USING ONLINE GEOCODING AND DIRECTIONS MAP SERVICES TO ENHANCE THE CAPABILITY OF ROUTE PLANNING AND MANAGEMENT SYSTEMS

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Abstract
Route planning for providing optimal transportation between offices and employees' residences for large organizations is a complex and challenging logistics problem when there are complex conditions and constraints involved. Effective route planning and management can help reducing operating costs. Typically, employees' address information, in most databases, is stored in the form of text. Route planning associated with geographical location data is; therefore, difficult to manage in such cases, plus it is difficult to generate clear, understandable results. If such text address data is converted into latitude-longitude coordinate data, the problem involving extensively uses of location data will be much more effective in finding and displaying results. Nowadays, there are various publicly available online map services that can be accessed via application programming interfaces from web applications. This paper is focused on developing a web application for route planning and management that accesses publicly available online map services in order to study efficiency and limitations of such online map services in the processes of geocoding and displaying the results on the maps; to be applied in a route planning system used by employees across nine provinces in the central region of Thailand.

Keywords
Route planning, route management, geographic information systems, online map services, geocoding

Introduction

Within an intensely competitive business environment, increasing revenues is difficult, and as a result, cost reduction becomes a key requirement of many business operations. Apart from production, there are other operations that affect overall costs, such as logistics. Effectively planning of employee transportations can help reduce logistics costs. The aim of this study was to design an effective employee transportation route planning system, while meeting required conditions. The factors that needed to be factored into the design included the duration of the longest trip made within the company, the number of vehicles and the distance from employees' homes to their destinations. It could be seen quite clearly that these journeys involve many coordinates, and so designing an application able to display geographical data would help improve information management, as well as the company's understanding of such information.

This paper describes the development of a web application, to be used to display spatial data for employee transportation route planning purposes. The development comprised three main steps, as shown in Figure 1. Step (1) involved converting employees' address information from the employee database, that stored in the form of text, into a latitude-longitude format, so as to be able to use such data as inputs for the route planning algorithms in subsequent step. The conversion of text addresses into latitude-longitude coordinates can be carried out by employing the geocoding technique. Nowadays, numerous online geocoding services are widely available, such as Google geocoding service, which was used in this case study. Step (2) used the latitude-longitude employee address coordinates and company locations to solve route planning problems, as the Vehicle Routing Problem (VRP), one designed to minimize the duration of journeys, from their starting points - taking into account stops - and on to the final destination. Details of the solution developed for this step are shown in (Jintawiwat, 2010). The results of the routing exercise were then stored in the database, to be used as part of a map display in step (3). During this step, Google Maps APIs (Google, 2012a) were used in order to enhance the effectiveness of the map displays and route information given.

This paper will discuss the details of the first and third steps shown in Figure 1, in which the first step involved converting the text addresses into latitude-longitude coordinates making use of the geocoding service, and the third step involved using online map services to display data within a web application. The details of step (2) are presented in (Jintawiwat, 2010).

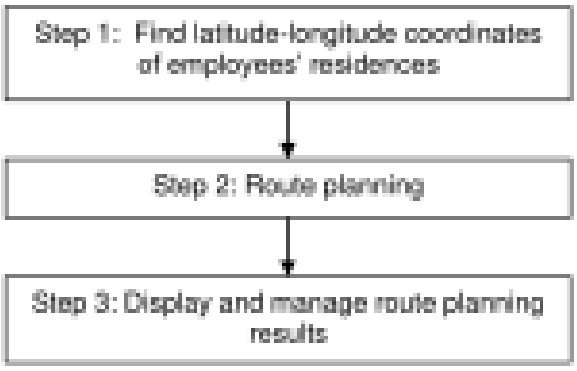

Figure 1: Main operating structure of the employee transportation route searching system

Geocoding

Geocoding involves converting geographical location data from text into latitude-longitude coordinates, and the effectiveness and accuracy of a geocoding service depends upon: (1) the completeness of the text address information to be used as an input, and (2) the size of the database of mapping data between the text addresses and latitude-longitude coordinates offered by a service provider. Currently, geocoding services are available in following three forms: (1) online geocoding services available for access via Application Programming Interfaces (APIs), such as Google Geocoding API, Microsoft's Bing Maps Geocode API, and MapQuest Geocoding API (Google, 2012b; Microsoft, 2012; MapQuest, 2012), (2) online geocoding services available for online access but not via API, and (3) stand-alone software package (Texas A&M University, 2012).

This case study employed the Google Maps API services, which feature a large amount of global address information which is updated regularly and consistently, resulting in high levels of accuracy, as well as good service reliability and stability. Also, API services are easy-to-use, high standard, with a wide variety of options. In addition, Google Maps API services are offered free of charge, assuming a maximum number of services are requested within a day, and the address information in a text string and latitude-longitude coordinates are returned in JavaScript Object Notation (JSON) form, or XML.

One advantage of employing the geocoding method to obtain latitude-longitude coordinates is its speed and its suitability for use with large data set, while obtaining coordinate information using other methods is difficult and costly. The usefulness of the coordinates data obtained by geocoding depends upon: (1) the completeness of the text address delivered to the geocoding service and its level of accuracy - which depends upon the level of completeness of the text address information, which should include the city, the postal code, the street, and the address point, and the last element is considered the most accurate result, and (2) the size of the mapping database held by the service provider containing the text address information and latitude-longitude coordinates, as the amount of data may vary in accordance with the density of a given community in a particular location (Roongpiboonsopita, 2010).

One disadvantage of geocoding is that errors may be produced due to a lack of mapping data – either text addresses and/or latitude-longitude coordinates in an area, or the density of mapping data is not high enough, which results in errors when converting the information into coordinates. For instance, if there is insufficient street information, a geocoding service will return the results as street centroids, or, in some cases, as city centroids (Roongpiboonsopita, 2010; Cayo, 2003)

Due to the high quantity of information used in this case study, the geocoding technique was seen as a suitable approach to use to obtain the required coordinates. The process for this step is shown in Figure 2, during which a web application retrieved the text address from the database, called the Google Maps API geocoding service, and received the results in the form of latitude-longitude coordinates, which were then stored in the database, to be employed by the company.

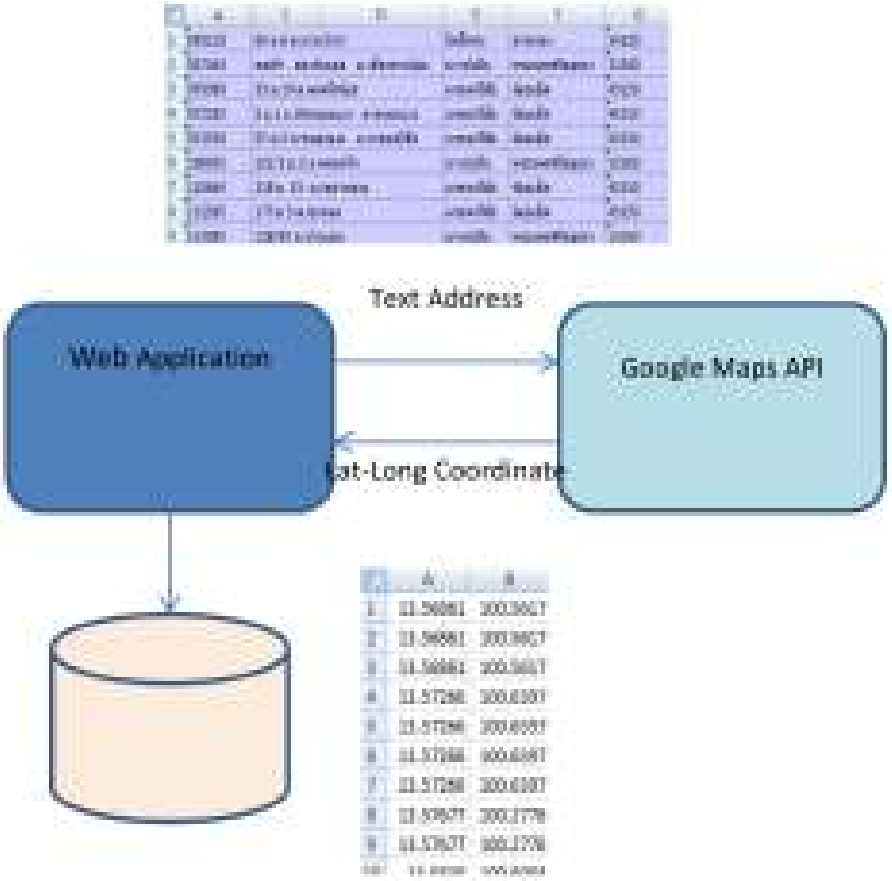

Figure 2: Use of the geocoding service to convert the text address information into latitude-longitude coordinates

Errors in geocoding process

As discussed, the results of geocoding may contain errors in terms of the latitude-longitude coordinates returned, depending upon the density of mapping and text data available for a given location in the database. Normally, the density of mapping data obtained from big cities is higher than from smaller cities and towns, leading to street centroids being returned as the geocoding results.

For the Thai data used in this study, in the Bangkok urban area the average error ranges between 10 and 30 meters - with a maximum error of approximately 200 meters. In the districts of other provinces, the average error lies between 100 and 200 meters - with a maximum error of approximately 500 meters, and in rural areas, the average error ranges from 200 to 500 meters - with a maximum error of approximately 800 meters

In rural areas, the high error level is due to low amounts of information and a low density of mapping data available in terms of both the text addressees and latitude-longitude coordinates. One solution that may be used to reduce the amount of error is to manually adjust the latitude-longitude coordinates one at a time, as shown in Figure 3. This method, however, is time consuming and so unsuitable when one has a large amount of information, and for users who are not familiar with the mapping data – a problem found in the case study company where many employees had difficulty understanding the information on the map.

Another method which might generate a higher level of accuracy would be to interpolate addresses from surrounding locations with more complete information using a keyword in the existing text address to search for a nearby location that contains more complete data.

Figure 3 Adjustment of a location obtained by geocoding the text address to the right

Data employed in the case study

The data used in this study was the address information of 20,095 workers across 9 Thai provinces, these being: Phra Nakhon Si Ayutthaya, Bangkok, Pathum Thani, Nonthaburi, Saraburi, Nakhon Nayok, Ang Thong, Lopburi and Singburi. The case study company is located in Bang Pa-in district, Phra Nakhon Si Ayutthaya, as designated by the ⊙ symbol in Figures 4 to 6.

The distribution of the information used in the study was divided into the Bangkok area (21%), urban areas (65%) and rural areas in other provinces (14%), with an average error of approximately 100 meters, an error margin which allowed for primary routing.

After converting text address information into latitude-longitude coordinates, Google Maps API was then requested to display geographical data, as shown in Figure 4, which shows the location and density of employee address coordinates. This map helped to establish a better understanding of the dataset's dispersion.

Figure 4: Location/density of employee address coordinates

The latitude-longitude coordinates of the employees' addresses and the company location could thus be used as inputs – to solve the routing problems; which consisted of two parts. The first part was used to carry out employee address clustering, so as to generate the stopping points, including the number of stops, the maximum distance from a residential address to a stop, and the average distance from a residential address to a stop. After the optimal stops were obtained, they were then used as inputs. The second part involved incorporating these stops into the routing planning system, based on the required conditions, these being the number of routes, the number of vehicles, and the maximum distance or duration of each route. The results of the route planning exercise were stored in the database, to be used for the display and management of the geographical information. There are three additional important database entities from the results in this step, these being the routes, the stops, and vehicles.

Figure 5 shows the results the routing results with the help of Google Maps API in displaying on the map. Within the system, the connections between stops along each route are estimated using a straight line – for ease and speed of display of the overall features such as stops, connecting lines between stops, and the farthest stop on each route. Figure 5 only shows stops along the route and the connecting lines between stops, while Figure 6 demonstrates the stops and a map of the results extracted from the clustering step - to find the optimal stops to use. When details of a route are required, users can click on a route and the appropriate details will appear, as shown in Figure 7.

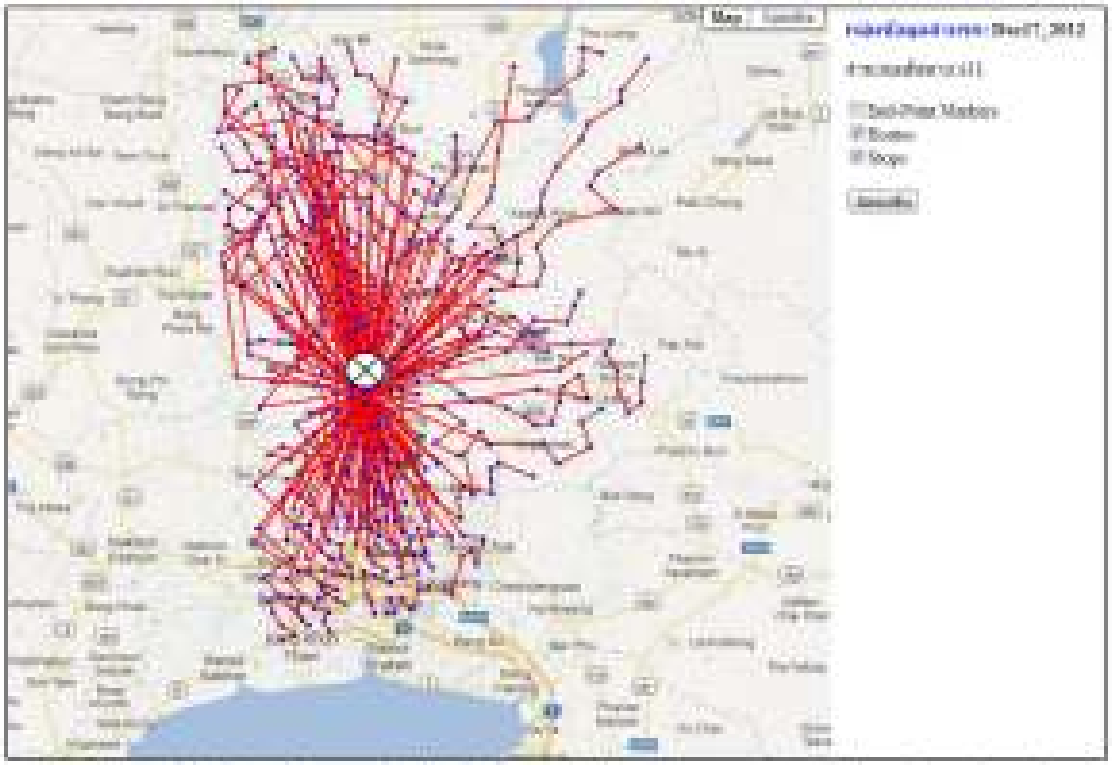

Figure 5: Geographical routing results displaying only the stops and connecting lines along the routes

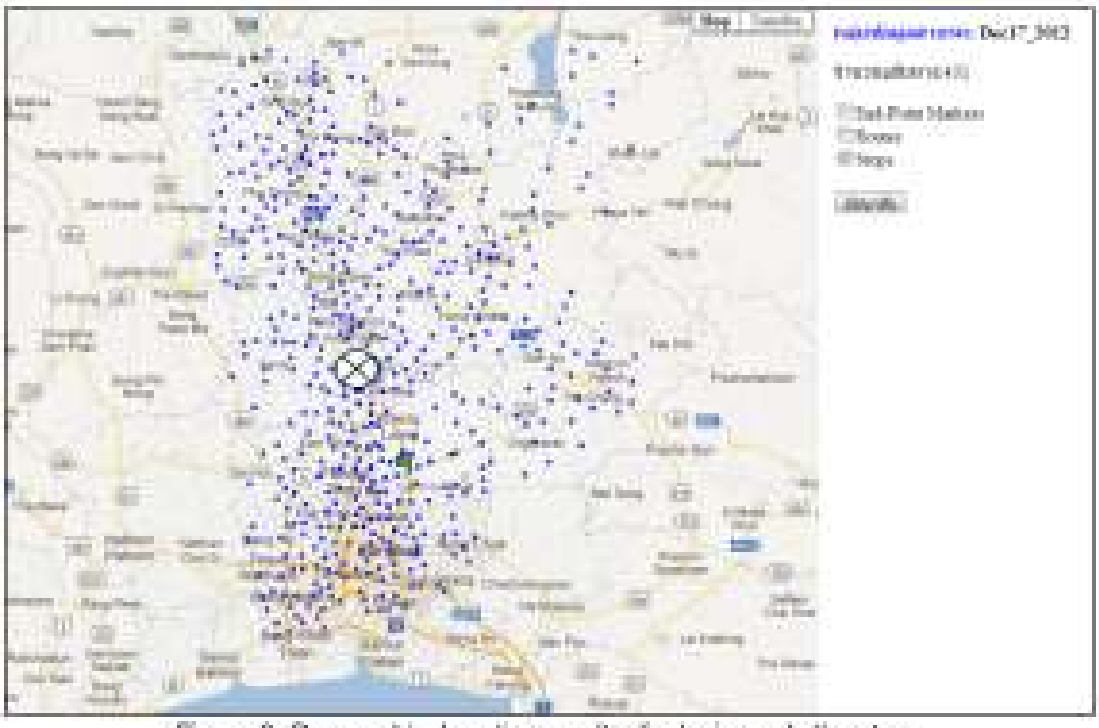

Figure 6: Geographical routing results displaying only the stops

Figure 7: Sample transportation details for one route

Figure 7 shows the details of a specific route by making use of the directions service contained within the Google Maps API services, displaying the route that passes a specific set of stops along the chosen route. The directions service provides the distance between consecutive stops, and the time it takes to reach these stops, which is calculated by Google Maps API. The figures obtained can be used to estimate the time of arrival at each stop, assuming the departure time is set. Furthermore, the routes and stops can be adjusted and the directions service then re-calculates the new routes, and provides new distances and times. The results obtained can then be updated in the system, to allow the web application to schedule the optimum stops and routes. The distance of each route obtained from the directions service, incorporating the requirements to pass specific points, can be used to ascertain other information, such as the total distance of each route and the total fuel costs. The duration between stops along a route can also be used for timetable planning purposes, and to enhance the utilization of each vehicle.

It can be seen that the geographical data display will not only help improve the company's level of understanding of the routes used and help it to deal with route adjustments, but may also be used to generate other useful geographical information. For example, users may want to find the nearest stop along a route, or when to leave in order to reach a particular destination at a given time. It can therefore be seen that to search for information based on data held in the form of text, numbers and tables might prove difficult. In contrast, if such data is held on an appropriate map display system, as shown in Figure 8 (which demonstrates the nearest five stops), and used together with the Google Maps API directions service, users should be able to access information on the nearest stops, distances and estimated traveling times, including the arrival times of the next vehicle, along a given route. As can be seen, the map display, working in tandem with Google Maps API, can be used for a variety of tasks, and will result in higher route planning efficiency.

Figure 8: Search functions for the nearest stops along a route

Conclusions

This paper has given details of a solution developed in order for the study company to carry out more efficient employee route planning activities. The solution uses a web application connected to online map API services, and uses a geocoding service to convert text address information into latitude-longitude coordinates. The system also provides directions – to find what routes pass certain stopping points, and uses a map APIs to construct geographical data, so enhancing the efficiency of the mapping display and the management of information. Even though location information obtained from the use of geocoding services still contains errors, this paper illustrates the usefulness of an application used to resolve geographical problems making use of a publicly available online map services, one which can be employed easily and quickly, and still provide good results in terms of displaying mapping information, and that may be used as the framework for a primary solution to be developed, in this case by the study company.

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