## Ant Colony Optimization (ACO) algorithm

Pierre-Paul Grassé, the French entomologist in the 40s and 50s of the 20th century, shone light on some interesting findings observed in some species of termites. He observed the reactions of these termites to something he called “significant stimuli” and found that those reactions themselves can also operate as significant stimuli for other insects in the colony, including the insect that produced them. This special type of communication found in these species was termed *stigmergy* and it was described with two main characteristics (Dorigo et al., 2006; Salman et al., 2020):

* It is an indirect, non-symbolic form of communication using the environment as a medium (i.e., communication through modification of the environment).
* The stigmergic information created is local (i.e., can only be accessed when in the vicinity/locus in which it was released).

Since then, stigmergy has been observed in many other species including ant colonies. In ant species, as the members travel in search of or returning from a food source, they deposit a chemical along the trails they traverse called *pheromone*. Other ants, upon inspecting a trail, can perceive these *pheromones* and, as a response, tend to follow the trail containing higher pheromone levels. As they traverse their chosen path, the also add their own deposited pheromone trail to the path, further increasing its pheromone concentration and further increasing the ‘attractiveness’ of this trail to successive ants on arrival. The remarkable efficacy of this pathfinding method implemented by ants was demonstrated by the thorough investigation performed by Deneubourg et al. (1990) into that exploratory pattern. In their, soon to become famous, “double bridge experiment”, they introduced a diamond-shaped bridge between the ant nest and a chemically unmarked arena for the ants to explore. This provided the ants with a binary left/right choice in such a way that the “dynamics of their cumulative choice [could] be easily quantified”. They noted that the ant’s stigmergic system exploited the positive feedback loop such that it, “after initial fluctuation, rapidly leads to one of the two forks becoming more or less completely preferred to the other” and eventually the whole colony converges on the use of only one of the bridges.

Diagram

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Figure 2 - Double Bridge experiment

Figure 1 -different length branches

Goss et al.(1989) expanded on this study by adding a food source to the arena and differing the size of the two bridges in the experiment. Again, the axis of entry is the same 30° on both sides of the bridges (total 60° between bridges) to minimize ‘loop back’ ant journeys and so that the forager has no preference for one or branch or the other based on position. In their experiment, at first, the ants were choosing equally between the short and long but “abruptly, some minutes late, one branch becomes visibly preferred”. The ants, at first choosing stochastically, the shortest bridge was the first to reach the nest, so on return the probability that they take again take the shorter path is higher as there is no pheromone trail attracting them to the longer path until those on that path finally arrive. Their choice then reinforces that pheromone trail as they deposit more on the way back, positively affecting bias towards this trail for all successive ants (Blum & Li, 2008). Their proposed model for that observed behaviour became the main source of inspiration for developing the Ant Colony Optimization algorithm we know today (Dorigo et al., 2006).

Dorigo & Blum (2005) defined the framework of the basic ACO as an iterative method through which the ants “probabilistically construct solutions to the combinatorial optimization problem under consideration, exploiting a given pheromone model”. The population of ants are set to traverse a graph, each ant building a solution by walking along the vertices in an iterative process to find the optimal route through the graph. In the algorithm, ants select the next vertex to visit using a stochastic mechanism that, like its natural counterpart, is biased towards the pheromones that have been left on that vertex. Finally, before at the end of each iteration, some of the solutions generated are used for performing a pheromone update.

Over time, ACO has become one of the most popular biologically inspired algorithms in literature (Blum & Li, 2008) and has found

### Initial Population

### Evaluating Fitness

## Bibliography

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