System Design of Automatic Parking Assist Based on ISO26262

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Abstract—The technology of intelligent driving cars is one of the key technologies of current automobile development, and the automatic parking assist system (APA, Auto Parking Assist) is a representative function of low-speed automatic driving. In order to improve the safety and reliability of the APA system, a hazard analysis and risk assessment of the APA system was carried out based on ISO 26262, safety objectives and functional safety requirements were derived, and then technical safety requirements were put forward and the system architecture design was carried out. And from the software point of view, the algorithmic design of the horizontal parking function is carried out, which further illustrates the feasibility of the technology.

1. Introduction

Auto Parking Assist (APA, Auto Parking Assist) is an intelligent parking assistance system that can quickly and safely drive the vehicle into a parking space automatically\textsuperscript{[1-3]}. It recognizes the parking space by sensing the surrounding environment information of the vehicle through ultrasonic and image sensors, and according to the relative position information of the vehicle and the parking space, generate the corresponding parking trajectory and control the speed of the vehicle and the steering wheel to complete the automatic parking. A schematic diagram of the parallel parking process of the automatic parking system is shown in Figure 1\textsuperscript{[4]}.

For the automatic parking system, ultrasonic radar is used to monitor environmental obstacles, parking spaces and other information, and the APA controller makes corresponding judgments based on the received information, and controls the steering and braking of the vehicle\textsuperscript{[5]}. However, with the upgrade of electronic control systems, electrical and electronic systems have become more complex\textsuperscript{[6]}. The safety risks caused by systemic failures and random hardware failures will further rise, so functional safety issues are very important, so this article focuses on intelligent driving cars The key technology of automatic parking system is designed for system functional safety and algorithm design based on horizontal parking function.
2. Function definition of APA system

By analyzing the functions of the parking system and the parking process, the parking system mainly constructs five control systems: ultrasonic control system, image processing system, electric power steering control system, vehicle speed control system and vehicle control system. The above system constitutes the control system of the automatic parking system. There is a unified CAN (Controller Area Network) communication protocol between each system. The vehicle control system can collect the communication information of each module and coordinate the cooperation between the modules to realize the parking Control of the entire vehicle's actuators during the vehicle process, so as to complete the parking operation safely and quickly. The boundary block diagram of the automatic parking system is shown in Figure 2, and the external element function list is shown in Table 1.

3. Analysis of the top-level requirements for the functional safety of the APA system

The combination of functional failure and driving scenario is called a hazard event. After the hazard event is determined, the safety integrity (ASIL) of the entire vehicle of the hazard event is evaluated based on three factors: severity (Severity), exposure rate (Exposure) and controllability (Controllability). Therefore, the Hazard Analysis and Risk Assessment (HARA) method can be used to identify the hazards caused by faults in related items, and divide them into categories and formulate corresponding safety goals, so as to avoid unreasonable risks.
For the function of "detecting obstacles or people during parking", to assess the risks and hazards of related items, first analyze its potential hazard events "no obstacles or pedestrians detected" and "provide wrong information". Obstacles or pedestrian locations. The safety goals and their corresponding ASIL levels are determined by systematic assessment of the hazardous event itself. The following HAZOP analysis, hazard analysis and risk assessment are carried out on the function of "detecting obstacles or people during parking", as shown in Table 2 and Table 3:

Table 2. HAZOP analysis of APA system

| ID | Function malfunction | Vehicle-level hazards | Scene |
|----|----------------------|-----------------------|-------|
| 1  | Detect obstacles or pedestrians detected | No obstacles or pedestrians detected | Automatic parking, pedestrians on the track, the speed is less than 10Km/h, city streets, normal weather conditions |
| 2  | Provide wrong obstacle or pedestrian location | Can't stop in time, hit obstacles or pedestrians | Automatic parking, pedestrians on the track, the speed is less than 10Km/h, city streets, normal weather conditions |

Table 3. Hazard analysis and risk assessment of APA system

| ID | Malfunction | S | E | C | ASIL |
|----|-------------|---|---|---|------|
| 1  | No obstacles or pedestrians detected | Parking at low speed, hitting people, causing injuries, | Normal parking, E=3 | There is a blind spot when parking, and the controllability is low, C=2 | ASIL A |
| 2  | Provide wrong obstacle or pedestrian location | Parking at low speed, hitting people, causing injuries, | Normal parking, E=3 | There is a blind spot when parking, and the controllability is low, C=2 | ASIL A |

The safety goal is the top-level goal derived from the development of functional safety technology for the entire system. The above-mentioned function of "detecting obstacles or people during parking" has carried out a hazard analysis and risk assessment. According to the analysis result, the safety target “SG_01 should be able to detect pedestrians on the parking track when parking automatically”.

After obtaining the safety goal, the corresponding functional safety requirements (FSR) need to be proposed. The following functional safety requirements are proposed for "SG_01", as shown in Table 4.

Table 4. Functional safety requirements of APA system

| ID | Description of FSR | ASIL |
|----|--------------------|------|
| 1  | Short-range ultrasonic radar should provide real-time radar environment sensing signals to APA | ASIL A |
| 2  | Short-range ultrasonic radar should avoid providing false radar environment sensing signals to APA | ASIL A |
| 3  | Long-range ultrasonic radar should provide real-time radar environment sensing signals to APA | ASIL A |
| 4  | Long-range ultrasonic radar should avoid providing false radar environment sensing signals to APA | ASIL A |
| 5  | The APA power supply system should ensure that the ECU receives the correct power of the vehicle | ASIL A |
| 6  | APA should perform power-on and runtime diagnosis for short-range ultrasonic radar and long-range ultrasonic radar. When one of the above sensors fails, APA should be able to detect and exit the function, and send a system failure alarm signal to IHU | ASIL A |
| 7  | APA should protect the signal received from ECU (IHU/EPS/ESC/IMU/TCU) | ASIL A |
| 8  | APA should calculate the parking position spatial information data based on the received radar environment sensing signals, determine the expected driving trajectory, and detect pedestrians and two-wheeled vehicles on the driving trajectory | ASIL A |
| 9  | When APA judges that there are pedestrians or obstacles on the driving track, it should send an obstacle warning signal to IHU | ASIL A |
4. Technical safety requirements and system design of APA system

The functional safety concept specifies the safety goals of the system and the safety functions required by the system to achieve these safety goals. The technical safety concept needs to implement the following two parts.

(1) Further refine the safety functions proposed by the safety concept, and obtain the technical implementation plan of the safety functions.

(2) Analyze the realization path of the safety function, find the single point and latent fault that causes the safety function failure in the system or technical scheme, and propose safety measures or safety mechanisms to cover these faults.

Specifically, the steps to derive technical safety requirements and technical safety concepts from functional safety requirements are as follows.

(1) For each FSR, formulate the technical plan of the functional path in the system's initial architecture elements in detail.

(2) FTA or FMEA analysis is carried out with the FSR implementation technical solution as the object, and the single-point failure and double-point failure that violate the FSR in the implementation technical solution are identified.

(3) Develop corresponding safety mechanisms for single point of failure.

(4) Develop diagnostic mechanisms or safety measures to avoid latent faults for double-point faults.

(5) The safety mechanisms in (3) and (4) form the technical safety requirements TSR.

(6) Allocate the exported TSR to the hardware and software of the specific realization elements, and optimize the system architecture design.

The preliminary architecture of the automatic parking system after being assigned to the safety-related elements is shown in Figure 3.

![Figure 3. Block diagram of the APA system architecture](image)

In order to achieve the above FSR, the TSR in Table 5 is obtained according to the FMEA analysis.

| ID | Description of TSR                                                                 | ASIL | Remark |
|----|-----------------------------------------------------------------------------------|------|--------|
| 1  | The LIN communication diagnostic module should monitor the LIN messages input by the short-distance ultrasonic radar and the long-distance ultrasonic radar, and perform communication protection verification. When the verification fails, the MCU exits the function response, records the DTC, and sends the system fault signal. | ASIL A | FSR1-4 |
| 2  | The power module should monitor the voltage input from the KL30. When the voltage is too high or too low, the MCU stops the function response, but does not stop the CAN message transmission, and records the voltage status in the DTC | ASIL A | FSR5   |
| 3  | APA should perform power-on and runtime diagnosis for short-range ultrasonic radar and long-range ultrasonic radar. When one of the above sensors fails, APA should exit the function, record DTC, and send a system failure signal | ASIL A | FSR6   |
The CAN communication diagnostic module should monitor the CAN messages input by IHU/EPS/ESC/IMU/TCU and do communication protection verification. When the verification fails, the MCU exits the function response, records the DTC, and sends a system failure signal ASIL A FSR7.

APA should jointly calculate the parking position spatial information data based on the radar environment sensing signals of the short-range ultrasonic radar/long-range ultrasonic radar, determine the expected driving trajectory, and detect pedestrians and two-wheeled vehicles on the driving trajectory ASIL A FSR8.

When APA judges that there are pedestrians or two-wheeled vehicles on the trajectory according to the radar environment sensing signal, APA sends an obstacle warning signal to IHU ASIL A FSR9.

APA should perform CRC check on the signal sent to IHU, frame counter, overtime monitoring ASIL A FSR9.

5. Software implementation strategy for horizontal parking

The horizontal parking module contains a signal input module, including parking information acquisition after finding a parking space, vehicle self-positioning information, vehicle coordinate update, front and rear radar signals, and side radar signals. The real-time status update of the vehicle is mainly used for the initial calculation of the parking starting point information of the first parking after the parking space is found, and the subsequent real-time posture and position information of the vehicle. The horizontal parking module is divided into an algorithm module, a logic module, an anti-collision module, and an adaptive angle control module. The horizontal parking algorithm module calculates the parking starting point during horizontal parking according to the initial parking position information after the vehicle searches for a parking space, and realizes path planning according to two arcs.

The algorithm flow chart of horizontal parking is shown in Figure 4.

![Algorithm flow chart of horizontal parking](image)

Figure 4. Algorithm flow chart of horizontal parking

(1) Find a parking space. After the car finds a parking space and parks, it outputs the parking position information to the path planning module.
(2) The path planning module starts to calculate the initial parking starting point.
(3) The vehicle module calculates real-time vehicle position and coordinates based on parking information and positioning pulses.
(4) Then enter the algorithm module, update the algorithm information in real time, output the target path, the vehicle wheel angle, and output the steering wheel angle through adaptive angle control.
(5) At the same time, the horizontal parking logic module outputs the parking guidance signal of the vehicle according to the real-time coordinate information of the vehicle.
(6) The anti-collision module receives front and rear radar information and outputs anti-collision prompt information.

6. Conclusion
In this article, we start from the general and very high-level consideration of the related hazards of pedestrians that cannot be detected in the automatic parking process. Through the process described in ISO26262, we gradually prove the needs and usefulness of specific technologies. Through the process of functional safety concepts and technical safety requirements, we first proved the requirements for the key functions provided by automatic parking, and then covered how to use them correctly to achieve safe operation in our automatic parking process. It also describes the function of horizontal parking from the perspective of algorithm, which shows the feasibility of this technology.

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