Design of Project Functional Module for One Intelligent X-by-wire Chassis

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Abstract: With the development of automotive electronic technology and the integration of automotive system, X-by-wire technology can be used to drive automobile. This paper designs the project functional module of one intelligent X-by-wire chassis, describes and records the algorithm and functional modules in this project; it can be used as the standard for product testing and acceptance after review.

1. Introduction

With the development of science and technology, some cumbersome and low-precision mechanical systems will be replaced by sensitive and high-precision electronic sensors and actuators, the traditional control mechanism, operating modes and actuators of automobiles have gradually begun to change. X-by-wire can bring more design space to car designers, and it is easier to achieve integrated control, so that the total weight of the vehicle is reduced, so it is used by more and more companies. This paper is mainly applicable to the design description of the car body components and algorithm functional modules in the intelligent X-by-wire chassis project.

2. Overview of Functional Module of the Whole Vehicle

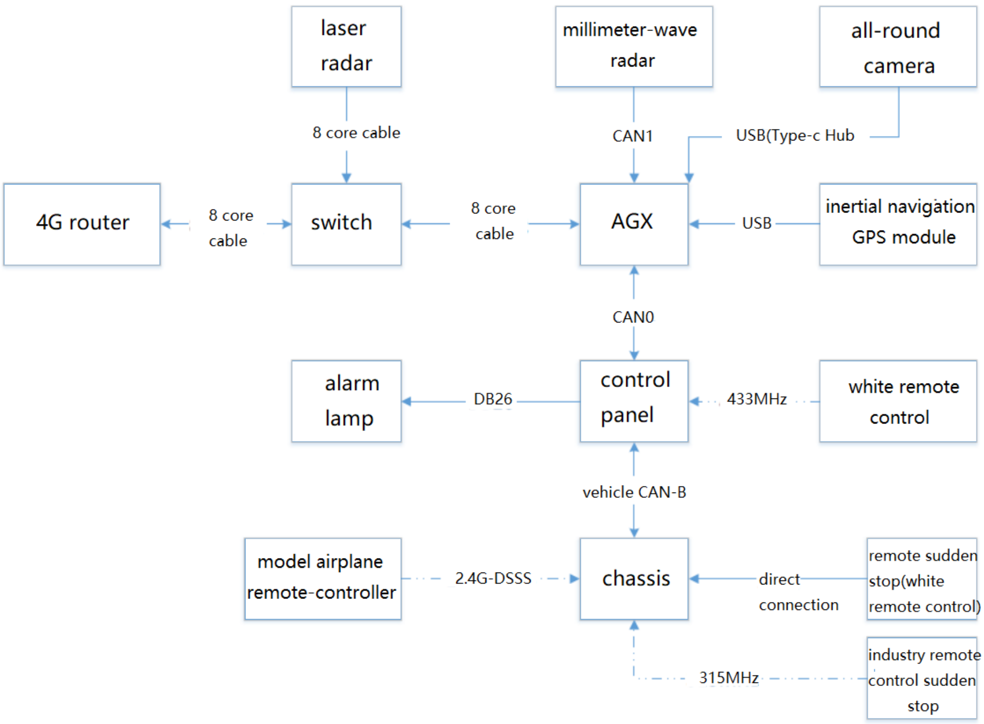

Fig.1 intra-vehicle data link topological graph

2.1 Overview of vehicle functions

As shown in Fig.1 above, the data link topology inside the vehicle is divided into three layers. The bottom layer is centered on the vehicle chassis; the model airplane remote control transmits the continuous control of two channels through the 2.4G band DSSS code, and controls the front wheel steering and the rear wheel propulsion. The middle layer is centered on the control board, the control board mainly completes the mutual conversion between the high-level protocol and the vehicle chassis control protocol, and control alarm lamp prompts when the fault occurs. The highest layer is centered on the NVIDIA AGX platform, it forms a local area network with laser and 4G router via switch, receives data of laser radar and remote desktop control requests from other terminals, millimeter wave radar feed data through AGX original CAN1 channel; four surround cameras distributed around the roof are connected to the AGX through USB Type-c docking station; the inertial navigation GPS integrated navigation system is connected to the AGX via the common USB interface. Under the current architecture, the vehicle can realize manual remote control driving, and realize automatic tracking driving by relying on the inertial navigation GPS integrated navigation system, laser radar and millimeter wave sensor, and realize the perception of obstacles to stop and autonomous bypass etc.

2.2 Line connection

There are 10 lines from the car body, as shown in Table.1. The overall switch layout is shown in Fig.2; there are 9 switch buttons: power supply, inertial navigation, industrial personal computer, laser radar, millimeter wave radar, display, router, AGX and switch. The power button is the main switch, and the vehicle can be powered on only when it is pressed. The rest are the switch buttons for the sensor, when the power button is pressed and the 8 button switches are pressed, the corresponding 8 modules will be powered.

Table.1 list of car body line

car body line (totally 10)			
serial number	line	quantity	note
1	power line	2	access switch power supply
2	CAN line	2	access control board
3	relay control line	4	act as relay, control main switch
4	emergency stop switch line	2	emergency stop

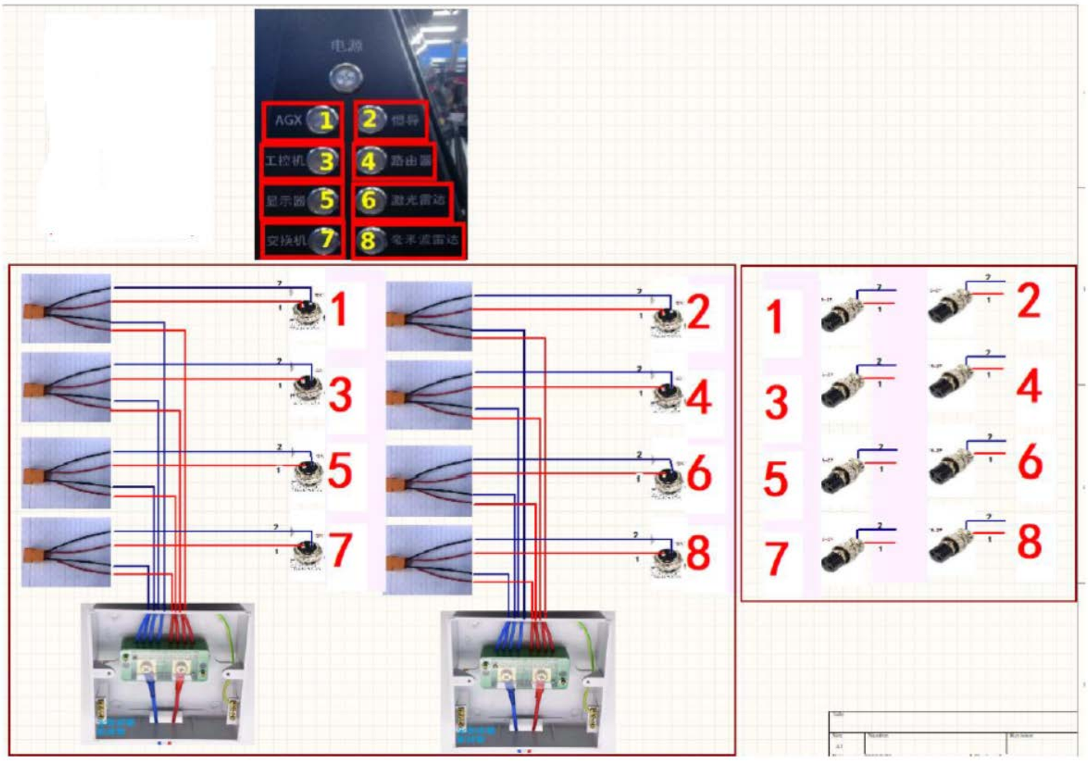

Fig.2 wiring diagram of overall switch wiring

Note: red: +12V: blue: GND

Serial number of each sensor: serial number 1: AGX, : serial number 2: inertial navigation, serial number 3: industrial personal computer, serial number 4: router, serial number 5: display, serial number 6: laser radar, serial number 7: switch, serial number 8: millimeter wave radar

2.3 System module description

2.3.1 Data analysis module of all-around camera

a) Demand analysis

Read the data stream of the all-round camera for later image processing.

b) Function definition

Read the image data stream of the all-around camera and the important parameters of the camera, convert the above data into a message and release it.

2.3.2 Data analysis module of laser radar

a) Demand analysis

Read the raw data of the three laser radars and provide to the corresponding data processing module for data processing.

b) Function definition

Read the laser radar data by the driver and convert into point cloud data and release.

2.3.3 Data analysis module of millimeter wave radar

a) Demand analysis: analyze the millimeter wave radar data and release the corresponding millimeter wave data to the data processing module;

b) Function definition: data analysis of millimeter wave radar;

c) There are six millimeter-wave radars used in this project, including forward millimeter wave radar, backward millimeter wave radar, and four angular millimeter waves, of which the front side two angle millimeter wave radar does not conflict with the rear two angle millimeter wave radar CAN bus message ID, and can be separately fused, while the angular millimeter wave supports data transmission through the Ethernet line.

2.4 Sensor calibration

2.4.1 Millimeter wave radar

(1) Millimeter wave radar coordinate system $O_rX_rY_r$

The coordinate system origin O_r as the installation position point on the millimeter wave radar, X_r is the direction of the radar main axis, and Y_r is the left side of the radar.

(2) coordinate system OXYZ of car body

The car body coordinate system moves with the car. The coordinate system origin O as a fixed point on the car body, X is in front of the car and Y is in the left of the car.

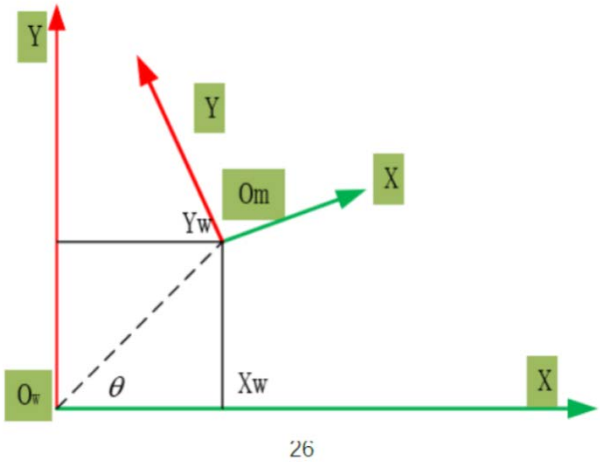

Fig.3 millimeter wave coordinates

(3) Millimeter wave radar is converted to car body coordinate

The millimeter wave radar can obtain the x, y coordinate information of the target without the z coordinate information of the target, therefore, the conversion of the millimeter wave coordinate system Om to the car body coordinate system Ow can be regarded as the conversion of the two-dimensional XY coordinate system, the relationship between Om and Ow is nothing more than translation and rotation. As shown in the figure above, the conversion relationship of millimeter wave coordinates to the car body coordinate system can be derived as follows:

$$\begin{bmatrix} X \\ Y \\ 1 \end{bmatrix} = \begin{bmatrix} \cos\theta & -\sin\theta & X_w \\ \sin\theta & \cos\theta & Y_w \\ 0 & 0 & 1 \end{bmatrix} * \begin{bmatrix} X_w \\ Y_w \\ 1 \end{bmatrix}$$

The transformation matrix consists of two parts: the rotation matrix brought by the angle and the translation matrix produced by the translation. The translation amount of the translation matrix can be understood as the coordinates of the millimeter wave radar device in the car body coordinate system, namely the distance from the millimeter wave radar to the obstacle. Therefore, the translation matrix can be well obtained and can be measured directly with a tape.

2.4.2 Laser radar

(1) Radar rectangular coordinate system $O_rX_rY_rZ_r$

The radar rectangular coordinate system is fixed to the radar, the origin O_r of the coordinate system as an initial point on the radar. X_r is the direction of the main axis of the radar, Y_r is the left side of the radar, and Z_r is above the radar.

(2) coordinate system OXYZ of car body

The car body coordinate system moves with the car. The origin O of coordinate system origin as a fixed point on the car body, X is the front of the car, Y is the left side of the car; Z is the top of the car

(3) Calibration of laser radar to car body coordinate system

The point cloud coordinate in the laser radar coordinate system are represented by $(x_1 y_1 z_1)$, and the point cloud coordinate in the vehicle body coordinate system are represented by $x_v y_v z_v$, and the external parameters are calibrated, namely The point cloud coordinate in the radar coordinate system is converted to the car body coordinate system by formula(1),

$$\begin{bmatrix} x_v \\ y_v \\ z_v \end{bmatrix} = \boldsymbol{R} \begin{bmatrix} x_1 \\ y_1 \\ z_1 \end{bmatrix} + \boldsymbol{T} \tag{1}$$

The relative rotation angle between the two coordinates includes three independent variables, $\alpha\beta\gamma$ is used to represent the yaw angle, pitch angle and roll angle, respectively, and the constituent 3×3 rotation matrix is calculated by formula(2).

$$\boldsymbol{R}(\alpha,\beta,\gamma) = \boldsymbol{R}_z(\alpha)\boldsymbol{R}_y(\beta)\boldsymbol{R}_x(\gamma) = \begin{bmatrix} \cos\alpha\cos\beta & \cos\alpha\sin\beta\sin\gamma - \sin\alpha\cos\gamma & \cos\alpha\sin\beta\cos\gamma + \sin\alpha\sin\gamma \\ \sin\alpha\cos\beta & \sin\alpha\sin\beta\sin\gamma + \cos\alpha\cos\gamma & \sin\alpha\sin\beta\cos\gamma - \cos\alpha\sin\gamma \\ -\sin\beta & \cos\beta\sin\gamma & \cos\beta\cos\gamma \end{bmatrix} \tag{2}$$

In formula (2):

$$\boldsymbol{R}_z(\alpha) = \begin{bmatrix} \cos\alpha & -\sin\alpha & 0 \\ \sin\alpha & \cos\alpha & 0 \\ 0 & 0 & 1 \end{bmatrix} \boldsymbol{R}_y(\beta) = \begin{bmatrix} \cos\beta & 0 & \sin\beta \\ 0 & 1 & 0 \\ -\sin\beta & 0 & \cos\beta \end{bmatrix} \boldsymbol{R}_x(\gamma) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\gamma & -\sin\gamma \\ 0 & \sin\gamma & \cos\gamma \end{bmatrix} \tag{3}$$

Set any two points P_1 and P_2 in the space, after the vector $V = P_1P_2$ is normalized in the coordinate system C_1 and C_2 and denoted as V_1 and V_2, respectively, $V_1 = RV_2$, V_1 and V_2 are called a vector with the same name. Only two or more corresponding V_1 and V_2 are needed. The solution of the rotation matrix R can be realized. Based on the calibration of the rotation matrix, the translation vector T can be solved by passing a point with the same name. The normal vector of the two sides of the reference object is obtained as the vector with the same name, and the intersection of the two sides and the ground as the point with the same name to obtain the calibration parameters.

2.4.3 Integrated inertial navigation

The line connection is firm and the antenna is laid out properly, the SIM card with network traffic has been placed in the inertial navigation system. The vehicle is place in an open environment to ensure that the satellite signal is good, after the inertial navigation module is powered on, the WIFI hotspot launched by the inertial navigation module is connected by using PC or other devices. After connecting to the hotspot, log in to the inertial system management page, click the "network settings " column in the navigation bar, and observe whether the SIM card operator and dialing status are connected. Click to enter the IO setting column to observe whether the RTK-GPS working status is normal; and it is normal if the status is connected. Click to enter the inertial navigation setting, according to the actual position of the GPS antenna and the inertial navigation module on the vehicle, fill in the page parameters in the vehicle parameter settings, and save after completion. Finally, click to enter the inertial navigation status page to observe the inertial navigation status, when the inertial navigation status is already integrated navigation, the calibration has been completed.

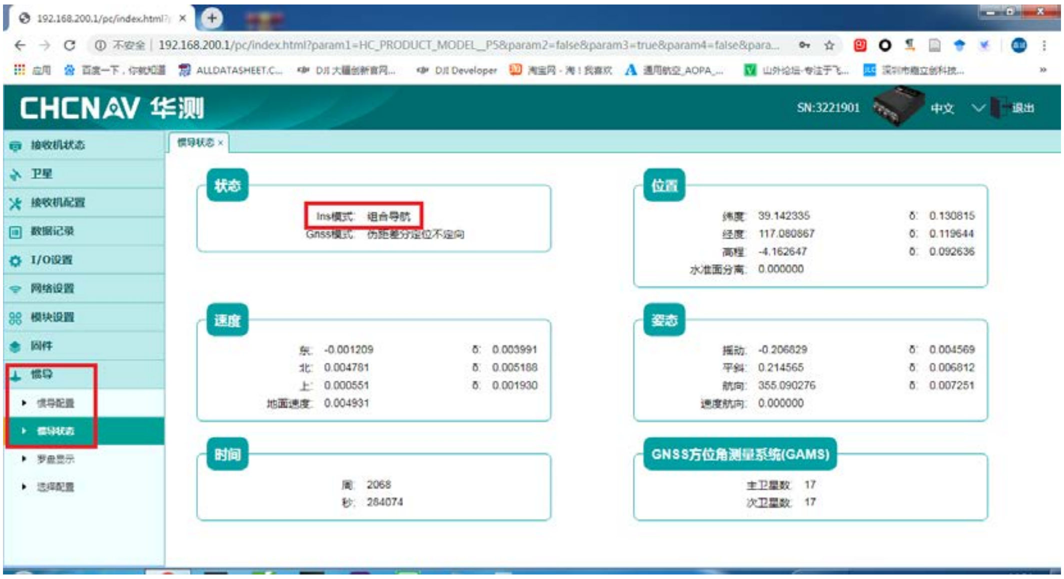

Fig.4 status page of inertial navigation

2.4.4 All-round camera

(1) Calibration purpose

The calibration of the all-round camera is divided into two parts, the internal parameter calibration and the external parameter calibration. The internal parameter of the all-round camera describes the tangential and radial distortion coefficients of the lens, the offset of the focus and the imaging plane, the aspect ratio of the pixel, etc., the internal parameter calibration is only related to the internal structure of the camera and do not change with the position of the camera. The external parameter calibration is related to the position of the camera and the selection of the world coordinate system.

(2) Internal parameter calibration method

The internal parameter calibration method uses Zhang Zhengyou's checkerboard calibration method, namely selects a flat checkerboard image and prints it on a flat cardboard/wood board. We use a specially made 8x11 alumina glass plate with good diffuse reflection properties for corner detection of OpenCV. As shown in Fig.5:


Fig.5 camera calibration image

OpenCV use the cv::findChessboardCorners function to find the pixel position of the corner point on the checkerboard in each image, and then calculate its corresponding homography matrix. OpenCV requires at least three different homography matrices to find the internal parameters of the lens, so it is necessary to take at least three photos in different positions. Then through the OpenCV built-in function cv::fisheye::calibrate(), find the inner parameter*outer parameter*rotation translation matrix K and distortion parameter D, and save K and D to the yaml file. Each camera only needs to be calibrated once, and each time the camera is called, it is read directly from the yaml file.

After using for a period of time, due to vehicle vibration and other reasons, the internal structure of the camera may change slightly, resulting in changes in the internal parameters, therefore, it is necessary to re-calibrate the internal reference at intervals.

(3) External reference calibration method

The calibration clothes with a checkerboard pattern are placed around the car to ensure that adjacent cameras can see the checkerboard and the two-sided markers in their common view, as shown in the Fig.6:

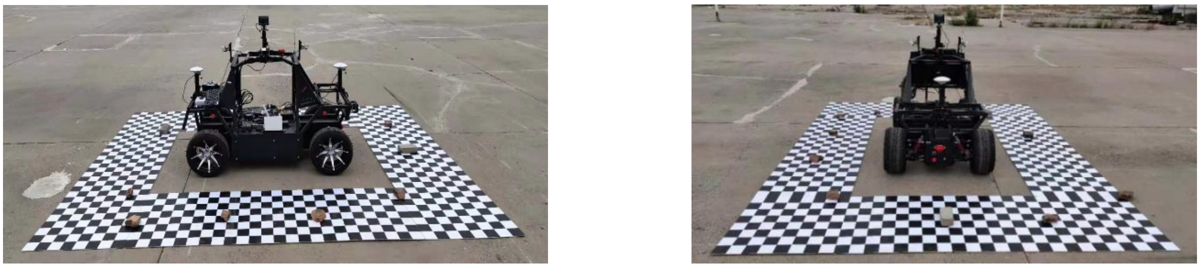

Fig.6 calibration image of camera external parameter

The size of the calibration board used in the above figure is 80*80cm, the checkerboard of each calibration board is 10*10cm, the inner edge of the left and right calibration board is 27.5cm away from the wheel, and the edge of the front and rear calibration board is 35cm away from the front and rear edges of the car. There are 4 calibration board front and back, and 5 calibration plates on the left and right, respectively.

6) All-round panorama display

After completing the internal parameter and external parameter calibration in the all-round camera, execute the show_round_view.py script, and the panoramic view after splicing will be displayed, if the display effect does not reach the desired effect during use, we can check if there is a modification or the omission of the execution script in the above steps. All-round panorama as shown in Fig.7:

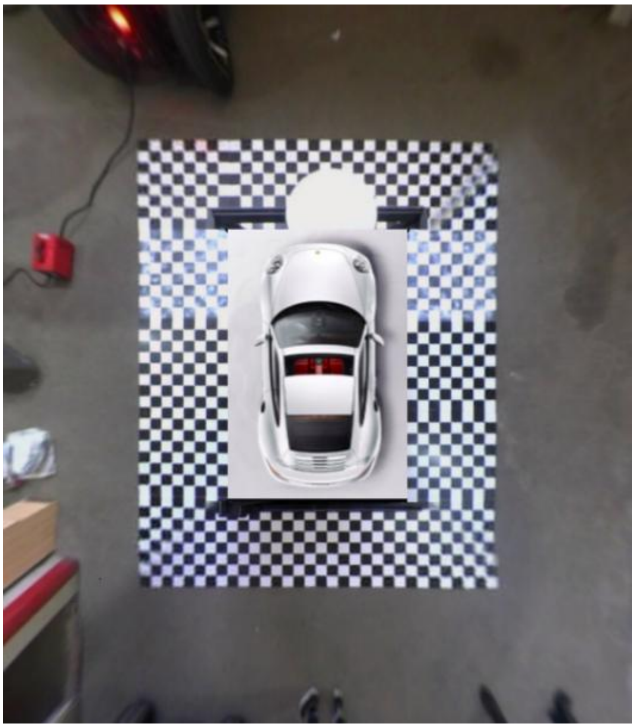

Fig.7 all-round panorama

3. Introduction to Remote Control Module

3.1 Function introduction to remote control button

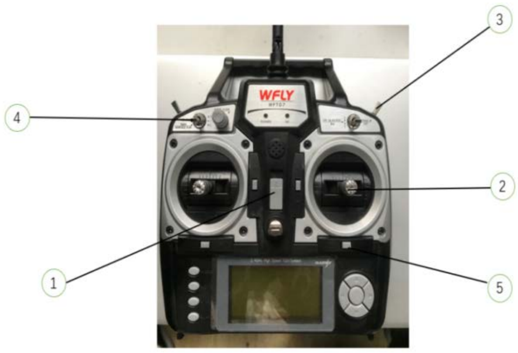

Fig.7 remote control

The introduction to each component:

(1) Remote control power switch;

(2) Control lever: the lever up is forward, the lever down is backward, the left is left steering, and the right is right steering,

(3) Emergency brake switch: three gears, the lower and middle gears are in normal use mode, and the uppermost gear is the emergency brake; push the lever slowly and slightly before pushing it, adjust the speed and direction after the vehicle moves;

(4) Control mode switch: the upper position is the driverless mode, and the middle position and the lower position are the remote control mode;

(5) Fine-tuning button: there are four zigzag fine-tuning buttons on the remote control, do not touch it by mistake, please keep the value as 0 and we can see it on the screen.

3.2 Function introduction to emergency stop remote control

Fig.8 emergency stop remote control

Open the on button on the side of the remote emergency stop switch, press the whole vehicle to implement the emergency stop mode, press the off button to close the emergency stop mode.

4. Introduction to Charger Module

The charger is a fully automatic intelligent charger that provides operating power for the whole vehicle, the image is as follows:

Fig.9 charger

The charger air plug uses only 2 wiring holes, and the copper wire part is an effective wiring head.

Fig.10 charger joint

Charging operating instructions

Make sure that the chassis parking point is ventilated and protected from rain. Turn off the emergency stop switch and the main switch. Connect the charger charging cable plug to the socket and chassis charging interface. Open the panel main switch. When the charging indicator is red, it indicates that it has entered the charging state. Turn off the main switch and continue charging until the green light is on.

5. Instructions for the Remote Control Chassis

5.1 Pre-use safety check

Check whether the four emergency stop buttons on the car body are pressed; check whether the emergency stop button on the remote control is adjusted to the emergency stop state, if the two emergency stop modes have been adopted, the emergency stop state will be canceled, check whether the main switch is on (green light is on) and the other eight sensor switches are on (green light is on), check whether the operation control lever is working normally.

5.2 Manual driving mode

The steps which control the vehicle to enter into the manual driving mode are as follows:1. Turn on the main power switch and 8 sensor switches; the light turns green; 2. Turn on the switch on the side of the AGX module; 3. Observe the status of 4 lights of the inertial navigation, and the last two lights are always on, which shows the integrated inertial navigation works normally, if the last light does not turn green, it is always on, and the whole vehicle can be driven to an unobstructed field and waits for the integrated inertial navigation state. 4. Turn on the remote control switch and turn the control mode switch to the middle or lower position to enter into the manual driving mode.

5.3 Automatic driving mode

The steps which control the vehicle to enter into the automatic driving mode are as follows: 1. Turn on the main power switch and 8 sensor switches, the light turns green; 2. Turn on the switch button marked by the red circle on the side of the AGX module; 3. Observe the status 4 lights of the inertial navigation, the last two lights are always on, it shows integrated inertial navigation and position decoding has worked normally, the orange light flashes shows that the position solution has not been completed, and the green light is always on, it shows that the integrated navigation works normally; 4. Find the application adc-hcp2 and double click in the operation screen interface; 5. View the inertial navigation parameter information and the number of satellites is more than 6 shows that the inertial navigation state is better; 6. Search the application qt, open and run the ADCgq program; 7. Jump to the auto-driving tour interface; 8. Select the Test button, enter into the interface to select the default value, and press save; 9. Jump back to the main interface, select Run interface, observe whether the position calculation of the vehicle is correct, whether the point cloud of laser radar is correct, whether the millimeter wave data is correct, 10. Jump back to the main interface, select the start button; 11. Turn on the remote control switch; the control mode switch is turned to the upper position to enter into the driverless mode.

5.4 Stop operation instructions

1 Stop

2. Turn off the remote control

3. Disconnect one of the emergency stop switches (emergency stop switch control drive, brake, steering power supply);

4. Disconnect the main switch;

Note: In case of unexpected circumstances, press the emergency stop switch, turn off the main switch when starting the car again, and then restart the vehicle according to the start-up process. In the driverless mode, control the motor brake separately, and the driving and steering power supply will not be disconnected, please pay attention to sending the brake release command before sending the drive command.

6. Conclusion

This paper describes the installation and commissioning of an intelligent X-by-wire chassis in detail analyzes the design of the algorithm and function modules in this project, it should be used as the standard for product testing and acceptance after test, and can provide references for data resource center project staff.

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