

Building a 'smart' monitoring system for bee colony observation

MY PROJECT IN 60S - INTERNSHIP REPORT ABSTRACT

Honeybees (*Apis mellifera* L.), of crucial importance for both ecological balance and human economy [2][4], face very high mortality rates causing great concerns [2]. Despite their key significance in pollination of plants and crops, limited understanding exists regarding their intra-hive collective behaviour. This research work, undertaken at the MOBOTS laboratory (EPFL), aims to develop new tools to deepen our understanding of honeybee collective patterns [1] and investigate potential mitigation to bee colony decline. The primary objective of the author's internship has been co-designing and constructing a monitoring system for an observation hive, containing a honeybee colony. The system had to meet the usability, efficiency, and reliability standards to enable intra-hive study, while addressing the bees' specific biological and environmental constraints. The project emphasized the implementation of mechanical and electronic monitoring elements required for reliable in-depth behavioural study.



Fig.0 - Western honeybees (*Apis mellifera* L.) contribute greatly to valuable crop pollination [7].

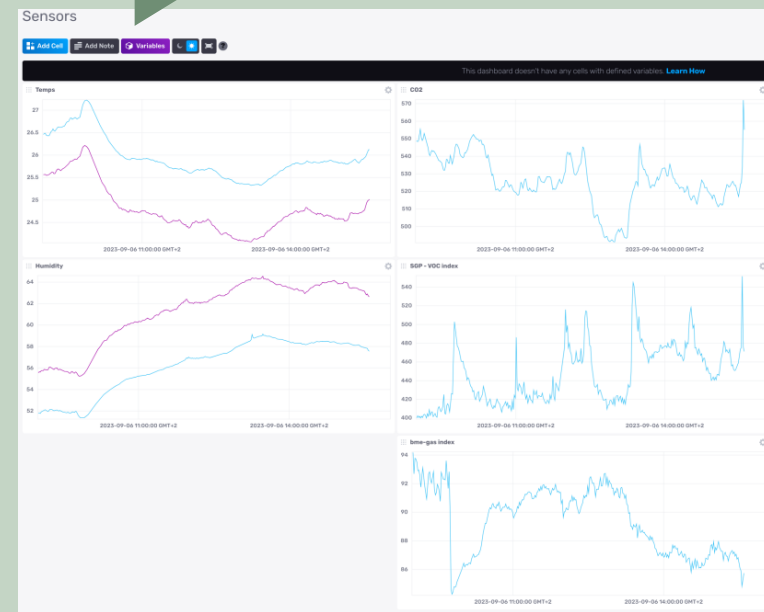


Fig.7 - Web-accessible data from the sensors, visualized using graphing tools.

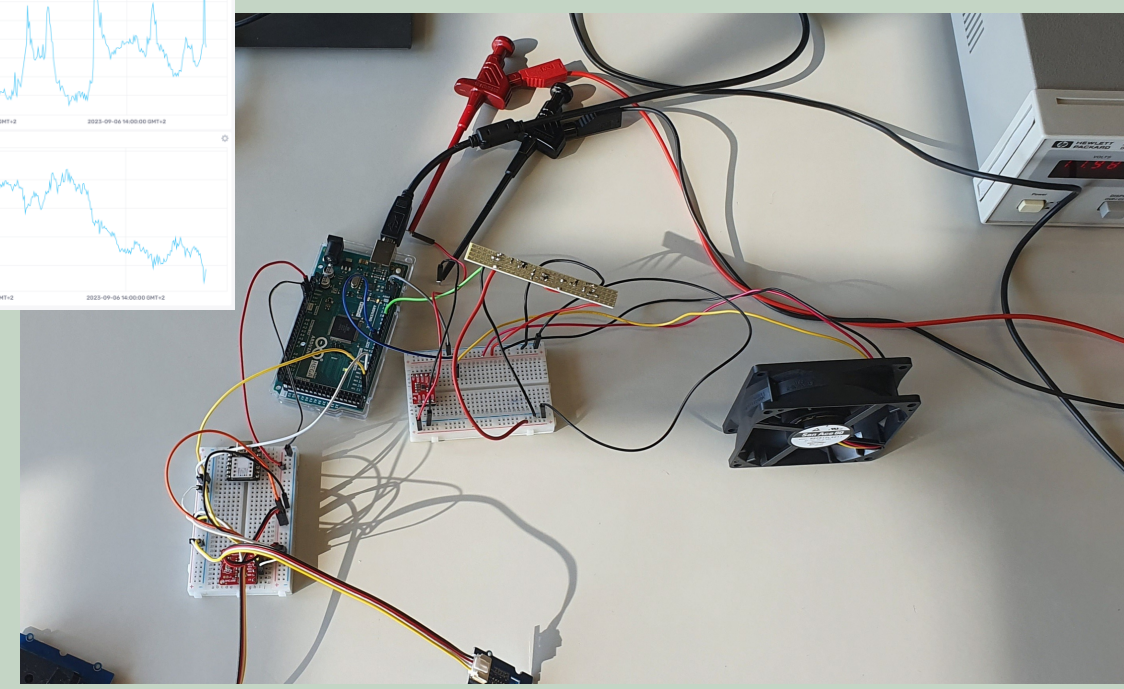


Fig.6 - Sensing environmental metrics (temperature, humidity, Co2, gas) and fan control, while communicating them to a computer for data-logging

1 - INTRODUCTION

- Honeybees contribute significantly to pollination, with deep impact on the food supply and global economy [2][4][7].
- Concerns raised due to high mortality rates, particularly the Colony Collapse Disorder [2].

Laboratory project aims to find new methodologies for understanding and mitigating threats to bee colonies. One way to do this is through analyzing their behaviour deep inside the hive, hence the need of a specific monitoring system for an observation hive.

2 - METHODOLOGY

Internship project in three axes :

- **Mechanical aspects** : Co-designing the monitoring system's setup and 3D-to-be-printed elements using AutoDesk FUSION 360 and Prusa Slicer.
- **Computer Vision tools** : Use of ArUco markers (Fig.1) & OpenCV for precise camera alignment and frame tuning in the hive (increase footage quality).
- **Electronics within the hive** : Low-power computers (Raspberry Pi's) for visual footage acquisition; microcontroller-managed sensors for monitoring environmental metrics and ensuring appropriate conditions for bees at all time.
 - Sensor Integration :
 - Measuring temperature, humidity, CO2, UV light, and specific gases for bee health insights and emergency reaction triggering.
 - Ensures real-time monitoring and emergency handling, with data logged online for accessibility.

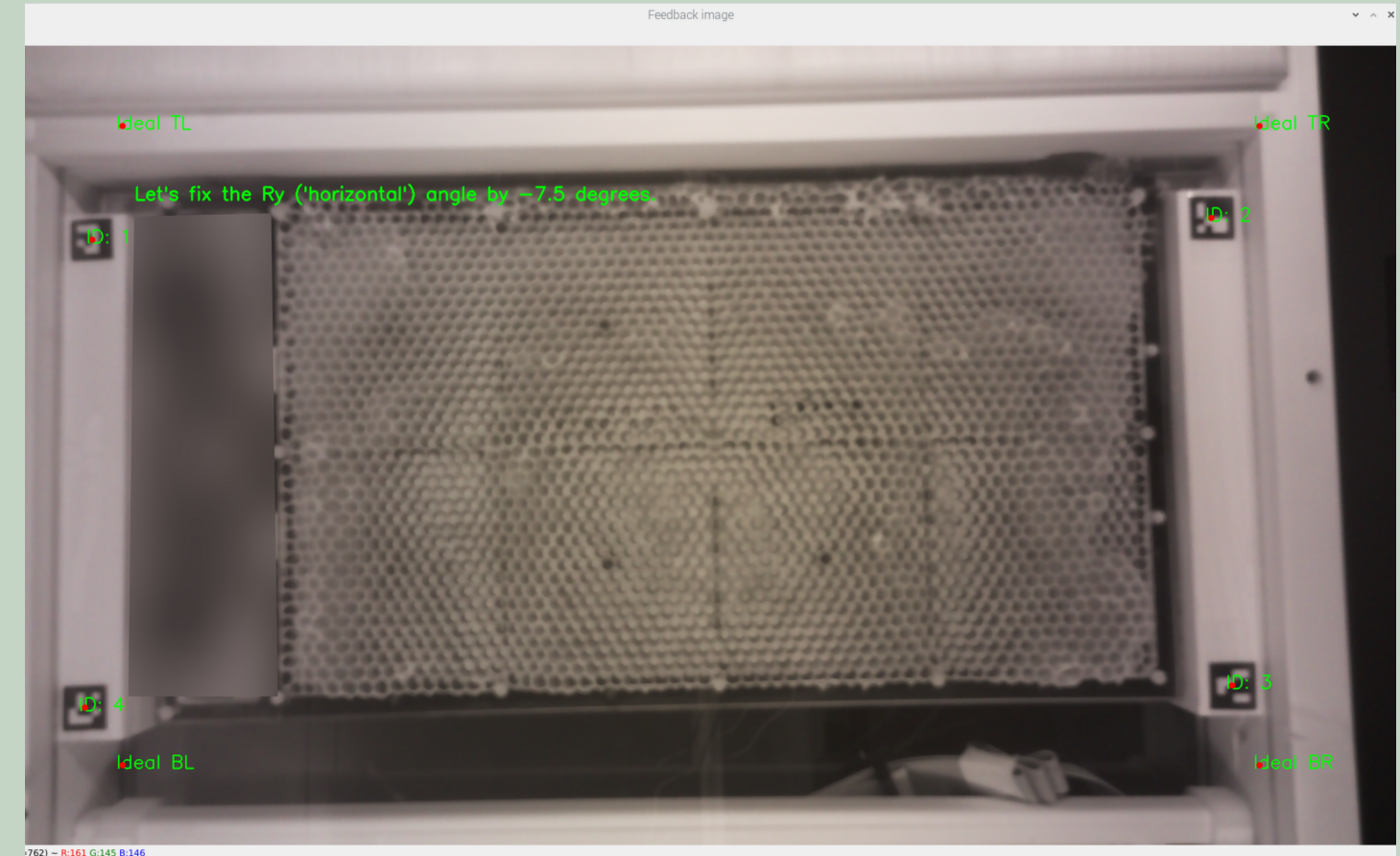


Fig.5 - Computer Vision script running on the Raspberry Pi, showing markers detected and providing feedback to the user (text in green, command prompt in black).

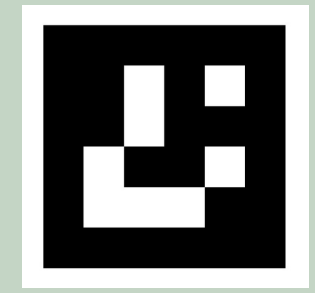


Fig.1 - ArUco marker with encoded value 4.

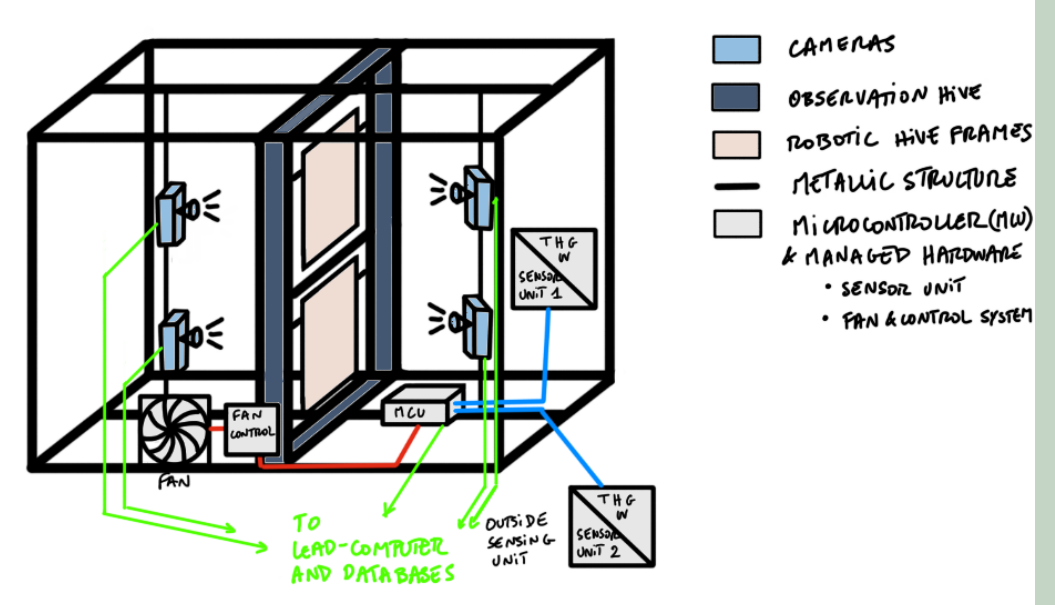


Fig.2 - The monitoring system proposed, based on a modular approach.

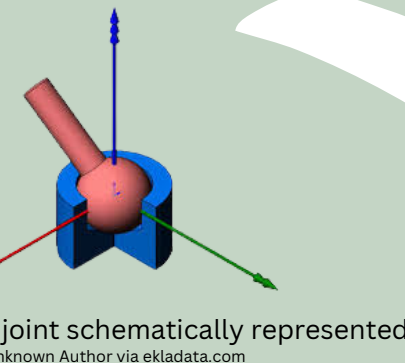


Fig.3 - A ball joint schematically represented.

3 - RESULTS AND CONCLUSION

Tools developed with supervisors during the internship :

- **Mechanical aspects** :
 - **Modular design of the monitoring system** (Fig.2) for better usability and ease of transport, allowing precise placement of all components thanks to a metallic frame structure with rail system.
 - **Application-specific 3D-Printed Raspberry Pi case with 3 DoF camera holder** (ball joint equivalent) (Fig.3-4), allowing precise footage framing and secure placing within the hive module.
 - **Building the system's structure, 3D-Printed LED holders** (Fig.8) for precise light orienting, etc.
- **Computer Vision tools** :
 - **Camera-aligning script** providing feedback and corrections to be made by the user (Fig.5), attesting of the versatility and relevance of computer vision tools in device tuning.
- **Electronics within the hive** :
 - **Design of the electronic monitoring system** given constraints of resilience, price, reliability in emergency handling, ease of installation and use, remote/on-field accessibility and limiting heavy data transfers by on-spot data processing (please see the full report).
 - **Test of sensor integration** :
 - **Successfully sensing environmental metrics** (Fig.6), triggering emergency procedure (fanning) and making data remotely accessible online (Fig.7).
 - **Design and binocular soldering** of a multiple-transistors SMD fan control system (on, off, speed).

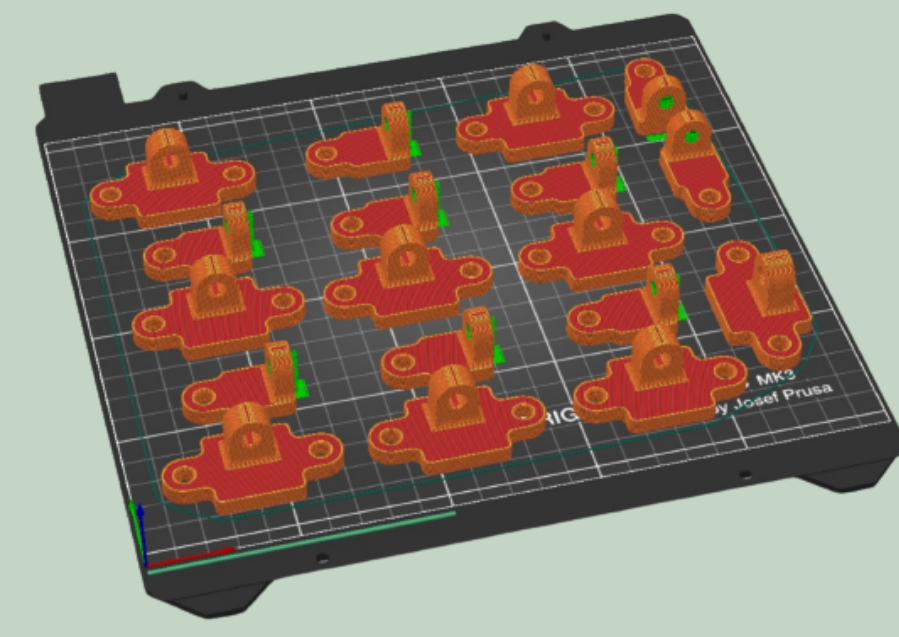


Fig.8 - 3D-Printing of LED holders. This technique has shown to be cheap and efficient, perfect for manufacturing most custom mechanical components within the module.

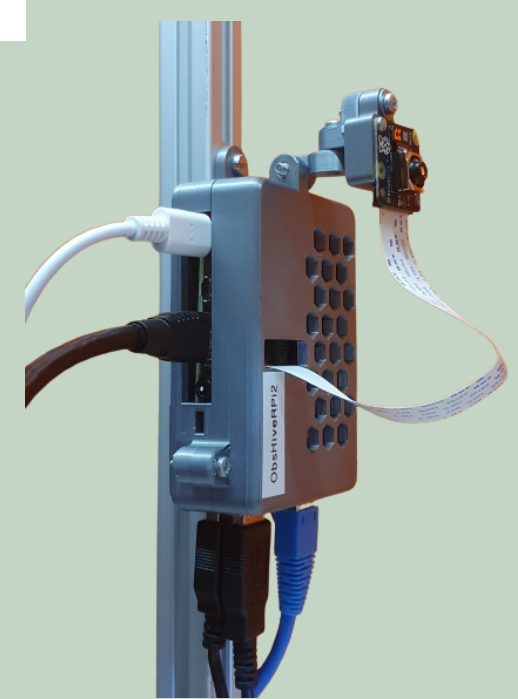


Fig.4 - Custom-designed Raspberry Pi and camera holder, 3D printed.

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