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A Calculation Method of Vehicle Mileage Based on an Adaptive Distance Algorithm

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Abstract. Aimed at the problem of inaccurate statistics caused by interference and noise data during a vehicle mileage statistics process, a vehicle mileage statistics method based on adaptive distance algorithm was given in this paper. By using the continuous satellite positioning data of specific vehicle, all satellite positioning data could be divided into low speed mode and high speed mode according to a predetermined speed threshold. An adaptive distance algorithm is developed, so the drift noise can be easily separated by the algorithm in real time. With some validations of real vehicle running data, compared with the existing algorithms, the algorithm developed in this paper has a good anti-interference ability to the satellite positioning noise data generated by the vehicle running conditions of parking and low speed. The influence of the drift noise on the vehicle mileage statistics can be effectively eliminated. At the same time, the algorithm can automatically filter the satellite positioning data whose latitude and longitude beyond the reasonable coordinate range. Experimental data shows that the algorithm can effectively improve the accuracy of vehicle mileage calculation.

Keywords: adaptive distance algorithm, drift noise, mileage, satellite positioning data, vehicle

1 Introduction

Satellite positioning system (such as the global positioning system GPS\ BeiDou Navigation Satellite System, etc.) has brought great changes to our daily life, with which the vehicle location can be acquired easily. Meanwhile, it can facilitate the conduct of the traffic statistical work, such as vehicle mileage statistics. The vehicle mileage statistics is of great importance, especially when road transportation enterprises are doing work about security and energy management. At present, the satellite positioning system has been widely used by road transportation enterprises at all levels and even by individual users. Thus, how to make full use of these massive satellite positioning data to calculate accurate vehicle mileage has important theoretical value and practical significance.

At present, it may cause the vehicle positioning location not accurate due to the sensing error when using satellite positioning data to calculate the vehicle mileage, commonly known as “drift”. The positioning locations are randomly distributed in a circle centered by actual location and may change at any time, especially when the positioned vehicle is at a low speed or static state. The common method to get the vehicle mileage is to calculate the vehicle mileage per second by the real-time speed and accumulate. However, due to drift mentioned above, when the vehicle is virtually at a standstill, it is possible to sense the changes for satellite positioning system and the false speed information will be reported, leading to errors on the vehicle mileage statistics [1-4].

In this case, the researchers use different algorithms to solve this problem, for example by setting the

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speed threshold to avoid mileage accumulation when vehicles are motionless. Specifically, it does not accumulate the mileage unless the speed is higher than a certain threshold. Such methods have the following disadvantages: if the filter threshold is too high, the low speed running mileage can't be accumulated, on the other hand, if the filter threshold is too low, the purpose of filtering speed is not achieved. Such statistical methods will cause error about 10%, depriving statistical significance. There are also scholars using a large number of repeated driving tests to correct the error between the actual measured distance and satellite positioning data, but there is no verification and description of the statistical accuracy of this method, and the implementation costs and generality are also limitations [5-7].

Therefore, In order to solve the above problems, this paper proposes a calculation method of vehicle mileage statistics to complete vehicle motion state judgement and calculate accurate vehicle mileage according to the judgement only relying on satellite positioning data, not depending on other ways such as speedometer or accessing pulse signal. The method could provide important basic data for road transportation management.

This paper proposes a method to calculate the mileage of vehicles using satellite positioning data and the adaptive distance algorithm. Based on the technical ideas of this article, the author of this article has applied for and obtained the authorization of China's national invention patent [8]. By using the continuous satellite positioning data of specific vehicle, all satellite positioning data could be divided into low speed mode and high speed mode according to a predetermined speed threshold. An adaptive distance algorithm is developed, so the drift noise can be easily separated by the algorithm in real time. With some validations of real vehicle running data, compared with the existing algorithms, the algorithm developed in this paper has a good anti-interference ability to the satellite positioning noise data generated by the vehicle running conditions of parking and low speed. The influence of the drift noise on the vehicle mileage statistics can be effectively eliminated. At the same time, the algorithm can automatically filter the satellite positioning data whose latitude and longitude beyond the reasonable coordinate range. Experimental data shows that the algorithm can effectively improve the accuracy of vehicle mileage calculation.

2 Principles of Adaptive Distance Algorithm

As is shown in Fig. 1, the existing references and empirical analysis show that its location on the map is randomly distributed in a circle centered by actual location and may change at any time when drift occurs. In response to this situation, this paper presents an adaptive distance algorithm aimed at effectively isolating the drift noise from normal low speed driving data.

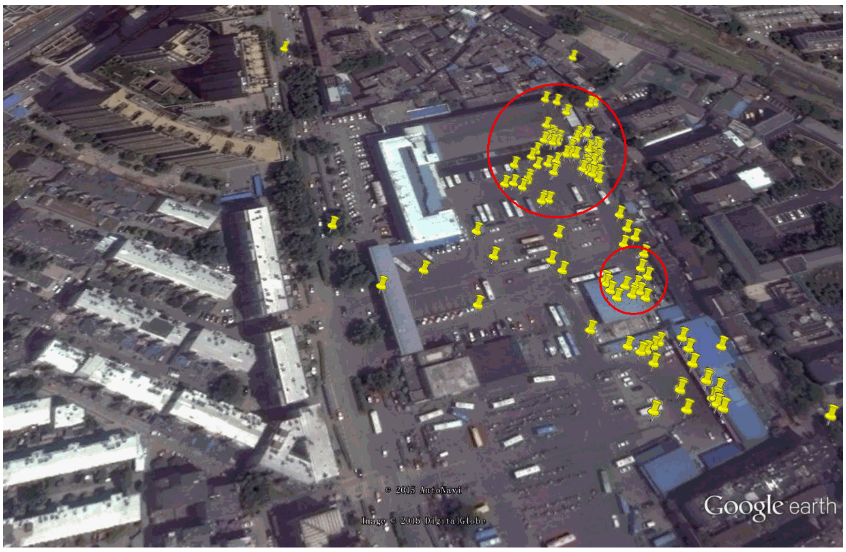


Fig. 1. Vehicle satellite positioning data with drift noise

All the possible low-speed drift data records are selected from the satellite positioning data set in Fig. 1 to form a data set N, while the low speed threshold is set at 5.5 m/s. For all data records in the data set N, the distance between adjacent records and distance between each record and first record are calculated. The original data and calculation results are listed in Table 1. The spherical distance formula is adopted to calculate the distance between the two satellite positioning records:

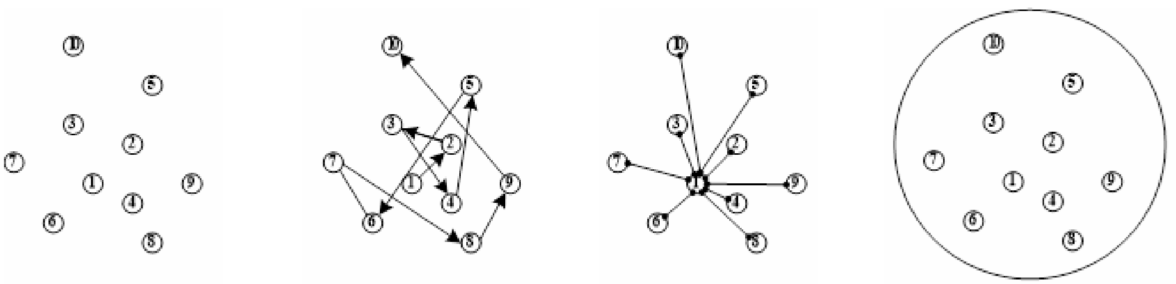
$$D(x_1, y_1, x_2, y_2)=R\times\arccos[\sin(x_1)\times\sin(x_2)+\cos(x_1)\times\cos(x_2)\times\cos(y_1-y_2)]. \quad \textbf{(1)}$$

Where x_1, x_2 are latitude, y_1, y_2 are longitude, and R is the radius of the earth.

Table 1. Original data and calculation results of possible low velocity drift

Number	Longitude	Latitude	Speed (m/s)	Distance between each record to first record	Continuous distance between each record to first record
1	117.3000	31.8699	3.75	5.64	5.64
2	117.3000	31.8699	4.11	10.05	10.09
3	117.3000	31.8698	4.44	14.58	14.63
4	117.3000	31.8698	4.81	21.32	21.37
5	117.3000	31.8697	4.97	29.05	29.16
6	117.3000	31.8696	5.06	34.68	34.79
…	…	…	…	…	…
512	117.3014	31.8691	2.17	160.60	514.25
513	117.3014	31.8691	2.22	158.56	516.67
…	…	…	…	…	…
1107	117.3019	31.8675	4.11	316.06	1921.28
1108	117.3019	31.8676	3.83	318.22	1925.06
1109	117.3019	31.8676	3.92	320.06	1929.91

As is shown in Fig. 2(a), 10 points drawn on the map are taken from data set from the table.



(a) possible drift points (b) S_L (c) S_{oi} (d) drift points fall in a circle with a Perimeter of S_L

Fig. 2. Possible drift points and their distance from each other

It can be seen in Fig. 2 that drift points gather near the first point, however the distance between each point and first point should be increased in normal driving process. According to the results in Table 1, the possible drift points always fall on the circle with a diameter that equals continuous distance between each record to first record, as shown in Fig. 2(d). And the drift persists until the distance between each point and first point exceeds the diameter that equals continuous distance between each record to first record.

The following parameters should be calculated respectively from the first record in the set N:

——The distance between the current record and the first record S_{oi}, S_{oi} is valid only when $S_{oi} < 60\times i\times V\times m/f$, otherwise it should be abandoned.

——The distance between the current record and the next record $S_{adjacent}$, $S_{adjacent}$ is valid only when $S_{adjacent} < 60\times i\times V\times m/f$, otherwise it should be abandoned.

——The continuous valid distance between current record to first record S_L, $S_L = S_L + S_{adjacent}$.

In the formula, i is the current record number, V is the low speed threshold; f is the collection times of satellite positioning data per minute, namely the acquisition frequency; w is the error correction value of adjacent points distance to filter abnormal adjacent recording distance value; m is the error correction value of distance between any two points to filter abnormal distance value between current record and first record.

Then the adaptive distance algorithm is given.

Algorithm 1. *The adaptive distance algorithm (basic principle of realization)*

1: **Input:** The distance between the current record and the first record S_{oi};
The distance between the current record and the next record $S_{adjacent}$
The continuous valid distance between current record to first record S_L, $S_L = S_L + S_{adjacent}$.
2: **Initial Settings:** S_{oi}, $S_{adjacent}$ and S_L all $<60 \times i \times V \times m/f$.
3: **Output:** the accumulated mileage under low speed S_{low}
4: **for** i =1, 2, ..., the last record of the set N **do**
5: if $S_{oi} > S_{adjacent}/\pi$ then
6: $S_{low} = S_{low} + S_{adjacent}$
7: else $S_{low} = S_{low}$
8: **end for**

3 Implementation of Vehicle Mileage Calculation Method Based on an Adaptive Distance Algorithm

Filter all satellite positioning data records of the specific vehicle in statistical time from the monitoring center database system or from storage unit in vehicle terminal. According to the setting threshold, the speed of all records is divided into low-speed mode and mid-high speed mode. The vehicle mileages in two models are calculated using different algorithms. Detailed algorithm is as follows:

(1) Choose all continuous adjacent records whose satellite positioning speed is less than or equal to V from the first one, forming record set N and V is the speed threshold.

(2) If the records number i<b (b is the minimum number of records which can be set manually), choose the one before first low-speed record and the b-1 records after it and then calculate the distance $S_{adjacent}$ as the valid accumulated mileage S_{low} only when $S_{adjacent}<60 \times w/f$, $S_{low}= S_{low} + S_{adjacent}$. In the formula, f is the collection times of satellite positioning data per minute, namely the acquisition frequency; w is the error correction value of adjacent points distance to filter abnormal adjacent recording distance value and it is generally assumed that the limit speed of road vehicles should be no more than 100 m/s =360KM/h, so w can be set to a certain value, such as 100. After the calculation, S_{low} can be given.

(3) If i>b

(a) From the first record in set N, calculate the distance between each two adjacent records $S_{adjacent}$ until the last one only when $S_{adjacent} <60 \times w/f$, $S_L=S_L+ S_{adjacent}$. S_L is got after the calculation.

(b) Compute the distance S_{oi} between first record and the others and it is valid only when $S_{oi} <60 \times i \times V \times m/f$. m is the error correction value of distance between any two points to filter abnormal distance value between current record and first record. It is generally assumed that the maximum distance is the continuous straight distance with a speed V. The value of m is taken from the interval [2, 5].

(c) compute S_{oi} and S_L/π, if $S_{oi}> S_L/\pi$, the accumulated mileage under low speed $S_{low=} S_{low} +S_L$, otherwise, the vehicle is judged to be parking or the satellite positioning signal is in drift state, not accumulated into the mileage.

(4) If the speed of first satellite positioning record is more than V, Choose all continuous $S_{adjacent}$ records whose satellite positioning speed is more than V from the first one, forming record set N:

(a) Calculate the coordinate distance between the current record and next adjacent record $S_{adjacent}$ from the first record in set N, and compute the distance S_v between the current record and next adjacent record using speed.

(b) If $S_v>S_{adjacent}$, S_H (the valid mileage of adjacent records) = S_v; if $S_v<S_{adjacent}$ and $S_{adjacent} <60 \times w/f$, then $S_H = S_{adjacent}$

(c) $S_{mid\text{-}high} = S_{mid\text{-}high} + S_H$

(d) Repeat the above steps until the last record of this set and then $S_{mid\text{-}high}$ is given.

(5) If the speed of (*i*+1) record ≤V, take the (*i*+1) record as the first one and repeat step 1 to step 3; If not, take the (*i*+1) record as the first one and repeat step 4 until *i* is the number of the last record and complete all the calculations.

(6) All S_{low} and high $S_{mid\text{-}high}$ in the calculation process above are summed up, getting the final calculation of total mileage S_{total}.

As is mentioned above, the calculation formula for calculating the distance S_V according to the speed is as follows:

$$S_V = (v_1+v_2)/2\times t$$

Where v_1 and v_2 are the satellite positioning speed of current record and the next record and t is the satellite positioning time difference of current record and the next record.

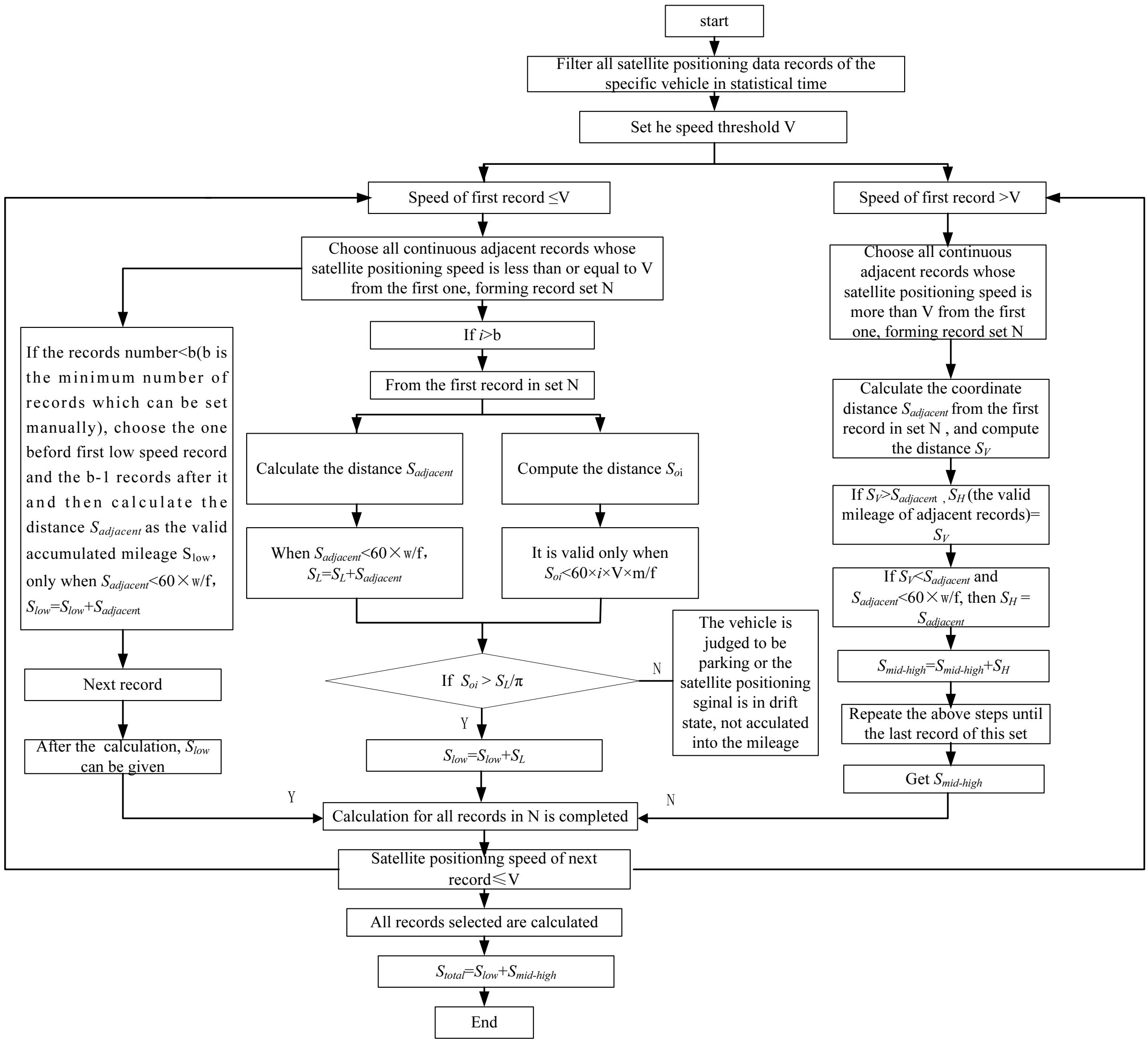


Fig. 3. Flow chart of vehicle mileage calculation algorithm

4 Performance Analysis

The algorithm proposed in this paper is verified, select all the satellite positioning data of an operating bus in 15:03~16:03 2015/5/28 and there are totally 3309 satellite positioning data records shown in Table 2. It can be seen from the Google earth that the route including two adjacent stations, situations like low speed driving, mid-high speed driving and waiting for traffic signals are all covered in vehicle driving conditions.

Based on the speed threshold set by users, the initial threshold V=5.5m/s. All satellite positioning records are divided into low-speed mode and mid-high-speed mode. The mileages in two models are calculated using different algorithms. The parameter w in the algorithm is 100, and the value of m is 2.

Table 2. Satellite positioning records in the specific time of the sample vehicle (part)

Number	Time	Longitude	Latitude	Satellite positioning speed (m/s)
1	2015/5/28 15:03	117.3	31.8699	3.75
2	2015/5/28 15:03	117.3	31.86985	4.11
3	2015/5/28 15:03	117.3	31.86981	4.44
4	2015/5/28 15:03	117.3	31.86977	4.81
5	2015/5/28 15:03	117.3	31.86971	4.97
6	2015/5/28 15:03	117.3	31.86964	5.06
7	2015/5/28 15:03	117.3	31.86959	4.97
8	2015/5/28 15:03	117.3	31.86954	5.03
…	…	…	…	…
…	…	…	…	…
3307	2015/5/28 16:03	117.2311	31.89833	13.19
3308	2015/5/28 16:03	117.231	31.89831	12.42
3309	2015/5/28 16:03	117.2308	31.89829	11.22

Input the data in Table 2 to Google earth and the real distance between the first record and the last record measured by its own tools is 13.1 km. Accumulating the coordinate distance of adjacent satellite positioning records in Table 2 and the distance calculated is 15.15 km. According to the algorithm proposed in this paper and parameters, the vehicle mileage in this period is 13.4 km, the accuracy reaching 97.6%. The drifts of the satellite positioning data appeared in Fig. 1 are effectively eliminated, and the mileage calculation results have not accumulated distance of drift points in the proposed algorithm. The comprehensive comparison results further validate the proposed algorithm.

In particular, the low speed threshold V of the algorithm is verified by different values.

The following gives the comparison results of the two methods in Table 3 and Table 4. The method proposed in this paper is abbreviated as AD algorithm, and the method accumulating the coordinate distance of adjacent satellite positioning records is abbreviated as CD algorithm.

Table 3. The low speed threshold V of the algorithm which is verified by different values

V (m/s)	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7
AD algorithm results (km)	15.0	14.7	14.2	14.0	14.0	13.8	13.9	13.4	14.3	13.8	13.8
CD algorithm results (no matter the value of V) (km)	15.15	15.15	15.15	15.15	15.15	15.15	15.15	15.15	15.15	15.15	15.15
Real distance (km)	13.1	13.1	13.1	13.1	13.1	13.1	13.1	13.1	13.1	13.1	13.1
AD Accuracy (%)	85.5	87.8	91.6	93.1	93.1	94.7	93.9	97.7	90.8	94.7	94.7
CD Accuracy (%)	84.4	84.4	84.4	84.4	84.4	84.4	84.4	84.4	84.4	84.4	84.4

Select the total mileage of 1100 km, a total of 60000 satellite positioning data, and the accuracy of this algorithm is verified.

Table 4. The accuracy of this algorithm is verified

V (m/s)	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7
algorithm results (km)	1086.5	1086.1	1085.8	1086.2	1085.6	1083.5	1086.5	1088.1	1084.1	1084.4	1085.2
CD algorithm results (no matter the value of V) (km)	1216	1216	1216	1216	1216	1216	1216	1216	1216	1216	1216
Real distance (km)	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100
AD Accuracy (%)	98.8	98.7	98.7	98.7	98.7	98.5	98.8	98.9	98.6	98.6	98.7
CD Accuracy (%)	89.5	89.5	89.5	89.5	89.5	89.5	89.5	89.5	89.5	89.5	89.5

Thus the proposed algorithm ensures high mileage calculation accuracy for complex route in short distance and a relatively more accurate mileage calculation for longer routes, especially compared to the CD algorithm.

5 Conclusion

Compared with the vehicle mileage calculation methods based on the existing literature using satellite positioning data, this paper proposed a novel calculation method of vehicle mileage based on an adaptive distance algorithm. On one hand, this method help the remote monitoring center to realize vehicle mileage statistics, and avoid checking the vehicle's odometer one by one, using satellite positioning data without external sensors or other OBD vehicle equipment. On the other hand, various types of satellite positioning data are supported without the restriction of terminal brands and models, to avoid the cost of replacing the terminal equipment and monitoring platform. In addition, the acquisition frequency requirements are relatively broad, and the analysis and fault tolerance of the satellite positioning data are more comprehensive, effectively reducing the cost of the implementation of the method and saving the user's wireless communication traffic. This method can effectively overcome the problem in the existing mileage calculation methods that correcting errors between measured distance and algorithm results needs a large number of actual driving tests, the implementation cost of which is too much. It can also effectively eliminate static drift caused by the accumulated error in the calculation of longitude and latitude using satellite positioning information. The problem that the positioning data is not accurate (latitude and longitude beyond the reasonable range) have an impact on the accuracy of the calculation and other issues are also solved by the algorithm. It is proved that the method is accurate and reliable, and can be used in production through the actual operation data of the road transportation enterprise satellite positioning system.

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