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The Design of an Intelligent Fast Continuous Vialog

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Abstract: Surface evenness affects vehicle safety, service life and passenger comfort. A road surface with poor evenness will cause resistance to the running of the vehicle, causing the vehicle to generate vibration bumps, hinder the driving safety of the vehicle, and cause localized water accumulation and accelerated rode damage speed. In order to make the vehicle safe, passengers feel comfortable, road life growth, road flatness detection is particularly important. The detection, evaluation and analysis of the surface evenness, pavement cracks and rutting size of the road surface that has been opened to traffic, it is great significance for the scientific assessment of road construction grades and road surface conditions. In order to overcome the shortcomings of the existing continuous vialog, this paper designed a new type of continuous vialog based on the fast continuous surface evenness algorithm.In this paper, the contact distance measuring device and the measurement method of the ordinary gyroscope are used to realize the sampling, calculation and analysis processing of the elevation value and the surface evenness standard deviation. The experiment proves that the continuous vialog has the advantages of high precision, small error and low cost.

1. Introduction

In recent years, with the rapid development of China's transportation industry, especially the mode of road transportation has played an important role in the vigorous development of the national economy [1].The index of surface evenness directly affects the service life of the road, the driving safety of the vehicle and the comfort level of the human body [2].Therefore, in order to make the vehicle safe to travel, the passenger feels comfortable, the road life is increased, and the detection of the road surface evenness is particularly important.Currently, the commonly used surface evenness evaluation indexes include: ARS average adjustment slope, BI bumpy accumulation index, CP surface evenness index, QI 1/4 vehicle index, NAASRA index, international surface evenness index and so on [3].According to the research literature, the algorithm of most continuous vialogs at this stage is to calculate the IRI first, and then calculate the σ value by σ=0.6IRI [4]. This algorithm is derived from Wei Xiaodan in the study of the international surface evenness index IRI as the evaluation index of surface evenness. By using the level gauge and the hand-inferred surface meter, the international surface evenness index IRI value and the continuous surface evenness standard deviation σ are calculated. The value is then tested for correlation between the two indicators. The test results show that the international surface evenness index IRI and the surface evenness standard deviation σ can be converted by the formula σ=0.6IRI.However, this algorithm is calculated by statistics [5]. Theoretically, there is no correlation between the two indexes in mathematics, and different literatures have different conversion methods for the two indexes [6].Among them, Xu Yongxin analyzed the use method and working principle of the surface evenness test vehicle in the "Research on the method of surface evenness detection", and

established the corresponding relationship between the surface evenness and the test data, and gave different conversion methods: IRI = 1.0319σ + 0.2711.Based on this, it is found that different devices use IRI value to convertσ, there will be different correlation, simple correlation conversion, the value can not guarantee the requirements, and the algorithm based on IRI value to obtain σ is not universal [7]. Therefore Zhang Jinning et al. proposed a fast continuous continuous vialog algorithm for calculating σ from elevation values. In this paper, a fast continuous continuous vialog is designed based on this surface evenness algorithm to measure the main index elevation value of the algorithm and calculate the standard deviation σ of the surface evenness.

2. Method of measuring elevation values

The biggest difficulty in the design of the fast continuous vialog is to determine the standard elevation value.There are three methods commonly used in the detection of the standard elevation value, namely the leveling method, the laser ranging plus inertial device compensation method, and the gyroscope/angle sensor relative elevation method. The leveling method is to use a level or total station to measure the road surface elevation.This method is a conventional measurement method, because the measurement speed of this method is slow, cannot achieve the purpose of fast, this method is not used.Compensation method based on laser ranging and inertial device generally includes height of non-contact sensors (such as laser, infrared, visible, ultrasonic sensors) accelerometer, and the longitudinal distance, the height of non-contact sensor were measured the vertical distance to the road surface, vertical acceleration and longitudinal distance along the cross section, a section can be obtained in the corresponding calculation formula of elevation data, its working process for the first through laser sensor measuring equipment to the vertical elevation of the road, and then use the acceleration sensor to measurethe absolute displacement of the laser sensor in the vertical direction due to the bump during the running of the vehicle, thereby correcting the laser sensor. In the measurement process, due to the measurement error caused by bumps, the real road surface longitudinal elevation information is obtained.The precision of such devices mainly depends on the laser and acceleration sensor, which are not suitable for this study due to their high price.The gyro/angle sensor relative height method passes the mechanical mechanism to ensure precise control of the step size, and then the angle change is calculated by the angle measuring sensor or the high-precision gyroscope and converted into elevation, and the elevation series is generated by the cumulative method. This method stems from Face's development of an instrument that can replace the leveling method, the Dipstick, which is equipped with a small counter that automatically records elevation data. Although the gyro/angle sensor relative elevation method has better precision and higher efficiency than the level method, it still cannot meet the fast demand. At the same time, such equipment has the highest price in the same kind of equipment, so this solution is not adopted.

Based on this, this paper proposes a relative elevation method using ranging and compensation to measure the elevation value of the road surface, which is completed by using a contact distance measuring device plus an ordinary gyroscope. This method combines the advantages of laser ranging plus inertial device compensation and gyroscope/angle sensor relative elevation. The non-contact measurement in the laser ranging plus inertial device compensation method becomes contact measurement, and the form of the laser is not used, which not only reduces the cost but also increases the accuracy. In addition, the replacement of high-precision gyroscopes and angle measuring devices by ordinary gyroscopes helps to reduce the cost of the equipment.

3. Hardware design

The fast continuous vialog mainly consists of two parts: an elevation measuring device and a gyroscope correction device. The working principle is to fix the rapid continuous vialog on the car, the trailer or the trolley through the bracket, measure the fluctuation of the ground by the elevation measuring device, and at the same time, use the gyroscope to correct the change of the angle of the device and correct it. The mechanical structure of the fast continuous vialog is shown in Figure 1.
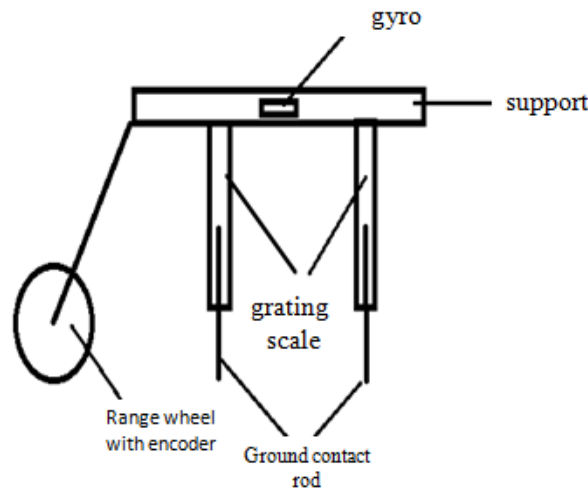
Figure 1. Mechanical structure of fast continuous vialog.

The actual measured road surface elevation value is calculated according to the theoretical formula (1):

$$h_{i+1} = h_i + l_2 - l_1 - l \times sin\theta \tag{1}$$
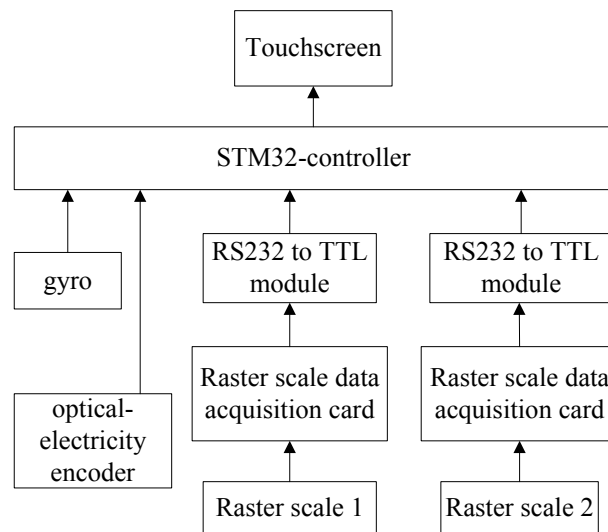
Where: h_{i+1} is the elevation of the new measuring point; h_i-- the elevation of the original measurement point; l_2-- the indication value of elevation measurement sensor 2; l_1-- the indication value of elevation measurement sensor 1; l-- the distance between two elevation measurement sensors.

The contact type distance measuring device in the elevation measuring equipment uses a grating scale as the measuring element.Grating scale has the advantages of high precision, good stability, fast speed and strong anti-interference ability, and is widely used in high-precision displacement measurement fields such as measuring instruments and numerical control machine tools. The gyroscope correction device adopts the nine-axis MPU9250 accelerometer electronic gyroscope, which has the advantages of small size, light weight, low cost, high reliability, large range and easy intelligence. It is suitable for installation space and weight requirements and overload.

The continuous vialog is mainly composed of a main bracket, an elevation measuring device, a ground connecting rod and a measuring wheel. The control system consists of a scale 1, a scale 2, a grating data acquisition card, an RS232 to TTL level module, a gyroscope, an encoder, an STM32 controller and a touch screen. The system block diagram is shown in Figure 2.

The main bracket, the elevation measuring device and the measuring wheel with encoder are mechanically connected. The gyroscope is embedded on the main bracket to measure the inclination of the device, and the dip angle data is sent to the STM32 through the IIC/SPI protocol; the main structure of the elevation measuring device is the grating scale 1 and the grating scale 2, and the grating scale sliding block is connected to the ground connecting rod and the ground. The connecting rod is close to the ground, and the data collected by the two grating scales is sent to the RS232 to TTL converter according to a specific protocol through the data acquisition card, and converted into a TTL level input to the serial port of the STM32, and the data is parsed by the processor. Obtaining the elevation value of the ground; the measuring wheel with the encoder is in contact with the ground. Through the rotation of the wheel, the encoder coupled with the wheel transmits the level-coded data to the STM32 for encoding and counting, thereby obtaining the moving distance of the device.

STM32 collects the data of the grating scale, gyroscope and encoder, analyzes the data, displays the data on the touch screen, and can control the system configuration through the touch screen.

Figure 2 diagram:

Touchscreen
↑
STM32-controller
↑   ↑   ↑
gyro   RS232 to TTL   RS232 to TTL
         module   module
           ↑   ↑
optical- Raster scale data   Raster scale data
electricity acquisition card   acquisition card
encoder   ↑   ↑
          Raster scale 1   Raster scale 2

Figure 2. Flow chart of the rapid continuous vialog control system.

The specific test steps are as follows: (1) Before using the device to measure the elevation value of the road surface, the equipment is horizontally calibrated by the gyroscope inclination data to find an absolutely flat road surface. (2) Adjust the two-way ground connecting rod and the encoder measuring wheel fixed by the grating scale to ensure that the two parts fully touch the ground. (3) Start the device to enter the measurement mode. (4) The device performs real-time elevation value detection and stores the elevation value to the SD card. (5) The device detects the moving distance through the encoder, displays and stores it to the SD card. (6) The device detects the tilt angle through the gyroscope and stores it on the SD card. (7) Each value can be read through the system screen, or the height, movement distance and inclination data in the SD card can be read by connecting the USB Slave interface of the STM32 through a PC.

4. Software design

The control system software is programmed by Keil, according to the flow chart shown in figure 3, the system initialization is first carried out, including contact type distance measuring device initialization, gyroscope correction device initialization and encoder initialization; then the grating scale, gyroscope and encoder are sequentially Send instructions to complete the data request and data reception of the transmitter; detect whether the data is received or not; detect whether the parsed data is correct; output the data to the display interface.

The collected standard elevation value is obtained by the device, and the algorithm formula of the fast continuous vialogis as shown in the following formulas 2 and 3, and the standard deviation of the evenness is obtained according to the algorithm.

$$d_i = \left(d_{0(i-15)} + d_{0(i+15)}\right)/2 - d_{0i} \tag{2}$$

$$\sigma_i = \sqrt{\frac{\sum_{i=1}^{N}(d_i - \bar{d})^2}{N-1}} \tag{3}$$

Where: σ_i——the calculation value of the surface 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 as a calculation interval , the correction value of the road surface unevenness deviation (mm) collected at a certain distance; $\bar{d}$——the average value (mm) of the N road surface concave and convex deviation displacement values collected in a calculation interval; N——a calculation interval is used for calculation The number of test data for standard deviation.
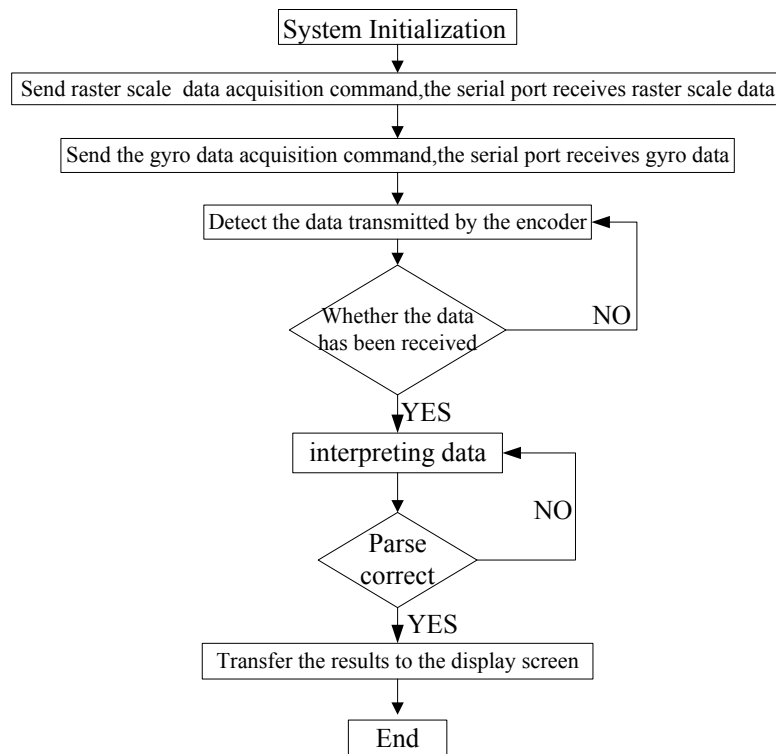
Figure 3. Software control system flow chart.

5. Test results

In accordance with the requirements of JJG (traffic) 024-XXXX continuous vialog (draft for comment), in order to obtain the surface evenness standard value, the two-wheel trace longitudinal elevation data of the test lane must be measured, and the sampling interval is 100mm. The specific plan is as follows:

Use a total station and chalk to draw a 100m long straight line on the standard road, mark the start and end points, mark the points at 100mm intervals along the starting point of the test line. The relative elevation data of each point of the test line is measured by a precision level. During the measurement process, the difference in line of sight between the front view and the rear view (or middle view) should be strictly controlled. The measurement length per station should be 10m when measuring, the level gauge is set in the middle, and the vertical distance of the erection position from the test line is not less than 3.75m. The section is measured with an automatic surface evenness measuring instrument and the elevation value is output. Calculate the surface evenness standard values of the two devices according to the formula (2) and (3). The developed equipment was verified through experiments. The standard values of this equipment were compared with the level equipment, and the results are shown in Table 1. As can be seen from the table, the device error is about 0.01 mm at maximum, which can achieve the intended purpose.

Table 1. Comparison of measurement errors between fast continuous vialog and level.

Standard values	Measurements	Errors	Standard values	Measurements	Errors
1.304706	1.345805	0.041099	1.088615	1.111093	0.022478
1.024592	1.053903	0.029311	1.228306	1.2437	0.015394
1.156418	1.161975	0.005557	1.513746	1.530894	0.017149
2.420903	2.432235	0.011332	1.0246	1.055366	0.030766

6. Conclusion

The fast continuous vialog designed in this paper adopts the contact detection method combining the contact distance measuring device and the gyroscope correction device, and uses the grating scale, the gyroscope and the encoder to perform data sampling, receiving and analysis, and has a small sampling interval. High precision, small error, simple operation, light weight and low price. The fast continuous vialog fundamentally improves the detection efficiency of the continuous vialog and reduces the project acceptance cost. The research of the rapid continuous vialog can provide valuable experience for the research of other vialogs in the transportation industry, and has a positive effect on promoting the inspection of the transportation industry.

Reference

[1]   Wang Gang,Yu Shanshan.2017.Transpoworld.36.032:72-73
[2]   érgio Pacífico Soncim; Igor Castro Sá de Oliveira; Felipe Brandão Santos; Carlos Augusto de Souza Oliveira;2018. Road Materials and Pavement Design.1448-1457.
[3]   Lu Sun. 2003.Mathematics, Computers in Simulation. 2(61):77-88.
[4]   Zhang Yi, Ma Ronggui, Ding Hui.2007.Transportation and computer. 25(5):13-16.
[5]   Rahma Ktari; Fazia Fouchal; Anne Millien;2017. Christophe Petit; European Journal of Environmental and Civil Engineering.27-42.
[6]   Xu Yan.2019.Science & Technology Ecnony Market. 415.1:14-16.
[7]   Iván Moyano.2016. Mathematics of Control, Signals, and Systems. Vol.28 (4)