Functional Design (FD)

Company: REVO

Place, date: Enschede, 15th March 2024

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Version: 1.0

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Table of Contents

1 Introduction

The project aims to create a vehicle capable of autonomously following a line. This is achieved through the integration of hardware and software, resulting in a car that moves independently along a predetermined path. The core mechanism involves a sensor detecting light reflections off the line, which, after processing, guides the car forward and steers it along any turns in the path by adjusting the wheels.

This document outlines the functional design of the project, elucidating fundamental principles and the vehicle's conceptual framework. It includes detailed descriptions of both the software and hardware components involved.

Additionally, it covers the requirements analysis and the electronic aspects essential for project realization. Furthermore, it discusses the project's management and conceptual strategies. All pertinent information and project details are contained herein.

2 Analysis of requirements

This analysis must aim at proving the principal feasibility of the functional and technical requirements as formulated in the SR- This chapter presents the objectives and methodologies for developing an autonomous vehicle project as stipulated by the stakeholders and our team.

The focus is on creating a self-guiding car that operates within specific physical dimensions and timeframes, incorporates eco-conscious practices, and remains within the team's capabilities and budgetary constraints.

Requirements Set by Stakeholder:

Ride autonomously.

Approach: Develop a program that autonomously guides the car using sensor feedback.

Work for at least 30 minutes.

Approach: Ensure through calculations and measurements that the vehicle's electrical features meet performance standards.

Follow the track line (20mm).

Approach: Implement sensors to detect and follow the line.

Stop at the end of the track.

Approach: Devise a method to detect the end of the track and signal the program to halt.

Avoid obstacles.

Approach: Integrate sensors to detect obstacles and program the car to take appropriate actions, such as navigating around them.

Find the track line.

Approach: Use sensors or a camera to locate and follow the track line.

Have a body (Separate parts of a car shield).

Approach: Produce an wooden model assembled by pieces to ensure ease of process and its perspective in testing (wood cutting is tremendously faster than 3d printing).Finish with the shield that can be attached to the body of RC car.

3 Elaboration of chosen principle to functional design

3.1 Overview of functional design

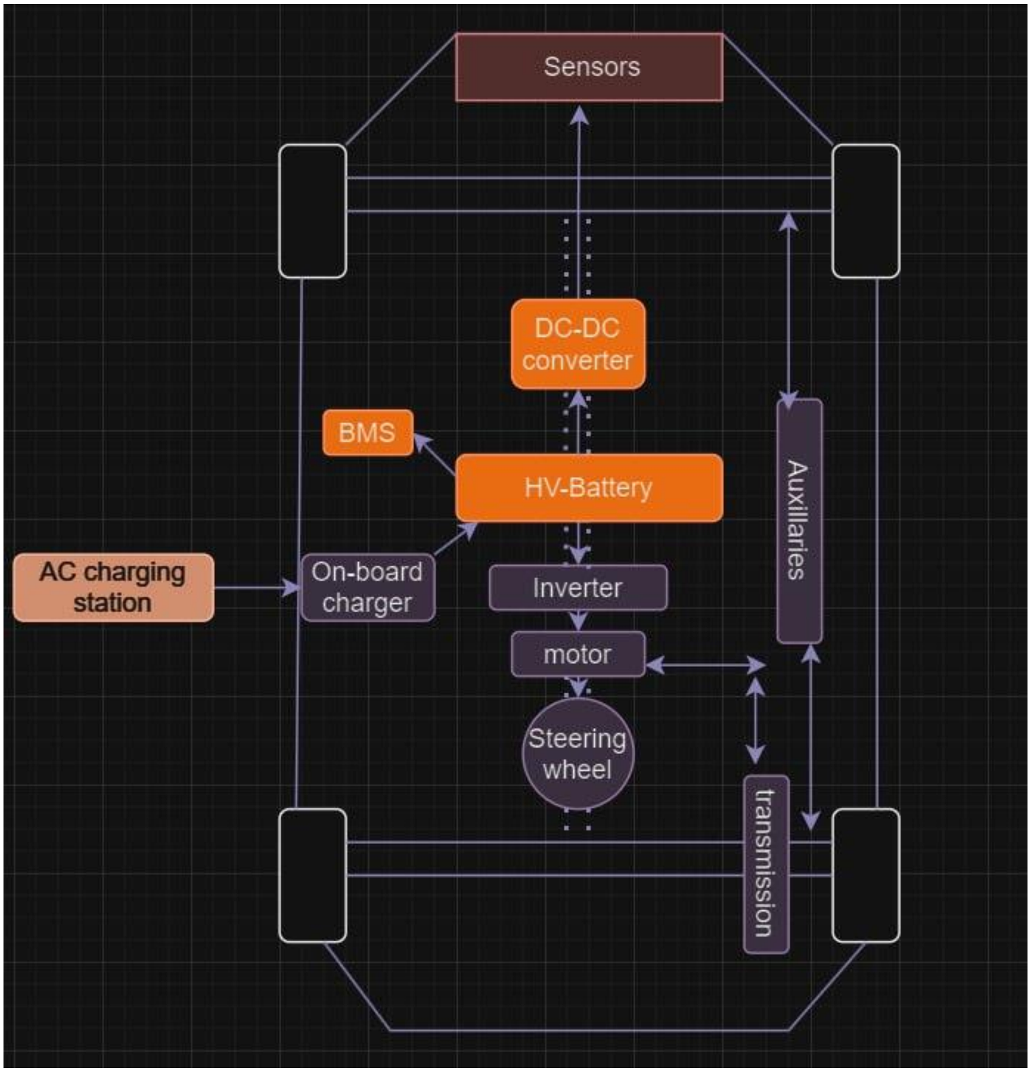

Figure 3.1 – Block diagram

The chosen design concept features a four-wheel drive system powered by a DC motor, controlled by a microcontroller. The system uses a combination of ultra-sonic and AR sensors for navigation and obstacle detection. The chosen design of the car is divided into 4 sub-categories: mechanical, electrical, sensors and microcontroller.

3.2 Elaboration of functional design

The functional design is divided into the following sub-sections:

3.2.1 Mechanical

The mechanical layout includes:

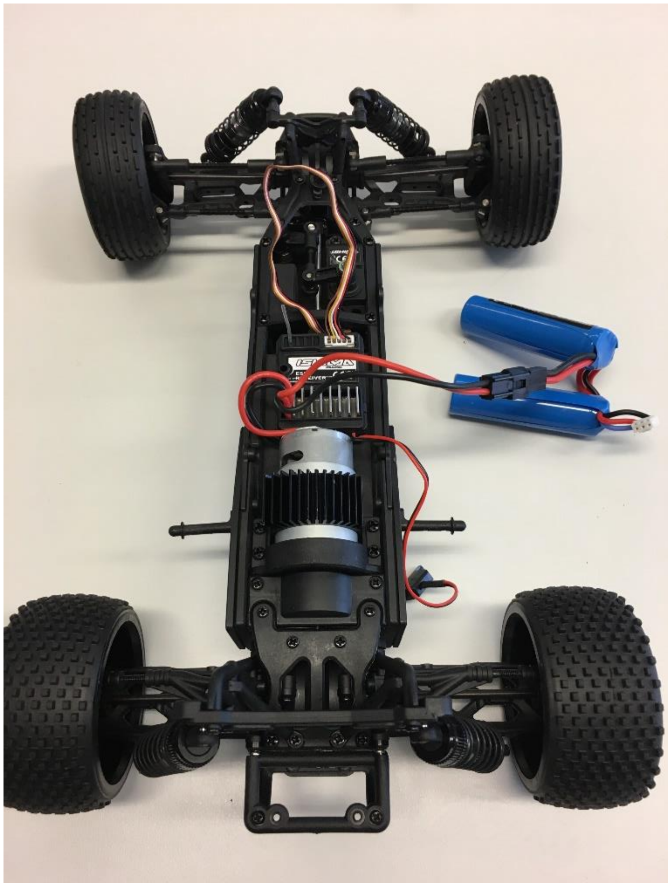

Figure 4.2 – ISH-010 base frame

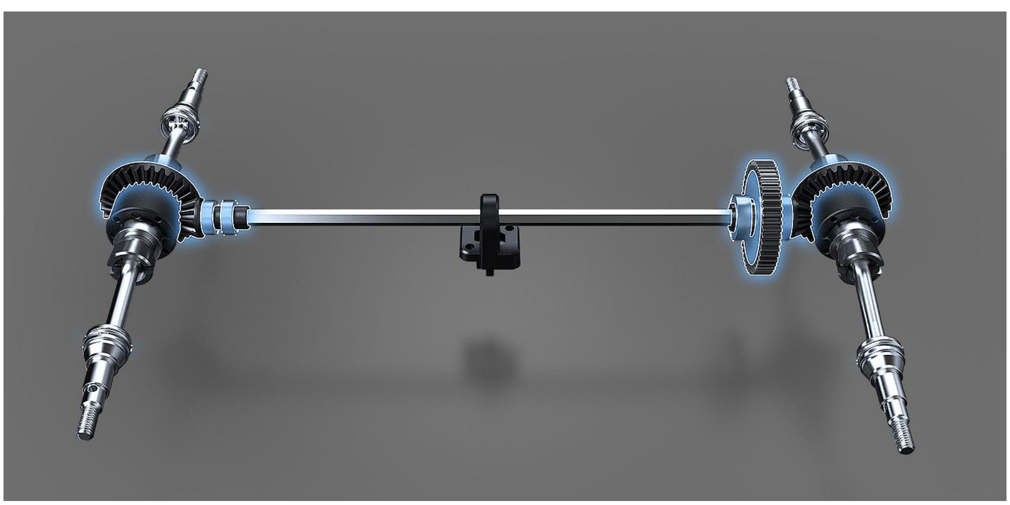

Figure 4.3 – Transmission and steering wheel

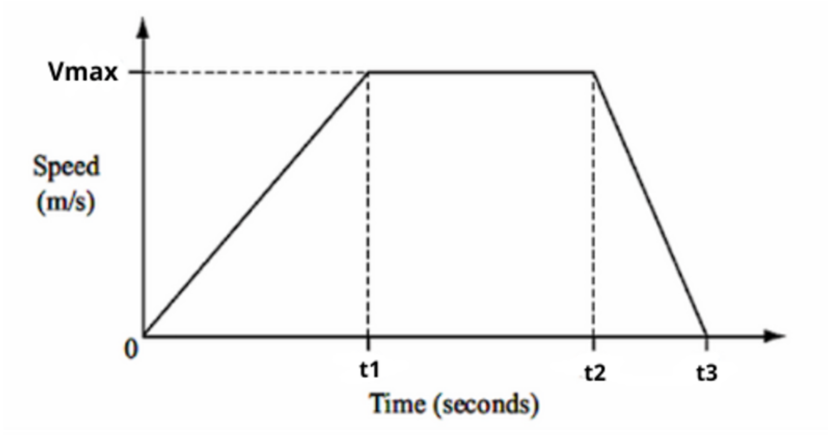

Figure 4.4 *– Velocity to Time relationship*

The mechanical component of our design is built for durability and precise control. Here's a breakdown of the key mechanical parts:

- Motor - converts DC to mechanical energy to produce motion
- Steering wheel - connected to the motor and rotates in Z-axis to move
- Transmission - connected to the steering wheel and rotates the wheels in X-axis
- Auxiliaries - to provide better bounce-tolerance
- ISH-010 – base frame provided by Saxion. It's the foundation to which all mechanical parts are anchored

3.2.2 Electrical

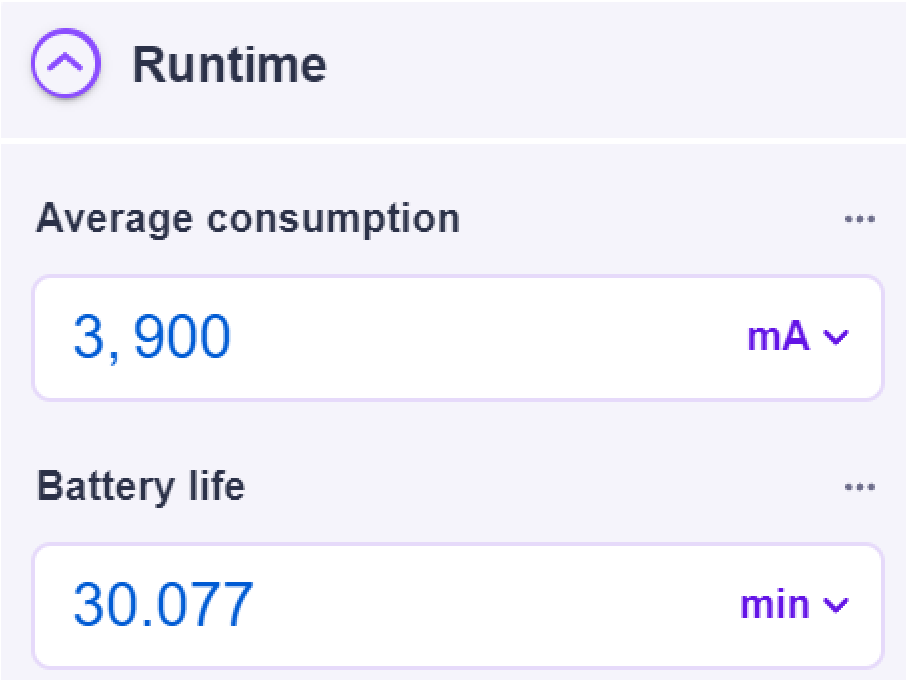

***Figure 4.5** – Runtime of the battery calculator*

The electrical system is centered around a NiMh 8,2V 2300mAh battery, ensuring a minimum operational time of 30 minutes. The discharge safety is set to 15% to avoid over-discharge. Voltage conversions for various components are carefully planned to ensure compatibility and efficient power distribution.

***Figure 4.6** – REELY - NiMh Battery 8.2V,2300mAh*

The electrical system layout arranges all the parts and wires to make sure everything gets the right amount of power.

- HV Battery: It's the main power source and comes with a smart system to keep it running 30 minutes non-stop.
- BMS - carefully monitors and controls the battery's charge and discharge processes to prevent damage and extend the battery's life
- DC-DC convertor- steps down the high voltage to lower voltages suitable for different parts of the system
- Motor Driver - transforms direct current (DC) from the battery into AC for the motor
- On-board charger - manages the charging of the HV battery from an AC charging station
- AC charging station - provides an interface for the vehicle to connect to the electrical grid

3.2.3 Electronic

There are lots of options that we could choose as a base for our project. For example:

Usage of personal computer, implementing project using Raspberry Pi single boarded computer, or maybe use USP-32. Also, there is a broad field on choosing the way to implement main purpose of autonomy of our car – we could use Camera for both line tracking and obstacle avoidance or use different kinds of sensors.
Nonetheless we have stopped on the Arduino as we concluded that it will be easiest and most efficient option regarding flow of information and its communication. In such a case we would only additionally use sensors and would only need only USB connection for Arduino to communicate with it and update the code. A switch or button could be used to start the main algorithm when the system is turned on.

3.2.4 Sensors

Sensors are a crucial aspect of the electrical design, providing the necessary data for navigation and interaction with the environment.

Line Tracking Sensor: The vehicle is equipped with infrared light sensor and infrared LED responsible for detecting the white line on the track. The IR LED illuminates a surface with infrared light; the sensor then picks up reflection and based on intensity distinguishes the contrast between the track and the line, providing input to the control system to ensure that the car stays on course.

Obstacle Avoidance Sensor: To navigate around obstacles, ultrasonic sensors are placed around the vehicle. These sensors produce high-frequency sound waves that reflect from the objects in the vehicle's path. The time it takes for the echoes to return is calculated to determine the distance to potential obstacles. Finally, the accelerometer/gyroscope sensor will use this information to navigate the car avoiding collisions or to detect the upcoming ramp.

The information from these sensors is sent to the car's main control unit (Arduino), where the software processes the data to make decisions about the vehicle's movements.

3.2.5 Software

Software approaches and options used:

- Integrated development environment: Arduino IDE, Clion, Visual Studio Code.
- Programming languages: C/C++
- Arduino features such as Interrupts, external libraries.
- Main algorithms – line detection, obstacle detection, ramp detection.

Main principle of the software part: code is implemented within a loop that iterates through the whole program while Arduino is working, what lets us to periodically update all information within the system to successfully adjust the trajectory and acceleration of our car in real time to complete the track.

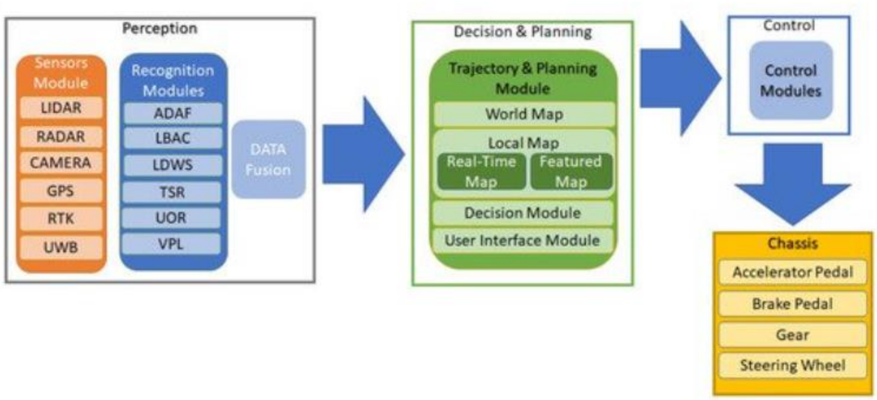

Figure 4.7 - System Architecture for AVs. [3] - see references chapter.

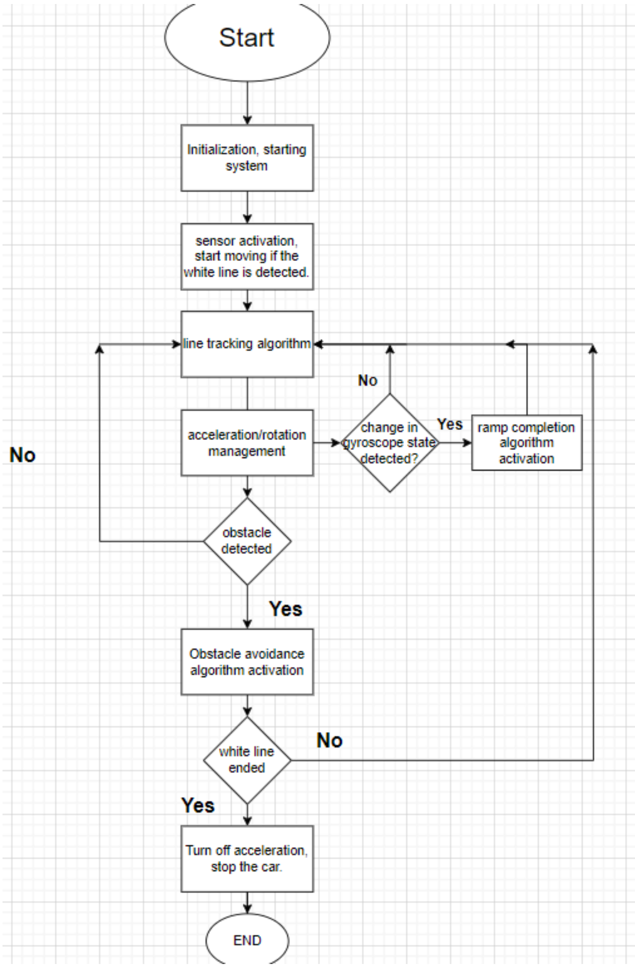

Figure 4.8 - Flow chart describing main algorithm of our program.

3.3 Functional design integration

Safety:

The main concern regarding safety is acceleration management and the battery. Our team must implement a reliable algorithm of car speed control to be sure that during testing it will not crash into surrounding objects and damage its parts. And the second thing that should be considered is battery strengthening – Li-Ion battery could potentially lead to a hazardous explosion or set on fire if experienced damage.

Speed:

After analyzing videos on Saxion's "Saxion - Autonomous RC Challenges" YouTube channel (https://www.youtube.com/@saxion-autonomousrcchallen2946) our team concluded that we aim on passing the given track in under 45 seconds.

Accuracy:

- Obstacle: Our idea is that car will measure distance to the obstacle in front of it with help of ultrasonic sensors. In such case a predefined algorithm of obstacle avoidance will be activated.
- Line tracking: Program will continuously execute line tracking algorithm, looking for a white line using a set of Infrared sensors that will help to distinguish the line and follow it accurately. Position of the car relatively to white line will affect its acceleration so it can speed up during straight parts and slow down during turns.

Cost:

Some core elements for the project will be given to our team, leaving us with a budget of 50 Euros to buy any additional parts. Our team aims to fit in that range of expenses and not spend more, unless extra circumstances arise.

Maintenance:

Some core parts of our project such as battery, brushed DC motor, gears, etc. can wear out and be damage in result of long usage, but in our case The time frame of our project is not long enough for the parts to experience these problems. Nevertheless, we are ready for any circumstances and will replace broken elements with the help of university.

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[3]		https://encyclopedia.pub/entry/8473
		http://www.mjxrc.net/goodshow/14210-14210.html

Appendix A: