Recording and tracking of locomotion and clustering behaviour in young honeybees (*Apis mellifera*)

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Introduction

Comprehensive studies using a one-dimensional temperature gradient revealed, that freshly emerged honeybees display a preference for temperatures similar to the one measured in the brood nest. For *A. mellifera* this temperature was found to be at approximately 36 °C [1]. Subsequent experiments in temperature organs, closed glass cylinders in which bees are exposed to a rather one-dimensional gradient, showed that single bees are able to find the optimum temperature in a steep gradient.

In contrast to that, recent studies at our department, using a two-dimensional gradient, showed that single bees were not able to find the optimum neither in flat nor in intermediate gradients, while sufficiently large groups of bees preferably form clusters in areas at the optimum temperature in intermediate gradients. We interpret this ability as an effect of swarm intelligence and the aim of our present study is to determine the basic mechanisms of this complex behaviour.

Material and Method

During the early stage of development of our experiment we encountered several challenges: We had to stabilize the gradient within sufficiently narrow confines by keeping a constant room temperature. In order to improve the camera's image quality we needed to illuminate the scene without shadows. Insufficient resolution of the camera posed a major problem for the tracking algorithm because the used tracking program was not able to distinguish between two or more bees which are too close. At present our experimental setup consists of the following components:

We observe the bees in a circular arena with a diameter of 60 cm, surrounded by a plastic wall with a height of 9.5 cm. To make sure the bees remain in the arena, we coated the wall with Teflon-spray. Covering the arena is not necessary, because freshly emerged bees are not yet able to fly.

The arena is situated in a small room on the top of a table. We are able to control the ambient temperature within narrow constraints to generate various temperature gradients in combination with one or two heating lamps which are located at different positions above the arena. We use ceramic heaters which are normally used for terrariums. To survey the temperature gradient in the arena we use an array of 64 highly sensitive temperature sensors which slightly protrude from the ground. We use self-designed electronics and software to collect the sensor data which are recorded and used as a feedback for automatically stabilizing the temperature gradient by controlling the power of the ceramic heaters. The temperature data are also stored for later evaluation. To provide an experimental environment that is close to natural conditions in the hive, we refrain from using visible light and use infrared light to illuminate the scene, because light with wavelengths beyond 660 nm is invisible for bees [2]. The 6 lamps for illuminating the recording area consist of halogen light lamps with infrared filters mounted in front of the lamp in a way that no visible light can shine through and they are distributed regularly around the arena.

For recording the bees' behaviour we use an infrared-sensitive surveillance camera which is fixed 70 cm above the centre of the arena. We record the videos digitally on a HD-recorder and extract one frame per second and process each frame with a self-written MatLab program, which computes the position of every single bee in the arena over time. Each bee is identified by computing the difference between the frame containing the bee and a reference frame of the empty arena. Possible noise is excluded by introducing a threshold for bee detection. The program produces an Excel file containing the positions of the bees at every time step and the average temperature of every sensor during recording time. We use Visual Basic to further compute the local temperature of the bees' positions, the distance to the optimum temperature (i.e. 36 °C), the distance each bee covers per time step, the angular deviation relative to the previous position and the number of bees in every potential cluster. The whole setup enables us to automatically record and evaluate a large number of samples of the bees' behaviour.

Further studies

In order to achieve even better results, we will make use of the currently evolving recording technology and employ higher resolution cameras. Further improvements to the tracking algorithm will allow us to identify cluster sizes with less or no error, and our current experimental setup will be extended to fit the needs of a wider array of research interests.

The parameters describing the bee's behaviour, which are a results of our experiments, will be included in the studies and experiments of the A*rtificial Life Lab* in our department where the derived algorithms will be implemented into Jasmin III robots [3].

References

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