CONTAINER ROUTING IN MULTIMODAL AND TIME – DEPENDENT NETWORK USING GENETIC ALGORITHMS

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ABSTRACT

This article deals with the intermodal transportation problem for the commodities delivery between different locations. The time – dependent shortest path planning, in which the travel time along each arc is a known function of the departure time along the arc, is a very important problem and arises in many practical application such as a routing system of a container used in the time – dependent intermodal transportation. Given a fixed timetable of the bi – intermodal transportation network (using trucks and trains), this article proposes a genetic algorithm – based method to route a container from a source to destination such that the total transportation time between these nodes to be minimum.

Keywords: time – dependent network, intermodal transport, genetic algorithm, container routing, time – dependent shortest path problem.

1. Introduction

In our days the intermodal transport plays a key role in international logistics having significant effect about both the carriers benefits and customers benefits. For the long distance transport of goods, taking into account the selection of the optimal routes a single mode of transportation can no longer satisfy the customer's requirements. Intermodal transportation is a combination of two or more transport modes to move the cargoes or passengers from one source to a destination [1].

The general time-dependent shortest path problem is at least NP-Hard since it may be used to solve a variety of NP-Hard optimization problems such as the knapsack problem. However, depending on how one defines the problem, it may not be in NP since its output is not polynomially bounded [2].

The routing of a container from one source to a destination has practical application, because the most of transport companies don't have the possibility to form, in railway traffic system, new trains to transport the goods, but they can attach wagons of goods at the existed trains.

In the time-dependent shortest path problem, it's assumed that the travel time along each arc is a function of the departure time along the arc, and all such functions are known in advance over all time.

The remainder of this paper is structured as follows. In Section 2 is presented the state of the art of the treated problem, in Section 3 will be described the problem, notation and the basic concepts. Section 4 presents the proposed method based on genetic algorithm technique. In Section 5 are outlined the results. Finally the conclusions are presented in Section 6.

2. State of the art

The Multimodal Transportation Problem (MTP) has been addressed by many authors proposing different methods and applications to solve it. In [3] the authors propose a new approach to time-dependent shortest path in multimodal networks. The approach derives, from initial graph, a more simplified and non-time-dependent structure, called abstract graph, by using Ant Colony Optimization. Then, a time-dependent Dikstra's algorithm is used to compute the shortest path on the new structure. Based on the characteristic of the container multimodal transportation to choose a variety of transportation models and routes, in [4] the authors propose a model for multimodal transportation organization to minimize the total cost under the consideration of the transport costs between nodes, transfer costs and average delay costs for mode change.

In [5] the authors propose genetic algorithm-based algorithm to find simultaneously several alternate routes depending on different criterion according to driver's choice such as shortest path by distance, path which contains minim number of turns, path passing mountains or by the side of the a river. An algorithm of shortest path in multimodal network has been proposed in [6]. The proposed algorithm identifies the set of constraints concerning of time planning and the sequence of modes utilized to find the optimal path from source to destination.

In [7] the authors use a technique based on label correcting algorithm for shortest path from source to destination in multimodal transport. They consider a path to be viable if the sequence of the nodes respects the set of constraints.

3. Problem description

The problem which needs to be solved can be described in this way: select optimal transport route and the optimal combination of transports modes to minimize the total trip time from site source S to site destination D. Between any two cities that are connected, there are a variety of transportation modes (M) to choose from. The transport mode can be changed in each city. The input to time-dependent shortest path problem is a directed network $G=(V,E,M,T,C)$, where $V=\{v_1,...,v_n\}$ is the set of nodes, $E=\{e_1,...,e_l\}$ is the set of arcs, $M=\{m_1,...,m_k\}$ is the set of transport modes, T represents the *departure time* of each transport mode from each node to a connected node, C is the set of travel times between nodes ($c_{ij}(t)$ gives the travel time along arc $(v_i,v_j)\in V$ if one departs at time $t\in T$ from node v_i). An arc will be called *time-dependent multimodal arc*. The node v_i is connected with the node v_j if exists the arc $e:V\times V\to E$ which bounds v_i and v_j. A time-dependent multimodal arc $e:V\times V\to E$ is defined as $(v_i,v_j)^{c_{ij}}_{m_k,t_d}$, where $v_i,v_j\in V, m_k\in M$, $c_{ij}\in C, t_{d_{ij}}\in T$ are defining above. The arc e means that it may go from the node v_i to v_j using transport mode m_k, which leaves from v_i at t_d and the travel time along $(v_i,v_j)\in V$ is c_{ij}. The quantity $(t_{d_{ij}}+c_{ij})$ gives the time of arrival at e_j if one departs at time $t\in T$ from the node v_i.

Given $G=(V,E,M,T,C)$, will be called route r between two nodes v_p and v_q the set of arcs $r=((v_p,v_{p+1})^{c_{p,p+1}}_{m_k,t_{d_p}},...,(v_{q-1},v_q)^{c_{q-1,q}}_{m_k,t_{d_{q-1}}})$, where $\forall j\in\{p,p+1,...,q-1\}\Rightarrow(v_j,v_{j+1})\in E$, $v_j,v_{j+1}\in V$, $m_k\in M$, $c_{j,j+1}\in C$, $t_{d_j}\in T$. Moreover $\forall i\in\{p,p+1,...,q\}$ doesn't exist $j\in\{p,p+1,...,q\}\setminus\{i\}$ such that $v_i=v_j$, which means that a route doesn't have two identical nodes. So the cycles aren't allowed here. If R represents the of the routes from $G=(V,E,M,T,C)$, then the function $f:R\to\Re^+$ is the cost of the route $r\in R$, where $\Re^+$ is the set of positive real numbers. Into a time-dependent multimodal network, $G=(V,E,M,T,C)$, the Time-Dependent Shortest Path (TDSP) between two nodes $s,d\in V$ is defined as the route $r_{shortest}$ from s to d such that $f(p)$ to be minim.

In this paper the time-dependent intermodal transport network it's defined as graph G, where:

- $M=\{m_1,m_2\}$, $m_1=train, m_2=truck$;
- V represents the set of transit points of time-dependent multimodal transport network; in these points, the container can be unloaded from a transportation mode and loaded on other transportation mode or on an identical mode; the time of unloading/loading it isn't taken into account, but the waiting time in transit points is allowed;
- E is the set of physical routes between the transit points;
- $T=\{t_{d_1},...,t_{d_n}\}$ represents the set of timetables of each transit point; $\forall i\in\{1,...,n\}$, $t_{d_i}=\{t_{1_i},...,t_{k_i}\}$ indicates the departure times of the transportation mode from i to connected transit points;
- C is the set of travel times for each departure time.

It is supposed that the cargoes from container cannot be divided. So the transportation mode that takes the container in a transit point has the capacity to move whole cargo forwards.

The proposed algorithm must determine:

- the train or truck on which the container of cargo will be loaded at source s;
- the departure time t_{d_s} from source s;
- the transit points in which the container will be unloaded/loaded on other transportation mode;

such that the container will arrive to destination d through a route of type $r_{shortest}$. So the proposed algorithm will determine the $r_{shortest}$ such that $(t_{arrival}-t_{departure})$ to be minim, where $t_{arrival}$ is the arrival time at destination and $t_{departure}$ is the departure time from source. The waiting time in transit points is allowed in this case.

4. Proposed method

In this paper the proposed method is based on the genetic algorithm, which is an evolutionary method. *Genetic algorithms* (GA) are stochastic P-meta-heuristics that have been successfully applied to many real and complex problems (multimodal, multiobjective, highly constrained problems, etc). Compared with most of the classical algorithms, genetic algorithm has lots of advantages, such as: widely viable solution, group searching, no information assistance, internal heuristic random search, parallel computing, etc [8]. A key role of the genetic algorithms is that they can solve complex problems which aren't polynomial problems. These techniques have been applied for combinatorial optimization problems, where exact optimal solutions are hard to be determined. A drawback of these techniques is that cannot ensure an exact optimal solution, but they can provide other practical solutions [9].

The steps of genetic algorithm are depicted in fig. 1.

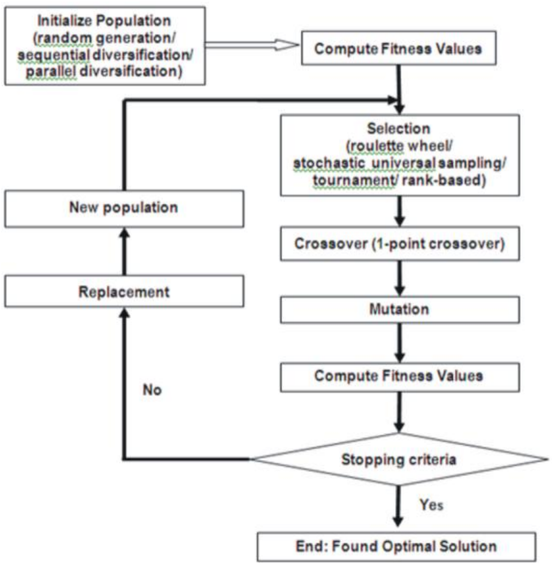

Fig.1 – Genetic algorithm framework

The description in pseudo-code of the implemented genetic algorithm is as following:

1. *Find the way of encoding of the solutions(chromosomes);*
2. *Use the random generation for finding initial population of size* $No_{individuals}$*;*
3. *Find the fitness of each solution to be evaluated;*
4. *Use roulette strategy to select the parents for genetic operators(use the same strategy during the algorithm);*
   4.1 make the crossover and mutation;
   4.2 evaluate the fitness function.
5. ***If** stopping criteria is attained then **Go to step 6***
   Else
   5.1 use elitism strategy for replacement;
   5.2 create new population of size $No_{individuals}$*;*
   5.3 go to step 4.
6. *Stop the algorithm. Select the best individual.*

4.1 Algorithm description

In fig. 2 is depicted an example of time-dependent multimodal transportation network forming of 5 transit points and 24 arcs.

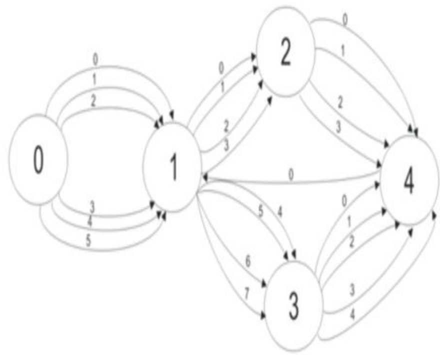

Fig. 2 – Example of time-dependent multimodal transportation network

In fig. 2 $V=\{0,...,4\}$ represents the set of transit points, $T=\{t_{d_0},...,t_{d_4}\}$, $t_{d_0}=\{t_1,...,t_5\}$, $t_{d1}=\{t_1,...,t_7\}$, $t_{d_2}=\{t_1,...,t_3\}$, $t_{d_3}=\{t_1,...,t_4\}$, $t_{d_4}=\{t_1\}$ is the set of timetables of each transit pointes. It can observe that between two connected nodes p and q there are more oriented arcs which represents the timetable between those nodes.

Table 1 contains the timetables for a period of 24 hours for the network depicted in fig. 2. This timetable one may change from day to day. With the data from table 1, fig 2 can be read as: for instance node 1 has two connected nodes (node 2 and node 3) and there are 8 possible routes; the routes with id 0,…,3 is the timetable to arrive in node 2 and the routes 4…7 is the timetable to arrive in node 3. For instance: the route which goes from node 1 at node 2 with id 0 means that the container is moved with the transport mode $m_2 = truck$, departure time is 6:20 and the travel time is of 20 minutes. For example if we want to move the container from node 0 to node 4 there are more possible routes. In fig. 3 are depicted two of them. Figure 3 can be read using table 1.

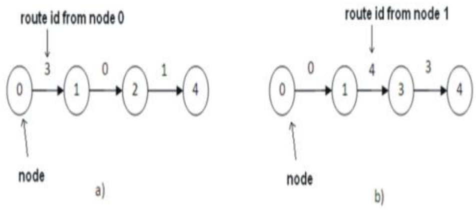

Fig. 3 – Two of the possible routes from node 0 to node 4

Table 1. The timetable for fig. 2

Node	Neighbors	Type of transport	Dep. time	Trip time	Id route
0	1	Train	5:30	0:30	0
		Truck	9:20	0:20	1
		Train	13:0	0:15	2
		Truck	7:40	0:10	3
		Truck	6:40	0:35	4
		Train	2:20	0:40	5
1	2	Truck	6:20	0:20	0
		Truck	7:20	0:5	1
		Train	12:0	0:3	2
		Truck	14:20	0:12	3
	3	Train	6:10	0:10	4
		Train	10:10	0:7	5
		Truck	8:0	0:8	6
		Train	10:0	0:3	7
2	4	Truck	6:20	0:20	0
		Truck	7:30	0:15	1
		Train	12:4	0:5	2
		Train	11:4	0:12	3
3	4	Truck	6:30	0:25	0
		Truck	11:30	0:15	1
		Train	10:20	0:5	2
		Train	8:10	0:3	3
		Truck	10:2	0:2	4
4	2	Train	8:30	0:26	0

4.2 Chromosome codification

In order to use genetic algorithm, feasible solution of the problem needs to be coded into symbol string. Each bit of the spring represents a gene. The length of the chromosome is fix one and it is equal with the number of transit points from the multimodal network. For the multimodal network represented in fig. 2 the chromosome has the length equal with 5. The gene is represented by a transit point and the gene's allele value is the *id* of the chosen route on which the container is moved from the current transit point in a connected transit point. An example of chromosome codification is depicted in fig. 4.

0	1	2	3	4
3	0	1	x	x

Fig. 4 – Chromosome codification

In fig. 4 the first line represents the nodes of the network and the second line represents the allele's value of each corresponding gene. The decoding of the chromosome is making using the data from table 1. For instance the decoding of chromosome from fig 4 is made in fig. 3 a). In fig. 4, the allele's value labeled with *x* can take any possible value because these aren't important in chromosome decoding as one can be seen in fig. 3 a); these genes don't enter in route calculation from source to destination.

4.3 Fitness function

Each chromosome represents a feasible solution and each solution (chromosome) has a fitness function. This function is used to measure the environmental adaptability of a chromosome.

The cost function of the route r, named *travel function,* is defined as $f(r) = c_{i,i+1} + t_{w_{i+1}}$, $\forall i \in \{p, p+1,..., q-1\}$; $c_{i,i+1} \in C$ represents the travel time from node i to next node $i+1$ and $t_{w_{i+1}}$ represents the waiting time or the unloading/loading time of the container in node $i+1$ $\forall i \in \{p, p+1,..., q-2\}$. The scope of the proposed algorithm is to find the route r from source to destination such that $f(r)$ to be minim. The smaller *travel function,* $f(r)$, the better fitness function is.

4.4 Crossover operator

The selection of the individuals is made using roulette method. Each individual gets a probability to be selected for genetic operators: mutation and crossover. This probability depends on value of fitness function. The better of fitness function of the individual, the better the probability to be chosen. After the selection of the individuals for crossover operator it is used a selection random method of the crossover point. For the two parents chromosomes x_{p1}, x_{p2} a random positive integer *n* which is between *1* and *N-1*(chromosome length) is generated. The bits from *1* to *n* which are in x_{p_1} are put in x_{p_2} and vice versa. After the crossover operator result two offsprings.

4.5 Mutation operator

For the mutation operator has been randomly chosen one gene (node) and for this is generated a random number between 0 and $nrRoute-1$, where $nrRoute$ represents the number of routes which go from that node to his neighbors, the length of the timetable of that node to connected nodes. The new generated number represents the value of the new allele of that node.

4.6 Replacement

The replacement phase concerns the supervisor selection of both the parents and offsprings population. As the size of the population is constant, the replacement phase allows to pull and replace individuals according to a given selection. In this paper has been used the elitism strategy. Elitism always consists in selecting the best individuals from the parents and the offsprings.

4.7 Stopping criteria

Many stopping criteria based on the evolution of the population may be used. The proposed algorithm stops after a number of generations which is established *a priori*.

5. Experimental results

In this section the experimental results are presented in order to demonstrate the correctness and the performance of the proposed method.

The application has been implemented in Java programming language. The proposed algorithm has been tested on a time-dependent multimodal transportation network of 20 nodes and 89 arcs, which is depicted in fig. 5. Because of space limits the timetable is not presented here.

time-dependent shortest path from node source 0 to node destination 10. The proposed algorithm must determine the train or truck on which the container of cargo will be loaded at source s, the departure time t_{d_s} from source s and the transit points in which the container will be unloaded/loaded on other transportation mode such that the container will be arrived to destination d through a route of type $r_{shortest}$. The results can be observed in right side of fig. 5. The time-dependent shortest path has 31 minutes and it is represented with green color in fig. 5.

The optimal route was obtained for a population of size 500 and the number of generations equal with 200. The optimal route is presented in fig.

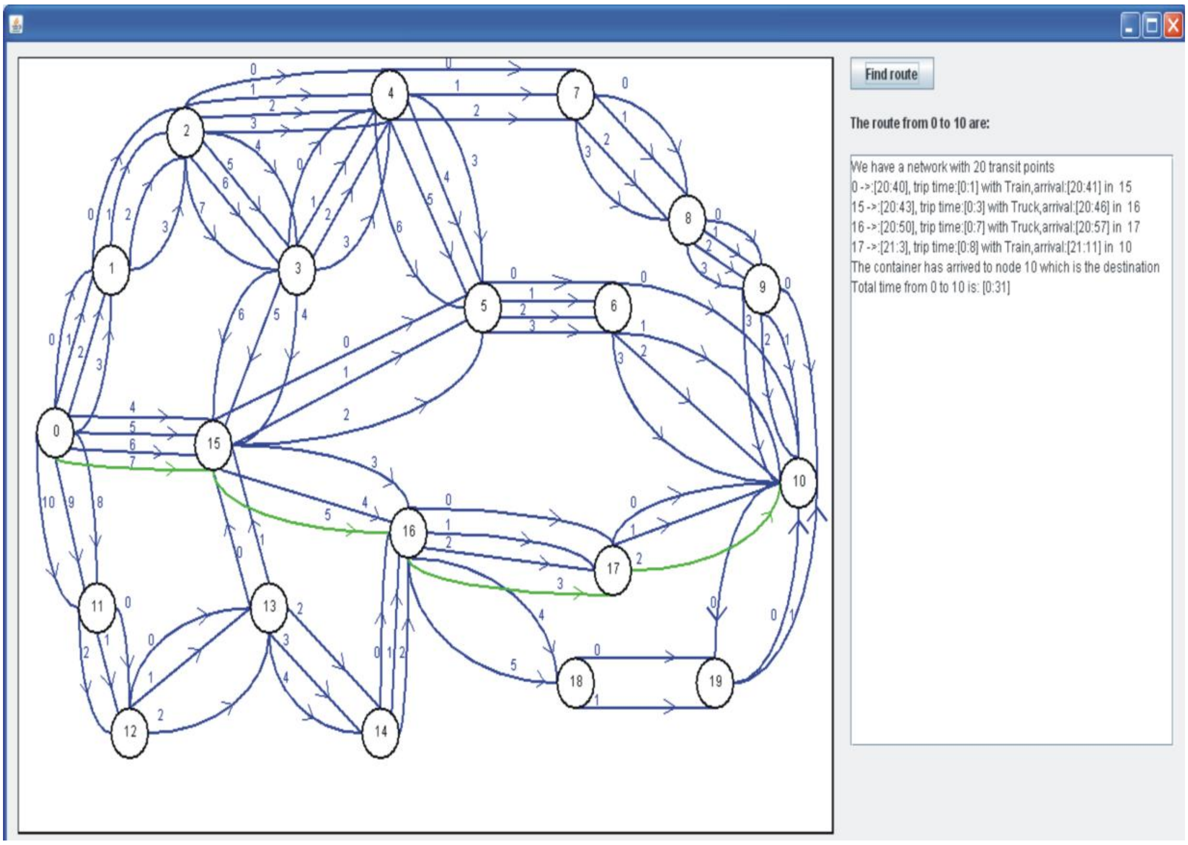

Fig. 5 – The multimodal network representation and the obtained result

Each node can have one or more connected nodes and in each transit point the container can wait a time t_{w_i}. The initial population has been generated randomly. The multimodal network has been tested for different sizes of the population and different numbers of the generations. It has been observed the algorithm gives good results and for an appropriated setting of the population and generations size we obtained the optimal route. It has been searched the

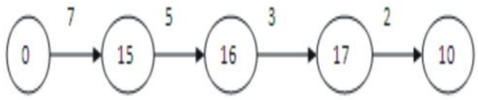

Fig. 6 – The time – dependent obtained shortest path

6. Conclusions

In the process of container transportation there are a variety of nodes of transportation that can be selected. According to the relationship between the transportation mode selection and the transport path optimization, a genetic algorithm-based method to solve the time-dependent shortest path problem in multimodal transportation network has been treated in this paper. The proposed algorithm had to determine the train or truck on which the container of cargo will be loaded at source s, the departure time t_{d_s} from source s, and the transit points in which the container will be unloaded/loaded on other transportation mode such that the container will be arrived to destination d through a route of type $r_{shortest}$.

Finally a simulation example shows the correctness and the effectiveness of the proposed algorithm. Time-dependent shortest path problem plays a very important role in international logistics having significant effect about both the carriers benefits and customers benefits.

For future work is desired to use improved techniques for generate initial population, for crossover and mutation operators in order to diversify the population for all search space which will have a good effect upon the size population and number of generations and, the most significant, will improve both the running time and the obtained solution.

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