

TRAVEL TIME ESTIMATION BASED ON INCOMPLETE PROBE CAR INFORMATION

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ABSTRACT

Different technologies and methods can be used for the generation of real-time traffic information based on Floating Car Data (FCD) technology. In many cases the probe car information consist a more or less time gap between the available position data of the vehicle. However, if the distance between the available positions is too large then the route between these positions is not unique and has to be estimated.

In this paper we propose a method of a “smart OD router” who improves spatial precision and travel time estimation significantly for incomplete probe car information.

INTRODUCTION

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Real-time traffic information based on Floating Car Data (FCD) technology can be generated by different technologies and methods [1, 2]. During the past decade an increasing number of commercial and private vehicles have been equipped with Global Positioning System (GPS) devices. Many research projects have been implemented using these vehicles as probe-cars, to determine traffic status and to provide traffic information. This concept is called Floating Car Data (FCD) supplying valuable basis data on actual traffic conditions. Good results for incident detection and travel time estimation require a vehicle tracking interval of 15-60 seconds in urban areas [3].

However, in many cases probe car information is incomplete because the probe car information consist a more or less time gap between the available position data of the vehicle (e.g. the communication links between traffic centre and probe cars lack bandwidth). If the distance between the available positions is too large then the route between these positions is not unique and has to be estimated. Frequently only location and time stamp of trip origin and destination (i.e. O-D matrix) are available.

Furthermore, calculating mean speed for a longer section could lead to imprecise speed information on the individual road elements. This is particularly the case when the estimated path contains different types of streets, with both low and high free (or normal) speeds. In this case the speed of the street with low free speed can be overestimated and at the same time, the speed on a highway can be underestimated by the average speed.

Consequently, it is important to use a method to correctly estimate the whole route and to estimate travel times on smaller sections in case of incomplete probe car information. The method of estimation is the subject of this paper: it explains the application of a “smart OD router” and shows examples that this method improves spatial precision and travel time estimation significantly.

METHOD

The road network is represented by a digital map, a graph consisting of nodes and edges. The positions of the probe cars are assigned to an edge of the graph by a map-matching algorithm [4]. The graph can have several attributes assigned to its edges. If the route of the probe car between two subsequent position data is not unique then a shortest path algorithm based on the length attribute of an edge can be used (e.g. that of Dijkstra [5]). Several other edge attributes can be also used for the route estimation, like e.g. type of street (e.g. main or minor street) and historical travel frequency. Furthermore, the curves can be also represented; the left curve could have a higher resistance, for example. In transport modelling literature, using certain labels assigned to roads for estimation of route choice is referred to as labelling approach. Several possible labels exist [6]:

- (1) Travel time
- (2) Uncertainty or variance of travel time
- (3) Congestion level
- (4) Speed limits (or free / normal speeds)
- (5) Number of stop signs or stop lights
- (6) Number of Turns on route
- (7) Protected lefts at lights
- (8) Street type (e.g. street width, number of lanes)
- (9) Road condition

As mentioned above, shortest path is generally used to estimate the route between origin and destination. In the following, we propose a more advanced method that performs better than the simple shortest path method, according to our simulations. The first three improvements can be done on the basis of a digital map, while the fourth requires the existence of historical trip data.

The proposed method consists of the following 4 improvements:

(1) Filtering longer trips

The length of the OD route is evaluated: if it is above a certain threshold, then the trip is filtered out and not considered at all because the quality of estimation is not sufficient. The choice of this threshold is a compromise between quality of route estimation and quantity of available data. By increasing the length threshold, the quality decreases. On the other hand, by decreasing the length threshold, the amount of estimated routes decreases (see Figures 2 and 3).

(2) Preferring main streets

Main streets get less while small streets get higher resistance. This favours main streets, which corresponds to driver behaviour. This is achieved by dividing the length of the road by its free speed (v_{85}).

(3) Resisting curves

A resistance value is assigned to a curve in respect to its type (right, left and curve bending).

(4) Assigning dynamic meta-lengths

It is assumed that the actual routed vehicle prefers those road segments that are preferred in general. This is achieved by assigning higher resistance to less frequent used roads by the following method:

- Let A denote the average number of trips on a road over the whole network and t_e the number of trips on road e .
- Let the meta-length factor μ_e calculated as follows (see Figure 1):

$$\mu_e = \frac{1}{\frac{t_e}{A} + 1} + 1$$

- Road resistance is multiplied by μ_e .

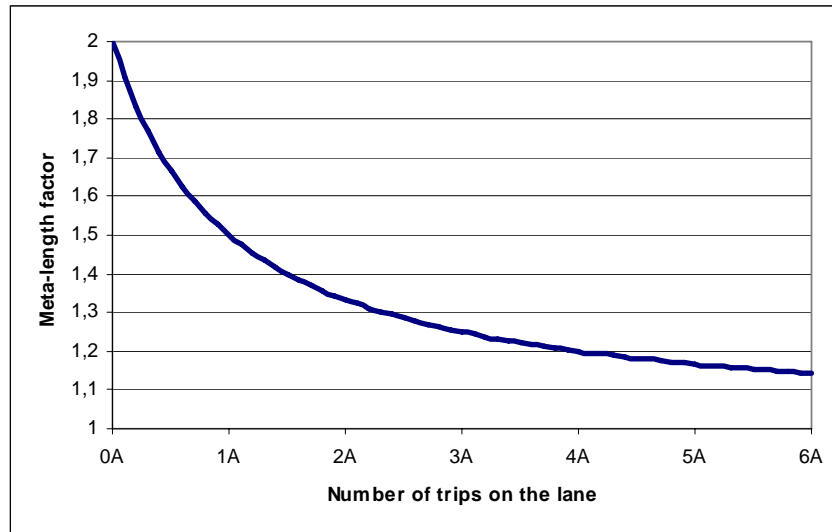


Figure 1: Function for calculation of dynamic meta-lengths

QUALITY PARAMETERS

The quality of the used routing algorithm can be measured if a reference route is available for the estimated route. We assume the reference path is correct because it is measured by GPS tracking. The following quality criteria are defined:

(1) Route overlap (or conformity)

Route overlap denotes the ratio of the length of estimated route that overlaps with the GPS reference route:

$$OVERLAP_{OD} = \frac{\sum_{\{e:e \in R_{ref} \wedge e \in R_{est}\}} l_e}{\sum_{\{e:e \in R_{est}\}} l_e}$$

Where l_e denotes the length of road e ; $e \in R_{ref}$ and $e \in R_{est}$ means that road e is used by the reference and estimated route, respectively.

(2) Spatial deviation

a) Average of route deviations: \bar{D}

The spatial deviation of the estimated route and the reference route is measured at every node of the measured route and the average of spatial deviation is calculated.

b) Standard Deviation of route deviations:

$$\sqrt{\frac{\sum_{i=1..n} (\bar{D} - D_i)^2}{n-1}}$$

(n is the number of routes, \bar{D} is the average of route deviations, and D_i the deviation of the i^{th} route)

NUMERICAL RESULTS

First, the quality of the shortest path OD router is evaluated based on taxi reference routes in Vienna from the FLEET [3] project. The probe cars deliver exact GPS position information in a time interval of 15 seconds. The performance of the algorithms is illustrated analysing 3600 taxi trips on two days (Sunday and Monday) in June 2005.

Table 1 presents the results how the proposed methods improve the quality of the routing: preferring main streets (v85), resisting curves, assigning dynamic meta-length, applying length-filter. Seven configurations have been considered. Using a shortest path routing algorithm (configuration 1) based on the origin and the destination of a taxi trip the route overlap is about 52% and the average route deviation is about 294 meters.

Applying the first 3 improvements (configuration 5), the average overlap (Av.Overlap) increases to 60,49%. By setting the length filter to 2000 metres (see Table 1, configuration 7), the overlap increases to almost 80% percent; however, the sample rate decreases to 10.5% since most routes are filtered out in this case. The average (Av. Dev) and the variance (Var. Dev.) spatial deviation also decrease to a fraction compared to the original router.

Configuration	1	2	3	4	5	6	7
V85	No	Yes	No	No	Yes	Yes	Yes
Curves	No	No	Yes	No	Yes	Yes	Yes
Meta-Length	No	No	No	Yes	Yes	Yes	Yes
Length-filter	No	No	No	No	No	4000m	2000m
Av.Overlap	52.27%	59.45%	54.29%	57.13%	60.49%	66.45%	79.53%
Av. Dev.	294.20	238.84	286.66	298.02	234.57	40.80	16.66
Var. Dev.	254.08	234.86	250.80	258.26	233.19	45.28	20.36
Sample rate	100.0%	100.0%	100.0%	100.0%	100.0%	31.0%	10.5%

Table 1: Routing quality and quantity with normal OD router versus smart OD router, applying different the improvement methods: v85, curves, meta-length, length-filter

Figure 2 shows the cumulative distribution of the distance between O and D. This analysis has been carried out on the same set of trips as the router evaluation on Table 1. According to this graph, the filter threshold has been set to 4000 meters, in which case about 70% of all taxi trips are considered.

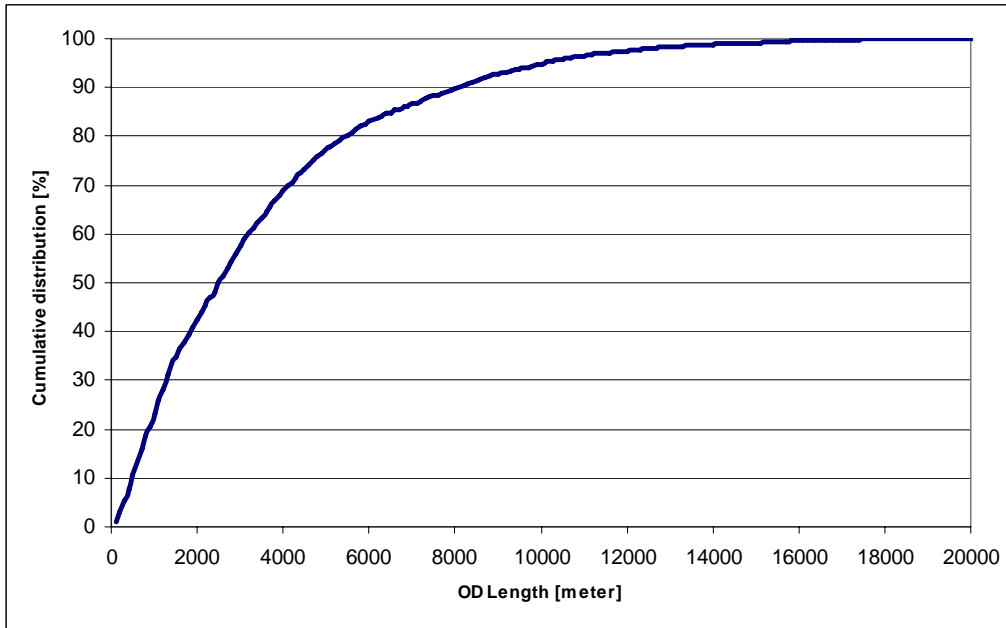


Figure 2: Cumulative distribution of route lengths for length filter optimisation

Figure 3 illustrates the benefits of the Smart OD router compared to the shortest path router. The improvement is 5% at 4000 meter and it is more significant if the length filter is set to a higher value (9%).

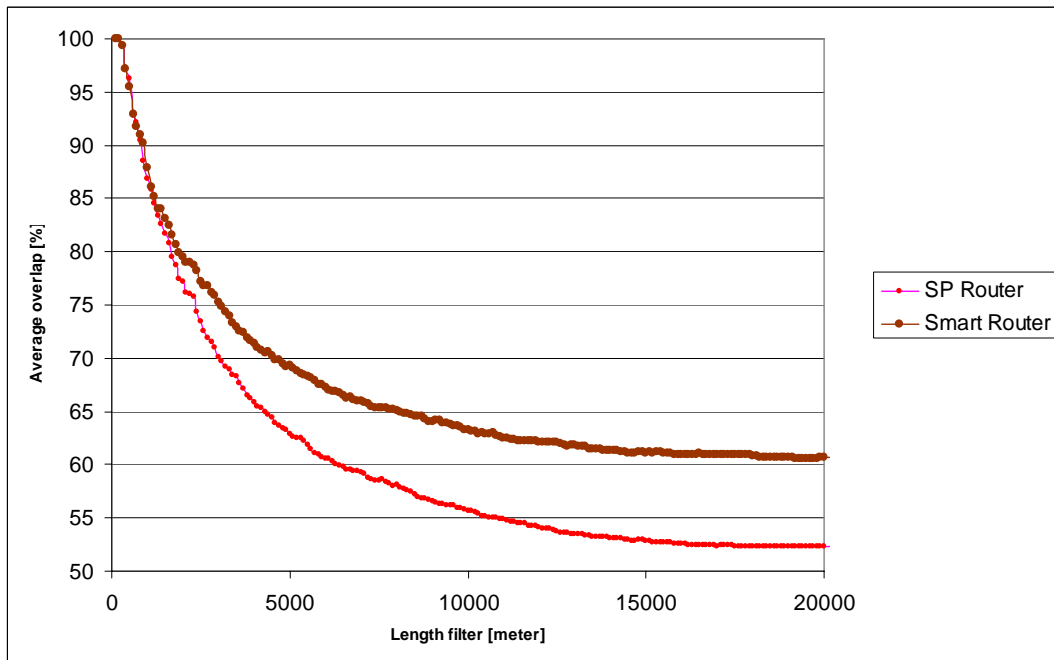


Figure 3: Average route overlap in function of the length filter for the shortest path (SP) and the smart router

SPEED ESTIMATION

An additional question is how to assign travel times of a longer trip having an average travel time to individual roads. As mentioned above, taking the mean speed for a longer section could lead to imprecise speed information on the individual road elements.

This is particularly the case when the estimated path contains different types of streets, with both low and high free (or normal) speeds. In this case the speed of the street with low free speed can be overestimated and at the same time, the speed on a highway can be underestimated by the average speed. Consequently, we have worked out a method that estimates the speed based on the deviation from the free speed (v85).

As proven in [5], the following formula can be used for speed estimation on road element e .

$$v_e = \frac{\bar{v}_p}{V_p} V_e$$

(v_e denotes the speed estimation on road element e , \bar{v}_p denotes the average speed on the path between the two subsequent messages and \bar{V}_p the historical average speed for the same path, and V_e denotes the historical travel time on road element e .)

This formula can be used for distributing a single speed value among more road elements. In [5] we have shown that it yields correct speed values, i.e., calculating their harmonic mean corresponds to the harmonic mean of the historical speeds.

CONCLUSION

In this paper the following results have been presented:

- (1) The necessity of improving route estimation between two position data (O-D) in case of incomplete probe car information has been defined.
- (2) 3 quality parameters to measure quality of the estimated path have been defined (if a reference path is available).
- (3) An improved routing algorithm has been proposed, which estimates driver behaviour better than the often used shortest path algorithm adapting itself to the behaviour of the reference trips.
- (4) This smart OD router ensures an improvement of routing quality: route overlap is increased to about 80% instead of 52%, while route deviation is reduced to about 17 meters.

More meta-length functions have been analysed (Figure 1). These will be presented in the final paper.

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