NaviGrips

Final report Engineering Design (4WBB0)

March 23, 2026

Group no: 214	
Name	**Student ID**
[redacted]	[redacted]
[redacted]	[redacted]
Tobias Wejbora	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
Roëlle [redacted]	[redacted]

1 Group effectiveness

The making of the NaviGrips was an idea of our multidisciplinary group. This group was made by the Eindhoven University of Technology to obtain a broad spectrum of knowledge and expertise. The focus of our group was to create a new innovative device that could be used for transport and mobility. This device should enable, facilitate, or encourage sustainable behavior. This group came together at least twice a week to work collaboratively on this project and believe they set up a great innovative idea. Within this chapter, the group, their strengths and their weaknesses are addressed. Furthermore, the process of the idea within our team is explained.

1.1 Group members

During the first meeting with a new group, it was important to get to know each other and each other's weaknesses and strengths. Table 1 is made to give an overview of the main strengths and weaknesses within the group. From these strengths and weaknesses, a first basis was built of what was expected from each member and what their contribution would be. The majors of the group members gave a first insight into the knowledge already present in the group; The majors are as follows:

Chemical Engineering, Mechanical Engineering, Data Science, Automotive Technology, and Biomedical Engineering.

Strengths	**Weaknesses**	**Technical skills**
Great in communicating	taking on too many tasks	CAD design
Good organization skills	a little to no experience with group projects	coding
Patient	perfectionism	sustainable product development
Realistic	procrastination	craft work

Table 1: Strengths, weaknesses, and technical skills

Besides the knowledge that was already present from the wide variety of studies, the strengths related to group work were divided at first. Most of the members had the following strengths: great communication, good organization, and awareness of the tasks at hand. Some members of the group had different strengths which provided a new angle in perspective within all our discussions. For example, one project member was motivated to help the disabled and tried to incorporate this within the design. Others are creative and innovative in their ability to think of solutions to the several problems that arose.

These strengths gave the group a great start as they are mandatory to get a project started. A well-structured planning was made to give direction for time management in the project. Next to that, task estimation and division were needed. Having the strengths in your group to put these things into action for the project is really important, as without them, no start can be made. Our strengths helped us in the end even more. It kept everyone focused on what was important and aware of all the deadlines that were coming up.

Besides teamwork strengths, technical skills were also discussed in the first meeting. All of the students in the group had a basic understanding of most of the essential skills. The skills that were most crucial for the project are Python and Arduino programming, CAD modeling, and understanding of circuits. The mentioned skills are necessary for creating the device. Some of the members had a better understanding of these skills, so they were assigned to take charge of one of their strengths. The mechanical engineering students worked more on CAD modeling and the data science student more on Python and Arduino programming. This division in tasks worked really well, and some of the members of the group without the expected technical skills even got a better understanding of them. To ensure all of the team members understood the entire product, all work was explained upon asking during the meetings. For example, whenever someone wrote a piece of code and another group member, who was not as experienced in this field, did not understand it. In this situation, the entire code was explained during the meeting. This gave the opportunity for extra insights and solutions from all six team members. The team members who found their strengths not within coding or CAD design made sure we had the best prototypes, presentations, and reports.

Nevertheless, every member of the group of course also has weaknesses. These weaknesses were heavily divided as well as the strengths. Some members had little to no knowledge of group work, the tendency to take on too much workload, or were a tad of a perfectionist. Within the group, the weaknesses had little effect on the group dynamics and the workload. This was the result of addressing them within the first meeting. This caused them to be known by all of the other group members and were thus taken into consideration at all times. Another aspect that helped a lot not to let our weaknesses derail too much of our project was our motivation. Everyone was eager to help others overcome their weaknesses and work on the project.

Apart from the previously said or obvious strengths and weaknesses a person came into the group with, personalities were also widely different. We had some extroverts and introverts in our group. This caused some differences in the activeness within each group meeting. Furthermore, we had some realistic and idealistic people in our group. This resulted in a difference in perspective and motivation to discuss certain topics. These differences were not noticed or said during the first meeting and were addressed later in the period. Together with each other, and with the help of the midterm evaluation, we talked about this and came to an understanding about each other. This improved our meetings a lot and more effective and better meetings were held.

1.2 Process of engineering design

To start the process, all of the team members brought their best ideas to the table. Some of the individual strengths and personalities already appeared within these ideas. The motivation among all team members to bring this device to realization caused all the ideas to be researched well. Once all the ideas were researched, they were presented. Within only a couple of meetings, we needed to choose a design. This was accomplished by listening a lot to each other and without any positive biases towards one's ideas.

The intermediate evaluation of the Preliminary Design presentation was very helpful for the group. Overall the presentation went very well, the pitch was very clear and our goal was very well-motivated. The fact that our design is sustainable as well as innovative was a big plus. This was the result of productive preparation from the group, such as splitting the tasks for the presentation equally and according to everyone's strengths and weaknesses.

After the evaluation, our group members also had some insights on what could be improved for the final presentation. Firstly, a poster was recommended for use during the presentation for a more clear overview of the device. Second, the presentation could be made a bit more interactive with the audience. During the intermediate presentation, we have already asked some questions to the audience about some struggles that we would like to resolve. But we think we can improve this by not only asking questions, but also giving a better understanding of the device via talking with, for example, the teacher or tutors.

Aside from the evaluation of the presentation, it was clear to the group that the focus should generally be more on the group's work, because of the inexperience of some group members in group work or other essential topics within our design, such as coding. It was necessary to improve on setting deadlines and to keep looking into each other's SSAs to stay informed on all the information.
Furthermore, it was exciting to experience the motivational effect team members had on each other. Whenever there was a small moment of lack of motivation, there was always one group member to spur some new stimulation into the group. For example, when our first CAD design was made or when the entire circuit was soldered and working.

In conclusion, teamwork was optimized a lot throughout the process of product design. Starting with formulating our strengths and weaknesses, giving and receiving feedback on each other, and motivating each other to make this design one to be proud of. The program helped a lot with giving intermediate feedback and supplying guidelines for our design process.

2 Design goal

In an era where cities are growing busier and the harmful impact of excessive automobile use is increasingly evident, there is a pressing need for innovative solutions to promote sustainable transportation. Urban cities are full of cars, leading to high carbon emissions and serious environmental concerns.

Cycling is an eco-friendly, healthy mode of transportation, but it comes with inherent safety concerns. Sharing the road with vehicles, navigating complex intersections and unmarked cycling routes, while also dealing with environmental factors makes safe cycling a priority.
When exploring unfamiliar areas while cycling, individuals are even more vulnerable as their attention is primarily directed towards ensuring accurate navigation and avoiding incorrect routes. This consequently makes cyclists dependent on navigational systems. However, navigational systems that consist of using the smartphone (traditional navigational systems), also disrupt the riders' focus. This amplifies the risks mentioned earlier, which further confirms the safety concerns that come with riding a bike. While cycling has the potential to bring significant societal benefits, the safety concerns associated with it pose a challenge to its widespread adoption.

The need for a safer and more user-friendly navigation system is evident. By developing a navigation system tailored to cyclists, we aim to enhance their safety and make cycling more enjoyable. This will further promote cycling and reduce the need for carbon-emitting vehicles.

Smartphones are used by 86% of the world's population and are mostly used as navigation devices in cars, on foot, or on bicycles. The most popular technique to show the user the path is through visual directions, such as displaying a map and the route on the phone's screen. Using audio instructions to tell a user when and where to turn is another common way to provide navigation.

When cycling, the visual method is not very effective, as it demands the use of a special mount for the phone. Lacking this mount makes cycling a difficult experience, as the user has to hold the phone in their hands, which is not only inconvenient, but also illegal in some countries. Even with a mount, always having to look at the screen might cause the rider to become disoriented and miss potential road dangers, making the trip hazardous. Wearing headphones for auditory instructions is risky as well, as the rider might not hear other vehicles or approaching pedestrians.

To continue, riders spent on average 28% of their time looking at the screen when using the visual navigation system in an unknown environment. Having to look at the screen was therefore not surprisingly one of the most heard complaints about the visual navigation system(Steltenpohl H., Bouwer A) [4]. Additionally, a 2011 study, Dick DeWaard et.al. [1] found that listening to music via headphones worsened bicyclists' response time to auditory signals and led to an overall worse auditory perception. Therefore, these surprising results solidify the argument that cyclists are highly susceptible to distraction when relying on such navigation tools. Allocating more than a fourth of the riding time to screen-checking further confirms the potential safety risks and validates the vulnerability of cyclists riding in unknown areas.

Another study, conducted to compare the navigation experiences of pedestrians using traditional navigation devices and haptic navigation systems, yielded insightful findings that have important implications for bikers(Pielot, M., Boll, S.) [2]. The study's most striking discovery was that pedestrians who relied on traditional navigation systems were more likely to experience near accidents.

While walking and biking are distinct activities, both share the common characteristic of navigating through their surroundings. Biking, however, is inherently more attention-grabbing and poses a greater risk due to its higher speeds and interaction with traffic. It requires a heightened level of focus compared to walking. Bicyclists must remain alert to their surroundings, traffic signals, and potential hazards. The need for continuous attention is evident, as even a momentary lapse in concentration can result in accidents or near-miss incidents. It becomes clear that visual navigation methods, such as glancing at a smartphone, can significantly divert a biker's attention from the road, amplifying the risk factor of biking.

The studies were conducted on safe routes with minimal traffic as a precautionary measure to ensure the safety of the participants. It should be noted that these controlled conditions were intentionally chosen to prioritize the well-being of the subjects. It is also important to note that real-world biking scenarios are far more complex and dynamic, with heavier traffic, unpredictable obstacles, and higher cognitive demands. As a result, cyclists are even more vulnerable in these situations. This underlines the need for safer, less distracting navigation methods to enhance rider safety in practical, high-traffic environments.

Despite the distracting nature of navigational systems, a noteworthy observation from a study was that riders tend to voluntarily reduce their speed and make conscious efforts to be more attentive. When confronted with the potential distractions riders instinctively respond by taking precautionary measures to lower risks and enhance their focus on the road. Moreover, B. Poppinga, M. Pielot, and S. Bol [3] confirmed that a navigation system that does not use maps allows faster orientation and fewer stops.

Therefore, there is a need for innovating a prototype with a navigation system that not only enhances the safety of the user but makes cycling more enjoyable and productive for the users.
In fostering innovative solutions for better cycling navigation, an imperative consideration is the inclusivity of diverse user groups, encompassing individuals with varying abilities and needs. By prioritizing accessibility in the development of a cycling navigation system, we aim to address the requirements of a wide spectrum of users.

For instance, individuals with visual impairments could benefit from a system that utilizes more intuitive cues specifically designed to convey navigation instructions without relying on maps and apps. This could involve different types of feedback for directions, that are much easier to understand and more intuitive.

Moreover, an inclusive navigation system should accommodate users of different ages and abilities. For instance, older adults or others with mobility limitations might benefit from a system with seamless navigation guidance without requiring intricate physical interactions. Simplicity in design and intuitive user interfaces can make the navigation system user-friendly for a broader demographic, including children, elderly individuals, and individuals with cognitive differences.

Inclusivity involves recognizing and addressing the diverse needs of cyclists to ensure that the navigation system is not only a safety enhancement, but a tool that fosters a more inclusive and accessible environment for all individuals, irrespective of their physical abilities, ages, or level of cycling experience. This commitment to inclusivity aligns with the goal of promoting cycling as a sustainable and universally accessible mode of transportation, contributing to a more connected and equitable urban environment.

The diverse and multi-talented backgrounds within our team are the driving force behind our capability to create an innovative cycling navigation system. Comprising creative thinkers who excel in ideation and constantly challenge the status quo, our team fosters an environment that encourages dynamic brainstorming sessions, allowing for the generation of groundbreaking concepts and the evolution of ideas. Furthermore, our team members possess adept programming skills, enabling the implementation of intricate functionalities within the navigation system. Those skilled in Computer-Aided Design (CAD) contribute by translating these concepts into tangible and visually comprehensive designs. Their critical thinking aptitude coupled with organizational and leadership skills ensure a streamlined and efficient development process. The team's flexibility and willingness to adapt to various roles and tasks, coupled with a collective hunger for new knowledge, are instrumental in contributing to any phase of prototype development. Even if not specialized in a particular domain, our team is committed to offering support and stepping into diverse responsibilities as necessary, fostering a collaborative and adaptable environment essential for the success of this project.

Our team is sure that the project will be a success, and our product will promote sustainable behavior by mitigating the safety concerns of cycling, making it more efficient, inclusive and ultimately, more enjoyable.

3 Functional design and solutions

To ensure the NaviGrips device functions as intended, various functions are required, each with their respective priorities established using the MoSCoW method. In this method, functions are categorized into four distinct groups, each bearing its unique significance within the overall project.

3.1 Must-Have (Constraints)

The "Must-Have" category encompasses functions that serve as the project's constraints, indicating the foundation on which the entire system relies. These are the non-negotiable features that define the core functionality of NaviGrips.

- Destination Input: At the core of our navigational device, we must ensure seamless destination input. We have identified three crucial approaches:
  - Plug-In
  - Wi-Fi
  - Bluetooth.

  These methods lay the groundwork for the device's primary purpose, enabling users to set their destinations.
- Turn-by-Turn Feedback and Arrival Notification: Providing real-time feedback and arrival notifications is paramount. To ensure user convenience, we have thought of multiple feedback channels.
  - Vibration
  - LED Signal
  - LCD Screen Notification
  - Heat
  - Sound

  These features transform the device into a dynamic and interactive navigation aid.
- Location Processing: Accurate location processing forms the bedrock of our project, three solutions are given for this.
  - GPS
  - Wi-Fi
  - Cellular Positioning
  - Bluetooth Beacons

  The use of one of these technologies is essential for reliable navigation and proximity detection.

3.2 Should-Have (Requirements)

In the "Should-Have" category, we address functions that, while not being constraints, are vital requirements for a comprehensive and user-friendly navigational system.

- Water-Resistant: To enhance the device's durability, we've established stringent requirements for water resistance.
  - Sealed Casing and connectors
  - Waterproof coatings and materials

  Implementing this feature ensures NaviGrips can withstand diverse weather conditions, providing users with reliability.
- Stop Function: The "Stop" function enables users to halt the device's guidance when necessary.
  - Physical Button
  - Touch-sensitive control

– Smartphone app control

These options should help increase user-friendliness and encourage sustainable behavior.

3.3 Could-Have

Our "Could-Have" category highlights functions that, while not essential, add value and versatility to the NaviGrips device. These features, if implemented, can elevate the user experience.

- Battery Life Indicator: Keeping users informed about battery status enhances device usability. We explored different indicators.
  - LED Signal
  - Vibration
  - Sound
- Distance Until Next Turn: Providing users with the distance to the next turn is a useful feature.
  - Voice command
  - LCD screen display
  - Magnets

3.4 Won't Have

Finally, in the "Won't Have" category, we list functions that, while intriguing, do not align with the project's primary objectives. These are features that, while innovative, may not be suitable for the NaviGrips device.

- Fill in Destination: Allowing users to fill in their destination directly on the device itself is a potentially attractive feature but may not align with the device's core function and may introduce complexity.
- Live Route Actualization: While real-time route updates are enticing, our primary focus is on the device's core functionality. Live route actualization, though beneficial, falls beyond the scope of our initial project objectives.
- Feedback Customization: While customization is a valued aspect of user experience, we prioritize core functionality over extensive customization features at this stage of development.

For each function outlined in the MoSCoW method, we have explored several solutions from the 'solution encyclopedia.' These solutions will guide our preliminary designs, incorporating different approaches to create diverse designs. Some constraints may have no solutions, while others may require multiple solutions to meet the criteria.

4 Design Concepts

We've come up with several concept designs to explore different product ideas that align with the functions we've previously outlined. Each concept will be introduced and explained to show how it works and its unique features. We'll also look at the challenges and user-friendliness of each concept, along with their pros and cons.

After evaluating these concepts, we'll pick the most promising one as the preliminary design. Once chosen, we'll work on improving it further, providing all the detailed refinements needed for its functions.

To start, our design concepts ideas share some functionalities such as:

- **Navigation:** The device receives navigation instructions from a laptop connected via USB, which communicates with the Arduino. The Arduino, integrated with the Google Maps API, processes the directions and translates them into a signal.
- **Stop Button:** The device includes a user-friendly stop button, easily accessible on the steering wheel, to pause or stop navigation when needed.
- **Arrival Notification:** When the user reaches their destination, the device provides a distinct signal or visual notification to alert them of their arrival.

In our concepts, we mainly focused on the signaling methods employed by each prototype and how these methods impact the overall riding experience. Therefore, each prototype provides different feedback, which will be further analyzed.

Moreover, we recognize the limitations of transmitting each trip individually from a computer to the device via USB. While we explored alternative connectivity options such as Bluetooth and Wi-Fi, we encountered challenges on both the coding and keeping the cost of the device under budget.

4.1 NaviGrips

4.1.1 Feedback: Vibration

Vibrator motors embedded in the bike handles generate vibrations to indicate specific navigation cues. For example, an upcoming left turn triggers vibrations on the left handlebar. Moreover, the vibration patterns will change as it gets closer to the turn.

4.1.2 Pros

- Tactile Feedback: Provides tactile feedback through vibrating handlebars, which can be especially useful in noisy or busy urban environments where other types of cues might be less effective.
- Minimal Distraction: Minimizes distractions as cyclists get feedback through vibrations.

4.1.3 Cons

- Limited Information: Vibrations may not convey detailed information, making it less suitable for complex routes. To solve this, various vibration patterns need to be implemented, but this might be confusing for the user and time-consuming to create.
- Potential for User Confusion: Implementing various vibration patterns for different types of turns could confuse users.
- Environmental Interference: External factors like rough terrain can disrupt vibration cues.
- Intensity and Comfort: Vibration intensity can affect user comfort, potentially becoming distracting during long rides.

4.2 NaviLights

4.2.1 Feedback: LED Signals

A set of LED lights, integrated into the handlebars or the bicycle frame, illuminate to indicate turns or other navigation instructions.

4.2.2 Pros

- Clear Visual Indicators: Provides clear visual signals, enhancing navigation understanding.
- Enhanced Visibility: Increases the visibility of navigation cues, especially useful in low-light or nighttime cycling.

4.2.3 Cons

- Limited Information: LED signals may have limitations in signaling complex navigation details.
- Visual Distraction: Depending on the placement and brightness of the LEDs, they can potentially be distracting and take your attention away from the road. It is also possible to distract other traffic participants.
- Limited Visibility in Sunlight: Depending on the brightness of outdoor sunlight and the quality of the LEDs, they may become less visible and harder to observe in bright, sunny conditions.
- Lack of Inclusivity: LED signal feedback, although easy to spot, might still pose a problem for visually impaired people

4.3 NaviScreen

4.3.1 Feedback: LCD Screen

A LCD screen, mounted on the handlebars, displays turn-by-turn directions with clear visuals.

4.3.2 Pros

- Detailed Visuals: Offers detailed visual navigation, including maps and turn-by-turn directions.
- Familiarity: Resembles traditional GPS devices, which many users are already familiar with.
- Information-Rich: Can provide a wealth of information beyond just navigation, such as speed, distance, and ride statistics.
- Versatility: Potential for additional apps and features beyond navigation.

4.3.3 Cons

- Distraction Risk: Requires cyclists to look at the screen, which may divert their attention from the road.
- Limited Visibility: Sun glare or reflections on the LCD screen can hinder visibility, especially in bright sunlight.
- Cost: LCD screens and associated hardware can be costlier to implement compared to the other prototypes.
- Power Consumption: The screen may require a substantial power source, affecting battery life.
- Lack of Inclusivity: Feedback on the LCD screen can be harder to be processed by visually impaired people

5 Final concept design

The selection of the final concept design, NaviGrips, was a result of a comprehensive evaluation process that considered the project's design goal, the functional specification, and its innovative, challenging, and user-friendly character. Let's break down the factors that led to the selection of NaviGrips as the ultimate choice.

5.1 Innovative Approach

NaviGrips stood out due to its unique use of tactile feedback through vibrating handlebars. This approach innovatively addresses the challenges faced by using the smartphone as the navigational system, aiming to reduce distractions and enhance safety for cyclists. The vibration-based signaling, though it has limitations, provides a different way to convey navigation cues that's relatively less distracting and more suitable for urban environments where visual or auditory cues might be less effective.

5.2 Challenging Nature

NaviGrips presented a challenge in terms of designing and implementing various vibration patterns to convey different types of turns. While this may be a challenging aspect of the design, it also adds depth to the user experience by providing nuanced navigation information. Overcoming this challenge is an opportunity to create a more sophisticated and effective navigation system. An additional challenge inherent in the selection of NaviGrips as the final concept design lies in the necessity to strike a delicate balance between multiple essential characteristics. Not only must NaviGrips function effectively in providing tactile navigation feedback, but it must also embody an elegant and compact design while ensuring durability and accommodating all essential components. The challenge is to seamlessly integrate the complex technical components into a small, ergonomic structure that is aesthetically pleasing without compromising on durability. This encompasses considerations, such as housing the vibrating motors, connecting mechanisms, power source and communication modules within the limited space available on the handlebars. To achieve this, the team must meticulously engineer the physical design, carefully selecting materials and manufacturing techniques to ensure the device is durable enough to withstand diverse weather conditions, shocks and vibrations during regular use, while maintaining an aesthetically pleasing and unobtrusive form factor. This delicate balance between elegance, size, durability and component integration is pivotal in crafting a final product that not only functions optimally, but also appeals to the user's preferences and enhances the overall cycling experience.

5.3 Functionality

NaviGrips meets the functional specification by addressing the core requirements identified in the design concepts. It provides navigation instructions through tactile feedback, incorporates a stop button for user control and offers arrival notifications. These functionalities directly align with the needs of cyclists who depend on navigational systems for safer and more enjoyable rides.

5.4 Inclusivity

The choice of NaviGrips also aligns with the inclusivity aspect mentioned in the design goal. While not explicitly mentioned, the tactile feedback approach has the potential to be more inclusive for visually impaired users compared to LED lights or LCD screens, which heavily rely on visual cues.

5.5 Scalability and Environmental Considerations

The concept's use of vibration feedback opens doors to potential scalability. As technology evolves, NaviGrips can be updated to provide more nuanced feedback, thus catering to the evolving needs of the cycling community. Furthermore, it has the potential to be environmentally friendly. With its low power consumption, it extends battery life, reducing the need for frequent charging or battery replacements—a feature that environmentally conscious cyclists are likely to appreciate.

5.6 Regulatory Compliance

In some regions, regulations limit the use of screens or lights on bicycles that could potentially distract or blind other road users. NaviGrips, being vibration-based, is less likely to face such regulatory challenges. It provides a compliant and practical solution for cyclists who must adhere to local regulations.

In conclusion, NaviGrips embodies a visionary approach to bicycle navigation, placing safety, efficiency and user-friendliness at the forefront. Its utilization of vibration feedback, along with innovative patterns, ensures an unmatched user experience. NaviGrips doesn't just address the needs of cyclists; it anticipates them, making it a concept poised to redefine the way cyclists navigate the urban landscape. As we embrace the future of cycling, NaviGrips promises to be a game-changer.

6 Technical specification

In our pursuit to create the ultimate user experience for our vibrating handlebars project, we've carefully defined the technical specifications and categorized them according to the MoSCoW method. The specifications below provide a detailed insight into the core requirements and potential enhancements.

6.1 Must-Have

The "Must-Have" category includes essential technical specifications that are integral to the project's core functionality:

- Vibrating Motors: Two vibrating motors are strategically integrated into the handlebars, one on the left and one on the right. The specifications for these motors are as follows:
  - Maximum supply voltage: 6 V
  - Average current consumption: 200 mA
  - Maximum rotation: 225 Hz
- GPS Module: A GPS module is essential for real-time location tracking, ensuring accurate navigation assistance. The GPS module's specifications include:
  - Supply voltage: 3.3 - 5 V
  - Current consumption: typical 40 mA, maximum 67 mA
  - Precision: 2.5 meters
- Batteries: To power the system for extended periods while remaining rechargeable, the project requires two LiPo batteries with specific specifications:
  - Voltage: 3.7 V
  - Capacity: 1250 mAh

  These batteries ensure the handlebars can provide uninterrupted vibration feedback.
- Encasing (Handlebars): The secure encasing on the steering wheel is crucial for mounting the handlebars. This component's specifications include:
  - Waterproof 3D printed material

  The waterproof material and precise dimensions protect the device in various weather conditions.
- GPS Data Processing: The project demands software capable of processing GPS data and calculating the user's current location and distance to the next turn. This component is integral to the core functionality of the device.
- Google Maps API Intergration: Seamless integration with the Google Maps API is essential for retrieving route information, including turn-by-turn directions. This integration ensures the navigation system provides users with accurate and up-to-date guidance.
- Vibration Control: A software component for controlling the vibrating motors is a must. This component relies on navigation instructions and the user's proximity to turns. It is a critical part of providing tactile navigation feedback.

6.2 Should-Have

In the "Should-Have" category, we address specifications that, while not constraints, significantly enhance the user experience:

- Compass: A compass is added to the device to set up the initial direction for user to go. This means that the user should turn around on the starting point to know what direction to go
  - I2C connection
  - Maximum supply voltage: 3.6 V
  - Enables 1° to 2° compass heading accuracy

6.3 Could-Have

The "Could-Have" category includes specifications that are not essential but can enhance the project:

6.3.1 Battery Life Indicator

We aim to implement a software feature to display the remaining battery life. While not a core requirement, this feature enhances the user's awareness of the device's power status.

6.3.2 Voice Navigation

Voice-based navigation, while not included in this version, is an intriguing possibility for future enhancements. It offers an alternative way of providing navigation guidance to users.

For this part we did not have anything to add. All of our technical specifications are mentioned above.

6.4 Won't-Have

Finally, in the "Won't-Have" category, we acknowledge specifications that, while innovative, do not align with the current project's primary objectives. Since none of the specifications will be implemented in the device, the technical specifications have not been thought of.

For each of these technical specifications, we consider various solutions and technologies to ensure the optimal performance of our vibrating handlebars. These specifications provide a comprehensive road map for our project, ensuring that we meet the core requirements while also exploring possibilities for future enhancements.

7 Detailing

Three key components in this project include the vibrators, the Python-to-Arduino connection and the casing. These choices were made to provide insight into haptic feedback, the method of transmitting directions to the Arduino, and the user-friendly and safe design of the casing.

7.1 Haptic feedback

The vibrators serve to provide haptic feedback to the user. There are two main options for vibrators in combination with the Arduino. The first option is to use vibrators that require a voltage supply below 5V. These are relatively inexpensive, costing around one or two euros and come in the form of a disk. The other option is to use vibrators that require a higher voltage, but this poses a problem due to the Arduino's maximum voltage of 5V. To use these vibrators to their full capacity, a step-up boost converter is needed, which increases the cost by approximately 2 euros for each, as both the step-up boost converter and the vibrators have a similar cost. In our design, the second option was chosen due to the evaluation of the design and the consideration of handle damping risks.

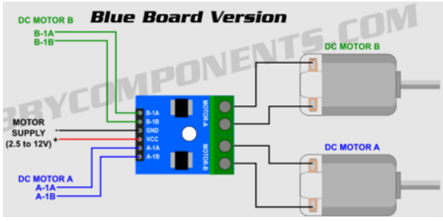


Figure 1: Motor controller with the vibrators

A schematic overview of the motor controller and the vibrators is depicted in Figure 1. Each motor controller can manage two vibrators, and for each vibrator, four pins are crucial. Two of these are the ground and VCC, connected to the step-up boost converter to provide sufficient voltage. The other two pins control the direction of the vibrations, either clockwise or counterclockwise. Both directions were tested, but the difference between them was not significantly sensible. Motor control is organized into functions, where different vibration patterns were tested and optimized for a pleasant and clear outcome. Table 2 is made to give an overview of the kind of haptic feedback at which moment.

Cause	Effect
50M	short
20M	long
slight turn	single
normal turn	double
sharp turn	triple

Table 2: Cause and effect of haptic feedback

7.2 Python-Arduino communication

The second component is not exactly a physical component but rather a connection. It's the link between the APIs and the Arduino. APIs, which stand for Application Programming Interfaces, act as bridges that enable different software systems to communicate and share information. In the context of retrieving directions from Google Maps, Google provides the Google Maps Directions API. Google mandates the use of a special key, known as an API key, to access their Directions API.

These APIs are obtained with Python, but the remaining code is written in C++ on the Arduino. Neither of these codes can be written in the other's language, causing a communication problem. To address this, various methods and codes were considered.

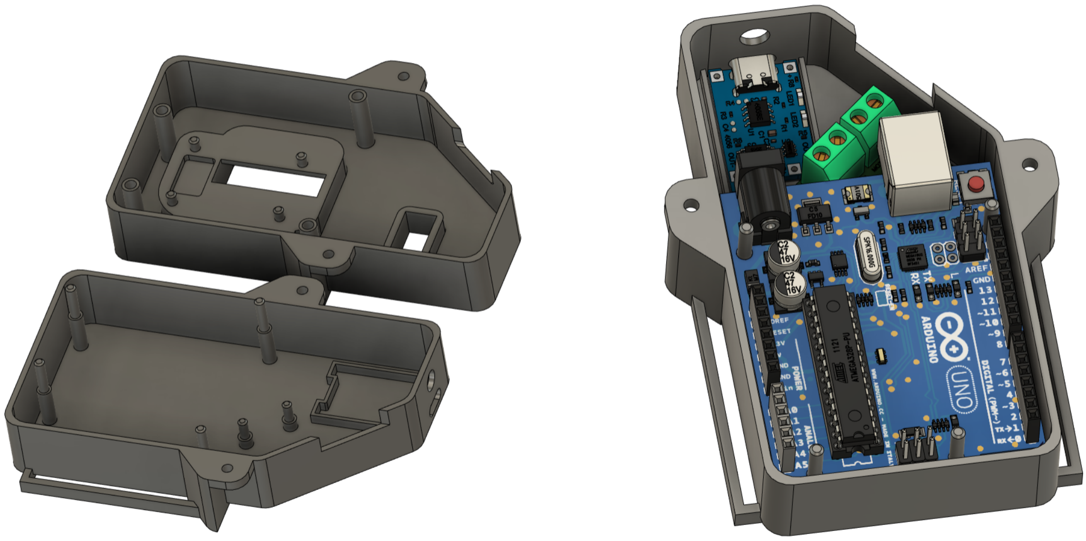
The initial solution explored was serial communication between Python and Arduino. This method involves establishing a connection between a Python program running on a computer and an Arduino microcontroller, allowing data exchange over a serial port. While this method is useful for many applications, using a USB port for this purpose can lead to data formatting issues and port over-occupancy. To mitigate these problems, a serial port with RS-232 was considered but was not within the budget.

Backup plans were devised, some focused on alternative ways to access the APIs, while others explored different methods of transmitting directions from Python to Arduino. Using other methods to access the APIs presented similar risks to the initial approach. Therefore, it was decided to copy the Python code's output and paste it into the Arduino. This approach was chosen to keep things simple, avoid unnecessary files on one's computer, and utilize a method familiar to everyone.

To further explain the coding in Python and Arduino table 3 is made with the which briefly describes the key features and the code. This table is set into the appendix.

7.3 Casing and Handles

7.3.1 The Casing



(a) Empty CAD model showing pin extrusions

(b) Lower compartment

Figure 2: Top Compartment

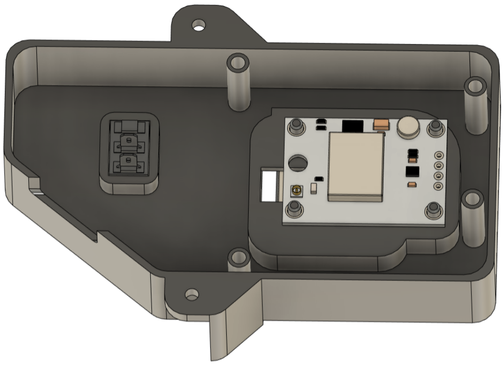
The 3d printed casing consists of 2 main parts that clamp together by screws on the sides in order to contain and shield the major electronic part needed for the product. The case relies on pin extrusions and border extrusions to position the various electronic components in order to fixate them inside the case, as seen in Figure 2a. This is done in order to limit the movement of the components inside the case so that damage is prevented as well as any unwanted wire disconnection. The case has an opening with a cap to close when not used, which allows the USB port of the Arduino to be accessed. On the sides, the case has rails which allows for the placement of a belt or zip ties to go in and around the case in order to secure the case firmly to any part of the bike.

Lower compartment:

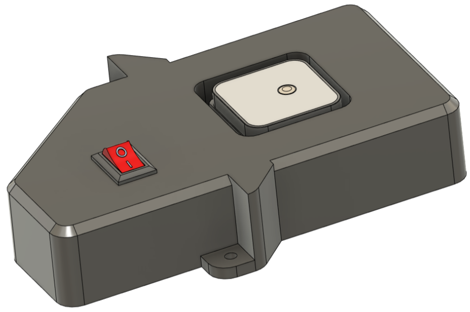
The lower compartment of the case locks the Arduino, motor controller, and charging port in place via the extruded pins, and also holds the 2 polymer lithium ion batteries. Moreover, there are 2 holes in the lower compartment for all the cables that need to go out to the handles where the vibration motors are, and another hole that allows the charging port to be accessed from the outside without the need to open the case.

Top compartment:

The top compartment contains the GPS module and the on/off switch. The GPS sits in a crevasse on top of the case that helps it stay in place and provides minimal material along the GPS signal path to ensure strong GPS connection. The position of these parts can be seen in the next Figure 3. All the other electric components that where not mentioned are not mounted and stay between the two case compartments, as they are small and can not move around in the case on their own.



(a) Inside of top compartment

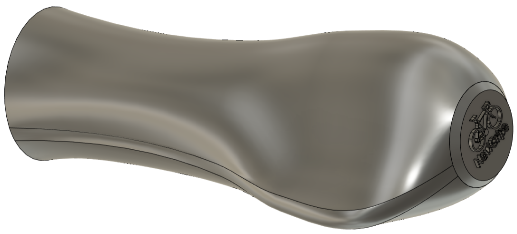


(b) Outside of top compartment

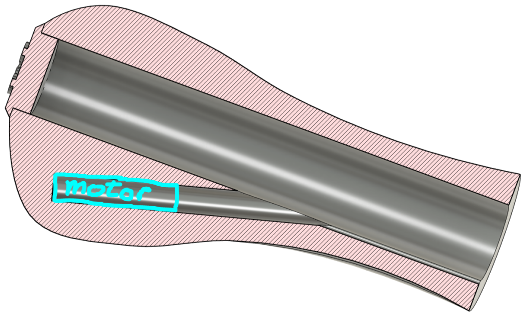
Figure 3: Top Compartment

7.3.2 Handles

The handles contain the motors and the compass magnetic sensor. The compass sensor is positioned there as it provides flexibility for the mounting location of the case as the handles are fixed and can not face the wrong way relative to the driver when put on, while the case could. The positions of the vibration motors are beneath the palms of the hands on the back side of the handle as seen in the figure below.



(a) Outside of Handle



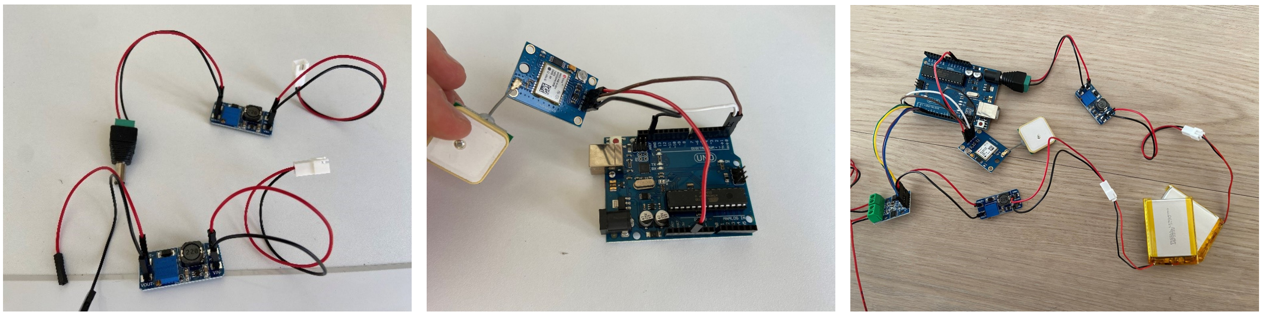
(b) Inside position of Vibration Motor

Figure 4: Handles

8 Realization

8.1 Assembly Process

The assembly of a prototype began with the ordering of electronic parts. Before the parts were permanently connected, preliminary tests were executed by using prototyping cables and pins (DuPont). Many electronic parts that were ordered did not come with header pins, thus, some were temporarily connected to test the circuits. These will not be included in the final material list and will be removed. Thus, in the final prototype, all components will be hard soldered together. The methodology of this testing can be seen in the figures below. The DuPont wires can easily be detached and re-ordered as required for testing.



(a) Custom DuPont connectors (b) Arduino DuPont connections (c) Electronics Overview

Figure 5: Prototyping Methodology

8.1.1 Assembly of the electronics:

The assembly process of the final design requires the use of multiple techniques, such as basic soldering, wire stripping, and de-pinning. The step-to-step assembly plan seen below can be used in conjunction with the electronics schematics seen in fig. 5c.

Step 1: Solder the positive and negative wires of the lipo batteries in parallel onto the bat+ and bat- terminals on the TP4056 USB-C Li-ion charger.

Step 2: Then, solder a positive and negative loose wire to the output terminals on the charger. Cut the positive wire in half, de-strip, and solder the rocker switch onto each end of the positive wire where it was cut.

Step 3: Next, solder the positive and negative wire to the voltage in ($V_{in}+$) and voltage in - ($V_{in}-$) on one of the voltage boosters.

Step 4: Then, solder two positive and two negative wires to the voltage out + ($V_{out}+$) and voltage out - ($V_{out}-$) terminals of the voltage booster.

Step 5: Solder one of the positive loose wire ends to the V_{in} port on the Arduino and the negative to a GND port on the Arduino.

Step 6: Then attach the other positive and negative wire to the voltage in + ($V_{in}+$) and voltage in - ($V_{in}-$) of another voltage booster.

Step 7: Solder another positive and negative wire to the output terminals of the voltage booster($V_{out}+$ and $V_{out}-$).

Step 8: Solder the other side of these wires to the VCC and GND terminals of the motor controller.

Step 9: Furthermore, solder 4 wires to the other terminals of the motor controller. The other side of these wires can be connected to the Arduino through digital pins of your choice.

Step 10: The 6V vibration motors come attached with 10cm loose wires. This is not long enough, thus, solder 1 meter of black and red loose wiring to each vibration motor. The 1-meter loose wiring can then be connected to the motor controller via the screw terminals.

Step 11: The GPS module is delivered with header pins by default. Thus, to solder wires directly onto the circuit board, it is best to remove these. This can be done by applying heat(using a soldering iron) to the solder on the underside of the board. Then pull the header pins out.

Step 12: De-strip and solder 4 wires to the GPS module terminal: VCC, GND, TX, and RX respectively. Then solder the TX and RX wires to the TX and RX ports on the Arduino. The VCC cable can be connected to the 5V pin on the Arduino and the GND cable can be connected to a GND pin on the Arduino as well.

Step 13: The compass module is placed in one of the handlebars. Thus, five, one meter loose wires must be de-stripped.

Step 14: Then, solder the wires to the following ports on the compass: VCC, GND, SCL, SDA, and DRDY. Note that: the wires have to be fed through the wire hole in the encasing before soldering them to the Arduino(see section 8.1.2. The VCC wire can go to the 3.3V port on the Arduino, the GND to GND, the SCL and SDA can go to analogue ports on the Arduino and the DRDY connects to a digital pin.

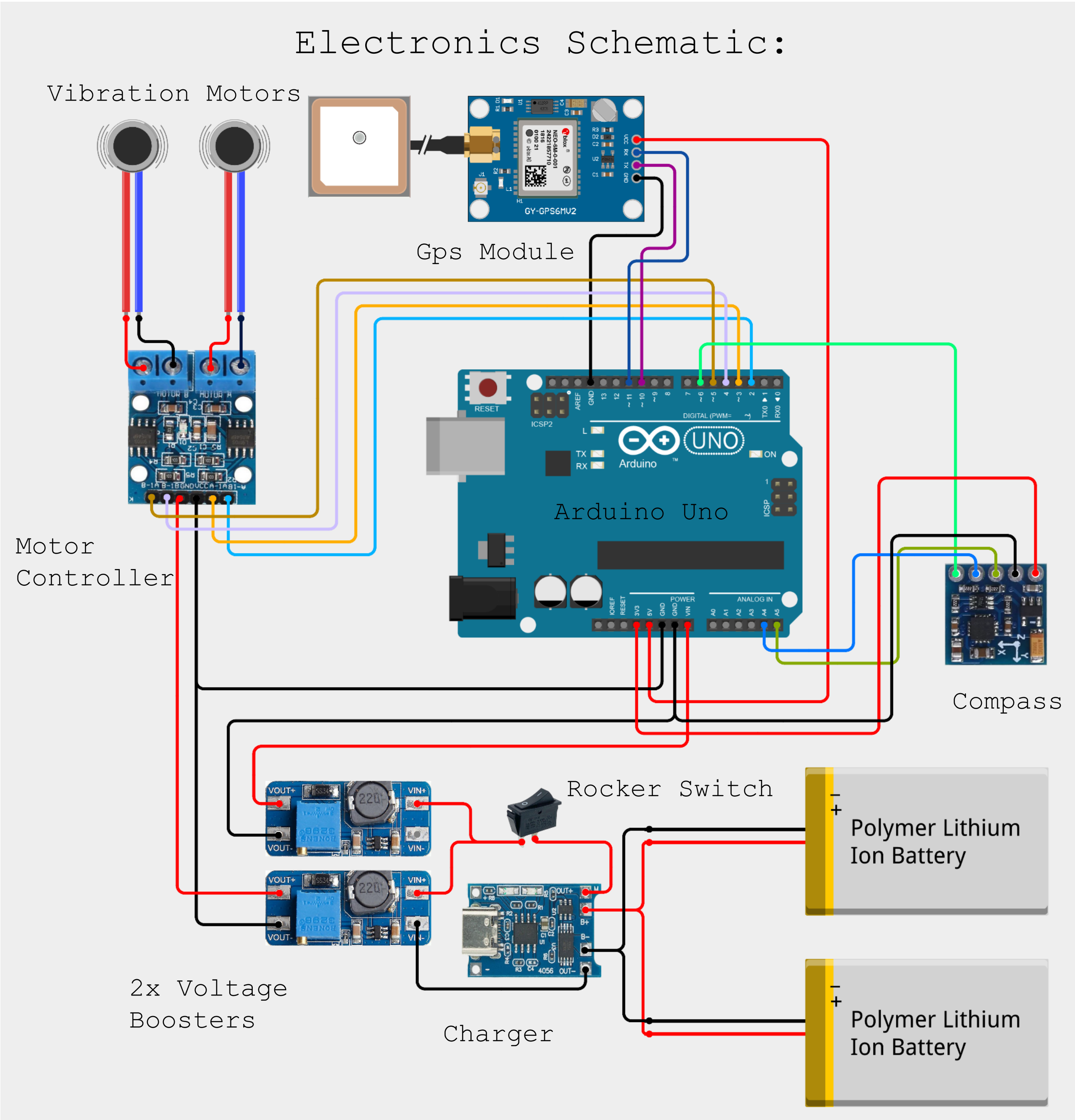


Figure 6: Electronics Schematics

8.1.2 Product Assembly

With the electronics assembly now completed, the next crucial step is to ensure that these components are securely housed within the encasing. Furthermore, the vibration motors have to be placed into the grips. Provided below are step-by-step instructions.

Bottom Case:

Step 1: Place the battery and USB-C charger into the holding.

Step 2: Insert the motor controller into the pins.

Step 3: Slot the wires for the vibration motor through the holes above the USB c slot.

Step 4: Place the Arduino on its stabilizing pins in the case.

Step 5: Feed the 5 wires for the compass through the same hole as the vibration motors.

Step 6: Solder the 5 wires to the Arduino making sure that: the VCC wire from the compass gets soldered to the 3.3V port, GND goes to GND, the two analogue cables go to SCL and SDA ports, and the digital port cable goes to DRDY.

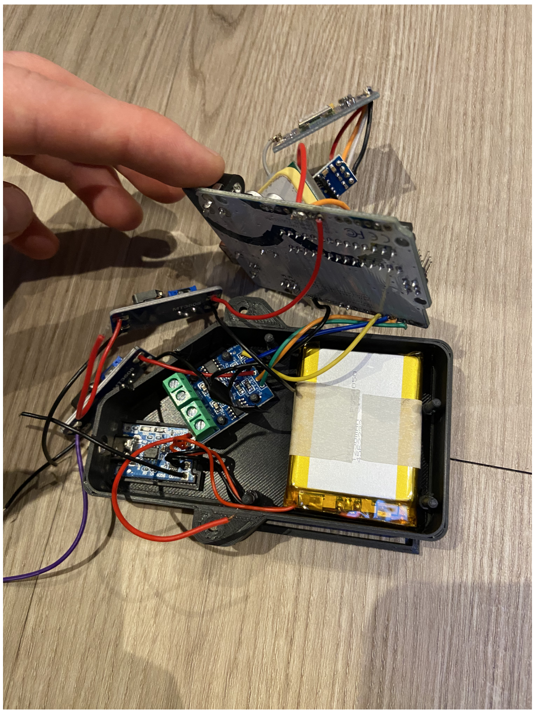
Top Case:

Step 1: Insert the GPS antenna through its designated slot. Then place it flat into its resting place on the top of the case.

Step 2: Connect the top case to the bottom case by aligning the pins(the same which the Arduino was placed on).

Step 3: To stop the two parts from separating, screw the two M2.5 x 10mm screws into their designated holes on the sides of the case.

Step 4: If desired, the caps used for making the case water-resistant can be attached to the case.



(a) Components placed in the encasing

(b) Final Protoype

8.2 PfP

FDM 3D printing is the main manufacturing process used during production. The rapid prototyping process allows for the cheap, quick, and reliable manufacturing of materials with different properties. Two different materials are used, PLA and TPU; PLA being a standard plastic, is used for the encasing of the electronics, and TPU is a flexible material used for the grips. In order to print TPU it is recommended to print at a slower speed and to use a printer with a direct drive extruder. This is due to the fact that the flexibility of the material makes it hard to feed to the extruder if it's not directly driven. There are four main steps during the production process:

Step 1: Create a CAD model using dedicated software. Keep in mind 3D printing constraints such as overhangs and fine detail.

Step 2: Use a slicer software to convert the CAD object into readable g-code.

Step 3: Manufacture the part using a 3D printer.

Step 4: Post-process the part if required(clean and trim plastic).

8.3 BoM

Part Name	Brand + Seller	Amount:	Price(€):
Uno R3 with USB cable	TinyTronics	1	11.5
Closed Vibration DC Motor 6V	TinyTronics	2	3.5
DC-DC Adjustable Step-up Boost Converter MT3608 2A	TinyTronics	2	4
GY-NEO6MV2 GPS Module	TinyTronics	1	13.5
Electrical PVC Copper Wire 0.33mm2 - Red - 1m	RV + AliExpress	2	1.3
Electrical PVC Copper Wire 0.33mm2 - Black - 1m	RV + AliExpress	7	4.6
Li-Po Battery 3.7V 1250mAh - JST-PH - LP554050	TinyTronics	2	17.5
Heat shrink tubing 2:1 - Ø 1.6mm diameter - 5cm - Black	TinyTronics	1	0.04
L9110S Bipolar Stepper Motor and DC-Motor Controller	TinyTronics	1	3.5
QMC5883L 3-Axis Compass Magnetometer Sensor Module 3V-5V	TinyTronics	1	2.75
Jumper wire multicolor 10cm	TZT + AliExpress	9	0.13
TP4056 USB-C Li-ion charger 1A with Li-ion protection circuit	TinyTronics	1	2.5
Standard Mountable rocker switch - Small	TinyTronics	1	0.45
53g of PLA at €16 per Kg	ACTIVEME via Amazon	1	0.85
99g of TPU at €22 per Kg	OVERTURE via Amazon	1	2.18
Velcrow Straps - 0.5 meter	Action	1	0.2
M2.5 x 10mm screws	LIYA Hardware via Aliexpress	2	0.082

Total(€):
68.58

Figure 8: Bill of Materials

9 Test Plan/Realization

Objective: To verify the functionality and safety of the handlebars with vibrating direction indicators.

9.1 I. Functional Testing

9.1.1 Vibration Motor Functionality

Measurement Instrument: Multimeter (to check voltage output)

Procedure:

- Connect the handlebars to a power source.
- Confirm that the vibration motors are operational by feeling for vibrations.
- Use a multimeter to measure the voltage output from the vibration motors. Ensure it matches the desired voltage (6V).

9.1.2 GPS Module Functionality

Measurement Instrument: None (visual confirmation)

Procedure:

- Ensure the GPS module has a clear line of sight to the sky for signal reception.
- Confirm that the GPS module successfully acquires and displays GPS coordinates on a connected device (e.g., a smartphone or computer).

9.1.3 Arduino Functionality

Measurement Instrument: None (visual confirmation)

Procedure:

- Verify that the Arduino is receiving power from the voltage booster and is operational.
- Confirm that the Arduino interprets the GPS data and sends commands to the vibration motors as intended.

9.1.4 Direction Indication

Measurement Instrument: None (visual and tactile confirmation)

Procedure:

- Test the handlebars in different directions.
- Ensure that the handlebars vibrate to indicate the intended direction (e.g., left or right).
- Confirm the vibration patterns are distinct and easy to distinguish.

9.2 II. Safety Testing

9.2.1 Voltage Calibration

Measurement Instrument: Screwdriver (for adjusting potentiometers)

Procedure:

- Verify that the voltage boosters are set to the correct output voltage (5V for Arduino and 6V for vibration motors).
- Use a screwdriver to adjust the potentiometers if necessary until the voltage is correct.
- Recheck the voltage output with a multimeter after calibration.

9.2.2 Electrical Safety

Measurement Instrument: None (visual inspection)

Procedure:

- Inspect all soldered connections and wiring for any signs of short circuits, loose connections, or exposed wires.
- Ensure that heat shrink tubing is applied correctly to prevent electrical hazards.

9.3 III. Ergonomic and Mechanical Testing

9.3.1 Handlebars Grip Fit

Measurement Instrument: None (visual inspection)

Procedure:

- Test how well the vibration motors fit into the grips.
- Confirm that they are secure and won't easily come loose during use.

9.4 IV. Charging and Battery Testing

9.4.1 Battery Charging

Measurement Instrument: USB-C Charger and Charging Current/Voltage Meter (if available)

Procedure:

- Connect the batteries to the USB-C charger.
- Verify that the batteries are charging.
- Optionally, use a charging current/voltage meter to measure the charging parameters to ensure they are within safe limits.

9.5 V. Overall System Integration Testing

9.5.1 Complete System Test

Measurement Instrument: None (functional and visual inspection)

Procedure:

- Verify that all components work together as a complete system.
- Confirm that the handlebars indicate directions accurately based on GPS data.

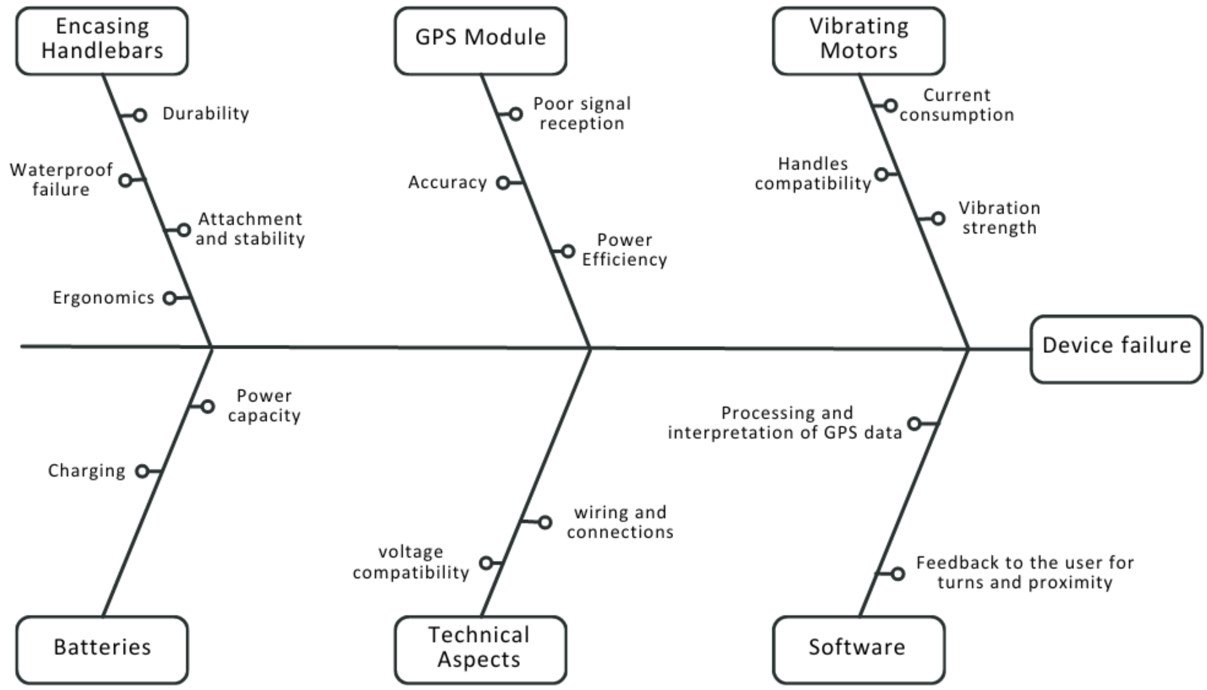


Figure 9: Fishbone diagram

Risk Management

Vibration Motors

Power Consumption:

- **Probability:** Moderate
- **Impact:** High
- **Solution:** Optimize the vibration patterns to conserve power. Implement a low-power mode when not actively giving directions.

Vibration Strength:

- **Probability:** Low
- **Impact:** Moderate
- **Solution:** Test various vibration strengths to ensure they're perceptible but not uncomfortable. Implement user settings to adjust vibration intensity.

Handlebar Compatibility:

- **Probability:** Low
- **Impact:** Moderate
- **Solution:** Test the device on various handlebar types to ensure compatibility. Provide adaptable mounting options.

GPS Module

Poor Signal Reception:

- **Probability:** Moderate
- **Impact:** High
- **Solution:** Use an external antenna or improve the device's placement for better signal reception. Look for an improved GPS module

Accuracy:

- **Probability:** Low
- **Impact:** High
- **Solution:** Calibration and testing to ensure accuracy. Implement algorithms to mitigate minor inaccuracies.

Power Consumption:

- **Probability:** Moderate
- **Impact:** Moderate
- **Solution:** Configure the GPS module to obtain coordinates at regular, spaced intervals to minimize power usage.

Encasing Handlebars:

- **Ergonomics & Durability:**
  - **Probability:** Moderate
  - **Impact:** High
  - **Solution:** Thorough testing for durability and user comfort. Iterative design improvements based on feedback.
- **Waterproof Failure:**
  - **Probability:** Moderate
  - **Impact:** High
  - **Solution:** Use high-quality waterproof materials. Perform rigorous waterproof testing and sealing of vulnerable entry points.
- **Attachment & Stability:**
  - **Probability:** Low
  - **Impact:** Moderate
  - **Solution:** Reinforce attachment points. Utilize adjustable mounts to accommodate various handlebar sizes.

Batteries

Charging:

- **Probability:** Low
- **Impact:** High
- **Solution:** Implement efficient charging circuits, use of USP-C. Provide clear user instructions for proper charging.

Power Capacity:

- **Probability:** Moderate
- **Impact:** High
- **Solution:** Optimize power consumption and potentially consider higher-capacity batteries if feasible.

Technical Aspects

Voltage Compatibility, Wiring & Connections:

– **Probability:** Moderate

– **Impact:** Moderate

– **Solution:** Thoroughly test connections. Implement failsafes to protect against voltage fluctuations.

Software

Feedback & GPS Data Interpretation:

– **Probability:** Moderate

– **Impact:** High

– **Solution:** Extensive testing of the software. Iterative improvements based on feedback.

10 Design evaluation

10.1 Evaluation:

In retrospect, the intended goal of the product is to provide and encourage a safer way to navigate while using a bike. This will ultimately promote the use of bicycles and thus reduce the number of people using other fuel-emitting forms of transportation. Evaluating NaviGrips, the group feels optimistic that the prototype design can be further transformed into a mass-produced device sold as an accessory, or even become standard on higher-end bikes. Furthermore, not only do we feel that this product encourages non-bike users to cycle, but we also believe that existing bike users will find our product useful too. The prototype displayed in this report has gone through many iterations, making it more creative and innovative over time. The design started off quite basic, with limited functions such as vibration motors and a GPS module. However, towards the end of the prototyping phase, a compass module, mounting straps, and an integrated battery charging system were added. These were not directly necessary; however, they improved the user experience by making the cycling experience more user-friendly. Although there are many positive aspects to the prototype, there are some areas that were lacking. The code behind the product is quite complex and thus could run smoother. The reason behind this is that given the time frame, this was the only approach that could have been taken. The code could still be more optimized so that there are fewer bugs and less run time. Furthermore, the chosen microcontroller could also be reconsidered, as there are a variety of different controllers, each optimized for different functions. An Arduino Uno was chosen simply because it was the most popular and there was a lot of documentation online regarding its functionality. In conclusion, NaviGrips fulfils its job of solving the intended goal of encouraging more people to use bikes. However, there are still future design improvements that will take NaviGrips to the next level.

10.2 Future Design Improvements:

The current prototype is not perfect and further design improvements are necessary for a final product to be put on the market. Listed below are the top three improvements that must be considered.

1. Better UI: Currently, in order to use the product, a laptop is required to load the directions onto the device. This is not very user-friendly and must be improved in the future. Given more time and funding, the ideal case would be a mobile app or inbuilt Google Maps integration where the device communicates over Bluetooth to receive real-time directions. Both options are viable, however, it would be more simple and user-friendly for the device to directly connect to Google Maps. This way, all the user has to do is turn the device on and connect it to their phone via Bluetooth.

2. More compact: Regarding the prototype, the group is pleased with how compact the current state of the design is. However, the compatibility of the design is limited by the size of the electronics inside. If the design was made into a final product and mass-produced, it would be possible to create or use custom electronics that are smaller in size. Ideally, it would be best if the electronics compartment was around the size of a display seen on E-bikes or smaller. This way, the electronics compartment could be mounted on the handlebars and the wires connecting the electronics to the grips would be shorter too.

3. More water-resistant: Given that there are many external parts to the product, many cables and ports have to be exposed to the outside leaving the electronics inside the encasing vulnerable. Within the given time frame and budget, 3D-printed caps were made to cover major ports within the casing. However, there are still holes in cables that are not suited for caps. In the future, these cables could be sealed using glue or they could have external cable braiding that seals the encasing. Lastly, the vibration motors inside of the handlebar grips are protected nicely, given that there is a good seal between the inside of the grips and the handlebars. However, if this seal is not good enough, water could leak into the grips and flow into the vibration motor hole, essentially drowning the motors. This would not be good for the longevity of the product. Hence, the vibration motor holes should also be sealed off with glue or plastic.

11 Individual contributions

11.1 Group Member 1:

My contribution to the project started with developing different concept designs. My main goal was to brainstorm designs that were out of the box, original and encourage sustainable transport. Furthermore, after the ideas were put on the table, I spent my time researching the feasibility of all initial design concepts. More specifically, which electronics we would need to make the product a reality. Once the group decided on around two possible product ideas, I made a cardboard model to visualise the idea better. This featured most aspects of the product in the form of cardboard, however, some components were generalized/grouped together. I then started researching what electronics we were going to use in the chosen design. This is the main tipping point at which my main focus relates to the CBL module 'Basics of Electronics'. Not being an electrical engineer made the content of this CBL module unfamiliar territory. Nevertheless, I wanted to gain more experience with electronics. I was able to do research and validate my findings regarding the compatibility of components. For example, choosing the microcontroller was a main discussion point and figuring out a way to provide all components with the correct voltages was also discussed. I would like to note that I was not perfect at balancing the materials and cost of the system. At the beginning of assembling the electronics, I had bought electronics that after further research were concluded to not be necessary. An example of this was the method of providing power to the Arduino which was changed from the DC jack port to the V_{in} port. Going back to the prototyping phase of the electronics, I focused on making it easy to arrange the electronics. To do this I used DuPont connectors and a breadboard. During this phase, I learned how to properly solder and de-solder header pins. This was also useful later since some of the components had header pins that needed to be removed. Furthermore, I have expanded my experience with using tools such as multimeters. After creating a prototype of the electronics, I was able to confirm that the electronic components worked. I then started working on solidifying the electronics into a permanent setup. This was a solder-heavy process and required a lot of patience. Another large part of my contribution to the project was communicating with teammates regarding the CAD design for the encasing and the programming of the electronics. There where multiple iterations of trying to accurately place the electronics inside of the encasing and this required a lot of teamwork. Overall, I feel like I played a solid role in the project. I learned a lot about electronic management and soldering which was a very hands-on job.

11.2 Group Member 2:

Contribution Overview to the Project:

I played a pivotal role in several significant areas throughout the project, primarily focusing on ideation, research, presentation preparation, and a variety of supportive roles to enhance the project's outcome.

Ideation and Research:

My involvement started with intensive research and the generation of diverse concept designs aimed at fostering sustainable mobility. After the main design concepts were chosen, I dedicated considerable effort to researching the ideas chosen for the project. My role extended to exploring numerous perspectives to ensure our choices were well-considered, even though not all ideas were integrated into the final product. This allowed the team to continuously have different options in case there were setbacks. I also delved into extensive literature review, researching multiple papers to validate the sustainability of the product. The process was quite time-consuming due to the limited availability of research directly addressing the specific product's sustainability factors. Nonetheless, despite the scarcity of explicit studies, I managed to navigate through a diverse range of related papers and found the needed information.

Presentation and Communication:

A crucial aspect of my contribution lay in the presentation and communication facets. I took charge of writing the video script and proposing scene ideas that were pivotal in both the midterm and final presentations. Collaborating closely with the team, we made sure that our video encompassed all essential details while keeping a simplistic approach that is easy to understand. Moreover, I meticulously wrote the content required for the slides and engaged in their design, ensuring that the visual representation of our work was cohesive and impactful.

Report and Documentation:

Another significant area of involvement was in documentation and report writing. I meticulously worked on various parts, especially the design goal, preliminary designs, functionalities, technical specifications ,final concept design, test plan, and risk assessment within the project report. My aim was to provide a comprehensive outline of our project's progress and goals.

Technical Involvement:

While my technical expertise is limited, I made attempts to contribute in this area. I explored programming initially but shifted my focus due to its complexity. After we chose 3 preliminary designs, I created a digital model for one of the designs so we get a better understanding of the idea. I assisted the team wherever possible, supporting them when they required help with technical aspects, and various other components within my expertise.

Overall Impact:

My approach to the project was multifaceted. I contributed extensively to brainstorming ideas, preparing and presenting content, providing constructive feedback, and boosting team motivation. While I believe I could have been more involved in the technical aspects, I am proud of the comprehensive impact I made through my dedicated contributions to different project dimensions.

This comprehensive involvement across various segments was geared towards ensuring a well-rounded and successful project outcome.

11.3 Group Member 3:

My individual contributions in the beginning stages of the project revolved around conceptualizing and brainstorming different ideas that would encourage sustainable transport. During this stage I focused my time on realizing the starting ideas and figuring out the feasibility of the initial concepts ideas. This included checking the prices of the parts that would be used and checking if some parts could even be manufactured by us if they could not get find online.

As the project advanced, I started working on CAD and modeling the components that the product would comprise of. This started with modelling the handles that were to be used making sure that they provided user comfort and ergonomic design which at the same time could effectively accommodate the vibrating motors, a critical component of the system in the early stages that was chosen. At this stage I refined my CAD modeling skills as I had never worked with complex smooth shapes before which made for an interesting learning experience that really showed me the capabilities of most CAD modeling softwares.

In the later stages, I was tasked with designing the casings for the various electronic components. This was a dynamic process, with constant modifications needed to accommodate the persistently varying selection of electronic parts. This stage was a significant chunk of my contribution to the designing progress as new iterations had to be made not just for the constant change of electronic parts, but also for tolerance changes and new ideas that needed to be implemented. An example would be the addition of rails to the sides of the casing which allowed straps to be added that made sure that the casing could be placed anywhere on the bike.

To conclude, my contributions significantly impacted the project's design process and the development of the final product.

11.4 Group Member 4:

I mostly contributed to the programming part of this project. Very soon after our idea was formed, I did research on API's, in particular the Google Maps directions API, on the internet. This research gave our group an idea of how we could use Google Maps in our project without too many complicated connections and without having to make an app. I had never heard of API's before this project, so I had to learn a lot about them.

I used this to learn to work with the API in python, which was the most efficient way to get outputs from the API and format them to make them usable. After getting these outputs, our group knew how to use this for our device, and what electrical components were needed for it to work. For example, we knew that the directions were given in "turn-left", "turn-right" formats, but we needed to specify the direction the user needed to head in at the start of their journey. This issue was solved with a compass connected to Arduino, because then we'd know exactly which way the user was facing.

I started working on the Arduino code after our components had arrived and have kept working on it until the final presentation. I also didn't know much about Arduino coding before this project, but being one of the main contributors to this taught me a lot about it. I learned to work with sensors like a GPS sensor and compass, and to send signals through the Arduino with vibration motors, mostly by looking at example code on the internet. I also learned about object oriented programming in Arduino, which we used to format the directions. I tried to make a connection between the python and Arduino code so they could communicate via a serial connection, but this ended up being too complicated for our limited time.

The coding overall was necessary to create routes for our user, which we did with the Google Maps directions API, but also to test our components and to make them work together, which was needed for the functioning of our device. Finally, it was needed to demonstrate the working of our device in the final presentation.

11.5 Group Member 5:

My individual contributions started with taking a leadership role in the group. In our group not everyone had experience with groupwork. For the project to go well a tight schedule is needed and some arrangements need to be made. I took this role upon myself for the first few weeks. After this the group got more accustomed to arranging this themselves. From that point I worked together with another group member on the report. In the beginning just notes were made on what we wanted to achieve with our project. We spent a lot of time just brainstorming and coming up with great ideas for sustainability and originality. I focused a lot on improving the device as much as possible, but I also knew that we had to make limits for what could be done on the project. Of course not all of our ideas were achievable and we had to cut quite a few.

For my CBL module, I focused on "Sustainable product development". This meant I was responsible for making the device as sustainable as possible, but mostly focused on the materials used. I researched the module as much as possible, even finding some sources on my own to use. For the device we tried implement the SPSD method. This was not entirely possible due to the availability of our materials. Since SPSD is not only focused on what materials are used but also if the device fulfils its traditional criteria, we succeeded in that. Our device has the right functionalities that also encourage sustainable behaviour. Since the device is assembled from parts, it is possible to recycle the device very well. This means that the device has a great product life cycle.

Overall, I steered the group in the right direction in the beginning phases of the project. After that I worked mostly on the report, but also knew what others were doing and how that reflected on the final product. During this project I improved my writing with the help of a group member. I learned how to brainstorm more effectively instead of just writing down the first thing that comes to mind. Besides that I also learned how to manage a group project from the beginning on.

11.6 Group Member 6:

At the project's outset, we generated numerous promising ideas. We conducted research on three of these concepts. Personally, I delved into an idea centered around an automatic bicycle pump designed to maintain the optimal tire pressure continually. I found great enjoyment in exploring this concept and strived to create a detailed prototype. However, as we progressed through the research phase, I came to the realization that this idea, while intriguing, was quite challenging and possibly unfeasible to complete within our constraints of seven weeks and a budget of 70 euros. This realization led us to ultimately opt for Navigrips.

We began with a focus on refining the concept. I created a model alongside some basic code using TinkerCad. Given the platform's limitations, the resulting simulation was rather simple. but, I used a lot of the finding of the CBL module. Shortly after, we conducted our first presentation, with me sharing the presentation responsibilities with a teammate. This was one of my initial experiences presenting in English, and I consider it a valuable learning opportunity.

Following the intermediate presentation, our emphasis shifted towards fine-tuning the project. Collaborating with a teammate, we concentrated on coding. She primarily worked on the APIs and the Python-to-Arduino connection, while my efforts were dedicated to testing individual components within Arduino and composing a pseudocode overview. Towards the end of this period, I noticed that additional support was available for coding, but there was still work to be done on the report. As a result, I offered to contribute to the reporting process and took on the responsibility. Whenever I encountered gaps in my understanding or required information on unfamiliar topics, I reached out to the person responsible for assistance. I believe we successfully delivered a good product and a report in the end.

12 Statement about use of AI

The use of AI tools such as ChatGPT was predominantly used during the research phase and for coding purposes. AI tools provided quick answers to component compatibility and coding-related questions.

AI was used for coding only in general ways, to show a way of thinking that we needed to solve certain issues. An example of this is when we didn't know how to write code to determine whether the user needed to look more left or right to face the correct initial direction, and we asked an AI program to show us a way to do calculations with angles between 0 and 360 degrees. We didn't use any AI at all during the writing of our python code.

References

[1] D. de Waard, K. Edlinger, and K. Brookhuis. Effects of listening to music, and of using a handheld and handsfree telephone on cycling behaviour. *Transportation Research Part F: Traffic Psychology and Behaviour*, 14, pp. 626–637 (2011) https://doi.org/10.1016/j.trf.2011.07.001.

[2] M. Pielot and S. Boll. Tactile Wayfinder: Comparison of Tactile Waypoint Navigation with Commercial Pedestrian Navigation Systems. *In: Floréen, P., Krüger, A., Spasojevic, M. (eds) Pervasive Computing. Pervasive 2010*, Lecture Notes in Computer Science, vol 6030. Springer, Berlin, Heidelberg.

[3] B. Poppinga, M. Pielot, and S. Boll. Tacticycle: a tactile display for supporting tourists on a bicycle trip. *in Proc. of MobileHCI'09, ACM Press(2009)*, pp. 1–4.

[4] H. Steltenpohl and A. Bouwer. Vibrobelt: Tactile navigation support for cyclists. *Proceedings of the 2013 International Conference on Intelligent User Interfaces.*, pp. 417–426. Association for Computing Machinery, New York, NY, USA (2013).https://doi.org/10.1145/2449396.2449450.

A Appendices

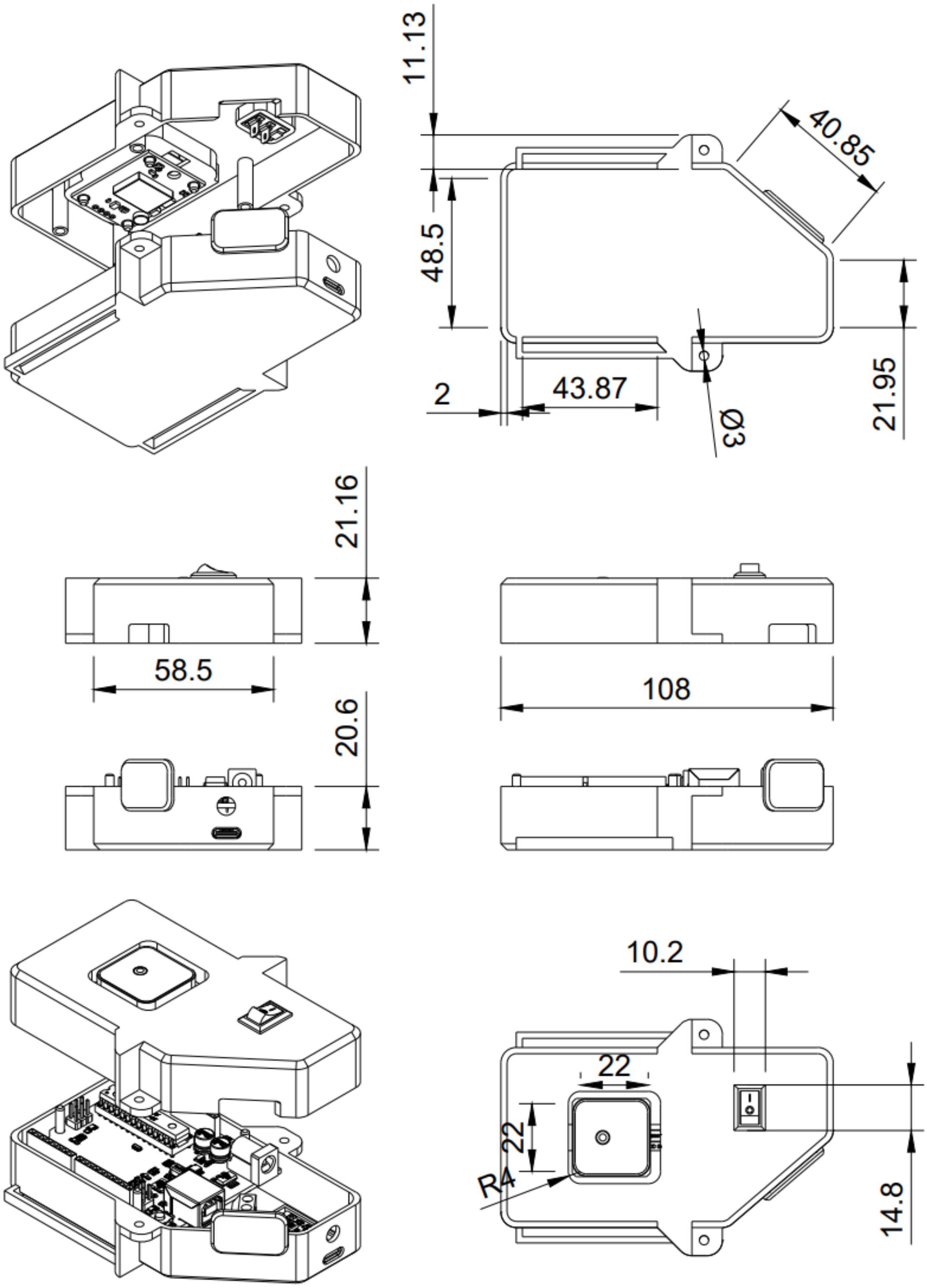


Figure 10: Dimensions in mm

Feature	Line of code
Python-code	
Getting directions from google maps	gmaps = googlemaps.Client(key= 'AIzaSyBUuDq7z_6yOQokRUyNpVMkooztTKCp_AQ') origin = **input**('Please enter an origin: ') destination = **input**('Please enter a destination: ') directions_result = gmaps.directions(origin, destination, mode='bicycling')

getting the starting direction and calculating the angle	start_instruction = directions_result[0]['legs'][0]
	['steps'][0]['html_instructions']
	start_direction = ''
	directions = ['north', 'south', 'east', 'west']
	
	for direction **in** directions:
	    if direction **in** start_instruction:
	        start_direction += direction
	
	directions = ['north', 'northeast', 'east', 'southeast',
	'south', 'southwest', 'west', 'northwest']
	
	def direction_to_angle(direction: **str**):
	    return **str**(directions.index(direction) * 45)

printing the directions in the right format	**for** leg **in** directions_result[0]['legs']:
	    for step **in** leg['steps']:
	        if 'maneuver' **in** step:
	            print('Place place'
	                + **str**(leg['steps'].index(step))
	                + '(' + **str**(step['start_location']['lat'])
	                + ','
	                + **str**(step['start_location']['lng'])
	                + ');')
	            print('Direction direction'
	                + **str**(leg['steps'].index(step))
	                + '(place'
	                + **str**(leg['steps'].index(step))
	                + ', "'
	                + step['maneuver']
	                + '");')
	
	print('\n')
	
	for leg **in** directions_result[0]['legs']:
	    for step **in** leg['steps']:
	        print('directions.add(direction'
	            + **str**(leg['steps'].index(step))
	            + ');')

Arduino-code	
object 'Place' is made containing an x and a y coordinate	Class Place{public: **float** x; **float** y; Place(**int** _x, **int** _y):x(_x),y(_y){}};
object Direction is made containing a place and maneuver	Class Direction{public: Place place; String maneuver; Direction():place(0,0),maneuver(""){}};
Making a list of directions	LinkedList<Direction> directions;

Directing one vibrator to turn on	if (distance<50&&distance>10){
	 if (dir.maneuver=="turn-left"){
	 motorLEFT("double short");
	} else if(dir.maneuver=="turn-right"{
	 motorRIGHT("double short")}

compare current location to the ones in directions list	for (int i=0;i<directions.size();i++) {
	  dir=directions.get(i);
	  dist=TinyGPSPlus::distanceBetween(...)

Table 3: Key features and code