Nest site selection in honeybee swarms: The colony as a cognitive unit

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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.

We study a particular decision making process inspired by real honeybee swarms seeking a new nest site. Each spring bee colonies split and half of the colony seeks a new place to establish their nest, in a process that involves exploring the environment and exchanging information with other members of the group. The key factors influencing the outcome of this decision process are the cost or difficulty to discover the possible sites and the honeybees capacity to asses the sites' qualities and to announce effectively their findings. A characteristic feature of this process is that bees announce their discoveries via a *waggle dance*, a dance that is livelier and longer the better quality the of the site is estimated to be. Other bees may explore, and consequently advertise, an already announced site instead of individually seeking in the environment a new discovery which to advertise. Favouring the best findings via longer advertisement periods allows an information cascade to be built and a collective, decentralized decision to be taken for the best possible option, to the extent on how easy it is to discover, how different in quality it is related to other options or how trustful are bees to one another.

The approach we follow is based on computer simulations of an agent-based model first presented in [1], and further studied in [2]. This model accounts for the cost and quality of the options and the group ability to either independently explore the environment or trust other members opinions. We study how the interplay of these factors results in a beneficial or detrimental choice for the group or even a stalemate between the options.

Interestingly, a honeybee swarm faced with such a scenario can be thought of as a single cognitive unit faced with a sensory discriminatory task [4]. Originally, the relationship between stimulus intensity (sound loudness, image brightness, time duration, for instance) and its perception was studied only in the domain of the human brain. Over the years it has been shown that results valid on the human brain are also valid for other organisms at different levels of complexity, from other mammals to fish or insects. Consequently, psychophysical laws that, for instance, relate the difference between stimuli intensity that can be properly discriminated (Weber's Law) or the reaction time necessary to correctly discriminate between different stimuli (Piron's Law) have been established at the individual level. It has only been in the last years that efforts have been made to explore the validity of these laws in the swarm level [3], inspired by the behavior of real honeybees. By means of the model under study we explore the applicability of these laws at the colony level, relating the stimuli intensity to the sites' qualities between which the swarm has to choose.

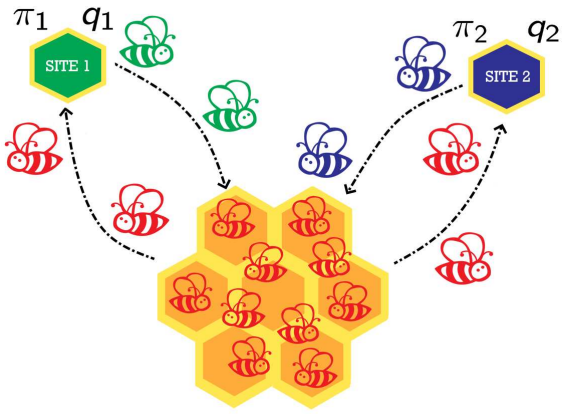

Fig. 1. Schematic representation of the model under study. The members of the group (bees) explore the environment and discover options (nest sites) with a probability π_i. They advertise their finding to the rest of the group for a time period relative to the site quality, q_i. Following the initial discoveries, bees will follow other bees advertisements with a probability λ.

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