CSE/ECE 848 Introduction to Evolutionary Computation

Module 3 - Lecture 12 - Part 5

Ant Colony Optimization

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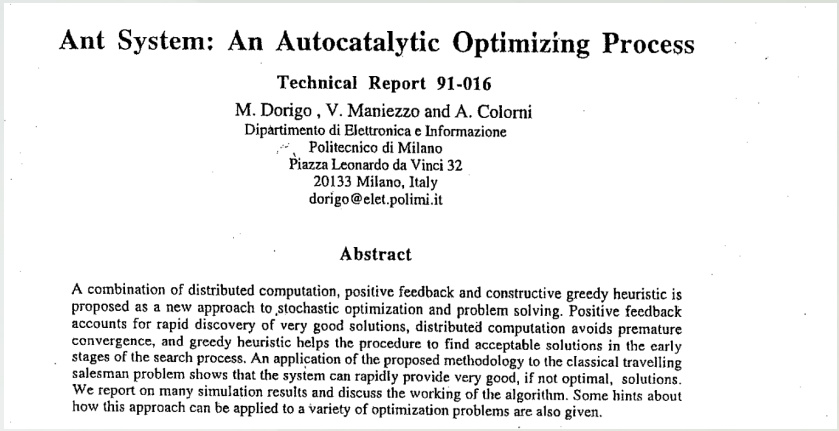
ACO

- Introduced in M. Dorigo, V. Maniezzo, and A. Colorni, The Ant System, Technical Report 1991
- M. Dorigo, 1992 PhD thesis
- General features
  - Swarm intelligence
  - Population-based
  - Stochastic
  - Derivative-free
  - Stigmergy



Ant System: An Autocatalytic Optimizing Process

Technical Report 91-016

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Abstract

A combination of distributed computation, positive feedback and constructive greedy heuristic is proposed as a new approach to stochastic optimization and problem solving. Positive feedback accounts for rapid discovery of very good solutions, distributed computation avoids premature convergence, and greedy heuristic helps the procedure to find acceptable solutions in the early stages of the search process. An application of the proposed methodology to the classical travelling salesman problem shows that the system can rapidly provide very good, if not optimal, solutions. We report on many simulation results and discuss the working of the algorithm. Some hints about how this approach can be applied to a variety of optimization problems are also given.

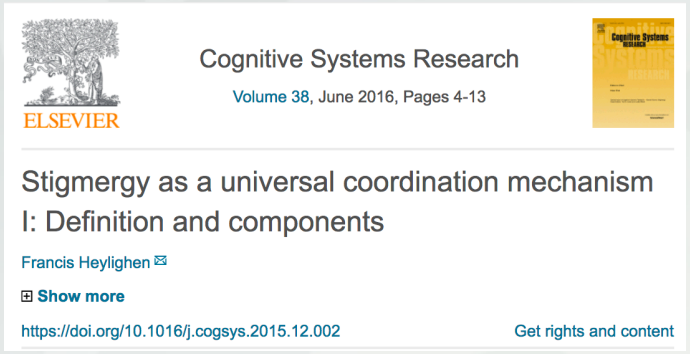
Stigmergy

A mechanism of indirect coordination

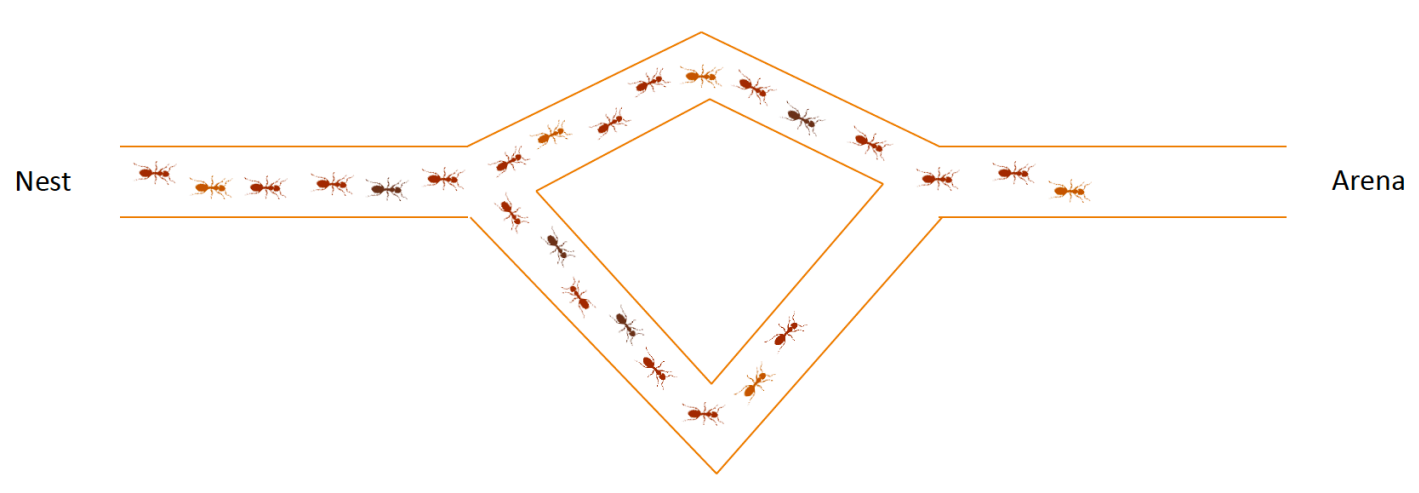
- Concept of Stigmergy first proposed by French entomologist Pierre Grasse` in1959 to refer to termite behaviour
- Stigmergy produces elaborate (self-organized) structures
- Main features:
  - Self-organized
  - Without planning
  - Without control
  - Without direct communication

Algorithmic Formulation

- Deneubourg et al. (1992) introduced the concept to algorithms for swarms

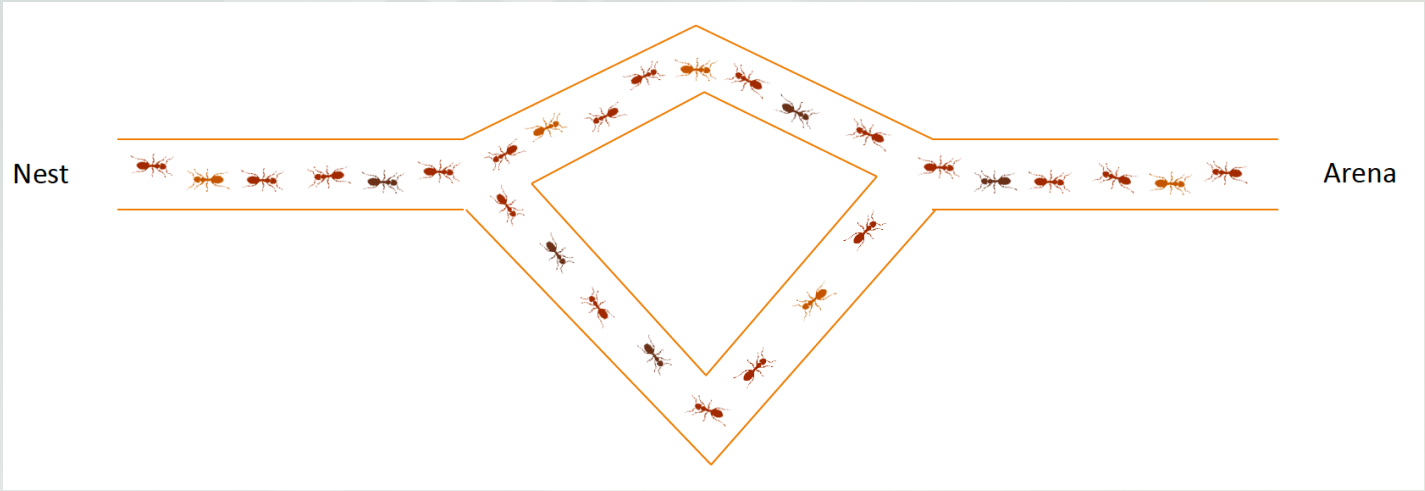


Ant Paths



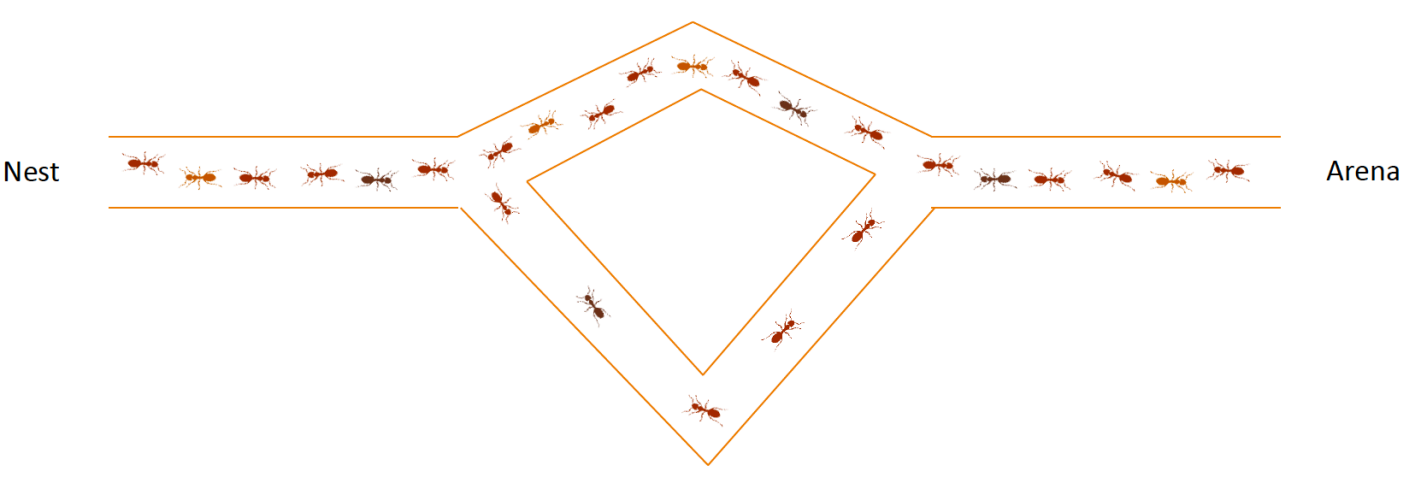
Ants moving between a nest and a food source

Ant Paths II



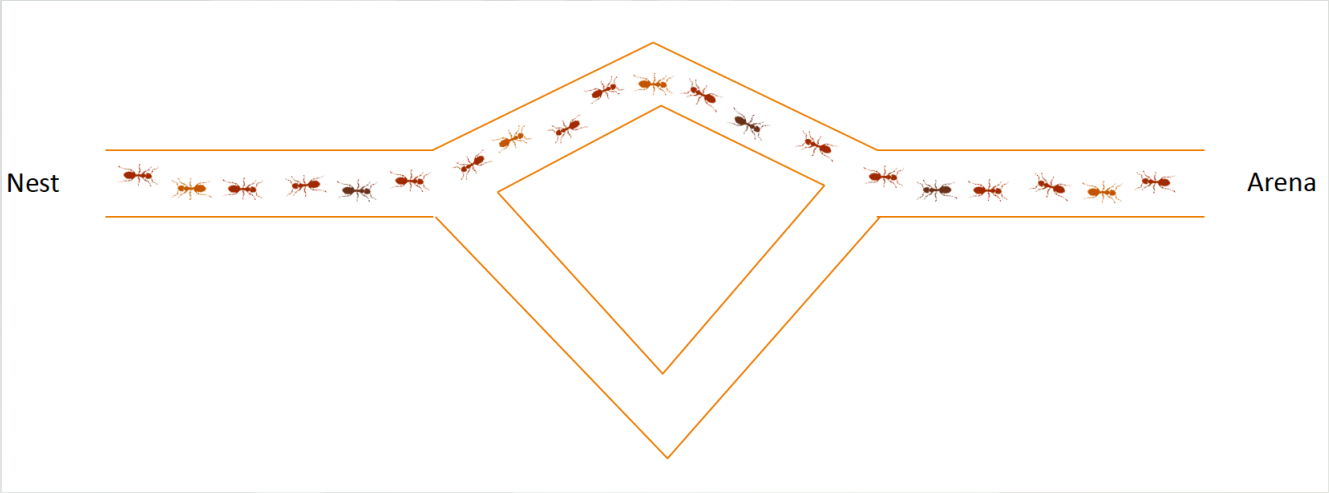
Frequency on short vs long paths

Ant Paths III



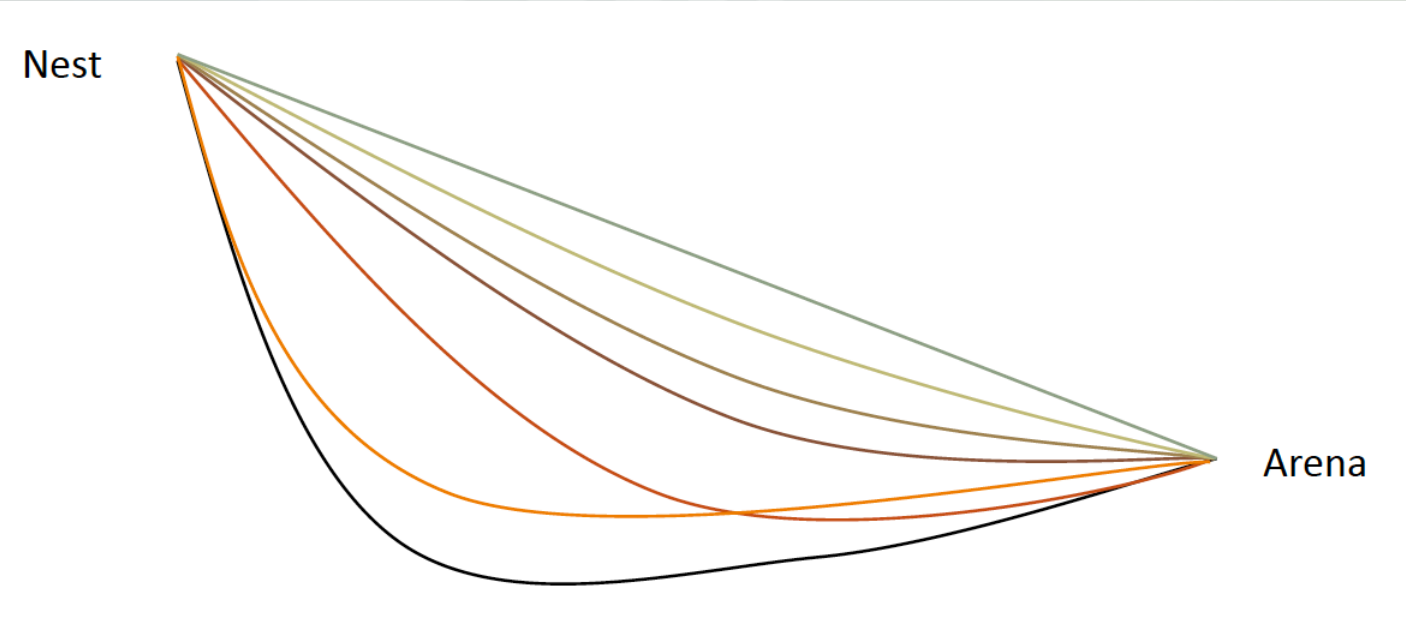
Pheromone trails with evaporation

Ant Paths IV



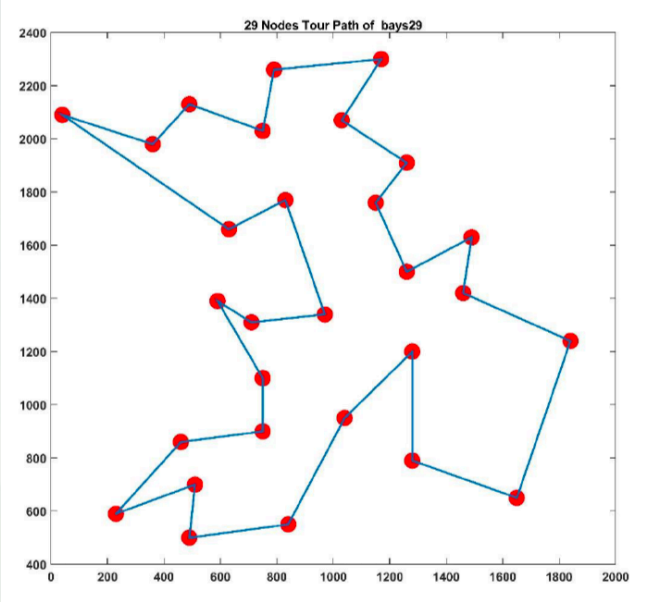
Adaption to optimize path length

Finding the Optimal Path



TSP

- Objective: Find the shortest route between cities
- Subject to:
  - Return to starting point
  - Visit each city once
- NP hard problem



ACO for TSP

- Distances between cities $d_{i,j}$
- Heuristic information about the link: $\eta_{i,j} = 1/d_{i,j}$
- Amount of pheromone on link: $\tau_{i,j}(t)$
- Probability for ant k to choose an edge i,j: $P^k_{i,j}(t)$
  - Acceptable edges

$$P^k_{i,j}(t) = \frac{\left(\tau_{i,j}(t)\right)^{\alpha}(\eta_{i,j})^{\beta}}{\sum_{l=acceptable}\left(\tau_{i,l}(t)\right)^{\alpha}(\eta_{i,l})^{\beta}}$$

  - Unacceptable edges $P^k_{i,j}(t) = 0$ (stored in a tabu list)
- $\alpha >= 0$ and $\beta >= 1$ are control parameters determining relative importance of trail vs visibility

Pheromone

- Evaporation (applied to all edges): $\tau_{i,j} = (1-\rho)\,\tau_{i,j}$ with an evaporation rate ρ, $0 < \rho < 1$
- Pheromone update for visited edges:

$$\tau_{i,j}(t+1) = \tau_{i,j}(t) + \sum_k \Delta\tau_{i,j}^k$$

$$\Delta\tau_{i,j}^k = \frac{Q}{L^k}$$

- Q: constant; L^k: total tour length of ant k

Algorithm

Initialization of pheromone of edges (τ_0) and randomly assign each ant to a city

while the terminate criteria not met

    for

        Build a tour for and ant k based on the probabilities, $P_{i,j}^{k}(t)$

    end

    Update the tour if it is improved

    for

        Update pheromones

    end

    Update the global best tour

end while

Variants to ACO

- Ant elitist system
- Rank-based ant system
- …