Exercise L3 swarm intelligence 2021

Question 1

a) How would you define swarm intelligence?

Swarm intelligence is the emergent collective intelligence of groups of simple/reactive agents, typically based on the social insect metaphor.

b) What is stigmergy?

Stigmergy is indirect interaction
↳ Non-symbolic form of interaction mediated by the environment.
Insects exchange information by modifying their environment.

2) Local information is only accessible by those insects that can visit the locus in which it was released/deployed.

c) What do we mean by emergence in swarm intelligence?

1) The understanding of the simple and individual behaviour of each single insect is not sufficient to explain the complexity of what social insects can do in terms of coordinated behaviour.

2) The collective emergent intelligence seems to be the "product" of the many reactive interactions between single agents.

3) The self-organizing properties of social insects seems to require

no need for low level individual complexity to explain collective behaviour.

Question 2

a) What is the transition rule (the probability of going to city j) in AS? Explain the variables and the parameters

$$p_{ij}^{k} = \frac{\tau_{ij}^{\alpha} \cdot \eta_{ij}^{\beta}}{\sum_{c_{il} \in N(s^p)} \tau_{il}^{\alpha} \cdot \eta_{il}^{\beta}}$$ normalization

where k is ant

i is start city

j is next city

$c_{il} \in N(s^p)$ is a city not visited yet

α, β are non linear parameters

$\eta_{ij} = \frac{1}{d_{ij}}$ is inverse length between city i and city j.

τ_{ij} is pheromone concentration on edge between city i and j

↳ What is the pheromone update rule in AS? Also explain the variables and parameters

$$\tau_{ij}' \leftarrow (1-\rho)\tau_{ij} + \sum_{k=1}^{m} \Delta\tau_{ij}^{k}$$

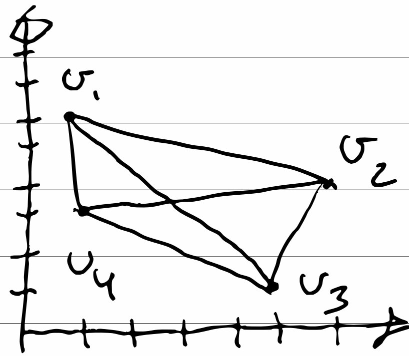
where τ_{ij} is pheromone concentration on edge between city i and j

ρ is evaporation rate

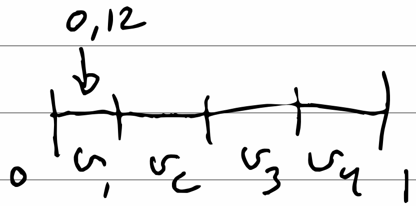
$\Delta\tau_{ij}$ is pheromones laid by ant k on edge ij if part of tour

$$= \begin{cases} Q/L_k & \text{if ant k used edge ij on tour of length } L_k \\ 0 & \text{if not part of tour} \end{cases}$$

c) Calculate a tour of one of the ants in TSP using ACO-AS.



$d_{12} = 5{,}099$ $\quad \eta_{12} = 0{,}196$
$d_{23} = 3{,}16$ $\quad \eta_{23} = 0{,}316$
$d_{34} = 4.47$ $\quad \eta_{34} = 0{,}224$
$d_{14} = 2$ $\quad \eta_{14} = 0.5$
$d_{13} = 5{,}652$ $\quad \eta_{13} = 0{,}172$
$d_{24} = 5{,}099$ $\quad \eta_{24} = 0{,}196$



$\Rightarrow$ k in v_1

* $v_i = v_1 \Rightarrow v_j \in \{v_2, v_3, v_4\}$

$$\sum \tau_{ij}^{\alpha} \eta_{ij}^{\beta} = \sum \tau_{1j}^{1} \eta_{1j}^{5} = \tau_0 \left(\eta_{12}^5 + \eta_{13}^5 + \eta_{14}^5\right)$$

$$= 10^{-6}\left(0{,}196^5 + 0{,}172^5 + 0.5^5\right) = 3.12 \cdot 10^{-8}$$

Going to v_2

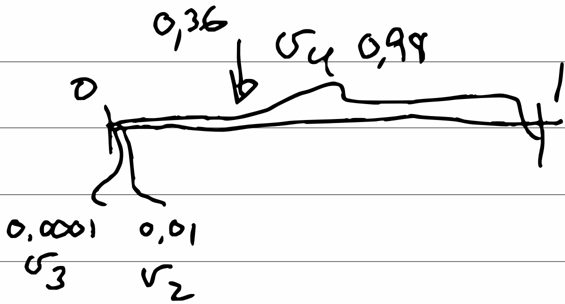
$$p_{12} = \frac{10^{-6} \cdot 0.196^5}{3.12 \cdot 10^{-8}} = 0.01$$

Going to v_3

$$p_{13} = \frac{10^{-6} \cdot 0,1722^5}{3,17 \cdot 10^{-8}} = 0,0001$$

Going to v_4

$$p_{14} = \frac{10^{-6}\, 0,5^5}{3,17 \cdot 10^{-8}} = 0.98$$



and $k=1$ chose city 4 (after city 1)

* $v_i = v_4$ $\quad v_j \in \{v_2, v_3\}$

$$\sum \tau_{4j}\, \eta_{4j}^5 = \tau_0 \left(\eta_{42}^5 + \eta_{43}^5\right)$$

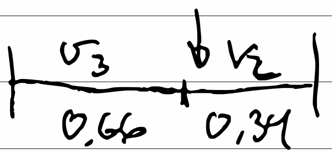
$$= 10^{-6}\left(0.196^5 + 0,224^5\right) = 8.53 \cdot 10^{-10}$$

Going to v_3

$$p_{43} = \frac{10^{-6} \cdot 0.224^5}{8.53 \cdot 10^{-10}} \approx 0.66$$

Going to v_2

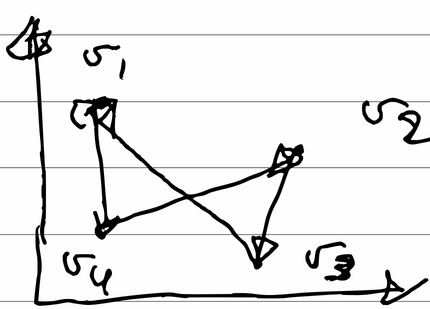
$$p_{42} = \frac{10^{-6} \cdot 0.172^5}{8.53 \cdot 10^{-10}} \approx 0.34$$



ant k=1 chose city 2 (after city 4)

* $v_i = v_2$ $v_j \in \{v_3\}$

must go to v_3



Tour length

$$L = 2 + 5{,}099 + 3{,}16 + 5.66$$
$$= 15.92$$

d) Calculate the tours of the rest of the ants assuming $m = n$ where m is the number of ants and n is number of cities.

Simulate by computer

e) Apply the AS pheromone update rule to the system. What is best tour now?

$$\tau'_{ij} \leftarrow (1-\rho)\,\tau_{ij} + \sum_{k=1}^{m} \Delta\tau_{ij}^{k}$$

$$\tau'_{14} \leftarrow \left(1 - \frac{1}{2}\right)\cdot 10^{-6} + \frac{100}{15{,}96} + \ldots +$$
$$0{,}5\cdot 10^{-6} + 6{,}28 + \ldots +$$