CHALMERS
UNIVERSITY OF TECHNOLOGY

Design of mechanism for Self-Driving Bikes

Bachelor's thesis in Mechatronics

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Cover: 3D-printed parts created in this project mounted on a bike

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Abstract

For cars with active safety systems, it is important that they reliably can pick up signals from the surrounding environment. The car's safety systems rely on sensors that are able to detect, locate and determine the direction of a bike. To test these systems a bike with self-driving capabilities was constructed. The bike has been modified with an add-on system of computer-controlled actuators and sensors to make it self-driving.

This report describes the design and build of a new mounting method to fix the add-on system on the bike with the purpose to make it easy to move the add-on system from one bike to another.

The results are seven 3D-printed components that are used to mount the add-on system. Tests confirm that the add-on system can be moved to a new bike with help of these 3D-printed components. However, the test also shows that one 3D-printed component needs a better way to be held in place when the bike is moving. How to solve this problem is discussed in the report.

Keywords: Portable, Add-on system, 3D-printing, Bicycle, Autonomous, Design, Self-driving, Module

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List of Acronyms and Abbreviations

GPS	Global positioning system
IMU	Inertial Measurement Unit
CAD	Computer Aided Design
STL	Standard Tessellation Language
PLA	Polylactic Acid
N/A	Not Applicable
Etc	Et Cetera
ABS	Acrylonitrile Butadiene Styrene

1 Introduction

1.1 Background

Self-driving cars, also known as autonomous vehicles, have become a hot topic and reality during the last decade.

In previous research projects [1] the Department of Electrical Engineering at Chalmers University has developed prototypes of self-driving bikes. These prototype bikes are able to drive and balance by themselves and make predefined turns/moves. The purpose of the bikes is to be used as test subjects upon testing and designing the car's safety systems for bike interactions. It is very important for the test bikes to be autonomous, as performing collision tests between cars and human-ridden bicycles are dangerous.

The basic regulator mechanism used in the prototype bikes is already developed. However, the add-on system and the modules it consists of are not compatible with different bikes than the prototype ones. Therefore, you’re not able to put the add-on system on a different bike and expect it to work. This report describes the designing, construction and validation of new mounting components and methods that would enable this.

1.2 Contributions

Seven 3D-printed components are designed, constructed, and tested. The seven components are made to enable and facilitate the movement of the modules, that the add-on system is composed of, between different bikes. The components are also designed to enable the modules to separate from the bike when enough force is applied in the case of an impact. The add-on system mounted on a bike will thereafter be used in self-driving vehicle safety system tests. By enabling and facilitating movement of modules between a variety of bikes, testing will be made easier and the mounting time for the entire add-on system will be reduced. Also, by making the modules within the add-on system able to separate from the bike the probability of them surviving increases in the case of a crash occurring during a test.
In short, the goals with the new components design are:

- Enabling the modules to easily separate when enough force is applied in the case of an impact
- Enabling the modules to be easily fitted to different adult bikes

1.3 Outline

In the second chapter, an overview and analysis of the bike and its existing modules are given. The analysis is performed with the objective to identify potential changes that can be made to the modules.

Chapter three documents the design of the new mounting components. It includes a short overview of CATIA-V5, and the mathematics used. The new design of the portable modules are explained.

Chapter four describes the Implementation of the mounting components that make up the portable add-on system. Since the components are 3D printed, a short section is dedicated to CURA, describing the 3D-printing process.

Chapter five is dedicated to the testing of the new portable components. It contains the test cases, the test results and comments about the results.

Chapter six includes a discussion of the results and potential future improvements. The chapter ends with a conclusion based on the report.

2 Analysis of the existing add-on system and potential changes

This chapter provides a general overview of the existing modules for the self-driving bike. An in-depth review and explanation of potential changes to key components within the modules are included. Figures and images of a bicycle and its parts are provided for a better understanding of the report.

To align the terminology used for the various bike components, the naming convention used in the figure below is applied.

Figure 1 – Bicycle and its components

2.1 Overview and analysis of the self-driving bike and its modules

The self-driving bike prototype, developed in the previous projects, consists of several components within modules that are added to a regular bike, thus making it autonomous. The components are:

- IMU, GPS and the steering motor controller, located in Electrical box 1, mounted on the top tube.
- Computer module, located in Electrical box 2, mounted on the down tube together with the battery.
- Pulse sensor and magnets mounted on the seatstay and spokes.
- Magnets, used to create the magnetic pulses, are fastened on the spokes of the back wheel.
- Steering motor, mounted on a platform attached to the head tube.
- A gear attached to the headset. The steering motor turns the stern through the gear.
- A timing belt, used to translate torque from the motor to the gear mounted on the headset.

The layout of the modules is showcased in Figure 2.

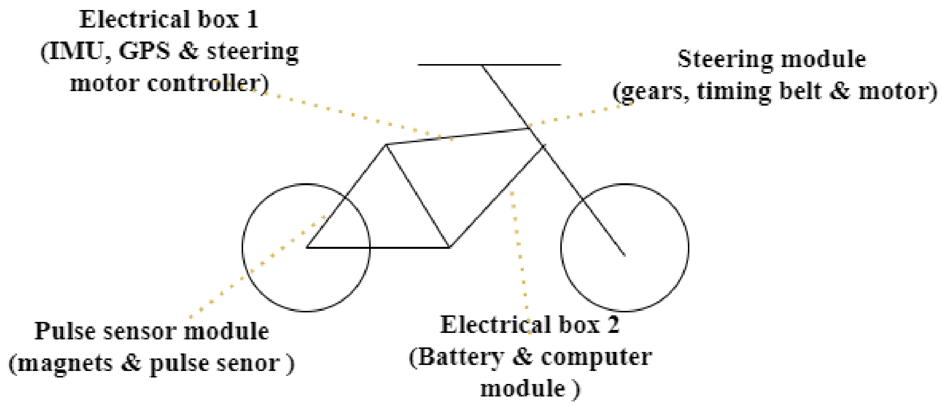

Figure 2 – Location scheme of the modules

2.1.1 Pulse sensor module

For this module to work it relies on a pulse sensor (reed switch sensor) mounted on the seatstay. The pulse sensor is connected to the box with the computer. The magnets are attached to the spokes, so when the wheel is spinning a pulse is picked up every time a magnet passes the sensor. The sensor sends the signal to the computer which by measuring the time interval between the pulses, calculates the speed of the bike. On the protype bikes the pulse sensor is glued to a small 3D printed component which is cable tied to the seatstay.

Analysis of the current module, with portability in mind, resulted in identifying an improvement area: the current module is not portable because every bike has a different distance between the spokes and the seatstay. When using the current module, the pulse sensor is in some cases too far away from the magnets to be able to pick up pulses. In other cases, the 3D printed component is too big and simply doesn't fit between the seatstay and the spokes.

The magnets are cable tied to the spokes. This solution only requires the wheel to have spokes to function and is therefore portable. Figure 3 shows the layout.

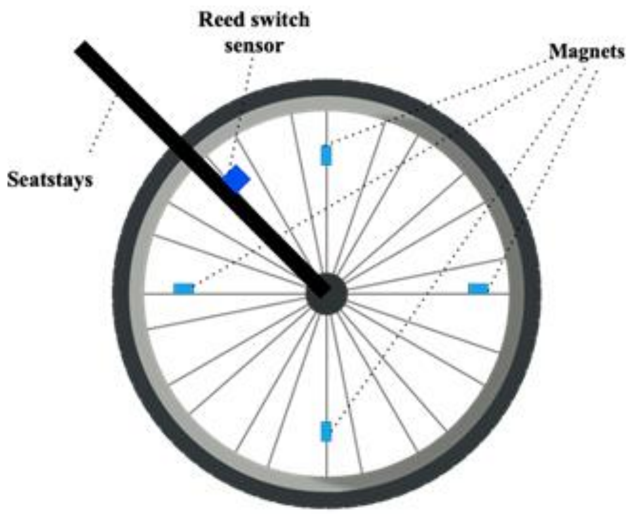

Figure 3 – Layout of the sensor and magnets on the wheel

2.1.2 Steering module

The steering module works by using two gears connected with a timing belt for torque conversion from the electrical motor to the headset of the bike, as seen in Figure 4. One gear is directly attached to the motor and the second gear is mounted and fastened in between the headset and the head tube of the bike. The motor can rotate in two directions depending on the current sent to it which enables the steering wheel to turn by rotating both clockwise and counter-clockwise. Having a belt for rotational conversion between the two gears has the advantage that the system remains fully functional in case a tooth breaks. Also, if the belt snaps, it is very easy to replace. Figure 4 shows the connection between the gears with the timing belt.

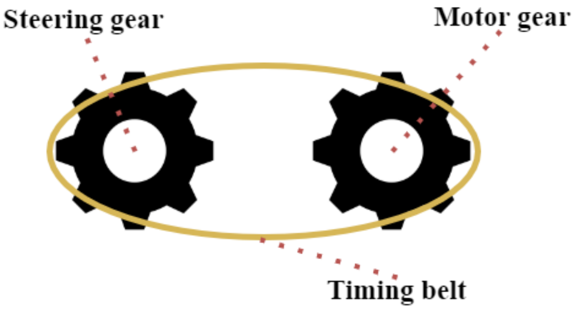

Figure 4 – Connection between gears with the help of the belt

The motor receives its functional parameters from the steering motor controller mounted inside Electrical box 1 and its energy supply comes from the battery inside Electrical box 2.

2.1.3 Electrical box 1

Electrical box 1 contains the IMU, GPS and the steering motor controller. The box is 3D printed and is specifically made for the bike used as a prototype. Therefore, the box can't be placed on any other bike than the prototype.

The layout of Electrical box 1 is shown in Figure 5. As seen in the figure, the box is divided by the top tube, which runs through the middle of the box, separating it into a left and right side for the components.

Analysis concluded that this module is not portable and needs to be improved so that the box can be mounted on any bike.

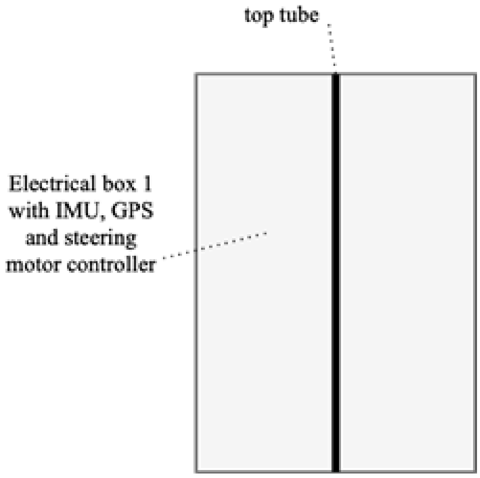

Figure 5 – Layout of box 1

2.1.4 Electrical box 2

Electrical box 2 contains two electrical components: the computer and the battery, which are placed as shown in Figure 6. The box is 3D printed, but it is mounted on a platform using clamps that are attached to the down tube.

The platform and its clamps are 3D printed and are not specifically made for the prototype bike. Therefore, it is considered portable. Unlike the module for box 1, the module for box 2 is not integrated into the bike. Instead, the module for box 2 is separated into two different elements, the platform and its clamps being one and the box the other. This module could be redesigned so that any kind of box could be attached to it but also making it possible for the box to detach when force is applied.

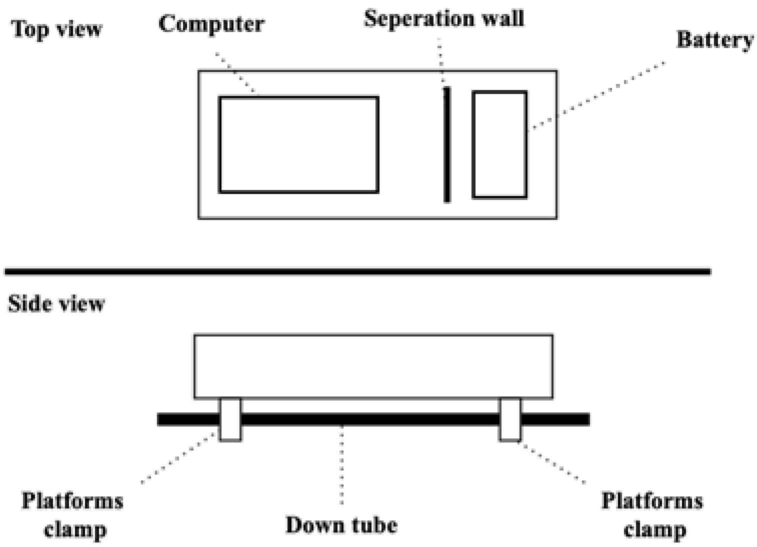

Figure 6 – Placement and layout of box 2

2.2 Potential changes and improvements to the mounting components

This section describes the potential improvements and design changes of the mounting modules. The design changes to the modules derive from the analysis and the predefined improvements areas which can be seen in previous chapters of report.

2.2.1 Changes to the pulse sensor module

The distance between the pulse sensor and the magnets is the most important factor for the pulse sensor module to function. In order for the module to function on different bikes the sensor distance to the spokes needs to be adjustable. This means that the component in the module that needs to be redesigned is the 3D printed component that the pulse sensor is glued to in the prototype bike. The new component should be universal and not bound to the distance between the seatstay and the spokes. This is why implementing a component where the distance between the sensor and magnets can be adjusted is most practical. This can be a platform that moves forward and backwards horizontally to achieve the perfect working distance. The idea is illustrated in figure 7.

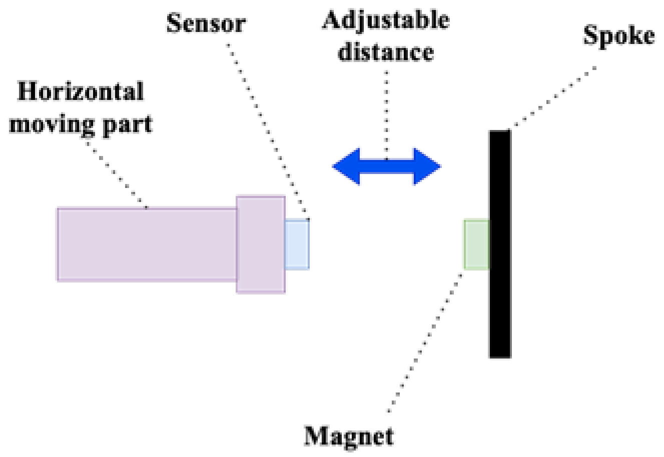

Figure 7 – Function of the distance regulating sensor case

2.2.2 Changes to the steering module

The main area of improvement to the steering module is making it portable without having to dismantle the headset/fork system of the bike. This will eliminate most of the steps in installing the steering motor and its gears, thus reducing the installation time too. Depending on the material the component is produced of it can be made cheaper in comparison to the gears used in the prototype bike.

The idea is to design a solution where the steering gear is separable. This allows direct mounting around the steering axis, as shown in the illustration below.

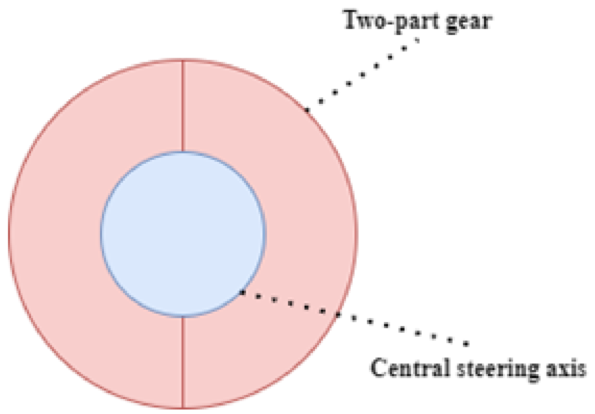

Figure 8 – Two-part separatable gear

Another area of improvement in the current module is that the platform, the motor is attached to, is welded to the bike. This makes the module for the platform non-portable. A solution to make it portable has already been applied in another version of a prototype bike. That solution uses two platforms: one that is connected to the motor and one that is mounted on the head tube. This solution has the disadvantage that it's complicated to mount/unmount and is hard to assemble.

The idea here is to replace the two platforms with a single solid component, which provides the optimal working distance, as in the prototype bike, but eliminates all mounting complexity.

2.2.3 Changes to electric box 1 and box 2

Having in mind the research only focuses on the mechanical solutions for the modules, any changes to the boxes and the electrical components contained inside them will not be done. Therefore, only the mounting aspects will be focused on and changed in order to achieve portability for the module. The idea here is to design a universal solution - a platform suitable for any bike and any box. The platform should also be designed in a way so that anything mounted on it can be detached when force is applied. The idea is illustrated in Figure 9, where a cross-section view is shown. The platform may use cable ties for attaching to the bicycle tubes.

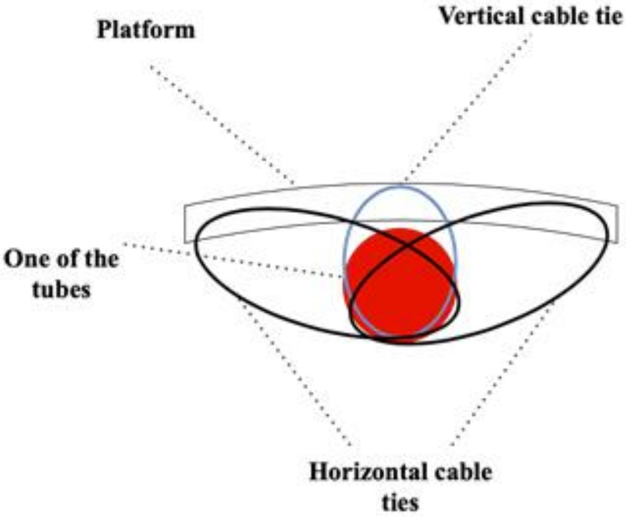

Figure 9 – Fastening method for the platforms

3 Design of the new components

This chapter describes the designing of the pulse sensor module, steering module and the platform module and the thought process behind the changes. The chapter also presents the problems during the designing phase and how they can be solved. An introduction to the CAD process and CATIA-V is presented so the steps in the designing process can be understood. CAD figures of the components will be presented here too.

Before the designing phase started a survey was conducted. The survey’s objective was to examine how much difference there was in measurement present between different bikes, which is illustrated in the chart below. The areas where measurements were performed can be seen in the illustration as well.

Name of the bike	Head tube measurement (cm)	Top tube measurement (cm)	Down tube measurement (cm)	Distance between the spokes and the seatstay (cm)
Tarfek Gent	15	11	14,5	5,5
Yokto Gent	14	10	14,5	5,5
Starren Alivio	15,5	11	14,5	6,3
Milli Lady	14,7	10	14,5	5,7
Karin Shi	14	10	11	5,7
Karin Lady She	13,5	10,5	10	5
Karin Lady She M	13,5	10,5	10	6,5
Monark Lady	16	15	N/A	6,5
Sjösala Mariedal Dam	13,5	11,5	11,5	6,3
Sjösala Amanda	13,5	11	11	6,5
Sjösala Isabelle	13,5	18	N/A	6,5
Ride by Crescent Dam	15,5	14	N/A	5

3.1.1 CAD in Catia-V5

Here a description of the CAD process in Catia-V5 is presented. This will give insight into how components are designed and created within Catia-V5. It will also help clarify the procedures described later in chapter 3.1.4.1, where the designing of a specific component is explained in detail.

The CAD process in Catia-V5 starts with sketching, in the sketching view where shapes and constraints are defined. There are many different constraints that can be set, such as; a defined length or angle or if lines should be in tangent or parallel to each other. When the sketch has proper constraints, the lines will light up green showing that the sketch is done correctly. After the sketch is done it can be “padded” in one or two directions to make the part go from a 2D sketch into a 3D solid. The CAD process continues with more sketches on the now existing solid features or elements on the solid. Another feature commonly used is “pocket”. A pocket removes material in contrast to the pad, which adds material. There’s an extensive list of tools that can be used in CATIA-V5, such as; “hole”, “mirror”, “fillets” etc., however, these were not broadly used throughout the designing phase. When the part is finished, it is converted to a STL file so it can later be used to 3D-print. More on this will be presented in chapter 4.

3.1.2 Designing the pulse sensor module

The analysis of the pulse sensor module, in the previous chapter, made it clear that an adjustment feature should be added to it. The new pulse sensor module therefore has a case component that allows the sensor to move horizontally with the help of two extension blocks as seen in the figure below.

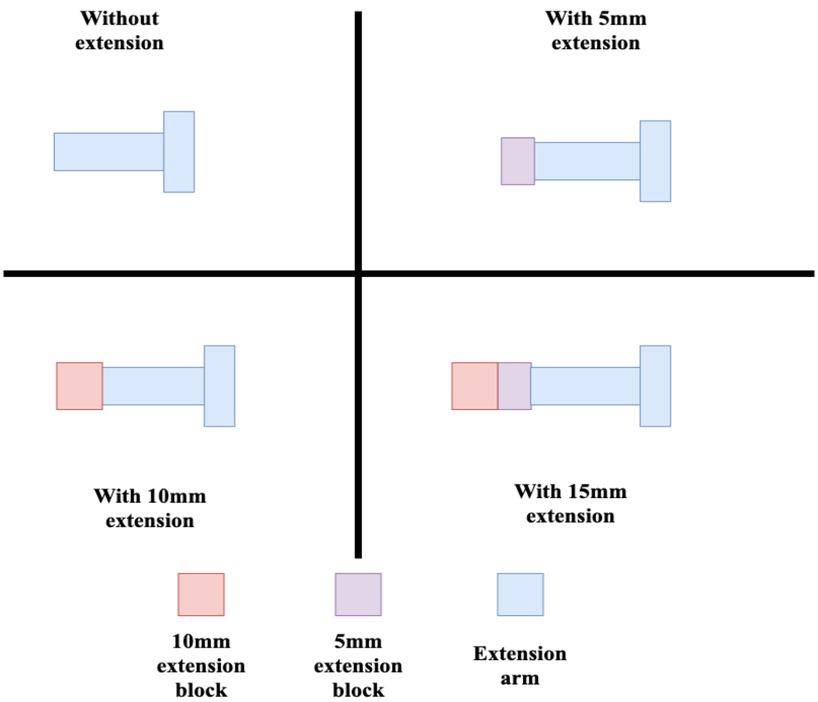

Figure 10 - Extension arm & Extension Blocks

With the new module the sensor can pick up pulses on any bike since the distance will be adjustable to match the optimal working distance regardless of the distance between the seatstay and the spokes. Having in mind the sensor’s working distance is 10mm, the extension blocks shown in figure 11 will allow the sensor to pick up pulses on bikes with any distance between seatstay and the spokes as can be estimated from the chart below.

Stages	Distance to seat stay from spoke	Maximum working distance
1. without any extension	41,6 mm	51,6 mm
2. with 5mm extension	46,6 mm	56,6 mm
3. with 10mm extension	51,6 mm	61,6 mm
4. with both extensions	56,6 mm	66,6 mm

With the two extension blocks shown in figure 10, the sensor now works on all the observed bikes in the survey. For the module to function it needs a case which can be attached and detached from the seatstay. The case should also be able to contain the two extension blocks as well as a component that the pulse sensor is mounted on. Cable ties will be used to attach the case in a similar manner to the extension component on the prototype bike

Instead of gluing the sensor to the extension component, as done on the protype bike to keep it stationary, the sensor will be attached to the case by either cable ties or two rubber bands. The component the sensor will be mounted on needs to be able to fit the sensor. The sensor's measurements are 20mm in length and 14mm in width [2]. The requirements on the case are therefore; being able to fit the extensions blocks and the component the sensor will be mounted on inside it as well as being able to attach and detach to the seatstay. The design of the module with all components mounted together is illustrated in figure 11 and 12. Each separate component can be seen in the appendix.

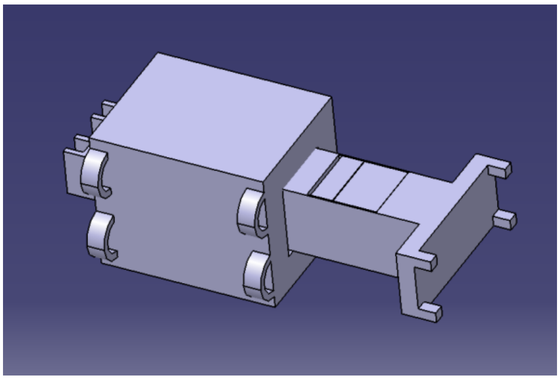

Figure 12 – CAD of case for speed sensor and associated parts, angle 1

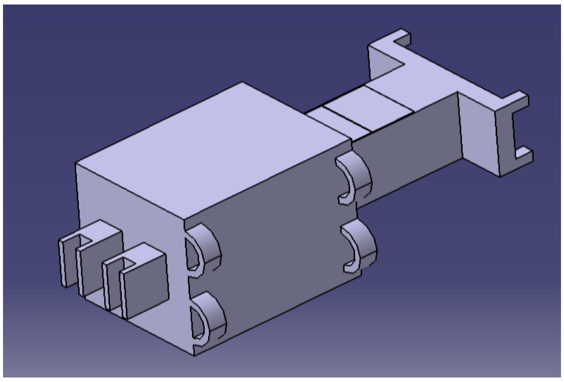

Figure 11 - CAD of case for speed sensor and associated parts, angle 2

3.1.3 Designing the platforms for the boxes

When designing the platforms for the boxes, simplicity was the main focus so if it breaks while being tested it could easily be 3D-printed without taking too much time. The platform needs to be designed so it allows the use of different boxes. This is because the type and dimensions of the box that will be used for the electrical components is unknown. There is still a need to set measurements on the platform so one can be 3D-printed and used for testing. The detaching mechanism will use velcro to function, when the bike is moving the velcro will hold the box to the platform and if enough force is applied to the bike the box is going to detach. The platform has a flat surface as can be seen in figure 13. This surface will be where the velcro is placed and the amount of velcro used will depend on the weight of the box.

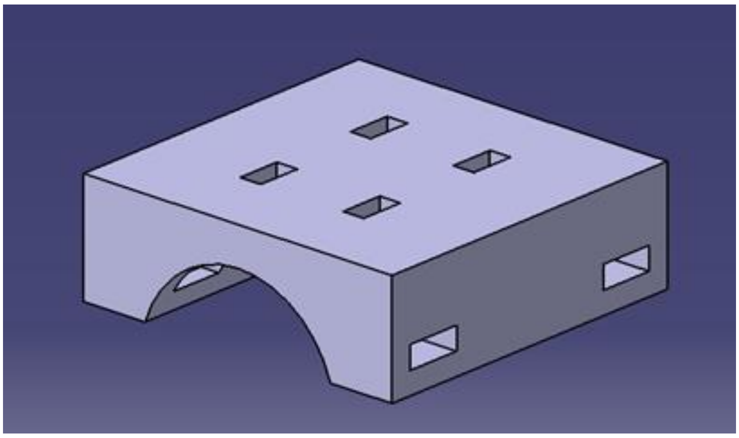

Figure 13 - CAD model of finalized platform

3.1.4 Designing the Steering module

The observation showed that different bikes have different measurements on the headtube. This means that if the gear should be able to turn the steering axis it needs a way to perfectly fit and transfer the torque. To cut down on the installation/mounting time and make it portable, the gear will be redesigned into a two-part system where the two parts come together similarly to puzzle pieces, as Figure 14 and Figure 15 showcases. Important factor when designing the gear is finding the correct formula/ratio for the teeth so it matches the already existing timing belt, which will be bought and not designed. More about this is presented in chapter 3.1.4.1.

The inner hole-circumference for the gear will be slightly oversized so it’s guaranteed to fit on any steering axis it is mounted on. For a smaller axis the gap will be filled with a thin silicon-rubber layer to make the binding force stronger. This will maximize the torque conversion as well as minimize the risk of slippage between the gear and the steering axis. This silicon-rubber layer will be separately bought instead of independently developed. The idea of using silicon-rubber as filament is already used when mounting bike accessories, this makes the module portable as well [3].

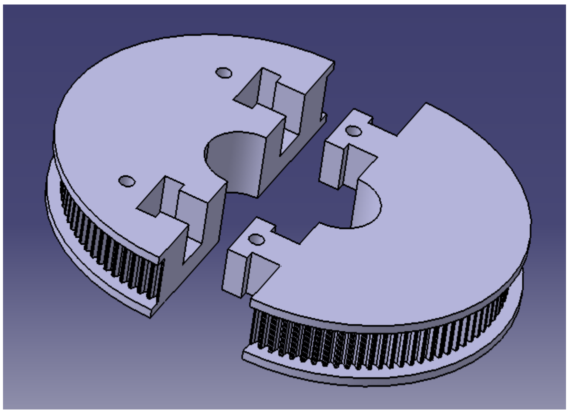

Figure 15 - CAD of two-part gear, disassembled

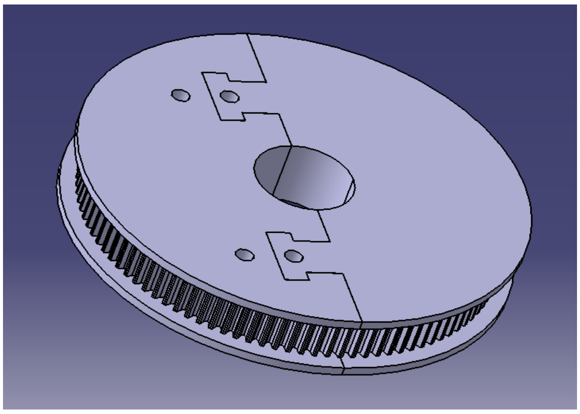

Figure 14 - CAD of two-part gear, assembled

When designing the extension platform for the steering motor, the platform for the boxes was used as a base. Similarly, to the platform used for the boxes the extension platform will be fastened to the bike with cable ties. The difference between them is that the platform used for the motor has an extension part where the motor will be placed on, as shown in Figure 16. This is necessary as the timing belt that connects the two gears has to be stretched enough for the torque to convert properly and with the maximum amount of efficiency. To design this component both the timing belt length and the circumference of the motor must be known so the exact measurement for the extension component can be determined. The motor will be attached to the extension platform using cable ties.

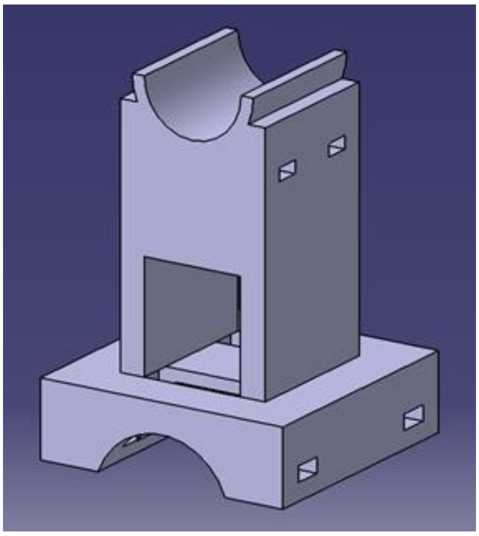

Figure 16 - CAD showcasing the extension platform

3.1.4.1 Calculating and designing the gear-teeth

This part of the research required reverse-engineering and creation of several spur gears with different individual teeth measurements, to achieve the best fit. This was necessary because the precise formula for the teeth is unknown. The only available predefined measurements were the tooth-pitch, tooth height and width of the timing belt. Important factors such as the different curvatures were completely unknown as this is something companies keep private. The measurements available for the HTD-standard timing pulley can be seen in the figure below.

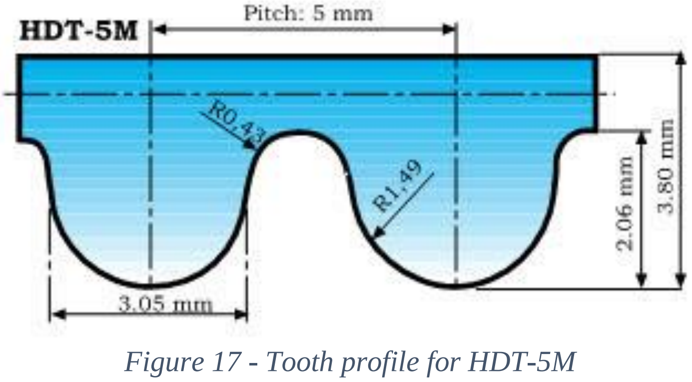

Figure 17 - Tooth profile for HDT-5M

A few guides, general formulas and tutorials were eventually found online on how to create a HTD standard timing pulley/gear which helped set the final dimensions for the teeth on the gear, which can be seen in the figure below

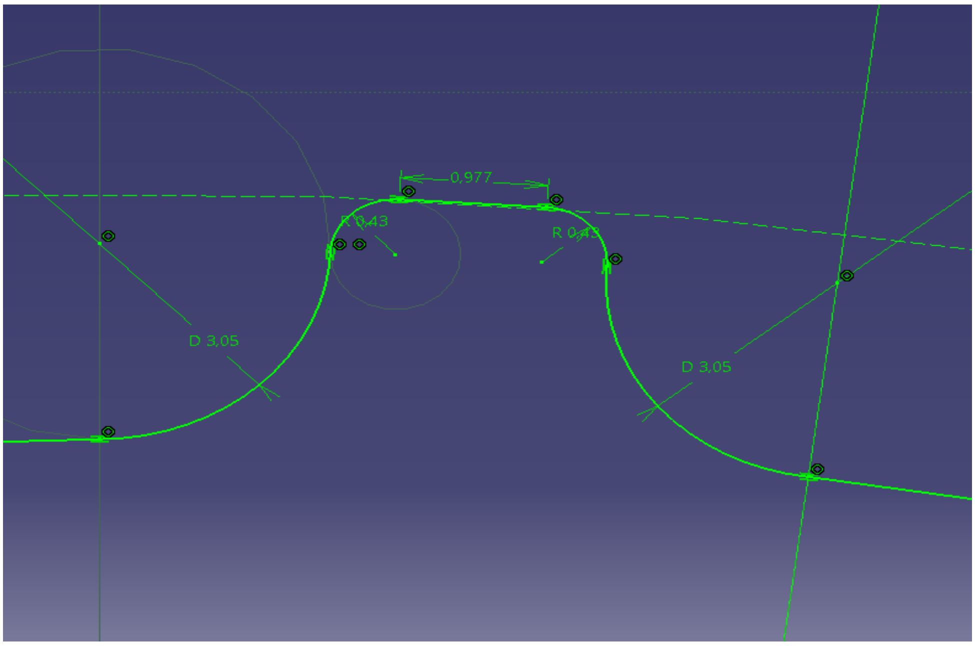

Figure 18 - Tooth profile for gear, in CATIA-V5

The concrete steps for reverse-engineering the teeth dimensions when you only have the measurements known from the figure 17 are:

- First determine the number of grooves that is needed (in this case its 50)
- The number of grooves is then the deciding factor for the outer diameter of the whole gear and it can be determined by using the calculator created by the user *Droftarts* on his parametric pulley page on *thingsverse.com* [4]. In this case the outer diameter measures to approximately 79,6mm.
- Next step is to determine the inner diameter of the pulley itself which is basically a 360° valley to valley measurement. The formula for calculating this is: **outer diameter - 2 * tooth height (mm),** which in this case measures to approximately 74,6mm.
- After this it's time to start forming the valley of the tooth profile. This is done by placing a smaller circle on top of the inner 74,6mm-circle. The diameter of the smaller circle is in this case be 3,05mm for the HTD 5M standard, as can be seen in Figure 17.
- The top arc is now formed by creating a small circle that is tangent to the outer 79,6mm circle and the smaller 3,05mm one. The diameter of this specific circle is 0,86mm.
- Next step will be to sketch the tooth pitch. For a timing pulley with 50 teeth there will be one tooth every 7,2 degrees (360/50 = 7,2). This means that the mirrored piece of the already designed part of the tooth will be 7,2 degrees to the side. Here you just need to repeat the above steps.
- All that's left at this step is to sketch out a line that follows the curvatures of the circles and then erase the remaining unneeded part of the circles. What's left after this is the exact profile of an individual tooth.

- Once the profile of the tooth is ready a tool is used to replicate all of the above steps and place them on the remaining spots around the timing pulley. The final product can be viewed in the picture below.

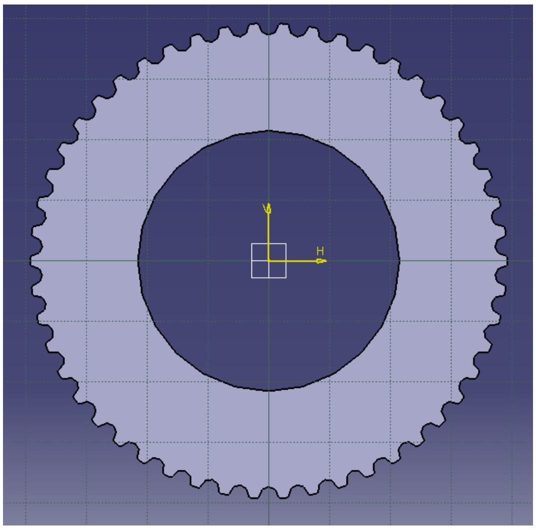

Figure 19 – CAD model of finalized gear

4 Implementation of the modules

This chapter presents the physical results that were obtained when implementing the ideas from the previous chapter. It also presents the parameters used to produce these components. The chapter starts with an introduction to the 3D-printing process and what factors and parameters are important for the overall function and structural integrity of the components being printed.

4.1 3D-printing

The Ultimaker 5 and Ultimaker 3-extended were the machines used to print the components and the software CURA was used to slice the CAD files from CATIA-V5. Slicing is a procedure that translates the CAD files to machine code, which allows them to be printed. Before printing there are parameters that need to be set in CURA. Some examples of these parameters are; how to orient the component so it is the most time efficient for the Ultimaker to print it. What material to use for the print and how much infill the components should have. 3D-printed components are virtually never made solid, instead there are different patterns printed inside them. This is called infill and the pattern used and how much of the component that is filled in can be determined in CURA. The materials for the filament used for the components are PLA and ABS which are the two most used materials when 3D-printing [5]. For choosing what kind of infill pattern suits each individual component the best recommendations from an external source are used [6].

There are also different printer cores to choose from when printing with an Ultimaker. The printer cores that are used for the components are AA 0.40mm and AA 0.25mm. The two letters show which filaments that the printer can use, and the numbers show the radius of the print core nozzle. For the components that require high precision, the AA 0.25mm nozzle is used, such as the steering gears. For the other components where the measurements do not need to be as precise AA 0.40 is used.

A comparison is made that illustrates the printing time difference when printing a component using both AA 0.25mm and the AA 0.40mm nozzle. As can be seen in the figures beneath it nearly takes AA 0.25mm four times longer to print the same component.

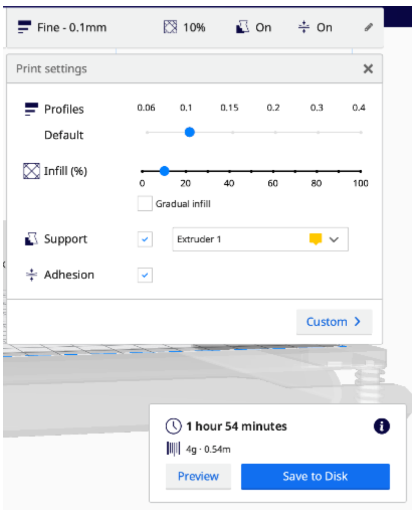

Figure 21 - Showcasing AA 0.25mm

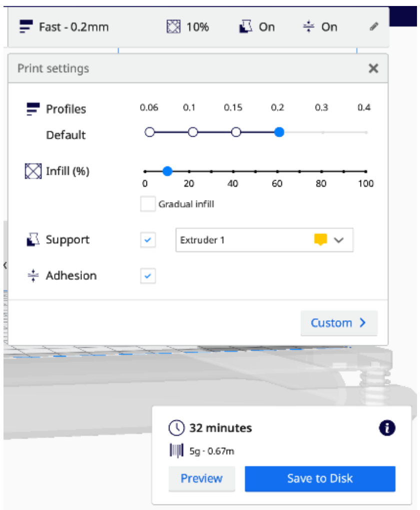

Figure 20 – Showcasing AA 0.40mm

4.2 Implementing the new pulse sensor module

The new pulse sensor module contains four new components. These are; the case, extension arm, short extension block and long extension block. Three generations of these components were produced. Each generation can be found in the appendix. The function of these components are presented below.

Components	Function
Case	• Holds the remaining components in place • Attaches to the seatstay
Extension arm	• Holds the sensor • Used for horizontal adjustments • Keeps the extension blocks inside it when they are not used
Extension block (short)	• Extends the sensor 5mm horizontally
Extension block (long)	• Extends the sensor 10mm horizontally

The specifications for the components in the third and last generation of the pulse sensor module are presented in the chart below.

Components	Material	Pattern type	Infill (%)	Nozzle (mm)
Case	PLA	Grid	40	AA 0.25
Extension arm	PLA	Grid	20	AA 0.25
Extension block (short)	PLA	Grid	10	AA 0.25
Extension block (long)	PLA	Grid	10	AA 0.25

4.3 Implementing the new steering module

The new steering module contains three new components. These are; Two gear components and one extension platform. The generations of these can be found in the appendix. The function of these components are presented below

Components	Function
Gear half (first)	• Interlocks with second gear half • Used for torque transfer • Attaches to the steering axis • Keeps the timing belt in place
Gear half (second)	• Interlocks with first gear half • Used for torque transfer • Attaches to the steering axis • Keeps the timing belt in place

Extension platform	• Holds the motor • Attaches to the head tube • Keeps the timing belt stretched

The specifications for the components in the last generation of the steering module are presented in the chart below.

Components	Material	Pattern type	Infill (%)	Nozzle (mm)
Gear half (first)	ABS	Cubic	70	AA 0.25
Gear half (second)	ABS	Cubic	70	AA 0.25
Extension platform	PLA	Grid	10	AA 0.40

4.4 Implementing the new platform module

The new platform module is a single component which is the platform. Two generations of the platform were produced, both can be found in the appendix. The function of this component is presented below.

Components	Function
Platform	• Holds the box • Attaches to down or top tube • Used to place velcro on

The specifications for the last generation of the platform are presented in the chart below.

Component	Material	Pattern type	Infill (%)	Nozzle (mm)
Platform	PLA	Grid	40	AA 0.40

5 Testing and Results

This chapter presents how the tests for the modules are performed and measured. The chapter also provides the test results and some comments. The chart beneath shows what is needed for the tests.

Tests	Equipment needed to perform the test
Test 1 - Pulse sensor functionality test	• 3D printed case • Magnets • Pulse sensor • Cable ties • Rubber band • Three bikes • Multimeter
Test 2 - Steering module Functionality Test	• 3D printed gear • Timing belt • Steering motor • Cable ties • Three bikes • double sided foam tape
Test 3 - Functionality Test of the Platform for the Boxes	• Platforms • Velcro • Cable ties • Box • Three bikes

5.1 Test descriptions and executions

This section describes tests, why they are performed and the objective of each one. It also describes what the desired outcome of each test is, so it is possible to determine whether the tests pass or not. The tests and their outcomes are presented in charts. Each test is performed on three different bikes to verify both the functionality and the portability of the add-on components.

5.1.1 Test 1 – Pulse sensor functionality test

Title: Pulse Sensor Functionality Test						
Test Objective: Determine whether the pulse sensor can pick up signals from the spinning magnets using the new case and extension blocks.						
Special Procedural Requirements: The test is performed on 3 different bikes with different seat stay dimensions.						
Test Execution: - Attach magnets and pulse sensor together with the new case and extension parts to the bike - Turn the bike upside down in order to let the wheel spin freely - Connect a multi-meter to the pulse sensor to read the resistance (Ohms) - Spin the wheel while measuring pulses						
Expected Result Each time a magnet passes the sensor, a pulse (low resistance) is picked up by the multi-meter						
Result (Bike 1):	Pass	X	Fail		N/A	
Result (Bike 2):	Pass	X	Fail		N/A	
Result (Bike 3):	Pass	X	Fail		N/A	
Comments: The test was successful on all three bikes.						

5.1.2 Test 2 – Steering module functionality test

Title: Steering Configuration Functionality Test						
TC Objective: - Determine if torque is successfully transferred between the gears, without any slippage, using the new prototype gear when the bike is stationary - Determine if the motor stays aligned with the help of the new platform throughout the torque conversion, while the bike is stationary						
Special Procedural Requirements: The test is performed on 3 different bikes with various head tube dimensions.						
TC Execution: - Remove the handlebars from the bike - Attach the new 3D printed gear to the steering axis - Attach the new platform to the head tube - Attach the motor together with the motor gear on the new platform - Place the timing belt between the gears - Reattach the handlebars back on the bike - Turn the handlebars and examine the conversion of torque and alignment						
Expected Result: - Torque is transferred as intended between the gears, without any slippage, when the handlebars are turned - Platform keeps the motor and gears in the right alignment throughout the test						
Result (Bike 1):	Pass	X	Fail		N/A	
Result (Bike 2):	Pass	X	Fail		N/A	
Result (Bike 3):	Pass	X	Fail		N/A	
Comments: The test was successful for all three bikes having in mind the test was performed while the bikes remained stationary. However, it was noted a misalignment occurred when the bike was moving and an attempt to turn the handlebars was made. This could lead to slippage.						

5.1.3 Test 3 -Functionality test of the platforms for the boxes

<table>
<tr><td colspan="7">Title: Functionality Test of the Platforms for the Boxes</td></tr>
<tr><td colspan="7">Test Objective:
- Determine whether the platform holds the boxes in place when the bike is in a moving state
- Determine if the boxes detach when force that simulates a crash is applied
- Determine if the platforms are placeable on the bike tubes</td></tr>
<tr><td colspan="7">Special Procedural Requirements:
The test is performed on 3 different bikes with different tube dimensions.</td></tr>
<tr><td colspan="7">Test Execution:
- Apply velcro on the box and the platform so they can be connected together
- Mount the platform on the bike
- Fill the box with weights to simulate the weight of the electrical components (1 kg)
- Place the box on the platform
- Move the bike around and examine if the box is held in place
- Apply direct force to the bike in the form of a push and examine if the box detaches as intended</td></tr>
<tr><td colspan="7">Expected Result
- The platform can be placed and stays on the tubes
- The box remains in place while the bike is in a moving state
- The box detaches when force is applied</td></tr>
<tr><td>Result (Bike 1):</td><td>Pass</td><td></td><td>Fail</td><td>X</td><td>N/A</td><td></td></tr>
<tr><td>Result (Bike 2):</td><td>Pass</td><td>X</td><td>Fail</td><td></td><td>N/A</td><td></td></tr>
<tr><td>Result (Bike 3):</td><td>Pass</td><td>X</td><td>Fail</td><td></td><td>N/A</td><td></td></tr>
<tr><td colspan="7">Comments: Test performed on bikes 2 & 3 (male bikes) were successful. Test on bike 1 (female bike) is deemed unsuccessful due the platform not being able to be mounted on the tube.</td></tr>
</table>

6 Discussion

In this chapter the final results of the project are discussed, and a few potential future improvements are suggested. A conclusion to the report is also included in the chapter.

6.1 Discussion of results

The whole add-on system was never tested together with all the modules installed and connected to the electrical components, at the same time. Instead, the functionality and practicality of all the modules was tested in separately designated tests. Thus, the self-driving capabilities which the add-on system aims to achieve can't be validated properly. Causes that contributed to this not being tested were things such as Covid-19 and the stop in the Suez Canal. These factors contributed to heavy delays in the flow of work. In retrospect meetings with the other groups working in parallel should have been planned as well. This would have facilitated the common aspects in the project making possible for each group to know what they will be working on. This would have also allowed for the groups to order parts together, saving time.

Another limitation the group suffered from was the limited knowledge concerning CAD and specifically CATIA-V5. If another group should continue the work presented in this report a suggestion would be to have an introduction to the software. This would allow for more complex and overall suitable components. However, more complexity would result in longer printing times and higher chances of failure when 3D-printing. This means balancing the complexity is key for future improvements.

6.2 Potential future improvements

Even though most of the tests were deemed successful there were still some potential changes that could be done to make the components easier/simpler to use or just to reduce the entire mounting time.

One of the components that could be changed are the platforms. With the current platform the cable ties are in the way for the velcro that connects the platforms to the boxes. A pocket could be implemented in the CAD sketch between the holes for the cable ties, so they are not in the way of each other. The figure below gives an understanding of how it would look.

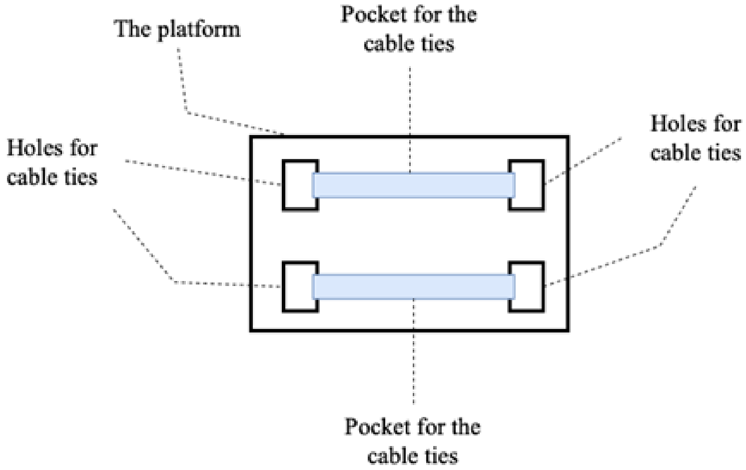

Figure 22 - Potential improvement to the platform

Another subject of improvement would be to change the zip-ties in certain key areas, such as the one regulating the vertical alignment of the motor and the one preventing the turning of the platform connected to the head tube, to something that allows more tension and harder fastening. It's suggested to replace the zip ties in these areas with steel hose clamps.

A further area of potential future improvement would be to eliminate the need to detach the whole handlebars and its associated parts when installing the timing belt, which connects the gears. From a mounting time point of view this would be favourable. However, a solution to this problem would drastically increase the complexity of the gear setup which is not preferable. A suggested solution would be to have some kind of leading elements on each side of the 3D-printed gear which the timing belt would travel along, see Figure 23. This would eliminate the need to detach the handlebars but would make the solution less sturdy/robust and raise the degree of complexity. This would require implementation of bearings and some kind of platform for the leading elements to stand on. Slippage between the gears and timing belt would likely be a problem in this case as well.

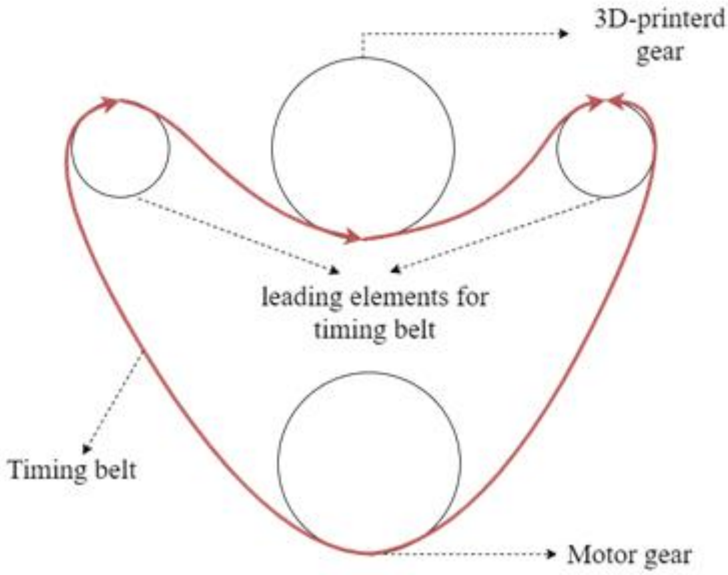

Figure 23 - Potential improvements to gear set up

6.3 Discussion of the tests and the final products

The conclusion that can be drawn are as follows:

- The tests performed on the components were mostly successful. However, a final test to validate the whole add-on system was never performed.
- Each module is portable on its own and functions.
- A solution in the platform module allows the electrical box to be detached when enough force is applied.
- The fastening methods in some areas could benefit from being changed to a solution which allows for more tension.

7 Bibliography

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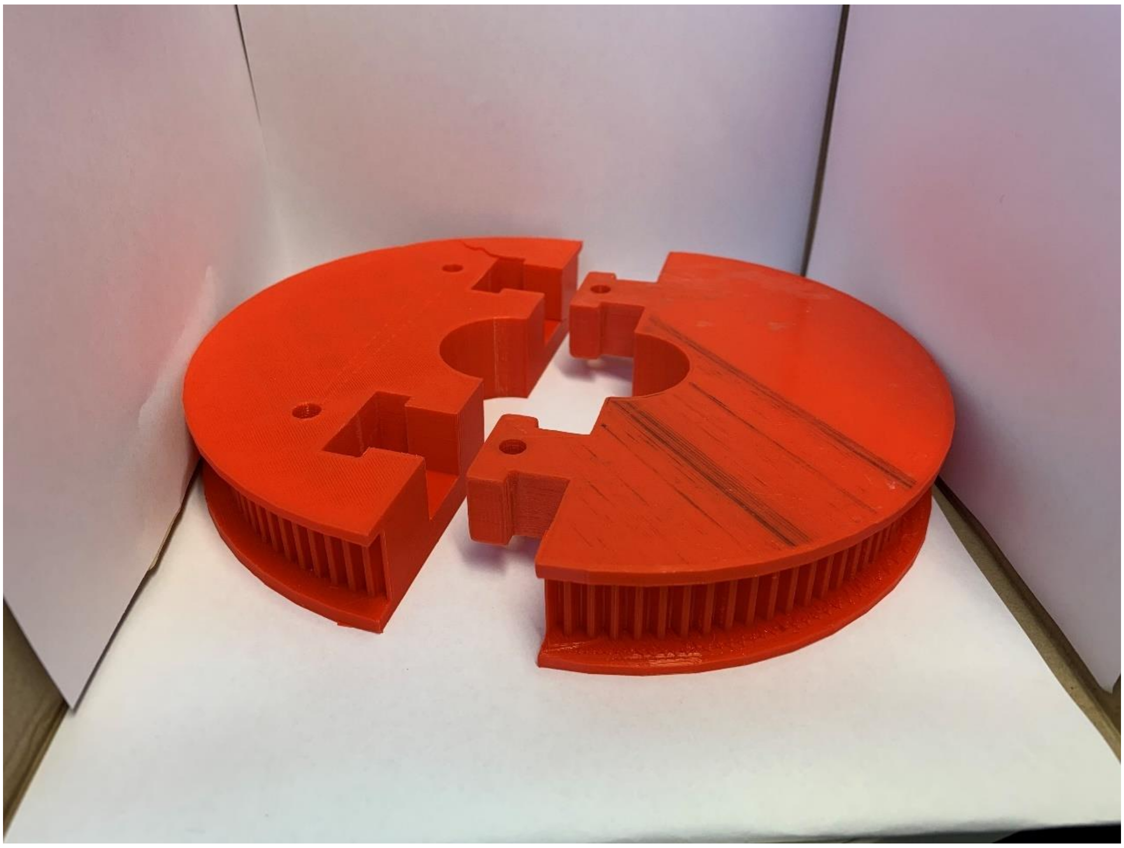
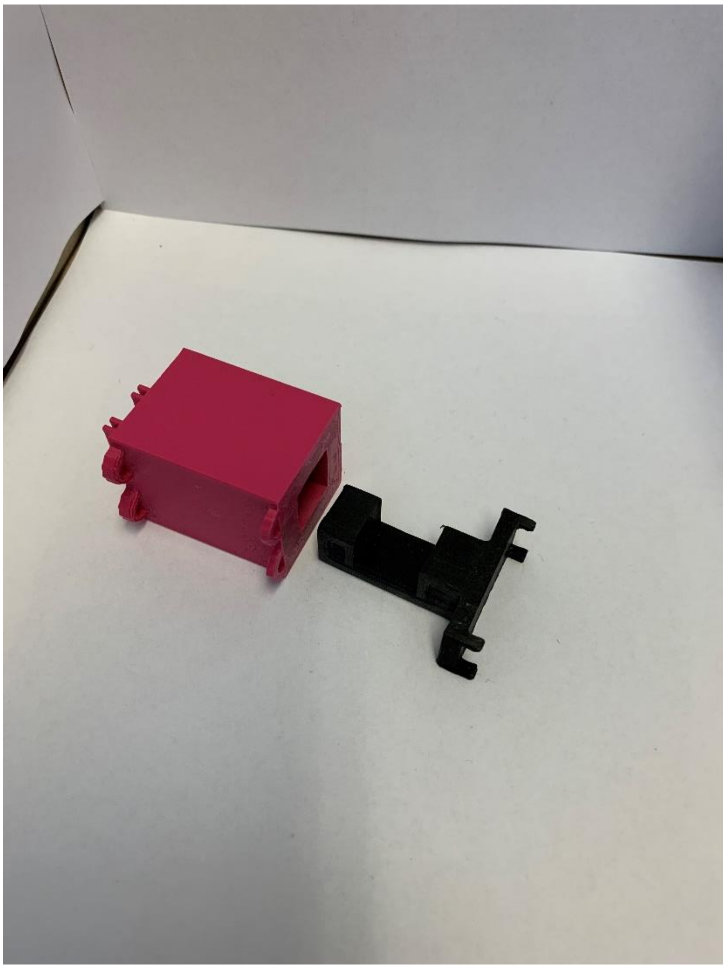
8 Appendix – Photos of final components

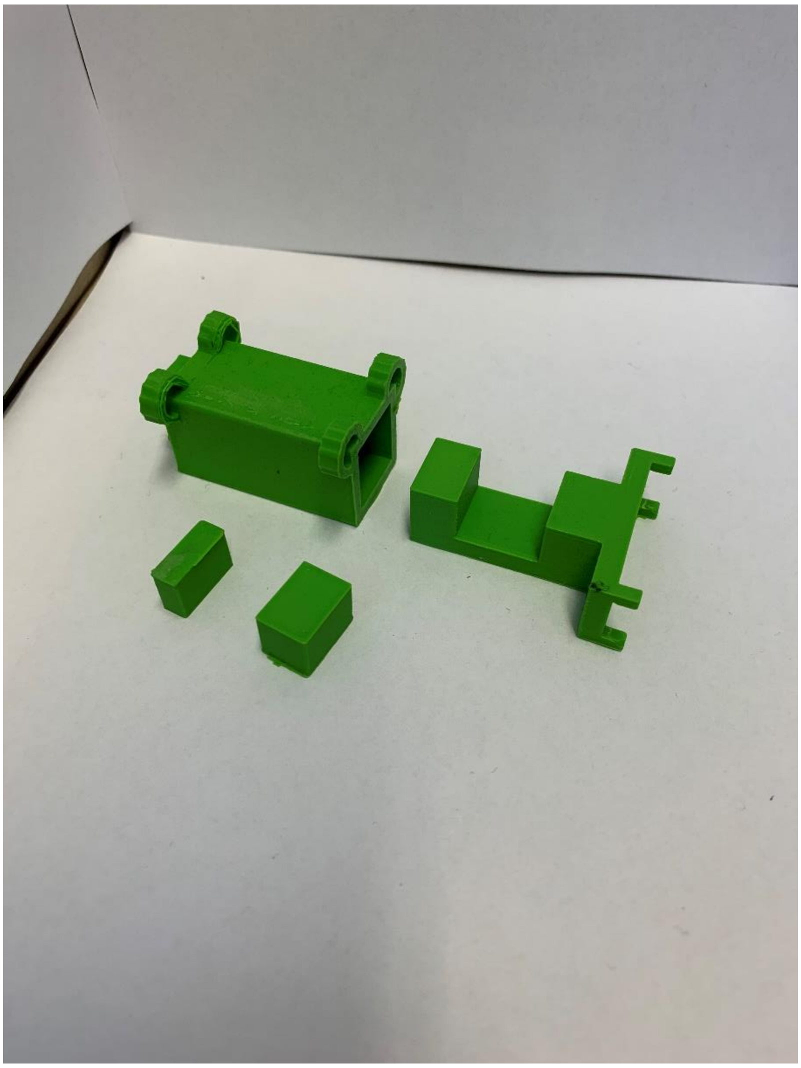
First prototype for the two-part gear



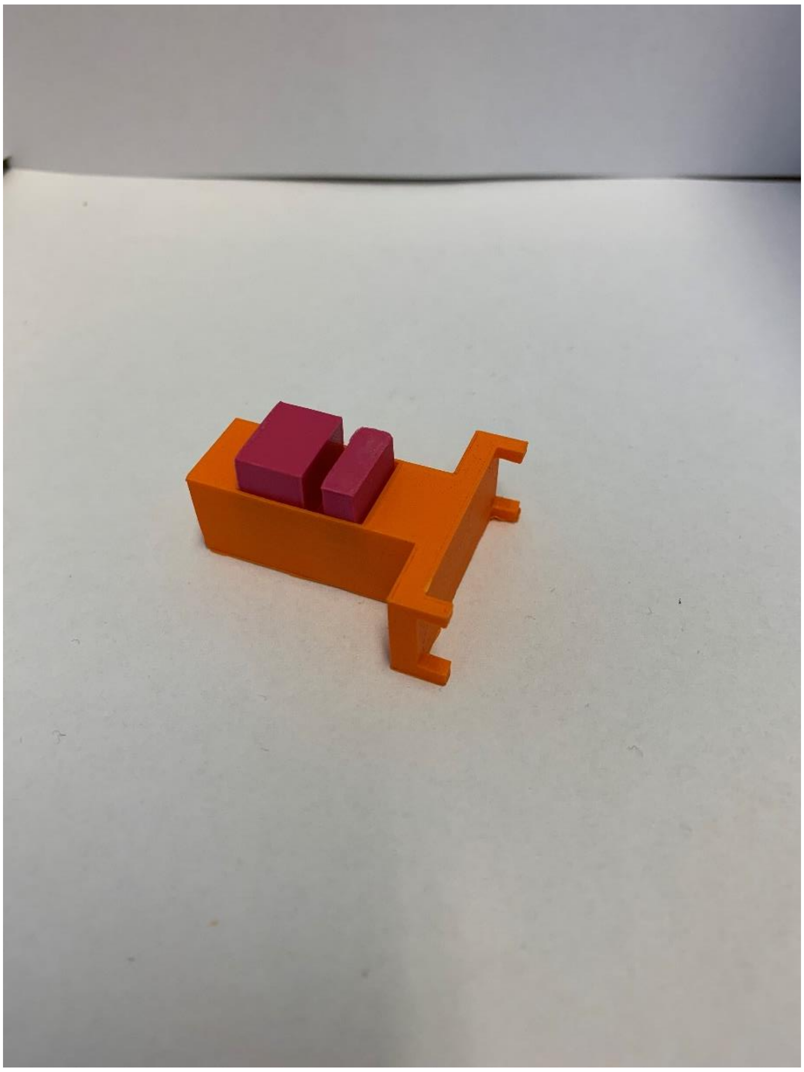
Different angle of the first two-part gear prototype



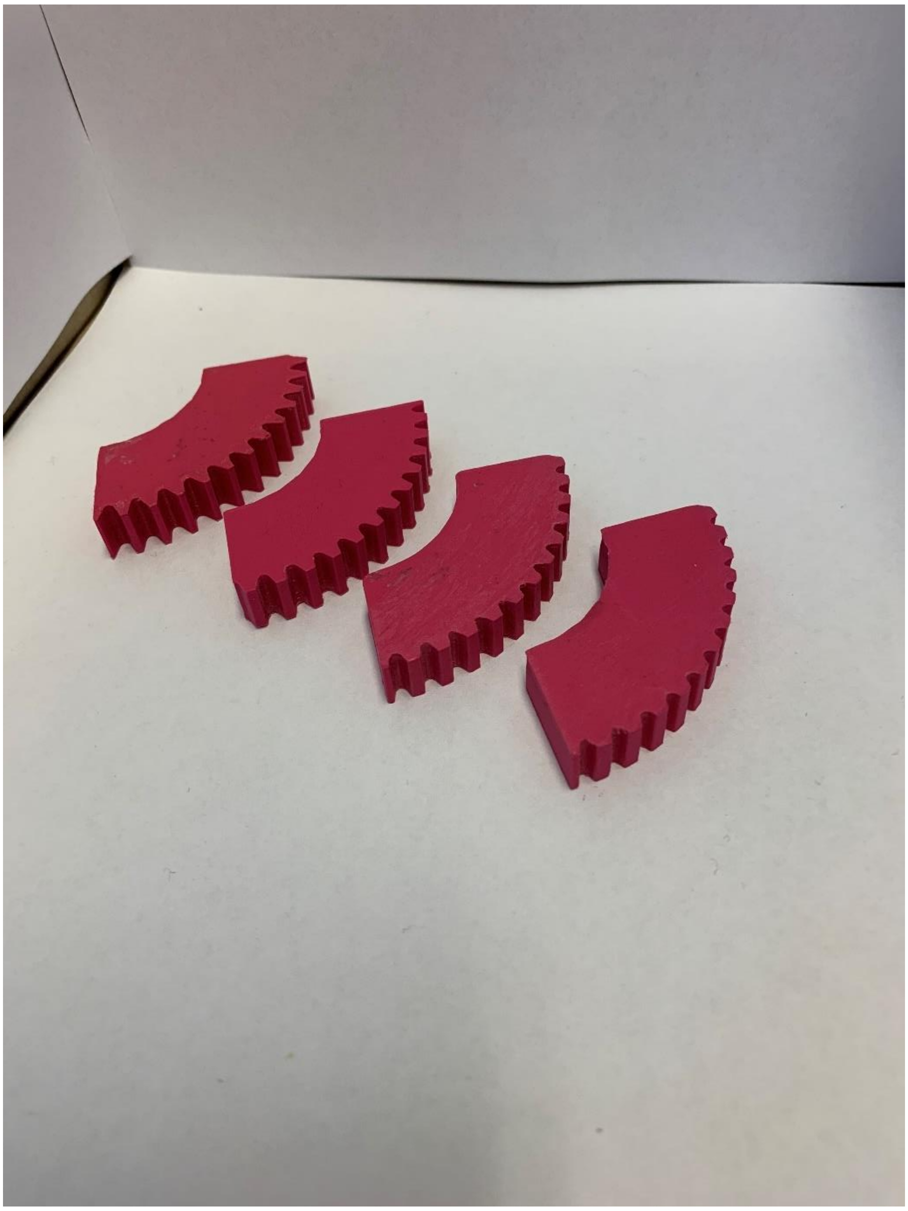
First generation of the speed sensor case and its associated parts



Second generation of the speed sensor case and its associated parts



Third and final generation of associated parts to the speed sensor case

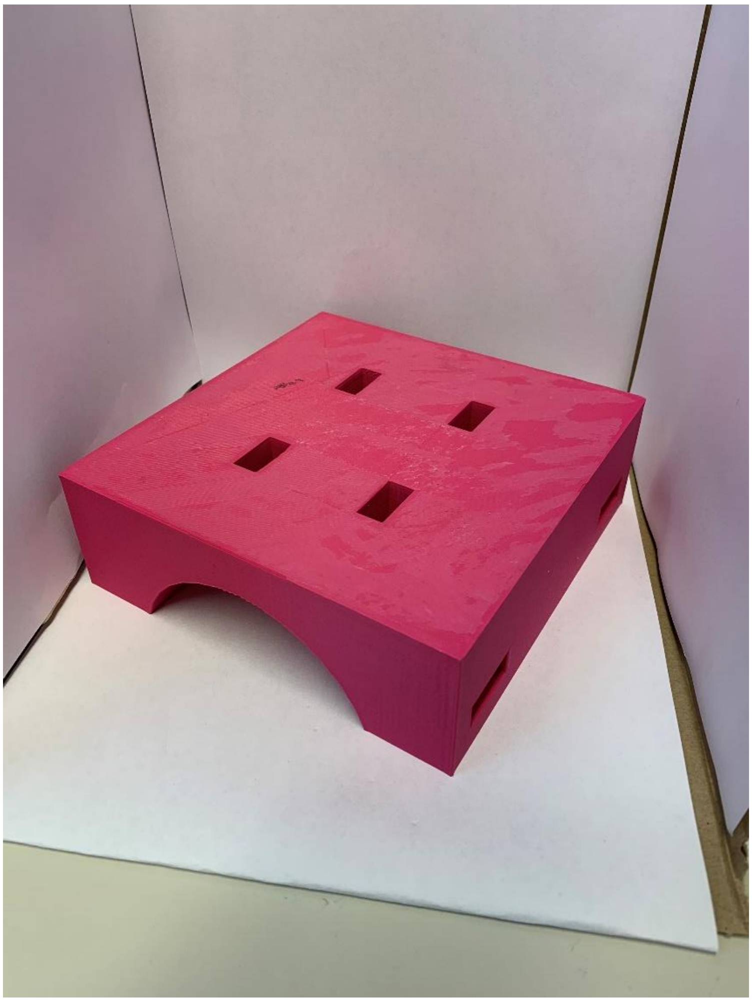


Quarter gear prototypes with different teeth dimensions

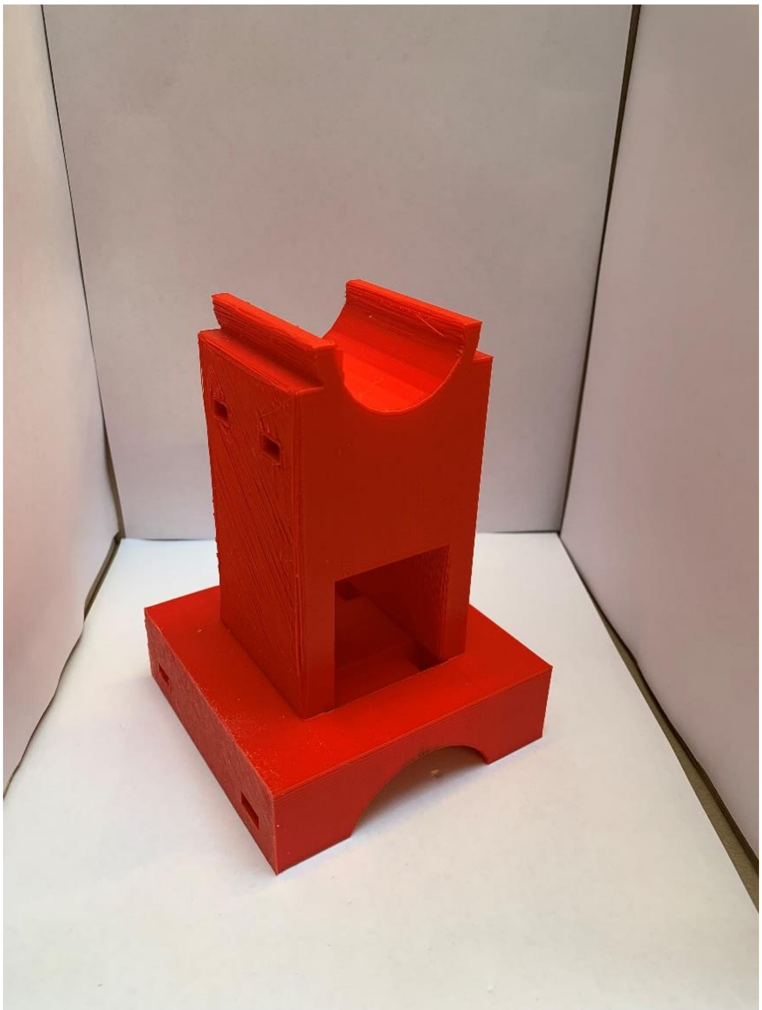
First successful gear prototype that matches the already existing timing belt

Final gear with integrated interlocking mechanism (separated)

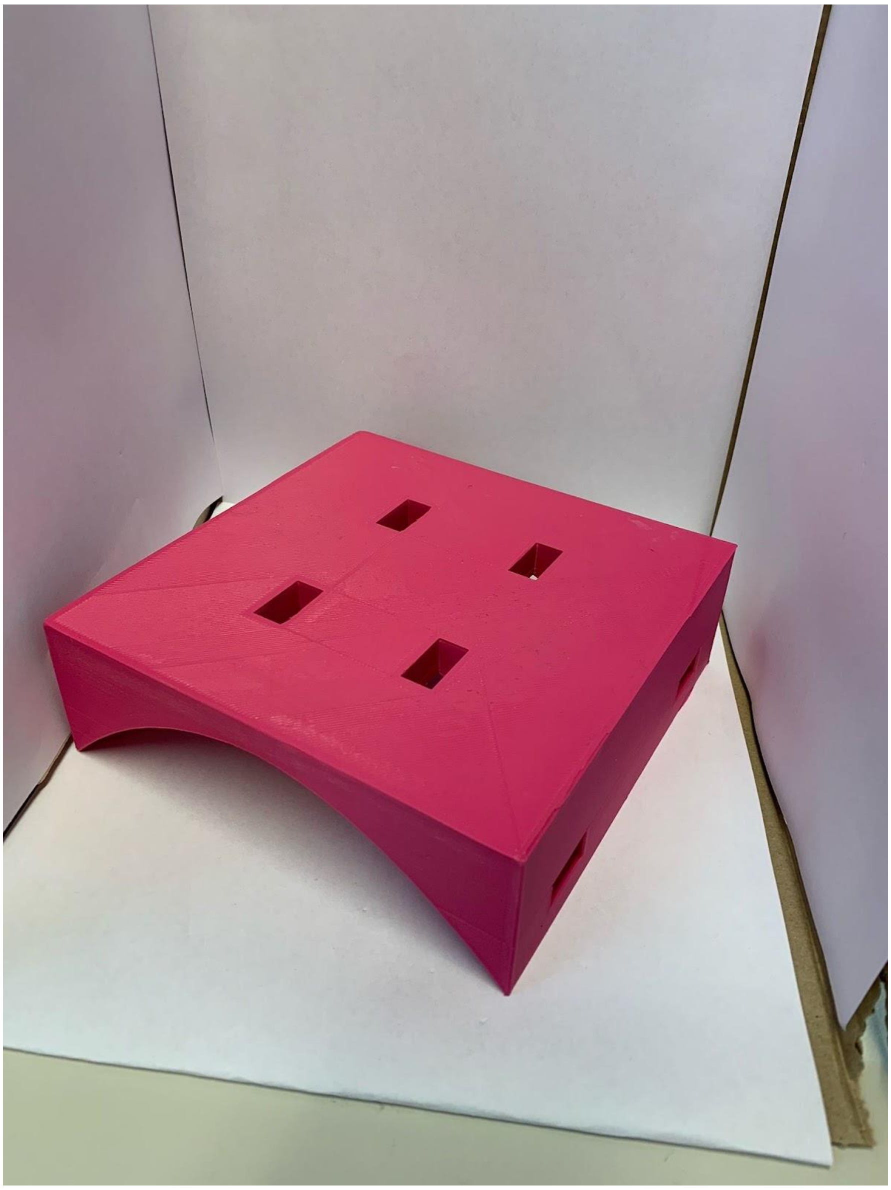
Final gear with integrated interlocking mechanism (interlocked)



Platform for boxes containing the electronics



Extension platform for the steering motor



First generation of the platform for boxes containing the electronics