ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Lecture with Computer Exercises:
Modelling and Simulating Social Systems with MATLAB

Project Report

Solving the Travelling Salesman Problem by Using an Articficial Ant Colony

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Agreement for free-download

We hereby agree to make our source code for this project freely available for download from the web pages of the SOMS chair. Furthermore, we assure that all source code is written by ourselves and is not violating any copyright restrictions.

Raphaela Wagner

Giandrin Barandun

Contents

1 Abstract

2 Individual contributions

2.1 Raphaela Wagner

With the aim of achieving a good model for solving the travelling salesman problem by the use of artificial ants Raphaela helped the group understanding the underlying paper and the included model. She contributed a great amount of explanations and ideas how to approach the whole project.
In a second step she took care of how to implement the raw data from the TSP-library into MATLAB and transform it to a usable form. Further more she coded the functions "eta.m", "global_pheromene_update.m", "test_funktionen.m" and "update.m" and helped improving and correcting the main program.
After the code was written she did a lot of testing with different problem sets and compared the solution of the program to known solutions.

When the group got stuck and did not see a way out of a specific problem she was the one to bring along a hot chocolate and cheer the group up again.

2.2 Giandrin Barandun

The paper which is thought to be reconstructed on the following pages was selected and suggested to the group by Giandrin and during the whole process he tried to have some influence on the project with his wide technical understanding of the problem. The codes for the functions "prob_dist.m", "calc_Lnn.m", "choose_city.m", "main_initialize_system.m", "coordinates.m" and "calc_dist.m" are his contributions as well as the collaboration on the main program. He searched the internet for known TS-problems and their solutions and put all data in a readable form. A lion's share for the program working at the end was his bug fixing in all the functions and programs and combining them to the running model.

3 Introduction and Motivations

4 Description of the Model

In this model a number of k ants is sent on a network of m cities with every ant starting at the same city. The next ant only starts when the previous ant has finished its tour which means there never are two ants in the network.

4.1 Choosing a City

Before moving on to the next city an ant has to decide where it wants to go. For this purpose it chooses randomly a number q between zero and one and if this number is smaller or equal than a certain parameter q_0 ($q \leqslant q_0$) looks for the city s which fulfils the following formula:

$$s = \arg\max\{[\tau(r,u)] \cdot [\eta(r,u)]^\beta\}, \qquad u \notin M_k. \tag{1}$$

The current city where the ant stays is denoted by r and only cities can be chosen which are not yet in the ants memory M_k which means the ant has not visited these cities. The matrix τ stores the information about the amount of pheromone on the edge between city r and city u and the function η gives the inverse of the distance between the two cities.
If the random number is bigger than q_0 ($q > q_0$) then the ant randomly chooses one of the remaining unvisited cities and accepts or rejects it according to the probability p_k:

$$p_k(r,s) = \frac{[\tau(r,s)] \cdot [\eta(r,s)]^\beta}{\sum_{u \notin M_k} [\tau(r,u)] \cdot [\eta(r,u)]^\beta} \tag{2}$$

This probability basically contains the same formula of τ and η as the one above but is now normalized with the sum over these relations of every unvisited city. One can clearly see that in the beginning the sum is big and the probabilities are small but favouring the edges with more pheromone and lower distance. At the end when only one city is left the sum equals the term in the nominator and the probability becomes one for the last remaining city.

4.2 Moving Forward and Updating

Once the city has been chosen the ant moves along the edge and the pheromone on the path is updated according to:

$$\tau(r,s) = (1-\alpha) \cdot \tau(r,s) + \alpha\tau_0 \tag{3}$$

The newly introduced parameters α and τ_0 are explained in chapter 6. This update reduces the amount of pheromone on the chosen edge and helps avoiding very strong edges which would be taken by all the ants.
At the time the first ant has finished the tour the second one can start while the first ant still keeps in mind the trajectory of its tour which means the sequence of the city it has visited and the length of its tour but deletes its memory such that it is ready for a new tour. When all ants have completed one tour the shortest one is rewarded with pheromone according to the formula:

$$\tau(r,s) = (1-\alpha) \cdot \tau(r,s) + \alpha\Delta\tau(r,s) \tag{4}$$

This update is intended to give the edges along the shortest path a little head start in the following round. With this step the first round is complete and the second round can start.

5 Implementation

5.1 Main program

In the previous section the theoretical understanding of the model was tried to be imparted to the reader. Following in this section is an overview of how the model was implemented in MATLAB.
To start with a main program (*main_initialize_system.m*) was written which reads the data of a specific TSP and puts it into an upper triangle matrix form which contains the distances between the cities as elements. Further more all parameters like number of rounds and number of contributing ants (agents) can be adjusted in this main program. At the end it activates the function *main_main.m* with the purpose to find the shortest route.
In the main function there are two for-loops, one for the number of rounds and one for the number of ants (agents). For every agent we have a memory of the visited cities (*M_k*)and a trajectory vector which saves the sequence of how the cities where visited. In the first step every ants chooses the next city with help of the function *choose_city.m* which is described below. The city is added to the memory of the ant and the trajectory vector and the pheromone on the edge is reduced according to the formula on page 75 in the paper. As long as there are unvisited cities this procedure is repeated for the agents and at the end the way to the start city is updated (pheromone, trajectory) and the memory reset. Then the second agent starts his tour.
After every agent has finished his route the shortest path is detected and the edges along this route are rewarded with pheromone with help of the trajectory vector and the function *global_pheromone_update.m*. At the end of this step the trajectory vector is reset for all ants and the second round can be initialized. After every round the shortest route of the current round is compared to the overall shortest route found until now and then kept or rejected depending on the result of the comparison.
When all rounds have been calculated the function gives the shortest path found in any of the rounds.

5.2 Choose the Next City

To choose which city the ant will go next two different methods are implemented according to the paper and one of them is selected based on a certain probability.

The first way to decide which city to go next is to optimize a function which depends on the amount of pheromone on the edge between the current city and the chosen one and its length. This method chooses the edge with the highest amount of pheromone and the shortest length whereas there are parameters to weight these two variables relatively to each other.
On the other hand a probability was assigned to every unvisited city again depending on the amount of pheromone and the length of the edge between the cities. Then a city was randomly chosen and accepted or rejected with its assigned probability.
At the end the function *choose_city.m* gives the number of the next city to visit back to the main function.

6 Simulation Results and Discussion

7 Summary and Outlook

8 References