A New Design of the Vehicle Detection System for Measuring Outline Size

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Keywords: dimension parameters, sensor; laser screen, upper-computer; vehicle, controller

Abstract. Vehicle dimensions parameters is an important part of vehicle trafficability parameters and vehicle operation safety testing. In order to measure the dimension parameters accurately, a new vehicle dimensions detection system which based on laser screen, ultrasonic sensor, and upper-computer control software is designed. It designs and debugs the system's hardware and software, and sets up test line, and the developed system is verified. Experimental results show that the system can detect the different models of vehicle dimensions with high accuracy, non-contact, automated testing, have the characteristic of stabilization, credibility, and error of calculation is lower than 1%.It solves the problem of high intensity of labor, inefficiency, and human error, which caused by China's vehicle testing institution to test vehicle outline dimension manually.

Introduction

In recent years, vehicle overload has been one of the reasons for road traffic accident, which shortens the life span of road and bridge and affects national property and human life security severely [1-5]. Road Vehicle Dimension, Axle Load and Quality Limit **(**GB1589O2004**),** state mandatory standard, aiming to govern oversize and overload from source has been come into effect on Oct. 1, 2014[6-8];Vehicle structure cannot be transformed arbitrarily in the test item of the overall vehicle of Operation Vehicle Comprehensive Property Requirement And Test Method (GB18565O2001) on Jun. 1, 2009, it raises new requirement of some technical parameters like dimension of motor vehicle and requires checking and examining dimension of motor vehicle strictly[9,10]. At present, the measurement of vehicle dimension by our country testing organization mainly use steel tape, angle ruler and maker post for manual measurement, the vehicle must remain stable with great labor intensity, low efficiency and big personal error, which cannot adapt to automatic detection or complete non-contact automatic measurement[11]. Therefore, studying vehicle dimension parameter non-contact quick test system, achieving correct measurement of dimension parameter of vehicle and providing an advanced vehicle dimension test method will have significance on governing oversize and overload from source so as to improve traffic safety.

Measuring principle

Dimension of vehicle includes length, width and height. Tie optoelectronic scanning technique with ultrasonic ranging technique and actual test task by using distributive control technology and advanced sensor. Combined with crafty mechanical structure, control working state of photoelectric sensor and ultrasonic sensor and collecting signal of sensor through singlechip to realize automatic, rapid, high precise and non-contact measurement of automobile dimension. Stereo structure of system is shown in the Fig. 1, T_1-T_{18} in the Figure is 18 pairs of laser screen, used for measure length of vehicle; install 6 ultrasonic distance measuring sensors on both sides of portal frame for measuring width of vehicle; install 3 ultrasonic distance measuring sensors on top of portal frame, used for measuring height of vehicle. The vehicle size range of device measuring is 2.2m<length<14.2m (length of vehicle is basically larger than 2.2m), width <5m, height <5m, and measurement of larger size of vehicle can be expanded on this basis.

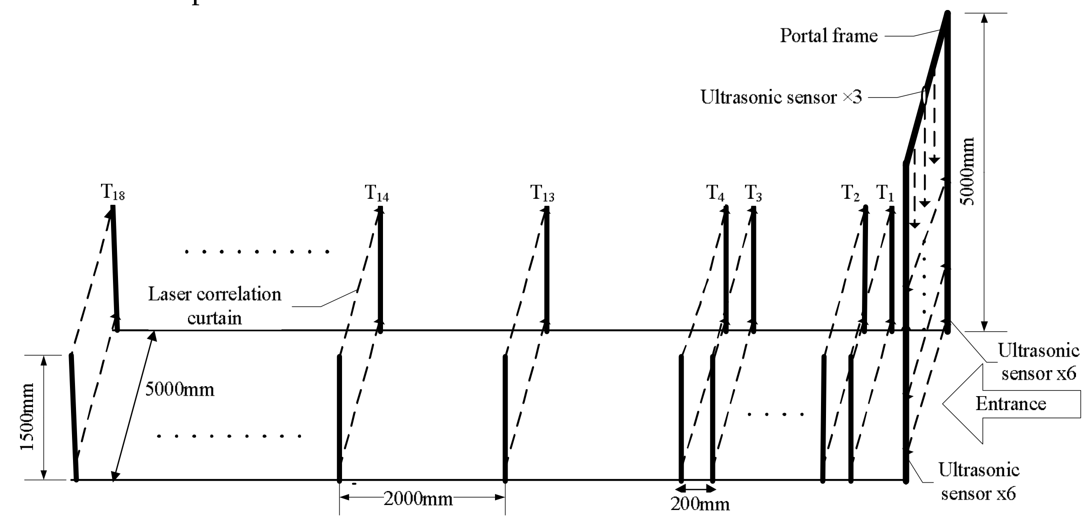

Fig.1 A perspective diagram of the system

Measuring principle of length.Length measurement mainly uses laser correlation light curtain. As is shown in the Fig. 1, $T_1 - T_{18}$ is 18 pairs of laser light screen, the space between adjacent light screens for the former 12 pairs $T_1 - T_{12}$ is l_1=20mm, the space between adjacent light screens for $T_{13} - T_{18}$ is l_2=2000mm. Figure 2 is the vertical view of 4 key states of measuring vehicle length by using laser light screen, the dotted arrow is laser projected by laser light curtain, the shadow is vehicle for testing. We can see from the state in Figure 2, The length of the vehicle to be measured . The value of the initial value is determined by the state 3 and state 2 in Figure 1.

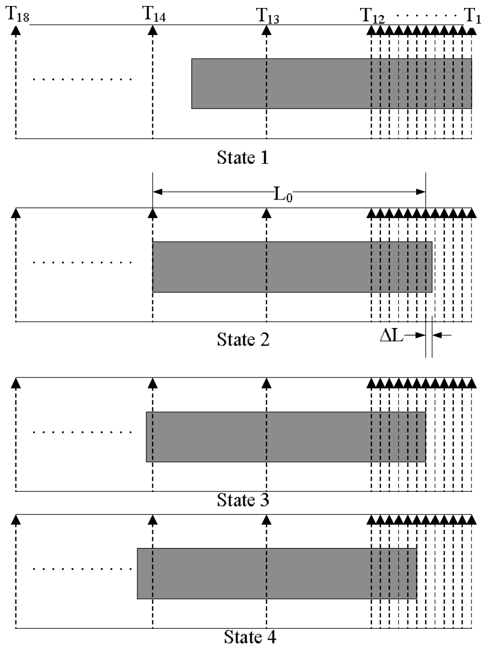

Fig. 2 Top view of key states for Length measuring

When vehicle to be tested drives into measurement area from entrance, when there is no obstacle among correlation light curtain, light curtain output signal N_i (i=1,2,……18)is at high level, otherwise the output signal N_i (i=1,2,……18) is at low level, the measurement calculation method is as follows:

(1) When vehicle to be tested enters length measurement area exactly, that is tail of vehicle has entered just in time, as is shown in state 1 of Figure 2, calculate algebraic sum of output signal by

laser light curtain $T_{13}-T_{18}$, $l_1=\sum_{i=13}^{18} N_i$, that is to calculate how many pairs of light curtain is blocked by vehicle.

(2) When vehicle to be tested blocks new laser light curtain of $T_{13}-T_{18}$, that is $\sum_{i=13}^{18} N_i = l_1 - 1$, as is shown in state 2 of Fig. 2, start timing device, calculate algebraic sum of output signal by laser light curtain T_1-T_{12}, $l_2=\sum_{i=1}^{12} N_i$ .that is how many pairs of light curtain are blocked by vehicle. Because the fixed space of laser light curtain $T_{13}-T_{18}$ is 2000mm, and the fixed space of laser light curtain T_1-T_{12} is 200mm, the length initial value of vehicle to be tested $L_0=((7-l_1)\times 2000+(11-l_2)\times 200)mm$.

(3) Since we have measured initial value of vehicle to be tested L_0, as long as we confirm the value of ΔL, we can calculate the length of vehicle to be tested, the value of ΔL is determined through state 3 and state 4 in Figure 2. Measuring principle is that 200mm short distance will be seemed as constant motion of vehicle. When vehicle continues driving the distance of ΔL as far as the new light curtain released in T_1-T_{12}, that is $\sum_{i=1}^{12} N_i = l_2 + 1$, as is shown in state 3 of Fig. 2. Set the time of reading timing device as Δt_1, at the same time, restart timing device again, thus Δt_1 is the wasting time of running ΔL by vehicle.

(4) When vehicle continues to drive 200mm, release new light curtain of T_1-T_{12} again, that is $\sum_{i=1}^{12} N_i = l_2 + 2$, as is shown in state 4 of Fig. 2, set the time of reading timing device as Δt_2, thus Δt_2 is running time of 200mm by vehicle. For it’s within 200mm of short distance, it can be seemed as constant driving, so $\Delta L \approx (200/\Delta t_2 \times \Delta t_1)mm$.

(5) Thus, length measured value of vehicle to be tested $L=(L_0+\Delta L)mm$.

Measuring principle of width and height. As is shown in Fig. 1, 6 ultrasonic sensors on both sides of portal frame are installer. Of them, $W_{L1}-W_{L6}$ are on left side and $W_{R1}-W_{R6}$ are on right side, used for measuring width of vehicles; three ultrasonic sensors installed on the top of portal frame H_1-H_3 is used for measuring height of vehicle. Since projection of ultrasonic sensor has certain angle, proper distribution of ultrasonic sensor can block width and height of the overall vehicle to be tested. The width of portal frame is 5000mm and the height is 5000mm.

When vehicle to be tested passes by portal frame, ultrasonic sensor will scan width and height of vehicle. 6 ultrasonic sensors on left side of portal frame will compare data measured after many times and get a minimum value WLmin, and the same for the right side for WRmin. Then, width of vehicle to be tested is $W=(5000-W_{L\min}-W_{R\min})mm$. 3 ultrasonic sensor at the direction of height will compare multiple groups of data and get a minimum value $W=(5000-W_{L\min}-W_{R\min})mm$, thus the height of vehicle to be test is $H=(5000-H_{\min})mm$.

Structure of measuring system

The system is mainly made up of laser curtain, ultrasonic sensor, LED display screen, length controller, width and height controller, voice controller and upper computer, etc. using RS485 bus for communication. Length, width and height controller all use STM32F103 as controller. 18 signal processing circuits are set in length controller, which transform theoutput signal of laser light curtain into binary signal to be identified by singlechip, used for judging whether there is obstacle among correlation light curtains. Width and height control panel includes 15 ultrasonic sensor drive circuits, the measurement preciseness of ultrasonic sensor reaches 1mm, blinding area is 20mm, and has temperature compensation function, the detective distance is 20mm-6000mm. voice controller is made up of segment type voice chip, there are 82 segments of voice message stored in the voice chip (including 0-9, A-Z, short name of each province, etc.). According to the command of upper computer, LED display curtain controlling 192*64point will display the hint information of measurement and result. Composition structure of measurement system is as shown in Fig. 3.

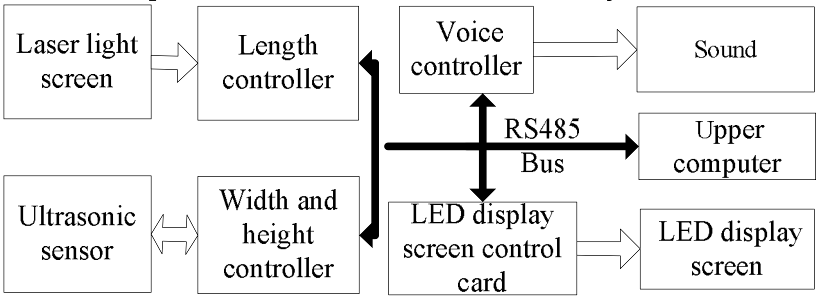

Fig. 3 Block diagram of the system

Software design of measuring system

Upper computer is written by Visual C++ software, coordinate and control the work of lower computer. When lower computer receives the command of starting sent from upper computer, it will be in measuring state. After measuring, it will send the data to upper computer. Upper computer will compare the measured data with standard data in database, and then send the measurement result and related information whether it is qualified to display screen for display and voice controller for report. When width controller receives the command of starting, it will start ultrasonic sensor. If the measured distance of height ultrasonic sensor is bigger than 5m, it indicates the vehicle enters width and height measurement area, start width and height measurement program to measure width and height. Ultrasonic sensor will scan the moving vehicle at the direction of width and height, and compare each measured result with the previous one and save the minimum value H_{min} at last; install 6 sensors on both sides at the direction of width. Compare six measured values of each sides and get a minimum value, compare it with the previous minimum value and save the minimum W_{Lmin} and W_{Rmin}. If remeasured value of height ultrasonic sensor is the distance from ground, it indicates the end of width and height measurement, calculate measured result and send it to upper computer, width $W = (5000 - W_{L\min} - W_{R\min})mm$, height $H = (5000 - H_{\min})mm$.

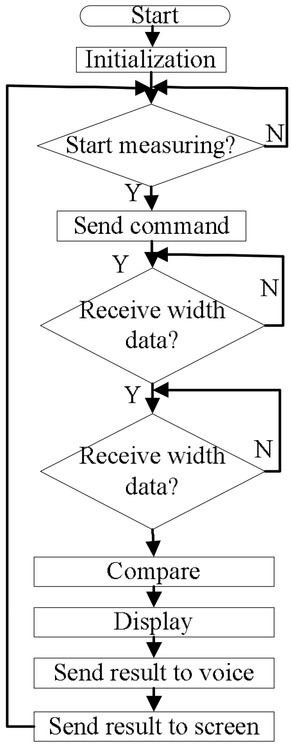

Fig. 4 Flowchart of program for upper-computer

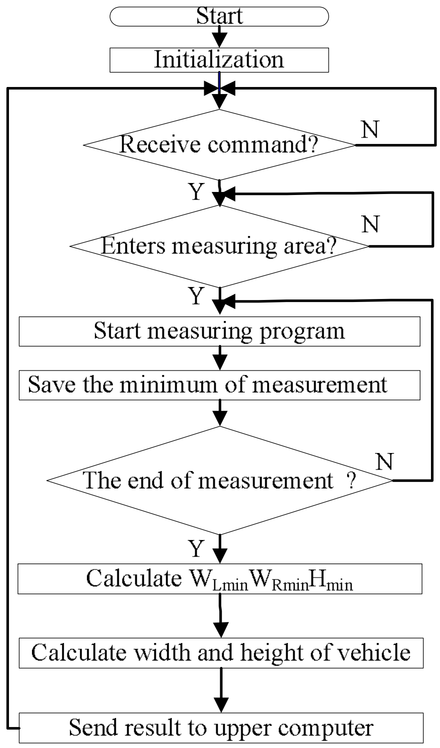

Fig.5 Flowchart of program for measuring width and height

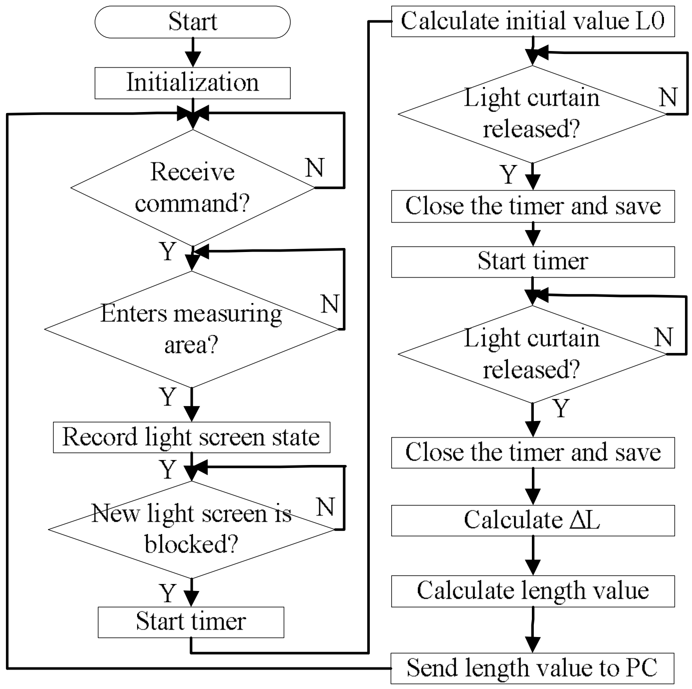

Fig.6 Flowchart of program for measuring length

After length controller receives the command of starting, it will start the function of length measurement. When T1 light curtain is blocked, it indicates vehicle has entered measurement area, when T1 is released, in indicates tail of vehicle has entered, that is, vehicle has entered length measurement area completely, record light curtain state at that time (which light curtains are blocked by vehicle). When the moving vehicle blocks new light curtain, start timer, calculate length initial value L_0, according to the state of light curtain and space of light curtains. When there are light curtains released, close timer, calculate timing time Δt1 , and start timer again. When there are light curtain released again, close timer, calculate timing time Δt2, then $\Delta L \approx (200/\Delta t_2)\times\Delta t_1$ mm, vehicle length $L=(L_0+\Delta L)mm$, send length to upper computer and measurement is over. system software diagram is shown in the Fig.4, Fig.5 and Fig.6.

Measuring test

In order to verify the measurement preciseness of system against different types of vehicle and stability of system, test device is installed in local vehicle testing organization, which guarantees the need of test for all kinds of vehicles. Test platform is as shown in Fig.7. because it's at test stage, use plastic film to cover key areas for waterproofing. There will be inevitably mechanical error during device installation. It will be corrected by measuring distance of light curtains, height and width of portal frame and software.

Test chooses three different types of automobile, small car, middle-size car and large car. Each car is tested for three times continuously, the speed is controlled within 10Km/h, and measured data is as shown in Table 1. It calculates comparative error and standard error of measured data of each vehicle type, and verifies measurement preciseness and stability of system. We can see from the measured data, the bigger the vehicle dimension is, the smaller the comparative error is; we can see from standard error, the discreteness and volatility of measured data is small, and the stability is good.

Error analysis of length measurement: mechanical error of length measurement has been corrected by software. From measurement principle, length measurement error mainly focus on the measurement of ΔL, $|\Delta L| \approx |(200/\Delta t_2)\times\Delta t_1| \le 200mm$, only when $\Delta t_1=\infty$ or $\Delta t_2=\infty$, that is when vehicle is in state 2 or state 3 of stop for a long time as is shown in the picture, the measured error is big, the maximum of absolute error is 200mm. As long as vehicle drives normally, the error is small, for it can be seen as constant driving within short distance.

Width and height measurement error analysis: the preciseness of ultrasonic sensor is 1mm, spreading speed of ultrasonic is V_c, the speed of vehicle to be tested is V_{car}, width of vehicle to be tested is W, height is H, and the scanning space of ultrasonic sensor at the direction of width $\Delta W=((5-W)/2V_c\times 2\times V_{car})m$, the scanning space of ultrasonic sensor at the direction of height $\Delta H=((5-H)/V_c\times 2\times V_{car})m$, spreading speed of ultrasonic V_c=340m/s, the small the dimension of width and height of vehicle, the farer from ultrasonic sensor, and the bigger the scanning space is. Suppose the minimum width dimension of vehicle is 2m, the minimum height dimension of vehicle is 1.5m, speed of vehicle to be tested doesn't exceed 10km/h, that is V_{car} =2.78m/s, thus $\Delta W=0.024m$, $\Delta H=0.057m$. Measure data for one time at width direction when maximum space is 0.024m, Measure data for one time at height direction when maximum space is 0.057m. This is the main reason for width error and height error. Reducing speed properly can increase preciseness of measurement.

Fig. 7 Experimental platforms

Table1 Measurement data of overall dimensions for the vehicle detection system

Vehicle model	demension	Standard value (mm)	Measured result (3 times mm)	Comparative error (%)	Standard deviation
VW POLO	Length	3970	3981 3986 3991	0.27 0.40 0.53	4.08
	Width	1682	1680 1690 1689	0.12 0.48 0.42	4.50
	Height	1462	1470 1458 1469	0.55 0.27 0.48	5.44
JAC Sunray	Length	5990	5995 5998 6003	0.08 0.13 0.22	3.30
	Width	2098	2101 2095 2092	0.14 0.14 0.29	3.74
	Height	2645	2646 2659 2656	0.04 0.53 0.42	5.56
Taihu bus	Length	11980	11992 11989 11998	0.10 0.08 0.16	3.74
	Width	2500	2512 2510 2507	0.48 0.40 0.28	2.05
	Height	3650	3655 3662 3660	0. 14 0.33 0.27	2.94

Conclusions

Vehicle dimension testing system realizes non-contact automatic measurement, overcomes a lot of problems of great labor intensity, low efficiency, personal error caused by using steel tape, angle rule and marker post to test vehicle dimensions in our country vehicle testing organization. Through measuring test of various vehicles, we can see from the testing data that, this system is of high preciseness, stability and reliability and to the requirement of state.

Acknowledgment

This project is supported by the Science and Technology Project of Anhui Province (1501031114), the Revitalization Plan Project of Anhui Province(2013zytz041). We would like to thank the sponsors.

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