REALIZATION OF AN OPTIMIZATION ALGORITHM FOR VEHICLE ROUTING PROBLEM

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Abstract: *One of the most interesting problems in logistic is the distribution optimization. A huge effort has been invested in cutting the transport costs via computer optimization of vehicle routing. Abstractly, the task is known as the vehicle routing problem and there exist many different algorithms for approximate solutions. The main goal of the problem is to carry out deliveries from the central storage facility to all customers incurring minimal costs and subject to certain additional constraints. Generally, putting VRP in practice presents a number of additional difficulties, from obtaining road network information, gathering data about shipments and packaging to efficient coding of algorithms. The purpose of this paper is to present the development and implementation of a transport routing application for a special distribution centre and customer network.*

Keywords: *transport, vehicle routing problem, optimizations*

1. INTRODUCTION

In professional circles plenty of models and tools, used for various physical distribution optimizations, are known. These tools are tailored to customer specific needs and as such cannot be easily implemented in specific cases. Therefore the basic properties and principles of these models are presented first and in the continuation a structure of the model, used for the physical distribution optimization in the largest Slovenian company for energy products distribution, is shown. Distribution optimization involves several interesting problems, ranging from the simplest ones like the calculation of the shortest and fastest paths between two different locations to more complex problems including several variations of the Vehicle Routing Problem (VRP). While the research can be carried out on a completely abstract basis (development of special algorithms, mathematical and statistical methods,…) for the purpose of the logistics research in the particular geographical area and particular type of transportation, the real life transportation data is required.

Such a research is highly interdisciplinary and involves experts from economics, logistics, computer science and mathematics. The first step in such cooperation is establishing a functional research tool which will enable us to work on the specific transportation network equipped with all the data required. It remains a constant challenge in the logistics to reduce the transportation costs. It is well known that certain transportation problems are computationally hard (NP hard), but with increasing computation power available, many instances of problems of practical size can already be calculated in a reasonable (acceptable) time, even on personal computers. Possibilities to access real transportation data and sufficient availability of computation power are sufficient conditions for a successful development of a computational research prototype system on which logistic analyses and research can be carried out.

2. COLLECTION, EDITING AND PREPARATION OF DATA

At the beginning the presentation of the data that are included in the optimization model is discussed, as their suitability is a key factor for the correct optimization and interpretation of the obtained results and solutions. The optimization includes the following databases: the geographical information systems (GIS) of the road network: geometrical data summed up in charts that present road sections and coordinates of places, warehouses and locations of recipients, lists of goods to be delivered and parameters of vehicle fleets (capacity, price per kilometer, regions of activity).

In recent years Surveying and Mapping Authority of the Republic of Slovenia established Cadastral register of the economic public infrastructure of the Republic of Slovenia (Zbirni kataster gospodarske javne infrastrukture) in which the data from geographic information systems covering Slovenian road infrastructure is stored. It is easily accessible to research community in Slovenia. The geospatial data includes complete Slovenian road network in the form of categorized road segments. The categorization can be used to determine approximate expected velocity of vehicles on the road segments. We believe that with further data collecting about the road segments on the national level will improve the informatization of our road network enabling us to carry out certain optimization with data of high quality.

The information on goods that have to be distributed is usually easily obtained from the information systems of storage facilities. Managing of such facilities without adequate information system is nowadays unimaginable. In our case, such system contains all the data about daily orders, destinations and other characteristics of goods like weight, size, packaging, etc. The orders typically contain the address of the customer. Through address the GIS coordinates of the location can be calculated enabling us to position the customer into the digital road network.

In the process of the delivery we assume that the goods orders are distributed to transportation units each with a single destination. Transportation units are packaged in the form of a few standard packagings (pallets, boxes, containers…). In our case we divide transportation units into two groups, namely the ones with a significant weight and volume (like pallets, containers…) and the others in smaller packagings (smaller boxes, envelopes…). The latter group includes the transportation units that do not occupy significant weight and volume capacities of transportation vehicles. We assume that the number of smaller units is so small that only the “heavy” transportation units are to be considered to occupy transportation vehicle capacities. For instance, if one truck can take 15 pallets, usually several smaller boxes more can be loaded on to or beside the palettes.

Our classification reduces to goods on pallets (or in containers) and the goods without significant weight and volume. Nevertheless, each transportation unit loaded on a transportation vehicle implies that the vehicle’s visit of the unit’s destination is mandatory.

Without proper consideration of processes involved in delivery the data model could not be realistic. Studying the process of delivery reveals certain conditions that have to be met if the optimization results are to be acceptable. A driver can deliver a limited number of goods depending not only on the capacity of his transportation vehicle but also on his limitations on working time and the length of the route. Certain customers may require deliveries in certain time windows. Relevant data is also certain knowledge 'embedded' in drivers. For instance, while our system may propose a certain route, an experienced driver may know that at this time of the day a particular road segment is terribly congested. All customers are not easy to reach at all the times as well. The knowledge about the drivers work processes is also necessary to take into account all time consuming little tasks that have to be done when delivering transportation units. From this point of view we still have a long way until incorporating all that knowledge. On the other hand, optimization algorithms may not look just for an optimal solution but also for less optimal solutions which are more robust in terms of changes required in cases of sudden change of plan.

3. THE MODEL FOR THE DELIVERY OPTIMIZATION

The optimization problem to be solved is a variant of a well known Vehicle Routing Problem (VRP) with certain additional constraints [8]. The usual presentation of VRP consists of a set of items that have to be delivered to a matching set of customers with a fleet of transportation vehicles in such a way that the overall transport cost is minimized. Each item has a corresponding item weight and each vehicle has a capacity, the maximum total weight it can carry. The road network is represented as a graph with weighted edges, where edge weights represent the cost of travel along that road (usually, the cost is proportional to the length of the road). For each customer and the initial distribution center there is a corresponding node in the graph.

For the standard VRP, vehicle capacities are the only constraints considered. Moreover, all vehicles are assumed to have the same capacity and the size of the vehicle fleet is not limited. In practice, more limitations have to be taken into account. The vehicle fleet is limited and inhomogeneous, with price per kilometer depending on the vehicle size. The driver has a limitation on the number of working hours per day and in most cases the route has to be finished within that time. A particularly nasty additional constraint is the requirement by certain customers to have deliveries at certain times. The later problem is known as VRP with time windows (VRPTW).

VRP belongs to the class of NP-hard problems [1], which means that exact solutions take time exponential in the number of customers. For this reason, exact solutions of VRP exist only for very small examples (~10 customers) or for certain artificially constructed graphs. In our application, the number of customers often exceeds few hundred and the road graph is quite arbitrary. However, there exist good approximate solutions that can be found in reasonable time. There exist a number of methods for finding approximate solutions of both VRP and VRPTW. Most are based on the idea of local optimization: start with an arbitrary configuration (assignment of customers to vehicles) and proceed by making small changes like reassigning a customer from one vehicle to another or exchanging the order of delivery for two customers on a single route. The simplest local optimization algorithm starts with a randomly generated configuration and at each step chooses the small change that most decreases the total cost. To prevent the violation of constraints, local optimization algorithms use the idea of penalties: every broken constraint carries an additional cost. By properly assigning penalties we can be quite certain that the algorithm will converge to a solution that respects the constraints.

The simple local optimization algorithm has the shortcoming that it always finds the nearest local optimum. An easy remedy is to repeat the algorithm many times with different random starting points or configurations. But there exist better strategies of avoiding local optimum, so called metaheuristics [2]. The technique we implemented is known as tabu search [6]; it allows considering configurations with worse cost than the current but prevents the same configuration to be checked again. Tabu search does not end after finding the first local optimum – it continues searching, always choosing the best configuration that has not been considered before. In this way it can take much longer than local search, but often finds much better solutions.

It is well known that the local optimization with tabu search for several hundred customers can be a time consuming task. A number of computer program optimizations are required to make the program run in acceptable time (a few minutes for a typical instance). First useful observation is that even though the road graph can be huge, only the shortest roads between customers and the depot can be used in an optimal solution. Therefore a much smaller graph can be precomputed that contains as nodes only customers and the depot and as edges only the shortest routes between each pair of such nodes. The shortest path calculation uses a combination of Dijkstra's algorithm and A* algorithm for fastest running time.

Another observation that can save a lot of time is that the cost can be recalculated incrementally after every change in configuration. To make further use of this, it is useful to maintain a list of best candidates for next configuration change, and at every step update only the part of list that has changed. Unfortunately, there is a tradeoff in the last technique: it can make the program significantly more complicated and difficult to adapt to changes in specification, especially changes in constraints. In order to take advantage of current multicore hardware we need to make the implementation parallelizable. This can be done either by processing several configurations in parallel or by running several instances of the program in parallel and choosing the best of the achieved solutions.

4. SIMULATIONS AND TESTS

To test the usability of the optimization model, we have built an computer application in C# that obtains the data about actual orders from observed company's information system and proposes optimal routes for delivery vehicles.

The geospatial data has been converted to PostGIS [5] format and stored in a PostgreSQL [6] database with the PostGIS extensions. For more efficient execution, some data about road distances has been preprocessed and is stored separately. To visually present the customers' locations and the solution we have created a GUI using SharpMap [7], the C# binding to PostGIS. Figure below shows the result of the optimization for the deliveries in one special case.

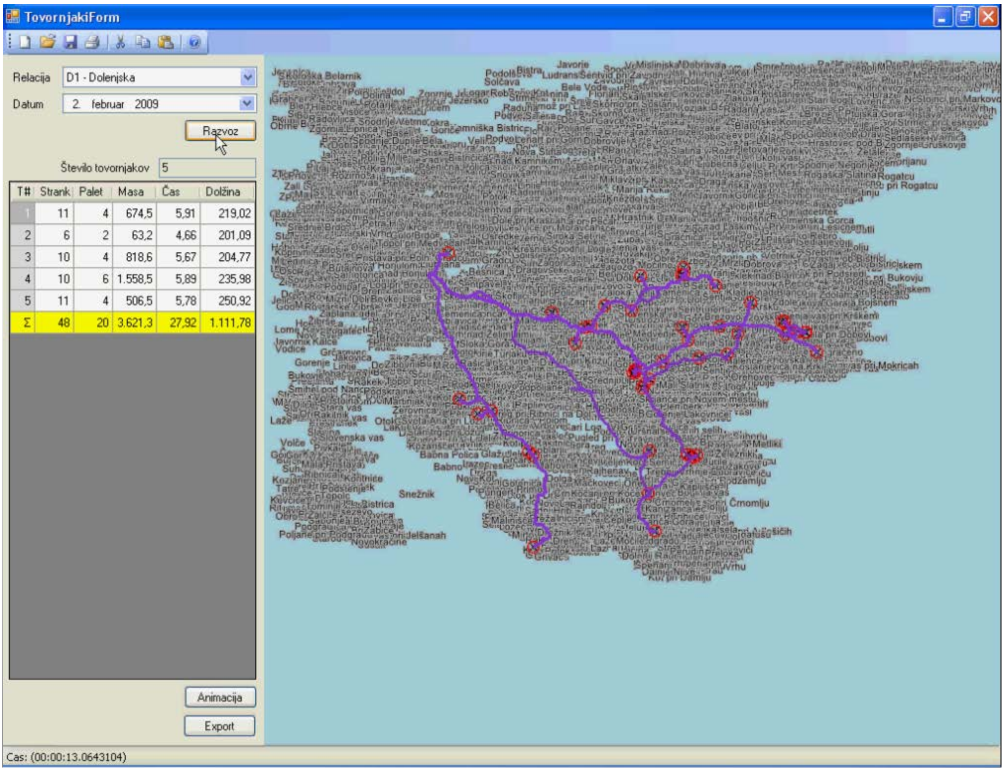

Figure : A screen shot from prototype tool implementation showing the choice of the vehicle and the routes to be taken.

For operational data, we currently use a snapshot of the observd company depot's database which contains all the data about the delivery items. The information about vehicle sizes has been obtained from the contracts with transporters. Unfortunately, the information system does not contain the data about actual transports that have been used, which complicates our evaluation of quality of the prototype application. Since the only information about the actual transport cost are monthly reports by the transporters, we cannot compare it with the calculated cost on daily basis; we can only compare the monthly cumulative.

5. CONCLUSION

At first glance, the distribution optimization appears to be an easy problem and the majority first thinks about reductions in the transport costs or physical distribution. As can be read in the paper it can be a really complex system, where transport is only one of many functions. Unfortunately, the presented model cannot be evaluated, because some data from contracts with external transportation companies and data with respect to cost prices of routes are in the studied company considered as business secrets. It is worth to mention that the proposed solution represent savings up to 30%.

The current result is an implementation of the optimization algorithm along with connections to snapshots of real data. To make the application more practical, we need to improve it in following directions: by comparison of obtained results with some known almost-optimal solutions we can inprove the algorithm to find better solutions. Second and more important in practice, we need to obtain and use the information about further important constraints for which we have no data, such as road restrictions for different vehicle types, traffic congestions, actual average times needed to travel a certain road, times needed to unload items from vehicle and other special restrictions.

REFERENCES

[1] Garey, M. R., Johnson, D. S. (1979) “Computers and Intractability: A Guide to the Theory of NP-Completeness”, W. H. Freeman & Co., New York.
[2] de Oliveira, H.C.B., Vasconcelos, G.C. (2008), “A hybrid search method for the vehicle routing problem with time windows”, Annals of Operations Research.
[3] PostGIS, http://postgis.refractions.net/
[4] PostgreSQL, http://www.postgresql.org/
[5] SharpMap – Geospatial application Framework for the CLR, http://www.codeplex.com/SharpMap
[6] Taillard, E., Badeau, P., Gendreau, M., Guertin, F., Potvin, J.-Y. (1997) “A Tabu
[7] Search Heuristic for the Vehicle Routing Problem with Soft Time Windows”. Transportation Science 31, 170-186.
[8] Toth, P., Vigo, D. (2002), “The vehicle routing problem”. SIAM, Philadelphia, Monograph on Discrete Mathematics and Applications, Philadelphia.