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PP-190 [Beekeeping Technology and Quality]

Automated entrance monitoring to investigate honey bee foraging trips using an open-source wireless platform and fiducial tags

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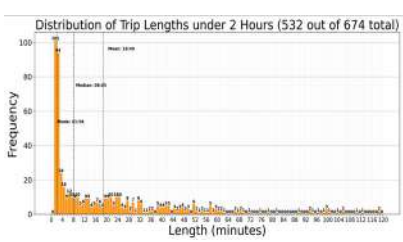
Abstract
Honey bee foraging involves tens of thousands of organisms making decisions about where to collect needed resources. Studying this is possible through direct observation, but the large number of individuals makes the implementation of technologies ideal to scale up this type of study. Consequently, there is a need for instruments that can facilitate accurate assessments of honey bee foraging at the colony level. To address this need, we developed an automated imaging system for monitoring the in-and-out activity of honey bee foragers as they walk through a customized entrance with a camera sensor at the hive entrance. We used AprilTags attached to each bees' thoraces to provide unique identification numbers that allowed the system to track in-and-out events throughout the foraging season of the colony. Our design relies on low-cost Raspberry Pi computers and cameras with commercially-available off-the-shelf components, making it easily reproducible with the open-source documentation provided. We successfully deployed and evaluated our system, demonstrating consistent results. Our results highlight the system's effectiveness in monitoring honey bee trips, which lays the groundwork for future estimations of foraging distances.

Read the entire article at:
Penaloza-Aponte, Diego et al. 2024. Automated entrance monitoring to investigate honey bee foraging trips using open-source wireless platform and fiducial tags. HardwareX, Volume 20, e00609.

The BeeCam-AprilTag system:

- A real-time detection system capable of identifying individual bees, retrieving their position and orientation using inexpensive tags.
- A system composed of multiple devices able to collect and share data via a local wireless network that users can access wirelessly for monitoring and data transfer.
- A portable system deployable outdoors that runs 24/7 for long periods.
- Built entirely with commercially available off-the-shelf components.
- An architecture and interface that is simple to install and operate by people with limited knowledge in electronics and programming.



Sample data showing trip lengths of tracked worker bees.

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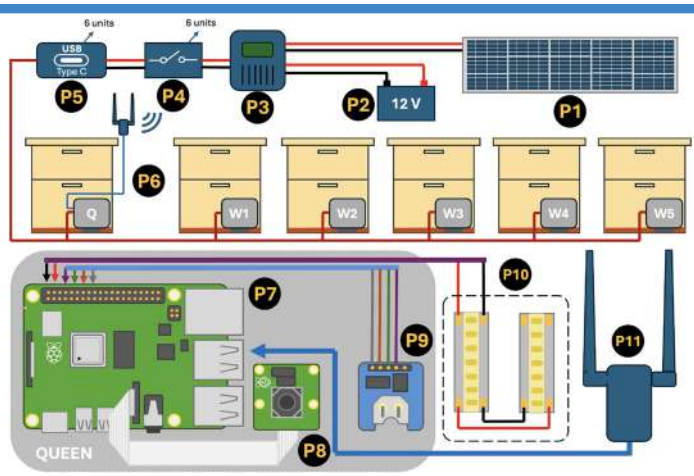
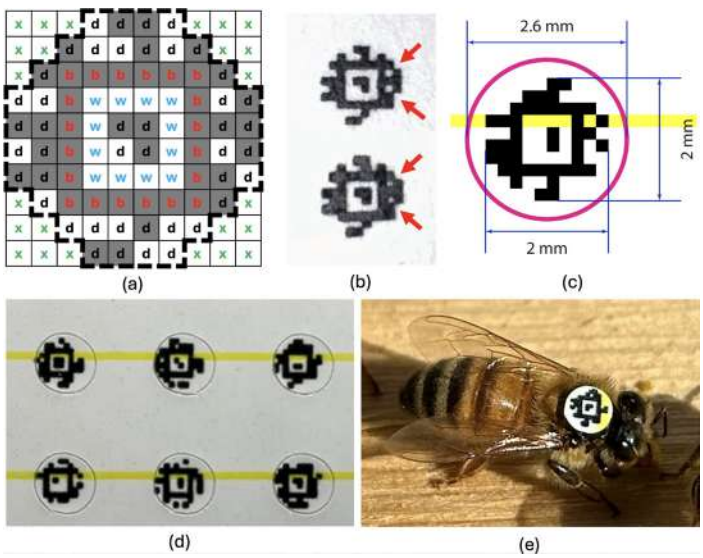


General system schematic describing the main hardware components. Labels P1 to P5 indicate the power module components, label P6 refers to the enclosures containing the electronics for each colony, and labels P7 to P11 denote the electronic components within the enclosure of the "queen" computer.

Hardware. (a) IP65 enclosure modifications. (b) Electronics inside enclosure. (c) Enclosure, 3-D printed entrance and landing board installed at colony entrance.



AprilTags: (a) Pixel-bit structure for the 44h12 circular tag family. (b) Printing quality comparison, with arrows indicating white pixels obscured by ink smearing. (c) Printed tag dimensions, showing the magenta circle for the cutting area and the yellow strip for tag orientation. (d) Tags printed and cut, ready for use. (e) Tag mounted on the thorax of a honey bee.

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Honey bee foraging is a complex behavior because it involves tens of thousands of organisms making decisions about where to collect pollen and nectar based on the quality of resources and the distance to flowers. Studying this aspect of their biology is possible through direct observations but the large number of individuals involved in this behavior makes the implementation of technologies ideal to scale up this type of study. Consequently, there is a need for instruments that can facilitate accurate assessments of honey bee foraging at the colony level. To address this need, this work aimed to develop an automated imaging system for monitoring the in-and-out activity of honey bee foragers as they walk through a customized entrance with a camera sensor at the hive entrance. We used AprilTags attached to each bee's thorax to provide unique identification numbers and directionality that allowed the system to track in-and-out events throughout the foraging season of the colony. Our design relies on low-cost Raspberry Pi computers and cameras, along with commercially off-the-shelf components, making it easily reproducible with the open-source documentation provided in our manuscript. Additionally, the hardware was powered using solar panels to allow for monitoring of colonies in remote locations. We successfully deployed and evaluated our system in six locations, demonstrating consistent results. Here, we present the details about the development of the system, data collected from multiple colonies, and post-processing analysis from one of our apiaries. Our results highlight the system's effectiveness in monitoring honey bee trips, which lays the groundwork for future estimations of foraging distances. Understanding the land area used by honey bee colonies is important in the consideration of apiary placement.