ICIC Express Letters
Part B: Applications
Volume **9**, Number **8**, August **2018**

ICIC International ©2018 ISSN 2185-2766
pp. **819–826**

DATA ACQUISITION AND PROCESSING OF DRIVING OPERATION SYSTEM FOR VEHICLE DYNAMICS SIMULATION

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Received February 2018; accepted May 2018

Abstract. *In order to extract more accurate driver's operation data in the process of vehicle dynamics simulation and transmit the real-time data to the 3D driving scene of the vehicle, the driving operation data acquisition system is designed and developed. The linear displacement sensor is used to collect the travel of the three pedals, the angular displacement sensor is used to collect the steering angle of steering wheel, and the position of the transmission joystick is acquired by the photoelectric coupler. Meanwhile, through the serial communication, the information interaction is realized between the acquired data and the vehicle dynamics model. The experimental results show that the designed driving operation data acquisition system has an accurate detection result, and works reliably.*

Keywords: Driving operation system, Data acquisition, Serial communication

1. **Introduction.** In recent years, with the rapid development of virtual reality technology, a powerful assist for the vehicle virtual reality test technology is provided. At present, the vehicle dynamics simulation technology based on virtual reality has been widely used in the field of automobile product design, virtual manufacturing and vehicle experiment, etc. It can also be used to optimize the design of road line and applied to the driving behavior analysis of vehicle drivers [1]. How to realize the real-time dynamic data acquisition of the status and parameters during the vehicle running is the key issue of the real-time vehicle dynamic simulation system. There are several data acquisition methods based on the programmable logic controller [2], the data acquisition card [3], and the controller area network bus [4], etc. The method based on the programmable logic controller has high cost and a large size. Also the method based on the data acquisition card has high cost and a limited interface. For the controller area network bus method, its hardware structure is complex and its applicability is not wide. Therefore, in order to solve the deficiency of the above methods, a new method combining the single chip microcomputer and the multi-sensor is proposed in the paper. The system developed in the paper has a small size and low cost. Besides, it can also capture the driver's various operation signals in real time.

Only the driver's various operation signals are collected in real time, accurately and reliably, and then the collected signals are processed and passed to the central control unit, the vehicle dynamics model can be used to calculate the instantaneous position and attitude data of the vehicle. Moreover, it is convenient to analyze and evaluate the performance of the driver-vehicle-driving environment closed-loop system.

For the paper, first of all, the hardware structure of the driving operation system is introduced. Then the analog signal data and the switch signal data are acquired and processed through the corresponding sensors, respectively. Meanwhile, the information

DOI: 10.24507/icicelb.09.08.819

interaction module of driving operation system is constructed through the serial communication. At last, the experiment of the data acquisition and processing of driving operation system is performed with the related algorithm proposed in the paper.

2. **Hardware Structure of the Driving Operation System.** In order to reflect the vehicle driving attitude under the driver's operation behavior as accurately as possible, the vehicle real time dynamic simulation system is mainly composed of driving operation system, vehicle dynamics model and 3D scene system. The main work of the driving operation system is to collect and process the driver's operation data. The processed data is transferred to a system based on the VC++ software through serial communication technology, displayed and calibrated in real time and then is converted to the corresponding vehicle parameters. Finally, these parameters are inputted to the vehicle dynamics model to achieve the reappearing of the vehicle's attitude in the 3D scene system. The working principle of the vehicle real-time dynamic simulation system is as shown in Figure 1.

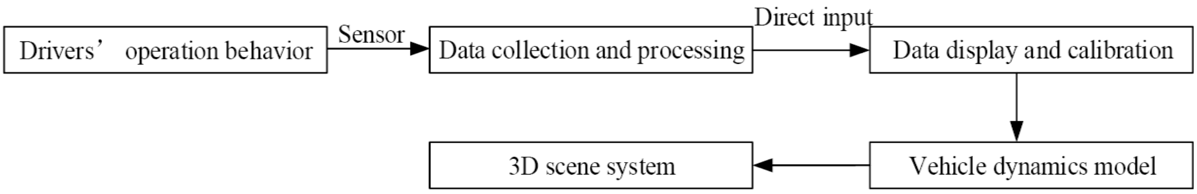


FIGURE 1. Working principle diagram of vehicle real-time dynamic simulation system

The driving operation system is an important part of vehicle real-time dynamic simulation system. In order to reappear driver's operation behavior accurately and decrease the complexity of the entire operating system, the driving control system in this paper is mainly composed of three parts: steering wheel assembly, three pedal assembly (accelerator pedal, brake pedal, clutch pedal), and transmission joystick assembly. The operator controls the current speed and other parameters through the accelerator pedal and brake pedal, also controls the wheel angle parameters through the steering wheel. The 3D scene simulation system will calculate the current position and driving attitude according to the vehicle dynamics model, and alter the car position and the operator's point of view in the scene based on the related data. Figure 2 shows the hardware structure of the driving operation system.

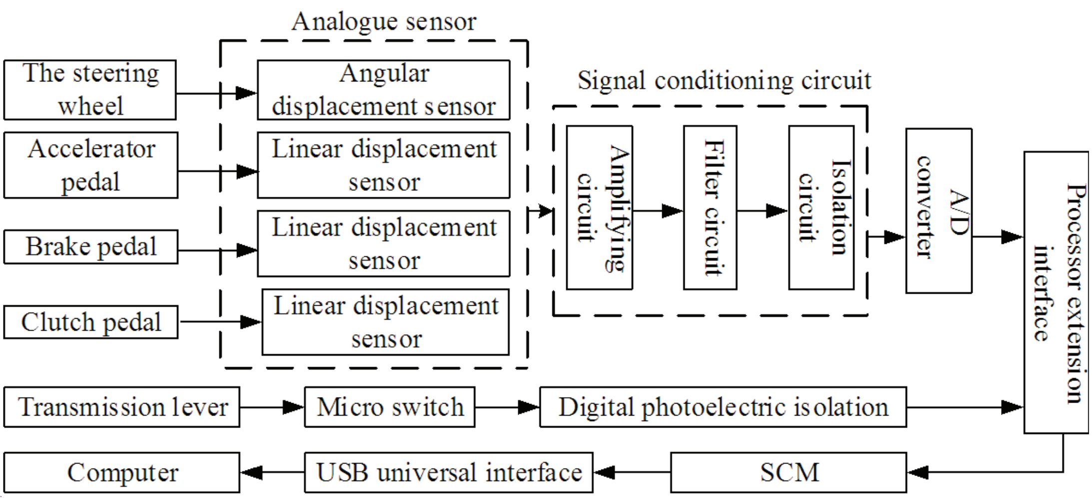


FIGURE 2. Hardware structure diagram of driving operation system

3. Data Acquisition and Processing of the Driving Operation System.

3.1. Data acquisition and processing of the analog signal. The driving operation system needs to detect the signals of the various operating parts. As a result, these signals are divided into analog signals and switching signals according to the different sensors used [5]. The displacement travel signal of the accelerator pedal, clutch pedal, brake pedal and the steering wheel angle signal are generated due to the movement of the driving operation mechanism, straight or rotate, which also determines that these signals are not only two states as the switch value, but a continuous process. The pedal travel of the accelerator pedal, clutch pedal and brake pedal represent the amount of the fuel supply, the level of the clutch engagement and the amount of the braking force, respectively. Due to the requirement of anti-interference ability during the analog signals collection, the linear displacement sensor is designed to connect with the three pedals mechanism. Therefore, the resistance change characteristics of the linear displacement sensor can accurately reflect the amount of the three pedals' stroke.

Combined with the pedal travel, after the signal of the linear displacement sensor is collected, several equidistant measurement points are selected to calibrate. On the basis of the measured data, the formula is fitted to obtain the linear relationship between the pedal displacement and the sensor voltage value. Table 1 shows the measurement data, and the fitted curve of the linear displacement sensor with accelerator pedal is as shown in Figure 3. Moreover, the relationship between the linear displacement of the accelerator pedal and the voltage is shown as follows,

$$L_{acc} = 13.25 \times U + 6.301 \tag{1}$$

Table 1. Calibration parameters of the linear displacement sensor with accelerator pedal

Linear displacement (mm)	0	15	30	45	60	75	90	105	120	135
Voltage value (V)	0	1.18	1.42	2.45	3.45	5.5	6.45	7.44	8.75	9.78

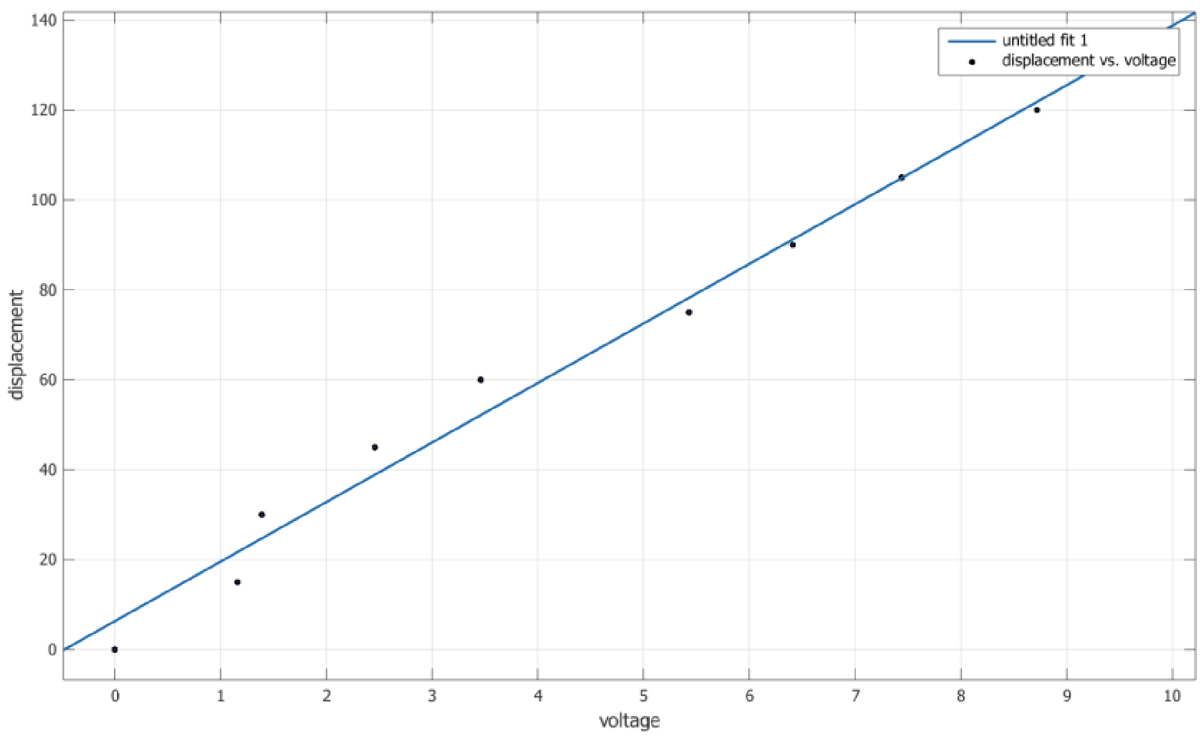


Figure 3. Fitted curve of the linear displacement and the voltage

The basic measurement unit of the steering wheel angular displacement sensor is composed of brush and resistor. In general, the adjustable resistance is fixed on the sensor housing, and the resistance of the brush is changed by moving the position of the brush on the resistor. When the rail is connected to the steady-state DC, the potentiometer can convert the mechanical displacement value into the electrical signals. Equation (2) and Equation (3) show the relationship among the resistance, voltage and angle.

$$R_a = R_{\max} \cdot \frac{a}{a_{\max}} \tag{2}$$

$$U_a = U_{\max} \cdot \frac{a}{a_{\max}} \tag{3}$$

where $a_{\max}$ represents the maximum measurement angle, $R_{\max}$ is the maximum resistance of the precision potentiometer angular displacement sensor, $U_{\max}$ is the maximum voltage of the precision potentiometer angular displacement sensor, and U_a is the voltage output of the precision potentiometer angular displacement sensor.

The function expression of the voltage and the steering angle can be fitted through calibrating the voltage value and the steering wheel angle. The relationship between the steering wheel angular displacement and the voltage is shown as follows,

$$\theta = -13.44 \times U^2 - 35.14 \times U + 725.60 \tag{4}$$

where θ is the steering wheel angular displacement, and U represents the output voltage.

The fitted curve of the steering wheel angular displacement and the output voltage is as shown in Figure 4. Figure 5 shows the pulse sequence produced in the sensor circuit during the steering wheel working with clockwise and anticlockwise, the rotation direction of the steering wheel can be determined according to the pulse sequence order of sensors A and B.

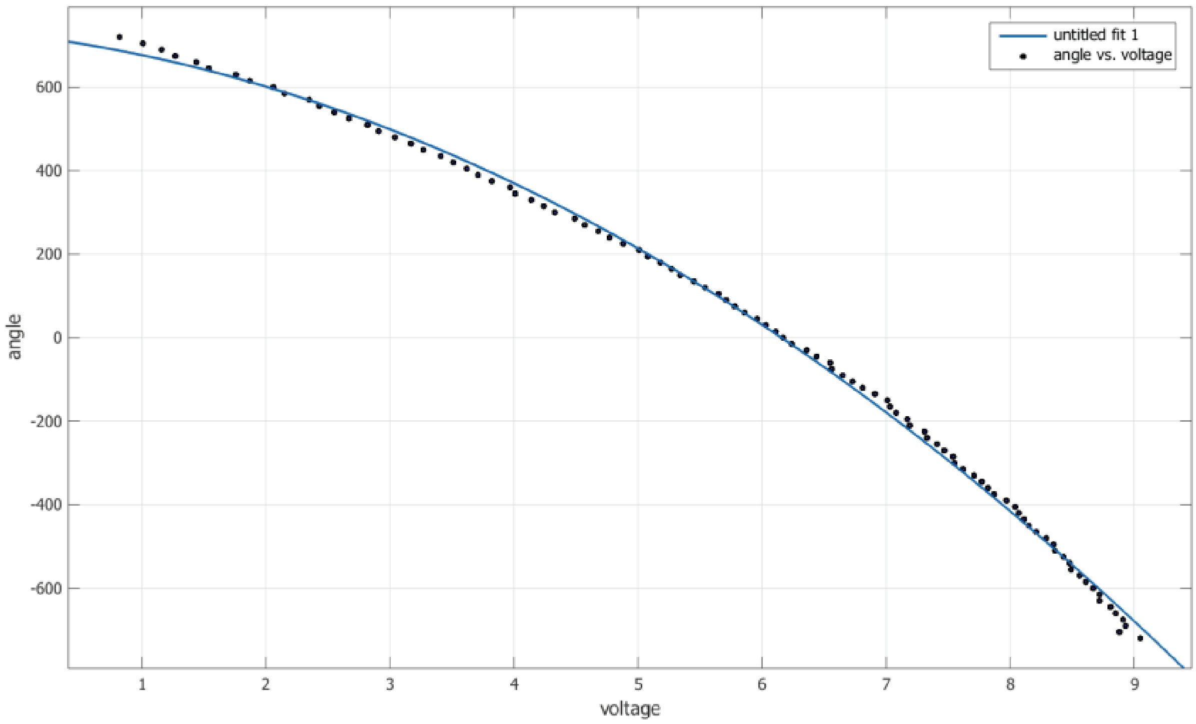
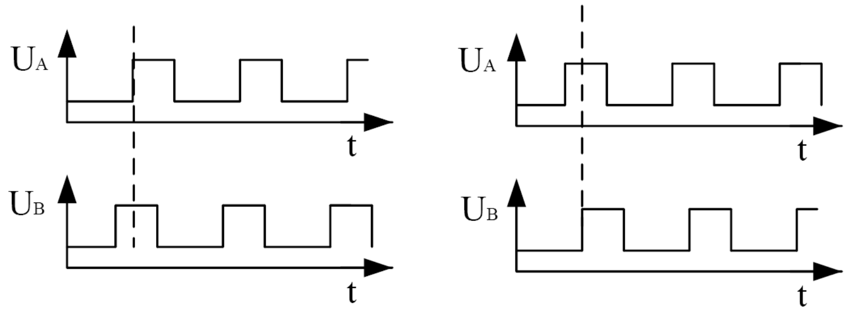


Figure 4. Fitted curve of the steering wheel angular displacement and the output voltage



(a) Sensor output pulse in clockwise (b) Sensor output pulse in anticlockwise

Figure 5. Direction detection of the steering wheel

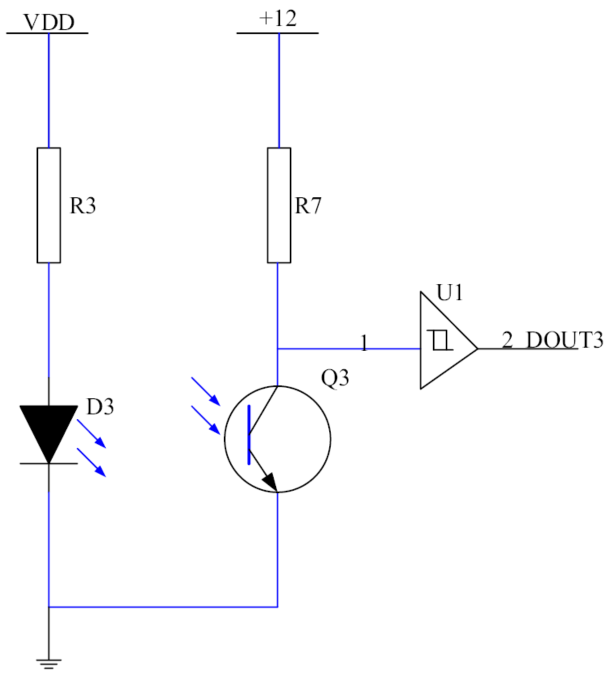


Figure 6. Gear level acquisition circuit

3.2. **Data acquisition and processing of the switch signal.** Since the shift lever position only changes suddenly during the shifting gear, and each gear has only "yes" or "no" state, the switch detection component is used to complete the gear signal acquisition. As the photoelectric coupler has characteristics of input isolation, output isolation, and anti-interference, the photoelectric coupler composed of the IR908-7C light-emitting diode and PT908-7C photosensitive transistor is used to capture the gear level. The principle of the collector circuit is as shown in Figure 6.

During the detection, the light-emitting diodes and photosensitive transistors are installed in the shift lever with symmetrical installation on both sides of the gear. The electrical signal applied to the light-emitting diode is used as the input signal, and the generation light is transmitted to the photosensitive transistor, so the reverse output signal is generated by the U1 inverter. Due to the obstruction of transmission operation lever, when putting into the gear, the photosensitive transistor cannot receive the light signal of the light-emitting diode, so the transistor is cut-off. Through detecting the output of the photoelectric coupler is in high or low level, the gear level can be determined.

4. **Information Interaction Module of Driving Operation System.** In order to achieve the real-time reappearance of the vehicle's attitude in the 3D scene system, the

driving operation data must be passed into the vehicle dynamics model. The driving operation data collected by the ATMEGA16 processor exchanges with the computer through the serial communication [6]. When the information passed through the serial communication, the baud rate must be set in the same, and the baud rate is usually 300, 600, 900, 1200, 9600, 38400 bps, etc. With the baud rate increase, the interference level by the signal is greater, and the transfer rate of the serial port will be limited. After several experimental tests, the interaction status of driving operation data is best when the baud rate is selected as 9600 bps. The algorithm design of the information interaction module based on the serial communication protocol is shown in Figure 7. Here, SCIDR stands for Serial Communication Interface Data Register, and RDRF stands for Receive Data Register Flag.

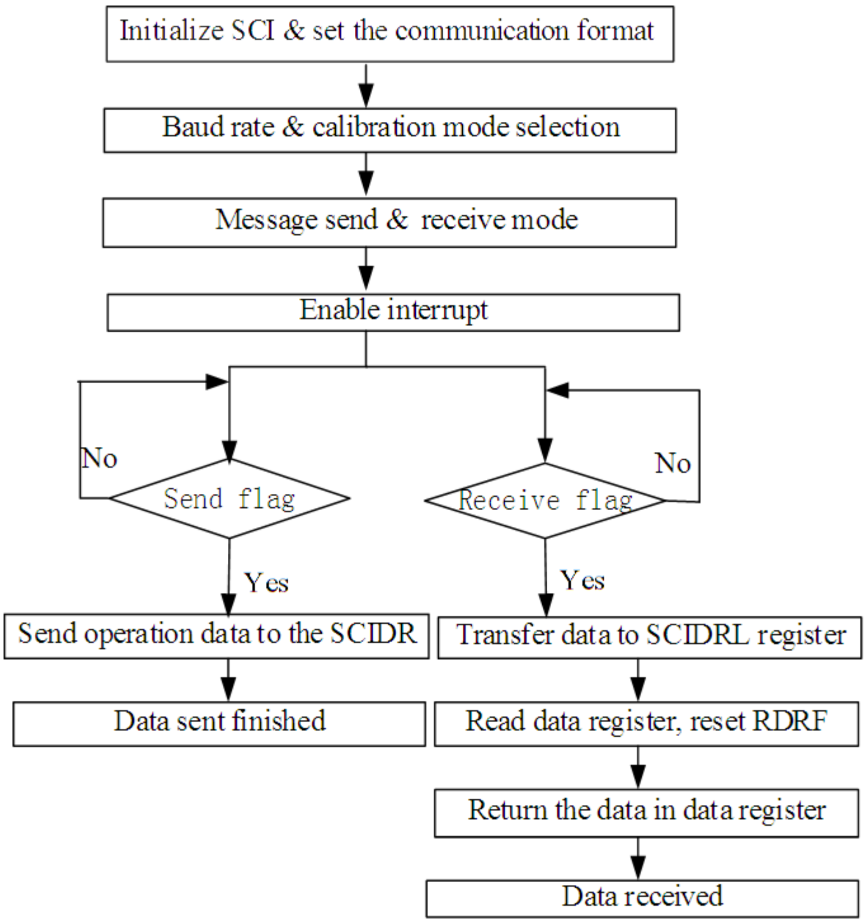
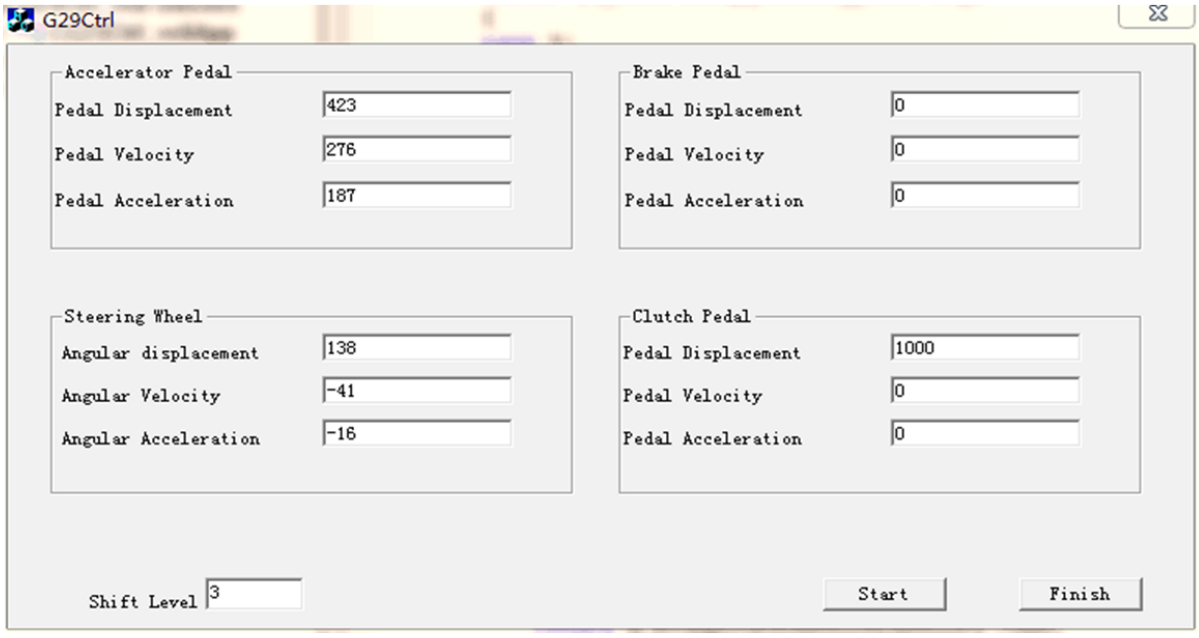
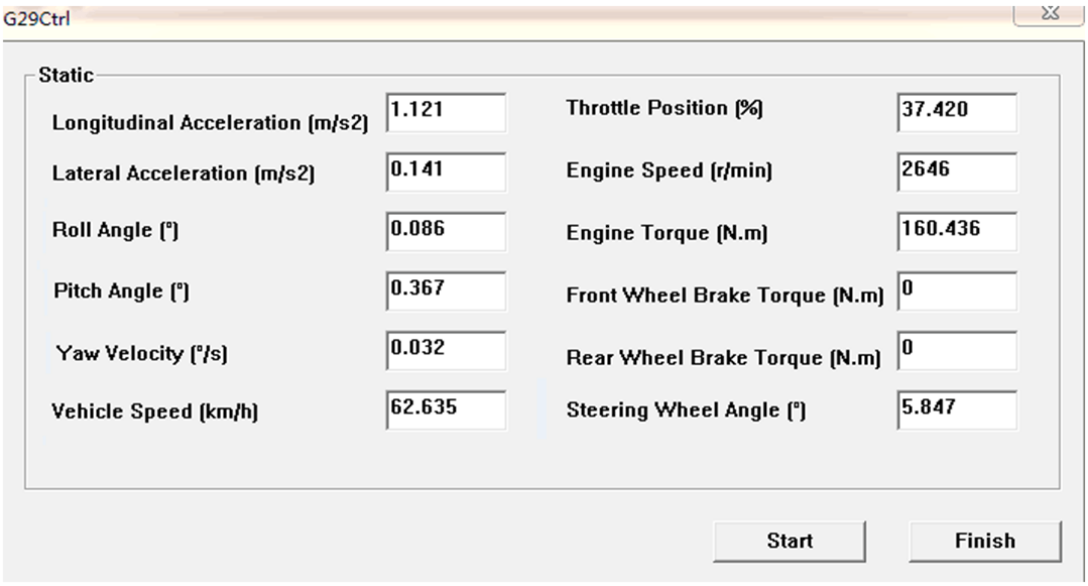


FIGURE 7. Algorithm design of the driving operation information interaction

5. **Experimental Test.** In order to test the effectiveness of the hardware structure of the driving operation system and the related algorithm proposed in this paper, experiment under real operation environment was done. Moreover, on the basis of the VC++6.0 software, the driving operation data acquisition system is developed. Part of the data acquisition result during the experimental test is shown in Figure 8. For Figure 8(a), the original data output interface is divided into four parts, that is, accelerate pedal parameters, brake pedal parameters, steering wheel parameters, and clutch pedal parameters. When the vehicle speeds up, the data output interface in Figure 8(a) can get the parameter values of the pedal displacement, pedal velocity, pedal acceleration, angular displacement, angular velocity, and angular acceleration. Some dynamics data can be got in Figure 8(b) after calibration and processing of the vehicle dynamics model, such as, vehicle speed, throttle position, engine speed, engine torque, longitudinal acceleration, roll



(a) Acceleration operation original data output



(b) Acceleration operation dynamics data output

Figure 8. Data acquisition result of the driving operation system

angle, pitch angle, yaw velocity, steering wheel angle, front and rear wheel brake torque. Therefore, the driving status parameters and the vehicle trace can be obtained with the above dynamics data.

Compared with other existing methods, the system developed in the paper has some technical merits, such as a small size of 10×10 cm^2, and low cost of 200 dollars. Besides, it can capture the driver's various operation signals in real time, and reliably.

6. **Conclusions.** The developed driving operation data acquisition and processing system can capture the driver's operation data accurately, and the function relation between the mechanical displacement and electric signal output can be established by the calibration. In addition, the driving operation information interaction module based on the serial communication protocol is designed to achieve the parameter transfer between the vehicle operation data and the vehicle dynamics simulation model. The experimental

result shows that the proposed driving operation data acquisition system has a higher measurement precision; it also can meet the basic needs of the driver's driving behavior analysis and the road design evaluation. For further studies, more road environmental factors must be considered to optimize system performance.

Acknowledgment. This work is partially supported by the Fundamental Research Funds for the Central Universities (No. 310822171116 and No. 310822171001). The authors also gratefully acknowledge the helpful comments and suggestions of the reviewers, which have improved the presentation.

REFERENCES

[1] R. G. Radwin, J. D. Lee and O. Akkas, Driver movement patterns indicate distraction and engagement, *Human Factors*, vol.59, no.5, pp.844-860, 2017.
[2] S. Dominic, Y. Lohr, A. Schwung and S. X. Ding, PLC-based real-time realization of flatness-based feedforward control for industrial compression systems, *IEEE Trans. Industrial Electronics*, vol.64, no.2, pp.1323-1331, 2017.
[3] Y. Zhang, J. Shao, G. Chen, J. Zhao and Q. Luo, Design of vehicle driving simulator data acquisition and control system, *Microprocessors*, no.1, pp.91-95, 2017.
[4] Y. Wang and G. Li, Development of driving simulator hardware in the loop brake test bench, *Automobile Applied Technology*, no.12, pp.147-150, 2016.
[5] S. Muhlbacher-Karrer, A. H. Mosa, L. M. Faller, M. Ali, R. Hamid, H. Zang and K. Kyamakya, A driver state detection system-combining a capacitive hand detection sensor with physiological sensors, *IEEE Trans. Instrumentation and Measurement*, vol.66, no.4, pp.624-636, 2017.
[6] Y. Liu, B. Xu and Y. Ding, Convergence analysis of cooperative braking control for interconnected vehicle systems, *IEEE Trans. Intelligent Transportation Systems*, vol.18, no.7, pp.1894-1906, 2017.