Collective decision making: From nest site selection in honeybee swarms to kilobot ensembles

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Collective decision making is a broad and interdisciplinary field of study where statistical physics, biology and social sciences meet. In our group we study collective decision making in groups formed by social agents in complex environments. We observe these processes constantly on social groups: from humans taking part in elections, social mammals herds or schooling fish moving together or insect colonies moving to a food source or a new settlement. Information flow is crucial to the outcome of a decision making process, and the extent to which group members are able to individually explore the available options, to asses their benefit for the group or to acknowledge the information that their colleagues have gathered are some of the most relevant factors mediating this process.

The poster focuses on a particular decision making process that takes place in honeybee swarms. Come the end of spring honeybee colonies split, and around two thirds leave the nest with the queen to find a new nest site. In this process, a fraction of the swarm inspects the surroundings to gather information on the possible new sites, estimating their quality (size, food availability, distance, etc.). Scout bees return then to the nest and perform the waggle-dance (fig. 1), which is the main information exchange method. Bees that have found a good site will perform a longer, lively dance while bees that have found a poorer site will dance for shorter times [1]. Bees that have not explored its surroundings will follow another bee's waggle-dance, i.e. they will get convinced by the dancing bee choice; altogether, bees dancing for poorer sites may switch their opinion to follow a better option. During this process of exploration, waggle-dance and dance following a quorum among the swarm will be built, presumably for the best possible site. This kind decision making process is known as a decentralized decision making process, as there is no leader nor hierarchy influencing the group's decision, but every agent contributes equally to the exploration and information exchange process. It has been argued that this mechanism is the most effective for a group to reach consensus for the best possible option - a phenomena known as *wisdom of the crowds* [7].

The approach we follow is based in an agent-based model with a mean-field approximation, and it was first presented in [2]. This model is built upon the most basic features that mediate this process: the chance to discover a site α (π_α), the quality of site α (q_α) - which is directly translated to the waggle dance duration -, and the group interdependence λ - this is how much bees take individual decisions by exploring (low λ) or how much they take into account other bee's opinion (high λ). This model can be implemented into an stochastic algorithm, allowing us to simulate different environment conditions (represented by these parameters) and characterize the system outcome. Furthermore, this model can be studied analytically by terms of a master equation [3]. We make use of these tools to compare our simulations with theoretical predictions and to gain insight from some features where stochastic simulations alone are not enough.

Our results regard the 2-site decision process, already studied by other models inspired by the honeybee scenario [4, 5]. We characterize the transition from consensus for the best possible site to no consensus, aiming to acknowledge if such an agent based system suffers some kind of phase transition as seen in other models, such as the voter model. Besides, we characterize the influence of the system parameters to one another and study their relation with he accuracy of the final stationary state and the necessary time to reach it. Finally, we aim to validate our findings implementing this model to a swarm of kilobots [6], small robots specially designed to study the process of decentralized decision making in swarms, in order to asses its behavior beyond the mean filed approximation, i.e. when unavoidable spatial effects may become relevant.

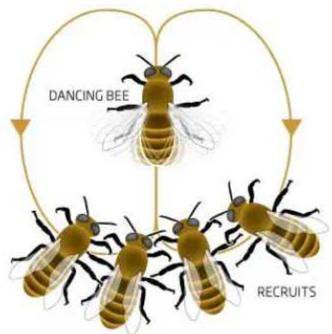

Fig. 1. Waggle dance mechanism. The dancing bee moves forward performing a lively dance and returns to the initial position. If the bee estimates that its site choice is good the dance is livelier and longer, and the return phase quicker. Other bees (recruits) may see this waggle dance and copy the bee's opinion instead of reaching out to explore.

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