Blending into the Hive: A Novel Biomimetic Honeybee Robot for the Analysis of the Dance Communication System.

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The honeybee dance "language" is one of the most intriguing examples of information transfer in the animal world. After returning from a valuable food source honeybee foragers move vigorously, in a highly stereotypical pattern, on the comb surface conveying polar coordinates of the field site to a human observer:

A tail-wagging forager moves forward in an almost straight line on the vertical comb surface, throwing its body from side to side in a pendulum like motion at a frequency of about 13 Hz. This so called “waggle-phase” is followed by a return-phase, in which the dancer circles back to the approximate starting point of the previous waggle, alternatingly performed clockwise and counter-clockwise such that the path of a dancer resembles the figure 8. Von Frisch found that certain dance parameters reflect properties of the food source. In the waggle phase, the body’s angle with respect to gravity approximates the direction to the food relative to the sun's azimuth. The length and duration of the waggle run correlate highly with the distance to the target location ([4],[12]). In addition to information regarding the location, the dance communicates also the profitability or quality of the food source with respect to the current hive’s needs. Foragers tend to dance more lively and perform longer dances when feeding on a highly profitable source ([6],[12]).

An amazing amount of knowledge on navigation, memory and communication in honeybees has been gathered ([2]) and we can rely on compelling evidence indicating that honeybees actually evaluate and use the information encoded in the dance. However, today, more than 60 years after its discovery, it still remains unknown how follower bees decode the information contained in the dance.

Follower bees, the bees standing in a close proximity to the dancer, are most likely to be recruited after attending several dance periods. In that process they actively pursue the dancer in order to remain in or establish a close contact with the her. They detect a variety of stimuli. Mechanical cues like antenna and head contacts to the body of the dancer are frequently observable and likely transmit information about the dancer's body orientation ([1],[5],[11]). Wing bursts in the waggle run produce complex patterns of laminar air flows, three-dimensional fields of short-ranged air particle oscillations and comb vibrations that might as well deliver meaningful multisensory input ([3],[7],[10],[14]). The body temperatures of dancers are significantly higher than those of non dancing foragers ([13]). Recently, a dance-specific scent has been reported ([15]) as yet another possible signal. Floral odors and regurgitated food samples are associated cues. However, after more than 60 years of intense research it is still unknown how exactly
information is encoded in the dance and how it is decoded by the followers. Which of the many stimuli carry information? Can we assign specific meanings to single stimuli? How do the followers use that complex mosaic of stimuli they perceive? Do bees extract such abstract concepts as angles to integrate them in and read them from the dance? Or is the encoding and the decoding process more of a memory playback and recording, respectively?

In order to investigate the characteristics of the communication process we are building a robotic honeybee that is able to reproduce all known stimuli, that can blend into the honeybee society and that enables us to finally resolve many questions that remained unanswered for a long time.

To tackle these questions, certainly the robot has to be able to emulate all known stimuli. The very dance motion, the base for all other stimuli, has been modeled using a parameter set identified through a statistical variance analysis of hundreds of dance trajectories that were captured from highspeed dance video recordings via an automatic tracking program. A small, life sized replica of a bee can be moved using a customized plotter in a two dimensional plane. The positioning system carries a 10 cm rod on whose end the body of the small artificial honeybee body is affixed. It can be inserted into the hive such that it “hovers” over the surface of the densely populated comb. The body can be heated with a precision of 0.5 °C and it can deliver small drops of sugar solution through a tiny syringe. The robot has wings that are vibrated with an electro-magnetic driver and therewith produces the above mentioned oscillating air currents and laminar air flows. We have developed a graphical user interface that allows us to control every stimulus individually and create a dance pattern using single or combinations of stimuli. The robot can be operated in three modes. In manual mode an experimenter can steer the bee replica over the comb with a joystick. Using the fire button a waggle run can be excited as defined by previously set parameters. In semi-automatic mode the robot moves in a trajectory defined by a dance model depending on 11 parameters such as various speeds, angles and durations for parts of the dance. By pressing a button on the console the experimenter can continue the dance or stop it by releasing it to prevent bees to be ran over. The robot can be positioned using four more buttons. In automatic mode two embedded camera modules are used for the obstacle recognition since human control often is not fast enough. The hive is back lighted using bright infrared light, a wavelength bees can not perceive. The image thus shows bright pixels where the light can pass through the wax comb and dark pixels where bees cast a shadow. A 70x30 pixel image of each camera is sent to the main controller at 70 fps and merged into a 360° obstacle map that is evaluated for bee shaped objects in second step. In automatic mode the robot delivers sugar drops having detected bees standing at the head, reduces its forward speed to avoid running into obstacles.

This robot is a powerful tool to investigate the bee dance from the closest point of view possible. In the summer of 2010 we have already begun testing the robot to have an influence on foraging. As of now, we have sent bees out to a previously visited location by means of the robotic dance. Concurring with experiments of Axel Michelsen and coworkers ([9]) we identified the wing buzzes to be essential to this process. However, the effect we have detected is
essentially of motivational nature. Since we have not used any floral odors associated to the feeders the question remains what might still be missing to direct them. Besides, the recruitment process seems to be very fragile. Often, the following behavior of potential recruits is interrupted for yet unknown reasons. This might be due to a high degree of disturbance as introduced by opening the hive or due to a missing resemblance of the stimuli emulated. In the next months we will investigate this. In the upcoming experimental season we will be able to extensively test the function of the robot and will furthermore be able to track the flights of recruits with a harmonic radar system ([8]).

References: