Development of monitoring system to assess honeybee colony health

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1. INTRODUCTION

In the last decades, beekeepers recorded millions of honey bee (*Apis mellifera*) colony losses due to climate change, crop chemical treatments, but mostly the parasitic spreading of mite, in particular *Varroa destructor*. The mite lives synchrony with the brood, parasitizing bees brood before capped. The growing mites start feeding on the larva, weakening without killing the host. Once the affected larva becomes a bee, it leaves the brood cell, by uncapping the wax cap, allowing the parental mites and its offspring to spread out. The weakening from the mite feeding leads to evident symptoms as bees unable to fly (deformed wing virus), helping mites to spread out and lead the colony to collapse. The presence of these viruses has been directly linked to colony losses [1], thus raising the need for more accurate techniques to measure and estimate the rate of infestation. The most used methods for detecting a *Varroa destructor* infestation is by manual sampling, [2]. Typically, a bunch of live bees (almost 300 bees) is put into a jar with alcohol or powder sugar and shaken until most mites fall off. An alternative consists of sampling the brood by opening brood cells and checking for mites presence. Lastly, a non-invasive method but still manual, makes use of a bottom sticky board placed under each beehive to monitor the natural mite drop. All these methods have drawbacks:

- *Time consuming:* collecting the sample of bees, brood cells or even the sticky board for extensive apiary might be unpracticable.
- *Statistical estimation:* being time consuming, beekeepers tend to sample just up to 5% of the entire apiary, making statistical estimation based on the sampled data.
- *Operator dependent:* manual procedures of collecting and counting the mite are prone to error estimation.
- *Season dependent:* procedures should be performed at least 4 times per year to have a reliable mite infestation estimation; however, during the cold season it is not recommended to inspect hives to collect the bee sample.

For these reasons, automatic monitoring inside the beehive might be a valid support tool for beekeepers to estimate the mite infestation level, limiting manual inspections and continuously monitoring the mite infestation level.

In this research project, authors are working on developing an image-based acquisition system to gather samples of health and sick bees inside the beehive, with the aim of providing a tool for beekeepers to support the decision-making phases to limit the spread of mites.

2. MONITORING SYSTEM: DESIGN CONSTRAINTS

There are several requirements to consider to allow the integration of a monitoring system into a beehive:

- *Non-invasiveness*: the system must be integrated with the beehive, preventing any disturbance for bees' daily activities.
- *Easy installation*: the interspace among frames is 10 mm with a frame thickness of 25 mm. Therefore, the monitoring system should be flexible to adapt to the most used hives and frames for beekeeping, considering the available limited space.
- *Cost efficiency*: hardware must be affordable to support a wide-scale application of the system.
- *Image parameters*: activities of the beehive are mainly carried out on frames populated by bees, even up to a few thousand, increasing the complexity of the monitoring system, which must be able to observe the area of interest to identify the mite (reddish-brown oval shape of 2 mm) present on bees in unstable conditions. Bees move both on the surface of the frame and in depth, meaning that the

monitoring system must adapt the depth of field, the field of view and the frame rate according to bees' activities, to reduce images' blurring effects.

3. MONITORING SYSTEM – EXPERIMENTAL SETUP

The acquisition system consists of:

1. One RGB camera (DFK ECU010-M12 ImagingSource) with a resolution of 1280x720 (0.9 Mp) and a frame rate up to 30 fps.
2. One liquid lens (Varioptic-C-S-25H0-026 Auto Focus Lens Module) with focal length ranging from 2 mm to infinity having an image circle diameter of 7.2 mm.
3. One custom array of white leds (18 leds) for ring illumination.
4. One controller (myRIO-1900 NI) to manage the camera, the liquid lens and the illumination.

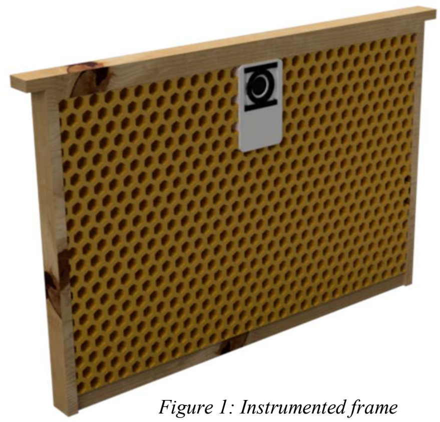

Figure 1: Instrumented frame

The first three hardware devices are embedded into a custom 3D printed case, less than 30 mm thickness, to be integrated in a brood cell frame, as depicted in Figure 1.

The instrumented frame inserted into the beehive records the bees (healthy and sick) on the frame alongside, during their daily activities. The liquid lens, by means of an automatic auto focus algorithm, adjusts the focus to get unblurred images even if bees cross the camera.

The advantage of using a camera-based instrumented frame combined with liquid lens, is to be, potentially, able to observe the youngest bees, which live closely with the brood and mites. Furthermore, the focal range of 2 mm to infinity allows to get bees' images either on the dorsal and abdominal side, covering areas most affected by mites.

The controller manages image acquisition, recording 2 minutes of activities at time intervals of 15 minutes. The autofocus algorithm (development on-going), running on the controller, adjusts the focus during the entire acquisition, whereas the illumination is kept constant.

The video frames are streamed to the queue to be saved on external storage memory or uploaded to the cloud if internet connection is available.

4. OUTLOOKS

The monitoring system under development is expected to take its first experimental campaign at the end of September, in a Lombard apiary. The main goal is to provide an in-field dataset, collected in uncontrolled conditions into a beehive, to compare artificial intelligence algorithms in detecting mites and even integrate those data to train a predictive model [3] to estimate the infestation level.

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