University of Guilan

Computational Intelligence

Subject12: Swarm Intelligence

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Agenda

- Intro
- Migrating birds optimization
- Ant colony algorithm

Intro

Assume that a group of people are looking for an underground treasure:

- Every individual with a metal detector to scan
- The closer you get to the treasure, the louder alarm will be
- Everyone can hear the alarm noise of the person beside him/her
- The louder the alarm is, the more people try to get close to you
- **So**: the chance to find the treasure increases for the whole group

Intro

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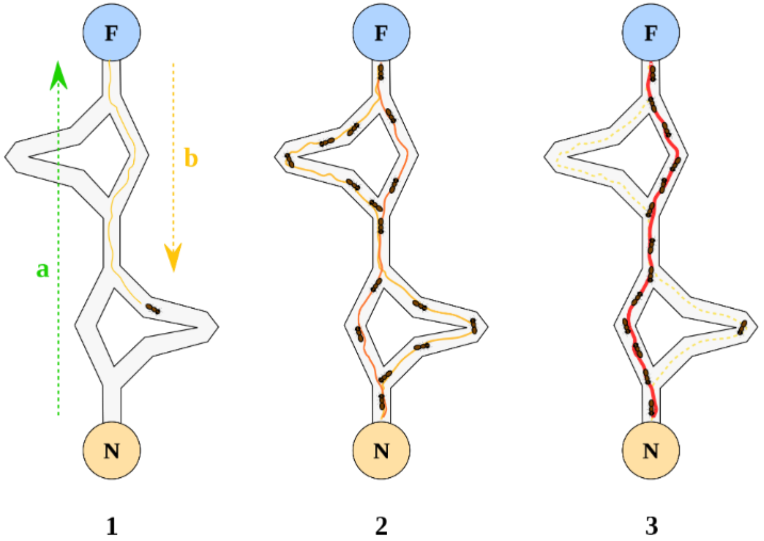
Important notes for the previous slide:

- A sample of **Swarm** behavior
- A population of simple agents
  - Interacting with each other and the environment
- Actually, group members try to solve a problem together
- The behavior of the group is more intelligent than individual’s behavior
  - Intelligent global behavior unknown to the individual agents
- Examples:
  - Ant colonies, bird flocking, bacterial growth

Intro

Swarm Intelligence (SI)

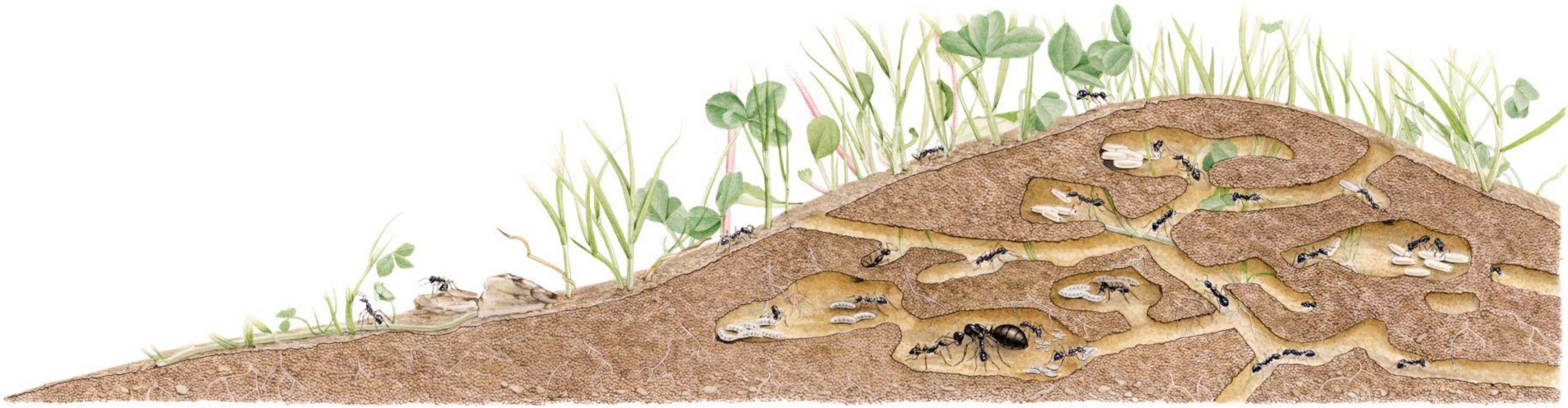
- The inspiration comes from biological systems
- Collective behavior of decentralized, self-organized systems.
- Applications:
  - Autonomous vehicles
  - Data mining
  - Locate and killing tumors
  - Routing
  - Social networks



Intro

Swarm Intelligence (SI)

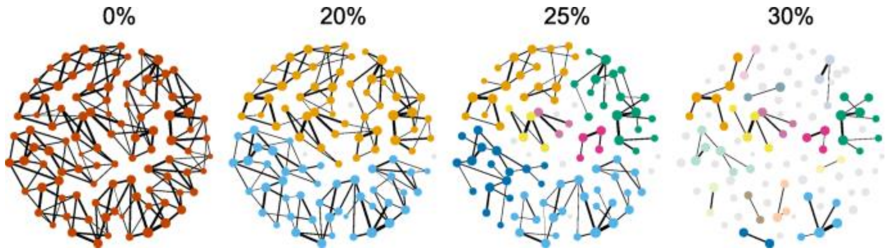
- Although individual might show simple behavior, the behavior of the group is complicated
- There is always a connection between the individual and group behaviors



Intro

Swarm Intelligence (SI)

- ***Main factor***: the relationship between individuals
  - Leads to optimization and improvement
- Some agents might play more critical roles
- The interaction between individuals can be **direct** or **indirect**
  - *Direct*: using sound, image, chemical change, etc.
  - *Indirect (Stigmergy):* leave signs in the environment for other agents



Intro

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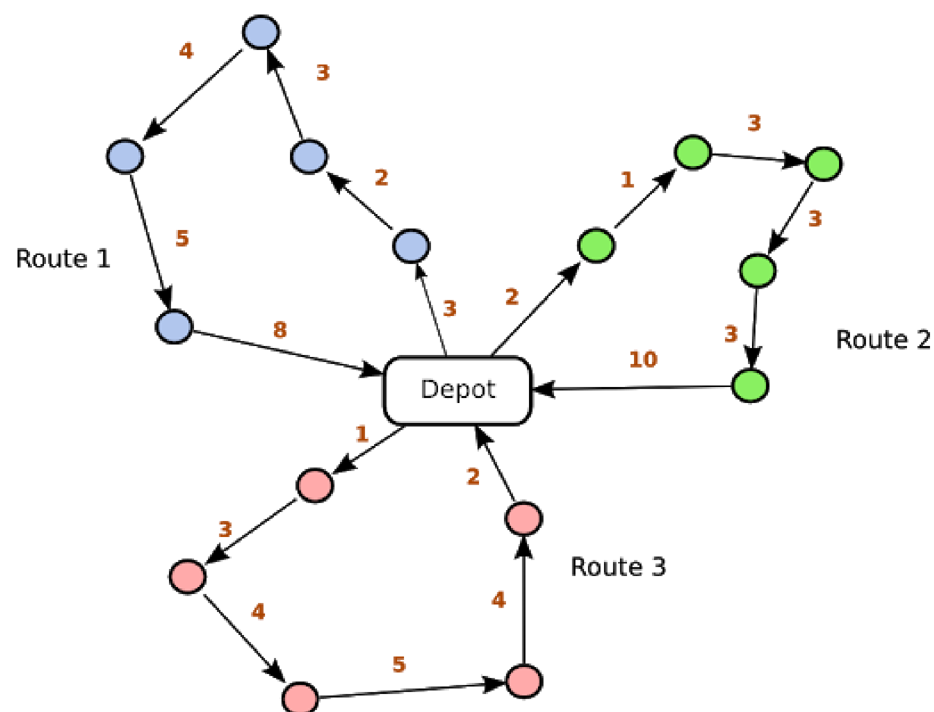
Some of the well-known algorithms

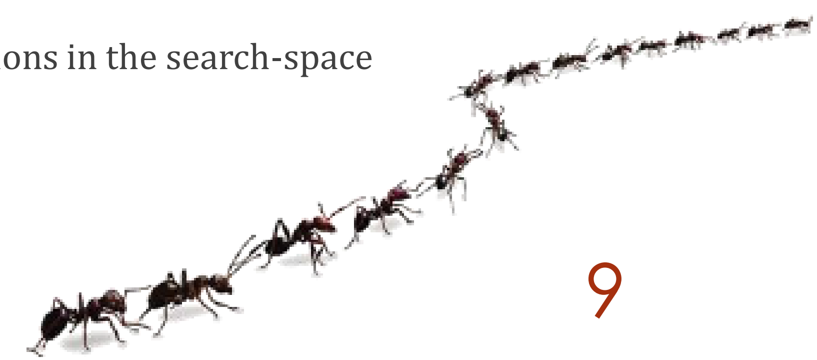
- Ant Colony Optimization
- Honeybee Hive Optimization
- Bee Colony Optimization
- Termite Colony Optimization
- Particle Swarm Optimization
- Cat Swarm Optimization
- Bat Algorithm



Intro

Particle Swarm Optimization (PSO)

- Inspired by bird flocks
- A population (swarm) of candidate solutions (particles)
- Optimization of a problem by iteratively improving candidates
  - Each iteration updates the best found solution
- Analyzing the movement of particles in the search space
  - Particle's movement ➔ local best known position
  - Swarm movement ➔ the best known positions in the search-space

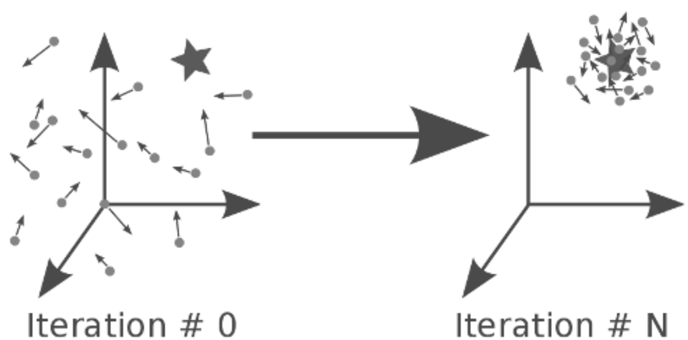


Intro

Particle Swarm Optimization (PSO)

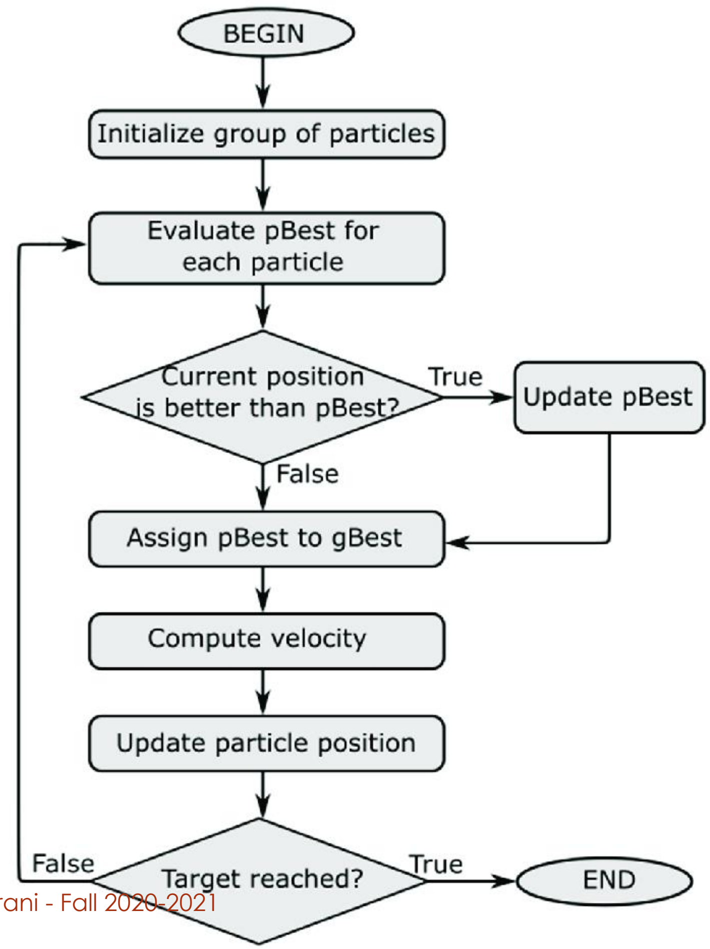
- Particles move in an n-D space which is called the Search Space
- Why? To find the best solution for the success of the swarm
- How? Based on knowledge or experience
- Output: the best local and general position

- **Three main steps:**
  - Finding the best agents
  - Fitness Calculation
  - Convergence



Intro

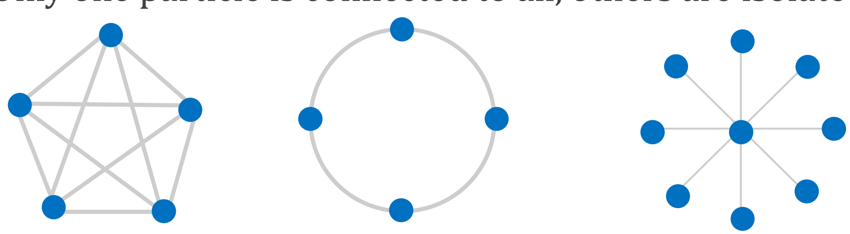
Particle Swarm Optimization (PSO)



Intro

Particle Swarm Optimization (PSO)

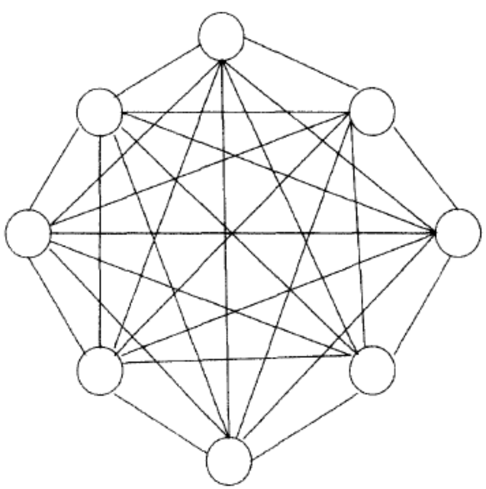
- Neighborhood Principle
  - Particles try to have a behavior similar to their best neighbors
  - The subset of particles with which each particle can exchange information
  - This can be done through different topologies:
    - Star: each particle is connected to all others and can easily find the best particle
    - Ring: each particle can only share information with its close neighbor
    - Wheel: Only one particle is connected to all, others are isolated



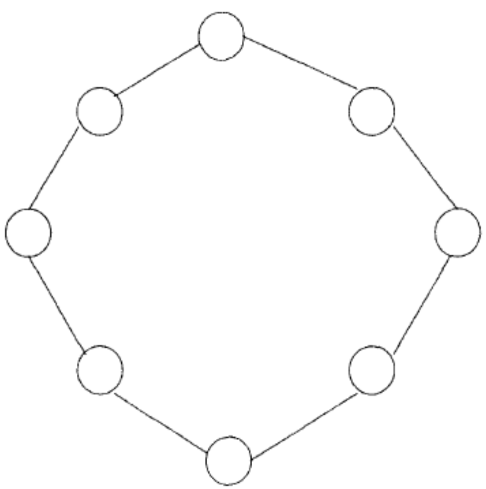
Intro

Particle Swarm Optimization (PSO)

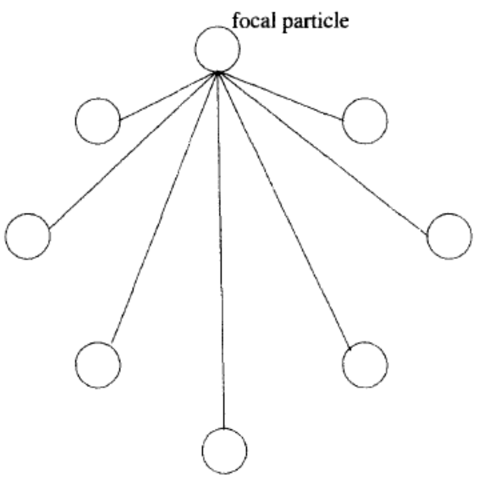
- Topologies



(a) Star Neighborhood Structure



(b) Ring Neighborhood Structure



(c) Wheel Neighborhood Structure

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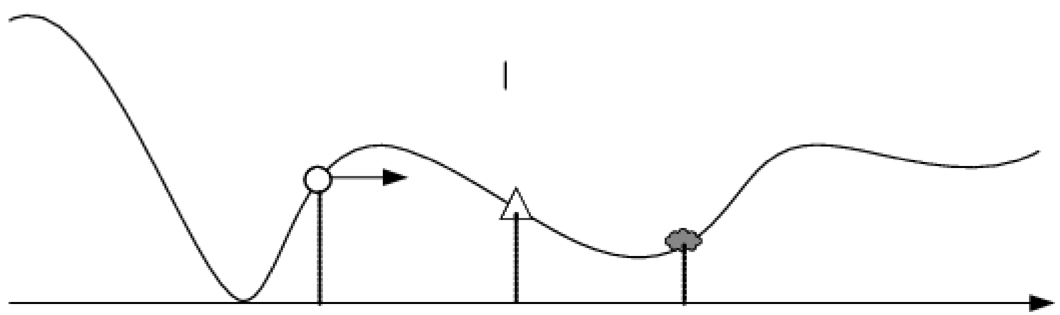
Particle Swarm Optimization (PSO)

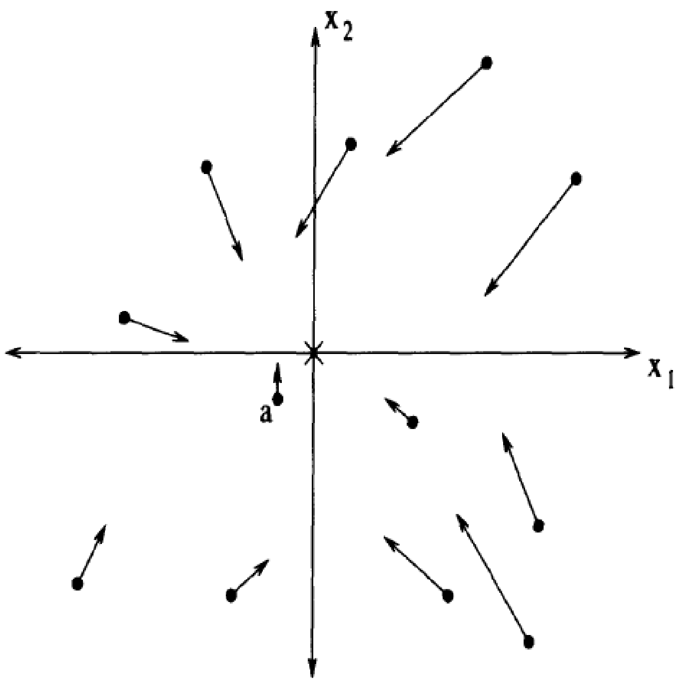
- *Individual Best*
  - Each particle only compares its state with the best possible state of itself
  - It has no further information about others



Intro

Particle Swarm Optimization (PSO)

- *Global Best*
  - This approach uses Star topology
  - Each particle tries to change its behavior towards the best particle's
  - Each particle uses its own experience to find the best solution



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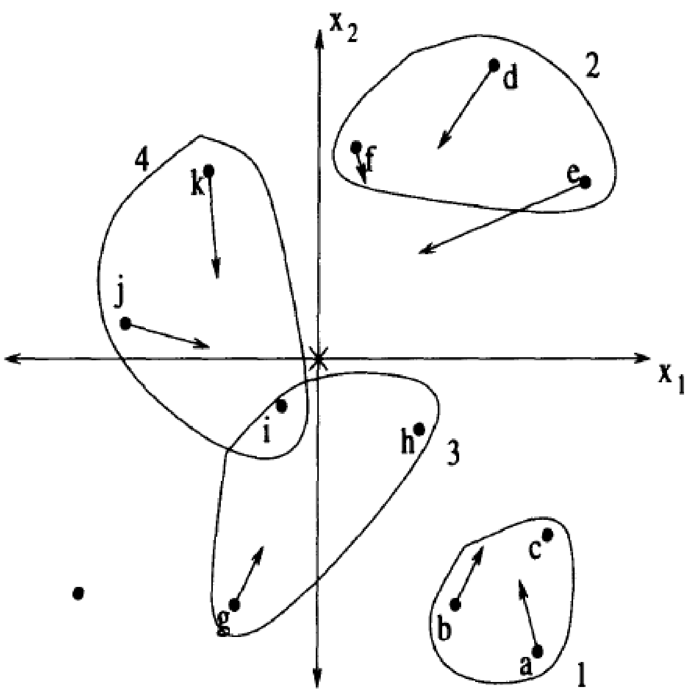
Particle Swarm Optimization (PSO)

- *Local Best*
  - This approach uses Ring topology
  - Each particle tries to change its behavior towards the best neighbor's
  - Each particle uses its own experience to find the best solution



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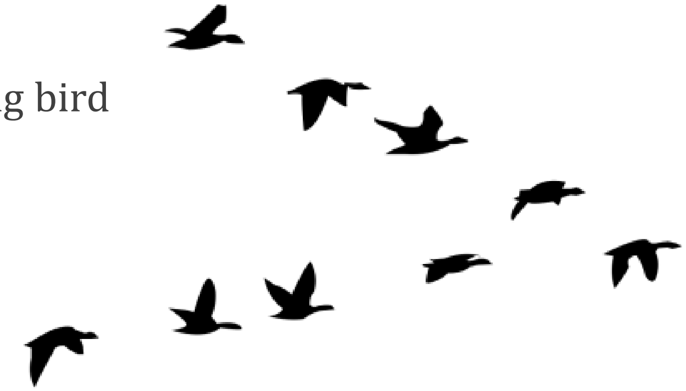
Migrating Birds Optimization

MBO Algorithm

- A neighborhood search technique
- Starts with a number of initial solutions (birds in a V formation)
  - Start: the initial solution, i.e. the leader bird
  - Progress: other birds trying to improve
- Replacement of the leader bird with following bird
  - It goes to the end of the left side
- Termination condition:
  - Reaching a predefined flapping parameter



Migrating Birds Optimization

```
(1)  Generate n initial solutions in V-formation
(2)  i = 0
(3)  while (i < I) do
(4)    for int j = 0; j < m; j++ do
(5)      Improve the leading solution by generating and evaluating k neighbors of it
(6)      i = i + k
(7)      for each solution S_r in the flock (except leader) do
(8)        Try to improve S_r by evaluating (k − x) neighbors of it and x unused best
           neighbors from the leader
(9)        i = i + (k − x)
(10)     end
(11)   end
(12)   Move the leader solution to the end and forward one of the solutions following it
       to the leader position
(13) end
(14) Return the best solution in the flock
```

Migrating Birds Optimization

# of neighbor solutions of leader bird $k \in \mathbb{N}^+; k = \{3, 5, 7 \cdots\}$

# of shared neighbor solutions $x \in \mathbb{N}^+; x = \{1, 2, \cdots, (k-1)/2\}$

# of neighbor solutions of remaining birds (except leader) $n = k - x$

0	1	0	1	1

S_0

1	0	1	0	0

S_1

0	0	1	1	0

S_2

1	1	0	0	0

S_3

0	1	0	0	0

S_4

Reference: https://doi.org/10.1016/j.procs.2017.06.012

Migrating Birds Optimization

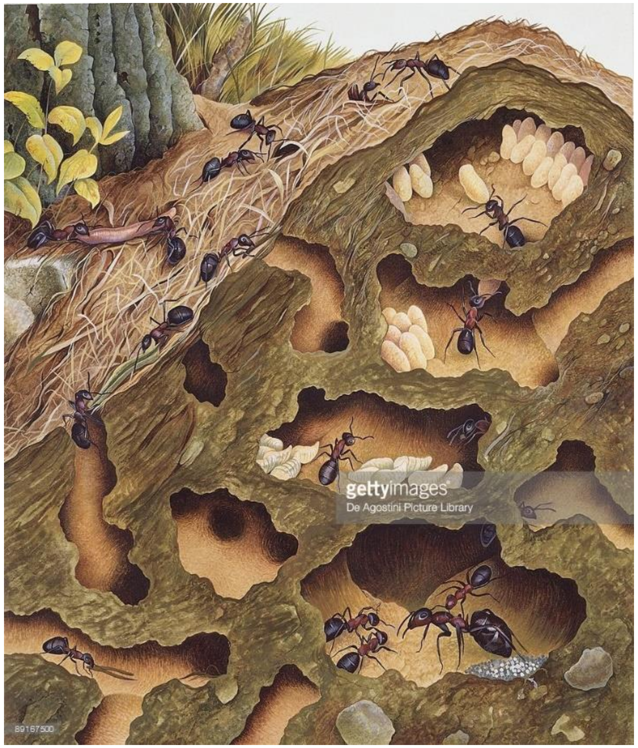
k=3
x=1

Bird	Permutation	Fitness (Sum of Profit)	Neighbor	Permutation	Fitness
			N_{01}	00110	80
S_0	01011	81	N_{02}	00101	71
			N_{03}	11001	41
			N_{11}	10101	81
S_1	10100	80	N_{12}	00110	80
			N_{13} (Shared=N_{02})	00101	71
			N_{21}	10010	60
S_2	00110	120	N_{22}	00011	51
			N_{23} (Shared=N_{03})	11001	41
			N_{31} (Shared=N_{12})	00110	80
S_3	11000	40	N_{32}	00010	50
			N_{33}	11001	41
			N_{41}	01010	80
S_4	01000	30	N_{42} (Shared=N_{22})	00011	51
			N_{43}	01001	31

Reference: https://doi.org/10.1016/j.procs.2017.06.012

Ant Colony Algorithm

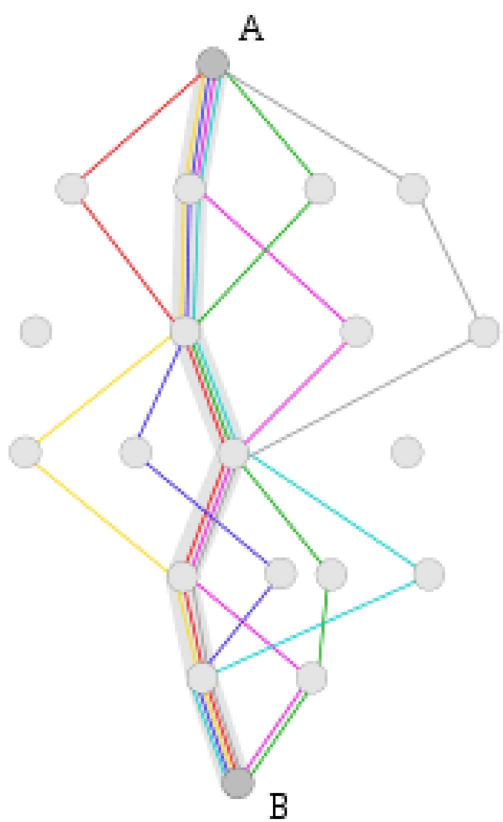
- A probabilistic technique for solving computational problems
  - Goal: finding good paths through graphs
- Inspired by the pheromone-based communication of biological ants
- Optimization (metaheuristic)
  - Artificial Ants + Local search
- Ambient networks of intelligent objects



Ant Colony Algorithm

Applications

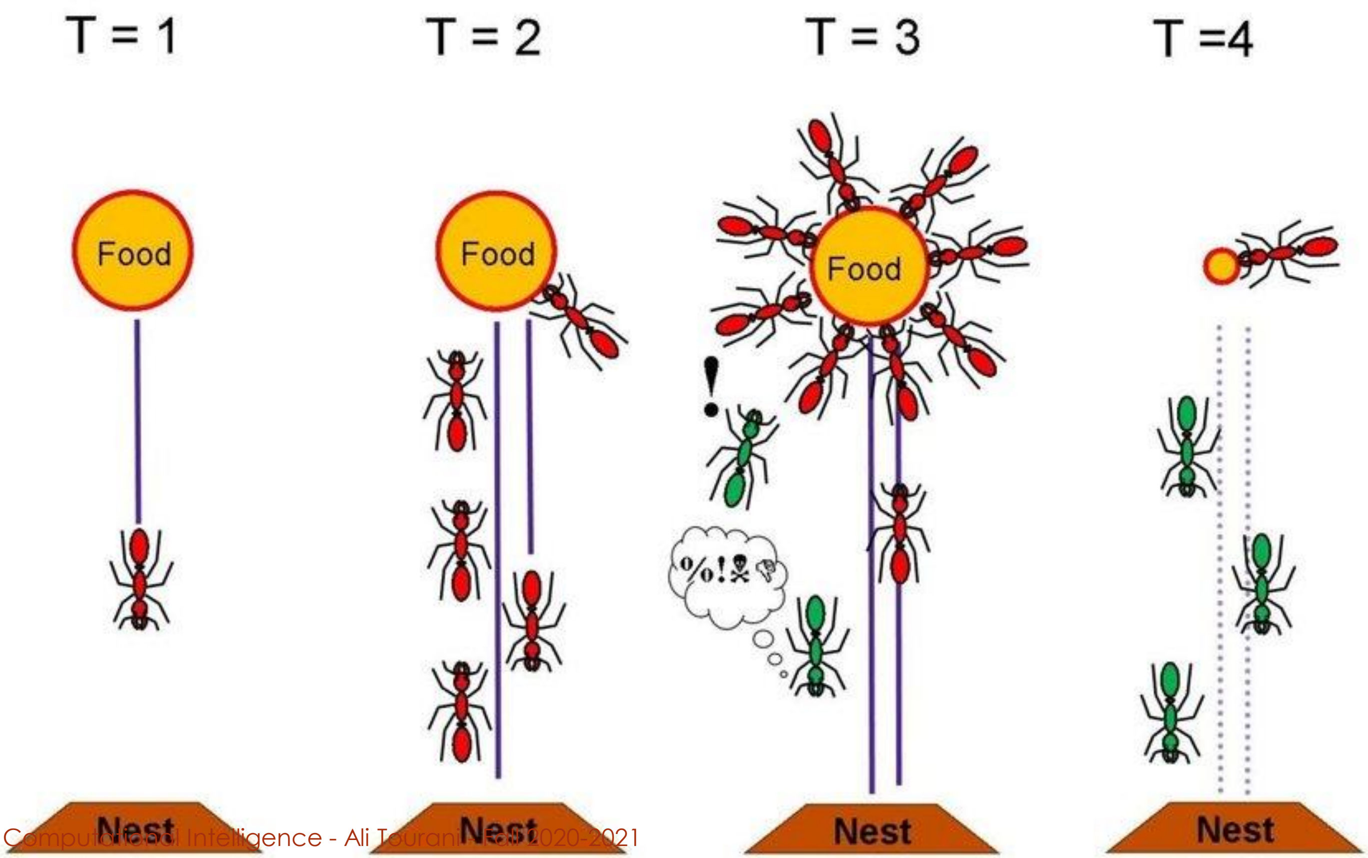
- Routing (networks/vehicles)
- Graph Coloring
- Scheduling
- Travelling salesman problem
- Antennas optimization
- Edge detection
- And so on …



Ant Colony Algorithm

- A good practice to find the optimal path in a Graph
  - *G=(Number of Nodes, Number of Edges)*
- Other variations of the algorithm
  - Simple ACO
  - Ant System
  - Elitist Ant System
  - Ranked-based Ant System
  - Fast Ant System
  - Min-Max Ant System

Ant Colony Algorithm



Ant Colony Algorithm

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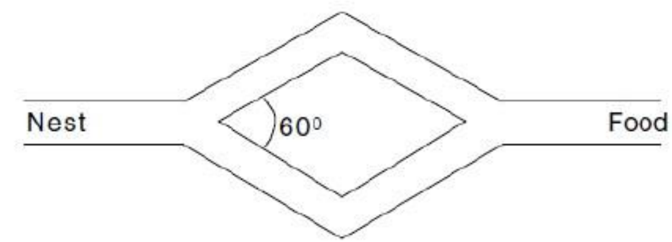
The behavior of ants

- Finding the shortest path from colony to food resources
- Indirect communication with other agents through pheromone
  - Stigmergy: exchange of information between ants via the environment
- Random search for food resources in the initial stage
- Improvement after finding food
- Following equal paths using pheromones
  - Path with more pheromone, more chance to be chosen
- Pheromone evaporation over time
  - The possibility of discovering a new path

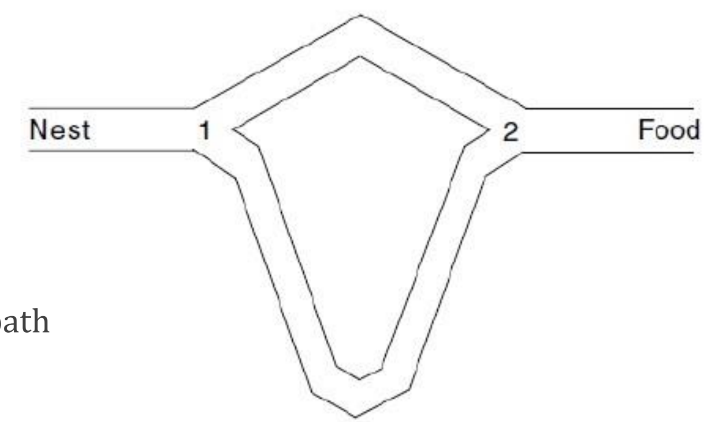
Ant Colony Algorithm

The behavior of ants

- *Equal length paths:*
  - Random selection of a route
  - *Return route*: route with more pheromones

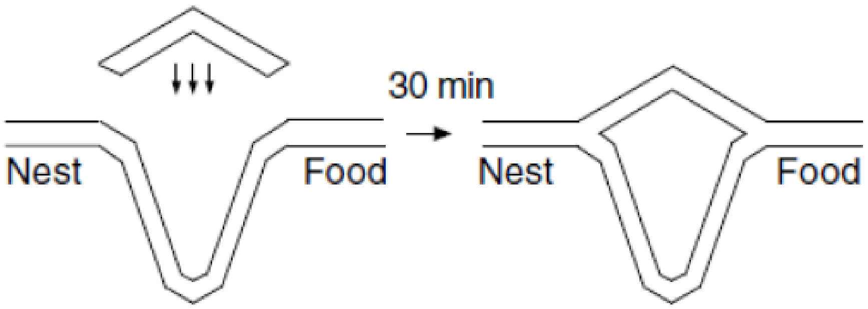


- *Two routes with different lengths:*
  - Random selection of a route
  - Shorter path ➔ path with more pheromones
  - Finally, choose the shorter path
    - A small percentage of ants still using the longer path



Ant Colony Algorithm

The behavior of ants



- *Adding a new route:*
  - Consider adding a shorter path after converging to the long path
  - Some ants use the shorter path (randomly) and others stick to the longer one
  - Why?
    - High density of pheromones in the long run
    - Slight evaporation of pheromones
  - The faster the evaporation, the less the optimal path is maintained
  - The slower the evaporation, the better the local catch

Questions?