Ruhr-Universität Bochum
Autonomous Vehicles and Artificial Intelligence
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RUB

Assignment 2

Requirements of an autonomous race car

Introduction

The purpose of this document is to provide a list of requirements for an autonomous race car. The document is split into several sections to cover all areas of concern including driving, developing and testing. These requirements can be understood as a starting point for development, the goal is to maintain and adapt them during development according to new findings.

Requirements

In the following chapter, all requirements regarding the functions of the car are defined. This includes a section regarding the quality at which the car needs to operate and the constraints that the car has to follow.

Functional requirements

In this section the functions of the car are defined. The majority of the requirements concern different driving functions that the car needs to be able to perform.

Driving Task Specification

- Maneuvers
    - The race car has to follow the given track autonomously.
    - The race car has to observe the environment and make decisions regarding the motion control.
    - The race can handle different track points in the race (e.g. starting point, finish line).
    - The car has to detect the left and the right cones and always position itself between them.
    - The vehicle should not be driven in reverse.
    - The race car needs to be able to participate in different race modes (e.g. skitpad, acceleration).
    - The race car needs to process sensor data and plan ahead such that it is able to move at a competitive speed.
    - The race car needs to be able to detect humans and stop if they are on the track.
    - The car needs to react appropriately as soon as it is in danger of damaging itself or other things.

- Motion control

    - The actuators need to be controlled in such a way that the race car is following the calculated path.
    - The current speed of the race car needs to be detected and adjusted to fit the anticipated movement along the calculated path.
    - There is an emergency button which activates the emergency brake.
    - There needs be a limit on the velocity while turning to prevent toppling of the car
    - If the race car goes of track it immediately stops after handling corrections faulty
- State
    - The car behavior is broadly defined by states:
        - The car is off: The car is standing still and all systems are turned off.
        - Booting state: The car is standing still and all required systems are booted up.
        - In AS Ready state the car is standing still but all systems are running in idl.
        - Driving State: The car is moving along the track while observing the environment and performing all processing to drive safe and competitively.
        - Finish-State: The car has arrived at the finish line and comes to a stop.
        - Emergency State: If the car is not already standing, it comes to a full stop and stays in emergency state until a human stops the program.
    - The state of the race car is marked and can be identified by a light

Development / Debugging

- The system is providing at least temporarily comprehensive log data of all driving decisions, driving state, sensor detections and sensor data interpretation.
- The logging behavior of the car needs to be adaptable according to development and racing mode.

Quality requirements

This section is about requirements that concern the quality at which the car operates. Quality requirements tend to be observable by non technical end users.

Environment

- The autonomous system can handle appropriately changes of the environment e.g.
    - wrongly positioned cones
    - weather changes (rain, bright sunlight, lunar eclipse, …)
    - road structure (e.g. potholes)
    - demolished cones

System

- The car is able to drive itself and complete the track with a competitive speed and high reliability. The car must not fail to complete the track 99% of the time.
- During all driving tasks the computer should not exceed 80% of its processing and memory resources, to ensure availability.
- Any internal error (e.g. ROS Node crash) should be handled appropriately (e.g. emergency stop, restart, …)
- If the system or any component is not responding (e.g. by heartbeat) the race car immediately stops.

Safety

- The car needs to perform an emergency break when a human is detected on the track.
- Sensor failures need to be detected and the car needs to be stopped within two seconds (performing an emergency break).

Constraints

This section is about constraints by which the car is bound to operate.

Motion

- The period of pressing the emergency button and the car stops should not exceed 2 seconds
- In case of an emergency break scenario, the car must come to full stop within 2 seconds.
- After the run the vehicle must come to a full stop within 30 meter behind the finish line on the track and enter the finish-state described in T 14.10.

Performance

- The cone detection should have at least 20 FPS and a very high accuracy (>95%).
- The race car is not allowed to drive faster than the software is able to fully detect its surroundings.
- The speed of the race car should be reasonable by at least 0.5 meter per seconds on average (no slow motion)

Others

- The vehicle must comply with all design constraints defined in the “Formula Student Rules 2022, Version: 1.0”.

Testing Strategy

This section is about testing the final product and making sure it complies with all of the above defined requirements. When all tests are passed, the car can be considered a finished product.

Software Tests

- The Software must be developed with a testdriven framework.
- For all functions, there must be a unit test written and all the unit tests must pass before deploying the software onto the car's hardware.
- All software components must be tested with an integration test upon deploying the software onto the car’s hardware.

System Test

- Simulation of the environment: The test is passed if the race car can complete the track in the following weather conditions:
    - rain
    - bright sunlight
    - fog
    - cloudy conditions
- Simulation system stress test: The test is passed if the race car is able to complete the track under the maximum allowed resource consumption
- Simulation track conditions: The test is passed if the race car is able to complete the track with the following conditions:
    - broken cones on the side
    - misplaced cones
    - extra cones in the background
    - tipped over cones
- Driving speed test: The test is passed when the car completes the track under the maximum allowed time specified by the “FS Competition Handbook”
- Sensor error test: The test is passed when the car stops as soon as the sensors operate at a lower rate then defined before.
- Emergency break test: The test is passed when the car performs an emergency break 99.9% of the time in all emergency scenarios like:
    - Emergency Button is pressed
    - Sensor error
    - Human jumps in front of the car