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AN ANT SYSTEM FOR A ROAD NET CONNECTING THE MAIN TOWNS OF ROMÂNIA

Elena Nechita , Gloria-Cerasela Crişan
University of Bacău, România

Abstract In this paper we use an *Ant System* for *Travelling Salesman Problem* (*TSP*) in order to solve a practical problem. The idea is to consider the main towns in the România and find the best route passing exactly once through each of them, given the existing road network.

Keywords: *Travelling Salesman Problem, Ant System, Ant Colony Optimization, Meta-heuristic*

Introduction. Due to its strategic position, our country became an important place for investors all over the world. Even some regions are more preferred than others (such as Bucharest, the western part including Timişoara and Arad, or the coast of the Black Sea with Constanţa), the problem of passing through all towns in a tour is obviously important. This can be of special interest for supply or distribution companies, in service area and for many other activities, too. In this paper we propose the use of a modern algorithm (an Ant System, reffered in the following as AS) for the Travelling Salesman Problem (reffered in the following as TSP) in which we take into consideration the most important towns of Romania, as vertices. These towns and the associated numbers (that have been assigned to the towns within the AS) are: 0 - Bucharest, 1 - Alba Iulia, 2 - Arad, 3 - Bacău, 4 - Baia Mare, 5 - Bistriţa, 6 - Botoşani, 7 - Braşov, 8 - Brăila, 9 - Buzău, 10 - Cluj Napoca, 11 - Constanţa, 12 - Craiova, 13 - Deva, 14 - Drobeta Turnu-Severin, 15 - Focşani, 16 - Galaţi, 17 - Iaşi, 18 - Oradea, 19 - Piatra Neamţ, 20 - Piteşti, 21 - Ploieşti, 22 - Rîmnicu Vîlcea, 23 - Reşita, 24 - Satu Mare, 25 - Sibiu, 26 - Suceava, 27 - Tîrgovişte, 28 - Tîrgu Jiu, 29 - Tîrgu Mureş, 30 - Timişoara, 31 - Tulcea.

Ant Algorithms. Ant Algorithms have been proposed in 1991 by M. Dorigo and his coleagues [5] as a multi-agent approach for the difficult combinatorial optimization problemes. Actually, there is an intense research concerning the extension and the application of the algorithms based on "Ant Model" in very many discrete optimization problems. Recent applications, very important ones for practical area, include verhicle routing, sequential ordering, graph colouring, resources allocation and information routing in communication networks. Ant Algorithms have been inspired by observing the real ant colonies. Ants are social insects whose behaviour concerns mostly the survival of the colony, to the detriment of the individuals. These aspects have drawn specialists' attention, due to the high degree of structuration of the colonies. A special aspect refferes to the fact that ants always find the shortest paths between the food sources and their nests. Walking on these paths, the ants deposit on the ground a substance called pheromones and so, they leave a track. Ants detect these tracks and choose the paths with the biggest concentrations of pheromones. The tracks also allow them to come back to their nests.

Observing that this behaviour could be used to project minimum-path algorithms, informaticians developed a meta-heuristic (*Ant Colony Optimization* - ACO), in which a colony of artificial agents (called "ants") cooperate, in order to find good solutions for discrete optimization problem. Cooperation is a key of the ACO algorithms. The resources are assigned to these simple agents that communicate in an indirect way - by means of the pheromone tracks mechanism. Starting from an initial state, each ant builds a solution. For this, the ant gather information about the characteristics of the problem and on the performances of the other ants and uses them in order to modify the state (or even the representation) of the problem. Ants can action concurrently and independently, but always having - by means of the permanent communication - a collective behaviour.

Ant System for a TSP having as vertices the main towns in România. The first applications of the ACO algorithms have been realized on the TSP problem, due to the fact that in this case the modelling process is simple and natural.

A general definition of TSP is the following. Consider a set N of vertices representing towns and a set E of edges fully connecting the vertices in N. Let d_{ij} be the length on the edge (i, j) in E (the distance between the towns i and j from N). TSP is the problem of finding a Hamiltonian circuit of minimal length for the graph $G = (N, E)$, namely a closed circuit in which every town is visited once and only once and whose length is the sum of the lengths of the edges that compose the circuit.

Ant Systems (AS) are the first ACO algorithms [6]. In an *AS*, the artificial ants build solutions (circuits) for TSP moving, on the graph of the problem, from a town to another. The algorithm performs NC (Number of Cycles) iterations. During each iteration, m ants (placed into the m towns) build a circuit executing m steps in which a probabilistic decision is applied - they choose the next town to be visited. When, being in the node i, the ant choose to move to node j (whose choosing probability has been maximum), the edge (i, j) is added to the current circuit and this step repeats until the full circuit is built. After the ants build the circuits (a circuit for each of them) they "lay" pheromones, represented by variables associated to the visited edges. These quantities of pheromones are proportional with the quality of the generated solutions and represent the way the ants indicate, one to each other, the "desirability" in choosing the edge (i, j): the smaller the length of the circuit is, the bigger the quantity of pheromones is. In this way, the search is directed to better solutions. There also appears the necessity of modelling the "evaporation" of the pheromones and this helps to avoid the stagnation phenomena (the situations in which all ants would find the same circuit).

At the end of an iteration, the algorithm keeps the best circuit. This is (eventually) improved in the next iterations.

The papers [1,4,5,7] present different results obtained with different AS, distinguishing by: the way to compute the probability of choosing the new town, the way of keeping the tracks of pheromones and/or different values for the parameters of the AS. The test problems are also variated, with m (the number of the cities) starting from 30 and up to 500. For example, in [4] the authors studied TSP for 500 towns in SUA. We proposed to apply the AS algorithm that we built for a problem with the above-mentioned 32 towns in Romania. The distances between towns have been taken from www.sosele.com.

The algorithm have been coded in Java and run on an IBM computer, 1,7 GHz and 256 MB RAM. The values of the parameters are: $\alpha = 1$ (controls the euristic, that depends on the distances between towns), $\beta = 5$ (controls the pheromones level), $Q = 100$ (represents a scale factor), $\rho = 2/3$ (controls the degree of the evaporation of the pheromones) and $NC = 1000$ (number of iterations).

In 100 executions, the best solution furnished by the AS for the proposed problem has 3304 km and corresponds to the following tour: Bucureşti, Ploieşti, Buzău, Braşov, Tîrgovişte, Piteşti, Craiova, Drobeta Turnu-Severin, Tîrgu Jiu, Rîmnicu Vîlcea, Sibiu, Alba Iulia, Deva, Reşiţa, Timişoara, Arad, Oradea, Satu Mare, Baia Mare, Cluj Napoca, Tîrgu Mureş, Bistriţa, Suceava, Botoşani, Iaşi, Piatra Neamţ, Bacău, Focşani, Galaţi, Brăila, Tulcea, Constanţa (and back to Bucureşti). The mean of the lengths of the solutions is 3365.42 (km) and the maximum length is 3396 (km).

In each run, the program offers a new solution, so that, if other criteria are considered too, the user can pick the solution that fits his interests. The authors are interested in solving some concrete problems and will answer to all those who require the program they designed.

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