An Integrated Experimental-Modeling Approach to Resource-sharing in Honeybee Swarms

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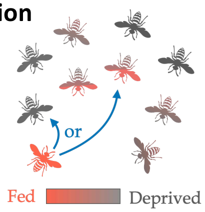
Introduction

- *Trophallaxis*, the direct transfer of food among nestmates in honeybees, serves not only as a feeding mechanism but also as a medium for information exchange among workers, helping them coordinate their activities [1].
- We use an integrated approach to build an agent-based model that is not only inspired by trophallaxis behavior, but also designed and validated using laboratory experiments on honeybees [2,3].

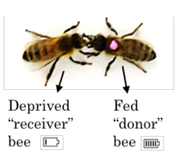
Main Research Question

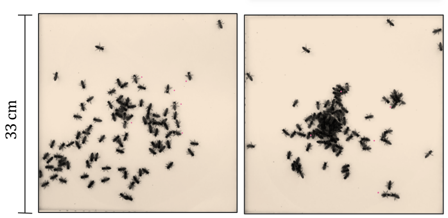
- How do local rules about the motions and interactions of bees affect the global efficiency of food distribution?



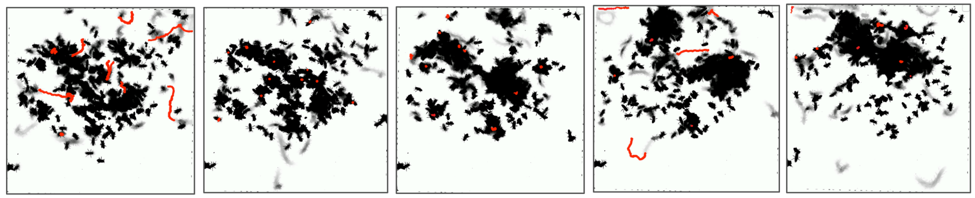
Behavioral Experiments

- Four different colonies of honeybees *Apis mellifera* L. were divided into two groups.
- One group was *deprived* of food for 24 hours before each experiment.
- The others had constant access to food.
- These *fed* bees, which comprised 5-10% of the whole population in each experiment, were carefully marked with a pink circle on their thorax.





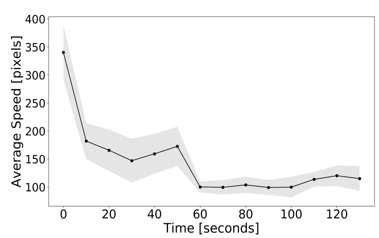
t = 0 t = 2 minutes

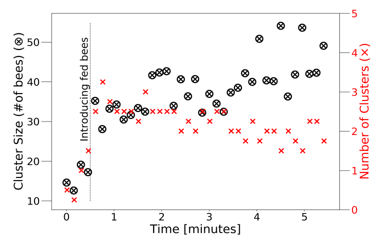


t = 10 seconds t = 1 minute t = 2 minutes t = 3 minutes t = 5 minutes

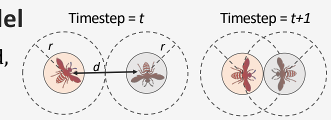
Experiments: Observations and Hypotheses

1. Fed bees decrease their speed shortly after they are introduced.
2. Bees start to aggregate as the fed bees are introduced to the group, as opposed to the more scattered arrangement at the start of the experiments.
3. The number of bees that join the clusters increases and the number of clusters decreases, with time. Perhaps this is due to attraction between the fed/deprived individuals?

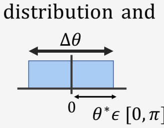




Data-Driven Agent-Based Model

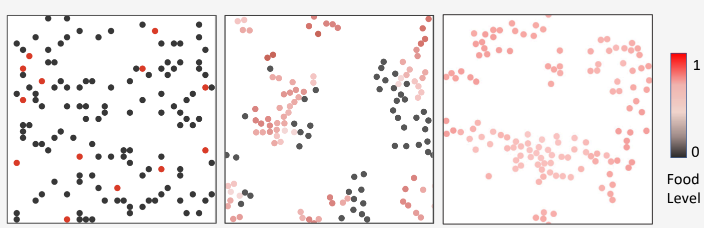


1. Check immediate r-neighborhood, If $d \leq 2r$, then agents will move one step toward each other at the next timestep (attraction parameter r)
2. Modify your heading by $\Delta\theta$ drawn from a uniform distribution and take a random walk step [4] (angle parameter θ^*)
3. Check for encounter (distance parameter d)
4. Exchange food: $f_i(n+1) = f_i(n) \pm \frac{\Delta f(n)}{2}$
5. Loop until the food distribution is uniform (variance threshold)



➢ Convergence: $\sigma^2(n) \leq \sigma^2_{threshold}$

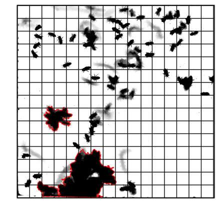
$$\sigma^2(n+1) - \sigma^2(n) \leq \Delta\sigma^2_{threshold}$$



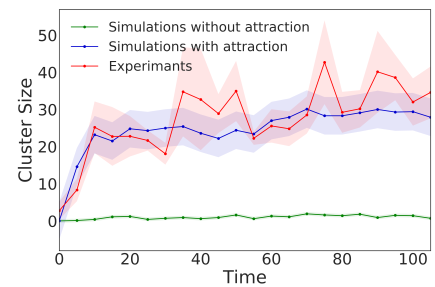
n = 0 n = 100 n = 150

Model: Validation

- We validated the model by comparing the size of the clusters in the real and simulated bees at each time step.

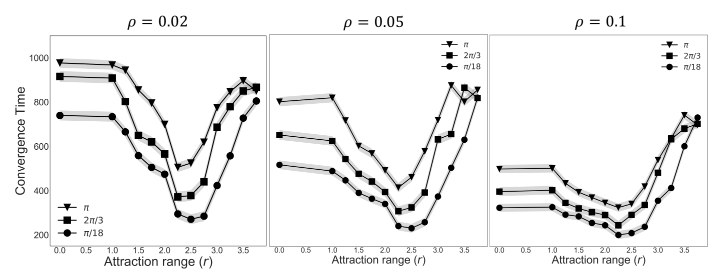


- These calculations showed that the model with attraction is a better match for the natural behavior of the bees compared to a homogenous random walk model of movement (i.e. simulations without attraction).



Model: Results

- *Higher densities* increase the encounter likelihood at each time step.
- *Lower turning angles* lead to broader, faster food distribution.
- *Short range attractions* increase the efficiency of food distribution.



References

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