COMP815 Nature Inspired Computing

Foraging Inspired Algorithms

Last Lecture – Particle Swarm Algorithm

- Particle Swarm Optimisation
  Bird Flock and Fish schooling examples
- Personal Best VS. Global Best
- Velocity Update rules and constraints

$$v_i^{(k+1)} = \underbrace{v_i^{(k)}}_{\text{Exploration}} + \underbrace{c_1 \cdot rand \cdot \left(pbest_i^{(k)} - x_i^{(k)} \right)}_{\text{Personal experience}} + \underbrace{c_2 \cdot rand \cdot \left(gbest^{(k)} - x_i^{(k)} \right)}_{\text{Social influence}}$$

Exploitation

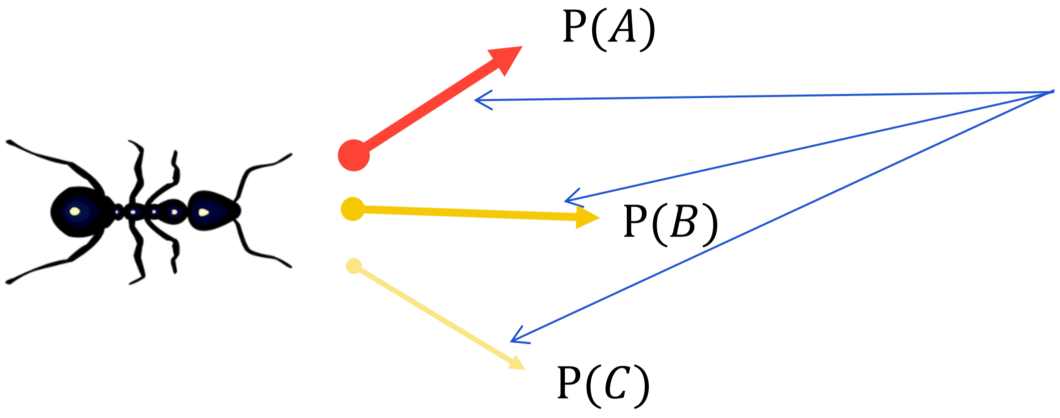
- Predator-Prey PSO

Ant Colony Optimization

Ants

- Have highly developed, sophisticated *stigmergy*
  - Communicate using pheromones
  - Lay trails of pheromone that other ants can follow

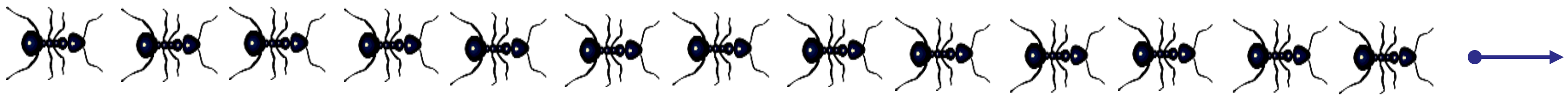
Follow the trail with thicker pheromone



$$P(A) > P(B) > P(C)$$

Finding the Shortest Path

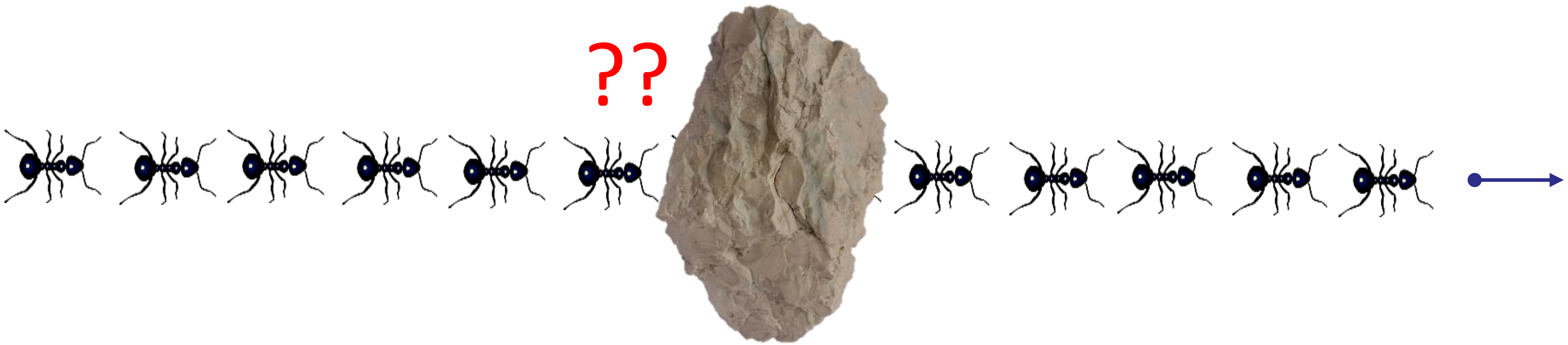
Ants are moving along a straight line



Finding the Shortest Path

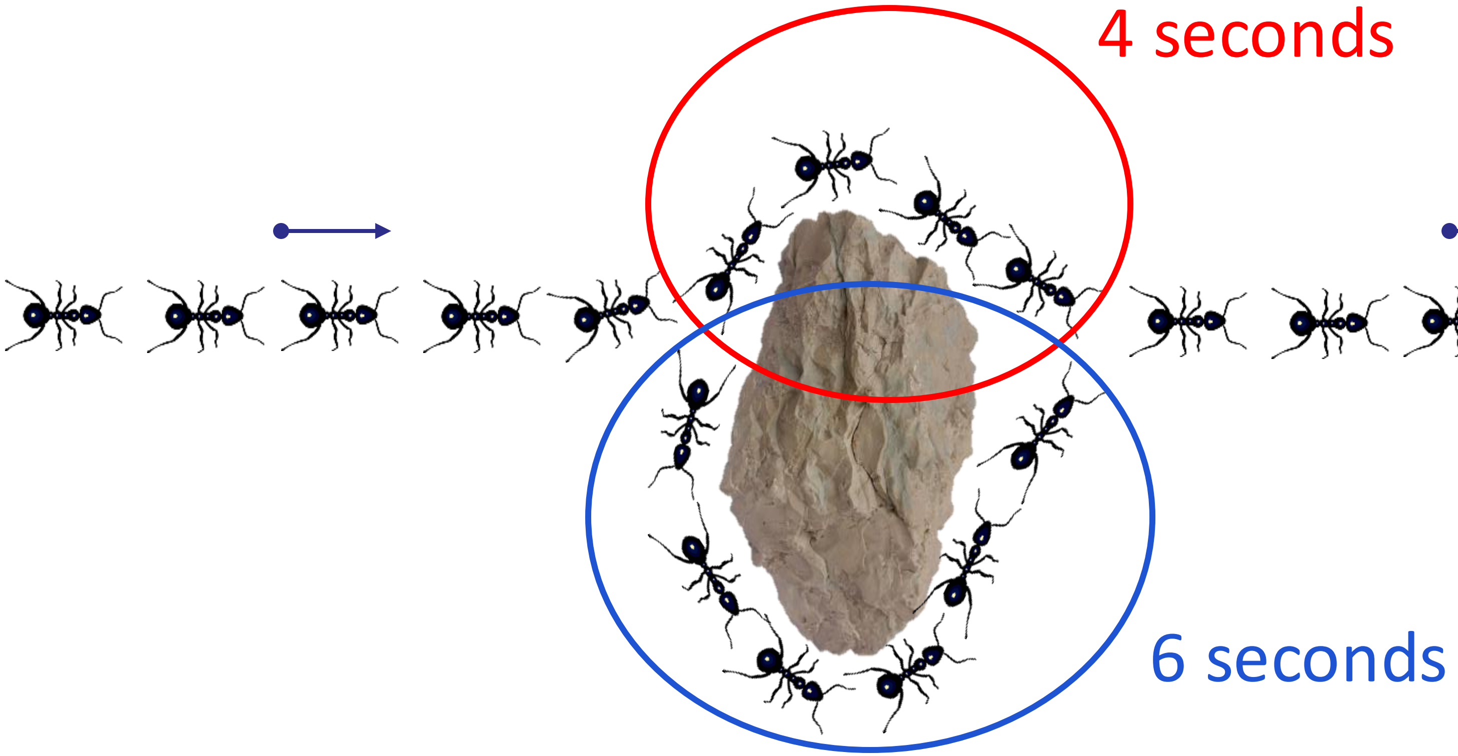
Ants are moving along a straight line

An obstacle appears on the path

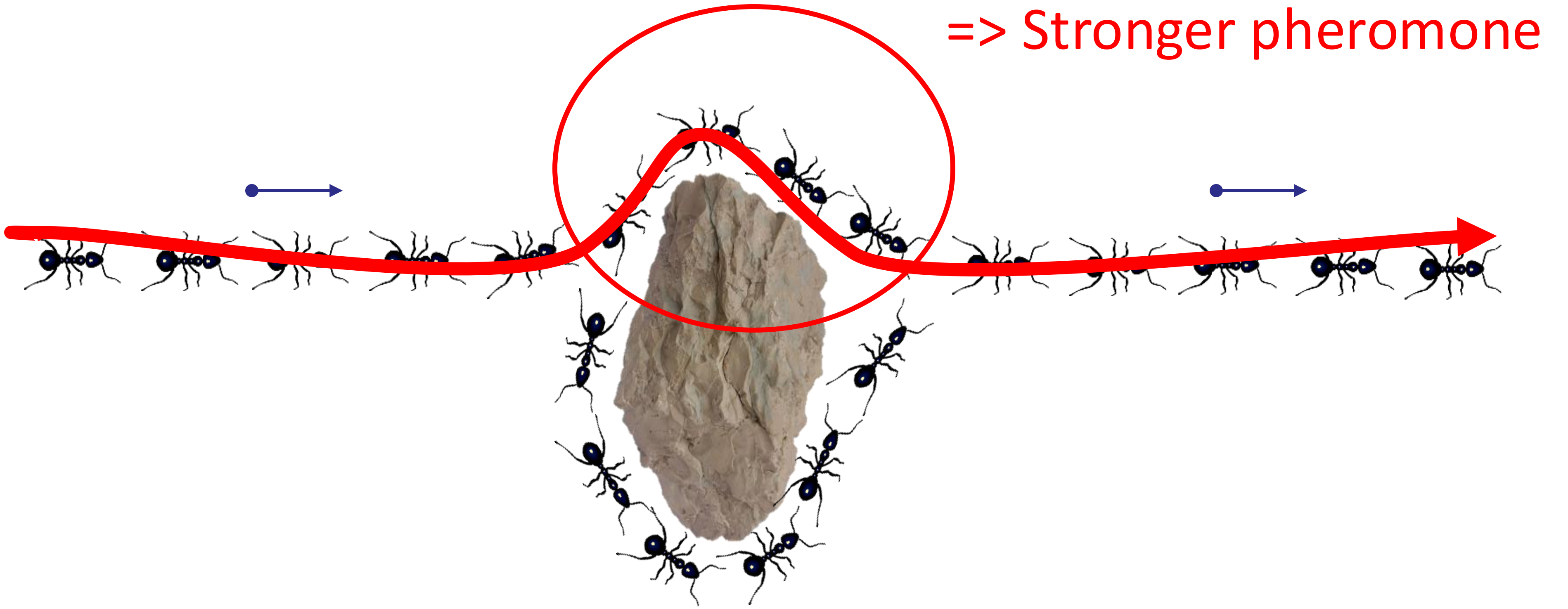


Assume one ant per second

Half turn left and half turn right



After a finite amount of time



Shortest Path to Food Source

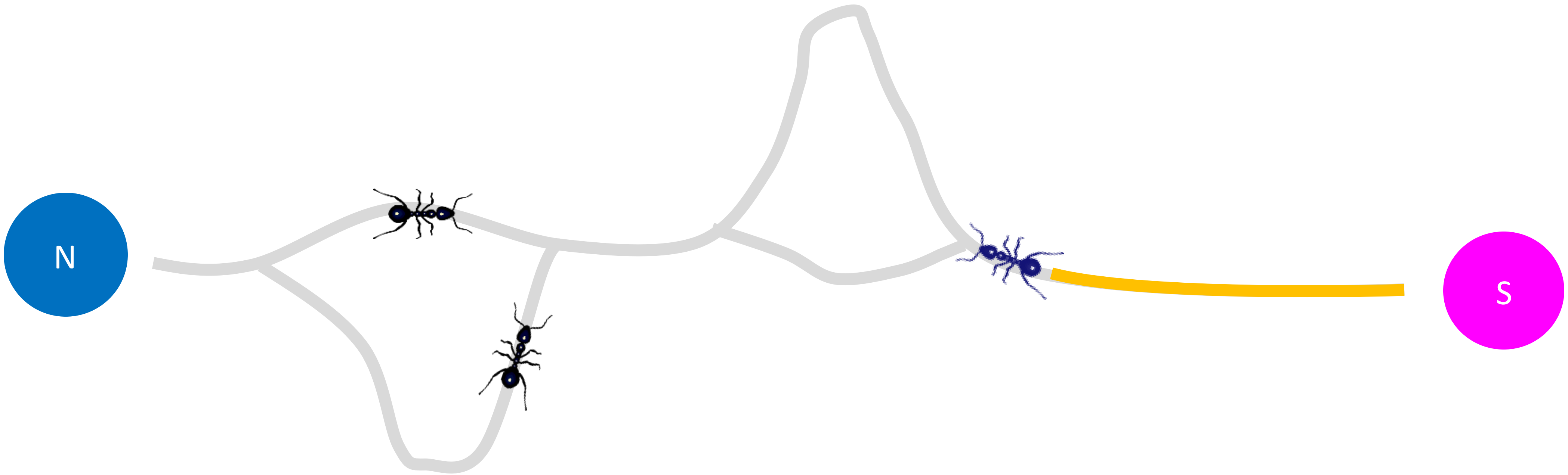
Ants travel randomly around the nest

Shortest Path to Food Source

One ant finds a food source

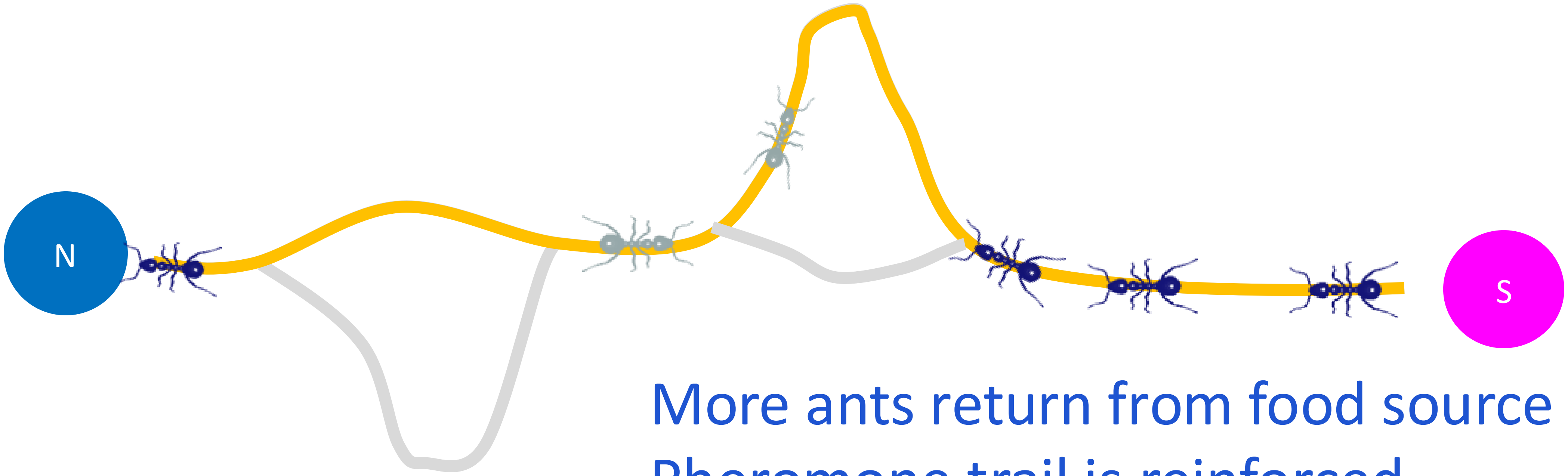
Shortest Path to Food Source

Returns to nest
Laying down pheromone trail



Shortest Path to Food Source

Other ants find pheromone trail
and follow it



More ants return from food source
Pheromone trail is reinforced

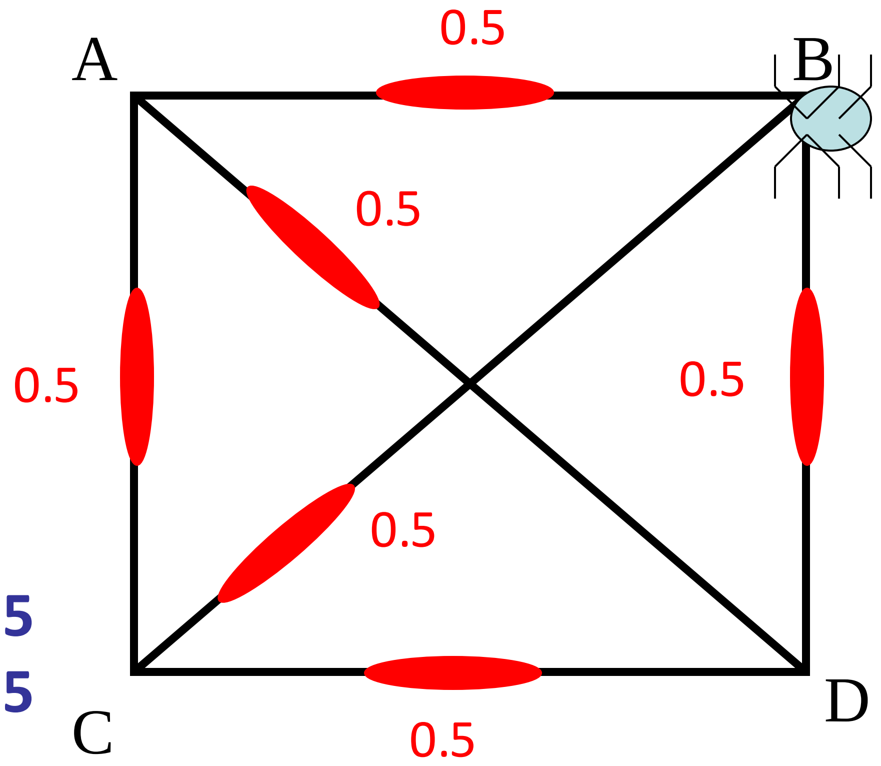
Ant Colony Optimization

- Basic idea:
  - Ants (particles) move along a graph
  - Choose where to go next depending on pheromone strength
  - An ants path represents a candidate solution
  - Pheromone is laid on the path of the ant, with the strength proportional to the quality of solution
  - Pheromone evaporates over time

Example: 4-city TSP

Initially, pheromone strength on each path is 0.5

Place an ant at a random node



Distances: **AB: 40 AC: 30 AD: 20 BC: 10 BD: 20 CD 15**

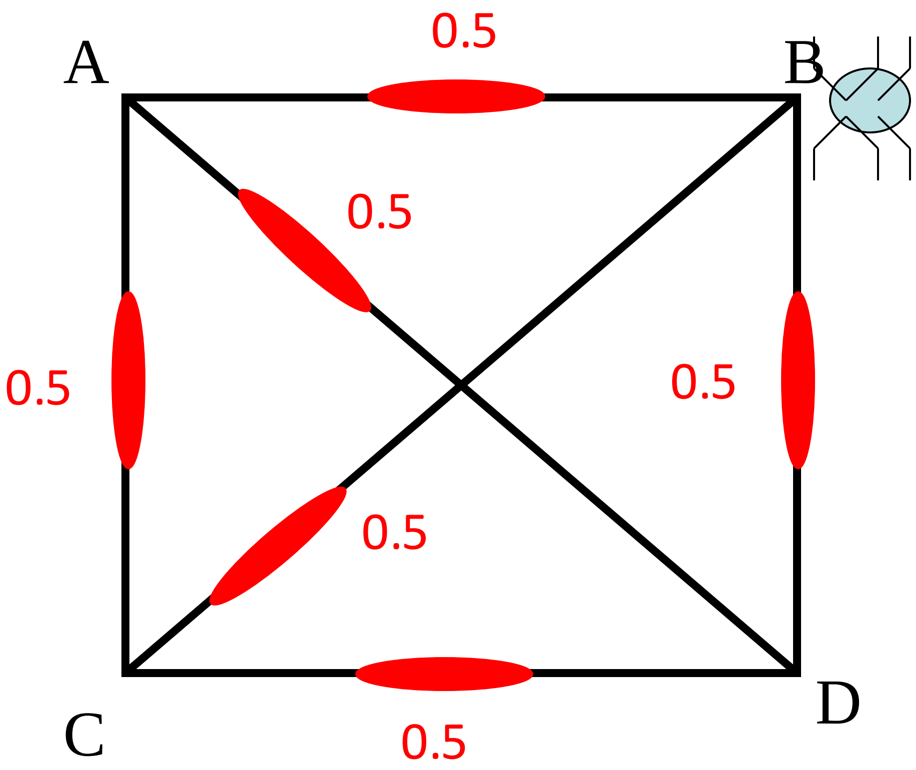
Total distances = **135**

Ant decides on next move
from current node *X* to next node *Y*
based on

$$\frac{\text{distance}(X,Y)}{\text{pheromone}(X,Y)}$$

Choose lowest value

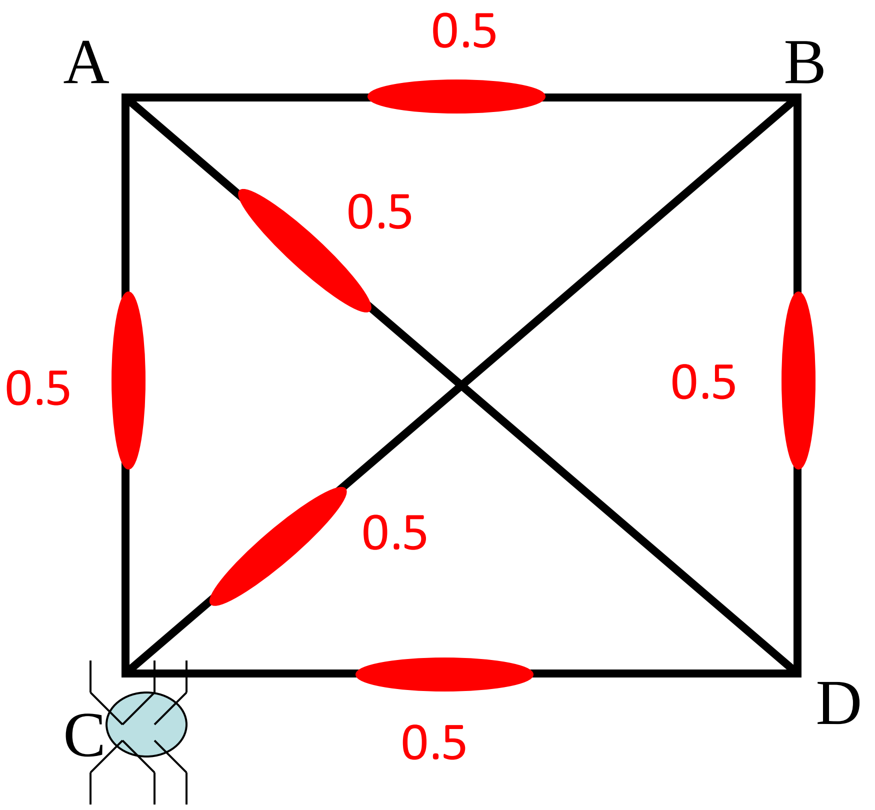
BA = 80
BC = 20
BD = 40



Distances: **AB: 40 BC: 10 BD: 20**

Choose lowest value except going back to B

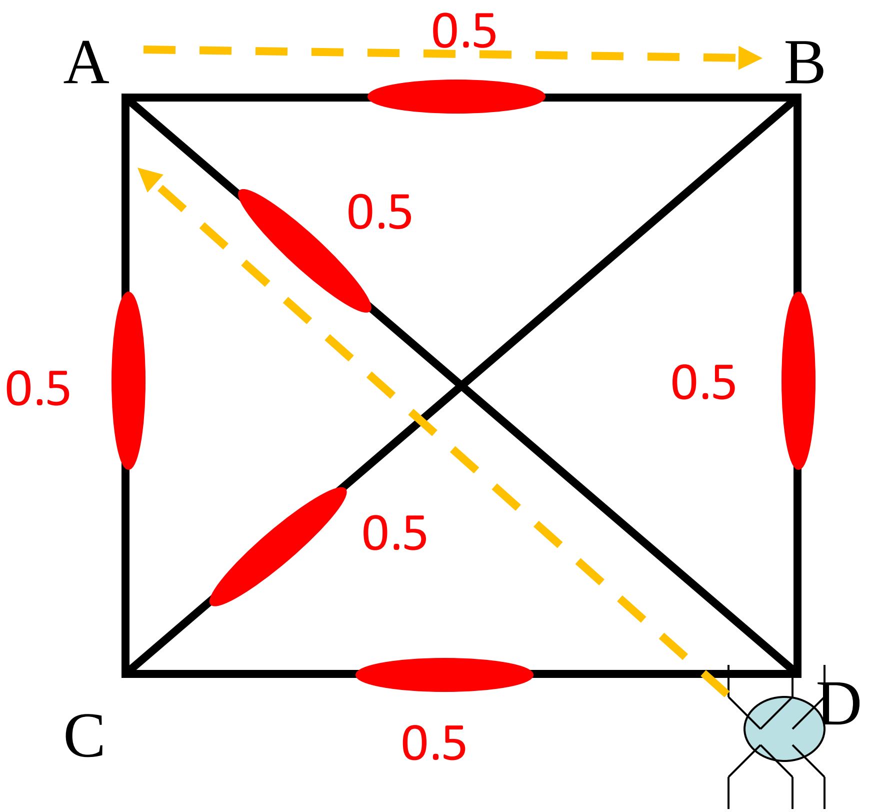
CA = 60
CB = 20
CD = 30



Distances: **CA: 30 BC: 10 CD: 15**

From D, only unvisited node is A

From A, returns to B



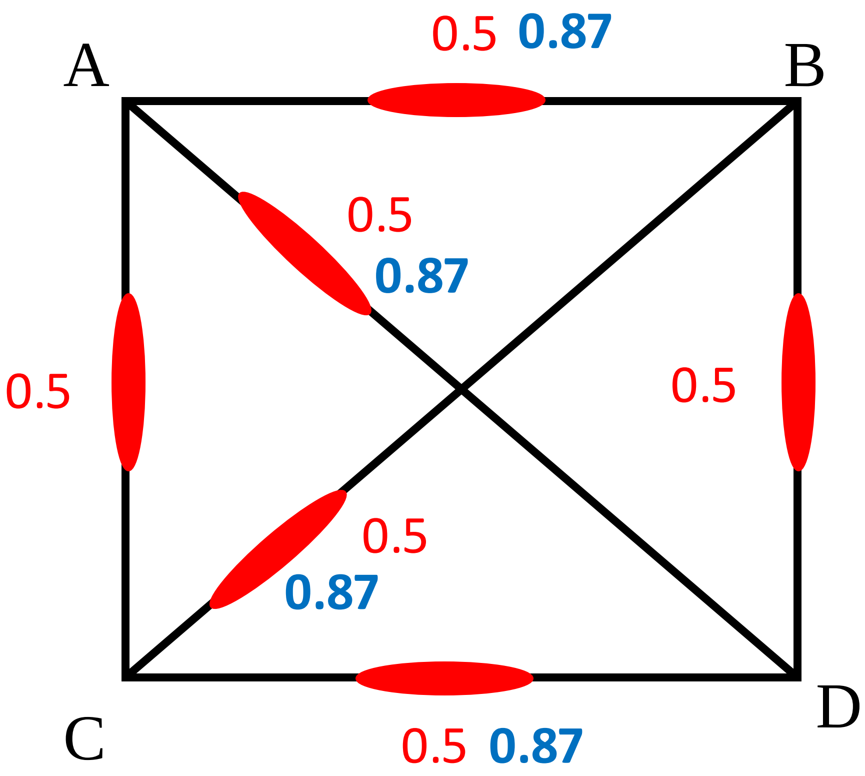
Tour = BCDAB

Fitness of tour = 10 + 15 + 20 + 40 = 85

Adjust Pheromone

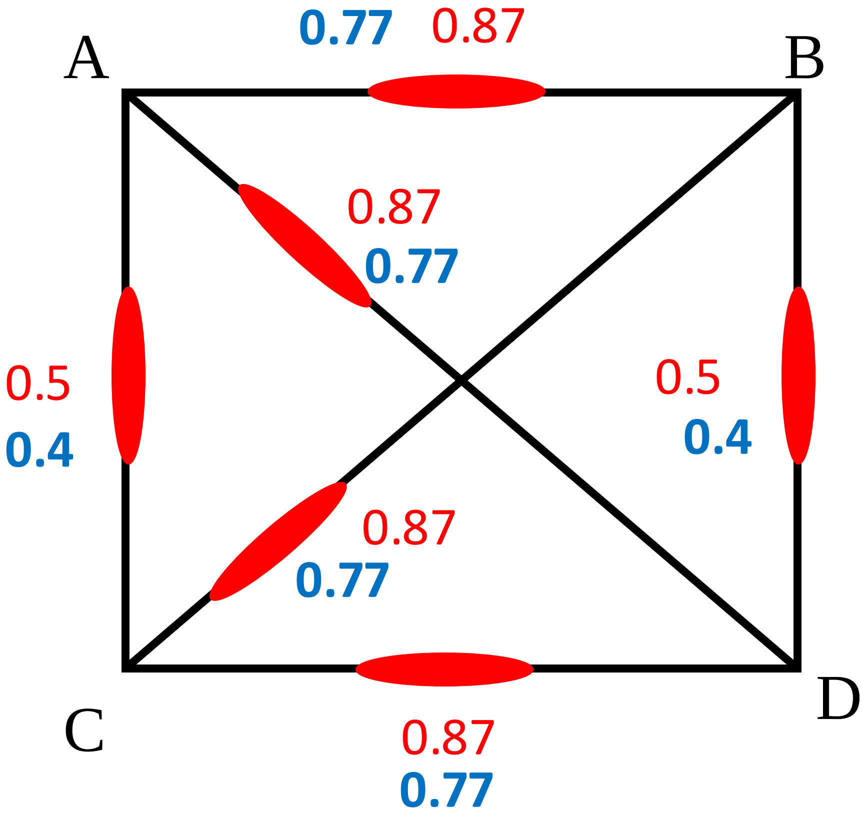
$$f = 1 - \frac{\text{route cost}}{\text{total distance}}$$

$$= 1 - \frac{85}{135} = 0.37$$



Pheromone decays a little, say, 0.1

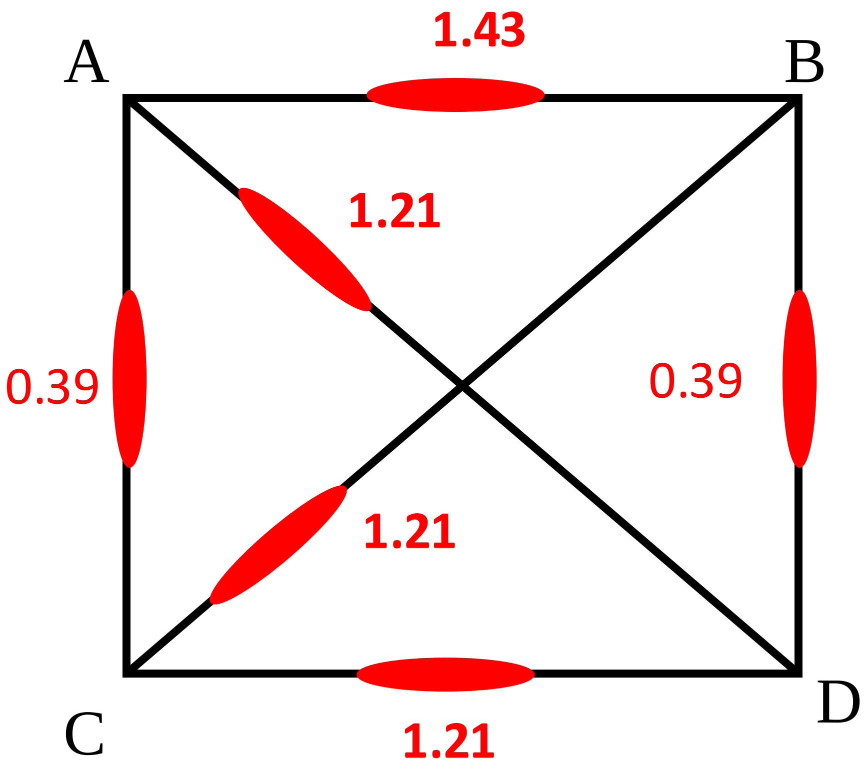
Remember the evaporates mechanism?



Work through the next cycle

Process continues until
one route stands out in terms of pheromone

B A D C B



Practical Implementation

- Usually has several ants exploring different paths
- Choice of next route to visit is *probabilistic*, not deterministic
- Need to balance <u>Exploration vs Exploitation</u> via a transition rule

Transition Rule

Probability that ant *k* will choose link that goes from *r* to *s*:

Current amount of pheromone on path from *r* to *s*

Heuristic value of link between *r* and *s*

$$p(r,s) = \frac{T(r,s) + H^{\beta}(r,s)}{\sum_{c \in U} \left[T(r,c) + H^{\beta}(r,c) \right]}$$

Heuristic strength

$$H(r,s) = {}^{1}\!/_{\mathrm{distance}(r,s)}$$

Set of unvisited cities

Global Pheromone Update

Pheromone decay rate

iteration

Number of ants

$$T^{(n+1)}(r,s) = \rho \cdot T^{(n)}(r,s) + \sum_{k=1}^{m} A_k(r,s)$$

$$A_k(r,s) = \frac{1}{L_k}$$

Amount of pheromone added to link (*r*,*s*) by ant *k*

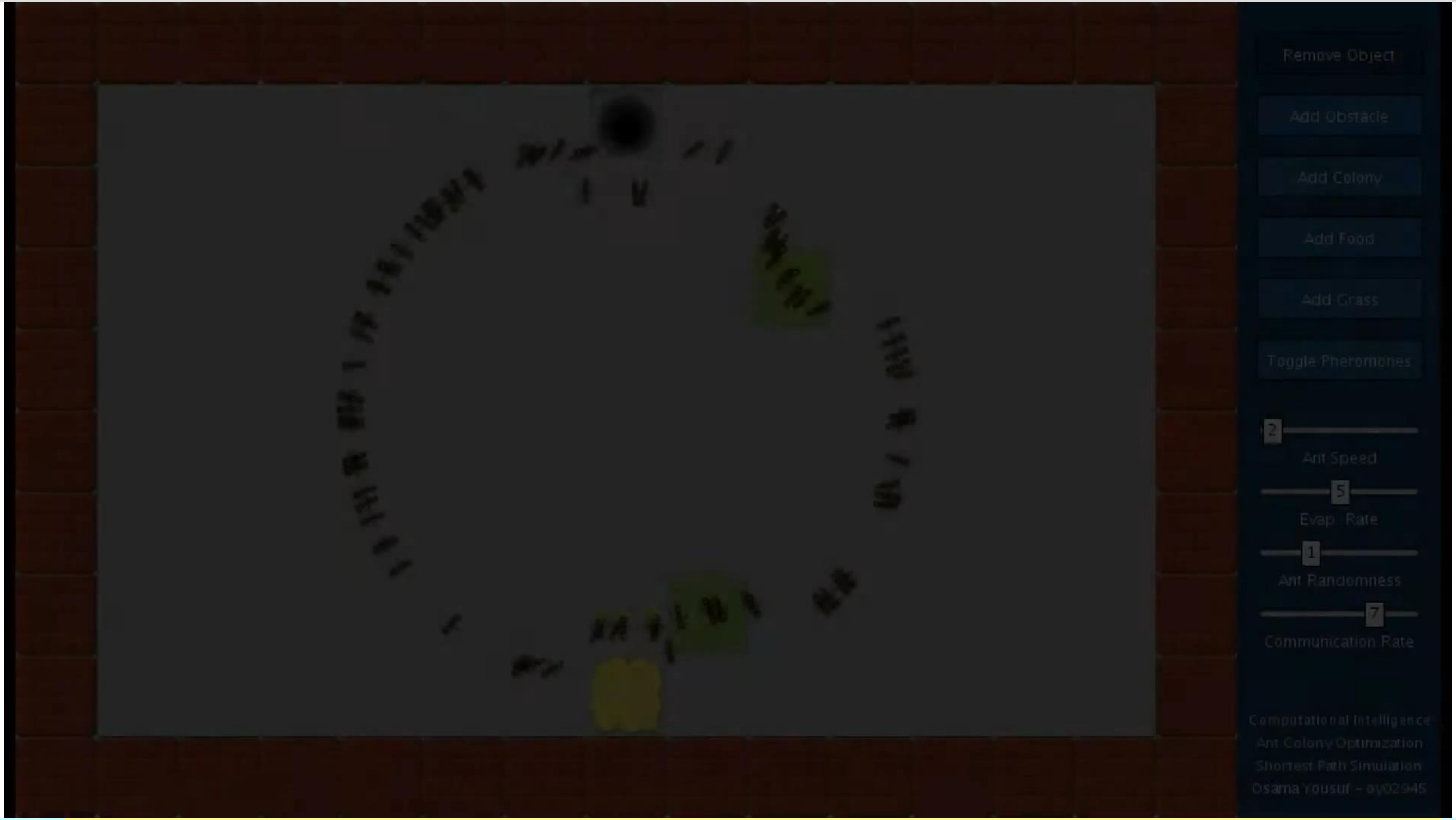
Length of tour completed by ant *k*

Design Choices (hyper-parameters)

- Number of ants
- Transition rule
- When are pheromones updated?
- Which ant should update pheromone?
- Termination criteria

An Video Demo

- URL



Credit to
[Osama Yousuf]

Other Swarm Intelligence Algorithms

Artificial **Immune** System

Bee Colony Optimization

Bat Algorithm

Cuckoo Search

Fireworks Algorithm

Intelligent **Waterdrop** Algorithms

Whale Algorithm

Summary

- Pheromones
  — Ant finding shortest Foraging path

- Ant Colony Optimisation
  — TSP example *w/* one Ant

- Practical designs
  — Transition rule
  — Global Pheromone update