Project System: Final report

Autonomous Race Car

Place, date: Enschede, 24th May 2022

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Abbreviations

MoSCoW	Must, Should, Could, Won’t have
PCB	Printed Circuit Board
CV	Computer Vision

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Introduction

Background

This project started at the beginning of February, to make and design an autonomous racing car. We at ACEcar, have worked hard and long to create a satisfactory product for out Stakeholders at Saxion University. To design something new and innovating and to combine our strengths to win the Saxion E-Race. This report will show our design and work method used to create the future winner of the Saxion E-Race.

Objectives

The MoSCoW method operates by splitting the clients' requirements into the most important ("Must"), all the way down to additions which would be nice to have, but are not necessary ("Could"), while also agreeing on things which are not feasible due to either timing issues or just not enough manpower ("Won't have").

Must:

- Ride autonomously.
- Follow the track line (20mm).
- Stop at the end of the track.
- Avoid obstacles.
- Find the trackline.

Should:

- Fit in a box of 400mm x 250mm x 200mm
- Drive for at least 30 minutes continuously
- Have a body (3D printed separate parts)

Could:

- Accelerate to the maximum speed.
- Automatic return to start for charging or restarting mission
- Have a drone that follows the car autonomously to either give visual track data or to just record the car driving
- Make the car faster with either better or multiple motors
- Process the car through the network.
- Have a light that indicates whether they oversee the vehicle.
- Manual control through either a physical remote or laptop/phone/tablet

Won't have:

- Solar powered batteries (which would contribute to sustainability and the renewable energy movement)
- More than two engines or batteries.
- An overkill engine
- Off road tires.

Methodology

The methodology we will use to develop our project is the V-model which we can separate into some steps.

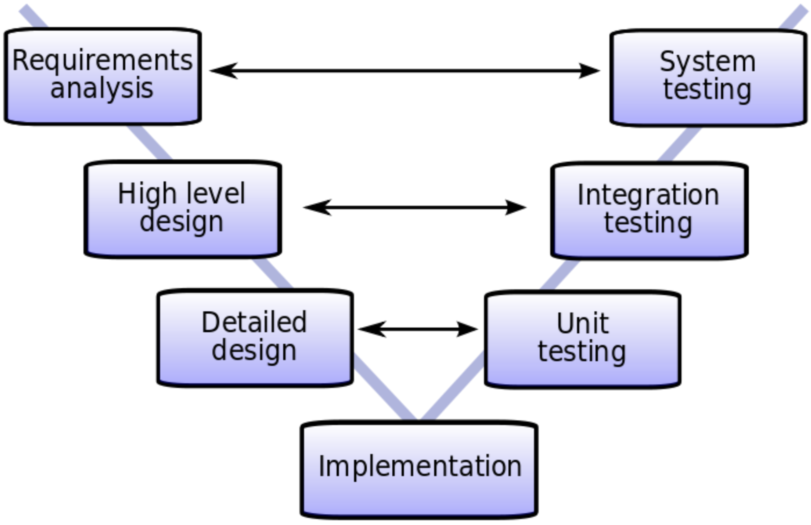


Figure 1: V-Model

- <u>REQUIREMENT ANALYSIS.</u>
  - Looking for what the user is requiring (behavior and specification of the system). To structure the user requirements, we will use MoSCoW method. Look at the technical requirements (what components do we need).
- <u>HIGH LEVEL (FUNCTIONAL) DESIGN.</u>
  - Figuring out how to create the system, trying to describe what steps the machine will take for different inputs. How the circuit is going to respond to the procedure.
- <u>LOW LEVEL (TECHNICAL) DESIGN.</u>
  - Creating a visible idea of the project (via schematic, flowcharts and drawings) and simulating if it works. Creating a more specific flowchart of how individual systems work.
- <u>IMPLEMENTATION.</u>
  - Making the result (PCB printing and loading code to Arduino).
- <u>TESTING.</u>
  - For each of the steps above we will have to do a test to detect and solve possible bugs and check if the project is meeting all the requirements.

Safety

For this project there are several things which should be followed in order to succeed and finish project in time without any delays. The safety principles can be divided into hardware safety, software safety and team safety. For the hardware safety, the current and voltage limit applies to a hardware to prevent it's burning or even exploding. The detailed limit could be found in technical design part, at the electronics. For the software safety some unit tests were done to check if the code works properly, and it won't have any bugs during the race. Also, tests if the applied software works good with hardware in order to prevent unexpected errors during the race. Backup plan was considered If something could go wrong, and the group lost everything or just a piece of something. For the group safety, some basic safety methods, which would been followed during work with electronics and 3d printers.

Structure

The following part of the report includes the execution of the assignment, which contains:

- Project Objectives
- Project activities
- Project boundaries
- Quality assurance
- Project organization
- Planning
- Costs and benefits
- Risk analysis

After that comes the Functional Design, Technical design, Result, Conclusion and Recommendation, References and lastly the Appendix.

Execution of assignment

Project Activities

Project setup
- Project plan.
- User requirements.
- Acceptance test plan.

System Requirements
- Functional requirements.
- Technical requirements.
- System test plan.

Functional Design (High level design)
- Concepts.
- Choosing a concept.
- Functional design concept chosen.
- Sub-system test plan.

Technical design (Detailed design)
- Technical block diagram.
- Calculating and selecting essential components.
- 3D and 2D mechanical design.
- Schematics and PCB design.
- Pseudo code.
- Module/Unit test plan.

Realisation
- Mechanical – Making components and module assembling.
- Electrical-Electronic – Making PCBs and module assembling.
- Software – module/unit coding.

Module/Unit Test

Sub-system Test
- Module integration.
- Test.

Factory Acceptance Test
- Sub-system integration.
- System Test.

Site acceptance Test

Finalization project
- Final report & Documentation.
- Personal contribution document.
- PowerPoint presentation.

Project Boundaries (scope and pre-conditions)

Start day: 11th of February 2022
End day: 26th of May 2022
Length of the project: 105 days
Budget: 50€ (Unless “ACEcar” convinces the stake holders to increase the budget)
The pre-conditions that must be met for the project to have a chance of success:

- Project members each need to be assigned a role that the members will be working on (design, programming, management, electronics, etc.)
- “ACEcar” needs to decide on what technical approach will be chosen
- The preliminary design of the vehicle needs to be thought out for the prototype
- A prototype of the product needs to be made for testing purposes
- All important documents must be filled in and submitted
- The parts list must include the required parts price and links to the parts

What doesn’t belong in this project:

- A website promoting our company and product
- personnel other than the ACEcar team working on the project.

SCHEDULE PROJECT SYSTEM 2021-2022 QUARTER 3 AND 4

Week 3.1	Week 3.2	Week 3.3	Week 3.4	Week 3.5	Week 3.6	Week 3.7
- Project Kick Off - Group Formation - 5 Members - Research - Group Meeting - Project Plan Gant Chart (Planning) - Risk analysis (Excel Sheet) Book Grit - Logo - Roles - V-Model - Scrum	- Research - Group Meeting - Project Plan Gant Chart (Planning) - Risk analysis (Excel Sheet) Book Grit	- Functional Design - Functional Blocs - 3 Functional Design Concepts - Block Diagram - High level flow chart - Testing requirements -	- Working out 1 Functional Concept - Platform - Shields - Sensors - Power Supply - Propulsion - Drawings - Schematics - 3-D Model View - Cover	- Low level design (flow chart) - Test cases - Protocols - Standards - Platform - Shields - Sensors - Power Supply - Propulsion - Drawings - Schematics - 3-D Model View - Cover	- Providing The platform and other items - Calculation Results - Simulation Results - PCB Design (Shields + ..) - Measurements Primarily Results - Test Results - Components/part list - Safety	- Calculation Results - Simulation Results - PCB Design (Shields + ..) - Measurements Primarily Results - Test Results - Components/part list
- Investigation Phase - research	- Project Plan Phase	- Functional Design Phase	- Technical Design Phase	- Technical Design Phase	- Technical Design Phase	- Test and Implementation Phase
	Monday 21th February 23:59 H Submitting Project Plan On Blackboard Individual	Monday 7th March 23:59 H Submitting Functional Design On Blackboard Individual	Go – No Go Meetings	Monday 21th March 23:59 H Submitting Technical Design On Blackboard Individual	- Order list - Midterm Presentation	-

Week 3.8	Week 4.1	Week 4.2	Week 4.3	Week 4.4	Week 4.5	Week 4.6
Assembling And Sub Systems Testing	Assembling And Systems Testing	Assembling And Systems Testing	- The Car has To Work 30 Minutes According Functional Design! - If Ok Then On Presentation Schedule		- Each Group Member Talks About His Part Of The Design (Defence) If Not Present - 1 Point Off In The Grade	- No Race No Mark
- Test and Implementation Phase	- Realisation Phase - Test Phase	- Realisation Phase - Test Phase	- Performance Test	- Fine Tuning	- User Acceptance Test	- Individual Student Performance Check
-	-	-	- Prototype Demonstration	Friday 27th May 23:59 H Submitting Final Report On Blackboard Individual	Presentations + Demo 30 Minutes	Race + Evaluation + Peer Assessments + - Logbooks
						Week 4.7 Retake

Figure 2: Project Schedule/Timetable

Quality assurance

The desired quality will follow the project objectives mentioned in the Introduction under Objectives.

Before the production of the product, an order list, project plan, a functional and technical design must be created and submitted for feedback. Either to improve or change the conceptualization of the product.
The quality of the product will be tested by phase tests known as, Module/Unit Test, Sub-system Test, Factory Acceptance Test and Site acceptance Test.
External advice might be requested from other parties or experts to evaluate the intermediate product/results.

Some tools that were used:

- Visual studio code.
- Draw.io.
- Altium.
- TinkerCad.
- SOLIDWORKS.
- Word.
- Teams.
- Excel.
- Python
- OpenCV

How our team thinks of Quality assurance steps.

1. **Define quality**

Quality is ambiguous, it can mean many things. For example, The Project Management Body of Knowledge (PMBOK) Defines quality as, "conformance to requirements and fitness of use", ISO 9000 defines quality as, "the degree to which a set of inherent characteristics fulfill requirement".
Whatever type or size of project you are managing, take the time to define the quality criteria for your current work so that your team members understand what it is, and how to reach and improve upon it.

2. **Commit to quality**

A company's commitment to quality must come from the top and be reinforced repeatedly. Unless a business views quality as its single, non-negotiable goal, workers will inevitably feel the need to make trade-offs and quality will slip.
As a project manager or leader, commit to quality, share the commitment with your staff and think about how you will handle the any conflict between your stated objective and an attractive cost-saving, short cut that compromises quality.

3. **Stick to the project requirements!**

Once you've defined the quality criteria and project requirements, stick to them! Balance continual project improvements with gold-plate requirements. Adding features, the customer did not request increases the potential for delays, and higher cost. Project Managers drive improvements and project quality but beware of out-of-scope extras creeping in.

4. Manage quality

Work with your project team to define a practical approach to managing quality, including applicable standards and quality processes. These are driven by your standards and quality processes contained in the project blueprint.

5. Perform quality assurance

Execute your quality management plan using the standards and processes defined in the project blueprint. Perform a quality audit to evaluate how well the team is following the plan and meeting your customer's expectations.

6. Control the quality

Ensure the deliverables are correct and free of defects and focus on quality from the beginning to the end of the project. Perform inspections to identify defects. Start as early as possible; identifying and correcting defects close to the point of origin saves time and money.

7. Focus on requirements

Requirements management and quality management go hand in hand. Clear, well-defined requirements lead to less rework and schedule delays. Focus on improving the requirements process—eliciting, analysing, documenting and validating them.

8. Follow the project processes

Follow the processes and tasks contained in your project blueprint. If you identify a more efficient way to do something, add this into the blueprint to continually improve the processes.

9. Lessons learned

Document lessons learned after project phases and at the completion of the project to evaluate your processes and 'bake' all the improvements into the project blueprint and translate them to future projects. This forms part of your knowledge management strategy: you build up a knowledge bank and use lessons learned in the last project for both existing and new projects.

10. Project De-Brief

The project de-brief is more than a casual conversation about what did and didn't work, it digs into why things happened (or didn't happen). A de-brief can sometimes be as painful as the project itself, especially when your project has failed, and you need to investigate where things went wrong. Rather than rushing headlong into your next project take time for a thorough de-brief with both your team and your client so that over time you continuously improve the consistency of quality in your projects and deliver more of them successfully.

Costs and benefits

Project costs:

- Man-hours, 140 hours per person.
- Main Budget 50 euros Max threshold of 10 euros
- Other facilities like space work or design tools are covered by our stake holders

Project benefits:

- Reflect on the specific Body of Knowledge and Skills of ACS and EEE
- Understand the Arduino and several Shields and Modules for data processing and control
- Do calculations, simulations and designing circuits for this Project
- Do electrical and mechanical measurements and software coding
- Do electrical and mechanical test measurement
- Implementing several electronic modules
- Building autonomous driving electrical Racing Car
- Work in a structured way to become a solution for a defined problem
- Experience Teamwork with individual responsibilities and work in a structured way
- Organize a scheduled group and supervisor meeting
- Report technical information with specific software tools
- Do an Oral presentation with PowerPoint for a select Audience
- Perform respectively as a chairman and as a secretary in the group meetings
- Convince the Graders of your individual knowledge and skills improvement (reflection)

Risk analysis

The risk analysis was done by filling in the risk analysis table in the Appendix.

After gathering all the information, our team scored a pretty good score in risk analysis, meaning we can successfully continue our work. There are also many more risks that we take care of, and our management team analyses all of them to try to better succeed. To summarize, all risk assessment methods are considered the foundation for all operational risk assessment methods. Our strength of effectiveness is based on our teams' simplicity and ease of use, acting as quickly as possible on the numerous risks that need to be assessed.

1. **Some members could be slacking off.**

Split the work evenly and democratically. group meetings to learn about problems and solve them together. If some team members refuse to work together or refuse to participate in any type of work, the team has no choice but to vote them out of the team and project.

2. **Not enough manpower or time to fulfil all the client's expectations.**

In order to ensure that all the client's expectations are met, it is important to thoroughly plan out the workload between group members - if something seems too taxing to be implemented then the client is alerted beforehand, so as not to deliver a subpar product.

3. **A mistake in the hardware or software.**

By having everyone from the group check both the software and hardware portions of the project, we can ensure a high standard of value is upheld. Although this would take some more time, it ensures that everything the group does is done correctly, and as Linus's law dictates: "given enough eyeballs, all bugs are shallow (Raymond and Torvalds, n.d.)".

4. **Failure of Components.**

To avoid future errors in the system or mis failure of components, we would like to have some extra pairs of sensors, wires, LEDs, and parts to guarantee the quality of our product.

5. **Poor management.**

A project's success is dependent on good management. A good leader is supposed to have good communication and interaction with the team. Therefore, high standards are always set for the project manager.

6. **Poor productivity.**

To avoid low productivity among team members, the team leader should exercise strict control. In addition, there could also be a spread of the workload between the other members to avoid this risk.

7. **Technical risks.**

There may be a technical issue like a device that is not working, and this will be a risk as one of the members is out of the project unofficially. A way to solve this problem is to borrow this member a device or he himself finds one.

8. **Bad timing.**

To avoid this software development risk, apply agile methodologies, ensure the maximum involvement of all team members in planning and estimating, receive feedback at all stages, starting from the earliest ones, and involve the owner or stakeholders.

Functional Design

Functional design of this project explains some basic ideas and show the concepts of a car. Description of a software and hardware part is provided below. Also, here provided a requirement analysis and electronics part of the project. Therefore, the concepts and management also provided. Below, the following will be found.

- Block diagram and description
- System operation Description
- System specification
- Test procedures

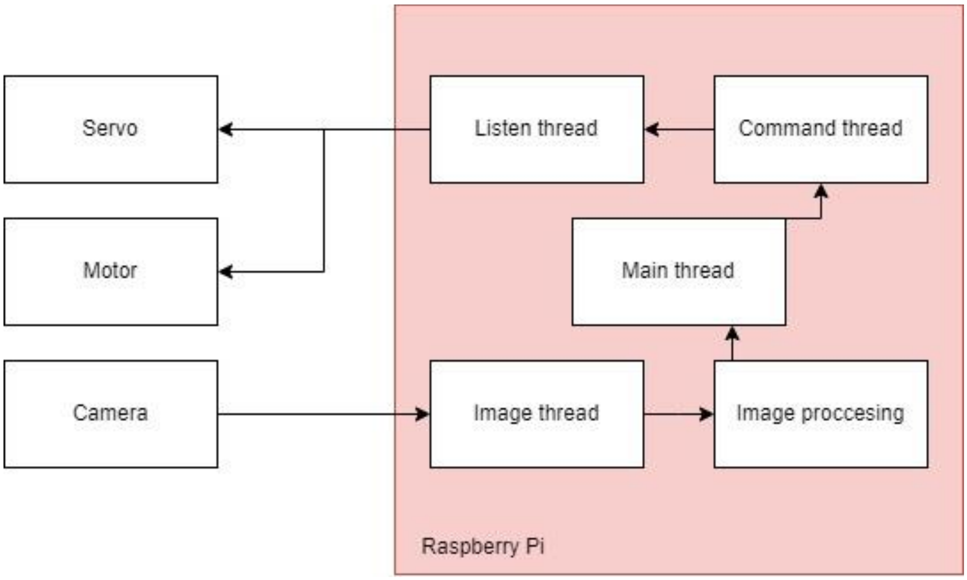


Figure 3: Architecture overview

The architecture of the car is built that the main computer for processing was Raspberry Pi, which consist of few threads such as image processing, main thread, and the command thread. The image thread takes data from the camera and sends it to the processor. Depending on the data raspberry pi provide the output for the servo which is used to rotate the car, and the motor, which is for speed.

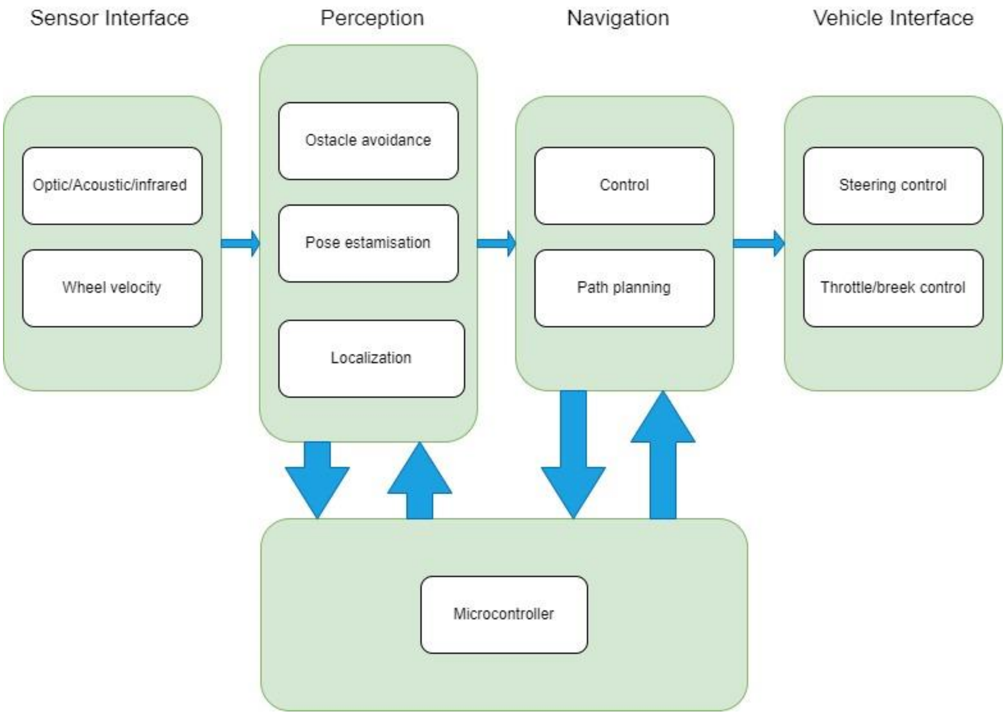


Figure 4: Software Block diagram

Software block diagram shows the subsystems of the project. Each of the subsystem represented below represent a function the car follows.

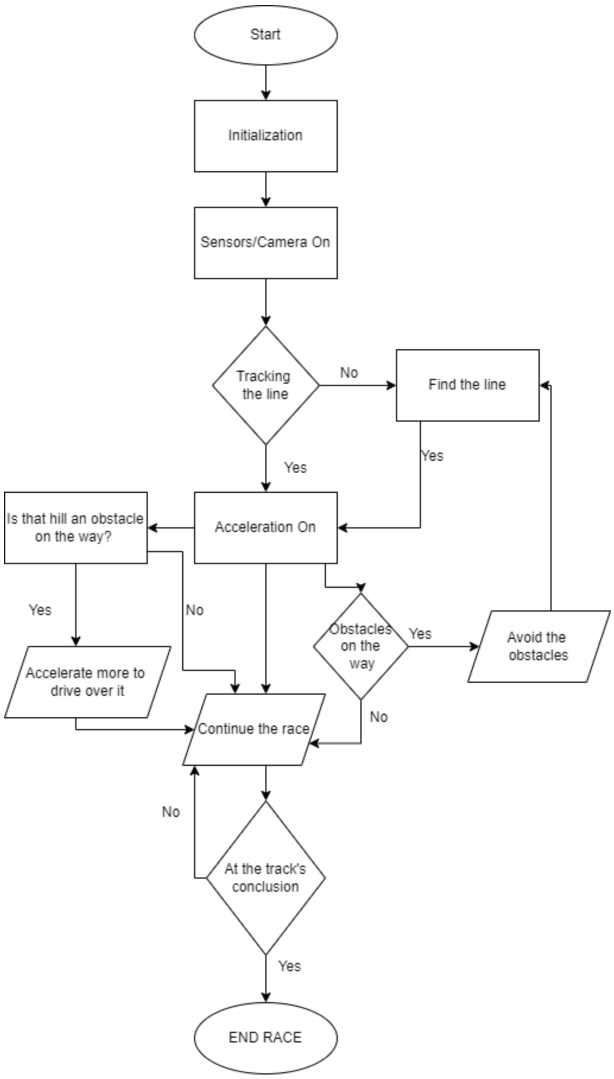


Figure 5: System states plus state transition diagram

State transition diagram shows exactly on which stage the car during the race and how the stages changes during the race.

Technical Design

Project files can be found on the GitHub repository: https://github.com/karolis1115/ACEcar

Technical Design Document for use by Ace Cars Projects provides guidance which is intended to assist the relevant management and technical staff, whether client or supplier, in producing a project-specific Technical Design. It is presented as blocks of software, electric and electronic diagram which includes software and hardware part of the project.

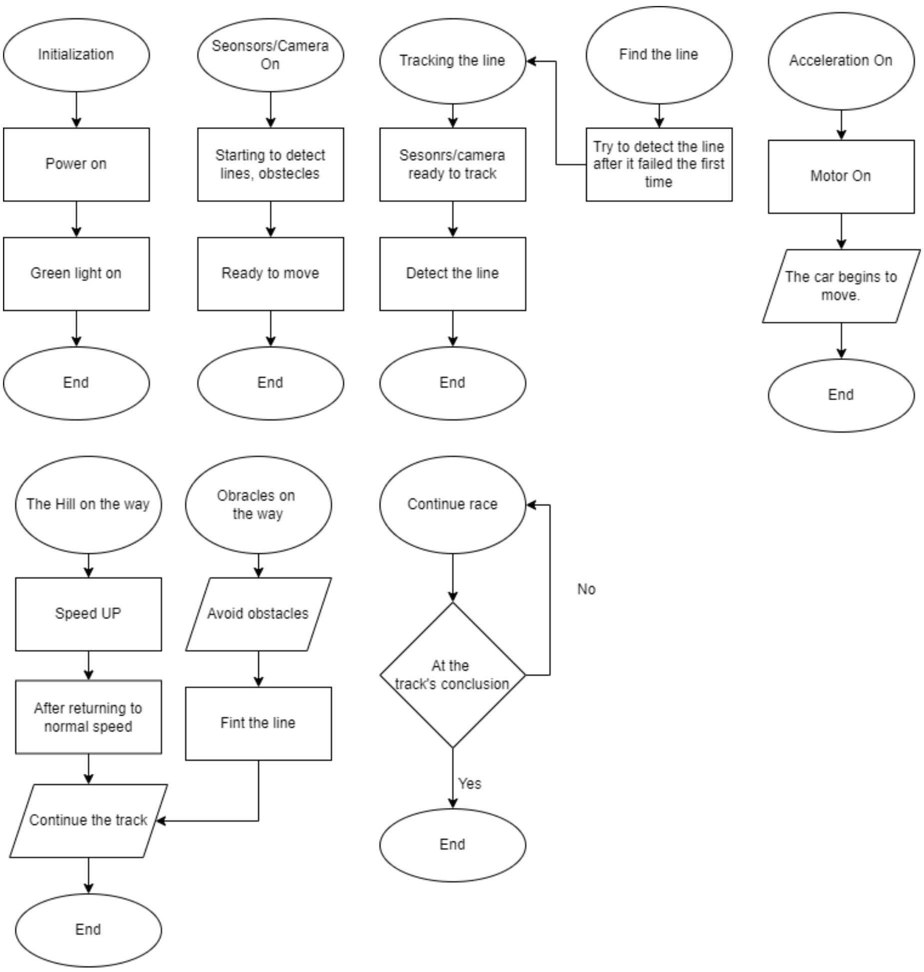


Figure 6: System Diagram

The above diagram shows all the steps the code goes through to complete the mission. From start to finish. Line following, obstacle avoidance, end detection.

Electrical

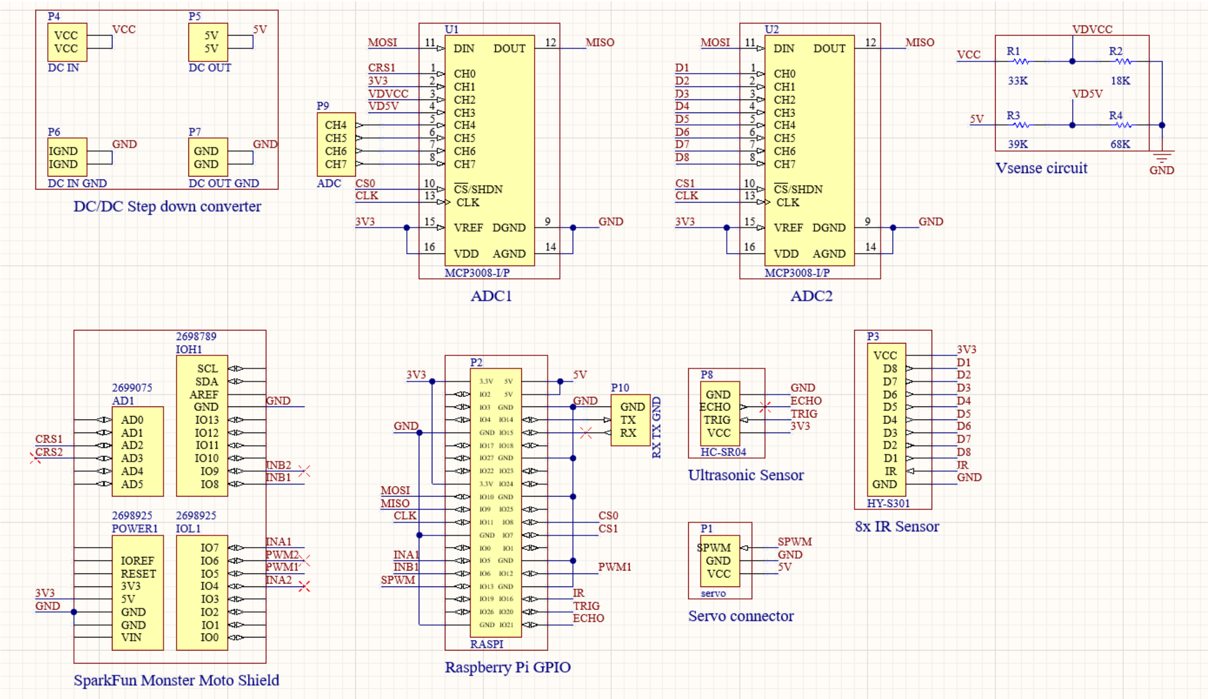


Figure 7: Electric circuit schematics

The schematic above depicts every part of the electrical and electronic system. From power to logic.

- **DC/DC Step down converter**- Used to step down Battery voltage down to 5V
- **ADC1(2)**- Analog to Digital Converted IC for voltage, current sensing and 8x IR sensor.
- **Vsense circuit**- 2 voltage divider to convert battery voltage and 5v to voltage levels suitable for measuring using the Raspberry pi and ADC.
- **SparkFun Monster Moto shield**- Pins for the motor driver in Arduino form factor
- **Raspberry Pi GPIO**- Raspberry pi's IO and power (5V 3V3)
- **Servo Connector**- Connector for steering servo motor
- **Ultrasonic Sensor**- connector for Ultrasonic sensor *Plan B)*
- **8x IR Sensor**- IR light sensor module for line detection *(Plan B)*

Plan B- In case the use of a camera and image processing libraries fails to achieve the desired goal ACEcar has decided to implement a backup approach to achieve its goals. In case of failure to achieve *Plan A (Camera + Image processing)* The team will use an IR line detection module and ultrasonic distance sensor to achieve said goals.

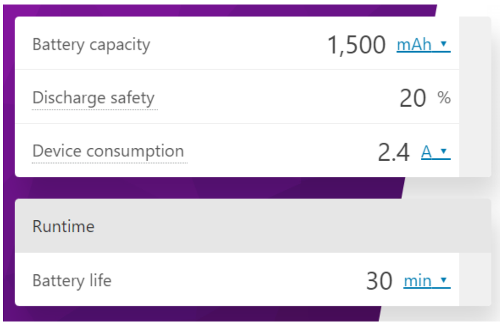


Figure 8: Battery Duration

Because the car has to be operational for at least 30 minutes on battery power this calculation shows the max current the car can draw to last 30 minutes (while leaving 20% battery to not over discharge it)

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)

To get the actual battery duration of the car, measurements were done and some calculations.

Power_max = Battery capacity * Voltage = 1.5 * 7.3 = 10.95 Wh

Battery duration = Pmax / Pmeasured

Voltage	No load(current)	Battery duration(hours)	Max load	Battery duration(hours)
7.3	0.9A	1.667	3.2A	0.47
PWM 70	0.75A	2	2.9A	0.52

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

Electronic

ACEcar decided to use a Raspberry Pi microcomputer to communicate with a PC. The Raspberry Pi will transmit video data using a camera connected directly to the raspberry pi's camera port. It will send the video data to the PC, where it will then use OpenCV to process the frames (detect the track, obstacles, and end). The PC will then send back control data to the Raspberry Pi, i.e., speed, steering, direction. ACEcar has figured out a way to transmit smooth video through the network without much latency.

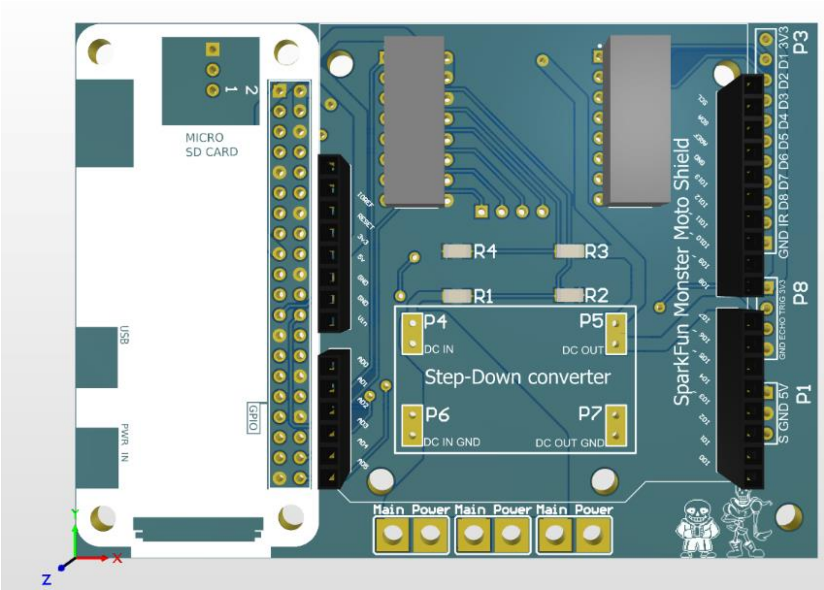


Figure 9: PCB Layout (top view)

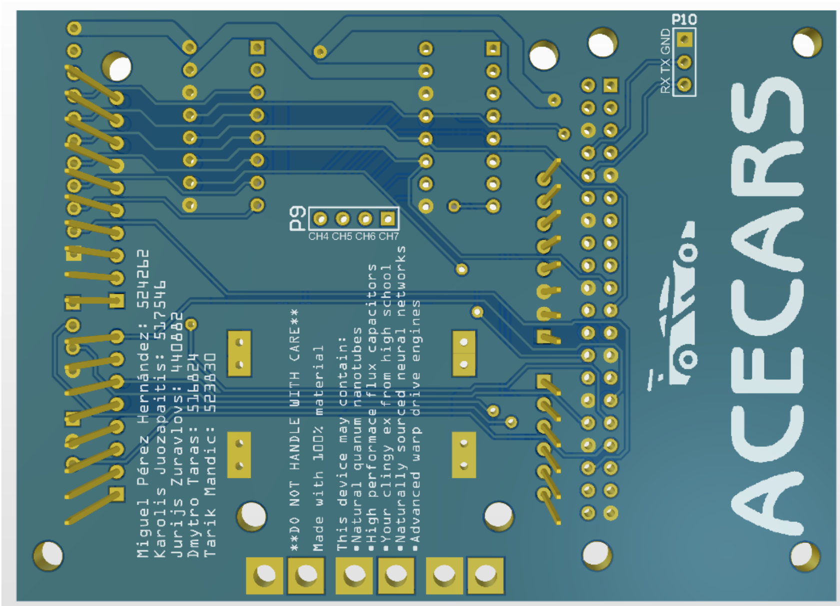


Figure 10: PCB Layout (bottom view)

ACEcar has decided to go with a Custom-made Printed Circuit Board (PCB). This approach has many advantages:

- The car can be made much more compact due to there being little to no wires.
- The PCB makes connections more reliable and robust since components are being soldered directly to the PCB.
- Troubleshooting and problem finding can be done much easier since every connection stays at the same place and with the help with the schematics a fault or error can be found much more efficiently.
- Using a PCB can also save space and make the inside look nicer.

Software

Project files can be found on the GitHub repository: https://github.com/karolis1115/ACEcar

The idea is to find the path using colour detection or edge detection and then get the curve using a summation of pixels in the Y direction, i.e., a histogram. We split the task into five different steps. This includes thresholding, warping, histogram, averaging, and display. The main idea was to use only OpenCV because it has a lot of essential information and possibilities which are used even in real cars.

- Servo turning algorithm, Initialization of servo, DC motor, batteries etc.
- Appendix B.

Low level flow chart.

- Appendix A.

Software block diagram.

- Appendix C.

Architecture Overview

- Python 3.x
- OpenCV
- Raspberry Pi
- Visual Studio Code.

These testing methods were conducted in order and include:

- Unit testing
- Integration testing
- System testing
- Acceptance testing

- Our team also first split the code into many subtasks, each of which was tested separately. After passing all the subtests, we start to put everything together and test it all together again, fixing all bugs or wrong code.
- Simply use the colour detection to find the path.

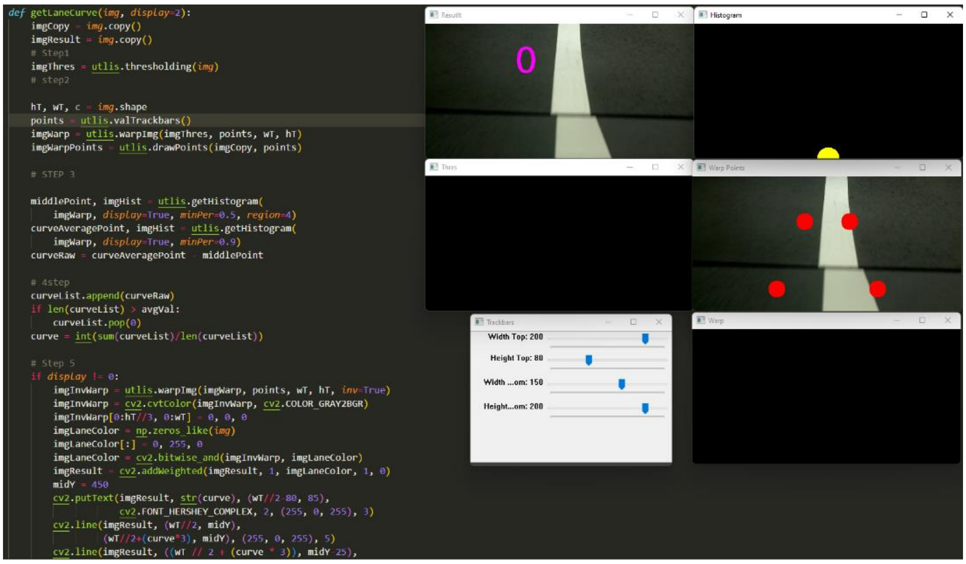


Figure 11: Detect white colour

- In this case, our team simply converts the image to HSV-colour space and then uses a colour range to find the proper colour. This colour could be found using the colour picker script. Which was tested on video from the race track.

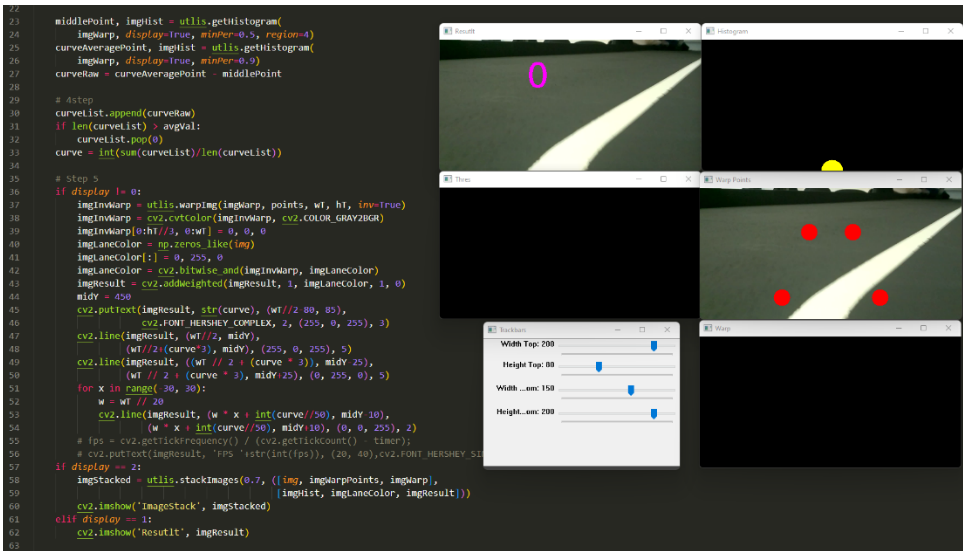


Figure 12: Finding the curve

- The most important part is to find the curve in our path. For the curve, the summation of pixels is used. Given that our warped image is now binary, it has either black or white pixels, we can sum the pixel values in the y direction.
- To find the center of the base, which will give the center line, and then compare the pixels on both sides.

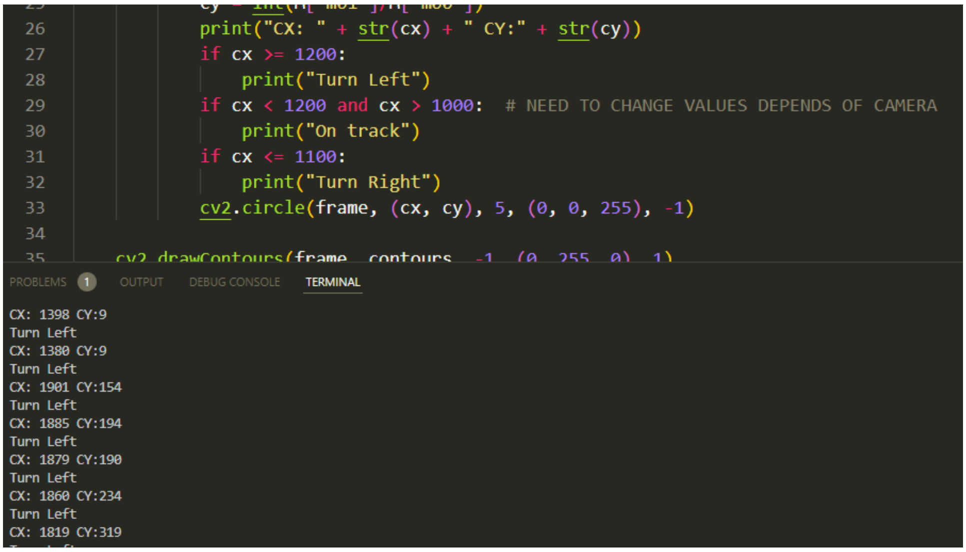


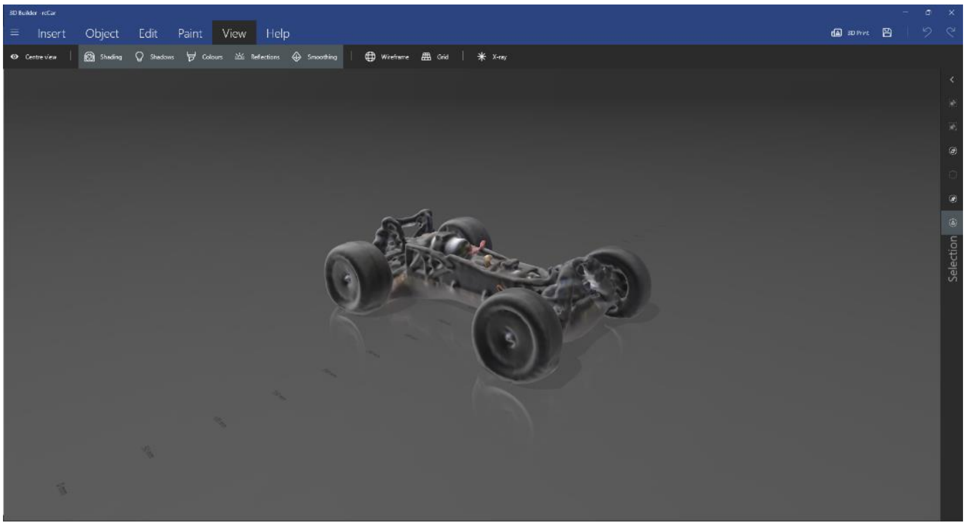
Figure 13: Calibration

- All the test procedures were completed in order to make the code simpler and more accurate. There was also a camera calibration and proper colour detection for all scenarios.

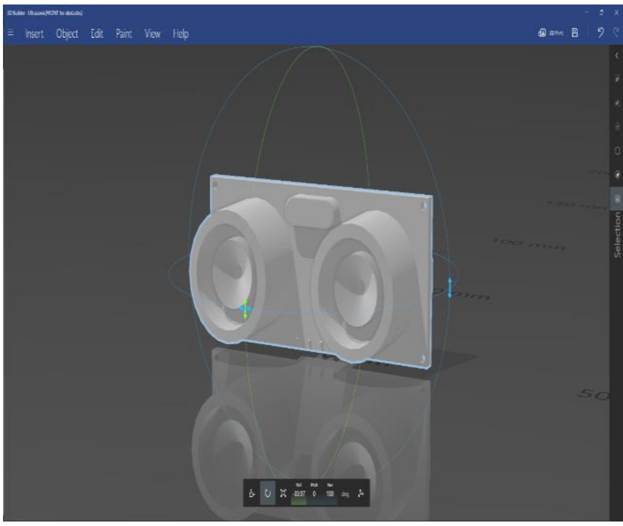
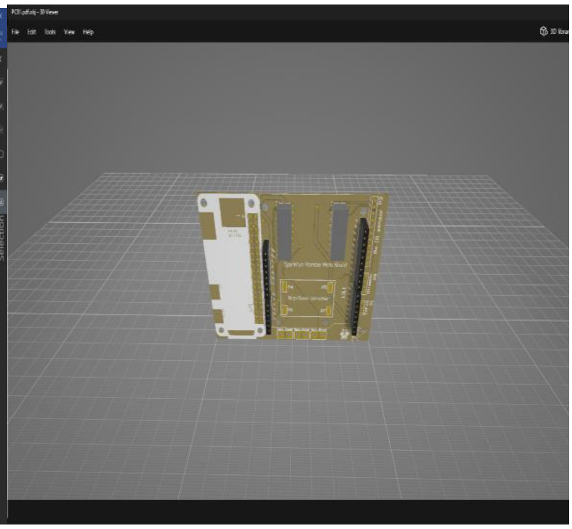
Mechanical - Physical Design

For the physical and mechanical parts of the project, we performed some calculations, estimating final velocity acceleration, etc. This is especially important to ensure the correct functioning of our design and to ensure its efficiency. Values like the mass or some forces we could calculate were necessary for making these calculations. Knowing the parameters, we could already create our body design and mountings for our components.

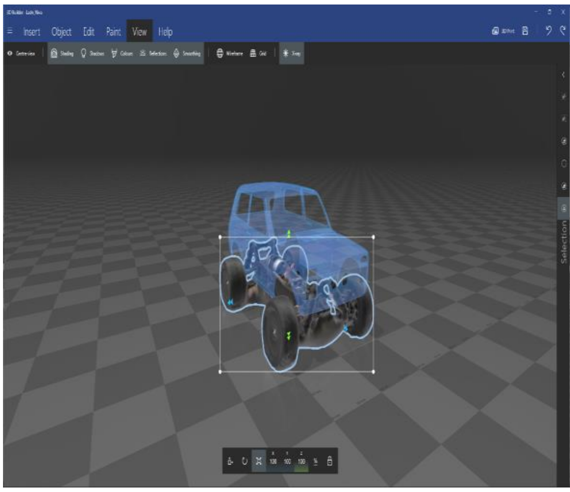
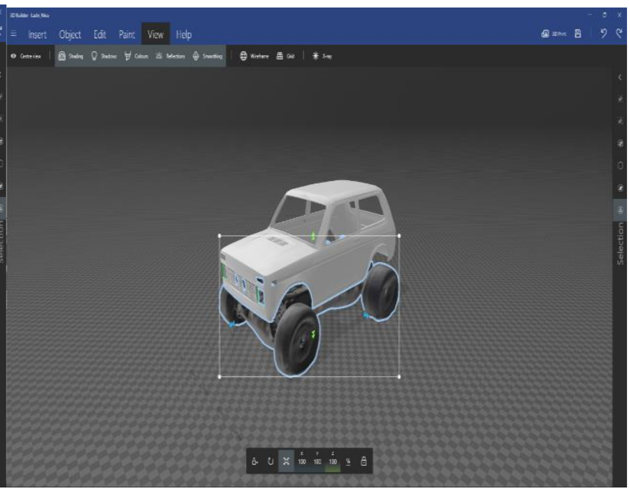
We first made a 3D scan of the base model RC car given to us. This way, we could more efficiently make certain that the design we were going to create was compatible with the already existing model. You can see a picture of this below.



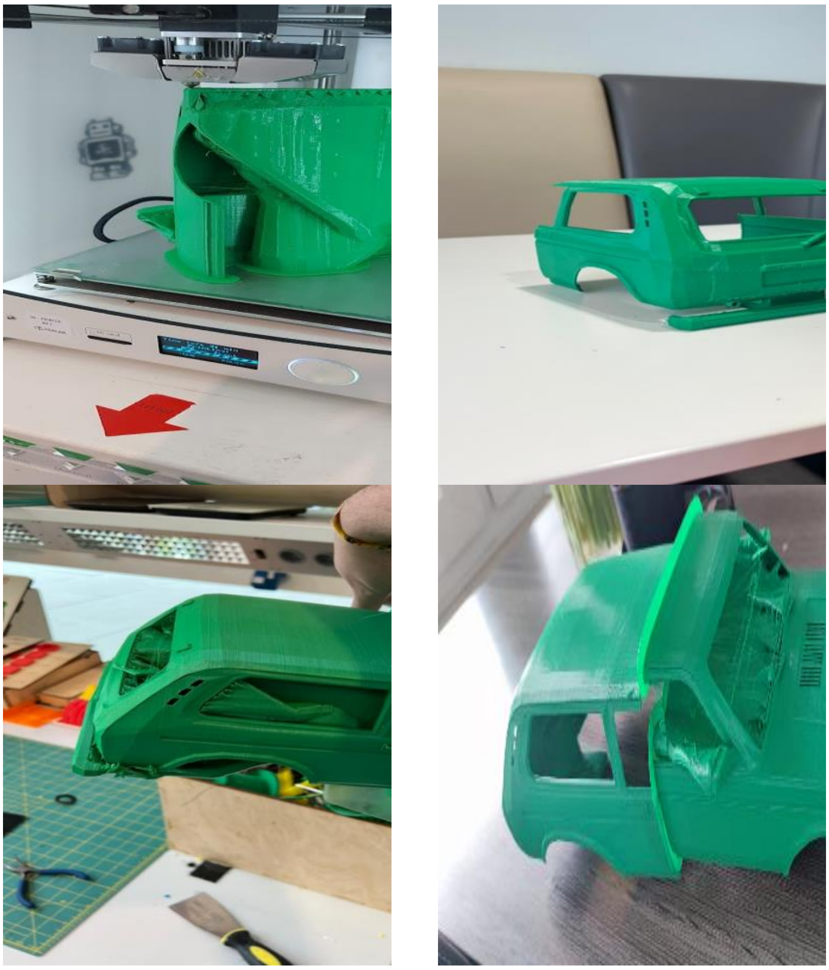
We also made some 3D models of the electronics we were going to use to make certain the size and the measurements were exact. Below you will see the PCB and our ultrasonic sensor, listed in the same order.

Following that, we started to develop our design on top of these things, ensuring that the car's mechanics worked properly.

As you can see, the body design fits perfectly with our base model and has space for electronics. This way we are more efficient and won't have to repeat the printing process, which is the most time-consuming. For printing, we had to split our design in two because one printer alone could not handle the entire print. And after printing, we had to take our models and join/perfectionate them, taking off supports and sticking them together.



Conclusion

To conclude, the AceCars team has created an autonomous racing car which was the main goal of the project. By the end, the car follows the line on track and shows a good result in speed. The project was hard but avoided all the risks and followed all the planning, the team performed good. Some of the design decisions was changed during the project such as 3d model of the body of the car and neural network to control the racing to a better one and were successfully involved in the project. Some software ideas were shown as impropriate during the test and were changed. The success of the project means that the following all the design ideas above will make a good racing car.

Recommendation

This was a fantastic challenge for our organisation. The entire staff was focused on making it great. By the conclusion of the academic year, we want to have built an autonomous racing car. AceCar will accomplish this by developing a truly unique product that is totally autonomous, capable of detecting the track line and avoiding obstructions. If this target is met, a brand-new product will be created that can be used in the future.

We must first acquire all the necessary information for building a racing automobile. We'll need to build a model, link all the necessary elements, make a customized 3D print, and programme it to do the job.

To meet all our objectives, we must take all electrical measurements, calculate colours, and construct a car appropriately. The team used a variety of measurements to determine how many resources were required and what needed to be done.

The most important task is to stick to the strict plan in order to achieve the greatest possible result.

References

[0] https://github.com/karolis1115/ACEcar - ACEcar GitHub project repository.

[1] Grit, R. (2010). *Project management.* Noordhoff Uitgevers.

[2] Bruyninckx, H. (2008, 7 March). File: V-model.svg. Wikipedia. Visited on 23 May 2022, from https://commons.wikimedia.org/wiki/File:V-model.svg

Appendix

Risk analysis

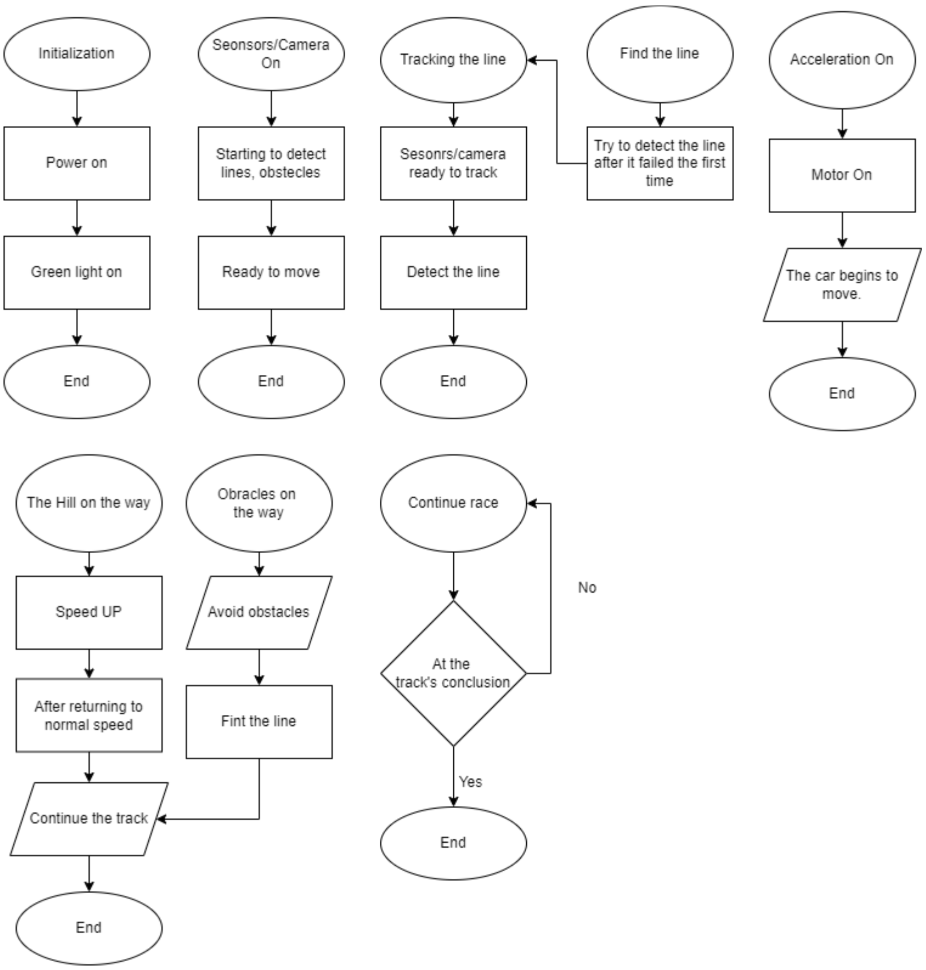
Risk	Value	Factor	Weight	Total risk
1. Estimated duration of the project?	0–3 months 0 3–6 months 4 - 6+ months	0 1 2	X4	0
2. Does the project have a definite deadline?	No Flexible Yes	0 2 4	x4	16
3. Is there sufficient time to complete the project within the set period?	more than enough enough not enough	0 1 3	x4	4
Complexity of the project				
4. The number of functional subsectors involved?	1 2 3+	0 1 3	x4	12
5. The number of functional subsectors that will make use of the outcomes?	1 2-3 4	0 1 2	x2	4
6. Is it a new project or one that has been adapted?	minor adaptions major adaptions new project	0 2 3	x5	15
7. To what extent do the present authorisations have to be adjusted?	Not minor extent medium extent major extent	0 1 2 3	x5	5
8 Are other projects dependent on this one?	No yes, though the deadlines are not tight yes, and the deadlines are tight	0 1 3	x5	15
9. What sort of reception are the users likely to give it?	Enthusiastic noncommittal interested	0 1 2	x5	5
10. Has the project been divided up into phases and is progress dependent on the coordination between them?	No a little strongly	1 2 3	x3	15
Project group				
11. Where do the project workers come from?	mainly internally partly internally mainly externally	0 1 3	x4	4
12. Where is the project located?	1 location 1 to 3 locations more than 3 locations	0 1 2	x2	0

13. The number of projects taking up more than 80% of peak hours?	1–5 5–10 5 – 10+	0 2 4	x5	10
14. The balance between subject experts and project experts?	Good Average unfavourable	0 2 4	x5	0
15. Are the users involved in the project?	to a large extent to a reasonable extent to a limited extent	0 1 3	x3	9
The project management				
16. Does the project management team have any knowledge of the subject?	a lot a reasonable amount little	0 2 4	x3	6
17. Does the project management have any knowledge of how to plan a project?	a lot a reasonable amount little	0 2 4	x3	6
18. How much experience does the project manager have with projects like this?	a lot a reasonable amount little	0 1 3	x3	3
19. Do the advisers have any knowledge of the field of research?	a lot a reasonable amount little	0 1 3	x5	0
20. Do the subject experts have much knowledge of the field?	a lot a reasonable amount little	0 1 3	x5	0
21. How involved in the project are the managers responsible for it?	Very reasonably involved only slightly	0 2 5	x5	10
22. Is there any chance that the project team will change during the project?	little chance some chance big chance	0 2 5	x5	0
23. Is the project group using existing methods or creating its own methods?	only existing methods some existing methods no existing methods	0 2 4	x4	0
Project definition				
24. Are the project members sufficiently aware of the problems and objectives?	yes, everybody most of them not all of them	0 1 5	x5	0
25. Is the field of research sufficiently demarcated?	yes reasonably	0 2	x5	10

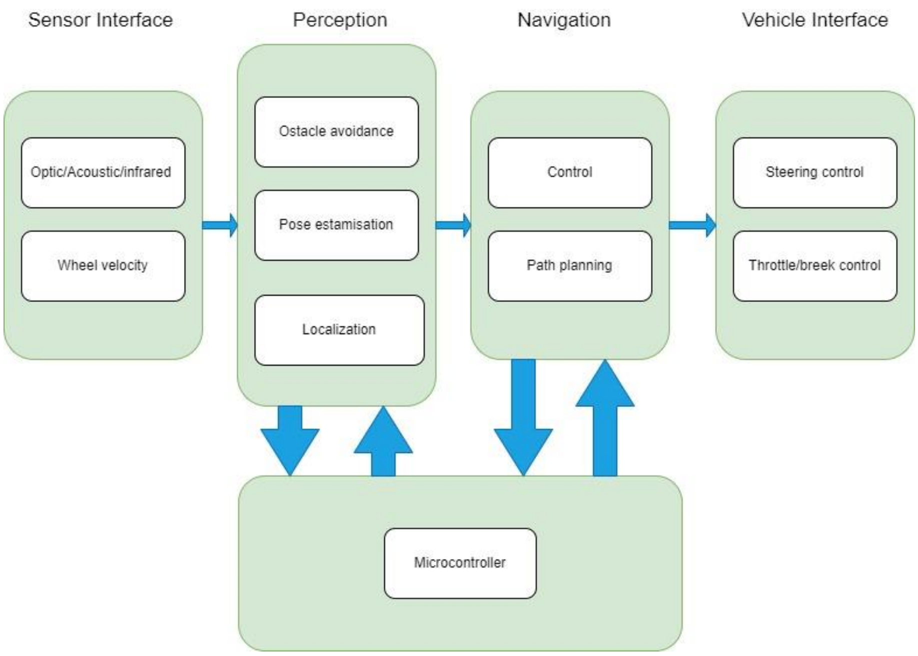
	not clearly	5		
26. Is there sufficient demarcation between this project and other projects?	considerable reasonable insufficient	0 1 3	x4	0
27. Has enough time been reserved for coordination and decision-making?	considerable reasonable insufficient	0 1 3	x4	0
28. Are the boundaries clearly demarcated?	Yes in general most of them are not	0 1 3	x4	0
29 Are the boundaries limiting enough?	Yes moderately no	0 2 5	x5	10

Risk percentage = $\frac{score}{\max score}$ x 100% = 35%

Appendix A: Software high level flow chart:



Appendix B: Software Block Diagramm [2]:



Appendix C: Architecture overview: