DOI 10.5162/SMSI2020/B3.1

Integrated Intelligent Sensor Systems for In-Hive Varroa Infestation Control in Digital Bee Keeping

Andreas König[1]
[1] Institute of Integrated Sensor Systems, TU Kaiserslautern, Kaiserslautern, Germany
koenig@eit.uni-kl.de

Summary:
Bees are recognized as an indispensable link in the human food chain and general ecological system. Numerous threats, from pesticides to parasites, endanger bees and frequently lead to hive collapse. The varroa destructor mite is a key threat to bee keeping and the monitoring of hive infestation level is of major concern for effective treatment. Sensors and automation, e.g., as in condition-monitoring and Industry 4.0 with machine learning offer help. Here, integrated in-hive gas sensing system for infestation level estimation and emerging novel in-hive optical approach for varroa counting are presented .

Keywords: Gas sensing, varroa infestation level, digital bee keeping, in-hive measurement

Introduction

Major issues from environmental pollution to invasive species are threatening our ecological system and the human food supply. Insects, and honey bees in particular, play a decisive role, e.g., for pollination. The varroa mite parasite is a major threat to bee keeping and the cause of many bee colony losses. The monitoring of the varroa infestation level is one important task of conventionally operating bee keepers. Though there is a community practicing treatment free bee keeping [1], the majority of bee keepers follows standard treatment practice, e.g., by formic acid, which needs to know the right time to start treatment based on the hive infestation level. Sensors and automation, like in home automation, condition-monitoring and Industry 4.0, can both alleviate hive keeping and also make it much more effective. Thus, in the last 10-15 years numerous approaches to digital bee keeping can be observed [1]. In our IndusBee4.0 project, in-hive integrated sensor systems and machine learning based data analysis is pursued. Here, options for in-hive gas sensing and in-hive vision-based varroa counting are investigated to achieve small, effective, and affordable intelligent integrated sensor systems for continuous in-hive-monitoring and state estimation, e.g., monitoring and reporting the desired infestation level.

Conventional Varroa Monitoring Methods

There are several standard methods available for conventional varroa infestation level assessment. They all have in common, that they imply substantial effort for the bee keeper and deliver results only at larger time steps. The analysis of hive debris including mites, dropping from the hive bottom and collected on a slider or tray, is most common. Usually, three days are expended until a manual, or more recently (semi) automated vision-based analysis, of the debris for the number of varroa can be conducted. The hive infestation level can be estimated from this count [1]. Another common approach, also denoted as flotation method, extracts a bee sample from the hive and drowns them to separate bees and varroa. The powder sugar and the CO2-based sedation are two alternative more bee-friendly variants. Again, hive infestation level can be estimated from the count. Sample adequateness will probably depend on the location of extraction in the hive. A more recent principle approach tries to scrutinize in and out going bees at the flight hole for varroa mites clinging to them, e.g., [3, 1]. The advantage is the availability of continuous monitoring at the hive, but the computational effort and real-time requirement is substantial and same bees will be counted several times, going on multiple missions a day. Thus, alternative simple and quasi continuous in-hive monitoring methods less are of interest.

Indirect Sensor Based Infestation-Level Estimation

Basic investigations in the past have revealed, that both the sound patterns emitted by bees as

DOI 10.5162/SMSI2020/B3.1

well as the air composition inside the hive host information, that correlates with the varroa infestation level, as determined by the conventional methods from the previous section. Hive sound patterns also allow to detect hints on 'missing queen', advent of 'swarming mood' etc. Thus, in our and many others previous work, microphones and signal processing and analysis have been applied, see e.g., [1]. MEMS microphones deliver in our Pi Zero W based **SmartComb** in-hive measurement system [1] the acoustical information on hive state, including continuous cues on varroa infestation.

Further, there are also early investigations on correlations of hive air composition and varroa infestation level. One recent intriguing work, based on a set of Figaro gas sensors and an external measurement system confirmed the existence and usefulness of such a correlation [2]. The availability of highly integrated gas sensing systems promote the improvement of the concept to cheap in-hive measurement systems, non-obtrusive to the bees, and continuously delivering registrations at any desirable rate. For instance, the Sensirion SGP30 multi-pixel sensor system [1] or the BOSCH Sensortec BME680 are candidates for this analysis. The latter sensor has the advantage, that the sensor heating temperature basically can be controlled and modulated for temperature cycles in measurement (virtual sensors).

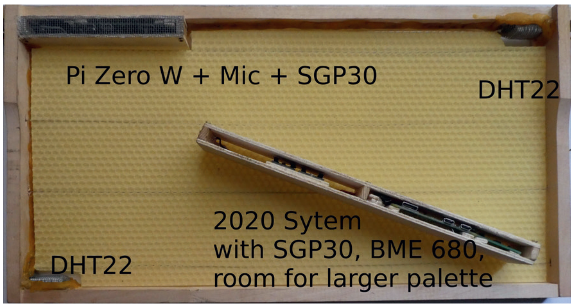

*Fig. 1. **SmartComb** with SGP30 from 2019 ready for hive insertion and the extendable 2020 version with SGP30, BME680 et al..*

The approach requires knowledge of true hive infestation level, which is not known. Estimates can be obtained by techniques of Section 2 or by an emerging novel alternative:

In-Hive Bee and Varroa Counting System

For honey harvest, there are two approaches: swapping the bees off with a bee brush or installing an intermediate floor equipped with bee escapes a day before. As illustrated in Fig. 2., the bees will move one by one through the narrow channel of the bee escape to rejoin with colony and queen. The vacated honey combs can be peacefully harvested. Additional exploitation option is to record and inspect the bees, as in flight hole inspection, by an embedded camera system., e.g., a cheap Pi Zero node and camera employing active illumination above 580 nm invisible to bees.

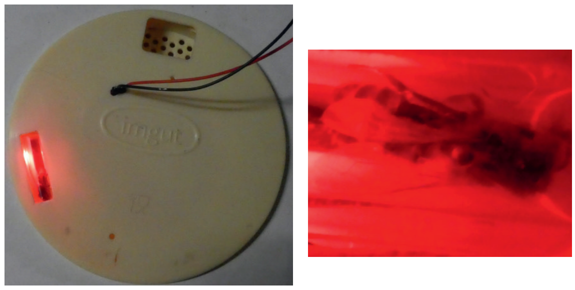

Fig. 2. Extended bee escape for varroa counting

Thus, a large unique bee sample could be drawn and bee and varroa counts determined. Processing could be done on host *post-mortem*.

Results

A low-cost, small, and unobtrusive in-hive monitoring system has been achieved [1] and extended with integrated E-nose capability. Fig. 3 shows a short campaign from a hive bottom in late winter 2020 as proof of functionality.

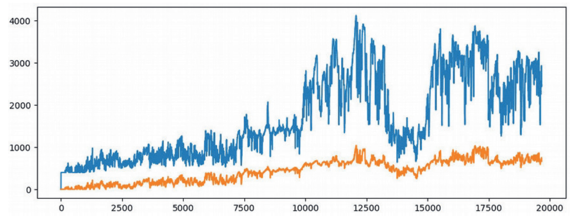

Fig. 3. eCO_2 (blue) and TVOC (orange) SPG30 data from hive varroa floor for 12 h from 10:30 am.

In contrast to similar E-nose projects, the measurement data obtained close to the brood nest in from April to August campaign first has to be correlated with conventionally determined infestation levels. Machine learning will help to create a virtual varroa infestation level sensor, potentially generalizable to foulbrood etc.

References

[1] A. König, IndusBee4.0 – Integrated Intelligent Sensory Systems for Advanced Bee Hive Instrumentation and Hive Keeper's Assistance Systems, Sensors & Transducers Journal, 237.9-10, *109-121 (2019)*

[2] A. Szczurek, M. Maciejewska, B. Bąk, J. Wilk, J. Wilde, M. Siuda, Detection Level of Honeybee Desease: Varroosis Using a Gas Sensor Array, SEIA'2019, Tenerife, 25-27 Sep. 255-256 (2019).

[3] L. Chazette, M. Becker and H. Szczerbicka, Basic algorithms for bee hive monitoring and laser-based mite control, 2016 IEEE SSCI, Athens, 1-8 (2016)