Robotics modelled on bees

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In a project funded by the Austrian Science Fund FWF, a research group from Graz is investigating the behaviour of young honeybees immediately after hatching and successfully transfers this to robots. The bees' brood-care strategies turn out to be surprisingly efficient.

It is well-known that bees live in highly organised systems. In contrast to wasps or bumble bees, their special form of organisation helps the entire colony survive in the hive. What has been little known until now was the behaviour of very young bees on the day of hatching. A research group headed by the zoologist Thomas Schmickl from the University of Graz has taken a closer look at their behaviour and found it to be more complex than expected. In a project funded by the Austrian Science Fund FWF, the researchers designed a behavioural model of the young bees and transferred it to robots, where the bee strategy turned out to be surprisingly effective.

Bees seek out warmth

"Newly hatched bees spend their first day doing nothing special. They clean the cells from which they hatched so that the queen bee can lay new eggs in them," explains Thomas Schmickl. "Previously, the behaviour of these baby bees was not given much attention, but it has been shown that it is essential for maintaining the hive system and enabling the colony to survive the winter." The temperature in the hive is of prime importance. A bee larva is the most rapidly growing creature on the planet. Within five days its body mass grows by a factor of one thousand. "No other creature in the world grows as quickly relative to its initial size. This is feasible only because bees heat up the brood nest to 35 to 37 degrees which makes their metabolism operate at full blast," reports Schmickl. In which cells the queen lays the new eggs depends on their temperature. Higher temperatures mean a more efficient use of the heat.

"The baby bees ensure that the brood nest is compact and that the generated heat is exploited efficiently. Which of the cells are cleaned by the young is essential for keeping the nest alive," says Schmickl. The freshly hatched bees show a preference for cleaning cells that have a higher temperature. "We simulated the situation in a lab trial and released bees in a field with different temperatures. We found that the young bees do not act out a simple programme but engage in relatively complex behaviour. Roughly speaking, we identified four types of behaviour: the 'goal finders' that zoom in on the warmest place, the 'random walkers' that go any which way, completely unconcerned by temperatures, the 'wall followers' which skirt the perimeter of the brood nest and the 'immobile bees' that don't do anything."

The colony acts like a brain

Schmickl and his team observed that the bee colony displays intelligent behaviour without individual bees being aware of the overall situation. They reliably find the warmest spot and ignore smaller warm areas. "Although the bees take the entire environment into account this doesn't happen in an individual bee's brain. Individual bees don't need to have scouted everything. The entire colony acts like a big brain and finds the best solution," explains Schmickl. "On the basis of one single equation we have generated a model which includes all four behavioural types and all hybrid forms."

Schmickl and his team successfully emulated this model with simple robots equipped with temperature sensors. According to the researchers, such physical tests are very important. "We know this from ant research. Historically, a great number of highly abstract swarm-intelligence models have been developed for ants. We studied them and found that all proposed algorithms for ant trails failed when re-embodied by robots," says Schmickl. "For that reason, we placed the focus of our project on robot embodiment and were able to extract a bio-inspired swarm algorithm which also works in physical embodiment."

Algorithms for life

In Graz, bee research enjoys a long tradition going back to Nobel laureate Karl von Frisch. Schmickl studied these insects already while writing his doctoral thesis and got started on biological modelling in an FWF project immediately after completing his thesis. In the context of that project he studied what happens in case of food scarcity, caused, for instance, by prolonged rainy spells. "I have seen cannibalism occur with the aim of regaining energy. I started to develop population models for bee colonies which took me to mathematical modelling. I drilled down deeper over the years, and now biological modelling is one of my main fields," adds Schmickl.

His interest also shifted to the algorithms themselves: "An attempt to further simplify the bee model produced an algorithm called PPS, Primordial Particle Systems," reports Schmickl. This no longer relates to bees. "It is about structures that are similar to cells and that are self-organising; they incorporate free particles, grow and then divide. The system is not unlike a primordial soup where something lifelike may develop spontaneously." The question is: how simple can an algorithm be to give rise to something that looks like life? "It is about biological pattern formation in general. This is another issue we want to pursue further," says Schmickl.

More information: Heiko Hamann et al. Analysis of Swarm Behaviors

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