Chapter 4

Primitive Ant Associations for N/W
4 Network Direction-finding Protocols for Primitive Ant Association

Two precise classifications of insect Associations have influenced approximately huge quantity of work in the particular domain of network direction-finding are ant colonies and bee colonies. Particularly, the capability of ant colonies to determine shortest path between their nest and antecedent of food with a pheromone laying following mechanism [91] has been reverse engineered and place to work in the common augmentation framework of the Ant Colony Optimization huge analytical [6,7,3].

The Ant Colony Optimization is a state-of-the-art huge analytical for a lot of problems in the domains of connection optimization and network direction-finding. Recently, the communication and recruitment strategies accepted for effective within a beehive have motivated the development of some novel algorithms for direction-finding problems. In the subsequent two classifications we consider independently the common standards after the ant and bee-inspired approaches to network direction-finding.

4.1 Shortest path behavior in ant colonies and the Ant Province Optimization
Meta heuristic

It has been observed that foraging ants in a province can converge on moving over the shortest path among dissimilar paths connecting their nest to a food source while moving ants lay pheromone on the ground and at each step they preferentially decide with a random component to locally move towards the adjacent areas marked by higher pheromone intensity.
At time $t = 0$ two ants leave the nest looking for food. No pheromone is present on the terrain. Each ant decides independently which way to go, and the random decision is biased by the amount of pheromone on each path.

At $t = 1$ the ant following the shortest path has reached the food site. She decides to go back along the same path since it is marked with a higher amount of pheromone than the other, which has no pheromone yet.

At $t = 2$ this ant is back to the nest, and a double amount of pheromone is now present on the shortest path.

At $t = 3$ a new ant leaves the nest and selects the shortest path due to its higher concentration of pheromone, further reinforcing in this way its attractiveness compared to the longest path.
Fig.1 Ant province convergence onto the shortest path as a result of the pheromone laying-following behavior of individual ants.

Shorter paths between the nest and the food source can be completed quicker and more frequently by the ants moving back and forth, and will therefore be marked with higher pheromone intensity. These paths will then attract over time more and more foraging ants, which will in turn increase the pheromone level of these paths, until there is convergence of the greater part of the ants onto the shortest path(s).

In a short time, the greater part of the ants will convergence on moving on the shortest path. The local intensity of the pheromone field encodes a spatially distributed measure of goodness locally associated to each moving decision. It is the result the above figure illustrates this in a simple scenario with two possible paths of dissimilar length. In a darker trail on a path indicates a higher amount of deposited pheromone of the repeated and existing path sampling experiences of the ants. In other words, it is the result of a collective reinforcement learning process [126, 27] happening at the province level.

This form of distributed learning and control based on indirect communication among agents which locally modify the environment and react to these modifications leading to a phase of global coordination of the agent actions is called stigmergy [122]. In nature, ant colonies, as well as other social insects, make use of a variety of dissimilar pheromone signals for stigmergic communications. The dissimilar pheromones are secreted by dissimilar glands, and differ both in their chemical composition and their volatility. Recent studies have shown that this complex indirect signaling system based on multiple pheromones is efficiently exploited to react and coordinate in dissimilar ways to dissimilar stimuli in the environment.
For instance, the presence of a predator fuels the release of a danger-type of pheromone, while the discovery of a prey to be carried into the nest stimulates the creation of an intense but short-lived type of pheromone which is different from the long-lived pheromone laid for the exploitation of an abundant source of food.

Pheromones can be not only attractive, as the ones described so far, but also repulsive. For instance, a branching leading to a bad route can be marked with repulsive pheromone to avoid its expectations selection. Stigmergic coordination is one of the keys to obtain self-organized behaviors not only in ant colonies but more generally across social systems. When stigmergy is at work, system’s protocols (interfaces) play a prominent role with respect to modules (agents) [29], which can be kept comparatively simple. A good stigmergic model supplies robustness, scalability, resolvability, and allows to fully exploiting the potentialities of the modules and of modularity. Stigmergic systems are paradigmatic examples of the swarm intelligence approach.

The ability of ant colonies to “solve” distributed shortest path problems using a number of minimalist agents and pheromonemediate stigmergic communications has been exploited in the framework of the Ant Colony Optimization meta heuristic, in which all the mechanisms at work in the ant province shortest path behavior have been reverse-engineered to define a nature-inspired meta heuristic for the solution of generalized shortest path problems in graph structures (notice that almost any network and combinatorial optimization problem can be formulated in terms of finding shortest paths in a graph [27]). The Ant Colony Optimization has meta heuristic features: repeated path construction by a distributed system of lightweight
agents called ants, the use of a stochastic decision policy to incrementally construct each path by an ant that moves step-by-step from one node of the graph to an adjacent one, stigmergic communications among the ants through node-local stigmergic variables called pheromone variables, collective stigmergic learning of the pheromone variables, which represent the parameters of the decision policy, that is, which encode the expected quality of each decision about the next node to include into the path under construction.

The application of the Ant Colony Optimization Meta heuristic to network direction-finding is quite straightforward. This results both from the intrinsic distributed architecture of the meta heuristic and from the fact that the problem of defining optimized direction-finding paths in a network environment can be configured as a particular instance of a shortest path problem, with the weights of the edges being energetic values depending on bandwidth, propagation delay, and input traffic.

4.2 Honey Bee Provinces for Aadvantage Concepts

More recently than ant colonies, also honey bee colonies have attracted a strong interest as a potential source of inspiration for the design of optimization strategies for energetic, time-varying, and multi-objective problems. Bee colonies show structural uniqueness similar to those of ant colonies, such as the presence of a population of minimalist social individuals, and must face analogous problems such as distributed foraging, nest building and difference, etc. Bees utilize a sophisticated communication protocol that enables them to communicate directly through bee-to-bee signals and when required, similar to ants, use stigmergic feedback cues for bee-to-group or group-to-bee communication. In these two modules of insects, communication and cooperation is realized according to radically dissimilar modalities due to the dissimilar nature of these insects.
In particular, while in the case of ants communication is achieved via a pheromone trail that is laid on the ground while walking, in the case of bees it is a form of visual communication that plays an equivalent role. In the following we momentarily point out and thrash out the chief mechanisms at work in a bee province which have found their application in the design of direction-finding algorithms.

4.2.1 Optimization strategy for Flexible and era-associated splitting up of effort

A honey bee province consists of morphologically uniform individuals with different temporary specializations [137]. The benefit of the organization is an increased flexibility to adapt to the changing environments. For instance, a nectar forager can become a water forager if the province is running out on its water supplies. More particularly, in honey bees division of labor is chiefly related to age: workers of dissimilar ages specialize in dissimilar tasks. Workers typically perform brood rearing for the first week, engage in other hive different duties when they are "middle-aged" (2-3 weeks old), and switch to foraging and province defense when they are about three weeks old. These phases can be adaptively modified in response to the alteration of province conditions.

4.2.2 Optimization strategy for Transmission within the province and employment of employee

As in the ant case, also in a bee province foraging is critical aspect for the survival of the province and is executed in a fully distributed and competing way. Foraging bees steady leave the hive searching for new sources of nutrient, bring the nutrient back to the hive, and try to recruit other bees to exploit the food site found by competing with each other during the recruitment process. Foragers announce a food source of interest to their
fellow foragers by doing a dance on the dance floor inside the hive [115, 114]. This dance is termed waggle dance. It is a particular figure-eight dance that encodes the direction of the food source in the angle from the sun, and the distance in the duration of each waggle-run [137].

If the distance is very short the waggle dance resembles a round dance. Foragers respond to the waggle dance with a strong preference for choosing nearer food sites over distant ones in order to increase the net energetic efficiency of the province. The waggle dance is a direct form of agent-to-agents communication. Nectar foragers, upon return to the hive, sometimes also perform across the hive a quite strange dance termed tremble dance. The tremble dance means that the forager has found a rich food source but upon return to the hive, after a certain threshold time, she could not find a food-storer bee to give her nectar. This suggests that the message of the tremble dance is to stimulate the bees inside the hive to increase and/or to switch to nectar processing activities, and to inhibit the outside foragers from recruiting additional bees. Basically the tremble dance is intended to activate behaviors that keep a province’s nectar processing rate matched with its nectar intake rate.

4.2.3 Optimization strategy for Problematic Collection of Food Locations

The unemployed foragers refrain from extensively surveying the dance floor to identify the best food site. On the contrary, they observe maximally two or three dances on the dance floor and then decide to follow the indications of one of them according to a stochastic rule. As a result, a province distributes its foraging force on multiple food sites such that when one rich food site has been almost fully exploited the province is already exploiting other sites [137]. In this way an effective balancing between exploitation and exploration is automatically obtained. chapter [127] has developed an approved agent-based model using
process algebra for the foraging behavior of honey bee colonies which provides some useful insights about the province-level strategy for the distribution of the exploitation activities.