Robotic systems that observe and modulate collective behaviours in honeybees

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ABOUT

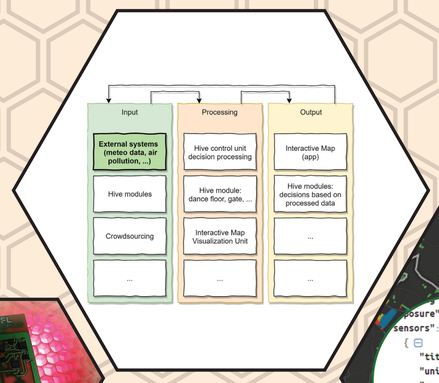
The **HIVEOPOLIS** project aims to develop a novel paradigm by creating new forms of interaction between nature and human society. We aim to establish a community of world-class actors in the emerging field of **bio-hybrid honeybee-technological systems** that research the path towards a novel living technology. This will employ a **new paradigm** that embeds technology (sensors, actuators, robots, algorithms) within a living animal superorganism (honeybees) to create a new symbiotic lifeform with novel characteristics concerning stability, resilience, robustness, efficiency, applicability, controllability and scalability.

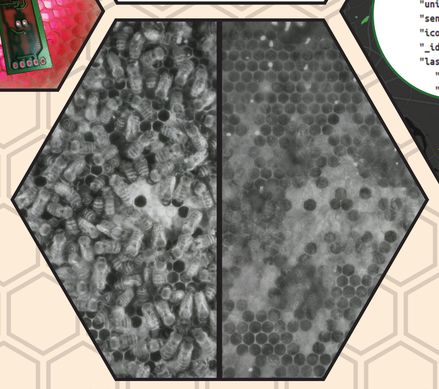
OBJECTIVES

- Develop a **technologically-augmented futuristic beehive** that supports the well-being and survival of bees in harsh, industrialized and urbanized conditions.
- Increase the environmental value of these beehives through a **focused and controllable ecosystem service**, coordinated between local hives, where specific optimization goals (pollination service, optimal food distribution) can be set.
- **Promote futuristic beekeeping** and the associated technologies to new emerging communities, including teaching STEM topics.

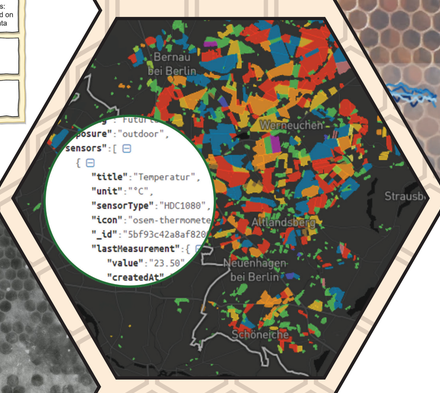
EXPERIMENTS & PROTOTYPES

Organising two-way information flow between humans and bees

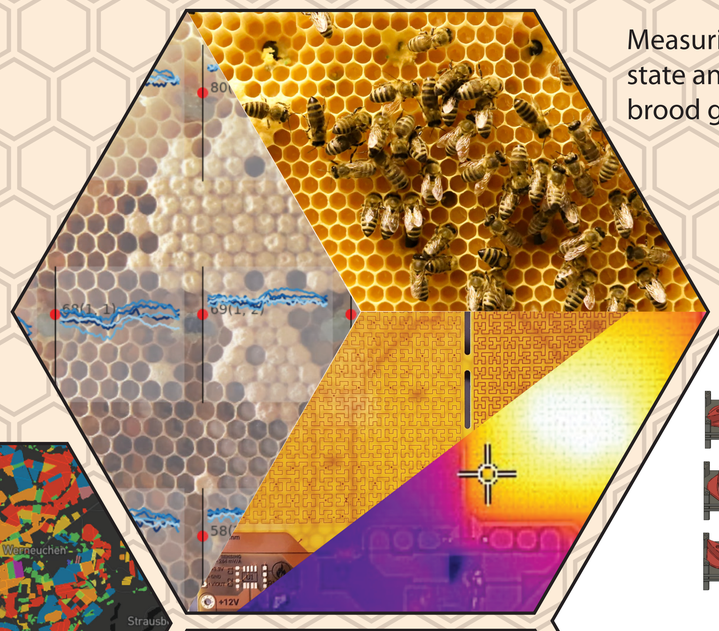


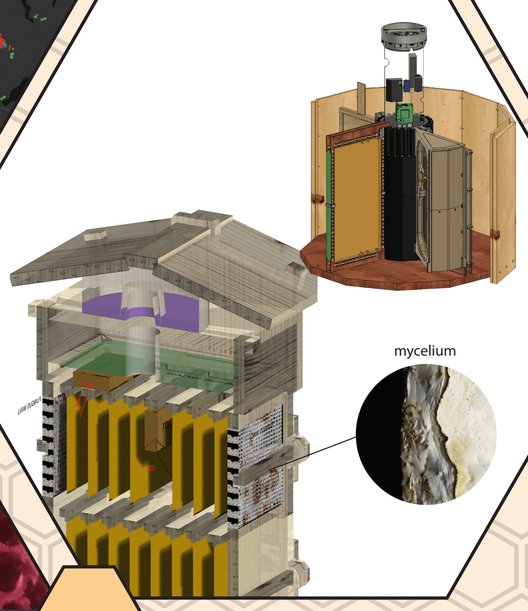


Enabling continuous brood state inspection

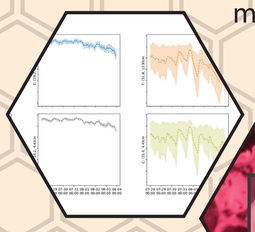


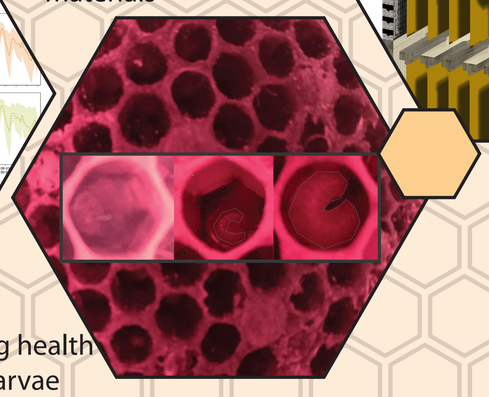
Measuring population state and modulating brood growth





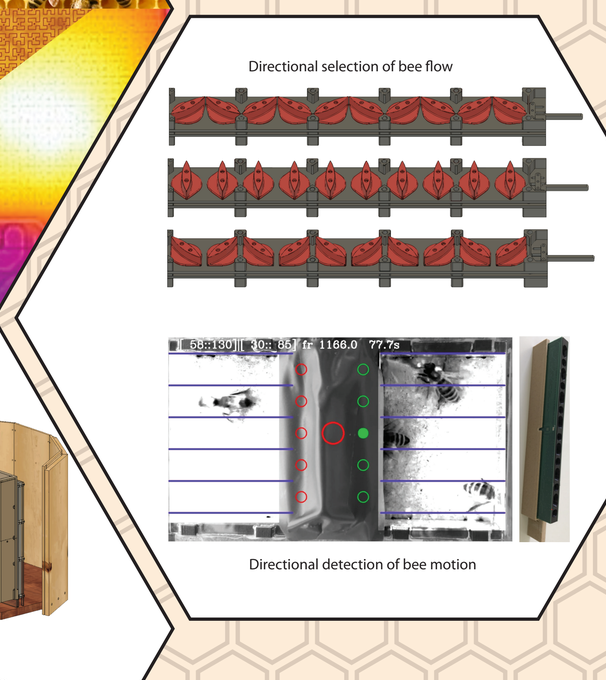
Exploring novel hive architectures and bio-materials





Detecting health state of larvae

Observing bee activity

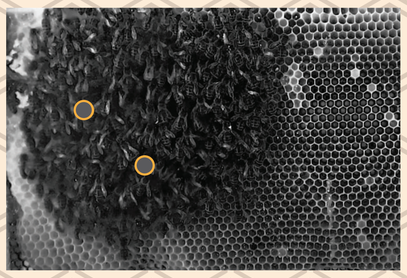


Controlling flow of bees

Extracting in-hive communications via vibrational data

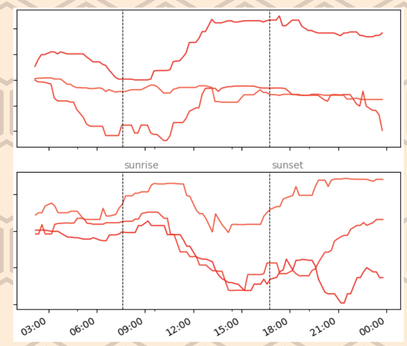
Honeybees use complex **vibrational** signals to **communicate** inside their hive. These include motion sequences called **"waggle dances"** to recruit others to forage at specific locations, and **"stop signals"** to suppress recruitment.
We have developed robotic systems that measure and generate vibrational signals, aiming to understand and **modulate what a colony forages for**, capable of targeting interventions guided by external information.

In our system we have simultaneously recorded vibrations and images, and aim to **identify signatures of** individual and group **behaviours** within the vibration time series data.



Measurement of vibrations

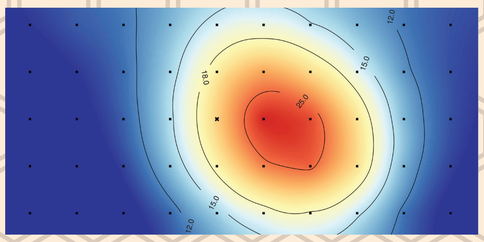
Cyclic behaviours



Modelling a bio-hybrid robot's influence on a bee colony cluster

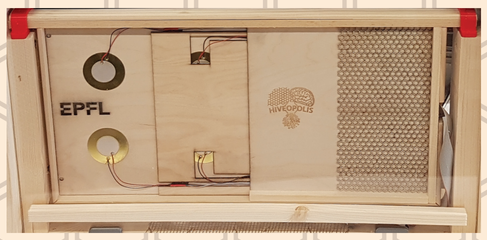
Honeybees form a tight ball, or **"cluster"** in the harsh temperatures of **winter**. The **self-organised structure** maintains sufficient warmth for the whole colony to survive.

We have developed a robotic device that uses thermal cues to interact with the cluster via arrays of sensors and actuators. We aim to better understand **how the animal collectives respond** to external and robotic-defined **thermal cues**, through experimentation and **computational modelling**.



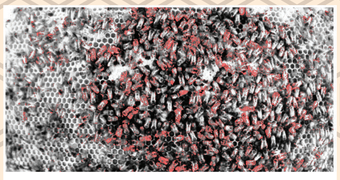
Detailed thermal map reveals colony state information

Honeybee-compatible robotic system including thermal sensor array

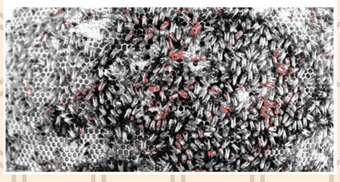


Piezo array embedded into honeycomb

Basal bee activity (red)



Specific pulsing signals reduce activity



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