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GIS-based Solution of Vehicle Scheduling and Routing Problems in Day-care Center

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Abstract Recent years, spatial data and observed data, such as digital road map, traffic route, vehicle speed, recordings events and others, are integrated and stored into the spatial temporal database systems. Various location-based services by using mobile phone are also becoming popular. In this paper, we focus on one of GIS-based scheduling applications concerning the availability of GPS technologies and spatial database for the actual vehicle routing problems. Vehicle Routing Problem (VRP) is the one of important problems in the research fields of transportation, frequently we consider variations of VRP, such as Vehicle Routing Problem with Time Windows (VRPTW) and Capacitated Vehicle Routing Problem CVRP (CVRPTW, CVRP with Time Windows). Mainly we use two spatial technical tools, "PhotoTrackr" and "ArcGIS", which record and analyze vehicle routes. By using these devices and tools, we compare the actual recorded routes and optimal routes, and discuss the characteristics of routes determined by the day-care center.

Keywords Vehicle Scheduling and Routing Problem, GIS, GPS, Day Care Center

1 Introduction

Recent years, it is easy to record traffic route and vehicle speed by using GPS devices and mobile phones. Various location-based services, such as Google Maps (`http://maps.google.co.jp`), MapFan (`http://www.mapfan.com`), Navitime (`http://www.navitime.co.jp`), are becoming popular in Japan.

In our previous researches[1, 2], we visualize the probing data of taxi in Nagoya metropolitan area and the probing data of patrol cars on Hanshin Expressway by using GIS softwares, we apply several data mining algorithms to traffic data and spatial database and derive patterns/rules. There are many research papers about spatial data mining technologies of traffic data, for instance optimization of travel plan, visualization of traffic jam, GPS assisted navigation, road design, and ICT-assisted traffic congestion[7].

In this paper, we focus on one of GIS-based scheduling applications concerning the availability of spatial database and GPS technologies for the vehicle routing problems[10]. Actually, various types of Vehicle Routing Problem (VRP), such as Vehicle Routing Problem with Time Windows (VRPTW)[3], Capacitated Vehicle Routing Problem CVRP

(CVRPTW, CVRP with Time Windows) and Vehicle Routing Scheduling Problems (PRSP), are discussed in the research fields of transportation.

We try to integrate spatial data and observed data, such as digital road map, traffic route, vehicle speed, recordings events and others, and store into the Geographic Information System (GIS). The vehicle scheduling and routing problems in a day-care center are important and time consuming. "Day-care/Day-service" is nursing for the senior citizen service, it is necessary to consider various constraints by the nursing facilities, number of cars, requirement of customers, location of the home and others. Based on actual GPS data, we analyze vehicle routes and discuss characteristics of optimal or feasible routes provided by using GIS tools.

In Section 2, we introduce VRP researches and VRP for Day-care and Day-service. In Section 3, we mention techniques of GIS and GPS, in order to discuss actual schedules and routes in the day-care center. Mainly we use two spatial tools, "PhotoTrackr" and "ArcGIS", which record and analyze actual vehicle routes. In Section 4, we transform from the data set of “Digital Road Map (DRM)” to the road network dataset. Using actual GPS log data, we discuss characteristics of analytical results by GIS tools. Finally, in Section 5, we conclude our experimental results and present some future works.

2 VRP Researches and Day-care/service

In this paper, we focus on one of GIS-based scheduling applications concerning the availability of spatial database and GPS technologies for the vehicle routing problems[9, 10]. Vehicle Routing Problem (VRP) is very important in the research fields of transportation, we frequently consider VRP with actual restrictions, such as Vehicle Routing Problem with Time Windows (VRPTW) and Capacitated Vehicle Routing Problem CVRP (CVRPTW, CVRP with Time Windows).

In several patents and research papers[5, 6, 8], 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.

In the paper [8], the home health care (HHC) services are becoming popular problems all over the world, the HHC 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.

3 GPS devices and GIS tools for route analysis

We record actual car routes by using GPS tracking device, “PhotoTrackr”, which is mainly designed for travelers seeking photo tracking functions. In our research, we try to record car trackings for day care service. Utilizing the PhotoTrackr mapping software and latest Geo-Mapping technology, we can record the exact routes by using the PhotoTrackr in Fig. 1.

Furthermore, based on the customers address and request for vehicle routings, we try to analyze car routes by using GIS software, “ArcView”, which is one of major GIS softwares, and which has various functions, such as visualizing, managing, creating, and analyzing geographic data. By using ArcView, we transform from geographic data to network data, and solve VRP by the left side tools presented in Fig. 2.

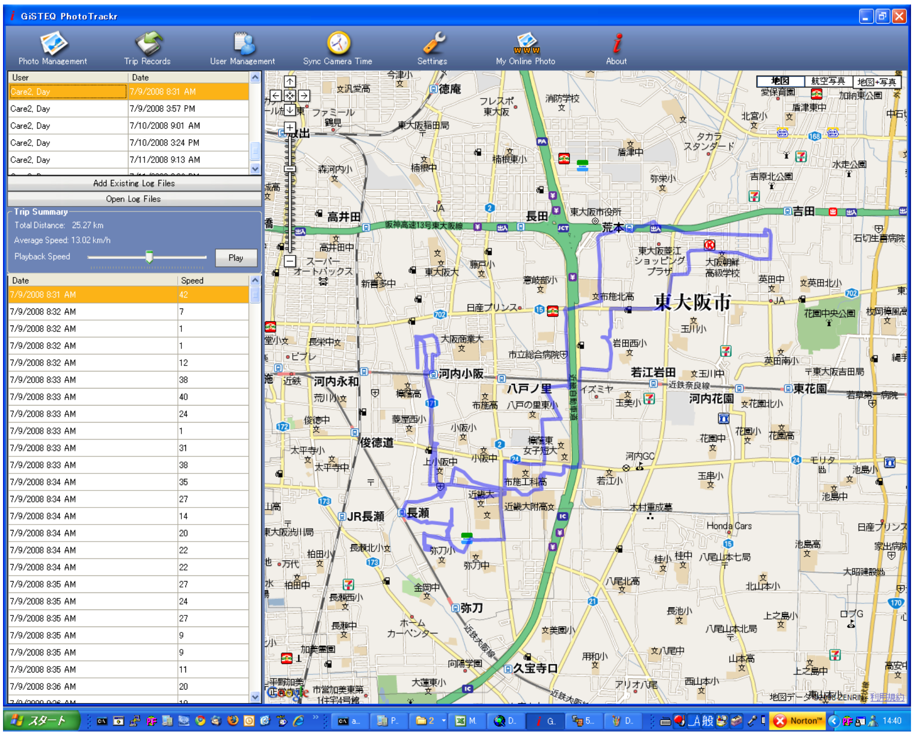

Figure 1: Observed data set by PhotoTrackr

4 Experiments: GIS-based Solution of VRP

In this section, by using PhotoTrackr and ArcGIS, we try to analyze actual driving records and discuss difficulties of this problem.

4.1 Digital Road Map data

In this analysis, we use the specific DRM format in several areas (Higashi-Osaka and Yao cities), and edit layer structured data of spatial objects with latitude and longitude, buildings and so on. We store the digital map data of Osaka urban area into ArcGIS, and the original map data is provided by CSIS.

All locations in this experiments exist in the "*513574*" and "*523504*" shape files in the GISMap for Road, firstly we have to convert these shape files to the network data as geodatabase format. The GISMap for Road have many fields such as "polygon, polyline, points, major roads, all roads, beacon," we need to remove meaningless fields and join tables of all roads and major roads by using ArcMap and ArcToolbox of ArcGIS 9.2.

In this experience, 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.

Secondly, by using ArcCatalog, we create the network dataset by selecting all roads

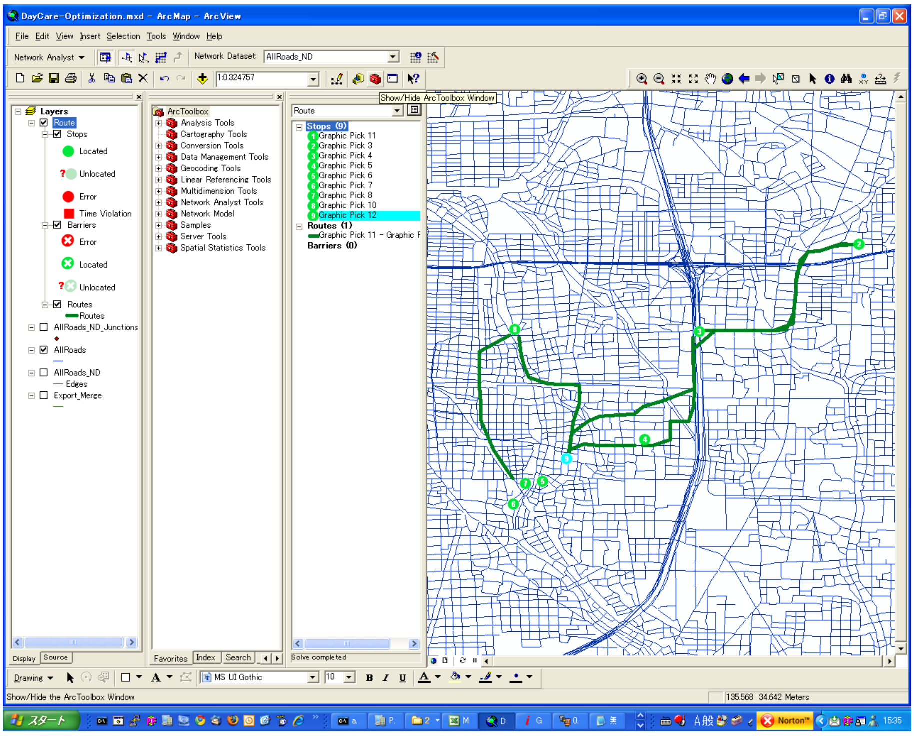

Figure 2: Finding Best Routes by ArcGIS Network Analyst

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.

4.2 Pick-up and Send-off Locations

Pick-up and send-off locations of customers are described by address of Japanese street names without latitude and longitude attributes. In this experiments, we consider 32 persons who live in "*Higashi Osaka City*" and "*Yao City*" all addresses are located in the area (34.63198N, 135.56696E) and (34.67748N, 135.62175E). The area of pick-up and send-off locations are not so concentrated. We show several data presented in Fig. 1.

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). For example, the person A1 lives in "Kowakae 1-X, Higashi Osaka, Osaka, Japan", this address is located at (34.64962N, 135.58269E) in Table 1.

Table 1: Output of Address Matching Data

Person	Address matching results	Longitude (E)	Latitude (N)
A1	Higashi Osaka/Kowakae/1/X	135.58269	34.64962
...	...	...	...
P	Higashi Osaka/Kotobuku/1/X	135.57037	34.6519
Z	Yao/Suehiro/3/X	135.59344	34.63198
A4	Yao/Sadou/2/X	135.59224	34.63583

4.3 VRP with Pick-up and Send-off Constraints

Table 2: Location and Customers Requirements

Seq.	Person	Longitude (E)	Latitude (N)	Restriction
1	X	135.6218	34.67748	—
2	M	135.6016	34.66792	—
3	C1	135.5951	34.65402	—
4	C2	135.5951	34.65402	—
5	A3	135.5827	34.64962	—
6	A2	135.5827	34.64962	—
7	E	135.5798	34.64683	—
8	D	135.5802	34.6491	—
9	K	135.5794	34.66792	late pick up time request

This day care center operates two cars for pick-up and send-off, average number of clients are about 8 per a car. For instance, one of scheduling tables with restriction is presented in Table 2. There are various constraints, such as"request of car number, making groups, having time window of pick-up/send-off, change of destination, temporal request of send-off location and others".

We summarize the data recorded by PhotoTrackr during three days, and we show total driving distance, average velocity, departure/arrival times and total time of pick-up/send-off in Table 3,4.

We compare the actual route operated by the day-care center in Fig. 1 and the optimal route provided by VRP algorithm in Fig. 3, and also try to evaluate the quality of other routes in other days. As experimental results, constraints of time windows are severe conditions, firstly day-care center have to satisfy these requests with time windows.

Furthermore, we recognize that the shape of optimal route is slightly different from the recorded route and the range of longitude and latitude are also slightly different from the actual pick-up location. The representative data with longitude and latitude have some errors at the address matching step, since the address matching function utilize the representative location. Or depending on the traffic conditions and customers requirements,

Table 3: Statistics of Recorded Log Data by Car No.1

Car No.1 Schedule	Distance	Velocity	Departure	Arrival	Driving time
2008/07/09 AM	9.54	8.4	9:04	10:06	1:02
2008/07/09 PM	11.6	10.54	3:27	4:22	0:55
2008/07/10 AM	12.28	6.89	9:06	10:34	1:28
2008/07/10 PM	14.89	9.91	3:24	4:33	1:09
2008/07/11 AM	23.24	9.66	8:37	10:43	2:06
2008/07/11 PM	16.27	7.48	3:26	5:11	1:45
Total	87.82				8:25

Table 4: Statistics of Recorded Log Data by Car No.2

Car No.2 Schedule	Distance	Velocity	Departure	Arrival	Driving time
2008/07/09 AM	25.27	13.02	8:31	10:28	1:57
2008/07/09 PM	8.32	11.97	3:57	4:37	0:40
2008/07/10 AM	12.18	10.01	9:01	10:32	1:31
2008/07/10 PM	19.26	10.96	3:24	4:46	1:22
2008/07/11 AM	12.68	10.43	9:13	10:21	1:08
2008/07/11 PM	10.96	10.54	3:36	4:33	0:57
Total	88.67				7:35

the actual location seems to be moved from input addresses to the locations. We can not neglect these errors in order to discover optimal routes.

5 Conclusion and Future Work

Based on the recorded route and best route provided by Network Analyst Tools, the difference is so small, the quality of making routes determined by day care center seems to be good. According to results of our experiments, most severe problem is the accuracy of address matching outputs. Furthermore, finding parking places, traffic conditions seems to be relatively difficult than car scheduling and vehicle routing problem.

Most of previous developed system seems to be very complicated and over spec for usual Day Care Centers in Japan. However, based on the day-to-day analysis discussed in research paper[4], we have to analyze day-to-day variability of actual routes during long-term. At present, the service provided by the commercial Car Route Finder (`http://www.mapfan.com/routemap/routeset.cgi`) in MapFan web site is quite useful and shows the limitation of the commercial vehicle navigation service with three destinations. In the future, we have to improve the higher resolution of address matching service and more accurate observations of traffic conditions in order to solve more severe constraints.

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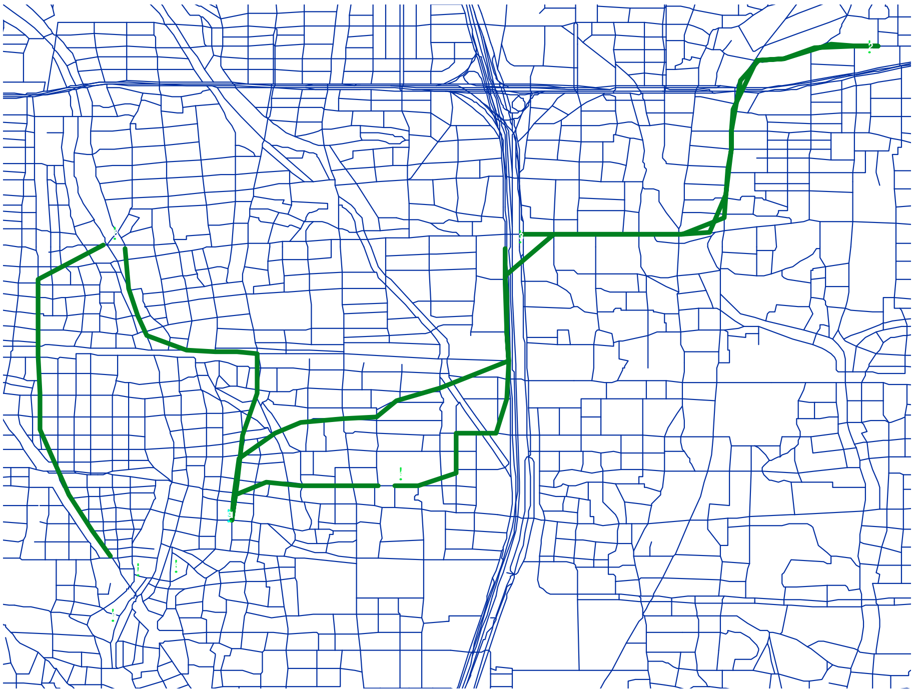

Figure 3: Best Routes Provided by ArcGIS Network Analyst

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