Research on a Fast Continuous Vialog Algorithm

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Abstract. Surface evenness affects vehicle safety, service life, and passenger comfort. The road surface with poor flatness will produce resistance to the vehicle driving, making the vehicle vibrate and bump, hindering the safety of the vehicle driving, and will also cause local water accumulation, speed up the road damage and so on. In order to make the vehicle safe, passengers feel comfortable, road life growth, road flatness detection is particularly important. In order to make the vehicle safe to travel, passengers feel comfortable, the road service life growth, and the detection of road surface evenness is particularly important. In order to overcome the shortcomings of the existing algorithms for pavement evenness, this paper has put forward a new fast algorithm that can be applied to the continuous vialog, and according to the elevation value obtains the evenness standard deviation σ. The results show that the algorithm is high reliability, which provides a reference for the upgrade of instruments and equipment, and makes up for the shortcomings that the continuous vialog cannot be tested quickly.

1. Introduction

In recent years, with the rapid development of the national economy, the transportation industry has also developed rapidly, especially the highway transportation mode has played an important role in the vigorous development of the national economy. At the same time, there are problems such as highway detection and maintenance have emerged, especially in the highway sections built and opened to traffic before, there have been obvious damage cracks, uneven pavement and other phenomena, which directly affect the service life of the highway and the safety of the vehicles. Therefore, it is necessary to establish perfect highway pavement maintenance management for scientific and efficient understanding of the condition of the paved road surface[1]. It also has great significance for the scientific evaluation of highway construction grade and road surface operation status to detect, such as the detection, evaluation and analysis of the evenness, pavement crack and rutting size of the road surface that has been completed[2]. Evenness affects vehicle safety, service life and passenger comfort. The road surface with poor evenness will produce resistance to the vehicle driving, make the vehicle to generate vibration bumps, hinder the driving safety of the vehicle, and cause localized water accumulation and accelerated road damage speed. In order to make the vehicle safe to drive, passengers feel comfortable, the road service life growth, the detection of road surface evenness is particularly important.

The developed countries in the world, such as the United States and Japan, have taken the pavement evenness as the main index to measure the service performance and maintenance quality of the road surface, and conducted regular testing it as an important basis for formulating road pavement maintenance management strategies. The pavement evenness can be used not only to measure the...
quality of pavement construction and the quality of pavement maintenance, but more importantly, the index of pavement evenness can be used to reflect the degree of human comfort in the process of driving. Therefore, this paper focuses on the research of the evenness algorithm.

2. Research Status of Evenness Algorithm
There are many different indexes in the aspect of road evenness evaluation indicators. For example, ARS can adjust the average slope, which is measured by the reaction equipment at a fixed speed; BI turbulence accumulation index, measured by a road gauge developed by the British TRRL; CP evenness index is proposed by the Belgian Road Research Institute (CRR), is calculated after moving average filtering of different widths for the measured value of APL72 measuring instrument; QI is 1/4 vehicle index, the predecessor of international evenness index (IRI), which is based on the elevation of the longitudinal section of the road; NAASRA index, proposed by the Australian Road Research Institute; International evenness index based on road section data and calculated by fixed parameter 1/4 vehicle model[3].

In order to study the correlation between the indicators, foreign researchers[4] simulated the longitudinal section of the road based on the road power spectrum density irregularity, and calculated the international evenness index (IRI) by Newmark continuous integration method and mathematical statistics method. According to the simulation and regression analysis, there is a very good linear correlation between the IRI and the standard deviation of the relative speed of the axle and suspension system. If the power spectral density of PSD evenness can be expressed by a polynomial function of the wave number, IRI can be calculated by the root mean square of the sum of the weighted coefficients in the PSD evenness regression analysis, which enables the highway management department to obtain the road IRI data based on the know road PSD evenness data, the inspection data of the highway management department and the automobile manufacturer can be compared with the same standard. Benneit[5] pointed out through research that the reaction evenness meter needs to carry out calibration for the international evenness index IRI to ensure the accuracy of its measurements. Old and Peter[6] pointed out through research that if there is irregular evenness power spectral density on the road, it needs to be analyzed and described by different independent parameters. In this case, IRI can't distinguish the significant difference in the longitudinal section of the road, and pointed out that the standard deviation of vertical elevation RMSH is better than the singular index IRI, mainly because RMSH reflects the vehicles in the short, medium and long range vibration situation of road evenness. Wei Xiaodan used IRI as the evaluation index of pavement flatness. In the study, the IRI and the continuous flatness meter σ value were calculated by using the level gauge and the hand-inferred surface meter, and the correlation test was carried out. The test results show that the IRI and σ indicators can be converted by the formula σ=0.6IRI. However, Xu Yongxin and Zhou Yan analyzed the use method and working principle of the evenness test in the "Research on the method of pavement evenness detection". In this paper, they have established the correspondence between the flatness and the test data and given some usual conversion methods: IRI =1.0319 σ +0.2711. Zhang Yi and Ma Ronggui[7] analyzed the road evenness detection method based on inertial reference, and on the basis of a quarter car model in the research of "laser pavement evenness detection based on inertial reference system research", In this paper, laser range finder is presented and the acceleration sensor output signal for road surface profile measurement and calculation formula of the relative elevation to achieve the multi-channel data acquisition and joint processing, introduces the data processing method of the sensor output signal, through the contrast test with precision level measurement method, results show that the detection method based on inertial reference has feasibility in the road surface evenness detection.

When most of the domestic laser evenness meters find the standard deviation σ, the usual algorithm is σ=0.6IRI, and the calculation is not performed by the original elevation. In this paper, a new fast algorithm that can be applied to continuous vialog is proposed, which provides a reference for equipment upgrade and makes up for the shortcoming that continuous flatness meter cannot be tested quickly.
3. Demonstration of laser flatness analyzer algorithm
The laser evenness meter is the most commonly used detection equipment in highway inspection. It has many advantages, such as being unaffected by the detection speed and not affected by the type of the vehicle body, so it plays an important role in the evenness detection market. Generally, the laser flatness meter is add an inertial reference unit to a laser sensor module. The working process is as follows: firstly, the vertical elevation of the equipment to the road surface is measured by a laser sensor. Then, the absolute displacement is generated in the direction, and the error is corrected by the accelerometer measuring device to obtain the real road pavement longitudinal elevation information. Finally, the international evenness standard deviation \( \sigma \) is calculated based on IRI.

According to the research literature, most of the algorithms for laser flatness meters at this stage is to calculate the IRI first, and then calculate the \( \sigma \) by \( \sigma = 0.6 \text{IRI} \). This algorithm is derived from Wei Xiaodan's research on the international flatness index IRI as the evaluation index of pavement evenness. IRI and \( \sigma \) were calculated by using a level gauge and a hand-inferred face meter, and then the correlation test was performed on the two indicators. The test results show that the IRI and \( \sigma \) indicators can be converted by the formula \( \sigma = 0.6 \text{IRI} \).

But this algorithm is calculated by statistics. There is no mathematical correlation between the two indicators. In different literatures, the conversion methods of this two indicators are different. Among them, Xu Yongxin and Zhou Yan in "research on the detection method of road surface evenness" have analyzed the operation method and working principle of the evenness test vehicle, and established the corresponding relationship between the flatness and the test data, and gave different conversion methods: \( \text{IRI} = 1.0319 \sigma + 0.2711 \).

In this paper, it is considered that the accuracy of the laser flatness meter and the accuracy of the continuous flatness meter cannot be verified before the establishment of the laser flatness equipment standard in the literature. As a result, the measured values and correlation of such equipment cannot be used as the algorithm for fast continuous evenness.

Due to the lack of theoretical correlation, this paper uses the level gauge to collect the road surface actual data, take some actual data and the original measured value of the continuous vialogvalue, and calculate based on the elevation value of the road surface. Then correlation between \( \sigma \) and IRI was calculated. The correlation curve is shown in Figure 1. We can get the relationship between \( \sigma \) and IRI: \( \sigma = 0.844 \text{IRI} - 0.234, \ R > 0.98 \).

Since the actual road segment data are relatively close and the values are relatively concentrated, the computer is used to simulate the road surface with different values in accordance with the actual segment. And obtains the original measured value of the continuous flatness value according to the simulated road surface, and then obtains the relationship between \( \sigma \) and IRI by correlation. As shown in Figure 2, it was found that \( \sigma = 0.741 \text{IRI} - 0.045, \ R > 0.99 \).

![Figure 1. Correlation curve between \( \sigma \) and IRI](image-url)
Figure 2. Computer simulation of the relationship between sigma and IRI on the pavement

Based on this, it is found that different devices use IRI value conversion $\sigma$, there will be different correlations, simple correlation conversion, the value can not guarantee the time, and the algorithm for obtaining $\sigma$ according to IRI does not have universality. Therefore, this paper proposes a fast continuous vialog algorithm for calculating $\sigma$ by elevation values.

4. Research on algorithm of fast continuous vialog
According to the research, the cross-section value of the existing laser evenness meter does not meet the requirements of continuous evenness. Therefore, this paper chooses to improve the algorithm design of the continuous vialog.

According to the characteristics of the continuous vialog, the evenness of E60 is calculated as a calculation interval per 100m, and one detection section (usually 1~3km) has several calculation intervals. After the evenness of each calculation interval is obtained from the measured value. The evenness of the test section is assessed by the control standard and the acceptance quality standard during the construction process. Based on this, we have put forward the method of three-meter vertical distance measurement to improve the fast continuous evenness eight-wheel meter. The equipment is used to measure the road surface elevation and then calculate $\sigma$ through the value of the road surface elevation.

The standard length of the fast continuous vialog eight-wheel meter is 3m, and there are four rows of wheels in front and rear. The two pairs are arranged in pairs to form a balanced type, which has the functions of balance and support. The distance between the shafts of the front and rear wheels is 3m. The middle is a 3m long frame that can be telescopic or folded. The frame is regarded as the follow-up reference of the eight-wheeled instrument. Its midpoint is the reference point of measurement and is located at the center of eight supporting wheels. The rack is equipped with a battery and a detachable test box, which can be used to display, record, print or draw the measurement results. In the middle of the rack, there is a measuring wheel that can rise and fall with the ground, and a detecting device such as a displacement sensor and a distance sensor is mounted thereon. When measuring, the measuring wheel is kept in contact with the road surface under the action of the spring, and the variation between the reference and the road surface is measured, and displacement data is automatically acquired. The front end of the frame is equipped with a traction mechanism, which can be pulled by human or automobile.

According to the measurement principle of the fast continuous vialog, the following algorithm is applied to the directly measured elevation value and $\sigma$:

$$d_i = \left( d_{0(i-15)} + d_{0(i+15)} \right) / 2 - d_{0i}$$  (1)
\[ \sigma_i = \sqrt{\frac{\sum_{j=1}^{N} (di - \overline{d})^2}{N-1}} \] (2)

Among them: \( \sigma_i \) —— the calculation value of the evenness of each calculation interval (mm); \( d_{0i} \) —— the original value (mm) of the road surface concave-convex deviation displacement acquired at a certain distance with 100m; \( d_i \) —— 100m A calculation interval, the correction value of the road surface concave-convex deviation displacement (mm) collected at a certain distance; \( \overline{d} \) —— the average value (mm) of the N road surface concave-convex deviation displacement values collected in a calculation interval; \( N \) — a calculation interval The number of test data used to calculate the standard deviation.

5. Verification of fast continuous vialog analyzer algorithm

In order to verify the scheme of fast continuous vialog, the algorithm was verified by the model established in this paper. The standard elevation value was measured by the level gauge and the measured elevation value is measured by the fast continuous vialog, then \( \sigma \) was calculated by formula 1 and 2. The results are shown in Table 1.

| Standard elevation value | Measured elevation value | Error  | Standard elevation value | Measured elevation value | Error  |
|--------------------------|--------------------------|--------|--------------------------|--------------------------|--------|
| 2.420903                 | 2.383224                 | -0.03768 | 1.088615                 | 1.070034                 | -0.01858 |
| 0.793996                 | 0.779551                 | -0.01444 | 1.228306                 | 1.24026                 | 0.011954 |
| 1.304706                 | 1.28118                  | -0.02353 | 1.513746                 | 1.483591                 | -0.03015 |
| 1.034822                 | 1.013604                 | -0.02122 | 1.0246                   | 1.005239                 | -0.01936 |

It can be seen from Table 1 that the error between the standard value and the measured value does not exceed 0.04, and the error range satisfies the design requirements of the algorithm. It shows that the algorithm has higher reliability, and the algorithm obtains \( \sigma \) directly from the IRI by the elevation value. It is proved that this algorithm has higher reliability and better versatility.

6. Conclusion

In this paper, we first demonstrated that the algorithm relationship between the standard deviation of the \( \sigma \) and IRI of the laser evenness meter has no universality. Different devices correspond to different algorithms. Therefore, it is not recommended to use IRI for the conversion of the \( \sigma \). But when it is used a reference value, can use \( \sigma = 0.6 \) IRI for simple conversion.

In this paper, a new algorithm is proposed by studying the fast continuous flatness algorithm. The algorithm calculates the continuous flatness standard deviation \( \sigma \) by the elevation value. The algorithm formula is as follows:

\[ d_i = \frac{(d_{0(i-15)} + d_{0(i+15)})}{2} - d_{0i}, \quad \sigma_i = \sqrt{\frac{\sum_{j=1}^{N} (d_i - \overline{d})^2}{N-1}} \]

The algorithm is verified by the established model, and the results show that the algorithm is more accurate. This algorithm can be applied to the fast continuous vialog, which has a good reference for the upgrade of the instrument and equipment, and also makes up for the shortcomings that the continuous flatness meter cannot be tested quickly. The proposal of the fast continuous vialog algorithm can provide valuable experience for the research of other evenness calculations in the transportation industry and play a positive role in promoting the development of detection work in the transportation industry.
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