

Ant Colony  
Optimisation

Dr Bart  
Craenen, Prof.  
Emma Hart

Introduction

Ant Colony  
Optimisation

Stigmergy

Artificial Ants

Examples

Pheromones

Summary

# Ant Colony Optimisation

Dr Bart Craenen Prof. Emma Hart

# This lecture

## Ant Colony Optimisation

Dr Bart  
Craenen, Prof.  
Emma Hart

Introduction

Ant Colony  
Optimisation

Stigmergy

Artificial Ants

Examples

Pheromones

Summary

- In this lecture we will discuss how Ant Colony Algorithms are used for optimisation
- The basic Ant Colony Optimisation (ACO) algorithm will be explained

## Covered Topics

- 1 Ant Colony Optimisation (ACO)
- 2 Stigmergy
- 3 Basic ACO algorithm

# Real Ant Colony Optimisation

## Ant Colony Optimisation

Dr Bart  
Craenen, Prof.  
Emma Hart

Introduction

Ant Colony  
Optimisation

Stigmergy

Artificial Ants

Examples

Pheromones

Summary



# Ant Colony Optimisation

## Ant Colony Optimisation

Dr Bart  
Craenen, Prof.  
Emma Hart

Introduction

Ant Colony  
Optimisation

Stigmergy

Artificial Ants

Examples

Pheromones

Summary

- Invented by Marco Dorigo in 1991 (as part of his PhD thesis) in collaboration with Colorni and Maniezzo.
- Draws inspiration from the behaviour of real ants to provide a method of optimisation.
- Normally works with combinatorial optimisation problems e.g. TSP, scheduling, facility placement, but extended for other types of problems as well.

# Ants – Shortest Path

## Ant Colony Optimisation

Dr Bart  
Craenen, Prof.  
Emma Hart

Introduction

Ant Colony  
Optimisation

Stigmergy

Artificial Ants

Examples

Pheromones

Summary

- When walking the ants leave a pheromone trail
- When choosing a route they are more likely to follow a route which has more pheromone deposited
- When the first ants are returning home they will tend to find more pheromone on the shortest path
- The rules are probabilistic - so mistakes can be made
- Pheromones evaporate allowing changes if a locally minimal route is found.

# Ants – Shortest Path

## Ant Colony Optimisation

Dr Bart  
Craenen, Prof.  
Emma Hart

Introduction

Ant Colony  
Optimisation

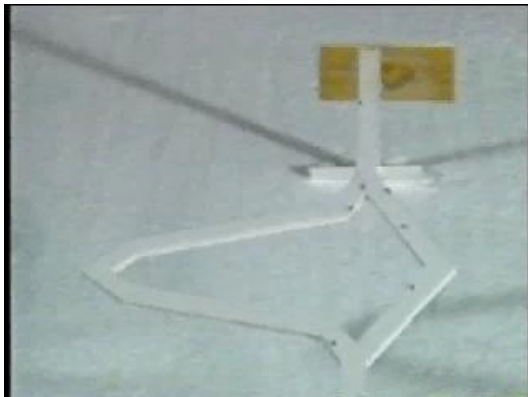
Stigmergy

Artificial Ants

Examples

Pheromones

Summary



# Stigmergy

## Ant Colony Optimisation

Dr Bart  
Craenen, Prof.  
Emma Hart

Introduction

Ant Colony  
Optimisation

Stigmergy

Artificial Ants

Examples

Pheromones

Summary

- Stigmergy is a particular kind of indirect communication exploited by social insects to coordinate their activities
- “La coordination des taches, la regulation des constructions ne dependent pas directement des oeuvriers, mais des constructions elles-memes. L’ouvrier ne dirige pas son travail, il est guidé par lui. C’est à cette stimulation d’un type particulier que nous donnons le nom du STIGMERGIE (stigma, pique; ergon, travail, oeuvre = oeuvre stimulante).” Grassé P. P., 1959
- “The coordination of tasks and the regulation of constructions does not depend directly on the workers, but on the constructions themselves. The worker does not direct his work, but is guided by it. It is to this special form of stimulation that we give the name STIGMERGY (stigma, sting; ergon, work, product of labour = stimulating product of labour).”

# Stigmergy

## Ant Colony Optimisation

Dr Bart  
Craenen, Prof.  
Emma Hart

Introduction

Ant Colony  
Optimisation

Stigmergy

Artificial Ants

Examples

Pheromones

Summary

- Allows simpler agents
- Decreases direct communication
- When the environment changes the agents respond appropriately

# Artificial Ants – Ant Colony Optimisation

## Ant Colony Optimisation

Dr Bart  
Craenen, Prof.  
Emma Hart

Introduction

Ant Colony  
Optimisation

Stigmergy

Artificial Ants

Examples

Pheromones

Summary

- We can have a colony of artificial ants which lay a trail in the search space of some problem.
- The problem might involve finding a shortest path but might be something else entirely – like, for example, making the right decisions in the construction of a timetable
- ACO uses artificial stigmergy

# Basic ACO Algorithm

## Ant Colony Optimisation

Dr Bart  
Craenen, Prof.  
Emma Hart

Introduction

Ant Colony  
Optimisation

Stigmergy

Artificial Ants

Examples

Pheromones

Summary

- When making a decision in the construction of solution to a problem (e.g. which city to visit next, or where to timetable the next event), we choose from the set of possible choices probabilistically based on the amount of artificial pheromone associated with making that decision.
- When we have finished the construction we adjust the pheromones on the decision path that we have taken according to how good the solution is.
- As we construct more and more solutions there is more and more information available about the probable “right” choices to make.
- Usually many ants construct a solution at the same time (i.e. with the same pheromone set)
- Pheromone is allowed to evaporate to avoid being trapped in local optima.

# Example: Routing

Ant Colony  
Optimisation

Dr Bart  
Craenen, Prof.  
Emma Hart

Introduction

Ant Colony  
Optimisation

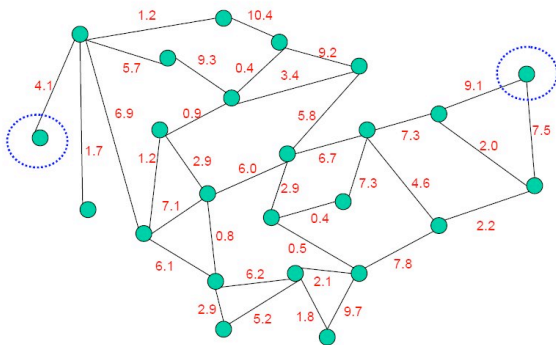
Stigmergy

Artificial Ants

Examples

Pheromones

Summary



Assume an algorithm to prevent loops and dead-ends

# Decision Making Example

Ant Colony  
Optimisation

Dr Bart  
Craenen, Prof.  
Emma Hart

Introduction

Ant Colony  
Optimisation

Stigmergy

Artificial Ants

Examples

Pheromones

Summary

- The chance of taking choice 2 might be calculated like this:

$$\frac{\tau_2}{\sum \tau_{t_i}} = \frac{0.7}{0.2 + 0.7 + 0.1 + 0.6 + 0.8}$$

Choice	Variable Name	Pheromone Value	Chance of Chosing
1	$t_1$	0.2	0.083
2	$t_2$	0.7	0.291
3	$t_3$	0.1	0.041
4	$t_4$	0.6	0.25
5	$t_5$	0.8	0.333

# Decision Making Example

## Ant Colony Optimisation

Dr Bart Craenen, Prof. Emma Hart

Introduction

Ant Colony Optimisation

Stigmergy

Artificial Ants

Examples

Pheromones

Summary

- We can increase the differences by raising the pheromones value to a power  $\alpha$ :

$$\frac{\tau_2^\alpha}{\sum \tau_{t_i}^\alpha} = \frac{0.7^\alpha}{0.2^\alpha + 0.7^\alpha + 0.1^\alpha + 0.6^\alpha + 0.8^\alpha}$$

Choice	Variable Name	Pheromone Value	$t_i^{\alpha=2}$	Chance of Choosing
1	$t_1$	0.2	0.04	0.026
2	$t_2$	0.7	0.49	0.318
3	$t_3$	0.1	0.01	0.006
4	$t_4$	0.6	0.36	0.233
5	$t_5$	0.8	0.64	0.415

# Adding Heuristic Information

## Ant Colony Optimisation

Dr Bart Craenen, Prof. Emma Hart

Introduction

Ant Colony Optimisation

Stigmergy

Artificial Ants

Examples

Pheromones

Summary

- We might like to add heuristic information about how to solve the problem.
- E.g. for routing this might be the cost of an edge
- The decision making process might take into account both the pheromone value and the heuristic value
- The probability of choosing path  $x$  becomes:

$$\frac{\tau_x^\alpha \eta_x^\beta}{\sum \tau_i^\alpha \sum \eta_i^\beta}$$

- The relative values for alpha and beta determine the relative importance of the pheromones and the heuristic

# Changing the Pheromones

## Ant Colony Optimisation

Dr Bart  
Craenen, Prof.  
Emma Hart

Introduction

Ant Colony  
Optimisation

Stigmergy

Artificial Ants

Examples

Pheromones

Summary

The pheromone matrix will be updated by:

- Each ant at the end of its route – depending on how good the route was
- Evaporation – usually after each set of ants has finished

# Summary

## Ant Colony Optimisation

Dr Bart  
Craenen, Prof.  
Emma Hart

Introduction

Ant Colony  
Optimisation

Stigmergy

Artificial Ants

Examples

Pheromones

Summary

- In this lecture we discussed Ant Colony Optimisation (ACO)
- ACO algorithms are particularly used to solve combinatorial optimisation problems (TSP, scheduling, routing, etc.)
- ACO algorithms have been adapted for many other types of problems as well

## Ant Colony Optimisation

- 1 Draws inspiration from real ant behaviour
- 2 Tries to find the shortest path through the search space
- 3 Uses artificial stigmergy
- 4 Handling the “Pheromone Trail” determines performance of the algorithm