DESIGN OF OPERATOR FOR SEARCHING TRAFFIC DEPENDENT SHORTEST PATH IN A ROAD NETWORK

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ABSTRACT:

Recently, Intelligent Transportation System(ITS) has been applied to satisfy increasing traffic demand every year and to solve many traffic problems. Especially, Advanced Traveller Information System(ATIS) is a transportation system to optimize the trip of each other vehicle. It is important to provide the driver with quick and comfortable path from source to destination. However, it is difficult to provide a shortest path in a road network with dynamic cost. Because the existing research has a static cost. Therefore, in this paper we propose an operator for searching traffic dependent shortest path. The proposed operator finds the shortest path from source to destination using a current time cost and a difference cost of past time cost. Such a method can be applied to the road status with time. Also, we can expect a predicted arrival time as well as the shortest path from source to destination. It can be applied to efficiently application service as ITS and have the advantages of using the road efficiently, reducing the distribution cost, preparing an emergency quickly, reducing the trip time, and reducing an environmental pollution owing to the saving the fuel.

KEY WORDS: Shortest Path Searching Operator, Shortest Path, Road Network, Traffic Congestion, Dijkstra

1. INTRODUCTION

The people using the vehicle are faced with a problem determined which path is optimal or best to travel from source to destination. The other problem is to consider a total time cost with traffic congestion cost. However, if we can not solve such a problem, we must decide a trip path based on restricted information with time. So, the mobile service for guidance of the road, vehicle navigation system, and the web service are developing. However, it only provides the information of restricted realm.

We need novel transportation system with combining intelligent technology of the electronic, the information, the communication, and the control engineering considering efficiency and stability of transportation system for solving these problems.

Advanced Traveller Information System(ATIS) is the transportation system that optimizes a trip of each other vehicle. It is important to provide the driver with quick and comfortable path from source to destination. However, it is difficult to find the shortest path considering the traffic congestion, waiting the traffic signal, traffic acid-ent, and construction area in a road network and to comp-ute a time cost with static cost as distance.

Therefore, in this paper, we propose the operator computing the shortest path and expecting a trip time to destination that consider dynamic cost as well as static cost as distance. The proposed operator compute the total time cost of the section with a current time cost of the section and a difference cost of the past time cost in a road network. Also, such an operator has the advantage of using the road efficiently, reducing the distribution cost, preparing an emergency quickly, reducing the trip time, and reducing an environmental pollution owing to the fuel saving.

The rest of the paper is organized as follows. Section 2 overviews related work. Section 3 illustrates the method generating time cost of the section in a road network. Sec-tion 4 presents our operator for searching traffic depen-dent the shortest path, and Section 5 concludes the paper with a discussion.

2. RELATED WORK

2.1 Traffic congestion cost in a road network

Generally, the traffic congestion is defined as the delay and the waiting of the vehicle occurring by various causes such as an overflowing traffic demand, a problem of the traffic structure, and a traffic accident in a road network. That is, when it is compared the traffic time consumed in a normal status of the traffic flow with the traffic time consumed in delay status of the traffic flow, it is defined as traffic time or increment of the delay.

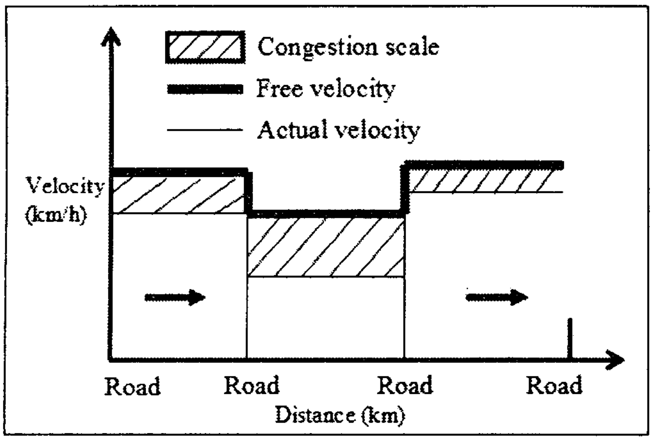

Figure 1. Definition of the traffic congestion

Figure 1 shows the definition of the traffic congestion. It defines the scale of the traffic congestion that the velocity of vehicle differs from traffic velocity as free velocity in specific section of the road [1]. When the driver usually consumes the traffic time more than the constant criterion, they recognize to occur the traffic congestion and the criterion may be changed by geographical feature, type of road facilities, and the time.

According to the congestion management system rule of USA, the traffic congestion is defined as status which can not manage any longer by the transportation system due to the vehicle intervention and the level of the transportation system management is explained to change by type of the transportation facilities, geographical position, and the time [1]. That is, when the traffic time usually increases more than constant criterion, the driver recognize that occur the traffic congestion. When the traffic velocity is less 60~70 % than free flow velocity, the driver recognize the traffic congestion [1].

Table 1. Criterion of the traffic congestion

Attribute / Road	velocity (km/h)	traffic rate (min/km)
expressway	below 60	above 1.0
highway	below 40	above 1.5
avenue	below 30	above 2.0

The traffic congestion differs from the type of the road. Table 1 shows when it is less than 60km/h in the expressway, it is defined as the traffic congestion and it is set up about 40km/h in the highway and 30km/h in the avenue [1].

2.2 Operator and system searching the shortest path

Güting proposed operators for computing the distance and the time dependent shortest path as following [2]. shortest_path returns the shortest path from u to v. u is a current node and v is a next node. Trip allows one to construct a time-dependent shortest path. Trip computes a description of a trip that moves from u to v at starting instant w. It is assumed that the vehicle traverses each route interval at the admissible speed of the respective time in the computation. Therefore, Shortest_path is the operator for computing a shortest path with network distance cost. Trip considers the time by admissible speed and route interval. The result of Trip is the description of a trip.

Two operators can not support the dynamic cost in a road network and only returned the description of a trip that is difficult to check in detail. Algorithms related such the operator is illustrated in [3]. It illustrated the system searching time-dependent shortest path in [3]. The time called in [3] is to consider a speed and the traffic. This system provides the shortest path by analyzing speed and traffic without shortest path algorithm in a road network. However, the system causes the problem of tradeoff between a time and a distance and of the winners group and the losers group. In [3], vehicles are divided into two groups. One is those who had benefit of a time (Winners) and the other is those who had to pay extra time on routes (Losers).

3. COST GENERATION METHOD OF THE SECTION IN A ROAD NETWORK

The cost of the section is the trip time in a road network. All vehicles obtain from the time, the position, and the velocity through GPS(Global Positioning System) and then transfer them to server. The server stores to compute from received data with time. It provides the vehicle with the shortest path service. In a previous work, the shortest path algorithm with time cost of the section can not apply a dynamic trip time. Time cost of the section explains with table 2 and figure 2 in graph.

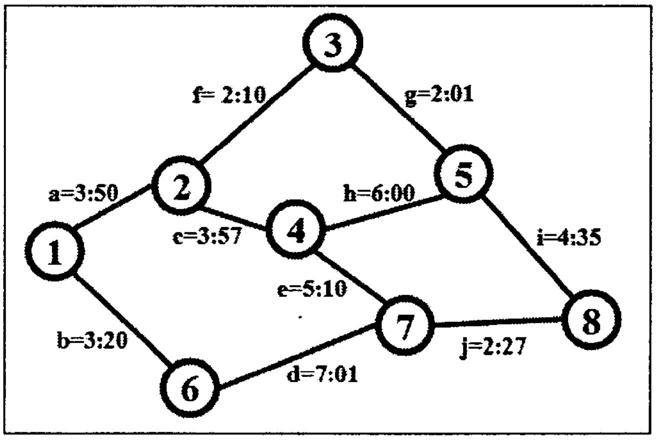

Figure 2. Graph with 8 nodes

For example, let's suppose that any vehicle travels from node 1 to node 3. In figure 2, it takes a 3:50 from node 1 to node 2 at 6:00 PM 13 October 2005 and takes 2:10 from node 2 to node 3. Therefore, It takes 6:00 from node 1 to node 3 through node 2. However, time cost of the section f may be changed for 3:50 arriving from node 1 to node 2. Searching a shortest path is difficult in a road network. Therefore, we can compute prediction trip time to sum current time cost obtained from node located currently and difference cost of the same section in the past from next section.

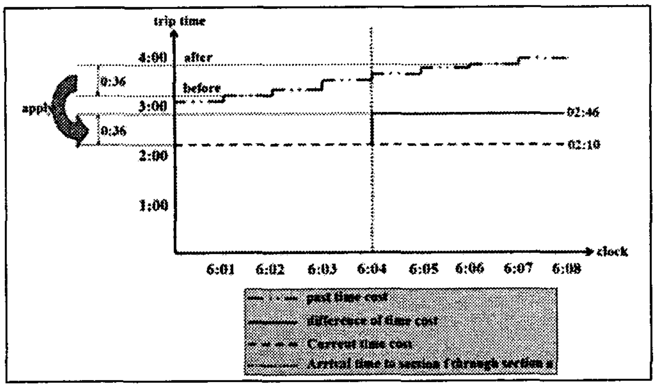

Figure 3. Time cost generation of the section f

Table 2 shows to stores current trip time cost(t) of all section per 1 minute. Current trip time cost(t) computes with the distance of the section and average velocity of vehicles in that section. Before entering the section f, time cost is 3:09 as shown in the figure 3. The time summing time cost from source to section f and current time cost of the section f is 3:46. Trip time difference of the section f(dif) is 0:36 by (2). Such as figure 3, it sums current time cost (t) of the section f as 2:10 and past trip time difference of the section f as 0:36. Such as this method, total time cost(T) of the section f is 2:46. After 6:04, we can check the changed cost in the figure 3.

Table 2. Trip time of each other section with time

section \ time	06:00	06:01	06:02	06:03	06:04	06:05	06:06	06:07	06:08	06:09	06:10
a	03:01	03:04	03:00	03:20	03:15	03:02	03:10	03:30	03:46	04:05	04:09
b	03:08	03:15	03:19	03:19	03:18	03:26	03:29	03:30	03:27	03:23	03:29
c	04:45	04:57	04:59	04:47	04:53	04:37	04:48	04:23	04:21	04:14	04:10
d	07:50	07:45	07:43	07:41	07:39	07:37	07:35	07:33	07:31	07:29	07:27
e	05:19	05:21	05:22	05:25	05:27	05:30	05:28	05:25	05:23	05:21	05:20
f	03:01	03:05	03:09	03:14	03:29	03:41	03:44	03:46	03:49	03:52	03:53
g	04:29	04:27	04:26	04:26	04:26	04:30	04:31	04:32	04:24	04:20	04:16
h	05:00	05:03	05:06	05:09	05:11	05:16	05:19	05:30	05:36	05:43	05:50
i	03:50	03:54	03:52	03:51	03:50	03:48	03:47	03:46	03:45	03:44	03:41
j	02:27	02:25	02:27	02:11	02:09	02:10	01:59	01:58	01:54	01:51	01:45

Formula (1) computes current time cost(t) to divide the distance of the section(d) by average velocity of vehicles in a road network. Table 2 is made from formula (1). Therefore, the result (t) of formula (1) current time cost of the section and the result (dif) of formula (2) is time cost difference with time in past information. We can expect total time cost of the section (T) by summing formula (1) and (2).

$$t = d/v \qquad (1)$$

$$dif = ac - bc \qquad (2)$$

$$T = t + dif \qquad (3)$$

Where

t = current trip time cost
d= distance of the section
v= average velocity of the vehicle
dif= difference between after costs and before costs among the past information
bc= consumed time from node u to node v
ac= current cost of node v + bc
T = total time cost of the section

Therefore, the vehicle consumes 3:50 from the node 1 to node 2 and we expect 2:46 increasing 0:36 from node 2 to node 3. If they are summed up, prediction trip time is 6:36 from node 1 to node 3.

4. PROPOSED OPERATOR

4.1 Scenario for searching traffic dependent the path

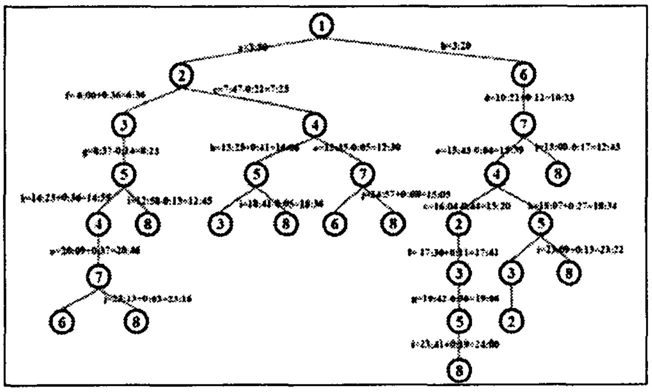

Figure 4. Tree searching the shortest path

Figure 4 shows a process that search the path using the dijkstra algorithm and cost generation method of the section from node 1 to node 8 in the graph of the figure 2. Now, let's assume that the vehicle locate in node 1 and the server computes current trip time cost with distance and velocity of the section located the vehicle for tripping on time dependent shortest path to destination as node 8. We use dijkstra algorithm for searching the shortest path. The cost from section a to section j is current trip time cost(t). If vehicle in node 1 searches the next node, it can search node 2 and node 6. For it selects time cost smaller than, it selects node 6. Total time cost of the section (T) is 3:20 from node 1 to node 6. If it searches next nodes from node 6, it can only search node 7. Total time cost of the section to node 7 is 10:33. This figure shows the tree that presents repeatedly the process of computing total time cost of the section, selecting nodes, and searching the path. Also, it shows that the path moving from node 1 to node 8 is 7 paths. The path that consumes the smallest cost as 12:43 is the shortest path. The trip order is the node 1, the node 6, the node 7, and the node 8.

4.2 Algorithms of the proposed operator

```
Algorithm init(Graph g, Node s)
 begin
  for each vertex v in vertices(g) do
   g.t[v]=infinity;
   g.S[v]=unreached;
   g.pi[v]=null;
  end for
  g.t[s]=0;
  g.S(s)= permanently labeled;
 end
```

Figure 5. Graph initialization function

Figure 5 shows the graph initialization function. All nodes in the graph g present infinity and node status is 'unreached' and parent node is nil. This function is used in the shortest path search function

```
Algorithm search(Node u, Node v, double w[][])
  begin
   if t[v] > t[u]+w[u,v] then
    t[v]=t[u]+w[u,v];
    t[v]=t[v]+dif[v]
    S[v]=temporarily labeled;
    pi[v]=u;
   end if
   S[u]=permanently labeled;
  end
```

Figure 6. Node search function

Figure 6 illustrates the function that computes a time cost of nodes. If existing time cost is more than new time cost when the vehicle trip to node v, it stores new time cost instead of existing time cost. Also, it sums stored cost and past time difference as proposed method in the section 3. Node status is 'temporarily labeled' and parent node is u. status of the node u is 'permanently'. *dif*[v] is the computed time difference cost by the section 3 time cost generation method of the section.

```
Algorithm shortest_path(Graph g, Node s)
Output the path with the cheapest time to destination
 begin
  init(Graph g, Node s)
  P={0};
  Q=Vertices(g)
  while not empty(Q) do
   u=ExtractCheapest(Q);
   AddNode(P,u); /* Add u to P */
   for each vertex v in Adjacent(u) do
    search(Node u, Node v, double w[][])
   end for
  end while
 end
```

Figure 7. The shortest path search function

Figure 7 explains the operator searching traffic dependent the shortest path using initialization function and node search function. This function adds to P selecting node with the smallest time cost of the stored nodes. Also, it searches node u and neighbour nodes and computes the time cost. It executes to repeat until the stored node is not in the Q such a operation.

5. CONCLUSION

In this paper, we computed total time cost of the section by summing current time cost of the section and past time difference of section in a road network. Based on computed the time cost, we proposed the operator that compute traffic dependent shortest path. Currently, we are implementing the system using proposed operator.

Acknowledgement

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