Functional Design (FD)

Project: Autonomous Race car

Company: ACEcar

Place, date: Enschede, 12th February 2022

Drawn up by: Jurijs Zuravlovs
Dmytro Taras
Karolis Juozapaitis
Tarik Mandic
Miguel Pérez Hernández

Version: 1.1

Drawn up by: Ali Yuksel

Place, date:	Enschede, 4.03.2022		
Prepared by:	ACEcar		
	Miguel Pérez Hernández	524262	524262@student.saxion.nl
	Tarik Mandic	523830	523830@student.saxion.nl
	Karolis Juozapaitis	517546	517546@student.saxion.nl
	Dmytro Taras	516824	516834@student.saxion.nl
	Jurijs Zuravlovs	440882	440882@student.saxion.nl
Version number:	[1.1]		
Clients:	A. Yuksel, A. Fiselier, Y. Kasemsinsup		

Table of Contents

I. List of figures iv
II. Abbreviations v
1 Introduction 1
2 Analysis of requirements 2
3 Concept Principles 3
3.1 Description of alternative concepts 3
3.2 Comparison of concept principles 5
3.3 Choice of most promising concept principle 5
4 Elaboration of chosen principle to functional design 5
4.1 Overview of functional design 6
4.2 Elaboration of functional design 6
4.2.1 Mechanical 6
4.2.2 Electrical 8
4.2.3 Electronic 9
4.2.4 Software 9
4.3 Functional design integration 11

I. List of figures

Figure 1 Project management.. **Error! Bookmark not defined.**
Figure 2 XKCD graph: walking back to my front door at night....................... **Error! Bookmark not defined.**

II. Abbreviations

SBC

DSP	Digital Signal Processing
FFT	Fast Fourier Transform
TL;DR	Too long didn't read
SBC	Single Board Computer

1 Introduction

The goal of the project is to build a car which will be follow a line. The car is moving due to hardware and software interweaving. Final product is a fully autonomous car which is following the line. The main idea is to use a sensor which takes the light and due to processing the car moves forward by the line. If the line turns the processor which see that the line is turned rotate the wheels and making the car to drive in a certain direction.

Goal of this document is to show the functional design of this project explain some basic ideas and show the concepts of a car. In this document description of a software and hardware part is provided below. Also, this document provides a requirement analysis and electronics part of the project. Therefore, the concepts and management also provided. All information this document includes can be found above.

2 Analysis of requirements

Requirements settled by stake holder

Requirement	Approach
1. Ride autonomously.	Create a program that will guide itself with the response of the sensors data
2. Work for at least 30 minutes.	Make sure by calculation and measurements the electric features and specifications that it will perform to that standard.
3. fit in a box of 400mm x 250mm x 200mm.	Create a model of the car respecting this dimension
4. Follow the track line (20mm).	Have sensors in order to track the line
5. Stop at the end of the track.	Figure out a way to know when the car reaches the end of the line and tell the code to terminate the program
6. Avoid obstacles.	Include sensors to have feedback if an obstacle is found in its path and be able to respond to it with an appropriate action (For ex: drive around the obstacle)
7. Find the track line.	Use input from sensors or a camera to find and track the line
8. have a body (3D printed separate parts).	Create a 3d model which will be possible to attach to the main body of the RC car.

Requirements settled by our team.

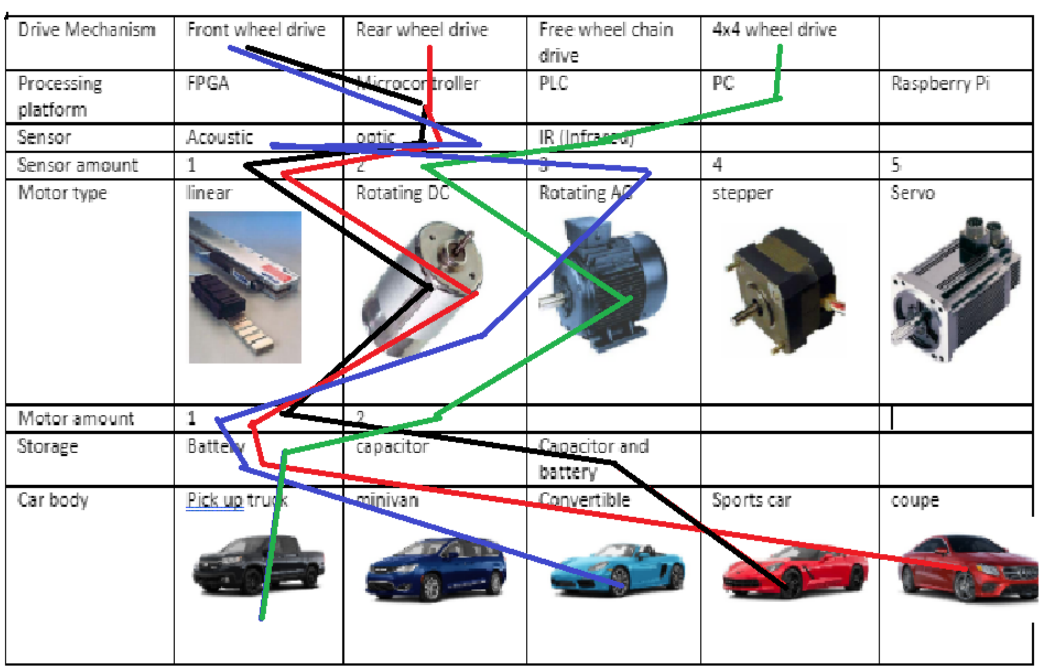
Requirement	*Approach*
1. Cost efficient	*Calculate beforehand and produce a budget with a margin of price tolerance*
2. Environmentally friendly project.	*Make sure the parts used are as eco-friendly as possible like recycled printing polysynthetic*
3. Development under our current knowledge	*Know the team skills and knowledge to make sure the project is not too ambitious*

3 Concept Principles

Morphological overview

Drive Mechanism	Front wheel drive	Rear wheel drive	Free wheel chain drive	4x4 wheel drive	
Processing platform	FPGA	Microcontroller	PLC	PC	Raspberry Pi
Sensor	Acoustic	optic	IR (Infrared)		
Sensor amount	1	2	3	4	5
Motor type	linear 	Rotating DC 	Rotating AC 	stepper 	Servo 
Motor amount	1	2			
Storage	Battery	capacitor	Capacitor and battery		
Car body	Pick-up truck 	minivan 	Convertible 	Sports car 	coupe 

3.1 Description of alternative concepts



Drive Mechanism	Front wheel drive	Rear wheel drive	Free wheel chain drive	4x4 wheel drive	
Processing platform	FPGA	Microcontroller	PLC	PC	Raspberry Pi
Sensor	Acoustic	optic	IR (Infrared)		
Sensor amount	1	2	3	4	5
Motor type	linear	Rotating DC	Rotating AC	stepper	Servo
Motor amount	1	2			
Storage	Battery	capacitor	Capacitor and battery		
Car body	Pick up truck	minivan	Convertible	Sports car	coupe

With the morphological overview, 4 different concepts were made.

1. Black
- Front wheel drive
- Microcontroller
- 1 Optic sensor
- 1 DC motor
- Capacitor & Battery
- Sports car

2. Red
- Rear wheel drive
- Microcontroller
- 1 Optic sensor
- 1 DC motor
- Battery
- Coupe

3. Green
- Four-wheel drive
- PC
- 2 IR (infrared)
- 2 AC motors
- Battery
- Pick-up truck

4. Blue
- Front wheel drive
- Microcontroller
- 3 sensors for either Optic & Acoustic
- 1 DC motor
- Battery
- convertible

Some comprehensive concepts:

5. Using an Arduino and a light sensor to see when it goes out of track and correct itself + an ultrasonic sensor to detect any obstacles **(The simplest concept so far).**
6. Using an Arduino/microcontroller with a light sensor array to detect the track and an ultrasonic sensor or rangefinder for obstacle detection/avoidance.
7. Using a raspberry pi with a camera and OpenCV to detect the track and depending on where the camera is mounted also detect the obstacles or use another distance sensor (rangefinder, ultrasonic) Demo: https://lejosnews.wordpress.com/2015/12/03/line-following-with-opencv/
8. Using a mini drone that has a camera and can stream video and be controlled over Wi-Fi for visual data which then a raspberry pi or a computer could calculate where the car and drone should drive/ fly (using OpenCV and ArUco markers) (the problem is the drone can only fly for +-5 minutes after fully charged so it would probably need to be wired up with a long but light cable) have the drone video stream and control working.

3.2 Comparison of concept principles

The difference between concepts 1 and 2 are the FWD and RWD and capacitor. The RWD is better because the sensor is placed in the front of the car, needing a better weight balance by putting the motor at the back. The capacitor will not be a good option for the RWD as the traction might be lost during the speed up. So, combining the capacitor with the FWD is better.

The 3rd concept is hard to do because of the processing with the PC, it is not clear how the communication will be done between the car and the PC.

The 4th concept is good, but with the Four WD, with only 1 DC motor will miss the option to add more speed to the car with the increased control that four WD allows.

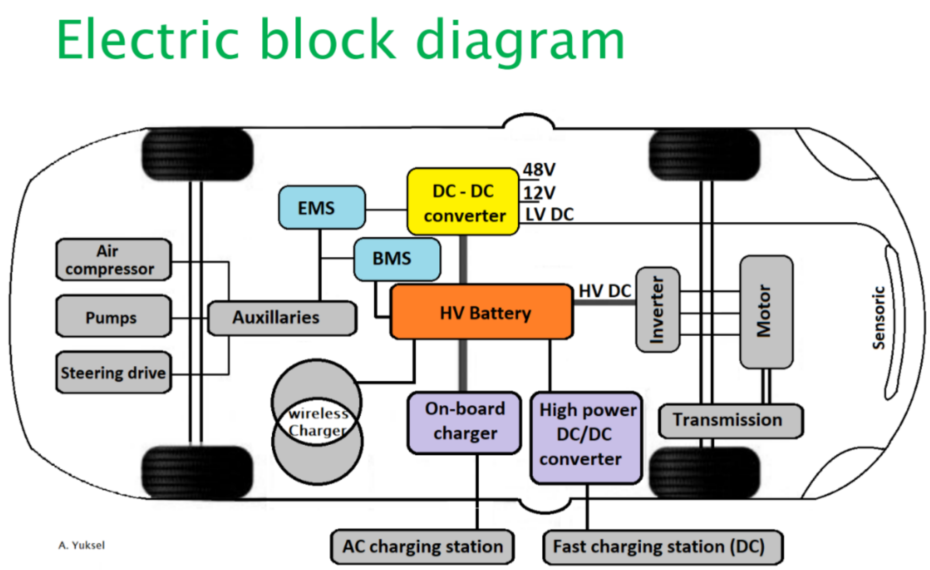
3.3 Choice of most promising concept principle

A combination of the combination is the best.

- Four-wheel drive
- Microcontroller
- 3 sensors for either Optic & Acoustic
- 2 DC motor
- Battery
- convertible

4 Elaboration of chosen principle to functional design

4.1 Overview of functional design



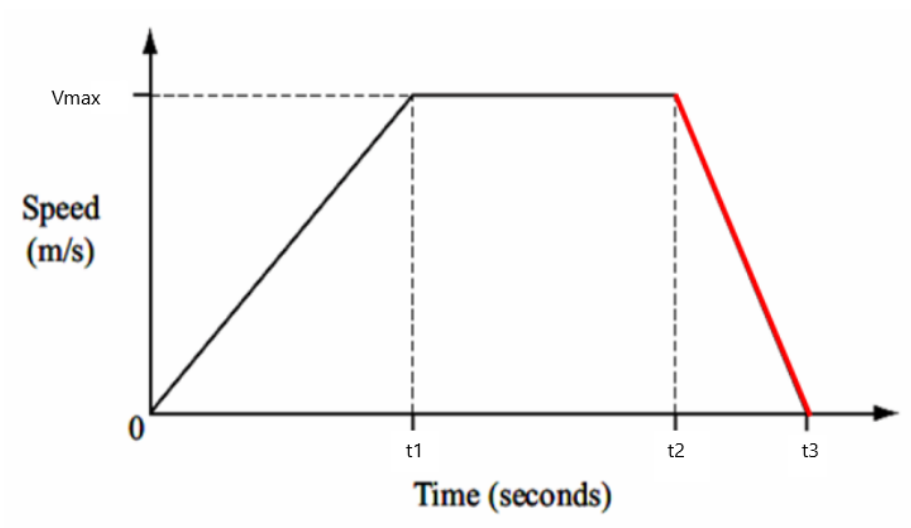
4.2 Elaboration of functional design

4.2.1 Mechanical

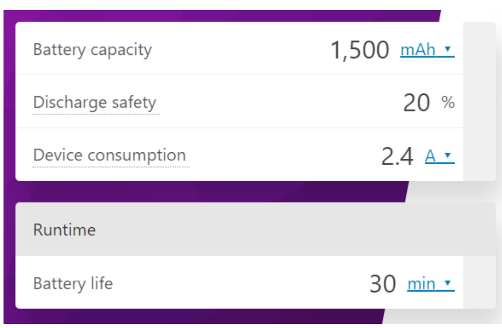
Base frame: ISH-010

Transmission and power design

Dynamic graph of our system



4.2.2 Electrical



Battery: Li-ion 2s 1p 7.4v 1500mAh

Discharge safety: 20% (The percentage left that is considered “fully discharged” to protect the battery from over discharge may be possible to go a bit lower but a lithium-ion (Li-ion) battery cannot be discharged below 2.5 volts and a lithium polymer (Li-Po) battery cannot be discharged below 3 volts, or battery damage will occur!).

Without Risking over-discharge, we could draw 2.5A continuously to get 30 minutes of power (if discharging 80% of the battery’s capacity)

Voltage conversions:

- Battery charger ->7.4v Li-Po
- 7.4v Li-ion -> Step-down converter (5v, 3.3v, …)
- 7.4v Li-ion-> Motor driver-> Motor(s)
- Step-down converter 5v-> Raspberry Pi, servo motor, Arduino, Camera, sensors…
- Step-down converter 3.3v-> Sensors

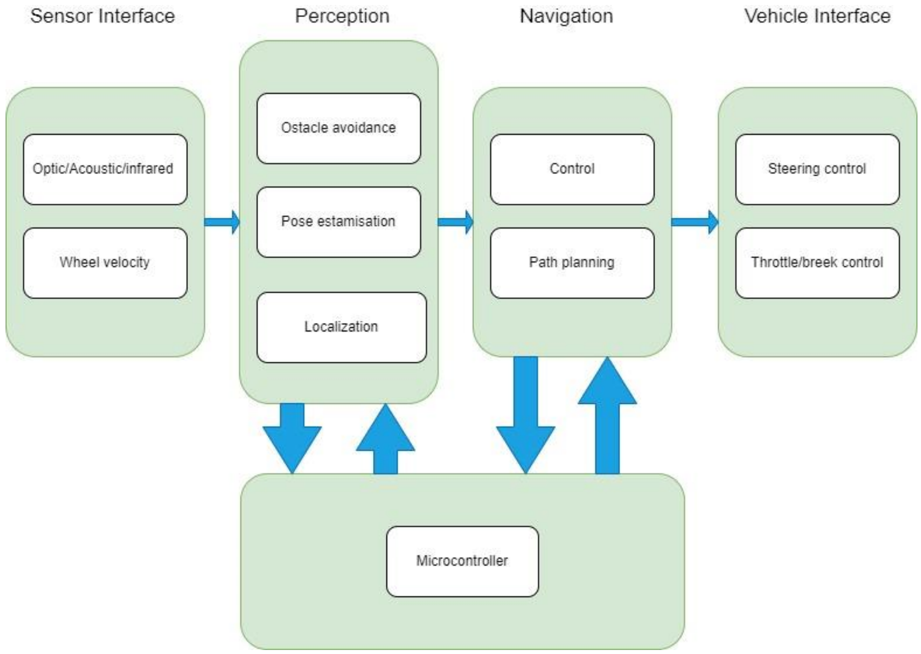
4.2.3 Electronic

- If we choose PC, we'd need to find a way to communicate control data and sensor/ video data between the car and PC. Potentially requiring a raspberry pi anyway. This might be a good option if we're going to need quite a bit more processing power than a raspberry pi can provide.
- If we choose a raspberry pi or similar single board computer everything could be connected locally, and we'd interface with the SBC through Wi-Fi or Bluetooth using SSH (Secure Shell Connect)
- If we use an Arduino (Meaning we'd only use sensors) we wouldn't need any way of wireless communication since the Arduino communicates through a USB to Serial chip meaning a USB cable is all that is needed to communicate with it and upload code, we could use a button to start the car or simply add a delay from when the battery was connected.
- Using a Camera for visual data would allow to use a single sensor (the camera) for line detection, obstacle avoidance and stopping at the end of the road. The capture rate would depend on the camera and the processing power.
- Using a light sensor array would make it simpler to implement everything but would also require the use of a distance sensor (ultrasonic, laser ranging (ToF), button…)

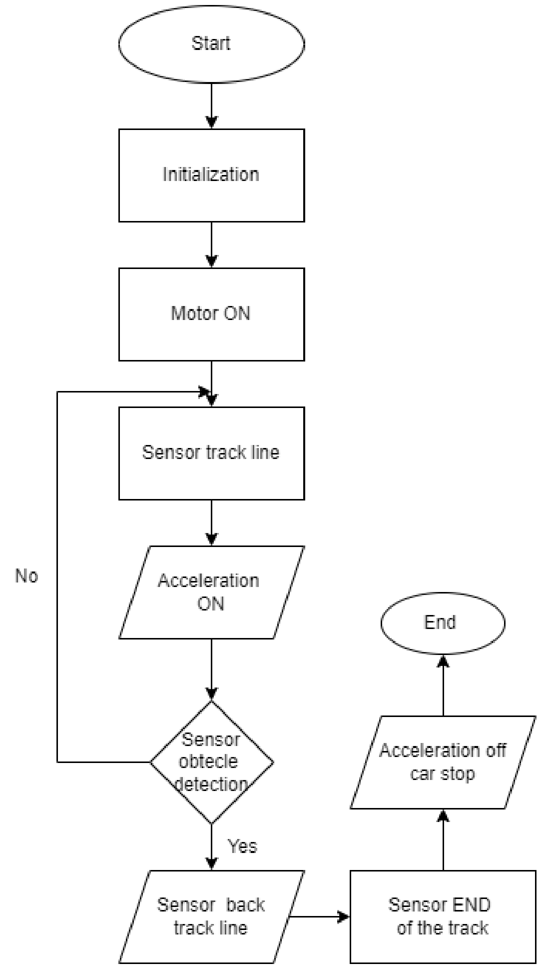
4.2.4 Software

- Actor – Critic algorithm for self – driving cars.
- In image processing, line detection algorithm - the Hough transform and convolution-based techniques.
- Architecture diagram with modules and interfaces.

Software Block diagram [1]



System states plus state transition diagram.



- Interrupts.
- Programming language and environment.
- C++, python, or C.
- Arduino IDE, Visual Studio Code, CLion.
- Minimum required 3.20(CLion)

4.3 Functional design integration

Safety:

- The most dangerous part of the car is the battery. If a lithium-based battery experiences damage it could potentially lead to a serious fire or explosion hazard. Battery reinforcement must be considered to ensure the safety of the car and the user in case of damage.

Speed:

- AceCar’s current goal is to complete the track in under 1 min.

Accuracy:

- The car should measure the distance of the obstacle and find a way to avoid it. Typically, an ultrasonic sensor will be a good fit for this problem (Other options exist).
- The car should be able to follow the white line without swinging side to side too much or it will reduce the speed.

Cost:

- With the provided parts the goal of an autonomous self-driving car simply cannot be achieved thus extra parts will be required. Depending on the parts used the price will vary greatly.
- *The base budged is around 50€ however if provided with satisfactory arguments the budged limitation may be lifted.*

Maintenance:

- DC motor: The provided motor is a “brushed” DC motor meaning as time goes on the carbon “brushes” will wear out and will typically require replacing the whole motor or replacing the brushes if the motor has such capability.
- Li-ion battery: The battery is considered a consumable and will lose its capacity bit by bit and one day will require replacing it.
- Gears: It is possible for the gears to break or wear out thus requiring replacements.

References

Number	Author(s)	Title
[1]	R. Gandhinathan	ROS Robotics Project (2019)
[2]	Yong, Jia Ying,	A review on the state-of-the-art technologies of electric vehicle, its impacts, and prospects (2015)
[3]	Abhishek Gupta	Policy-Gradient and Actor-Critic Based State Representation Learning for Safe Driving of Autonomous Vehicles (2020)