Master Thesis

Prototype Development of a Handheld Speed Camera

for the attainment of the academic degree
Master of Mechanical Engineering
submitted by

Muhammad Haziq Bin Mohd Sabtu

Technische Hochschule Brandenburg
University of
Applied Sciences
Fachbereich
Technik

Technische Hochschule Brandenburg
Department of Technology
Studiengang Maschinenbau
Reviewer 1: Prof. Dr.-Ing. Christian Oertel
Reviewer 2: Prof. Dr.-Ing. Peter M. Flassig

Brandenburg, 1. Oktober 2023

I, Muhammad Haziq bin Mohd Sabtu, student in the Mechanical Engineering program of the Brandenburg University of Applied Sciences, declare in oath that this thesis has been written by myself and has not been written with other than the other than the indicated aids.

It has not yet been presented to an examination committee in this or a similar form.

Muhammad Haziq bin Mohd Sabtu

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Abstract

Abstract

Keywords: Keywords1, Keywords2, Keywords3

Abstract

Kurzfassung

Schlüsselwörter: Schlüsselwörter1, Schlüsselwörter2, Schlüsselwörter3

1 Introduction

Project Introduction

Part I

Prototype Development

1 Methodic Product Development

...some text on comparison of other methods such as hanser and rodenacker ...

In this research, the methodic product development process by Pahl and Beitz [?] is utilized. The methodic product development process is a systematic approach to product development. At the core of this methodology is the systematic progression through various stages, each with its own defined objectives and activities. These stages include problem definition, conceptual design, embodiment design, detail design, and finally, the testing and evaluation of the product.

2 Task Clarification and Specification

Task clarification and specification is a critical aspect of the product development process. It involves clearly defining and understanding the requirements and expectations associated with a particular task or project. This step aims to eliminate ambiguity and ensure that all stakeholders have a shared understanding of what needs to be accomplished.

This step involves identifying the specific goals, constraints, and deliverables associated with the task. By clarifying and specifying tasks, engineers and designers can establish a solid foundation for the subsequent stages of product development, enabling them to proceed with a clear direction and focus. In order to achieve this, the following questions must be answered:

- What is the objectives of the solution?
- What properties must the solution include and what properties must it avoid?

By answering these questions, the requirements of the solution can be identified and specified. These requirements will serve as the basis for the subsequent stages of the product development process. The result of this step is a list of requirements which include the demands, expectations, and constraints associated with the task. [Pah07i]

2.1 Establishing the Requirements of the Prototype

Establishing requirements in product development involves capturing and documenting the needs and expectations of stakeholders. Two important aspects to consider when establishing requirements are demands and wishes.

Demands are the essential and non-negotiable requirements that must be fulfilled for the product to be considered successful. They represent the core functionality and characteristics that the product must possess to meet its intended purpose and provide value to the users. Demands are typically based on objective criteria and are crucial for ensuring the product's basic functionality and compliance.

On the other hand, wishes represent the desirable but non-essential requirements or features that stakeholders would like to see in the product. Wishes often involve additional functionalities, aesthetics, or user experience enhancements that would provide added value or differentiate the product in the market. While wishes may not be mandatory, they can contribute to customer satisfaction, competitive advantage, and overall product excellence.

In addition, all of the requirements defined is possible must be quantifiable. This means that the requirements must be measurable and testable. This is important for ensuring that the requirements are met and that the product is able to fulfill its intended purpose. According to Pahl and Beitz, it may be useful to define the requirements in terms of the parameters defined in Figure **??**.

2.2 Requirements of the Prototype

In this section, the requirements of the prototype will be established. The requirements will be divided into two categories.

2.2.1 Geometry

When designing a prototype, ensuring proper geometry size is crucial to enable users to interact with the device effectively. The geometry size determines the physical dimensions and proportions of the prototype, which directly impact its usability and functionality. However, the size of the prototype is subject to certain limitations, primarily based on the available production capabilities.

In the case of our prototype, we are utilizing a 3D printing service provided by TH Brandenburg. This research will utilize the Original Prusa i3 MK3S+ with maximum available bed size of 210 mm x 210 mm x 250 mm [Pru]. This limitation influences the size constraints we can work within during the prototype development process.

To adhere to these limitations, we have set the geometry size of the prototype to be about 10% offset from the maximum available bed size. This offset ensures that the prototype fits comfortably within the printing dimensions provided by TH Brandenburg. Due to the aforementioned limitations and considerations, we have set the maximum geometry size for the prototype to be 190 mm x 190 mm x 250 mm.

2.2.2 Energy

The energy requirement for the prototype is a crucial aspect that directly influences its usability and convenience. It is specified that the prototype must have the capability to operate autonomously for a minimum duration of 1 hour with the provided power supply. This requirement serves to ensure that the prototype can function independently, providing a seamless user experience.

By being able to operate for at least 1 hour, the prototype demonstrates its ability to sustain a reasonable runtime without the need for frequent recharging or reliance on external power sources. This ensures that users can interact with the prototype for an extended period, allowing for more in-depth evaluation and testing of its functionality and features. It enables users to engage with the prototype in real-world scenarios, facilitating a comprehensive understanding of its capabilities and performance.

2.2.3 Forces

The requirement for forces in the prototype focuses on two key aspects: the ability to withstand the weight of its components and the limitation on the total mass of the prototype.

Firstly, it is essential to ensure that the prototype can properly support the weight of its components without compromising its structural integrity or functionality. This requirement serves to ensure that the prototype is robust and durable, capable of withstanding the forces exerted by its components. It also ensures that the prototype can be handled and operated without the risk of damage or failure.

In addition, there is a specific limitation on the total mass of the prototype, which should not exceed 2kg. This encompasses the combined weight of all internal components, including the predefined components and any additional materials incorporated during the design process. Adhering to this mass limitation ensures that the prototype remains lightweight and manageable while meeting the desired performance criteria.

2.2.4 Materials

In designing the prototype, it is essential to consider the specific materials and components that will be utilized. For this project, there are predefined components that must be incorporated to meet the requirements. These components include the Raspberry Pi 4B, a 7-inch touch screen, the Raspberry Pi Camera V2, and the Veektomx 10000mAh power bank.

The predefined components serve as key building blocks for the prototype's functionality and performance. The Raspberry Pi 4B, a versatile single-board computer, provides computing power and serves as the central control unit for the prototype. The 7-inch touch screen enhances user interaction by providing a responsive and intuitive interface for input and output.

The Raspberry Pi Camera V2 enables image and video capture, facilitating various applications within the prototype. Lastly, the Veektomx 10000mAh power bank offers a reliable power source, ensuring the prototype's uninterrupted operation.

2.2.5 Ergonomics

In terms of ergonomics, the prototype has specific requirements related to its size, weight, and user handling. Firstly, the prototype must be designed to be small and lightweight. This ensures that it is compact and portable, allowing for easy handling and maneuverability. By keeping the prototype's size and weight minimized, it enhances user comfort and convenience during interaction.

Additionally, an important aspect of the ergonomics requirement is that the user must be able to hold the prototype properly. This entails considering the shape, grip, and balance of the prototype to facilitate comfortable and secure handling. The design should accommodate the natural contours of the user's hand, ensuring a firm and ergonomic grip. By optimizing the prototype's form and considering user ergonomics, it can provide a seamless and user-friendly experience.

2.2.6 Production

The production requirement for the prototype focuses on the manufacturing process and the materials used. The prototype must be designed to be manufactured using 3D printing technology. This ensures that the prototype can be produced using the available resources and capabilities. In addition, the prototype must be designed to be manufactured using PLA filament. This material is readily available and offers a good balance of strength and flexibility, making it suitable for the prototype's requirements.

2.2.7 Operation

The operation requirement for the prototype encompasses two key aspects: the ability to be used freehand and the capability to integrate with a tripod for improved stability.

Firstly, the prototype must be designed to facilitate freehand operation. This means that users should be able to interact with and operate the prototype comfortably and conveniently without the need for additional support or mounting. The design should consider ergonomic factors such as grip, button placement, and user-friendly controls, ensuring that users can manipulate the prototype easily and intuitively.

Secondly, the prototype should be capable of integrating with a tripod for enhanced stability when necessary. This feature allows users to attach the prototype securely to a tripod, providing a stable and stationary setup. By integrating tripod compatibility, the prototype can cater to scenarios where steady and controlled operation or positioning is required, such as capturing images or conducting experiments that demand minimal movement.

2.2.8 Assembly

The assembly requirement for the prototype emphasizes the importance of considering the ease of assembly and disassembly of its components. This design consideration enables users to access the inner components easily, facilitating maintenance and repair tasks.

By designing the prototype with ease of assembly in mind, it becomes simpler for users to put the components together without requiring complex tools or specialized knowledge. This promotes user-friendliness and reduces the time and effort required for initial assembly or subsequent modifications. Similarly, easy disassembly allows users to access the internal components when needed, simplifying troubleshooting, repairs, or component replacements.

Additionally, if feasible, the parts of the prototype should be designed with swappable properties. This means that individual components or modules can be easily removed and replaced, without the need to disassemble the entire prototype. Swappable parts enhance modularity, flexibility, and cost-effectiveness, as users can upgrade or replace specific components as needed, rather than replacing the entire prototype.

2.2.9 Costs

The cost requirement for the prototype focuses on the total cost of production. The prototype must be designed to be manufactured within a budget of 100 euros excluding the cost of the predefined components. This budget encompasses the cost of all materials and components used in the production process. By adhering to this cost limitation, the prototype can be produced within the available resources and capabilities.

2.2.10 Schedules

The schedule requirement for the prototype focuses on the time required for production. The prototype must be designed to be manufactured within a time frame of 2 weeks. This time frame encompasses the entire production process, from design to assembly. By adhering to this schedule, the prototype can be produced within the available resources and capabilities.

2.2.11 Durability

The durability requirement for the prototype includes considerations for resistance to dust and water, if feasible. While it may not always be possible to achieve complete resistance, efforts should be made to enhance the prototype's durability in these aspects.

Regarding dust resistance, the prototype should be designed to minimize the ingress of dust particles into its internal components and sensitive areas. This involves employing appropriate seals, filters, or protective enclosures to prevent dust from adversely affecting the prototype's performance or functionality. By reducing the risk of dust accumulation, the prototype can maintain its optimal operation and extend its lifespan.

In terms of water resistance, if feasible and relevant to the intended use, the prototype should exhibit a level of protection against water ingress. This can involve incorporating waterproof or water-resistant materials, seals, or coatings to shield the internal components from moisture. Ensuring water resistance enhances the prototype's durability and enables usage in environments where exposure to water or humidity is likely.

2.3 Requirement List

Table 1 and Table 2 on the following pages show the requirements list which included the requirements described in this chapter.

3 Conceptual Design

Following the clarification of the task is the conceptual design, where in this section of the product development process, designers engage in creative exploration and evaluation of various design ideas and concepts.

Pahl and Beitz describe conceptual design as the phase of the design process where the essential problems are identified through abstraction, function structures are established, appropriate working principles are sought, and these elements are combined to form a working structure. This process lays down the foundation for the solution path by elaborating on a solution principle, ultimately specifying the principle solution. [Pah07e]

Figure **??** shows the steps involved in the conceptual design phase.

3.1 Abstraction

Traditional solution principles or designs may not provide optimal answers in the presence of new technologies, procedures, materials, and scientific discoveries. Preconceptions, conventions, and risk aversion often hinder unconventional but better and more cost-effective solutions. To overcome fixation on conventional ideas, designers utilize abstraction, focusing on the general and essential aspects rather than particular details. By formulating the task appropriately, the overall function and essential constraints become clear, enabling objective solution selection. [Pah07f]

To help in identification of the essential problems, following abstraction techniques are used:

- Step 1 - Eliminate personal preferences.
- Step 2 - Omit requirements that have no direct bearing on the function and the essential constraints.
- Step 3 - Transform quantitative into qualitative data and reduce them to essential statements.
- Step 4 - As far as it is purposeful, generalise the results of the previous step.
- Step 5 - Formulate the problem in solution-neutral terms. [Pah07g]

Figure ?? shows the result of the abstraction process.

3.2 Function Structures

In the design process, a function refers to a specific action or purpose that a product or system should fulfill. It captures the essence of what the product or system is intended to do, focusing on the desired outcomes rather than specific solutions or components. Functions serve as the building blocks of a design, providing a clear understanding of the overall purpose and functionality of the intended product or system.

The function structure is a graphical representation of the functions of a system and their interrelationships. It is a hierarchical representation of the functions of a system, starting with the overall function and breaking it down into sub-functions. The function structure is a useful tool for identifying the essential functions of a system and for identifying the relationships between the functions. [Pah07a]

Figure ?? shows the representation of the function structure and the process of breaking down the overall function into sub-functions.

3.2.1 Overall Function

Based on the result of abstraction, the overall function of the system can be represented and visualized using a function structure diagram. This diagram, as shown in Figure **??**, shows the overall function, which will be broken down into sub-functions in the next step.

3.2.2 Sub-Functions

Subsequently, after the abstraction process, the overall function is further decomposed into several sub-functions. This division is guided by the function structure, which represents the interconnections and dependencies between the functions. By analyzing the main flow of the system and considering the desired outcomes, the sub-functions are identified and organized within the function structure.

The purpose of this decomposition is to reduce the complexity of the overall system and facilitate the identification of suitable solution principles that can fulfill the required functions. By breaking down the main function into smaller, more manageable sub-functions, designers can focus on addressing specific aspects of the system's functionality and finding appropriate design solutions for each sub-function.

It is important to note that a simple and straightforward structure is desirable in the function structure. Such simplicity often leads to the development of uncomplicated and cost-effective systems. By keeping the structure of the function hierarchy straightforward and easy to understand, the design process can be streamlined, and potential complexities can be minimized.

3.3 Developing Working Principles

In the process of developing working structures, one crucial step is to search for working principles. Working principles refer to the physical effects and characteristics that fulfill specific functions of the structure being designed. These principles are combined to create the working structure, and they encompass both the physical processes and the form design features.

The search for working principles aims to generate several potential solution variants, creating what is known as a solution field. This can be achieved by varying the physical effects and form design features. Often, multiple physical effects are involved in fulfilling a single subfunction or even multiple function carriers. [Pah07h]

In developing working principles, there are multiple available methods in idea generation. These methods are categorized into three groups:

- Conventional methods
- Intuitive methods
- Discursive methods

Conventional methods involve a systematic and data-driven approach. Designers gather information from various sources, such as literature, trade publications, and competitor catalogs, to stay informed about advancements and best practices. They analyze natural systems and existing technical systems to draw inspiration and identify opportunities for improvement. Analogies are used to substitute analogous problems or systems, leading to fresh perspectives. Additionally, empirical studies, such as measurements and model tests, provide tangible data for validating designs and predicting real-world performance. [Pah07b]

On the other hand, intuitive methods tap into creativity and associative thinking. Brainstorming fosters a collaborative environment where diverse perspectives generate a wide range of ideas without judgment. Method 635 adds structure to brainstorming, allowing for systematic idea development within a group. The Gallery Method combines individual work with group discussions, using sketches or drawings to explore solution proposals visually. Synectics involves combining apparently unrelated concepts to trigger new and fruitful ideas. [Pah07c]

Discursive methods provide systematic step-by-step procedures influenced by intuition and creativity. They involve deliberate analysis of physical processes, leading to multiple solution variants derived from the relationships between variables. This approach fosters a deeper understanding of the problem space, encouraging the discovery of novel solutions while maintaining a level of systematic rigor, making them effective for communication and collaboration among design teams. [Pah07d]

3.3.1 Searching for Working Principles

To find working principles, the following methods discussed in Section 3.2 were applied:

methods . . . methods . . . methods . . .

text and images . . .

3.3.2 Selecting Working Principles

As can be seen in Figure **??**, multiple working principles were generated. Each of these working principles can be combined to form a working structure and hence a wide range of solutions are available. However, not all of these solutions are feasible and practical. The task of evaluating each of the solution will consumed a lot of time and resources.

It is necessary to reduce the vast number of theoretically possible but practically unachievable solutions as early as possible. However, caution should be exercised not to discard valuable working principles, as they often play a crucial role in forming a favorable and effective working structure when combined with others.

Although there is no entirely foolproof method, employing a systematic and verifiable selection process significantly simplifies the task of selecting promising solutions from numerous proposals. This selection process consists of two steps: elimination and preference. Initially, all clearly unsuitable proposals are removed. If a substantial number of solutions still remain, preference is given to those that stand out as markedly superior. Only these preferred solutions are evaluated during the final stages of the conceptual design phase.

Pahl and Beitz suggest the following criteria for eliminating unsuitable solutions:

- Compatible with the overall task (Criteria A)
- Fulfill demands of requirement list (Criteria B)
- Realisible in principle (Criteria C)
- Within permissible cost (Criteria D)

These criteria are applied step by step to examine each solution. If any of the exclusion criteria are not met, the solution is rejected, and further criteria are not assessed. Additionally to the exclusion criteria, the following preference criteria are used to prioritize the remaining solutions:

- Incorporates direct safety measures (Criteria E)
- Preferred by the designer (Criteria F)

Criteria E to F are then used to prioritize solutions if there are still too many options after the initial screening. The remarks column provides explanations for excluding or favoring each solution. The final assessment of the functional principles is recorded in the rightmost column of the selection list.

image . . .

3.4 Combination of Working Structures

In this step, the working principles are combined to form working structures. The combination process is done with the help of Morphological Chart. The Morphological Chart is a tool that allows designers to systematically combine working principles to form working structures. It is a matrix that lists the working principles in the rows and the sub-functions in the columns. It is also important to note that the working principles are now updated based on the result from the selection process in chapter **??**. In the following Figure 18, the developed Morphological Box is presented with the identified functional structures. Due to the high compatibility among the identified functional principles, numerous different functional structures can be formed.

3.5 Firming Up into Principle Solution Variants

DIRECT TRANSLATE !!

The understanding of the solutions resulting from the functional structures is still relatively abstract, and therefore, a selection or evaluation cannot be conducted yet. To increase the level of information, preferably quantitatively but at least qualitatively, sketches, simplified assumptions, visualization models, or preliminary experiments are utilized [Reference 25].

In this chapter, the identified functional structures are now specified into concrete solution variants and presented in accurately scaled hand sketches. The accompanying text provides a brief explanation of their operation, along with potential advantages and disadvantages. The information obtained serves as the basis for the subsequent selection process.

Due to the constraints related to the available space and the predetermined positioning of the packaging system, there are minimal geometric differences among the individual solution variants. Distinctions mainly pertain to the areas of "rotation," "conveyance," and "storage" of the bags.

3.5.1 Solution Variant 1

The first solution variant is based on the working structure shown in Figure 18. Solution Variant 1 features a tablet-like design with components (Raspberry Pi, Battery, Camera, and Screen) arranged in a manner similar to that of a tablet device. The screen orientation is landscape, providing a wider display view. The device is meant to be held with a body grip for convenient handling.

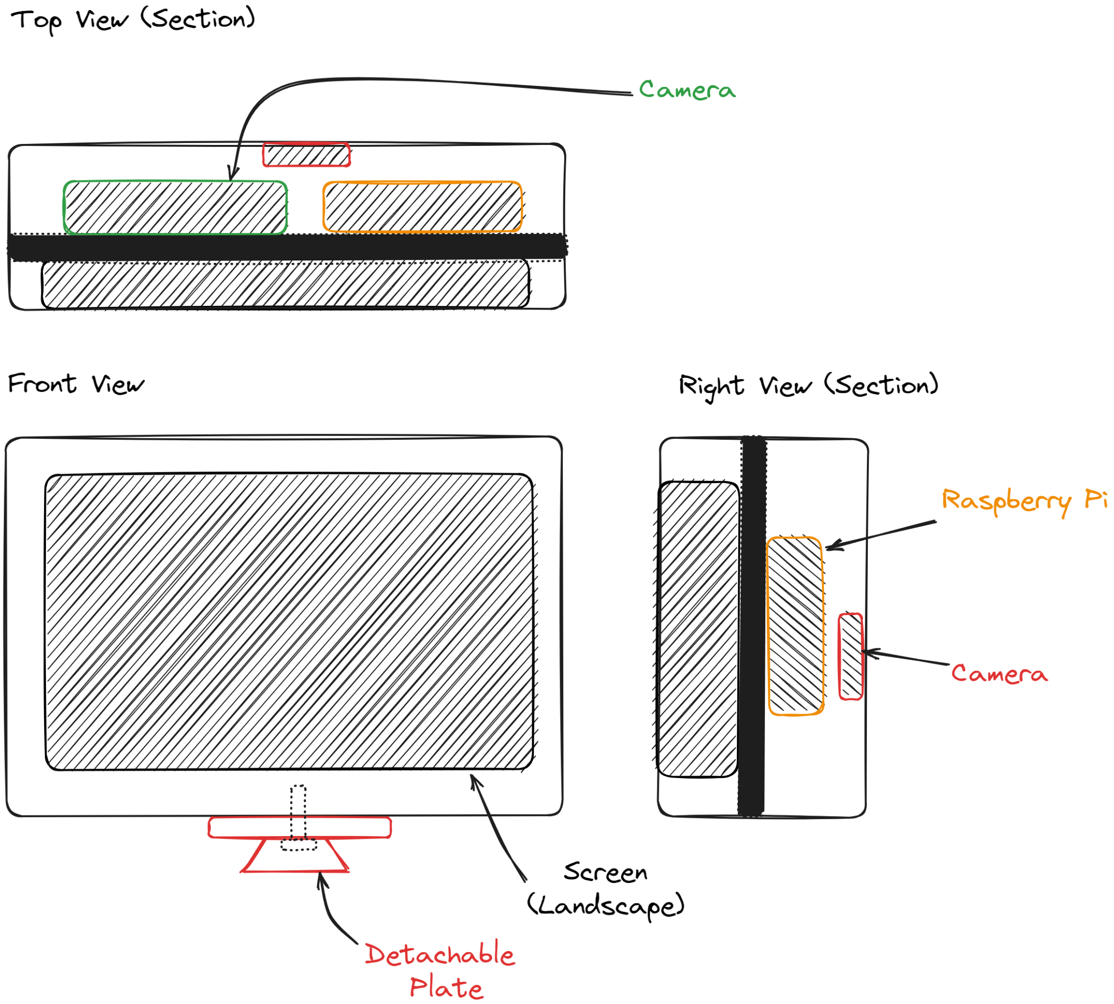

Figure 3.1: Sketch of Solution Variant 1

The battery is fixed inside the device, ensuring a seamless and integrated appearance. The chassis type follows a sandwich structure, comprising a top cover, main body, and bottom cover, providing a robust and secure enclosure for the internal components.

For mounting purposes, a detachable plate tripod system is utilized, allowing easy attachment and removal of the device from a tripod stand. The primary control mechanism is a touch screen, enabling intuitive and user-friendly interactions with the device's functionalities.

3.5.2 Solution Variant 2

Solution Variant 2 shares a tablet-like design with Solution Variant 1, with components (Raspberry Pi, Battery, Camera, and Screen) arranged in a manner similar to a tablet device. However, it also incorporates features of a handheld console.

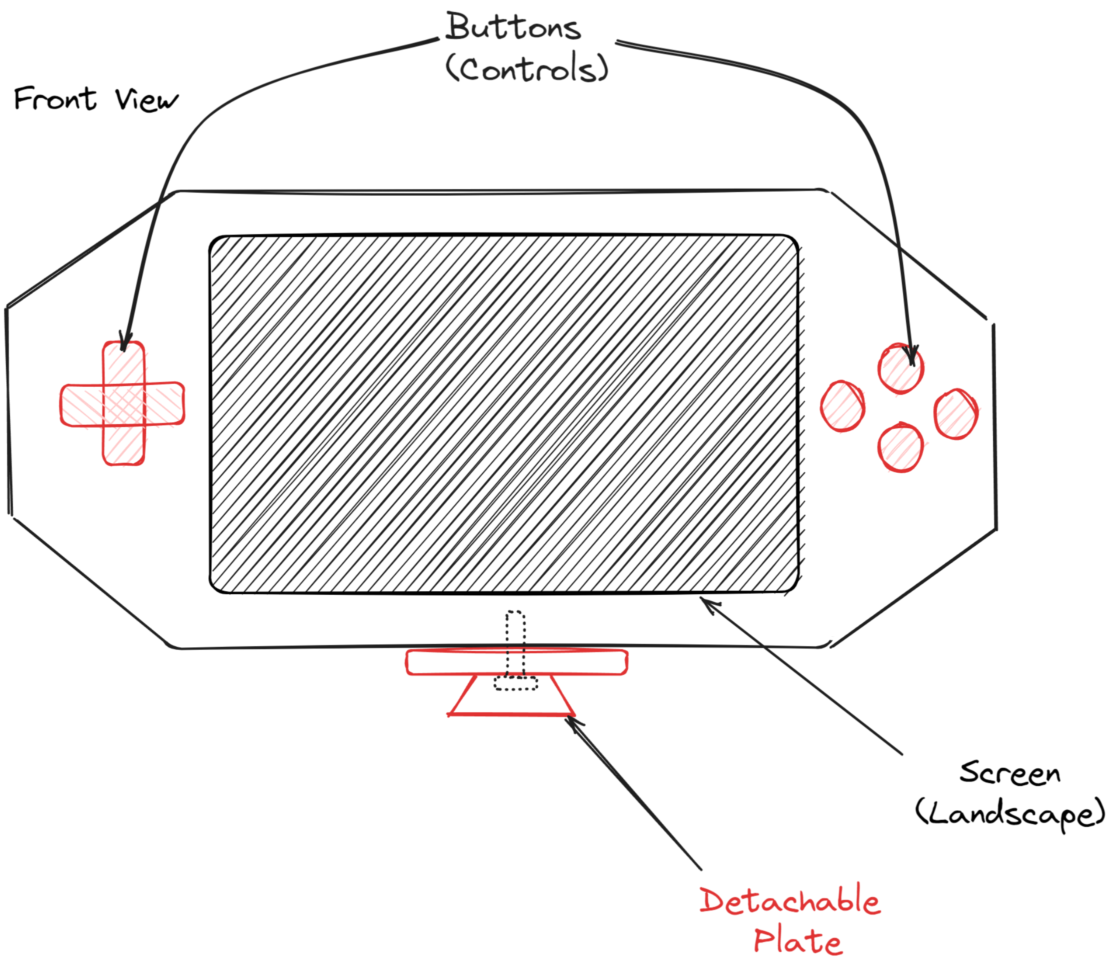

Figure 3.2: Sketch of Solution Variant 2

The screen orientation remains in landscape mode, providing a wide display view. The device is meant to be held with a body grip, allowing comfortable handling.

While the battery is fixed inside the device, in this variant, it employs a battery pack instead of a built-in battery, possibly allowing for easier replacement and extended usage periods.

The chassis type continues to follow a sandwich structure, comprising a top cover, main body, and bottom cover, ensuring a sturdy and secure enclosure for the internal components.

Similar to Solution Variant 1, a detachable plate tripod system is used for mounting, facilitating easy attachment and removal from a tripod stand.

However, the control mechanism in Solution Variant 2 offers an added feature. In addition to the touch screen, it incorporates physical buttons, providing users with multiple input options for interactions with the device. This combination of touch screen and buttons enhances versatility and usability in various scenarios.

3.5.3 Solution Variant 3

Solution Variant 3 maintains the tablet-like component placement, with the Raspberry Pi, Battery, Camera, and Screen arranged in a similar manner as the previous variants. However, a significant difference is the screen orientation, which is now in portrait mode instead of landscape.

With the portrait screen orientation, the device is designed to be held with a bump grip, offering a comfortable and secure way to handle the device in a vertical position.

Another change in this variant is the placement of the battery. Instead of being fixed inside the device, the battery is located externally. It is still in the form of a battery pack, but now positioned outside the main body.

Despite the changes, the chassis type remains a sandwich structure, comprising a top cover, main body, and bottom cover, ensuring robustness and protection

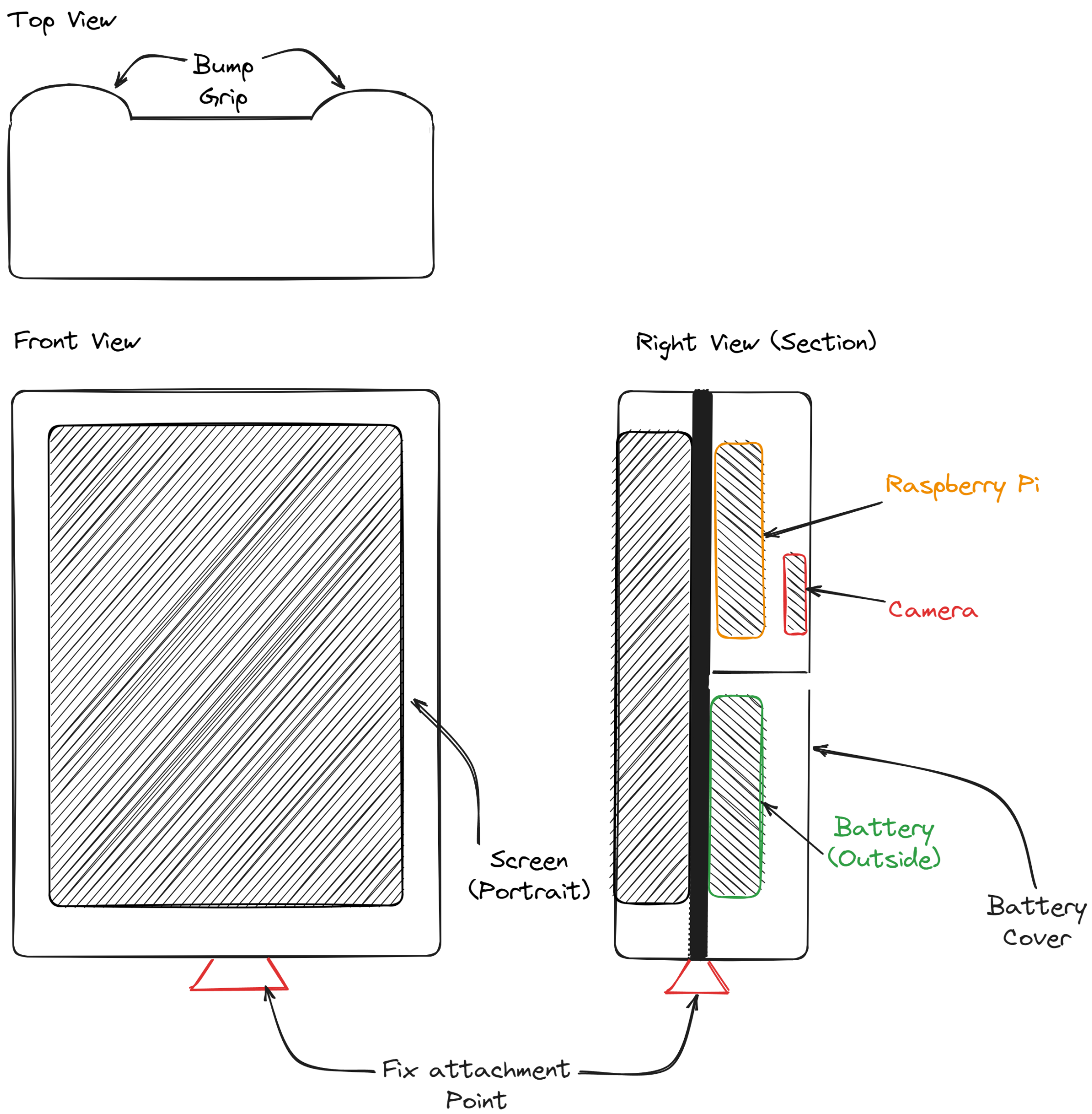

Figure 3.3: Sketch of Solution Variant 3

for the internal components.

The mounting tripod system remains unchanged, using a detachable plate for easy attachment and detachment from a tripod stand.

The control mechanism in Solution Variant 3 continues to be a touch screen, providing intuitive and user-friendly interactions with the device's functionalities.

One advantage of the portrait screen orientation is the increased stability of the components, as the center of gravity is now aligned at the center of the device. This alignment may offer better balance and control when using the device in various orientations, enhancing its usability and versatility.

3.5.4 Solution Variant 4

Solution Variant 4 also features a tablet-like design, with the Raspberry Pi, Battery, Camera, and Screen components placed similarly to the previous variants. The screen orientation remains in portrait mode.

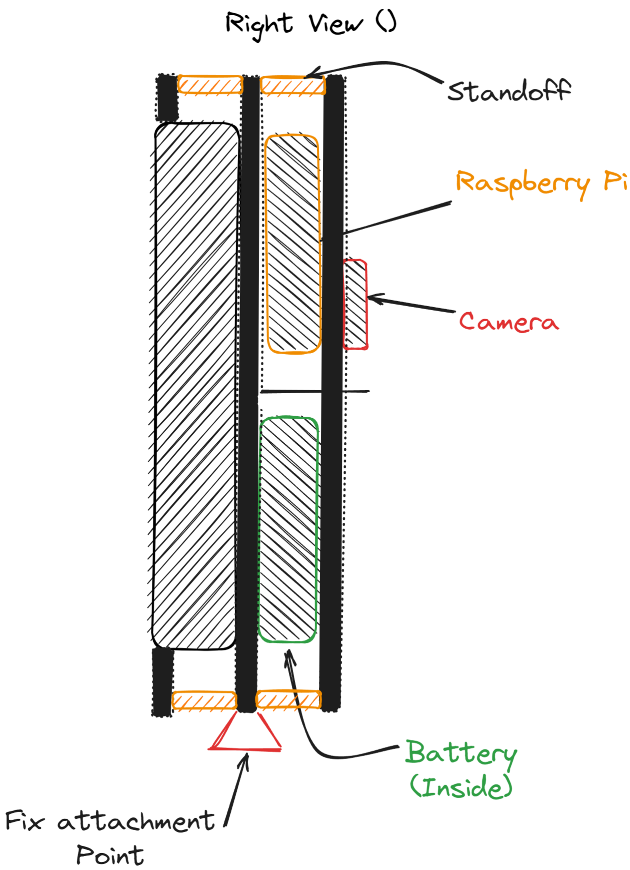

Figure 3.4: Sketch of Solution Variant 4

To ensure a secure and comfortable grip, the device is designed to be held with a bump grip, allowing users to handle it with ease.

In this variant, the battery is placed externally, and it takes the form of a power bank. This setup allows for convenient battery replacement or charging when needed.

The chassis type in Solution Variant 4 is different from the previous variants. It utilizes a skeleton design, with only the body layered and connected via standoffs. This lightweight and minimalistic chassis provides adequate support and protection for the internal components while reducing overall weight.

For mounting purposes, a fixed mounting plate is used, providing a stable attachment to a tripod stand.

The control mechanism remains consistent with the other variants, utilizing a touch screen for intuitive and user-friendly interactions with the device's functionalities.

3.5.5 Solution Variant 5

Solution Variant 5 introduces a different design approach with a Point of Service-like component placement. The Raspberry Pi, Battery, Camera, and Screen are arranged in a unique configuration where the screen is positioned at an angle, and the battery and Raspberry Pi are stacked on top of each other.

The screen orientation remains in portrait mode, providing a vertical display view.

For handling, the device is designed for a comfortable body grip, allowing users to securely hold and interact with the device.

In this variant, the battery is placed externally, and it utilizes AAA batteries with a battery holder. This setup offers the advantage of easy battery replacement and availability of standard batteries.

The chassis type follows a sandwich structure, consisting of a top cover, main body, and bottom cover, providing robustness and protection for the internal components.

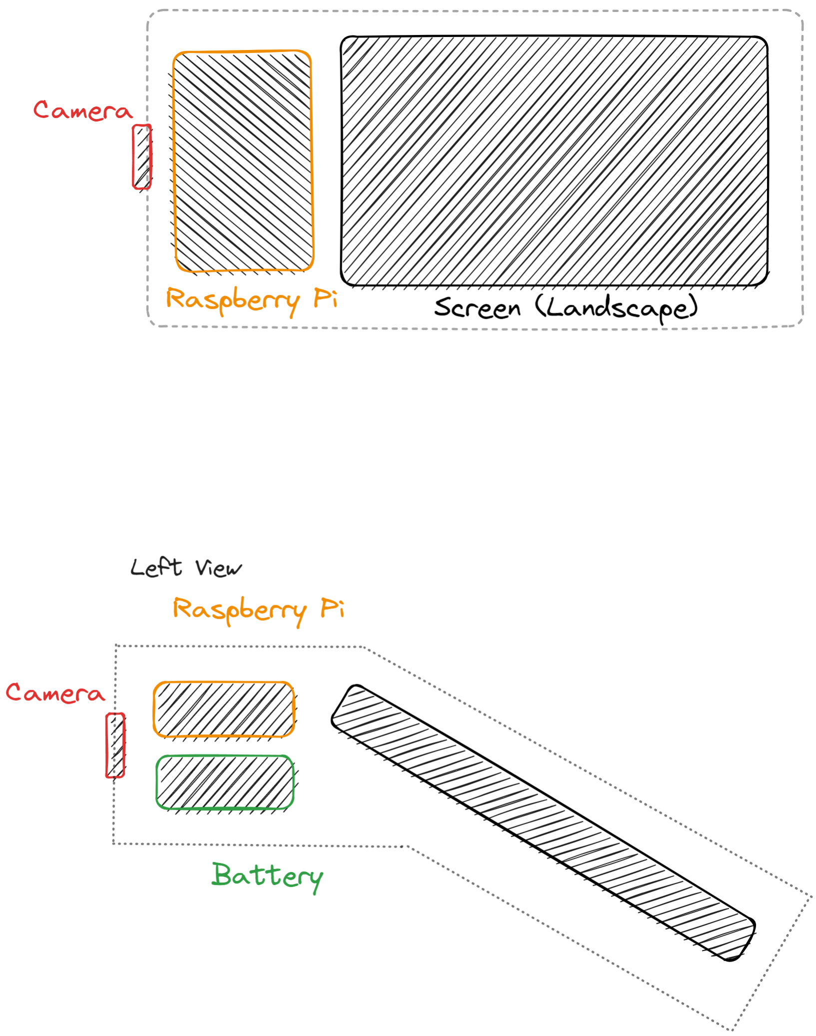

Figure 3.5: Sketch of Solution Variant 5

The mounting tripod system is detachable, enabling easy attachment and detachment from a tripod stand.

Similar to the other variants, the control mechanism uses a touch screen, ensuring an intuitive and user-friendly interface for operating the device.

3.5.6 Solution Variant 6

Solution Variant 6 features a Point of Service-like component placement, where the Raspberry Pi, Battery, Camera, and Screen are arranged with the screen positioned at an angle, and the battery and Raspberry Pi are stacked together.

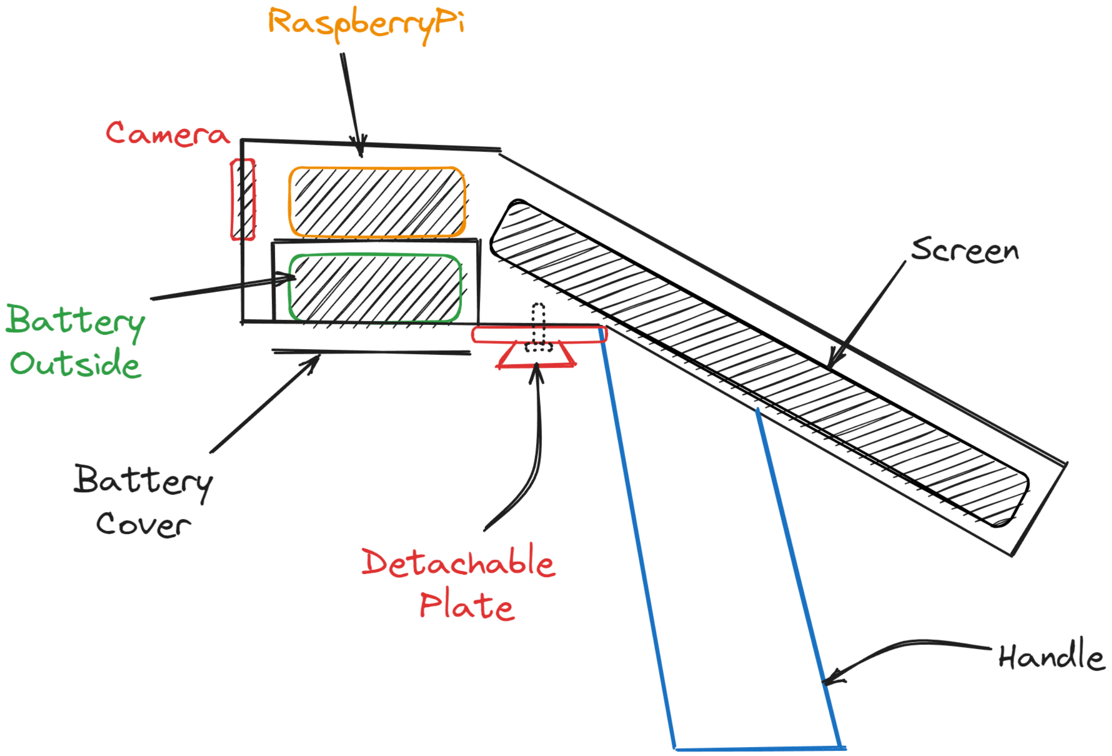

Figure 3.6: Sketch of Solution Variant 6

The screen orientation remains in portrait mode, providing a vertical display view.

For handling, the device is equipped with a pistol handle, allowing users to hold and operate it with a firm and ergonomic grip.

The battery is placed externally, and a power bank is used in this variant. This setup offers the convenience of easy battery replacement and ensures extended usage periods.

The chassis type in Solution Variant 6 adopts a bowl-like design, with a main body where all components are attached, and a top cover provides protection and encloses the setup securely.

The mounting tripod system is detachable, facilitating easy attachment and detachment from a tripod stand.

As with the other variants, the control mechanism relies on a touch screen, offering an intuitive and user-friendly interface for interacting with the device's functionalities.

3.5.7 Solution Variant 7

Solution Variant 7 presents a Handheld PC-like component placement, where the screen and battery are aligned, and the Raspberry Pi is positioned behind the screen.

The screen orientation is set in landscape mode, offering a wider and horizontal display view.

For handling, the device is designed with a bump grip, providing users with a comfortable and secure way to hold and operate the device.

The battery is placed internally in this variant, and a battery pack is used to power the device, ensuring an integrated and seamless appearance.

The chassis type adopts a bowl-like design, providing a secure enclosure for all components, safeguarding them from potential damage.

For mounting purposes, the device employs a detachable tripod system, making it convenient to attach and detach from a tripod stand.

The control mechanism in Solution Variant 7 combines both a touch screen and physical buttons, providing users with multiple input options for interacting with the device's functionalities. This combination enhances versatility and usability in various scenarios.

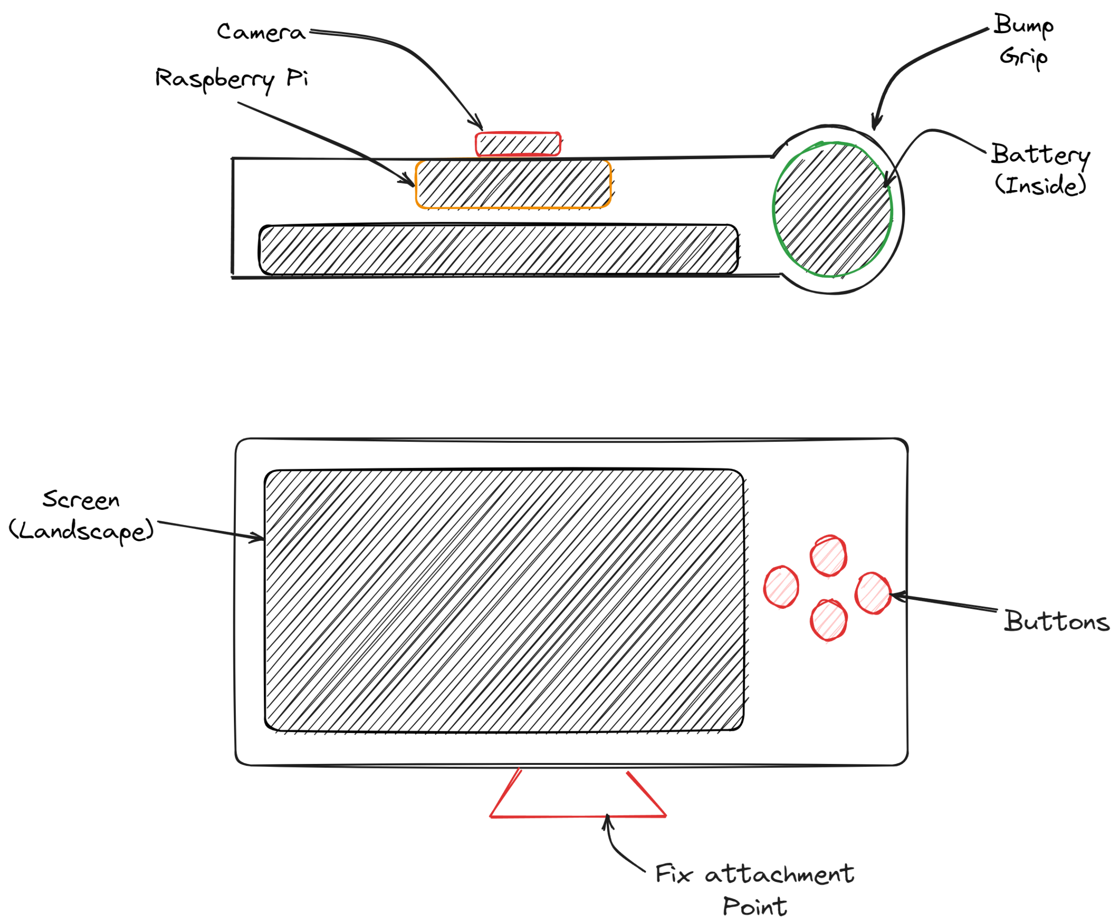

Figure 3.7: Sketch of Solution Variant 7

3.5.8 Solution Variant 8

Solution Variant 8 features a Camcorder-like component placement, with the Raspberry Pi, Battery, Camera, and Screen arranged similarly to that of a camcorder. The screen is placed at a hinge, allowing it to change angles for flexible viewing.

The screen orientation remains in landscape mode, providing a wide and horizontal display view.

For handling, the device is designed with a body grip, ensuring a secure and comfortable hold during operation.

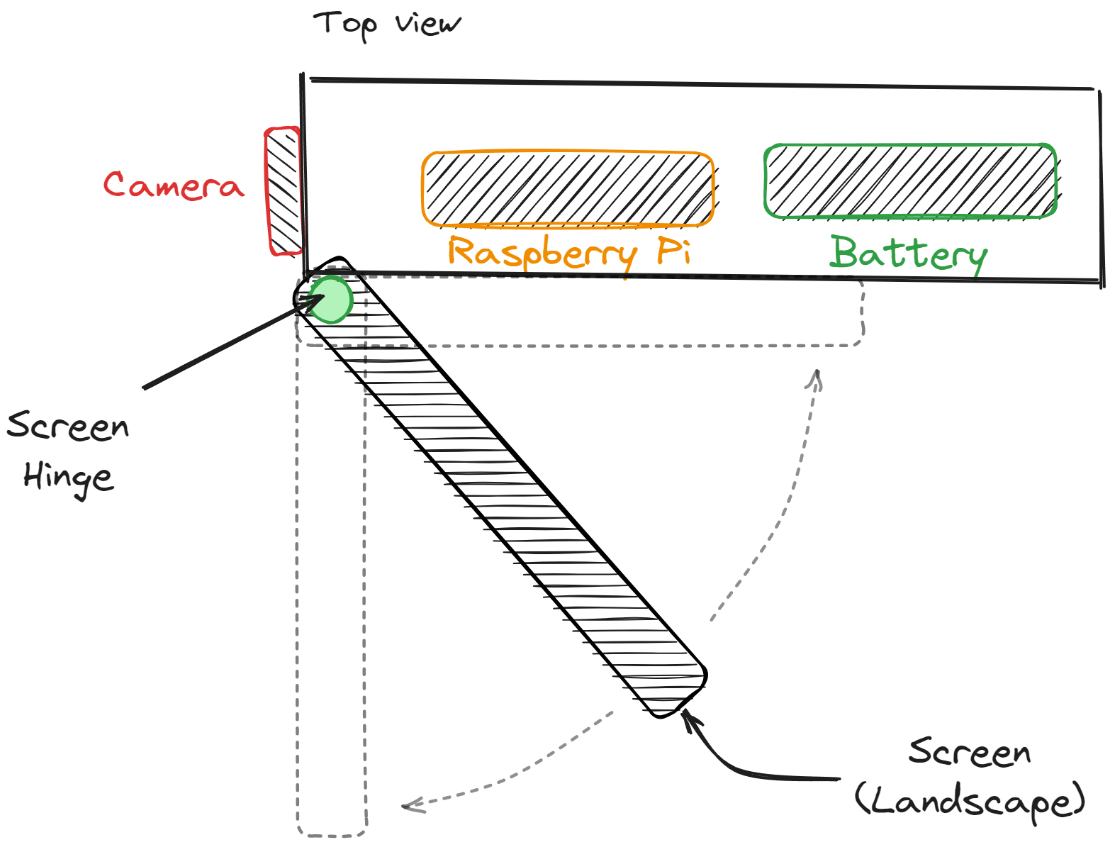

Figure 3.8: Sketch of Solution Variant 8

The battery is placed internally, and a power bank is utilized in this variant to provide a reliable power source for the device.

The chassis type follows a bowl-like design, offering a protective and sturdy enclosure for all components.

For mounting, a fixed mount tripod system is used, providing stability and ease of use when attaching the device to a tripod stand.

The control mechanism combines both a touch screen and physical buttons, allowing users to interact with the device's functionalities through intuitive touch commands or precise button inputs, offering enhanced control and flexibility in various situations.

3.6 Filtering of Solution Variants

The filtering process is conducted to select the most suitable solution variant for the project. The filtering criteria are based on the design requirements and the design objectives.

Page 1	Selection Chart								
SolutionsVariant	No.	Evaluate solution variants according to selection criteria						Decision	
		Compatible with the overall task	ulfill demands of requirement list	Realisible in principle	Within permissible costs	Incorporates direct safety measures	Preferred by the designer	Remarks: (+) Pursue Solution (-) Eliminate Solution (?) More Information Required (!) Check Specification	
		A	B	C	D	E	F		
S1	1	+	+	+	+	?	+	Might have problem with ergonomic	-
S2	2	+	+	+	+	?	?		+
S3	3	+	+	+	+	?	+		+
S4	4	-	+	+	+	+	+	Have almost no protection of inner components	-
S5	5	+	+	+	+	?	+	Less ergonomics due to wide body	-
S6	6	+	+	+	+	?	?		+
S7	7	+	+	+	+	+	+		+
S9	8	+	+	-	?	?	-	Too complex	-

Figure 3.9: Selection Chart for Solution Variants

As can be seen from the selection chart in Figure 3.9, the solutions S1, S4, S5 and S9 are eliminated and will not be considered for the next stage of the design process.

4 Embodiment Design

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intro

4.1 Basic Rules of Embodiment Design

- Clarity
- Simplicity
- Safety

4.2 Guideline of embodiment design

- Design for ergonomics
- Design for production

4.3 Preliminary Design Variant 2

This section delves into a detailed exploration of Solution Variant 2. Figure 4.1 shows the preliminary design variant 2 and different views and body measurement are shown in Figure 4.2. The main attraction of this design is the emphasis on ergonomic form and user-friendly features. The device incorporates a sleek and aesthetically pleasing design with rounded edges and a lightweight build, making it easily portable and comfortable to hold for extended periods. With a thickness of 46 mm (Figure 4.2b), the device strikes a balance between being slim and accommodating the necessary components for optimal functionality .

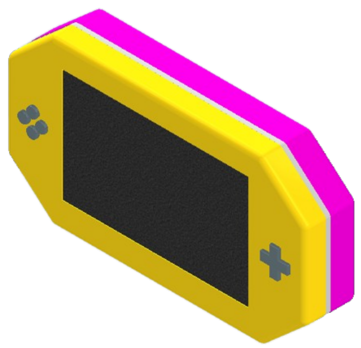
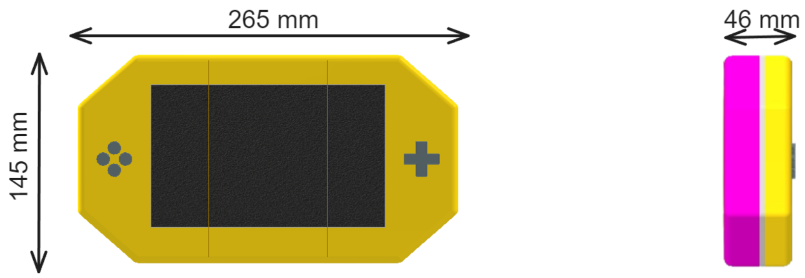


Figure 4.1: Preliminary design variant 2



(a) Front View **(b)** Right View

Figure 4.2: Views of preliminary design variant 2

The physical design of Solution Variant 2 follows a carefully crafted sandwich-like structure, consisting of a main body, top cover, and back cover (Figure 4.3). This design choice not only ensures the protection of the internal components but also facilitates ease of assembly and maintenance. The main body serves as the central hub, housing all the essential electronics and functional elements, while the top and back covers act as protective layers, safeguarding the delicate components from potential damage due to external impacts.

A key consideration in the design is the arrangement of the inner components within the device. Following a tablet-like configuration, the main LCD is thought-

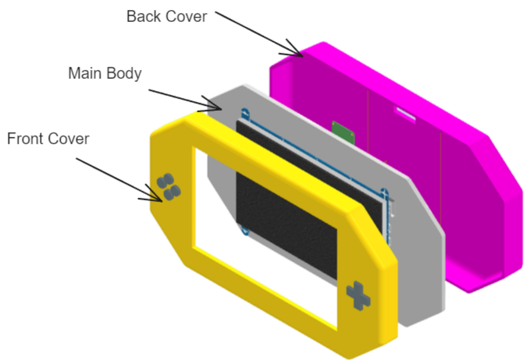
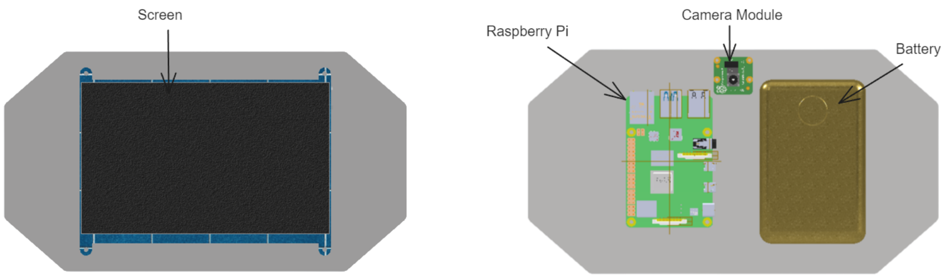


Figure 4.3: Body Components of preliminary design variant 2



(a) Front View

(b) Back View

Figure 4.4: Placement of inner components

fully positioned on the front side of the main body, providing users with a clear and interactive interface (Figure 4.4a). Meanwhile, the camera, Raspberry Pi, and battery are strategically placed on the back side of the body (Figure 4.4b), optimizing the distribution of weight and ensuring a well-balanced user experience. This arrangement also enhances the device's overall usability and convenience, making it suitable for a wide range of applications.

Ensuring the secure attachment of components to the main body is of paramount importance in the design process. Various methods for component fastening are considered, including direct attachment, threaded inserts, helicoils, side pockets, and bottom pockets as shown in Figure 4.5.

The simplest approach is direct attachment, where threads are designed into the 3D printed part to allow components to be screwed in. For more robust

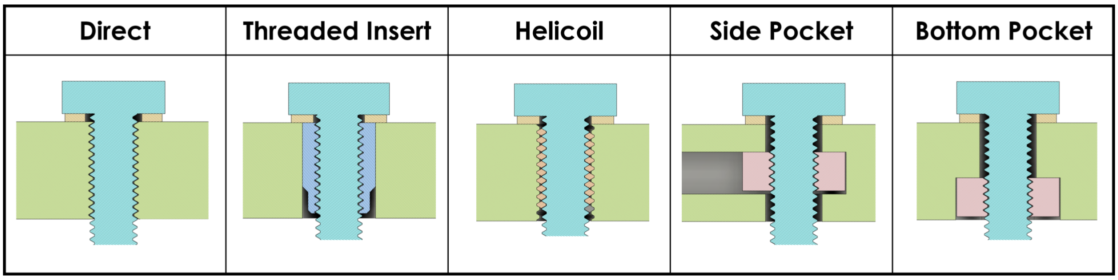


Figure 4.5: Methods to secure components [Her20]

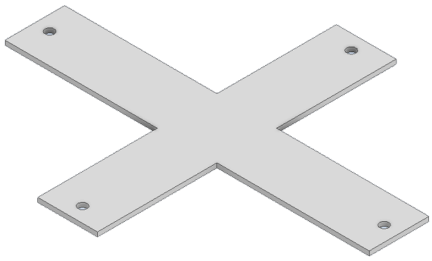
connections, threaded inserts can be used by designing holes in the 3D printed part and installing the inserts appropriately.

Helicoils offer durable threaded holes by inserting coil-shaped inserts into designed holes. Side pockets and bottom pockets involve creating cavities or slots in the 3D printed part to securely hold components. Each method offers its own set of advantages and challenges, and after careful evaluation, the variant opts for the use of threaded inserts due to their simplicity and robustness.

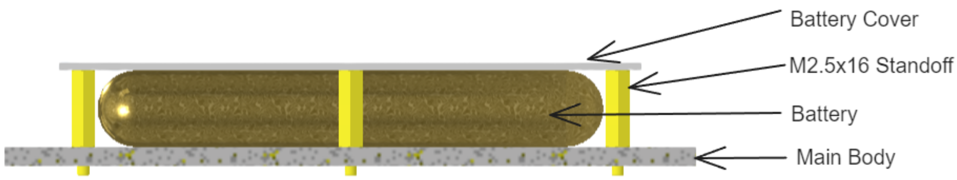
The battery, being a critical component within the device, requires special attention to prevent any undesirable movement or instability. Figure 4.6a shows the battery cover which will be attached to the main body, while Figure 4.6b shows the method of securing the battery to the main body.

To address this concern, an effective method for securing the battery firmly in place is implemented by utilizing a battery cover. The battery cover is then securely attached using screws and standoffs, ensuring that the battery remains in its designated position even during vigorous handling or movement.

Solution Variant 2 will employ a hybrid input method, combining both touch screen and physical buttons. The touch screen will be oriented in landscape mode, while the buttons will be positioned on either side of the screen (Figure 4.2a). To enable the integration of the touch screen, HDMI and USB connections will be established between the touch screen and the Raspberry Pi [Sun]. Additionally, to facilitate the functionality of the physical buttons, they will be connected to the Raspberry Pi using its GPIO (General Purpose Input/Output) pins [Sor21].



(a) Battery Cover



(b) Placement of components

Figure 4.6: Methods to secure the battery

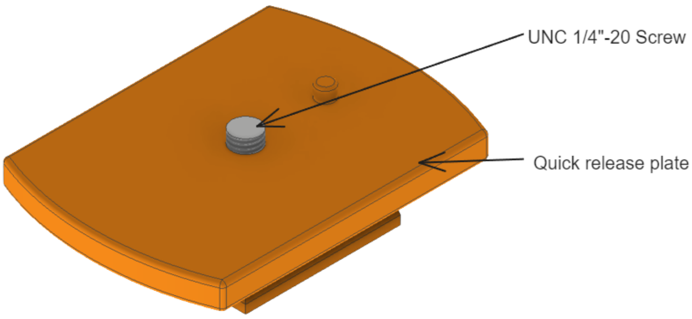


Figure 4.7: Quick release plate

In Figure 4.7, we can observe the quick release plate designed to be affixed to the tripod stand. For enhanced stability during usage, Solution Variant 2 can utilize the quick release plate which can be conveniently mounted on a tripod stand.

4.3.1 Cost Calculation

In this section, we will perform a cost analysis for producing Solution Variant 2. It is essential to emphasize that the cost calculation for the 3D printed parts solely considers the material cost and the estimated energy consumption during the printing process. Other expenses, such as the cost of the 3D printer itself, labor, and maintenance, are not factored into the calculation. Additionally, for better comparability with other variants, the costs of the Raspberry Pi, camera module, touch screen, and battery will not be included in the calculation. The formula used to calculate the cost of the 3D printed parts is as follows:

...

4.4 Preliminary Design Variant 3

Figure **??** presents an insightful glimpse into the conceptualization of preliminary design variant 3. Much akin to variant 2, the arrangement of components exhibits striking resemblances, wherein the screen adorns the frontal expanse, while the camera, Raspberry Pi, and battery find their abode at the rear. However, a notable deviation takes form in variant 3, as the screen's orientation transforms into portrait mode, and a fascinating alteration emerges in the positioning of the computational unit and battery—they are now artfully stacked atop one another.

The chassis structure, reminiscent of variant 2, boasts a harmonious triad of the main body, top cover, and back cover. Manifesting as the nucleus of the device, the main body houses an orchestration of vital electronics and functional intricacies. Meanwhile, the top and back covers diligently assume the mantle of guardians, cocooning the device's delicate components from potential harm inflicted by external forces.

A compelling divergence emerges in the form of a tactile innovation—a subtle yet meaningful bump graces the back cover. This augmentation is a deliberate endeavor to enhance the device's ergonomics, tailored to seamlessly nestle within the contours of the user's palm. The result is an intuitively comfortable grip that heightens user engagement and prolongs usability.

Distinctive alteration in battery placement marks yet another departure from variant 2's blueprint. Abandoning the concept of a dedicated battery cover, variant 3 strategically carves a snug slot within the back cover's canvas. This niche is bespoke to accommodate the battery, eliminating any possibility of unwanted shifts during device operation. Such ingenuity streamlines the process of battery replacement, ushering in an era of swift and effortless renewals.

The input methodology undergoes a streamlining, harnessing the prowess of the touch screen as the singular interface. This approach offers a streamlined user experience, unfettered by physical buttons, and seamlessly marries the screen with user interaction. A comprehensive elucidation of the touch screen's connection to the Raspberry Pi is expounded upon in a prior section, ensuring a symphony of function and compatibility.

The harmonious integration of the chassis with the tripod stand unfolds through a direct union. The tripod stand's mounting point affixes itself with grace to the underbelly of the main body. Meticulous scrutiny of the quick release plate's design yields an intriguing revelation—the focal point of attachment between the plate and the tripod stand rests upon the trapezoidal contour. Ingeniously, this prism becomes an organic extension of the main body, seamlessly embracing the tripod stand. The net result is an effortlessly achieved amalgamation, ushering the device into a realm of enhanced stability and versatile usage scenarios.

4.4.1 Cost Calculation

4.5 Preliminary Design Variant 6

The unveiling of Figure **??** offers an illuminating exposition of the preliminary design variant 6. This iteration boldly forges a distinctive path, setting itself apart by orchestrating its internal components in a configuration reminiscent of the point-of-service (POS) system. A prominent departure from previous renditions, this design choice strategically aligns the screen at an angle, fostering effortless user interaction. This ingenious placement optimizes screen visibility, facilitating seamless engagement for the user. Furthermore, a striking juxtaposition of the battery and Raspberry Pi unfolds on the device's frontal landscape, one atop the other. To ensure structural integrity, the attachment of these components is meticulously executed through the use of screws and threaded inserts, as previously elucidated.

Manifesting as an embodiment of thoughtful design, this variant is encapsulated by a bowl-like chassis structure. A symbiotic synergy of the main body, serving as the guardian of internal components, and a top cover, adorning the device with an added layer of protection, defines the architectural essence of this design.

The realm of user experience is skillfully curated through the seamless integration of a handle grip nestled beneath the device. This strategic implementation empowers users with a comfortable grip, ensuring prolonged usage remains effortless and enjoyable. Alternatively, this ingenious handle grip serves as an anchor point for attaching the quick release plate—a gateway to mounting the device on a tripod stand. This multifaceted utility imbues the device with enhanced versatility, seamlessly transitioning from handheld to mounted scenarios.

A familiar melody resonates in the input methodology and battery placement of this variant, akin to the orchestrations observed in variant 3. The touch screen takes center stage as the primary input mechanism, offering an intuitive and streamlined interaction experience. Similarly, the battery finds its abode within a specially crafted slot on the back cover, securely fastened in place by the steadfast embrace of screws and threaded inserts. This ergonomic battery placement facilitates easy removal and replacement, underscoring the design's practicality and user-centric ethos.

4.5.1 Cost Calculation

4.6 Preliminary Design Variant 7

The unveiling of Figure **??** offers a captivating insight into the preliminary design variant 7, a configuration ingeniously influenced by the handheld PC paradigm. In this rendition, the raspberry pi stakes its claim on the rear side of the screen, creating an integrated and compact composition. Concurrently, the battery aligns itself in symphony, gracefully nestling alongside the screen in a harmonious juxtaposition.

The design ethos extends to the chassis structure, which draws inspiration from the bowl-like form of variant 6. This architectural continuity ensures a cohesive aesthetic while enabling seamless integration of functional components.

In the realm of user handling, a clever innovation akin to variant 3 is introduced, albeit with a distinctive twist. A strategically positioned bump adorns the side of the body, offering an ergonomic touch that resonates with the user. Remarkably, this bump also serves as a sanctum for the battery, providing a secure and discreet enclosure within the device's contours. Notably, in variant 7, the battery finds its dwelling as a permanent fixture within the device, fortifying its structural stability.

The control mechanisms of this variant mirror those observed in variant 2, embracing a synthesis of tactile and touch interfaces. The touch screen assumes the mantle of the primary input mechanism, engaging users in an intuitive and seamless dialogue with the device. Complementing this touch-driven interaction, physical buttons find their abode along the device's side, imbuing the design with a secondary input avenue.

In a fitting culmination, akin to the design philosophy of variant 3, the integration of the device with a tripod stand materializes through a direct symbiosis. A trapezoidal prism, an architectural marvel in its own right, becomes an extension of the device's body, facilitating a straightforward alliance with the tripod stand. This elegant integration underscores the design's commitment to stability and adaptability, transforming the device into a versatile tool suited for a spectrum of scenarios.

5 Methodology

5.1 Design Methodology

Explaination of the design methodology from VDI 2221 [**?**]

- What is VDI 2221 and what are its key principles?
- What are the main objectives and goals of VDI 2221?
- What are the key stages or phases outlined in VDI 2221?

6 Task Clarification and Specification

6.1 Requirement of the Prototype

List of requirements for the prototype

Must have:

- Ergonomic - Comfortable to hold, Easy to use, Weight distributed evenly
- Portable - Lightweight, Small
- Size (MAX)
  - Length: 25 cm
  - Width: 25 cm
  - Height: 25 cm
- Weight (MAX): 3 kg
- Compliance and Regulation - Comply with the regulations of the country of use
- Cost - Affordable, < 300 Euro (including Pi, Camera and Screen)
- Appointments - Completed within 3 months
- Design - Components are packed in a chasis
- Camera - Camera must be presented in the prototype
- Power - Battery powered, Rechargeable battery, Duration min. 1 hour

- Control - Control via touch screen

Optional Requirements:

- Durability - Water resistance, Dust resistance
- Modular - Easy to assemble and disassemble, Swappable parts
- Features - Mountable on a tripod
- Fertigung - 3D printed parts

6.2 Requirement List

List of requirements will be generated from the must have and optional requirements (Section 6.1)

7 Concept Generation

7.1 Abstraction

- What is Abstraction?
- How does it defined and utilized in the design process?
- What are the benefits of using abstraction?

7.2 Function Structure

- What is a function structure?
- What is Black Box Method?
- Define the function structure of the prototype using the Black Box Method according to the requirements specified.

7.3 Idea Generation

This section will discuss the methods used for idea generation.

Methods used:

- Market Research
- Competitive Analysis

- Brainstorming

Method is suitable, due to the face that handheld devices are common in the market

7.4 Combination of Ideas with Morphological Chart

List of ideas from brainstorming will be combined with the function structure to generate a morphological chart

Atleast 3 Design Concepts will be generated from the morphological chart

8 Design

8.1 Concept Selection and Evaluation

- Explaination of the design and discussion of advantages and disadvantages
- What are the performance characteristics and limitations of each design option, and how do they align with the desired outcomes?
- What are the cost implications associated with each design option?
- What are the potential risks and uncertainties associated with each design option, and how can they be mitigated or managed effectively?

8.1.1 Design 1

8.1.2 Design 2

8.1.3 Design 3

8.2 Final Design

- How is the final design selected?
- What methods are used to evaluate the final design?

- Which evaluation criteria are being used?
- How well does each design option fulfill the functional requirements specified in VDI 2221?

8.2.1 CAD Drawing

Final CAD Design will be presented here. Including with the features

8.2.2 Bill of Materials

List of parts used in the final design

9 Conclusion

Conclusion of the project

Part II

GUI Development

1 Methodology

1.1 MVC Pattern

- What is MVC?
- What are the distinct responsibilities and roles of the Model, View, and Controller components in the MVC pattern?
- What are the benefits of using MVC?

The Model-View-Controller (MVC) pattern is a software architectural pattern that separates an application into three interconnected components: the model, the view, and the controller. The model represents the data and logic of the application, the view displays the data to the user, and the controller handles user input and updates the model and view accordingly. This pattern promotes separation of concerns, modularity, and code reusability in software development. [?]

1.2 Design Patterns - Thread Pool

- What is a thread pool?
- What are the benefits of using a thread pool?
- What are the drawbacks of using a thread pool?

A thread pool is a software design pattern that manages a pool of worker threads to efficiently execute tasks. Instead of creating a new thread for each task, a thread pool reuses existing threads, minimizing the overhead of thread creation. It improves performance and resource utilization by limiting the number of concurrent threads and providing a queue to handle incoming tasks.[**?**]

2 Requirements and Design

2.1 Requirements

Must have:

- Usability - Easy to use
- Performance - Fast processing by utilising multiple threads
- Responsiveness - Responsive GUI, avoid methods that block the GUI thread
- Error Handling - Handle errors gracefully, avoid crashing the application
- Scalability - For future development
- Documentation - user guides, Tooltips, comments
- Design - Clean and simple design

2.2 Wireframe

Program flow and GUI design will be presented in a wireframe.

* Flow of the program is not finalized, will be updated in the future

- All panels involved in the program will be presented here
- Flow of the program will be presented here.
- The arrangement of panels, both preceding and following another panel,

will be showcased here.

- What happens when the user clicks on a button will be presented here

2.3 GUI Design

Design of the GUI will be presented here. Panels, Buttons, Textfields, etc.

- Layout of the GUI will be defined here
- What panels will be used will be defined here

3 Solutions and Implementations

In this chapter, the solutions and implementations of the project will be presented.

3.1 Model

Implementation of the Model

- What is the Model?
- What are the key responsibilities of the Model?
- What is the primary purpose and responsibility of the Model component in the application's architecture?

3.2 View

Implementation of the View

- What is the View?
- What are the key responsibilities of the View?
- How does the View handle the presentation and visualization of data to the user?
- How does the View respond to user input and events, and how are these interactions managed?

- What are the mechanisms for updating the View based on changes in the Model or instructions from the Controller?

3.3 Controller

Implementation of the Controller

- What is the Controller?
- What are the key responsibilities of the Controller?
- How does the Controller handle user input and events?
- How does the Controller update the Model and View?

4 Testing

4.1 Unit Testing

Unit testing is a software testing approach that involves testing individual components or units of code in isolation to ensure they function correctly. It verifies the behavior of small, independent units of code, such as functions or methods, to validate their expected functionality and catch any defects early in the development process. [?]

5 Conclusion

Conclusion of the project

Part III

Indexes and Appendix

List of Figures

List of Tables

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A Appendix

- Docs
- Repository

A.1 CAD Drawings

A.2 Bill of Materials

A.3 Code snippets

A.4 Additional information, pictures, handout, etc.

prusa slicer data sheet rpi data sheet pi cam data sheet brass insert data sheet