Master Thesis

Prototype Development of a Handheld Speed Camera

for the attainment of the academic degree

Master of Mechanical Engineering

submitted by

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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

Contents

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

4 Methodology

4.1 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?

5 Task Clarification and Specification

5.1 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

5.2 Requirement List

List of requirements will be generated from the must have and optional requirements (Section 5.1)

6 Concept Generation

6.1 Abstraction

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

6.2 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.

6.3 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

6.4 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

7 Design

7.1 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?

7.1.1 Design 1

7.1.2 Design 2

7.1.3 Design 3

7.2 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?

7.2.1 CAD Drawing

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

7.2.2 Bill of Materials

List of parts used in the final design

8 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

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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