Study on Positioning and Mileage Error in Car-hailing Service based on the GNSS Traces

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***Abstract* – In recent years, car-hailing service has been rapidly developed in China, especially in the first tier cities such as Beijing, Shanghai and Guangzhou.Thecharge of car-hailing service is based on the service mileage.Therefore, it isimportant for the car-hailing service platform to calculate the service mileage accurately. In a given period of time, the service mileage equals to the summary of distance between adjacent positioning coordinates.In this paper, a research is made to study the relationship between the positioning error of adjacent positioning coordinateand the error of corresponding mileage. Vehicle experiment is carried out in five kinds of typical road conditions, which contains "elevated road above","elevated road below","tunnel", "shade" and "open-air". The results show that the difference between the positioning error of adjacent point has great influence on the cooresponding mileage error in the same period.**

Keywords* –*car-hailing service, positioning error, mileage error, road condition

I. INTRODUCTION

Taking taxi improves the convenience of people in their daily life, especially in the first tier cities such as Beijing, Shanghai and Guangzhou. However, due to the rapid growth of urban population, it is difficult for taxi companies to meet the growing requirementsofcar-hailing. In recent years, car-hailing service based on the internet has been rapidly developped in China. The corresponding research has been carried out. In the field of service efficiency, a prediction algorithm is proposed to increase the efficiencyof car-hailing resource utilization and reduce the reduce traffic jam time [1]. In [2] a multi-carpooling model is proposedin a distributed parallel computing environment, which can decreasethe waiting time and deadhead kilometres, as well as improve the passenger load. In the field of service quality, an optimization model based on both taxi-driver and passengers' preference is designed to maximum the degree of satisfaction and minimum the consumption of money [3].In [4] a dynamic pricing method is proposed to balance the service and thecost among different passengers who shared a certain route in their personal trip.In the field of identity authentication, anonymous mutual authentication protocol is designed to protect the private information of the drivers and the passengers [5].

In the field of mileage accuracy, the related research is still at the primary stage. Similar with the taxi service, the charge of car-hailing service is based on the service mileage and the time spent during the service. As service time is calculate based on the GPS time, which is accurate enough for the settlement, it is important for car-hailing service platform to calculate the service mileage accurately.Considered that, the service mileage equals to the summary of distance between adjacent positioning coordinates. The influence of positioning error on the mileage error in Car-hailing Service is studied in this paper.

II. POSITIONING ERRORAND MILEAGEERROR

The car-hailing service platform relies on the GNSS technology to obtain the real-time position information and based on which calculating the real-time service mileage. The calculation of the real-time service mileage generally includes the following steps:

(1) Collecting the GNSS positioning information at fixed time intervals, which is represented by the longitude, latitude, altitude and marked by thesampling timestamp;

(2) Converting the position information in geodetic coordinate system presented by "L,L,A" to ECEF coordinate system presented by "X,Y,Z";

(3) Using the techniques such as filtering and map matching to determine whether there is any abnormal point. If abnormal points existed, it will beeliminated.

(4) Calculating the distance between the adjacent position points based on the above position information;

(5) Summing the distance mentioned above to obtain the service mileage.

It is clear that the position information and the abnormal pointeliminating technologies in step (1) and (3) have an important effect on real-time mileage error. Therefore, in this section,the calculation method of position and mileage error will be summarized.

As shown in Fig.1,P_{n-1}, P_n and $P_{n+1}$is the real positioning coordinates atT_{n-1}, T_n and T_{n+1}.Q_{n-1}, Q_n and $Q_{n+1}$is the positioning coordinates provided by the GNSS receiver under test. In terms of positioning errors, the distance between P_{n-1} and Q_{n-1} is the positioning error of the receiver at the timeT_{n-1}.Similarly, we can get the positioning error of the receiver at the timeT_n and T_{n+1}. Positioning error can be divided into horizontal and vertical component, and the horizontal component can still be divided into east error, north error,Therefore, the relationship between the positioning error and the east, north and upper error component is shown in (1) and (2).

$$\Delta \mathrm{Horizontal}_n = \sqrt{\Delta E_n{}^2 + \Delta N_n{}^2} \tag{1}$$

$$\Delta \mathrm{Vertical}_n = |\Delta U_n| \tag{2}$$

where
$\Delta \mathrm{Horizontal}_n$: horizontal error component at T_{n-1}
$\Delta \mathrm{Vertical}_n$: vertical error component at T_{n-1}
ΔE_n: east error component at T_{n-1}
ΔN_n: north error component at T_{n-1}
ΔU_n: upper error component at T_{n-1}

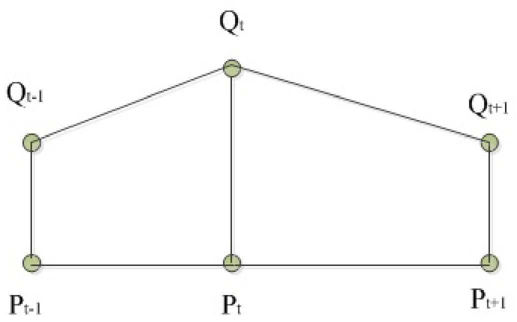


Fig. 1. Positioning coordinatesand mileage

In terms of mileage errors, the distance between P_{n-1} and P_n is the actual mileage value in the T_{n-1} ~ T_n period, denoted as $L_p(t-1)$. Similarly, we can get the mileage value $L_p(t)$ and $L_p(t+1)$. The distance between Q_{n-1} and Q_n is the mileage value provided by the receiver, denoted as $L_Q(t-1)$. Similarly, we can get the mileage measurement value $L_Q(t)$ and $L_Q(t+1)$. The mileage error in the period of T_{n-1} ~ T_n and T_n ~ T_{n+1} is shown in (3) and (4).

$$\Delta L(t-1) = \left|L_Q(t-1) - L_P(t-1)\right| \tag{3}$$

$$\Delta L(t) = \left|L_Q(t) - L_P(t)\right| \tag{4}$$

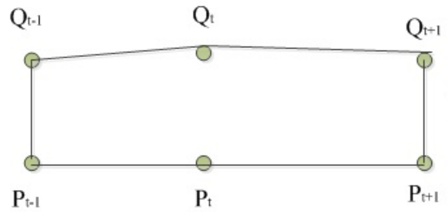
There may be three relationships between positioning error and mileage error:

(1) The greater the difference between the positioning error at time T_{n-1} and time T_n, the greater the mileage error in T_{n-1} ~T_n period;
(2) As shown in Fig. 2 (a), if the difference among the positioning error at time T_{n-1}, T_n and T_{n+1} is small and the two trajectories connecting Q_{n-1}, Q_n ,Q_{n+1} and P_{n-1}, P_n ,P_{n+1}do not intersect, the mileage error is small;
(3) As shown in Fig. 2 (b), if the difference among the positioning error at time T_{n-1}, T_n and T_{n+1} is small and the two trajectories connecting Q_{n-1}, Q_n ,Q_{n+1} and P_{n-1}, P_n ,P_{n+1}intersect, the mileage error may be large.

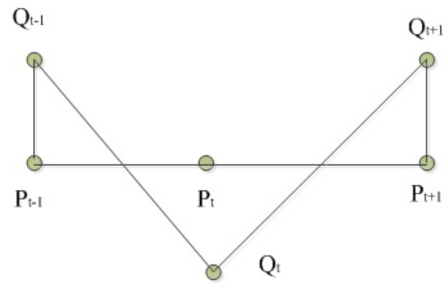
In order to verify the influence of the above statements in the actual environment, analysis will be made inthe actual outdoor environment.

III. EXPERIMENT AND DISCUSSIONS

In order to analyze the relationship between positioning error and mileage error, test environment and platformwill be introduced in the subsection A.Experiment design is described in the subsection B. Data analysis is summarized in the subsection C.



(a)



(b)

Fig. 2. relationships between positioning and mileageerror:

A. Test Environment and Platform

Test is carried out in the following road conditions: elevated road above, elevated road below, tunnel, shade and open-air. In the shade condition, road is screened by leaves. In the open-air condition, buildings on either sides of the road is not more than seven layers. The vehicle used in the test is equipped with inertial integrated GNSS receiver and UPS. A laptop is selected as the data recording device and the data format conforms to

IEC61162 protocol. After the experiment, the positioning information provided by the integrated GNSS receiver is used as the standard values to calculate the positioningerror and mileage error.

A NovAtelProPak6 inertial integrated GNSS receiver is selected, which contains base station, rover and UIMU-LCI. The receiver supports GPS, BDS, GLONASS, SBAS, QZSS and Galileo and other satellite positioning system. The base station is mounted on the reference point measured by the National Administration of Surveying, Mapping and Geoinformation. The maximum allowable error is less than ±5mm.

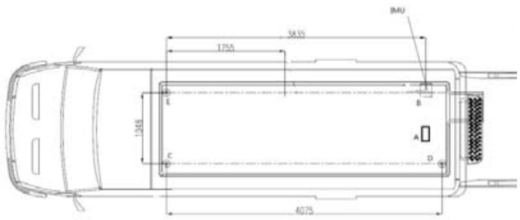


Fig.3 Size of the vehicle

Fig.4 Appearance of the vehicle

As shown in Fig.3, The size of the vehicle used in the experiment is about 1m × 4m and the configuration is shown in Table1.

In addition, the vehicle is equipped with UPS to ensure the need of 8h continuous testing.

Table 1. Configuration of vehicle

Location	Equipment
A	Rover and Transceiver
B	IMU
C	1st Antenna of rover
D	2st Antenna of rover
E	Antenna of receiver under test

B. Experiment Design

The experiment is carried out in Pudong New District, Shanghai, China.The road conditions and route planning is shown in table 2.

Table 2. Road Conditions and Route Planning

NO.	Condition	Route planning	Mileage
1	elevated road above	Middle Ring (Middle GaokeRoad~MiddleYanggao Road)	≈8km
2	elevated road below	Middle Ring (Middle YanggaoRoad~MiddleGaoke Road)	≈8.5km
3	tunnel	Middle Ring+Jungong Tunnel	≈12.5km
4	shade	Mingyue Road	≈5.0km
5	openair	Zhangheng Road	≈8km

During the test, the average speed of the vehicle is not less than 25km/h, and the average speed of the vehicle above the elevated road is about 60km/h. The GNSS information is collected using the laptop through RS232 communication interface. The GNSS information includes UTC, longitude, latitude, altitude, number of satellites used for positioning, velocity, course and DOP value.

C. Data Analysis

In this subsection, the way to correct the antenna offset between the receiver under test and the reference rover is to be introduced firstly, followed by which isthemethodamendingthe abnormal positioning point. Finally, the relationship between positioning error and mileage error will be carried out in detail.

Firstly, consider that the antenna of the receiver and the rover is located in different place, it is necessary to correct the offset for positioning data.Due to the vehicle traveling on the flat road, only horizontalerror is to be corrected. The information which is used to correct the east and north error is listed as follows:

(1) The antenna of the receiver and the rover is located at C and E in Fig.5.
(2) During the experiment the connection between C and E,“L”, is perpendicular to the directionof the vehicle.
(3) $\theta_t$isthe angle between the direction of the vehicle and the north directionwhich is provided by the GNSS receiver.

The correction of east and north components is shown in the equations (5) and (6).

$$\Delta E_{1t} = \Delta E_{0t} + L\cos\theta_t \quad (5)$$

$$\Delta N_{1t} = \Delta N_{0t} - L\sin\theta_t \quad (6)$$

where:

ΔE_{0t}:east error component before correction
ΔN_{0t}: north error component before correction
ΔE_{1t}: east error component after correction
ΔN_{1t}: north error component after correction
θ_t: course of vehicle
L:distance between C and E

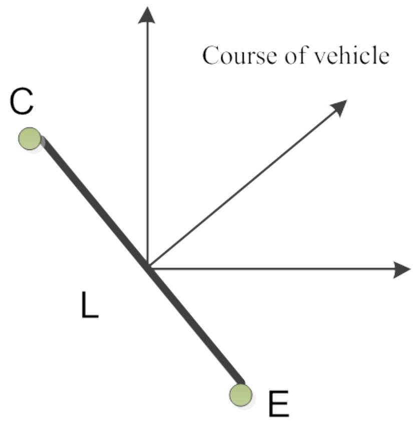


Fig.5 antenna offset correction

Secondly, as the reliability of GNSS receiver depends on the number of the available satellites and their geometrical distribution, the analysis only retained the positioning dataunder no less than 8satellites environment.The eliminateddata is replaced by the average value of neighboring positioning results.

Finally, the difference between the positioning error of adjacent point has great influence on the cooresponding mileage error in the same period. In order to distinguish the effects of random error, the difference mentioned above is divided into three intervals including “(0~1)m”, “(1~3)m” and “(3~50)m”. The intervals “(0~1)m” and “(1~3)m” belong to random error and only “(3~50)m” interval is considered to have a major on mileage error. The influence of road condition on the difference is analyzed at first. The experiment is carried out in five kinds of different environment listed in Table 2.

The influence of “shade” and “elevated road” is shown in Fig.6. Under “elevated road above”, “shade” and “open-air” conditions, most of the difference is smaller than 3m and the ratio of the difference smaller than 1m is about 80%, which is much larger than that under “elevated road below” condition. The ratio of the difference larger than 3m is about 45% under “elevated road below” condition. These results show that the influence of “elevated road” is much more important than shade on the difference between the positioningerror.

The influence of “tunnel” is shown in Fig.7. Under “elevated road above” and “elevated roadabove+tunnel” condition, the ratio of the difference in each interval is similar with each other. The ratio of the difference larger than 3m under “elevated roadbelow+tunnel” condition is much smaller than that under “elevated roadbelow” condition. These results show that, ifeffective method is taken to replace the abnormal data, “tunnel” will not exert serious negative effect on the difference value.

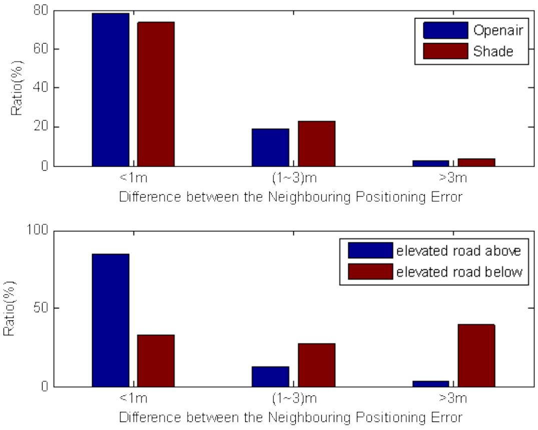


Fig.6Influence of “shade” and “elevated road”

The influence of each kinds of road condition on mileage erroris shown in table 3. Given by the inertial integrated GNSS receiver,“REF Mileage Value” is the reference mileage value. The mileage error of the receiver under each condition is listed along the third column. The fourth column is the ratio of the differencelarger than 3m. It is clear to see that the mileage error of receiver under“elevated road below” and “Tunnel+ elevated road below” conditions is much larger than that under other conditions, so is the corresponding ratios.

Table 3 Mileage error results.

Condition	REF Mileage Value (m)	Mileage Error (m)	Ratio (>3m)
elevated road above	7977.06	142.63	2.55%
	7985.90	94.08	3.33%
	7985.90	203.22	4.59%
elevated road below	8485.19	3090.52	32.26%
	8479.29	4026.43	43.75%
	8491.01	3152.02	42.66%
shade	4923.37	111.37	3.71%
	4926.14	104.87	3.25%
Tunnel+ elevated road above	12478.85	226.13	3.75%
	12476.44	344.81	6.82%
Tunnel+ elevated road below	12487.41	3035.06	28.13%
	12497.61	2498.75	22.46%
Open-air	8874.11	159.05	2.74%

According to the above analysis, the following conculsion may be drew: The difference of positioning error under “elevated road below” condition experiences a greater change than other conditions, so the mileage error is relative large;Shade and building less than seven layers have a small effect on the mileage error; Although the receiver cannot search satellites in the tunnel, the length of tunnel in theoretical and effective algorithm can be used to reduce the mileage error.

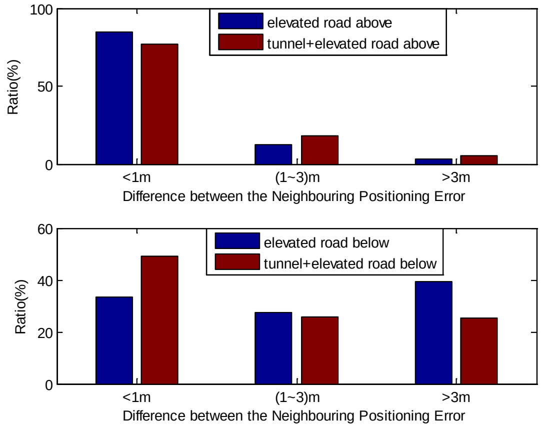


Fig.7The influence of “tunnel”

IV. CONCLUSIONS

In this paper, the relationship between positioning error and mileage error has been studied. The greater difference between the positioning error of adjacent point is, the larger mileage error appears. Experiments in five typical kinds of road environment have been taken out.The results show that the difference of positioning error under “elevated road below” condition experiences the greatest change than other conditions and so is the relative mileage error. In order to provide a more accurate mileage result, car-hailing service platform should employ effective methods to smooth positioning results especially under the case of poor satellite observation condition.

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