

## Research Article

# Algorithm Design of Early Warning Seatbelt Intelligent Adjustment System Based on Neural Network and Big Data Analysis

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With the purpose to guarantee the safety of drivers and passengers as well as lower the death rate collision, the early warning seatbelt intelligent adjustment system is designed by using big data analysis technology based on the aspects of hardware equipment, database, and software program. In the hardware system, microcontroller AT89C52 is applied as the control core. By means of the sensor detection and drive control, the early warning safety belt tightening, locking and lifting, and other functions are realized. Meanwhile, various components of the hardware system are coordinated through debugging several modules in the hardware system and using the modified circuit to connect them together. We determine the relational rules of the database and create the corresponding database table, to provide sufficient data support for the realization of software functions. Using the big data analysis method to process the real-time detection data received by the sensor, the software functions such as timely tightening of safety belt, humidity relaxation, and over-rolling prevention can be realized according to different driving conditions of drivers and vehicles, respectively. The conclusion is drawn through the system test experiment: compared with the traditional regulation system, the design system has a higher degree of regulation, and the application of the design results to the actual vehicle can reduce the crash fatality rate of about 22.4%.

## 1. Introduction

Traffic safety has always been a hot issue in people's daily life, so the safety insurance intelligent devices such as ABS and airbags are mounted in automobiles during recent years. Thanks to the greatly improved active and passive safety of automobiles, the number of deaths and death rates of car accidents in many developed countries have decreased despite the increasing number of cars. This shows that advanced safety technology can obtain obvious application effects. In order to ensure that the early warning seatbelt can maximize its protection role in car accident, a corresponding intelligent adjustment system shall be established, whose function is to control the working state and force limitation of the early warning seatbelt and then form a force buffer for the driver. Based on the background that research on the early warning

seatbelt intelligent adjustment system is in its initial stage without achieving any breakthrough results, this paper designs the corresponding early warning seatbelt intelligent adjustment system through big data analysis [1]. Characterized by large amount of data, fast speed, multiple types, high value, and strong authenticity, big data analysis refers to the analysis of large-scale data [2]. In this system design, big data analysis technology is mainly applied to the database and software functions as a method for processing and analyzing the initial collected data [3], so that the efficiency of system regulation function is enhanced. The design of intelligent adjustment system not only enables the traditional early warning seatbelt to play its role in the event of an accident but also can fully protect the driver and passengers during the entire driving process, thereby improving the safety factor of automobile [4].

## 2. Hardware of Early Warning Seatbelt Intelligent Adjustment System

The hardware of early warning seatbelt intelligent adjustment system can be divided into four parts: control module, data acquisition module, drive module, and terminal module. These four modules are connected together after modification [5]. The structural connection and distribution of the hardware system are shown in Figure 1.

**2.1. Circuit Module.** The circuit module is to connect the hardware devices in the hardware system and provide stable voltage for each module so as to ensure the normal operation of hardware system [6].

**2.1.1. Power Circuit.** The MC9S12XS128 chip, as the core component of power circuit, can realize direct power supply of 12 V automotive DC power supplies through connecting the fuse F1 to the power supply chip. By virtue of the working peak value at 750 mA, this chip can improve the power circuit better than traditional hardware system and avoid the loss of the whole hardware system circuit caused by circuit load. It is also necessary to insert a conversion chip in the power circuit to meet the voltage requirements of different hardware modules. The selected conversion chip is LM2940. In addition, a capacitor appliance, which includes two resistance devices, shall be installed in the power circuit to stabilize and decompose the voltage.

**2.1.2. Step-Down Conversion Circuit.** In general, the output voltage of automobile power circuit is 24 V, which can be adjusted via a conversion chip. Such chip can only convert the output voltage into one voltage, but the voltage required by different devices in the hardware system is not fixed, as shown in Table 1.

The step-down conversion circuit can be realized in two steps. First, the 24 V output by the power supply circuit is converted into a 5 V, and then it is converted into 3.3 V. The process of realizing step-down conversion is shown as follows:

$$V_{\text{Out}} = V_{\text{Ref}} \times \left(1 + \frac{R_1}{R_2}\right), \quad (1)$$

where parameter  $V_{\text{Ref}}$  represents the reference voltage of the step-down conversion circuit and  $R_1$  and  $R_2$ , respectively, represent the resistance of the step-down conversion circuit.

**2.2. Data Acquisition Module.** The core of data acquisition module is the sensor [7]. In this design, 5 types of sensors are installed, including vehicle speed sensor, webbing pull-out sensor, seating detection sensor, buckle sensor, and seat position sensors. A total of 10 data acquisition sensors are installed in the designated position with two in each type [8].

**2.3. Mathematical Model of the Drive Module.** The permanent magnet DC motor coming with a one-stage worm gear reduction mechanism is selected to provide power for the

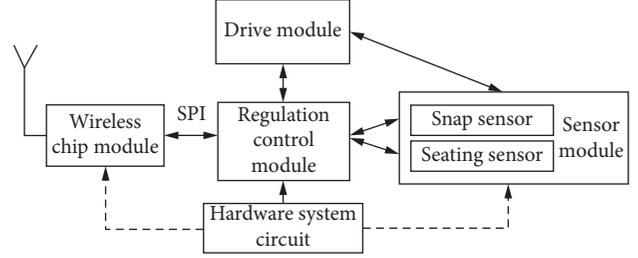


FIGURE 1: System hardware composition structure diagram.

TABLE 1: Hardware system demand voltage analysis.

Chip name	Model selection	Demand voltage
Seat node main chip	STM8S208R8	+5.0 V
Wireless transmission chip	SI4432	+1.8 V~+3.6 V
Seat inspection chip	MC33794	+5.0 V
Controller main core	STM32F103	+5.0 V

hardware system. After deceleration, the output speed of this motor is about 50 r/min, the rated power is 40 W, and the output torque can reach Nm. According to Newton's second law, the basic working principle of the drive module can be concluded as follows:

$$\begin{cases} u_a(t) = R_a i_a(t) + L_a \frac{di_a(t)}{dt} + E_a, \\ T_e = J \frac{d\omega}{dt} + B\omega, \\ E_a = K_e \omega, \\ T_e = K_T I_a, \end{cases} \quad (2)$$

where  $u_a$  is the input voltage of the drive motor,  $R_a$  is the resistance value inside the drive motor,  $L_a$  is the armature inductance,  $E_a$  is the induced electromotive force,  $T_e$  is the electromagnetic torque of the drive DC motor,  $J$  is the moment of inertia,  $B$  is the damping coefficient,  $i$  is the DC current in the motor,  $\omega$  is the output angle of the motor, and the parameters  $K_T$  and  $K_e$ , respectively, represent the torque creation and the induced electromotive force constant of the driving motor. Through the transformation and solution of formula (2), the transfer function of the DC drive motor can be obtained as

$$G_U(s) = \frac{K_T}{L_a J s^2 + (L_a B + R_a J)s + K_e K_T + R_a B}. \quad (3)$$

The devices in the entire hardware system can work coordinately by taking the motor transfer function shown in formula (3) as the working principle of the drive module.

**2.4. Adjusting Module.** The AT89C52 chip is applied as single-chip microcomputer in the adjusting module, which has an 8 bit data width processor and a total of 256 RAM units. In the adjusting module, the adjustment control

realization devices, such as pretightening unit, force limiter, and control node cluster coordinator, are connected to the single-chip microcomputer to realize the coordinated work between the hardware systems. For the sake of effectively realizing the pretightening function, a steel ball-type pretightening period is selected. Since the steel ball in the pretightening unit will move at a high speed under the action of explosive force, a sealing baffle shall be added and fixed to the steel ball collector with screws to prevent steel ball from bouncing out of the pretightening unit.

**2.5. Connection and Debugging of Hardware Devices.** In accordance with the method shown in Figure 1, all the components in the hardware system are connected for debugging. At first, the debugging process of hardware equipment needs to test the bare board, that is, carefully check the connection of printed circuit board according to the circuit principle. In this process, special attention should be paid to the power system to prevent the breakage of power supply and wrong polarity. Secondly, the break test function of the digital multimeter is used to test whether all the circuits on the bare board have circuit phenomena. After confirming the normal state of bare board, each component module unit in the hardware system is connected to the hardware motherboard. During this process, it is necessary to observe whether there is a missing device, whether the interface is firmly connected, whether the reverse polarity capacitor is distinguished, and whether the diode device is connected in the wrong direction. In case of an abnormal phenomenon, it is needed to analyze the reason, eliminate the fault, and test repeatedly until meeting the test requirements of the hardware system. The final test is a power-on operation test, that is, the power port is started in the hardware system to observe whether each hardware device can operate normally under the power-on environment. Before the power-on test, it is necessary to not only check whether the assignment of the external power supply voltage is at the required DIYYUAN voltage value but also repeatedly determine whether the polarity direction is correct, so as to avoid damage to device components caused by the short circuit at the power terminal.

### 3. Big Data Algorithm Design of Early Warning Seatbelt Intelligent Adjustment System

The prewarning seatbelt intelligent adjustment system database is set to adjust the system's mathematical algorithm [9]. The data stored in database include the vehicle parameter data, the basic parameter data of the seatbelt, the real-time seatbelt usage data, and the historical accident data [10]. The basic structure of database can be divided into the physical data layer, conceptual data layer, and user data layer [11]. In order to provide sufficient data support for the realization of system algorithm function, the real-time data collected by the sensor is processed in a unified manner and stored in the database in a fixed format [12]. Since the database table is the main unit of database, a database table firstly needs to be built through the sensor data, and then the

fixed database relationship rules shall be specified [13]. In this way, the database of early warning seatbelt intelligent adjustment system can be established.

All the information about seatbelt wearing status, such as the vehicle operating speed and the warning parameters of the seatbelt in different collision accidents, are saved in the database of automobile seatbelt intelligent adjustment system. In order to give more convenience to system users when querying the operating status of car seatbelt instantly, it is needed to not only strictly define the name of each field and the corresponding data type during the database design but also ensure that the parameters in the database are not defined in duplication. The information data  $\alpha_n$  that can better explain the parameter definition is selected in the specified database, and a weight calculation is performed on the data type formed by its secondary data information [14]:

$$C_T = \sum_{t=1}^T an(C_t - D_{st}). \quad (4)$$

In the formula,  $C_t$  represents the data level and  $D_{st}$  represents the information flow direction threshold. According to this, the effective definition under the parameter definition data constraint mechanism is as follows:

$$P_{PV}(t) = \max\{C_T, \eta_{PV}\}. \quad (5)$$

In the formula,  $\eta_{PV}$  represents the extreme value of constraint to maximize the output result of constraint effect and realize the definition of database data information. Based on the basic design principles of database tables, version SQL2016 is used for establishing independent database tables. The database table of automobile seatbelt information is shown in Table 2.

In the same way, database tables of vehicle history information and seatbelt automatic adjustment parameters can be built up.

## 4. Design of Mathematical Algorithm Model for Early Warning Intelligent Seatbelt Adjustment

**4.1. Real-Time Monitoring of Seatbelt Working Status.** The real-time monitoring of seatbelt working status can be divided into three steps. First, the real-time data of early warning seatbelt is collected; second, the big data analysis is adopted to analyze the collected parameter data; and finally, the work of seatbelt is judged based on the big data analysis results. Depending on the sensor installed at the seatbelt position, the collected real-time data of early warning seatbelt mainly include the pull-out length of the webbing and the limiting force. Big data analysis contains six basic aspects, namely, visual analysis, data mining, predictive analysis, semantic engine, data quality and data management, data storage, and data warehouse. Based on the data stored in the database, the working mode of seatbelt can be determined by following the steps of big data analysis. The working mode of early warning seatbelt can be roughly divided into nonworking, safe and dangerous states, which is

TABLE 2: Vehicle seat belt information.

Data parameter definition	Field meaning	Type of data
ID	Primary key	Number
Car_Route	Route	Text
Car_License	License plate	Text
Car_Driver	Driver	Text
Car_Seat	Number of seats	Number
Car_Seat_Number	Seat number	Number
..	..	..
Car_Seat_Number	Seat number	Number

judged according to the basic physical data of the driver and the vehicle speed.

**4.2. Design and Realization of Intelligent Adjustment Function.** The intelligent adjustment function is realized to ensure that the early warning seatbelt is always in a safe working status. However, during the vehicle driving, the safety mode parameters of seatbelt vary as the change of vehicle speed, so the early warning seatbelt needs to adjust its pretightening strength according to the actual operating conditions of the vehicle. In addition, when a vehicle crashes, the smart seat belt system will automatically adjust different safety modes, so as to maximize the personal safety of the driver and other passengers in the vehicle. In order to effectively realize the system intelligent adjustment function, seatbelt working modes are adjusted intelligently directing at the initial state of vehicle, the normal driving state, the state of a collision accident, and the state after collision accident.

**4.2.1. Design of Early Warning Reminder.** After the car engine is ignited, the control module in the hardware system switches to the working state and reminds the device to turn on. In this process, the sensor device detects the gravity of the seat, the speed signal, and the seatbelt signal step by step. If the gravity on the seat is greater than 0 and the seatbelt signal is 0, the early warning reminder program will be started immediately. If it is detected that the driver does not buckle up, the warning light flashes immediately, and the buzzer is activated to give a 1 min low-frequency and gentle buzzer, and then a 2 min high-frequency buzzer. If the driver still has not buckled up, the buzzer stops working, the indicator light continues, and the car speed is adjusted below 10 m/s by the controller. Once buckling up, the sensor status is adjusted, and the path between the power supply and the early warning device is disconnected to stop the early warning.

**4.2.2. Design of Initial Pretightening Adjustment.** The degree of seatbelt usage at the initial speed is determined according to people's body shape and weight, and then the initial pretightening force is set based on manual pull-out of the seatbelt. The pull-out amount of seatbelt is determined by the corresponding sensor and calculated as follows:

$$S_{\min} = T_{\min} \times V_{\max}, \quad (6)$$

where parameter  $T_{\min}$  represents the time that takes for the passenger to pull out the seatbelt and  $V_{\max}$  is the speed when pulling out the seatbelt. In this situation, the pretightening force of the seatbelt can be calculated as follows:

$$F_0 = PS_{\min}, \quad (7)$$

where  $F_0$  is the initial pretightening force and  $P$  is the initial preload coefficient.

**4.2.3. Design of Loading Intensity Adjustment.** The restriction force of seatbelt is related to the driving speed. Assuming that the real-time vehicle speed detected by the vehicle speed sensor is  $v$ , the pretightening restriction force of the prewarning seatbelt at the speed of  $v_x$  should be

$$F = F_0 + \eta(v_x - v), \quad (8)$$

where parameter  $\eta$  represents the coefficient of loading intensity, whose value is a constant determined by the vehicle model and scale. Next, it is needed to check whether the current seatbelt pretightening force reaches  $F$ . If it reaches  $F$ , keep the current status and continue to run; otherwise, the relevant controller shall be used to adjust the current pretightening force to  $F$ .

**4.2.4. Design of Intelligent Locking Adjustment.** Intelligent locking adjustment is to immediately adjust the seatbelt to the maximum pretightening state in the event of a traffic collision. If the starting angular acceleration of the intelligent lock adjustment controller is set at  $\varepsilon_0$  and the linear acceleration is set at  $a_0$ , then

$$M_0 = F \cdot L. \quad (9)$$

The initial working torque for controlling it can be calculated by formula (9). The parameter in the above formula represents the controlled length; then, the starting angular velocity can be calculated as follows:

$$\varepsilon_0 = \frac{M_0}{I}, \quad (10)$$

where  $I$  is the output current of controller. By substituting the result of formula (10) into formula (11), the pretightening acceleration of the seatbelt in the event of a traffic collision can be obtained.

$$a_0 = \varepsilon_0 \times S. \quad (11)$$

The calculation finds that, when a collision accident occurs, the early warning seatbelt is immediately adjusted to the maximum pretension state at acceleration  $a_0$ .

## 5. System Big Data Test

This system test is to verify the relevant performance and application value of the early warning seatbelt intelligent adjustment system designed based on big data analysis [15]. To this end, a car with intact seatbelt facilities is selected as the experimental environment [16]. The experiment is performed by dividing into two parts. One is the realization

TABLE 3: System regulation function test results.

	Security level A (mm)	Security level B (mm)	Security level C (mm)	Average value (mm)
Small passenger seatbelt tightening amount	38.6	38.4	37.9	38.3
Moderate occupant seatbelt tightening	48.1	47.2	45.6	46.9
Tightening of seat belts for tall passengers	57.2	55.9	53.8	55.7

effect of the system function is verified, which requires recruiting volunteers with large differences in body size. The other is to test whether the applied system can improve the survival rate of passengers in traffic collision accidents. In consideration of the high risk during test process, dummy with the same parameters is made as the research object. With the purpose to ensure the theoretical property of the experimental results, the traditional early warning seatbelt intelligent adjustment system is selected as a reference, so that these two systems are tested under the condition of same application environment and participants [17].

**5.1. Adjusting Function Test.** The volunteers are divided into three categories based on their heights, which are short passengers, medium passengers, and tall passengers. The short passengers indicate volunteers at height between 160 cm and 165 cm and weight about 50 kg; the medium passengers include volunteers at height between 170 cm and 175 cm and weight about 65 kg; the tall passengers are those at height between 180 and 190 cm and weight about 80 kg. In addition, three safety levels are set in the experiment, including safety level A (the vehicle speed is around 15 m/s), safety level B (the vehicle speed at 25 m/s), and safety level C (the vehicle speed at 35 m/s). At the same time, the key positions of seatbelt are marked to help observe the adjustment degree of early warning seatbelt under different security levels. In this way, the adjustment effect of seatbelt in one volunteer under three safety levels is obtained from a single experiment.

By means of the same method, the adjustment effect in three volunteers is tested, and the measurement equipment is used to quantify the test results. The results of adjustment test obtained through statistics and calculations are shown in Table 3.

Statistics obtains that the average tightening amount of the seatbelt in the designed system and traditional system separately is 46.9 mm and 38.4 mm, which proves that the designed system has a higher adjustment effect than the traditional system.

## 6. Conclusions

Nowadays, traffic safety has become a topic of concern around the world due to the increasing number of motor vehicles. However, since existing passive safety technology cannot adapt to the current traffic safety situation, it is quite important to study the early warning seatbelt intelligent adjustment system based on big data analysis in the field of active safety. Limited by the time and related conditions, there are still some shortcomings in this research, which remain to be further improved in the future.

## Data Availability

All data included in this study are available from the corresponding author upon request.

## Conflicts of Interest

The author declares no conflicts of interest.

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