AFTON TECH ROBOTICS

"Merging Technology and Imagination for a better Tomorrow"

Technical Specification Document

Team Name: Afton Tech

Robot Car Name: Afton SmartWheels

Challenge Category: WRO 2024 Future Engineers - Self-Driving Cars Challenge

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Nueva Esparta, 2024/03/10

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1. Self-Driving Cars Challenge Overview

The challenge demands the creation of an autonomous robotic vehicle capable of navigating a track autonomously, adhering to the WRO general rules for the 2024 Future Engineers category. The key learning focus areas encompass computer vision, sensor fusion, electromechanical system integration, action planning, control strategies, and optimal problem-solving methodologies in a team-oriented project setting.

1.1Game Description

Open Challenge: Complete three laps with dynamic inner track wall placements.

Obstacle Challenge: Navigate through three laps with randomly placed traffic signs, adhering to lane guidance indicated by the colors of the pillars and executing a parallel parking maneuver at the end. The traffic signs indicate the side of the lane the vehicle must follow. The traffic sign to keep to the right side of the lane is a red pillar. The traffic sign to keep to the left side of the lane is a green pillar. The continuation of the vehicle to the third round is indicated by the last traffic sign of the second round. A green traffic sign indicates that the robot must go ahead and continue the third round in the same direction. A red traffic sign indicates that the vehicle must turn around and complete the third round in the opposite direction. The vehicle should not move any of the traffic signs. After the robot completed the three rounds, it has to find

the parking lot and has to perform parallel parking. The starting direction in which the car must drive on the track (clockwise or counter clockwise) will vary in different challenge rounds. The starting position of the car as well as the number and location of traffic signs are randomly defined before the round (after the check time).

2. Our Solution

2.1Main Controller

Microcontroller: We selected the ESP32-S3 for its advanced features suitable for AI-enhanced IoT applications. It offers a balance of performance, power efficiency, and versatile IO capabilities, making it ideal for controlling an autonomous vehicle. The ESP32-S3's dual-core processor and ample GPIO pins provide the computational power and connectivity options necessary for real-time data processing and peripheral control. Programming is done using ESP-IDF, Espressif's official development framework, which offers a rich set of libraries and tools to develop sophisticated Deep learning applications.

2.2Vehicle Chassis and Drive Mechanism

Chassis Configuration: Our vehicle is built on a 4-wheel chassis, providing stability and robustness essential for reliable autonomous navigation. The rear-wheel-drive configuration is chosen for its simplicity and effectiveness in various driving conditions, while the front steering provides the agility needed for precise maneuvering and course corrections.

Motor Driver and Actuation: The L298 Dual H-Bridge Motor Driver is utilized for its reliability and ability to control up to two motors independently, facilitating complex motion patterns and precise speed control. This driver supports the high current demands of our motors while allowing for straightforward interfacing with the ESP32-S3, ensuring responsive and accurate drive control.

2.3Steering and Maneuverability

Steering Control: Precision in steering is achieved through a servo mechanism controlled by a PCA9685 PWM driver. This setup allows for fine-tuned adjustments to the vehicle's direction, enabling it to navigate the course with high accuracy. The servo's responsiveness and accuracy are crucial for the vehicle's ability to follow the designated path, adjust to dynamic obstacles, and execute precise parking maneuvers.

Mechanical Linkage: The steering system is engineered with a dual-rod mechanism, ensuring reliable transmission of control movements to the wheels. This design is optimized for minimal backlash and smooth operation, providing the vehicle with the ability to execute swift and precise directional changes.

2.4Sensory Systems and Computer Vision

Camera Module: The OV2640 camera module is chosen for its compact size, high-resolution imaging capabilities, and low-power consumption. It is crucial for our computer vision algorithms, enabling the vehicle to understand its surroundings, detect obstacles, and recognize track markers. The integration of night vision allows for consistent performance under varying lighting conditions, essential for robust autonomous operation.

Distance Sensing: Incorporating multiple VL53L4CD Time-of-Flight (ToF) sensors around the vehicle enhances its spatial awareness, enabling accurate distance measurement to obstacles and boundaries. These sensors are fundamental in creating a real-time 3D map of the vehicle's immediate environment, facilitating intelligent path planning and obstacle avoidance strategies.

2.5Autonomous Control and Software

ESP-DL Library: Leveraging the ESP-DL library allows us to deploy efficient deep learning models on the ESP32-S3, optimizing the vehicle's decision-making process. The library supports essential AI functionalities, enabling our vehicle to process complex datasets from the onboard sensors and camera, resulting in real-time navigational decisions and path optimizations.

AI Model Integration: The autonomous driving system is designed around a deep learning model that processes inputs from the camera and distance sensors. This model is responsible for interpreting the vehicle's environment, predicting optimal path trajectories, and making real-time decisions to control the vehicle's steering and speed. The model is trained off-line using advanced machine learning frameworks and then deployed to the ESP32-S3, where it operates in real-time to guide the vehicle.

Software Tools and Frameworks: The integration of ONNX and TVM frameworks supports the AI model's lifecycle from development to deployment. ONNX provides a flexible and open standard for representing machine learning models, allowing us to use a variety of tools for model training and optimization. TVM offers an end-to-end compilation stack, enabling us to optimize the model for high-performance execution on the ESP32-S3 hardware.

3. Conclusion

The technical specifications of the Afton SmartWheels reflect a carefully designed system optimized for the WRO 2024 Self-Driving Cars challenge. Our approach combines sophisticated hardware components with advanced software algorithms, resulting in a vehicle that is not only capable of autonomous navigation but also adaptable to the dynamic conditions of the competition. Through strategic planning, innovative engineering, and a focus on integrating cutting-edge technologies, Afton Tech aims to excel in the competition, demonstrating the capabilities of our Afton SmartWheels autonomous vehicle.