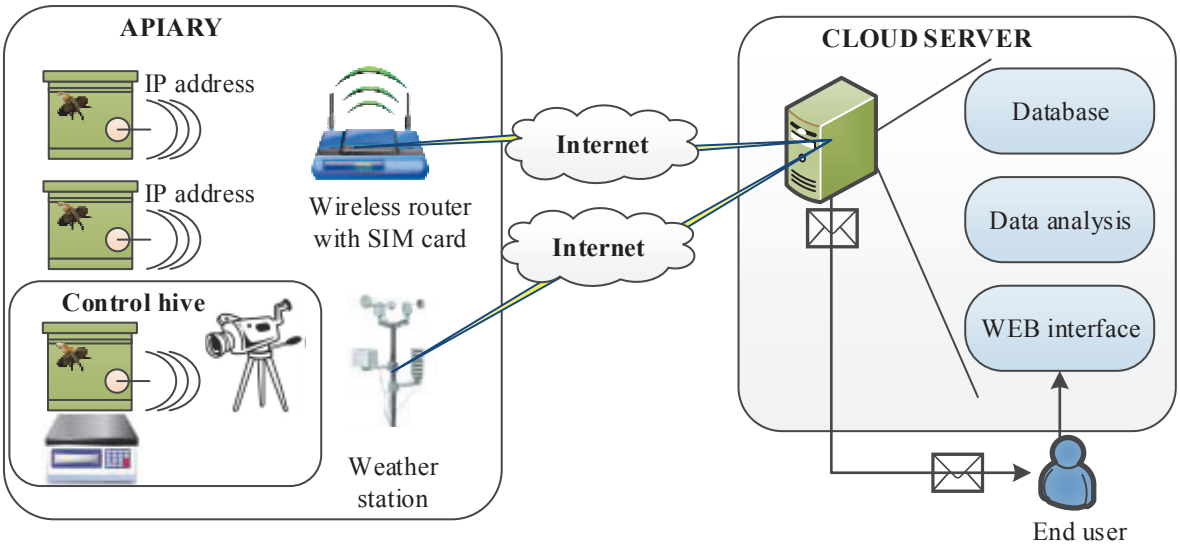

Figure 5. Smart apiary concept

Schematic view of smart apiary for implementation of Precision Beekeeping is demonstrated in Figure 5. Authors propose to use one control hive with automatic scale system and possible video monitoring, but all hives should be equipped with temperature and sound/vibration monitoring. In the future, as wireless technologies become less expensive system should be wireless. As apiaries usually are placed outside in rural areas, important part of the smart beekeeping is usage of alternative energy for powering all the devices. Most suitable power supply to this moment is usage of solar panels, which can be mounted on the hive.

Not only the monitoring, but also control of the microclimate in the beehive is discussable topic. Automatic beehive heating or/and cooling system implementation into practice can be considered. During hot summer cooling can be done to help bee colony to maintain stable temperature in the hive. In cold climates heating can help colonies to save its physiological resources during the passive winter period to overwinter with minimal food consumption, in addition colonies can be placed in special wintering building with stable microclimate conditions [22], [23].

For the successful application of the smart apiary management together with the hardware systems also software part should be developed and implemented. Data analysis should be done automatically based on pre-defined algorithms or using the neural networks, which can be integrated in the decision support system [15]. Software should be developed as a web system or/and mobile application.

III. CONCLUSIONS

Precision Beekeeping direction of the Precision Agriculture is still in developing stage. Nowadays there are different measurement systems available for real-time honeybee colony monitoring, but data analysis phase and development of decision support systems still to be improved.

Smart apiary management cannot be done without application of information and communication technologies, but each individual beekeeper should define what systems he needs most. Smart apiary management should minimize the manual inspection of colonies, and maximize the colony health.

The advantage of Precision Beekeeping would be the possibility to detect changes or problems in the colonies at an early stage giving the beekeeper the possibility to take counter measures to save bee colonies.

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SEVENTH FRAMEWORK PROGRAMME

ITAPIC Application of Information Technologies in Precision Apiculture