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Multi-Agents Scheduling and Routing Problem with Time Windows and Visiting Activities

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Abstract In our previous research, we compared the actual route recorded by a GPS device "PhotoTrackr" and the optimal vehicle route derived by using ArcGIS Network Analyst tool. VRP is the fundamental problem in the research fields of transportation, we focus on variations of CVRPTW (Capacitated VRP with Time Windows). Various types of VRP are studied to determine the optimal route under various constraints of locations, distance, time window and activities. Therefore it is difficult to straightly apply one case result to other cases, because the different constraints cause various difficulties. In this paper, based on previous results in our researches, we consider the problem of "Multi-Agents Scheduling and Routing Problem with Time Windows and Visiting Activities". Firstly, we introduce the result of "Vehicle scheduling and routing problems in day-care center".Secondly, based on other research result of "Scheduling of teachers for visiting high schools", we generalize the problems to VRP with time windows and visiting activities. Based on these case studies, we propose five parameters, such as"activities at the visiting points", "time windows", "numbers of visiting spots within a route", "total visiting time", "time-lag between different routes". We evaluate the quality of optimization based on three performance measures. Thirdly, we present our algorithm of k-means clustering under the constraints of visiting sequence. Finally, we use ArcGIS Network Analyst tool for computing cost of routes, and we evaluate the optimal visiting route with time windows and visiting activities.

Keywords Multi-Agents Scheduling Problem, VRP with Time Windows, GPS, GIS

1 Introduction

Recent years, various LBSs (location-based services) are becoming popular. Spatial data, digital road map and moving vehicle records using various mobile sensors, are integrated and stored into the spatial temporal database systems. There are many research papers about spatial data mining technologies of probing and streaming data, and there exit various applications, for instance, optimization of travel plan, visualization of traffic jam, GPS assisted navigation, road design, and ICT-assisted traffic congestion information systems[1, 8].

In our previous researches[3, 4], we visualize the data of probing taxi in Nagoya metropolitan area and the data of probing patrol cars on Hanshin Expressway by

using ArcGIS, and we analyze traffic data and derive patterns/rules by several data mining algorithms.

Furthermore, in our recent research "Vehicle scheduling and routing problems in day-care center"[5], we compared the actual route recorded by a GPS device gPhotoTrackrh and the optimal route derived by ArcGIS Network Analyst tool. In order to evaluate this problem, we have several steps, such as processings of DRM (Digital Road Map) data, definition of layer structured data of spatial objects and handling of WGS84 coordinate, furthermore we use the map matching service for pick-up and send-off locations of customers having street names without latitude and longitude attributes.

In this paper, based on experiences in our previous researches, we consider the problem of "Multi-Agents Scheduling and Routing Problem with Time Windows and Visiting Activities". In Section 2, we introduce VRP researches and applications of VRP shortly. In Section 3, we introduce the result of "Vehicle scheduling and routing problems in day-care center".

In Section 4, considering the problem in "Scheduling of teachers for visiting high schools"[2], we generalize problems to multi-agents scheduling and routing problem with time windows and visiting activities. Based on these case studies, we propose five parameters, such as "activities at the visiting points", "time windows", "numbers of visiting spots within a route", "total visiting time", "time-lag between different routes". We discuss optimization of load balance by k-means clustering with constraints[2]. We propose several parameters and extend the algorithm of k-means clustering under the constraints of visiting sequence. We also evaluate small example problems. Finally we conclude our experimental results and present some future works in Section 5.

2 Researches of various VRPs and case studies

Vehicle Routing Problem (VRP) is the fundamental problem in the research fields of transportation, we have variations of VRP, such as VRP with Time Windows (VRPTW), Capacitated VRP (CVRP), CVRP with Time Windows (CVRPTW). Various types of VRP are studied to determine the optimal route under various constraints of locations, distance and time.

There exist patents and research papers[7, 10], the vehicle routing problems in a day-care service center are discussed. "Day-care/Day-service" is nursing for the senior citizen service, it is necessary to consider many constraints by the nursing facilities, number of cars, requirement of customers, the pick-up and send-off locations and others. The HHC (home health care) problem usually consists of hard problems from a mathematical point of view, since it combines two well-known NP-hard problems: the vehicle routing problem and the nurse scheduling problem.

Furthermore, there are many case studies of VRP. for example, in [9], "school bus routing problem" is discussed, the problem is a variation of TSP with time-window constraints and route balancing. In [6], the problem is a real life waste collection as VRPTW. In order to improve the route compactness and workload balancing, a capacitated clustering-based waste collection VRPTW algorithm is

proposed. But it is difficult to straightly apply one case result to other cases, because the different constraints cause other difficult problems and constraints.

3 Vehicle scheduling and routing problems in day-care center

In this section, we introduce the results of our paper[5], we reconsider one of GIS-based scheduling applications concerning the availability of spatial database and GPS technologies for the vehicle routing problems.

Firstly, we recorded actual car routes by using GPS tracking device, "Photo-Trackr", which is mainly designed for travelers seeking photo tracking functions. Furthermore, based on the customers address and request for vehicle routings, we analyze car routes by using GIS software, "ArcView". By using ArcView, we transform from geographic data to network data, and solve VRP by the left side tools presented in Fig. 1.

In this paper, we use UTM projection and build up geodatabase transformed from the joined shape file. Then, we add "*Speed_km_h, Minutes, Name*" fields for network analyst tools. We also define the limit speed depending on the characteristics of roads. Furthermore, by using ArcCatalog, we create the network dataset by selecting all roads field and add "*Length, Minutes, Hierarchy, Oneway*" data sets. "*Length*" data set is "*Shape_Length*", we calculate average speed based on "*Shape_Length*" and "*Speed_km_h*", and store into "*Minutes*" data set. "*Hierarchy*" data set also depends on the class of roads.

We use "*ArcGIS Network Analyst*" as one of additional tools, which provides various solutions to discover the closest stations, the best shortest route and scheduling cost. Here, we use the best shortest route by clicking several stops in the network database.

Pick-up and send-off locations of customers are described by address of Japanese street names without latitude and longitude attributes. Firstly, we need to convert from the name of addresses to the WGS84 longitude and latitude at the street-level by using "*the address matching service.*" By using "*Free Address Geocoding service for CSV formatted file on WWW*" (http://www.tkl.iis.u-tokyo.ac.jp/ ˜sagara/geocode/overview.html), we have geocoding data provided by National-Land Information Office (http://nlftp.mlit.go.jp/ isj/index.html).

We compare the actual route operated by the day-care center and the optimal route provided by VRP algorithm, and evaluate the quality of other routes in other days. As experimental results, constraints of time windows are very severe.

4 Multi-Agents scheduling and routing problem with time windows and visiting activities

In this section, we extend the results of "Vehicle scheduling and routing problems in day-care center" and introduce the constraint of "Visiting Activities". For example, in the problem of "Scheduling of teachers for visiting high schools", they have meeting time within time range, properties of time windows are more com-

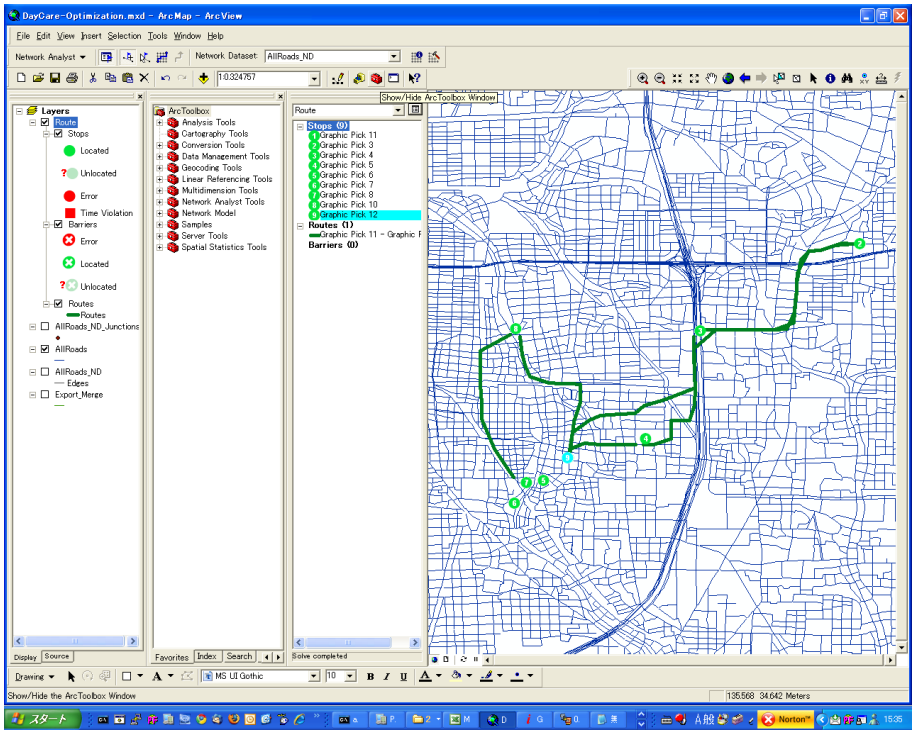

Figure 1: Finding Best Routes by ArcGIS Network Analyst

plex. So we generalize those problems to VRP with time windows and visiting activities.

In order to solve the extended problem, we introduce five parameters based on previous case studies, such as “activities at the visiting points”, “time windows”, “numbers of visiting spots within a route”, “total visiting time”, “time-lag between different routes”.

We have to consider the fairness of activities and workload balancing is very important aspects, the workload balancing depends on three parameters, ”α : minimize the total time cost of all agents”, ”β: minimize the difference between each agent”, ”γ: minimize the number of visiting points between agents”. We define the tradeoff cost function with these three parameters α, β, γ, then we solve ”Multi-Agents Scheduling and Routing Problem with Time Windows and Visiting Activities”.

Before an execution of problem solver, we prepare sets of k clusters satisfying constraints of time windows, then we derive optimal routes for all sets. In order to derive k clusters, we propose the algorithm of k-means method under the constraints of time windows in Algorithm1.

Finally, we use ArcGIS Network Analyst tool for computing cost of routes, and

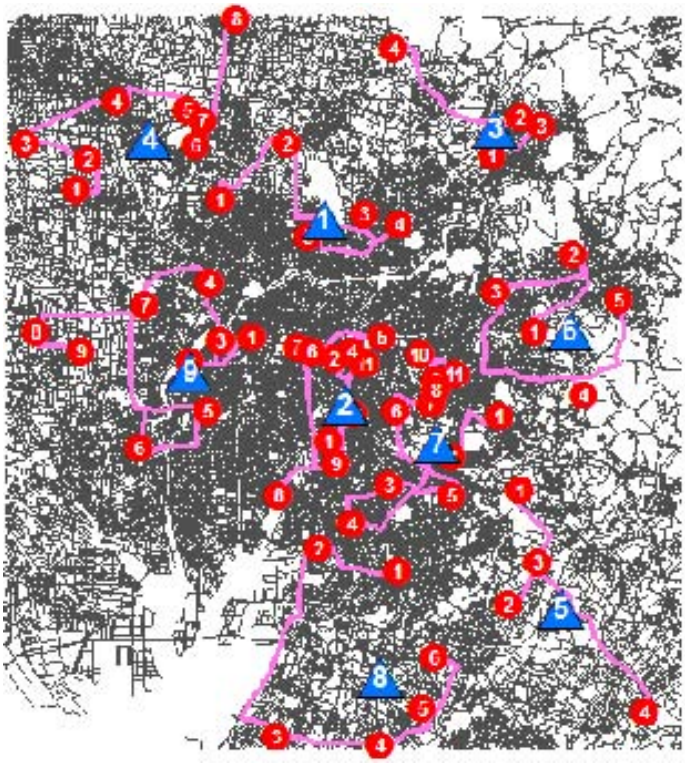

Figure 2: Multi-agents scheduling results of visiting high schools[2]

we evaluate the optimal visiting route with time windows and visiting activities presented in Fig. 2. We also validate the output result based on the actual vehicle routes in a day-care center.

5 Conclusion and future work

In this paper, based on our previous researches, we generalize the problems to the problem of "Multi-Agents Scheduling and Routing Problem with Time Windows and Visiting Activities". We propose five parameters, such as"activities at the visiting points", "time windows", "numbers of visiting spots within a route", "total visiting time", "time-lag between different routes". We evaluate the quality of optimization based on three performance measures. We also proposed the algorithm of k-means clustering under the constraints of visiting sequence. By using ArcGIS Network Analyst tool for computing cost of routes, we evaluate the optimal visiting route with time windows and visiting activities.

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References

[1] F. Giannotti and D. Pedreschi, "Mobility, Data Mining and Privacy : Geographic Knowledge Discovery," Springer, 2008.

[2] K. Kato, "The solution of the Vehicle Routing Scheduling Problem for Optimization of Multi Costs," Master Thesis, Graduate School of Mathematical Sciences and Information Engineering, Nanzan University, 2009.

[3] H. Kawano, H. Takada, Y. Ishii, Y. Hisari and T. Hasegawa, "Data Mining in Hanshin Expressway Traffic Data Warehouse Models of Clearance Duration for Incidents," Proc. of the Joint Symposium of Seoul Metropolitan Fora & Second International Workshop on UPIMAP, pp.226-232, Seoul, Korea, 2006.

[4] H. Kawano, Y. Ishii, I. Komoto and T. Hasegawa, "GIS Visualization and Analysis of Traffic Flows: Congestion Patterns in Hanshin Expressway Data Warehouse," Proc. of International Conference on Systems Science, Poland, pp.121-128, 2007.

[5] H. Kawano, M. Kokai and W. Yue, "GIS-based Solution of Vehicle Scheduling and Routing Problems in Day-care Center," Proc. of Operations Research and Its Applications, 7th International Symposium (ISORA'08), pp.336-343, World Publishing Corporation, 2008.

[6] B.I. Kim, S. Kim and S. Sahoo, "Waste Collection Vehicle Routing Problem with Time Windows," Computers & Operations Research, Vol.33, pp.3624-2642, 2006.

[7] Nissan Motor Co., Ltd., "Pick-up Support Service Tools and Systems," Patent P2005—11033A, 2005.
http://www.j-tokkyo.com/2005/G08G/JP2005-011033.shtml (in Japanese)

[8] S. Shekhar and S. Chawla, "Spatial Databases: A Tour," Prentice Hall, 2002.

[9] L. Spasovic, S. Chien, C. Kelnhofer-Feeley, Y.Wang, Q. Hu, "A Methodology for Evaluating of School Bus Routing - A Case Study of Riverdale, New Jersey," Transportation Research Board, Vol.80, No.1-2088, pp.1-17, 2001.

[10] J. Steeg and M. Schröder, "A Hybrid Approach to Solve the Periodic Home Health Care Problem," Operations Research Proc. 2007, pp.297-302, Springer, 2007.