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The Approximate Shortest Distance Route Intelligent System
For Traveling in Taiwan

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Abstract

In a well known problem, there are N! possible routes for tourists to visit N cities, with each city passed through once before the return to the departure city. It is difficult to find the shortest route among N! possible routes quickly and effectively. This research proposes a method that integrates the Hungarian Method and the Branch-and-Bound Method in Operation Research, Nearest Neighbor in Data Mining, and Rule Based Inference in Artificial Intelligence to find the approximately shortest distance route and the distance. It also uses object-oriented programming to construct the Approximate Shortest Distance Route Intelligent System for Traveling (ASDRST). The ASDRST needs only a personal computer and it can find the approximate shortest distance route and corresponding distance quickly and effectively compared with other systems. Its accuracy is more than 99.8% in a pass-through of 42 cities.

1. Introduction

There are N! possible routes for a tourist to visit N cities, with each city in the route passed through exactly one time before the return to the departure city. How to find quickly, effectively and easily with an acceptable accuracy the route of approximate shortest distance round-trip from among such a large number of routes? Of course, the complexities and solving times increase dramatically as the city number grows. From studies involving the US and Germany we find there were usa1509 and d15112 [6] systems to determine the correct shortest-distance round-trip route for 15,09 American cities and 15,112 German cities respectively in 1998 and 2001. Unfortunately, both systems had few practical uses due to high hardware and software requirements, difficulty of use, long solving times, and lack of flexibility for applications. In reality tourists need to solve practical problems using personal computers that are easy to use and solve problems fast and effectively with acceptable accuracy.

2. Literature Review

In 1954, G. Dantzig, R. Fulkerson, and S. Johnson proposed the Cutting Plane Method which solved the problems of the shortest distance route and the integer programming for passing through 42 cities [2]. E.L. Lawler and D.E. Wood proposed the Branch-and-Bound Method which used the Minimal Spanning Tree to solve the shortest distance route problem [3]. Han-Chu Liu used several algorithms to analyze the solutions for the shortest distance route [4]. D. Applegate, R. Bixby, V. Chvátal, and W. Cook used a cutting plane algorithm to verify the correctness of the shortest distance route solutions from pcb3038, fkn4461 and pla7392 systems that were used for solving the problem of shortest distance route for 3038, 4461 and 7392 cities respectively [5].
The shortest distance route system was developed starting from the year 1954 when G. Dantzig, R. Fulkerson, and S. Johnson proposed the dantzig42 that solved a route that passed through 42 cities as shown in Fig. 1. In 2001, D. Applegate, R. Bixby, V. Chvatal, and W. Cook proposed the d15112 system for a city number up to 15,112 [6]. Though the d15112 system could find the shortest distance route for passing through 15,112 cities, it needed high-end hardware to run and much time to solve. It was not practical for finding a shortest distance route from among a large number of cities.

Fig. 1 The Shortest Distance Route Solved by Dantzig42 System (from paper [1])

This paper proposes a computing method to find the approximate shortest distance. The method integrates the Hungarian Method for Assignment Problems and the Branch-and-Bound Method in Operations Research, the Nearest Neighbor Method and the K-means Clustering Algorithm in Data Mining, and the Rule-Based Inference in Artificial Intelligence.

3. Computation of the Approximate Shortest Round-trip Route for Traveling

3.1 Expressions of the Shortest Round-trip Route for Traveling

A traveling route passes through n cities. $D_{ij}$ represents the distance from city i to city j. If a tourist sets out from city 1, passes through cities 2, 3, ..., n in order, and then returns to city 1 with each city in the route passed through exactly one time, the total distance of the route is $D_{12} + D_{23} + D_{34} + \cdots + D_{nj}$.

The distance of the shortest round-trip route from n! possibilities can be expressed as equ. (1)[1]

$$\text{Minimum } \{ \sum_{i=1}^{n} D_{ij} \} \quad (1)$$

Subject to $1 \leq i, j \leq n$

It can be simplified as equ. (2)

$$\text{Minimum } \sum_{i,j} W_{ij} D_{ij} \quad (2)$$

Subject to $\sum_{j} W_{ij} = 1, \sum_{i} W_{ij} = 1, W_{ij} = 0 \text{ or } 1$,

$W_{ii} = 0, D_{ij} \geq 0$, for $i,j = 1, 2, 3, ..., n$.

The $D_{ij}$ is called the Distance Matrix and all the element values in $D_{ij}$ are integers. $W_{ij}$ is called the Weight Matrix. All the algorithms discussed in the paper review paragraph are applied to find the Weight Matrix $W_{ij}$ that satisfies equation (2) with the minimum value.

3.2 Calculation of the Approximate Shortest Distance Round-trip Route for Traveling

If we directly use the Hungarian Method for assignment problems to find the approximate shortest distance route for the traveler’s round-trip, the resulting route could reflect the inconsistent conditions of the $D_{ij}$ selected since $D_{ii}$ may not be equal to $\infty$, or both $D_{ij}$ and $D_{ji}$ may lie along the same route, or $D_{ji}$, $D_{ij}$ and $D_{ij}$ may all lie along same route. If we use only the Branch-and-Bound Method for solving, we need to set all cities as starting cities in turn. Though the shortest distance route would be found, it would take many complex calculation procedures and require a long time to find the solution. So it seems not to be a practical method. If we use the Nearest Neighbor Algorithm, however, only the approximate shortest distance route would be found, and the route errors could be enlarged if there were any outliers as shown Fig. 2.

Fig. 2. City 8 and City 23 are outliers
To reduce the problems mentioned above, this paper proposes an approximate shortest distance route computing method that integrates the Hungarian Method and the Branch-and-Bound Method in Operations Research, the Nearest Neighbor Algorithm and K-mean clustering algorithm in Data Mining, and finally the Rule-Based Inference in Artificial Intelligence. The expressions and definitions used in this method are briefly described as follows:

(1) Distance Matrix (D): $D_{ij}$ denotes the ground distance from city $i$ to city $j$.

$$
D = \begin{bmatrix}
D_{11} & D_{12} & \cdots & D_{1n} \\
D_{21} & D_{22} & \cdots & D_{2n} \\
\vdots & \vdots & & \vdots \\
D_{n1} & D_{n2} & \cdots & D_{nn}
\end{bmatrix}
$$

Where $D_{ij} = \infty$ (stands for the nonexistent route), $i = 1, 2, \ldots, n$

(2) Relative Distance Matrix (RD):

Definition ($D_{k \text{row}} \min$) denotes the minimum value of $D$ in $k^{th}$ row. Then

$$RD_{ij} = D_{ij} - (D_{i \text{row}} \min)$$

(3) Relative Shortest Distance Matrix (RSD):

Definition ($RD_{i \text{col}} \min$) denotes the minimum value of RD in $k^{th}$ column. Then

$$RSD_{ij} = RD_{ij} - (RD_{j \text{col}} \min)$$

(4) Shortest Distance Limit (SDL):

SDL is the lower bound value of the shortest distance route from all possible routes. That is, the distances of any possible routes must be greater than or equal to SDL. Then we have

$$SDL = \sum_{k=1}^{n} [(D_{k \text{row}} \min) + (RSD_{k \text{col}} \min)]$$

(5) Critical Departure City (CDC):

The city satisfying the element value is zero in RSD. Then we have

$$RSD_{ij} = 0, i \neq j$$

In equ. (3) to (7), sub-label $i$, $j$, $k=1, 2, 3, \ldots, n$ The $n$ is the total number of passed through cities.

With the Hungarian Method, we found the assignment of the shortest distance had been reached if all the values of assigned elements in RSD were zero. This showed the Hungarian Method had the functionality of the shortest distance assignment. The Branch-and-Bound Method was used to determine the SDL for all possible routes. It helped to decide whether a route was a shortest route or not. The K-mean Clustering in Data Mining contributed by clustering together the element values in D at an early phase to avoid the enlargement of solution errors when there were two or more similar outliers. The Nearest Neighbor Method was used to find the approximate shortest distance and its route from the assigned CDP. The principle of Rule-Based Inference in Artificial Intelligence had the ability to determine a result from the antecedents.

3.3 The Approximate Shortest Distance Route Intelligent System for Traveling

By using the computing approach for finding the approximate shortest distance above, we employed object-oriented programming, constructing a highly practical and easy to use Approximate Shortest Distance Route Intelligent System for Traveling (ASDRST). The ASDRST only requires a personal computer and can find the approximate shortest distance route and its corresponding distance quickly and effectively.

3.4 Verification and Implementation of ASDRST with Practical Examples

To compare results from using the practical data in papers reviewed [1], we chose the Distance Matrix D with the same total city numbers $n=42$ in turn for implementation and verification.

Click the “Browse” button to import the Distance Matrix file (in csv file format) as shown Fig. 3. The file is generated by Microsoft Excel and contains the same data for 42 cities in paper [1]. Click the “Calculate” button. The comparison result is shown in Table 1.

![Fig. 3. The distance matrix of 42 cities](image)
Table 1. Comparison of Results

<table>
<thead>
<tr>
<th>Items</th>
<th>Results from our system</th>
<th>Results from paper [1]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approximately shortest distance</td>
<td>799</td>
<td>798</td>
</tr>
<tr>
<td>Execution Time</td>
<td>47 seconds</td>
<td>99.87%</td>
</tr>
</tbody>
</table>

Click the "Browse" button to import the Cost Matrix file (the data is one way ticket cost of taking train in Taiwan). The output result of solving for the approximate shortest cost route passing through 60 cities in Taiwan is listed in Fig. 4.

![Fig. 4. The result of solving of for 60 cities in Taiwan](image)

The approximate minimum cost of passing by train through 60 cities in Taiwan is displayed for dajia, chingshuei, shalu, changhua, yuanlin, ersheui, doulan, dounan, chiai, shinying, lunqian, shanhuia, tainan, gangshan, tzuoying, kaoshing, fengshan, jiochitun, pingtung, choujou, fangliau, dassu, taimalii, jrbien, taitung, luye, guanshan, chshang, fulii, dulgli, yuli, ruesuei, guangfu, wanrung, fenglinc, shualien, jrsjhi, jian, hualien, suao, suanenstation, dongsan, luodung, ilan, jiaoshui, fulung, keluing, badu, sungshan, taipei, wanhua, shulin, banchiau, taoyuan, jungli, hsinchu, junan, miaoli, fengyuan, taichung.

The approximate minimum cost is shown to be 1912, the approximate minimum cost limit is 1527, and the CPU time for a PC (Pentium 4-166MHz, 512MB RAM) is 1312 seconds (about 22 minutes).

4. Conclusions and Future Work

Based on the analysis above, this research establishes the following results:

1. The research proposes a method that integrates the Hungarian Method and the Branch-and-Bound Method for Assignment Problems, Nearest Neighbor in Data Mining and Rule Base Inference in Artificial Intelligence to find the approximate shortest distance route and the distance. It also uses object-oriented programming to construct a system that is highly practical and easy to use. It requires only a personal computer running Microsoft Excel and VB.Net. The ASDRST can find the approximate shortest distance route and the distance quickly and effectively compared with other systems, and its accuracy is more than 99.8% at a pass through city number of 42.

2. It takes about 22 minutes of computing time passing through 60 cities in Taiwan to find the approximate shortest distance route by train. The method is acceptable for practical use.

3. The maximum city number in a route is 255, meeting the actual needs of general tourists.

4. The method can also solve the route distance for the user-assigned route in user-defined visiting order. This provides the user with the opportunity to compare the route with the approximate shortest distance route and the distance to decide what kind of journey to take.

Future work planned in this study is the user will be able to click on and select city names on the map of Taiwan directly and solve for approximate shortest distance (or cost) and the corresponding route.

5. References


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