The Application of Floyd Algorithm for Returning Path Algorithm with Constraints of Time and Limit of Load

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Abstract. Under ideal condition, there are lots of Shortest Path Algorithms such as Dijkstra, Floyd, Johnson algorithms. However, putting these algorithms into use is not as we expected. The reasons cause the problem may be in the Returning Problem mentioned in the following paper. Shortest Path Algorithms only focus on the shortest path between the points, without paying attention to figure out the direct solution from the Starting Point to the Passing Points and finally to the Starting Point. A Shortest Path Algorithm applied in actual practice will be introduced in here, then another case will be introduced and analyzed to explain the following Algorithm: Under the Constraints of time and limit of Loading capacity, figure out the Shortest Path Algorithm through the Starting Point to the Passing Points and back to the Starting Point. At last , the algorithm is of feasibility and practicability.

Keywords: Shortest Path Algorithm, Returning Path, Single Source Point and Multi-sources Point, Time Window Constraints, Load Limit, Weighted Node

1. Introduction

There are many cases indicate that an effective algorithm to calculate the best route from the starting point, covering the nodal points and finally returning to the starting point under the restrictions on time and loading value is in great need. Here are some common cases in real life:

Case 1: Goods delivered by unmanned aerial vehicles (UAV). With the restrictions on battery energy and cargo weight, the normal flying time of a UVA to pick up goods and deliver the goods back to the starting point is about 30 minutes. Hence, an energy-saving route is needed.

Case 2: Self-driving tour to an unfamiliar city. In an unfamiliar city, the tourist will be found of a time-saving route to to more tourist attractions and come back to the hotel easier to have a rest and restart in better condition for the next day. So an easier plan and time-saving route is very practical.

Case 3: School buses pick up and send back students. The number of school buses is fixed . Thus, to make maximum of the school buses in a time and energy saving route is in need.

Since the need of shortest path algorithm is so important, the purpose is to figure out the algorithm that can be put into use with high efficient. The author applies the most commonly used shortest path algorithms into real practice, gets the shortest path matrix. With matrix, the most ideal rerouting path is chosen to put into the schematization to return when the time and loading value surpasses the designated value. The same method is applied to arrange the rest of the nodal points.

2. The choices on the Shortest Path Algorithms

The most famous and commonly accepted Shortest Path Algorithms are Dijkstra, Floyd, and Johnson Algorithms. A brief analysis is necessary to find out a better one. It is as followed:

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2.1 Dijkstra Shortest Path Algorithm is based on the path from the starting point to nodal point.

The time complex rate is O(n2) [1]. However, the returning path not only contains this path, but also other passing points and the distances among the these passing points. Hence, only applying the Dijkstra Shortest Path Algorithm is not enough to solve the complex real problems. Someone may think that if repeatedly apply the Dijkstra Shortest Path Algorithm to the passing points; then the shortest paths among the passing points will be acquired [2]. In real practice, this may cause the repeating calculation of the same nodal points which may make the time complex rate to O(n3) may lead to the instability of the passing points. Taking the UAV as an example, the passing point to fetch the goods may differ from the next time, and this will lead to the changes in the passing points. Thus, to get the shortest path, the computer has to spend a lot of time to calculate the path again.

2.2 Floyd Shortest Path Algorithm is based on the shortest path algorithm of multiple starting points whose time complex rate is O(n3) [3].

In spite of the relevant high time complex rate, this algorithm is easy to figure out the shortest path of all the nodal points, without recalculating when the passing points are changed[4]. What it needs to do is to find out the shortest path among the path matrix. Thus, the Floyd Shortest Path Algorithm is very practical, and it will be applied in the algorithm of this paper.

2.3 Johnson Shortest Path Algorithm is also based on multiple starting points.

The time complex rate of the sparse matrix path is O(VElgV). Theoretical, Johnson Shortest Path Algorithm is regarded better than the other two shortest path algorithms[5]. If we apply the Ford and Dijkstra Algorithms, Authorization means the traveling time and the loading value on the nodal points.In practice, most of the path graphs are not sparse matrix path[6] , let alone its algorithm which is using the re-authorization with proper influences on the time and loading program. Therefore, the Johnson Shortest Path Algorithm is not suitable for the calculation of this paper[7].

From all the analysis listed above, Floyd Shortest Path Algorithm is applied in this paper.

3. The Detour Algorithm

From the starting point, figure out the shortest path to cover the other passing points and finally get back to the starting points. To prove that this path is the shortest, a simple model diagram[8] (Fig.1) can show us. Since the path of the diagram has adopted the shortest path algorithm to filter the shortest path, the paths between the nodal points are the shortest[9]. S is Starting Point, Pi (i=1,2,3) are the nodal points , Lk (k=1,2,3,4,5) are the shortest weights of the nodal points. Three path routes:

A: Starts from S, cover Pi, then get back from the Pi(S↔P1, S↔P2, S↔P3);

B: Starts from S, cover all the Pi, then get back from the same path(S->P1->P2->P3->P2-P1->S);

C: Detour Algorithm. Starts from S, cover all the Pi, then gets back directly the LAST P(S->P1->P2->P3->S).

Detailed analysis can be shown as followed:

Route A: A=2*L1+2*L4+2*L5, Route B: B=2*L1+2*L2+2*L3, Route C: C=L1+L2+L3+L4 .

Now we need to prove that: C<A and C<B.

A-C=2*L1+2*L4+2*L5-(L1+L2+L3+L4) =L1+L4+2*L5-L2-L3, according to the Triangle Theorem, we can get: L4+L5>L3 and L1+L5>L2, so L1+L4+2*L5>L2+L3, and so A-C>0,the result is C<A.

B-C=2*L1+2*L2+2*L3-(L1+L2+L3+L4)=L1+L2+ L3-L4, suppose that L2=0, then, L1,L3,L4will form a triangle, according to the Triangle Theorem, L1+L3>L4,however in real life, L2>0, thus L1+L2+L3-L4>0,we can get B-C>0, so C<B.

From this simple diagram, Detour Algorithm is shorter than the other two Algorithms. In the following paper, we take the value of A-C or B-C as the Path Value of the Detour Algorithm, then PV[10](P1,P2) means that starts from S and bypasses P1,P2 and gets back to S.

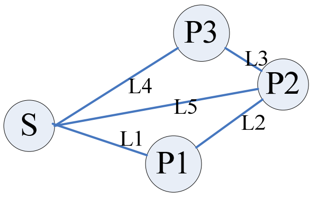

Fig.1 Simple model diagram

4.The Returning Path Algorithm

To make it easier to understand, we take the school bus picking up the students as example:

All together, 10 points to picking up the students, and the number of the students are shown in Fig. 2(network diagram) as the nodal points. There are two kinds of school buses, they are 20seats and 40 seats and share the same driving time--within 30 minutes. The Edge Weight in the diagram means the time (minute). We put the time as the value of the distances. Details are as followed:

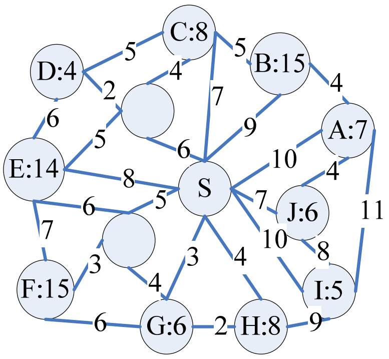

Fig.2 network diagram

	S	A	B	C	D	E	F	G	H	I
A	10	—								
B	9	4	—							
C	7	9	5	—						
D	8	14	10	5	—					
E	8	18	14	9	6	—				
F	8	18	17	15	13	7	—			
G	3	13	12	10	11	10	6	—		
H	4	14	13	11	12	12	8	2	—	
I	10	11	15	17	18	18	17	11	9	—
J	7	4	8	13	15	15	15	10	11	8

Fig.3 the shortest matrix

4.1 Figure out the shortest matrix

Floyd Shortest Path Algorithm is applied here to get the shortest matrix shown in Fig.3 to show the distance from S to the students picking up points.

4.2 Figure out the PV matrix.

According to the Detour Algorithm, the fist two lines of shortest matrix should be noticed firstly. As in Fig. 4, the Edge Weight from S to A is 10, to B is 9, while the Edge Weight from A to B is 4. Thus, the PV(A,B)=15. Fig.4 shows the detailed matrix transformation of the first two lines.

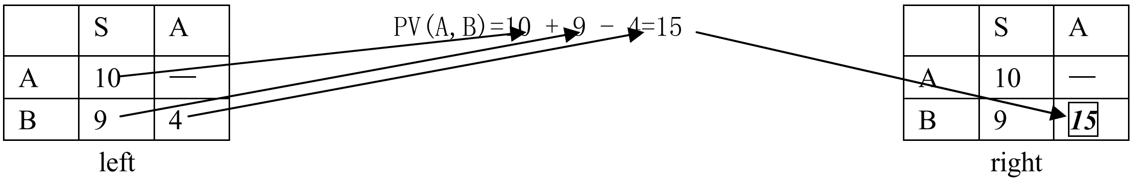

Fig.4 the matrix transition diagram

Employing the same method, the first three lines of the shortest matrix will be shown in Fig. 5.

The Edge Weight from S to A is 10, to C is 7; the Edge Weight from A to C is 9, thus the PV(A, C)=8.

Fig.5 shows the detailed matrix transformation of the first three lines.

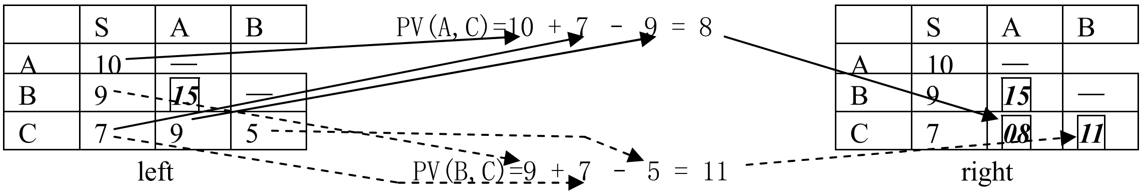

Fig.5 the 1-3 line of matrix transition diagram

We can deduce the rest from this method: add one more line, get the PV from this point to the other points, then replace the value of the shortest matrix. When it comes to the 10th line (replacing from line A to line J), the result will be shown in Fig.6 (PV matrix).

	S	A	B	C	D	E	F	G	H	I
A	10	—								
B	9	15	—							
C	7	8	11	—						
D	8	4	7	10	—					
E	8	0	3	6	10	—				
F	8	0	0	0	3	9	—			
G	3	0	0	0	0	1	5	—		
H	4	0	0	0	0	0	4	5	—	
I	10	9	4	0	0	0	1	2	5	—
J	7	13	8	1	0	0	0	0	0	9

Fig.6 the PV matrix

ID	path	PV	ID	Path	PV	ID	path	PV
1	A–B	15	9	A–C	8	17	B–I	4
2	A–J	13	10	B–J	8	18	F–H	4
3	B–C	11	11	B–D	7	19	B–E	3
4	C–D	10	12	C–E	6	20	D–F	3
5	D–E	10	13	F–G	5	21	G–I	2
6	A–I	9	14	G–H	5	22	C–J	1
7	E–F	9	15	H–I	5	23	E–G	1
8	I–J	9	16	A–D	4	24	F–I	1

Table.1 PV Value ranking table

From the Fig. 6, except for column S, if other value stands for the shortest path for the school bus covering the nodal points, then the Contribution Value raised. The school bus does not need to pass all the nodal points. There are two kinds of school buses, they are 20seats and 40 seats which share the same driving time--within 30 minutes. The following two situations:

A: the school bus is fully occupied, and it needs to take them back to school.

B: the driving time has reached 30minutes, and it needs go back to the school.

4.3 The choices for the path and the arrangement of the buses

The PV and the path information from Fig.6, arrange the PV in descending order and get Table 1.

If choose A-B, A-J, B-C as the paths, the contribution value of the efficiency is the utmost. If make a detour,,choose these paths first. If we choose C-D, the driving time will be over 30 minutes, thus, the bus need to drive back to the school. In Fig. 7(picking up students Route 1), the route for picking up the students. Starting from S (hides the other paths) , Route 1 is the chosen path and a 40-seat school bus is needed. The number of the students is 36 and the driving time is 27 minutes.

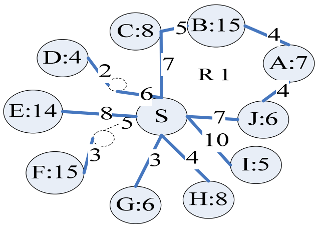

Fig.7 picking up students R 1

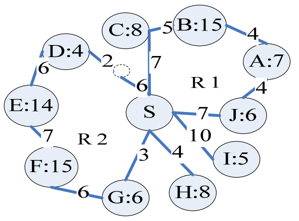

Fig.8 picking up students R 2

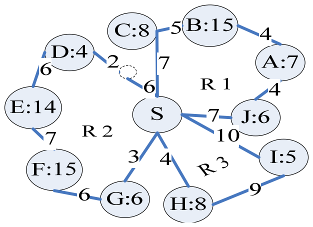

Fig.9 the best returning path

The details are as followed:

Since adopting Route 1, skip C-D and pay attention to D-E, A-I, and E-F. As Route 1 is not connected with other route, then A-I is excluded. Thus it can connect with D-E, E-F. Closely exam I-J,A-C,B-J,B-D,C-E in the Fig.7, they share the same situation as A-I. They can be excluded.

If we connect F-G, Route 2 is the chosen path. Why not connect G-H? Because the driving time for Route 2 (S-D-E-F-G) is 30 minutes, if we connect H, the time will be more than 30 minutes. In this situation, a 40-seat school bus drive within 30 minutes to pick up 39 students (Fig. 8).

Connect H-I, and form Route 3. A 20-seat school bus drive 23 minutes to pick up 13 students.

So far, the detour of the route has accomplished. Fig.9 is the best returning route and we need not to make reference to Table 1(PV Table). From Fig.9, we can get the conclusion that: the school needs two 40-seat and one 20-seat school buses. And the 40-seat school buses will take Route 1 and 2; while the 20-seat school bus will take Route 3. If the school begins the lessons at 8 o'clock, in ideal condition, the school bus can start out at 7:20, and get back at 7:50.

5. Summary

After testing in Baidu, Tencent and Goethe map, the result shows that: if without the demands as time limits, loading limits, returning path and more choose-able nodal points, Baidu Map has more advantages than Tencent map and Goethe map. Since Baidu Map can cover more view spots, but it can not fulfill the need of other demands. The first author of this paper has adopted this algorithm in the software system and got funds from the Guangdong Province Outstanding Young Teachers Training program Funded Project (Grant No. 2015S02 - Jianfeng Luo). And Special Funds for Demonstration Projects of Dongguan Polytechnic College (Grant No. ZXHQ2014d001 - Jianfeng Luo). The project ZXHQ2014d001 cooperates with the Dongguan Hu Yitong Freight Ltd and gets funds from this company. The software whose Copyright Registration Number is 2014SR146664 has been put into use of the company and received high evaluation. The authors sincerely hope that this paper will be beneficial. Please contact with QQ:251048547 for further cooperation.

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