JÖNKÖPING UNIVERSITY
School of Engineering

industriDESIGN

Artificial Intelligence in the Industrial Design Process

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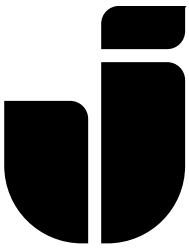

JÖNKÖPING UNIVERSITY

School of Engineering

Artificial Intelligence in the Industrial Design Process

Artificiell Intelligens i Processen för Industriell Design

Hugo Jonasson

This degree project is performed at the School of Engineering in Jönköping in the subject field Industrial Design. The project is a result of the master program Industrial Design. The writers are responsible of the result, conclusions, and reflections.

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Abstract

This report covers the subject and impact of utilizing artificial intelligence tools for image generation in the process for industrial design. By evaluating the tools available on the market at the time of writing the report establishes a toolbox of relevant tools to the design process. These tools are then used to restructure established design processes into a new process and set of guidelines that incorporates these tools as a central part of the design process.

The report then covers the “test run” of this process by developing a concept product, which in this case is a camera for a specific brand. Finally the report covers the implications and potential further developments needed in order to fully incorporate artificial intelligence in the design process, along with potential ethical implications of utilizing these tools to aid in the creation of commercial products.

Sammanfattning

Denna rapport behandlar ämnet och effekten av att använda verktyg för artificiell intelligens för bildgenerering i processen för industriell design. Genom att utvärdera de verktyg som finns på marknaden vid tidpunkten för rapportens författande etableras en verktygslåda med relevanta verktyg för designprocessen. Dessa verktyg används sedan för att omstrukturera etablerade designprocesser till en ny process och uppsättning riktlinjer som integrerar dessa verktyg som en central del av designprocessen.

Rapporten täcker sedan "testkörningen" av denna process genom att utveckla en konceptprodukt, som i det här fallet är en kamera för ett specifikt varumärke. Slutligen behandlar rapporten konsekvenserna och potentiella ytterligare utvecklingar som behövs för att fullt ut integrera artificiell intelligens i designprocessen, tillsammans med potentiella etiska konsekvenser av att använda dessa verktyg för att underlätta skapandet av kommersiella produkter.

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1 Introduction

1.1 Background

Artificial intelligence (AI) tools have recently broken through into mainstream consciousness with tools like Midjourney, Stable Diffusion, and DALL·E 2 being used to produce intricate artwork at record speed. However, AI tools have so far primarily been used in 2D conceptual art, and there is potential for them to have applications in industrial design and product development as well.
Industrial design is the process of creating and developing new products, including their form, function, and aesthetics. The field of industrial design is constantly evolving, and new technologies are continually being developed to aid in the design process. AI tools, with their ability to analyze data and generate new ideas, have the potential to revolutionize the way products are designed.
Recent advances in AI have led to the development of new tools that can be used in the design process, such as generative design, which uses algorithms to generate new design options based on specific criteria, and computer-aided design, which uses AI to assist in the creation and manipulation of 3D models. These tools can aid in inspiration, ideation, and other stages in product development, making the design process faster and more efficient.
However, despite the potential benefits of AI in industrial design, there are also ethical considerations that must be explored. The use of AI in product development raises questions about the role of human creativity, the potential for AI to displace human workers, and the ethical implications of using AI to design products.

1.2 Boid

Boid is a design studio based in Gothenburg with a focus on both digital and physical product development. Originally a part of Chalmers, it is now an independent studio that works both in the industry and with research projects.

1.3 Objectives

The goals of the thesis are as follows:

1. To provide an overview of the landscape of AI tools and their potential use in industrial design and product development. This will include an analysis of the strengths and weaknesses of current AI tools and how they can be integrated into the design process to aid in inspiration, ideation, and other stages in product development.
2. To develop an industrial design workflow or model that utilizes the right AI tools to support faster and more creative ideation for physical design and styling. This will include the identification of specific AI tools that can be used to aid in specific stages of the product development process, and the testing of the effectiveness of the proposed workflow.
3. To develop a custom AI model, trained on industrial design imagery, to aid ideation with an industrial design focus. This will include the collection of industrial design imagery and the training of the custom AI model using machine learning and computer vision techniques.
4. To showcase the use of the tools and resulting workflow through a reference project that develops a concept product. This will include the application of the tools and workflow

to the design of a specific product, and an evaluation of the effectiveness of the tools and workflow in the design process.
5. To consider the ethical implications of using AI in product development and to suggest best practices for ethical use. This will include an analysis of the potential controversies surrounding the use of AI in product development and the identification of best practices for ethical use of AI in industrial design and product development.
6. To build upon and use the processes and skills taught during the program when it comes to the process of industrial design and the tools for creating and realizing ideas, while incorporating the new elements of using AI to augment the process.

1.4 Research Questions

Research Questions:
1. How can the design process be altered to take benefit from the use of AI?
2. What changes must a human make to an AI generated concept in order to create a viable product?

1.5 Delimitations

This project will not go into depth on the underlying systems that power AI and how they are created. It will also use existing AI solutions and tools to produce the required results for the project, rather than developing own systems.
Training an AI on industrial design imagery is something that will be explored to assess whether its plausible to do within the scope of the project.
The thesis will also only briefly touch on the more advanced capabilities of AI that are not covered by the industrial design process.
The trial of the developed process will also be shortened in order to fit in the specified timeframe.

1.6 Disposition

The report will first present the background and introduce concepts and theories that are relevant for the thesis. It will then describe the methods that will be implemented. From there, the approach chapter will be split in to two parts. The first part will explain how AI can be integrated into the industrial design process. The second part will detail a "trial run" industrial design project using the developed process.

2 Theoretical Background

2.1 Artificial Intelligence

Artificial Intelligence (AI) is a branch of computer science that deals with the development of intelligent machines that can perform tasks that would normally require human intelligence, such as perception, reasoning, and decision-making. There are different approaches to AI, but the main categories are: rule-based systems, which use a set of predefined rules to make decisions. Expert systems, which use knowledge from a specific domain to make decisions. And machine learning, which uses data to improve the performance of a model over time. [1] The most relevant use of AI for this thesis is the use of computer vision, which allows for an AI to interpret and generate images. [2, 3]
In recent years, advances in AI have led to the development of new tools that can be used in the design process, such as generative design and computer-aided design. Generative design uses algorithms to generate new design options based on specific criteria, allowing for the exploration of a larger design space in a shorter amount of time. [4]
One of the main advantages of AI in industrial design is its ability to analyze data and generate new ideas. For example, by analyzing data on consumer preferences, AI can help identify patterns and trends that can inform the design process. Additionally, AI can be used to simulate the performance of a product, allowing for the identification of potential issues before the product is physically manufactured. [4]
However, despite the potential benefits of AI in industrial design, there are also ethical considerations that must be considered. The use of AI in product development raises questions about the role of human creativity, the potential for AI to displace human workers, and the ethical implications of using AI to design products. It also raises questions in regard to using the creative work of other individuals to train AI models. [5]

2.1.1 Deep Learning

Deep learning is a subfield of machine learning that utilizes artificial neural networks (ANNs) to learn and model complex relationships within data. This technique has been increasingly popular in recent years due to its ability to automatically extract and learn features from raw data, without the need for manual feature engineering.

Deep learning architectures are composed of multiple layers of interconnected nodes, with each layer processing and transforming the input data before passing it to the next layer. These networks are typically trained using large amounts of labeled data, where the network learns to make predictions by minimizing a cost function that measures the discrepancy between its predicted output and the true output.

One of the key advantages of deep learning is its ability to handle high-dimensional data, such as images and audio, which are difficult to represent in a concise feature space. Additionally, deep learning can automatically learn complex patterns and relationships in the data, making it particularly useful for tasks such as image and speech recognition, natural language processing, and autonomous driving. [6]

2.1.2 Computer Vision

Computer vision enables computers to be able to read information and interpret images, videos, and other visual media. Depending on the AI utilizing this information, the AI can then use this information to make recommendations or perform different tasks. It works very similarly to human vision, with the main difference being that human brains already possess a lifetime of training and context associations to tell different objects apart and derive meaning from what we see.
In order to achieve a working vision system, the computer must first be trained. This is usually achieved by using huge datasets containing a large number of images or other visual media and is often tailored to what the developers intend to achieve with the specific AI system. [3]
Algorithms allow for the system to teach itself to tell images and their content apart, rather than having a human tell the AI what each individual image is. The main technologies used to achieve this are deep learning and convolutional neural networks (CNN). Deep learning is a form of machine learning where the algorithms are inspired by the human brain to process and learn from large amounts of data. This means that, just like humans, it deepens its knowledge through repetition. [7]

2.1.3 Stable Diffusion

Stable Diffusion is an image synthesizing AI technique built on a latent diffusion model, which is a type of deep learning neural network built with likelihood-based models. It is built on several advanced partial differential equations used to represent gaussian noise. Which is a method used to essentially obscure the image in various stages. The AI then runs calculations to resolve and remove the noise several times until the equation system is seen as "stable", thus producing a viewable image from prompts or other image data. The model is trained by feeding the AI a large number of images that have been scraped from the internet and then categorized prior to the training. The categorization can either be manual or be done through other AI systems. One of the advantages of stable diffusion models is the fact that it lends itself to image-to-image translation. Meaning that it can take an uploaded image and a text prompt and combine these into a result. It is also open-source, which means that the community can alter and create improvements to the system as the research progresses. [8]

2.1.4 DALL-E 2

DALL-E is an image synthesizing AI that works through a system of CLIP (Contrastive Language-Image Pre-training) encodings. CLIP is used to train an AI in the relationship between and image and its language counterpart, allowing the AI to understand the meaning of an image and associate phrases to images it deems close in context. This requires a huge amount of data, which in the case of DALL-E translates to around 650 million images.
Essentially, DALL-E works by running this system in reverse. When the AI is trained to encode and recognize context, meaning, and language associations this process can be reversed again with a separate decoder. This allows DALL-E to accept text input, compare it to its massive database of encoded images, and then decode this back into an image which matches the text input received. [9]
There are also variations of DALL-E, with one major alternative being called Craiyon, previously DALL-E mini.

2.1.5 Midjourney

Midjourney is a product from an independent research lab, and the process behind its image generation remains proprietary. Ran through a command interface in a chat program, its very user friendly, with a low barrier of entry. It produces results similar to the systems mentioned in 2.1.3, so it is reasonable to assume the models behind it share similarities. [10]

2.1.6 Craiyon

Craiyon is built on technology that resembles that of DALL-E 2, and was previously called DALLE Mini. It is a fast tool that produces a large number of images in a short time span, albeit with lower fidelity and quality than many other tools.

2.1.7 Lexica

Most likely built on a custom Stable Diffusion model, Lexica is a user-friendly online image generation tool with an accompanying database. This database makes it suited towards learning to operate AI tools, as all the images stored in the database are associated with their respective parameters, meaning that any user could reverse engineer a particular image and learn how it was created.

2.1.8 Prompt Engineering

Since image-based AI relies heavily on prompts, which is the input in form of text, being able to sufficiently create these prompts becomes a crucial part of creating satisfactory results.

Prompt engineering for artificial intelligence (AI) refers to the process of optimizing, and properly utilizing phrases and parameters to feed to the AI for processing. This is an important area of study because it can greatly enhance the performance and usability of AI models and heavily impacts the generated results, especially those that rely on language-based inputs.

Prompt engineering enables users to communicate with AI systems more easily and accurately. By crafting effective prompts that use natural language, users can convey their intentions and queries to an AI model in a way that is easy for the model to understand and act upon. This is particularly relevant for applications such as question answering, chatbots, and language translation, where the quality of the prompt can have a significant impact on the accuracy, usefulness and quality of the AI-generated response or image.

Another benefit of prompt engineering is that it can help address the issue of bias in AI models. By carefully designing prompts that are unbiased and neutral in their wording, developers can reduce the risk of perpetuating harmful stereotypes and inaccuracies that may be present in training data. Moreover, prompt engineering can be used to augment existing bias mitigation techniques, such as data pre-processing and model regularization, to further improve the fairness and inclusivity of AI systems. [11]

To achieve effective prompt engineering, researchers and developers must be well-versed in a range of technical skills, including natural language processing, machine learning, and software engineering. They must also possess a deep understanding of the specific application domain and the intended audience for the AI system. In addition, they must be able to iteratively test and refine their prompt design to ensure that it produces accurate and reliable outputs. As AI continues to play an increasingly important role in society and development, prompt engineering will become an increasingly essential skill for researchers, developers, and practitioners in the field. [11]

2.1.9 Dreambooth

The development of large text-to-image models represents a significant advancement in artificial intelligence, allowing for the creation of high-quality and varied images from textual prompts. However, such models often have limitations in their ability to mimic the appearance of subjects in a given reference and generate new versions of them in different contexts.

Dreambooth is a method for personalizing text-to-image diffusion models. By using a few images of a desired subject or concept as input, Dreambooth can fine-tune a pre-trained text-to-image model, such as Stable Diffusion, to learn how to associate a unique identifier or phrase with that specific subject. This embedding allows for the generation of new photorealistic images of the subject, which can then be placed in various scenes, poses, views, and lighting conditions that are not present in the reference images. Dreambooth training allows the model to achieve this while preserving the trained subject's or topic's essential features. [12]

2.1.10 ControlNet

ControlNet is a system developed for Text-to-image diffusion models that aims to bring further control of the generated images to the user. It works by injecting itself into the neural network blocks that create an AI model. These blocks are parts of the program that handle different functionality such as computer vision and image generation.

ControlNet allows the user to use a greater variety of input such as sketches, edge maps, depth maps and normal maps to generate images with greater control. The system acts as an extension of existing diffusion models and is specifically trained on the above-mentioned inputs to produce the best results. An example that applies in the case of industrial design could be to render an image with visible normal maps, and then use this image to rapidly iterate surface finishes and materials through Stable Diffusion.

It also creates the potential for greater cooperation between AI and designer, as ControlNet allows Stable Diffusion to accurately interpret and generate images based on the sketches of the designer. [13]

2.1.11 Breadboard

Breadboard is a media browser built specifically for AI generated content, which makes it a powerful tool for this thesis. Since the volume of images that can be generated in a short span by AI tools is very large, having a system to view, organize and inspect these images become crucial. Breadboard allows for automatic import of images into the software and allows the user to see the parameters used to create the images at a glance. This becomes very important when trying to create consistent imagery and have full control of the generation process.

The ability to tag and organize images becomes a crucial tool to choose images based on certain attributes or design elements. Breadboard's search function also allows for search by specific prompts used to generate the images. [14]

2.2 Industrial Design

Industrial design is the process of creating and developing new products for manufacturing, including their form, function, and aesthetics. It is a multidisciplinary field that involves the use of design, engineering, and marketing to create products that are both functional and visually appealing. The goal of industrial design is to create products that are not only functional but also easy to use, aesthetically pleasing, and meet the needs of consumers.
The process of industrial design typically includes research, concept development, prototyping, testing, and production. During the research phase, industrial designers gather information about consumer needs, market trends, and new technologies that can be used in the design process. In the concept development phase, designers create initial sketches and models of the product. During the prototyping phase, the design is refined, and a physical model of the product is often created. The final design is then tested to ensure that it meets safety and performance requirements before it is put into mass production. [15, 16]
Industrial design is an ever-evolving field, with new technologies and materials being developed all the time. In recent years, there has been a growing trend towards sustainable design, which focuses on creating products that are environmentally friendly and use sustainable materials.

2.3 The Design Process

2.3.1 Design Thinking

Design thinking is a human-centered approach to problem solving that involves understanding users' requirements and perspectives, coming up with innovative ideas, prototyping and testing solutions. It was initially created by the design firm IDEO in the 1990s and has since been extensively embraced as a tool for innovation by businesses in both the public and commercial sectors. [17]

Theories and methods based on design thinking often involves five stages: empathize, define, ideate, prototype, and test. The goal of the empathy stage is to understand the user and their needs through study and observation. In the define step, a point of view and the problem are established. During the ideate stage, brainstorming and idea generation techniques are used to generate a variety of potential solutions.

A physical or digital representation of the solution is created during the prototype stage to test and refine the concept. Finally, the prototype is evaluated and refined based on user feedback during the testing stage.

Design thinking can be applied to a wide range of problems, from the development of business models and organizational processes to the design of products and services. It is distinguished by a focus on experimentation and iteration, which enables rapid exploration of multiple solutions as well as rapid learning. [18]

In summary, design thinking provides a framework for developing innovative solutions based on a thorough understanding of users and their needs. This means that design thinking can help organizations overcome complex challenges and drive growth and success by following a structured process and taking a human-centered approach.

2.3.2 Design Thinking Bootleg

Bootleg is a set of tools and methodologies developed by designers, teachers, and students from around the world which outlines a general design process and recommended steps to take during the design process. Bootleg is comprised of five "modes" identified as the different stages of a design project. These five are Empathize, Define, Ideate, Prototype and Test.
Empathy forms the basis of human-centered design and involves building empathy for the end user, this involves observation, engaging with the users and immersing yourself in their experiences.
Define refers to the part of the process where you distill the findings from the empathy stage into concrete needs and requirements needed to properly define the project and understanding the challenge presented.
Ideate is the stage where the more tangible parts of the process begin. This is where the exploration of a wide range of concepts starts. The goal is to generate a wide space of potential solutions with high quantity and variety.
The Prototype stage is where the feasibility of ideas is explored. By creating physical and digital prototypes that the user can engage with, you can gauge their response and feelings towards these, and get an understanding of how the user receives the product.
The testing stage is when feedback is gathered, and the solution is refined from user insight. Testing is highly iterative as the insights gained might require you to go backwards and further refine the result. [19]

3 Method

3.1 Literature review

A literature review will be conducted to survey the AI landscape and find what Ais are relevant for the field of industrial design, and how they operate. The review will also look at current design methodologies the identify parts of the process where AI can be integrated. The literature review will serve as a tool to gather and summarize relevant articles and knowledge that will form the basis of knowledge for the development of the process. [20]

Since artificial intelligence is a rapidly developing field, the approach for finding relevant literature had to change slightly. Rather than focusing on finding well-established peer reviewed articles in the field, focus was instead put on finding the latest and most relevant research and studies relating to the topic. This puts a heavier emphasis on state-of-the-art information and making sure that the thesis is up to date with the latest developments in the field.

3.2 Boid Design Process

The Boid design process is a variation of design thinking utilized at Boid and features some changes.
It is the main process that will be looked at in this thesis and the workflow/process will be developed to suit this process. The Boid process can be seen in figure 1.

Figure 1, Boid Process

3.3 AI Process Development

Since the goal of this project is to integrate AI tools into the industrial design process, this stage of the thesis will be used to evaluate and determine what characteristics of available AI tools make them potentially suitable for the process. The thesis will also touch upon what variables within these tools are relevant for the result, and finally choose one or multiple AI tools to proceed with to the trial project stage.

3.3.1 AI Evaluation

In order to determine the most suitable AI tool for the intended case, a set of criteria will be established and handful of chosen AI tools will be evaluated according to these criteria. To keep the AI generated images consistent, the same prompts will be used in all of the tools.

The criteria used for evaluating image-based AI tools are as follows.

1. Image quality: The quality of generated images is a crucial factor in evaluating image generation models. This includes factors such as image resolution, sharpness, and realism.

2. Diversity and novelty: The ability of a model to generate a diverse and novel set of images can indicate its creative potential. This relates directly to being able to use the AI generated images as inspiration.

3. Consistency and coherence: An image generation model should produce consistent and coherent images, meaning that the AI should consistently produce acceptable results.

4. Computational efficiency: The speed and resource usage of a model is an important factor, as this can impact its practical use.

5. Generalization: The ability of a model to generate images beyond its training data is important in evaluating its robustness and generalization.

6. User control: The level of user control over the generated images is a consideration. This includes control over factors such CFG, guidance scale and other quality parameters.

7. Robustness to input: The ability of a model to handle diverse and complex input, such as text or images, is a key factor in evaluating its practical use.

8. Accessibility and usability: The ease of use and accessibility of an image generation model is important. This means barriers of entry and how easy the UI is to interact with.

3.3.2 AI Selection

According to the list generated in the previous step, different AI tools will be tested and assigned an optimal spot in Boid's design process.

3.4 AI training

In order to better adapt current image generating AI tools, one of the goals of this thesis will be to create and optimize a model which focuses specifically on industrial design and creating imagery that is relevant to the design process. Since creating an AI model is a complicated undertaking, pre-existing tools and software will mostly be used to achieve this goal.

3.4.1 LoRA

LoRA stands for Low rank adaptation and is a method for fine-tuning Stable Diffusion models by providing the software with training images and associated image captions, similar how to Dreambooth operates. It allows the user to "bias" the Stable Diffusion Model towards the provided images. In this case, this software will be used to tailor Stable Diffusion towards industrial design imagery.

The benefits of LoRA over Dreambooth is the low requirements in terms of time and computational power. Training a model with LoRA can take a couple of hours, in comparison to days with other methods such as Dreambooth. [21]

3.4.2 Kohya WebUI

Kohya WebUI is a graphic user interface which allows for easy implementation of the Stable Diffusion training scripts created by the developer bmaltais. While it allows for a variety of different training methods, such as Dreambooth, LoRA training is the most relevant for this project. [22] [23]

3.5 Ideation

The ideation process for this project will be slightly different to a traditional industrial design product. Common techniques such as sketching, moodboards and brainstorming will be combined with photo synthesizing generative AI tools in order to further expand on the number of available concepts and ideas and will also aid in the process of further developing concepts.

3.5.1 Moodboard

A moodboard is a visual tool that helps to convey the desired aesthetic and style for a final product. It typically includes elements such as materials, colors, images, and text that are arranged in a collage format for easy viewing. By creating a mood board, designers can effectively communicate the concept behind their design and clarify details such as color choices, materials, and finish. In regard to this specific thesis, the moodboard might diverge a bit from more traditional approaches and include AI generated elements.

3.5.2 Brainstorming

Rapidly generating a wide variety of concepts, ideas, and solutions in a short amount of time without limitations is what the methodology of brainstorming is all about. During this method, any idea can be explored and expanded upon without fear of rejection, which means that ideas should not be criticized too harshly. The spontaneous nature of this process is its main advantage as it often leads to the creation of ideas and concepts that may not have been possible in more restrictive environments. These ideas can then be evaluated and may be incorporated into the final product, either partially or in their entirety.

3.5.3 Sketching

Sketching will serve as the primary method for visualizing and refining generated concepts. This is done in order to more easily be able to communicate the concepts to stakeholders and other relevant parties, and also to create a better understanding of the generated concepts. Sketches created for this project will be both physical and digital.

3.6 Specification of Requirements

The specification of requirements is a document generated from the information gained during the research phase or given by the client. A list of concrete and clear requirements provides the foundation for the project and creates guidance in terms of what the project is supposed to achieve without the need to start concept generation. Once concepts start to be generated, they are systematically compared to the set requirements in order to evaluate the viability of the concepts. [24]

3.7 Concept Selection

Concept selection will be done entirely in collaboration with the company in the case of this project, as they will serve as the client for the purpose of this thesis. This means that Boid will be providing feedback on presented concepts and ultimately decide which aspects and design elements that will be implemented in the final concept of the trial process.

3.8 3D Modeling

To be able to precisely represent the dimensions, proportions and design elements of the final product 3D Modelling will be used. This project specifically will use Rhinoceros 7.

3.9 Rendering

In order to accurately represent the final product of the trial project, several renders will be produced through the use of KeyShot. The aim of these is to accurately represent form and material of the final project and create presentable images that convey the design and functionality of the chosen concept in the best possible way.

4 Implementation and Results

4.1 Literature Study

4.1.1 Consumer reactions to AI design: Exploring consumer willingness to pay for AI-designed products.

The article defines AI as: "a system's ability to interpret external data correctly, to learn from such data, and to use those learnings to achieve specific goals and tasks through flexible adaptation."

Some are trying to use "AI designed" as a marketing tactic. AI can design products by predicting consumer demand and behaviour, reducing risk and cost in the innovation process. Which could have a large impact on the product design process.

But humans can more easily capture the emotional needs of customers, something which AI traditionally struggles with. AI is often considered more rational and logical when designing, which could equally be a strength and weakness as it fails to consider the emotional and human aspects of design. At the idea generation stage, for example, when confronted with large amounts of data, human innovators can be overwhelmed, whereas AI algorithms can make predictions and generate ideas that human experts may not detect. Humans always inherently have a level of bias when making creative decisions, which AI can aid with when it comes to screening ideas.

There is a strong relationship between AI and novelty to consumers. Higher levels of novelty can often lead to increased curiosity for the product and cause people to want to explore it. Thus, as general knowledge about AI increases, the novelty and customer curiosity on products labelled as "AI Designed" might decrease.

"*When consumer knowledge is low, consumer willingness to pay is higher for AI-designed products than for professional-designed products; curiosity mediates the path from the design source to the willingness to pay. However, when consumer knowledge is high, the willingness to pay for AI-designed products is attenuated; curiosity does not play a mediating role"*

The article confirms the theory that users are more willing to pay for AI-designed products. It also confirms that this is based on curiosity. This study excludes factors such as quality perception, symbolism, and design aesthetics, however. This basically means that a good number of factors that are very important to industrial design are not investigated.

The study was also able to verify that the more knowledgeable people are, they are less willing to pay for AI Design. The study also found that users are more willing to pay for AI design in utilitarian products, and more willing to pay for human designed hedonic products. [25]

4.1.2 In Search of Design Inspiration: A Semantic-Based Approach: Special Issue on Artificial Intelligence in Design

This article is part of the EU funded project TRENDS aimed at developing a software tool that supports inspirational stage of design. In this specific article, the effects on automotive design is explored.

The paper chooses a different approach to using AI in the industrial design process. Rather than using image generation, the researchers use a tool called OntoTag which is a semantic based image retrieval algorithm. Which means that rather than generating new images, the researchers use already existing images. OntoTag is built specifically for designers and uses algorithms and designer specific phrasing and language to index and retrieve the information specifically for designers.

Researchers found that designers often use specific phrases to "anchor" their searches for inspiration in a given domain, ex "cars" + futuristic + colorful.

They also found that the level of creativity in design is closely linked with the level of abstraction. Which allows the researchers to speculate on whether more "diffuse" AI imagery provides better inspiration, rather than fully generated images. This is because designers often take inspiration from data that is not directly related to the field being worked in.

The paper also touches upon the idea that individual style if often considered important to designers and artists alike, which means that there could be difficulties or a learning curve when working with AI as inspiration, as AI often provides very concrete images of potential concepts. The design process is highly personal, and AI might not be a "one size fits all" tool.

Designer may wish to retrieve images for inspiration representing abstract concepts rather than low-level descriptions. Basically: semantic based image retrieval.

In summary, AI can help in the very early stages of product development by creating tools that allow the designer to retrieve inspiration based on more abstract concepts. Basically, AI can help the user create moodboards and trendboards to fuel inspiration in the process. [26]

4.1.3 Explaining Artificial Intelligence Generation and Creativity

In order to understand creativity in relation to artificial intelligence, this article sets out to first understand what human creativity is. The report explains that human creativity generally works by association. By associating different, often unrelated concepts, humans are able to create novel concepts that often meet the criteria for being creative.

Creativity is often seen as an inherently human trait, but AI is starting to play a central role in the creative process, whether autonomously or as a tool for designers. Article aims to explain AI for creative fields.

The article find that the image generating artificial intelligence DALL-E 2 apparently meets the criteria for general creativity and goes on to explain that Creative AI is a special case since novelty is especially important. Creative AI is often set to extrapolate rather than interpolate, which means that they look beyond their training and "take inspiration" from it rather than meshing together a result from the dataset available to it. This is with the goal of combining "ingredients" that have never been combined before, with the goal of creating something new and novel.

The article also touches upon the need to build trust between human and AI and theorises that XAI (Explainable Artificial Intelligence) will play a large role in this endeavour. Due to the massive complexity of AI systems, most users do not know exactly how they function, or how they retrieve and utilize their data. This leads to uncertainty and potential distrust towards the results produced by artificial intelligence. [4]

4.1.4 The Quest for AI Creativity

This article from IBM details their experiences and findings regarding what creativity means, and how it relates to artificial intelligence

Image synthesizing AI is often built on generative models that work by mimicking the data it has been trained on. By adjusting the parameters or vectors you can get "brand new" results that are similar to the data that it has been trained on. Creativity still needs to be defined, it often relates to something being novel, unexpected and yet useful. And it is generally easy for AI to come up with something novel randomly. But it is very hard to come up with something that is novel, unexpected and useful

The article argues that you can coach an AI in the right direction with parameters, but also raises the question whether it can be taught to create without guidance, and whether it can understand what is objectively beautiful. The article goes on to explain that we can train AI into understanding what is beautiful, but having it create something that is considered beautiful from scratch might be difficult. Teaching computers to be creative is different from how humans learn to be creative.

IBM specifically then states that they are not trying to recreate the human mind, rather create systems that work alongside humans in order to aid and inspire for creativity and help people come up with more frequent ideas. AI can also help with more mundane tasks in the creative process. Such as looking through hours of footage or picking images.

While the article heavily discusses AI creativity, it also goes on to stress the importance of the "human soul/touch" in creative work. [27]

4.1.5 The Role of Artificial Intelligence in Achieving the Sustainable Development Goals

This article discusses the role that artificial intelligence might play in meeting the SDGs set up by the UN, and the possible implications it might have on sustainability, both positive and negative.

One of the major problems that AI is facing in association with the SDGs is the fact that information technology is set to use up to 20% of the earth's electricity by 2030. The datacentres required to run and maintain such advanced technology takes a heavy toll on the electricity usage. This, in turn, stresses the importance of finding and expanding on renewable energy sources to power our new artificial intelligences.

AI is often based on the needs and values of the country where it is being developed, meaning that it could cause clashes if deployed in other areas of the world where the culture and mindset might be vastly different.

An example where AI has been used to polarize is the social credit system deployed in China. Which analyses information of the populations lives and might have grave consequences. It

might also produce a larger gap between those who can afford to use AI and those who cannot afford it.

Since AI is inherently biased by the training material it receives, it might "unknowingly" be discriminating genders and minorities. It might also inherit social biases from the media it is trained on. AI might contribute to higher inequalities since technology often benefits the more highly educated. Meaning low to mid income countries might even fall further behind as they may not be able to afford the systems deployed by high-income countries. [28]

4.2 Evaluation of Available image-based AI

The Evaluation of the different models was done by creating a set of 3 prompts which was then run on each of the AI. The prompt was kept the same across all models for consistent evaluation. Each AI was allowed to generate a minimum of 4 images, which then served as the basis for the evaluation of the models.

The three prompts created to evaluate the different tools were:

1. "A futuristic and sleek small digital camera, with a simplistic and minimalistic design, Product photography, behance, pinterest design, light background"
2. "A tabletop dishwasher with a clean and modern design, soft curves, grey, black and white materials. octane render, 8k, bright background"
3. "A portable gaming console with a touch screen and forest green highlights, product design sketch, visible brushstrokes, greg Rutkowski"

The criteria on which the models were evaluated are the ones defined in 3.3.1.

4.2.1 Midjourney

Figure 2, Midjourney Images

1. Midjourney produces some of the best AI generated images currently. While the results may at times appear a bit "painterly"
2. Midjourney has been one of the most consistent in being able to produce diverse and novel ideas, often being able to create "new" concepts.
3. Midjourney's quality is consistent, and the images produced are almost always coherent.
4. Midjourney can be quite slow at times, depending on the load on the network and other factors.
5. Midjourney appear to be one of the best in terms of generating images that hold little to no resemblance to the images you might imagine it's been trained on.
6. User control is vast, If a bit complicated. It's able to take a variety of parameters to modify the end result.
7. Midjourney handles a variety of inputs and is often able to create usable results.
8. Midjourney runs through a command prompt interface through discord, which can be convoluted and difficult to use in some cases.

4.2.2 Stable Diffusion

Figure 3, Stable Diffusion Images

1. The quality of images can vary, but in general the results are good and usable. It does however fail in the third test. Resolution and aspect ratio is adjustable.
2. With manipulation of the CFG scale you can produce quite novel results with the trade-off of lower quality and vice versa. It doesn't like to stray form training material in some cases.
3. Consistency varies depending on the subject. In the example of the camera, a lot of generations had to be run in order to produce coherent images where the perspective and lens wasn't skewed.
4. Speed is the main advantage of local. Run on a Nvidia RTX 3080, it produces results faster than any other of the tested options.
5. The model of stable diffusion run for these tests tends to have some issues when it comes to producing "new" results. Using an image input and setting the CFG scale high can alleviate these problems slightly.
6. Local stable diffusion offers by far the most control of input and output with a variety of different parameters.
7. Handles both text and image input well.
8. While the UI offers a lot of options, it is easy to navigate and use without much prior experience.

4.2.3 DALLE – 2

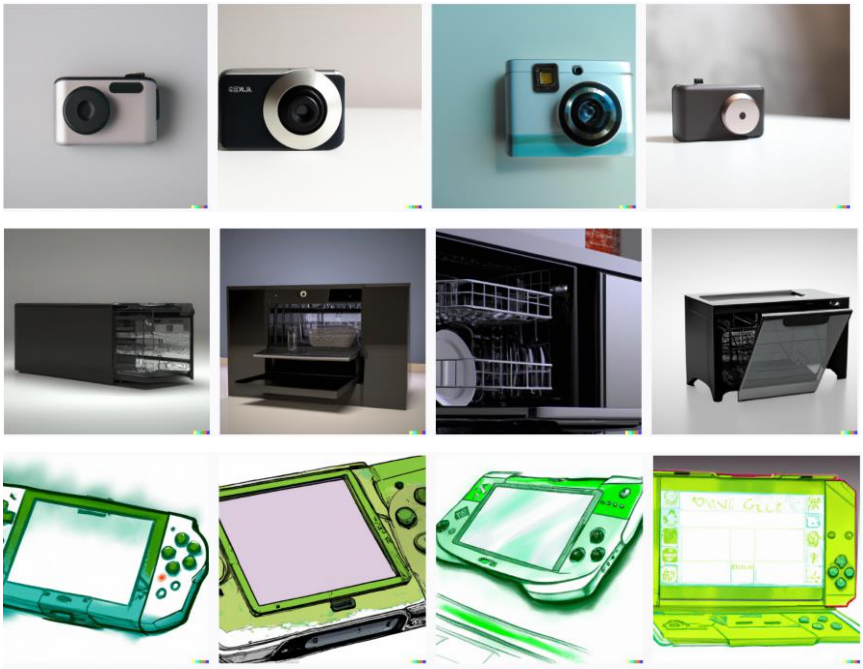

Figure 4, DALL-E 2 Images

1. The image quality varies heavily from prompt to prompt. It often leans towards more "photographic" results, but often creates broken images with elements that overlap and make little sense. It also struggles when asked to produce sketches.
2. While DALLE has proven capable of creating interesting shapes, it's lacking in terms of detail when creating concepts for design
3. Consistency is lacking and the coherence of images in these cases vary wildly. With some being great images while order is bland or unreadable at times.
4. DALLE is quite fast, with no real major complaints.
5. DALLE seems to struggle in creating design concepts that create "new" features and inspiration
6. User control is good; the UI is good, and it provides the user with control over the guidance scale.
7. DALLE takes both text and image input.
8. Since DALLE runs on its own website, the UI is tailored for it and allows for easy adjustments.

4.2.4 Lexica

Figure 5, Lexica Images

1. Lexica is one of the top contenders for image quality and produces a unique style of images most of the time.
2. While the images are of high quality, novelty can sometimes be a bit lacking.
3. Lexica produces incredibly consistent, high-quality results that almost always form a coherent image without major artifacts and errors.
4. Lexica works very fast, no complaints regarding the speed of generation.
5. Lexica appears to be a bit held back by its training material in some cases, but it generally doesn't prove to be a major issue.
6. Provides the user with control of what model to use and the guidance scale. Also has resolution and aspect ratio options.
7. Does not take image input but handles text input very well.

Lexica uses its own website with very simple UI that is easy to use even for beginners.

8. Lexica runs from its own website and provides the user with control over the prompt, negative prompt, resolution, and guidance scale.

4.2.5 Craiyon

Figure 6, Craiyon Images

1. Quality of images can be quite lacklustre, resolution quite small.

2. While the images generated are quite simple, it often provides a good amount of variety since it produces 9 images per prompt. These 9 often vary a lot in form and design.

3. Consistency is quite low, as it seems to be very dependent on the prompt, it struggles with certain styles and products. See test 2 for example.

4. On the lower end of the scale in terms of speed, but nothing too dramatic.

5. Craiyon seems to struggle with producing generalized images that remain coherent in certain areas. See test 2 and 3.

6. Craiyon is very simple in terms of control and only offers control of the prompt. No guidance scale or resolution.

7. Craiyon only takes text input.

8. Extremely easy to use as there is essentially only a textbox.

4.2.6 AI Selection

Based mainly on input from Boid and the conducted evaluations, Stable Diffusion was chosen to be the main tool for the development of the process. Stable Diffusion was chosen due to it being a free software and its ability to be ran locally without the need for advanced computing hardware and data centers. It also has the ability to be constantly improved with plugins and exact manipulation of the variables that affect image generation. This gives the designer a much larger degree of control over the process and the produced results.

4.2.7 Design Process and AI

The chosen approach to the development of the process in this case was to utilize artificial intelligence as a tool, rather than a full replacement for the designer in order to test and explore the impact of the individual designer on the final product and what changes a designer must make to an AI generated concept in order to generate a viable final product.

By looking at the literature study we can also see that Ai tools often possess an inherent level of bias, which can hopefully by counteracted with intervention from the actual designer.

4.3 Process Development

4.3.1 Process Outline

The first draft for the process took a "maximalist" approach to the use of AI tools and was created as a way to explore the full potential of artificial intelligence in the workflow. This first draft can be seen in figure 7.

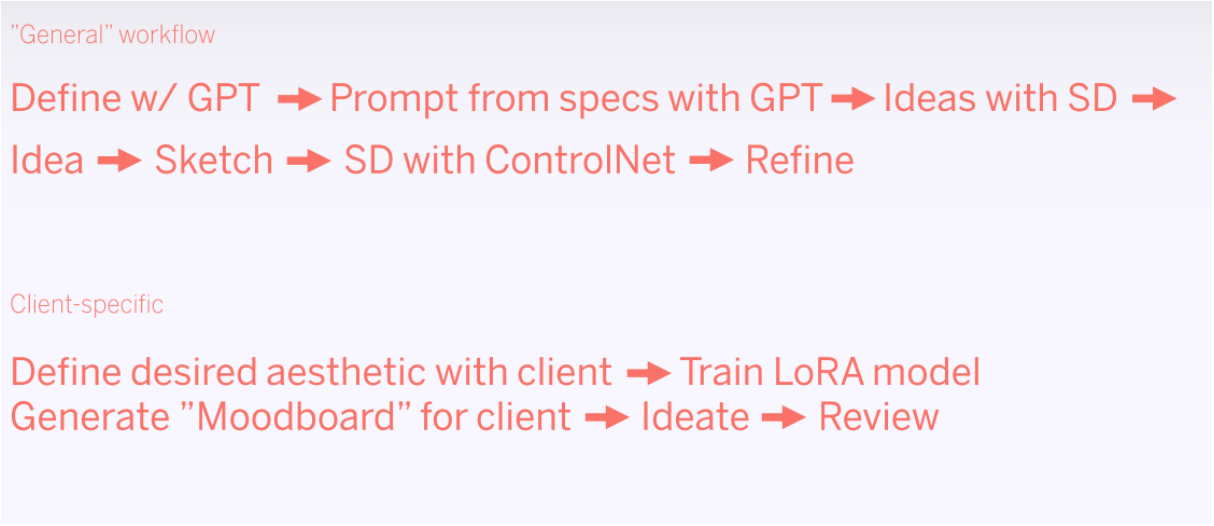

Figure 7, Initial Process Draft

After further considerations and discussions with Boid, this process was deemed flawed, as it completely neglects specifications and requirements for clients, ideation loops and manual refinement.

Following this feedback, the process went back to the drawing board to be refined. It was decided that the process would cater to the strength of the chosen and available AI tools, which was ideation. By using design thinking as a base, discussions were held with the goal of finding the ideal tools for each part of the process. These processes were then briefly tested alongside their respective tools for each individual part of the process to find whether it was feasible. The idea then became to split up the process up into two main phases, the first being defining the project and generating the initial images, and then secondly refining the information and images into a tangible concept which would then be refined into a final concept. To reflect the fact that the process is non-linear and supports iteration and ideation, an iteration loop was added between these two main sections. The resulting process can be seen and is explained further in 4.5.

4.3.2 AI Training

The goal of the AI training was to produce a model that skews the results of Stable Diffusion towards the aspects of product design. Stable Diffusion at its core generally struggles with creating appealing designs and lacks an understanding of surfaces and design elements. With the help of LoRA, three models were created in an attempt to remedy this. Images were gathered from the internet with the intention of representing a wide variety of design elements, forms, styles, and materials. The material was manually assembled according to the tastes of the author and focused on modern and contemporary design. In order to be able to invoke all of the training material at once some special tags were added to each image. For general product images, all of the material was tagged with *"HUID2"* or equivalent phrase, depending on the model. This allows us, during the prompting, to pull from all of the trained images. And all of the materials were tagged with *"HUIDMAT"* coupled with a specific keyword. In the case of black anodized aluminium that keyword would be *"KeyAnodizedBlack"*.

All images were cropped to 512x512 pixels and were then given individual captions in order to give the AI an understanding of what each image depicted, allowing for elements of these images to be used for image generation. A selection of the images used to train the models can be seen in figure 8.

Figure 8, Selection of AI Training Material

4.3.2.1 HUGTRTEST1

HGTRTEST1 was the first test model created. The goal of this model was to determine whether AI training was a viable approach to solve the issue of Stable Diffusion lacking an understanding of design.
22 images were gathered and prepared according to 4.2.2. Each image was given 100 training steps and the total training took around 1 hour for this model.
The results of the model were promising, as it showed an immediate improvement in Stable Diffusions ability to recognize and implement design elements such as surfaces, shapes, and split lines. The model did however struggle with creating complete products, often just combining different shapes and elements that would result in unintelligible results. It also struggled with cropping images and reproducing fine detail. The model struggled mostly due to the small dataset, which was remedied in the next model. Example images from the model can be seen in figure 9.

Figure 9, HUGTRTEST1 Sample

4.3.2.2 HUID1

HUID1 was an attempt to improve the general performance of the model and address the issues that stemmed from the small dataset utilized in HUGTRTEST1. The dataset was increased from 22 to 142 images. Apart from that the training process remained the same with 100 training steps and captioned images. The total training time for this model ended up being around 2.5 hours. This model proved to be a clear improvement over HGTRTEST1 as it was able to easily and consistently produce coherent images that looked like product renders. It is able to produce clear distinctions between product parts and integrate different design elements.
It did however struggle with fine detail such as buttons and dials and lacked a sense for how these different functions should be placed and integrated into the image. Example images from the model can be seen in figure 10.

Figure 10, HUID1 Sample Images

4.3.2.3 HUID2

HUID2 was an attempt to create a much more powerful and final model capable of re-creating and implementing a larger variety of design elements than before and increase the model's capabilities of incorporating different materials and textures. In order to achieve this, the dataset was massively increased to 500 images of products, textures and materials. The training process was the same with slight modifications to the captioning of the images to be able to invoke specific materials and textures during the generation of images.
100 training steps per image resulted in a total training time close to 7 hours for HUID2. The model is able to produce even more consistently coherent results and creates a larger variety in design elements, which is great for inspiration but also means that producing specific desired results might prove more difficult. It also trades interesting smaller details for a more coherent image. But its ability to render out fine detail outclasses the abilities of HUID1. Example images from the model can be seen in figure 11.

Figure 11, HUID2 Sample Images

4.3.3 Prompt Creation

To create the best results from Stable Diffusion, prompts need to be structured in a specific way, and consider a few factors. Prompts in stable diffusion are written in a priority order, which means that the image generation will prioritize words based on the order that they are entered. By making sure that the object we want to generate is early in the sequence, we maximize our chances of getting usable results. So a good start for a prompt to generate a camera could be: *"A modern camera with lens attached"*.

It is also possible to either bypass or enhance the priority order by using brackets. The number of brackets determine the priority. Since the camera is the main priority in this prompt, we use: *((A modern camera with lens attached))* to further define it.

Stable Diffusion generally produces better results the more detailed the prompt it, so adding a variety of attributes for it to include will often result in images with higher levels of detail and fidelity. So in this case, we add the following words to the prompt: *"with shutter button, with charging dock for file transfer and charging of the device, Sony, compact and lightweight"*

After this we define the style of the image, since we want the generated images to be product renders we add keywords to ensure this. Keywords here are quite flexible, but by using words often related with quality images such as "8k" we ensure more consistent quality. The keywords chosen in this case are: "*product render, 8k , sharp focus, white background"*

Since we will be using a custom trained model of Stable Diffusion specific phrasing is used. In order to load the model the phrase *"<lora:HUID2:1>"* is required. The number after the colon determines the weight of the model. And to invoke all of the training material, the phrase *"HUID2"* is also used in the prompt. By putting all of this together we generate a prompt like this:

"((A modern camera with lens attached)), with shutter button, with charging dock for file transfer and charging of the device, sony, compact and lightweight,HUID2, matte, (HUID2), product render, 8k, <lora:HUID2:0.8>, sharp focus, white background"

In order to remove potentially undesirable attributes from appearing in the images we also use a negative prompt. These are generally much simpler and takes the form of a list with words for the AI to avoid. All generations during this thesis uses the same set of negative prompts which are:

"deformed, bad proportions, unrealistic, fantasy, out of frame, out of focus, cropped, bad product, not centered, incomplete, sketch, drawing, ugly, overexposed, underexposed, unrealistic, wood"

4.4 Trial Project

In collaboration with Boid, a specific product was chosen to evaluate the process on. The product chosen was a mirrorless camera. The goal of the trial project was to verify that the process works as intended and identify areas where potential refinement might be needed.

4.5 Resulting Process, AI Industrial Design Workflow

The process is developed in collaboration with Boid, having been tailored to their feedback and experiences. The process is built on this basis along with other accepted methodologies and theories such as Design Thinking. The process itself puts a lot of focus on the ideation stage and onwards of the process, as this is where the impact of AI tools is considered to be the most relevant given the existing Boid process and available AI tools. The process is split up into six steps but it, as many design processes, is non-linear and includes a lot of iteration loops and reflections for improvements and changes. An easy to read graphical representation has also been produced and is available in figure 12. The six steps are as follows.

4.5.1 Define

This stage sets the foundation for the rest of the process. It is very reminiscent of design thinking's empathize and define stages. This is where we talk with the client and the users and gather the required information needed. This is also where we try to get answers to questions such as what the requirements are, what aesthetic style the client wants and what products are already on the market. With this information in mind, we can start utilizing AI tools. With the help of Kohya WebUI and LoRa models, we can train a personalized image generation model that is tailored to the defined project. If this training path is chosen, the model could serve as the basis for the following steps.

4.5.2 Prompt

The Prompt stage is where the utilization of AI tools really starts. Using the project description generated in the previous stage we can start ideation. By creating prompts that accurately reflect what the client and user wants, we can produce images in Stable Diffusion. The goal of creating these images is to gather inspiration and get a sense of what the defined product might look like. To speed up the process in this stage, previously created prompt templates can be utilized to speed up the process. Since prompts often have a lot of overlap and in the case of product design often have a lot of prompts in common.

4.5.3 Evaluate

With images generated from the Prompt stage, we can start to evaluate these images. By using a software called Breadboard, tagging and categorization of the images can be sped up significantly. Remove images that does not represent relevant attributes and design elements and tag the desired elements accordingly. These images will serve as inspiration and as a personalized moodboard for the product in question. It is also important to actively consider is these design elements are actually feasible to design and manufacture. We will return to this stage to gather more inspiration as the ideas and concepts are refined.

4.5.4 Iterate

The Iterate stage serves as an intermediary between the Evaluate and Refine stages. The main purposes of this stage are to verify, iterate, test and validate the findings from the Evaluate and Refine stages. The other main purpose of this stage is to incorporate client feedback into the project to ensure that the project stays on the right track. By placing this early in the process, we can ensure that the needs and wishes of the client are aligned with and reduce the risk of having to make changes later on in the process.

4.5.5 Refine

With our AI generated images organized, the process of creating and refining the concepts can start. Here we will create sketches and/or rudimentary 3D-models to input into Stable Diffusion with the help of ControlNet. This will help in further exploring the concepts that might be interesting, by retaining the shape and lines of the proposed concepts. It can also give the designer a head start in regards to the CMF process, as they can try out a variety of materials before deciding on what might be used. This stage is also a good place to use the rudimentary 3D models to evaluate ergonomics and shape. By refining these aspects in this stage, it lowers project risk and allows for iteration and improvement on these aspects if needed. Using the information learned from this stage along with client and user feedback, we can loop back to the Evaluate stage to further iterate, verify and validate the findings.

4.5.6 Clarify

In this stage of the process the final tweaks are made. This is where the final sketches would be made and refinements to the concepts and generated images done. The objective of this stage is to get the concepts ready for presentation to the client. If the client approves the concept the process moves on to its final stage.

4.5.7 Finalize

With the concept approved, the focus switches to finalizing the project. This means making the CAD-models, renders and potential physical prototypes. At this stage of the project, all major issues should have already been resolved during the Evaluate, Iterate and Refine stages, which means that this part of the process should ideally involve minimal chances and iteration. While working in CAD, the designer can use Stable Diffusion with ControlNet to try out different material choices in order to finalize the CMF specifications of the product.

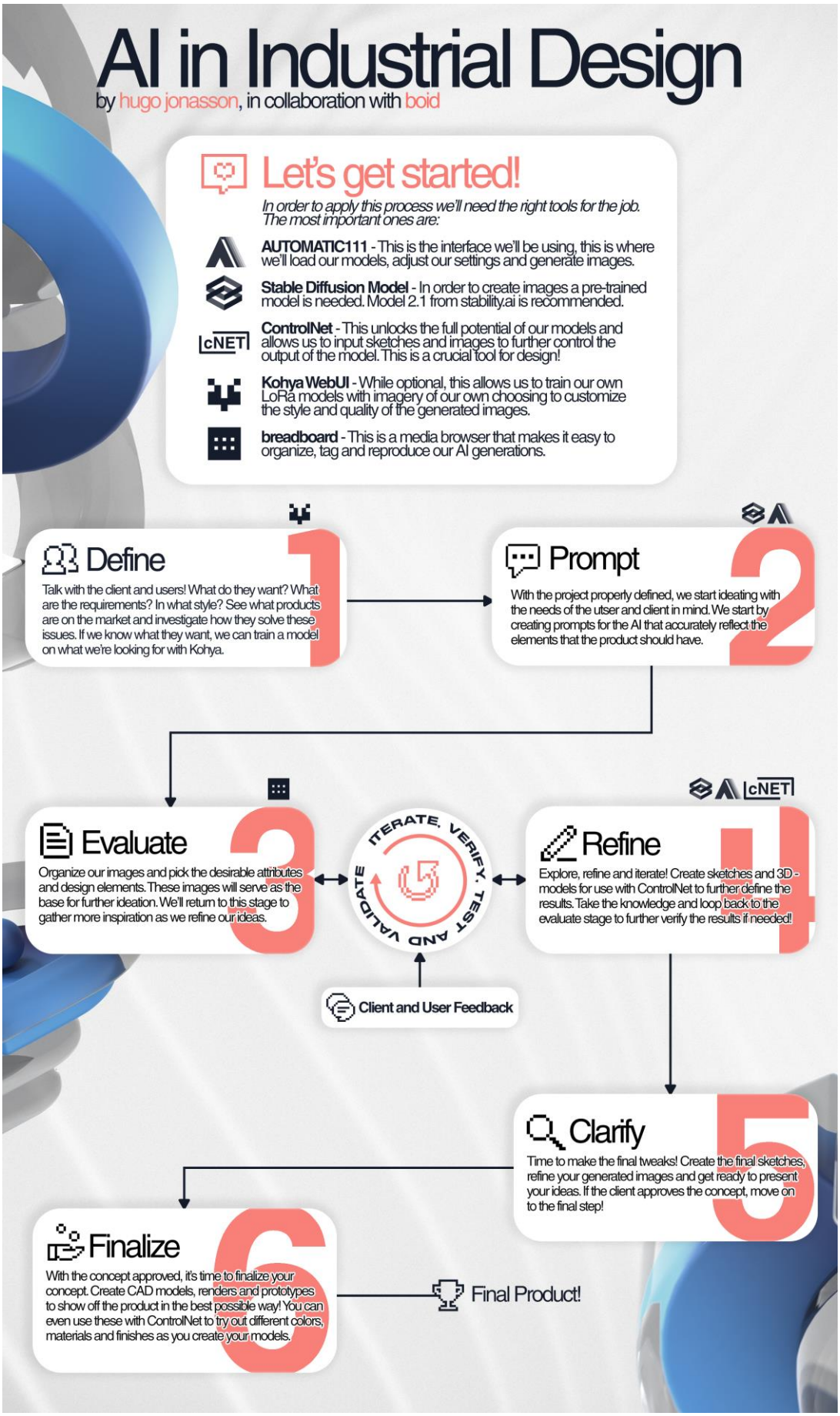

Figure 12, Developed Process

4.6 Trial Project Implementation

4.6.1 Define

In order to fit the trial project into the defined timeframe, the define stage was shortened, and the research done was sped up. The specifications for the product were decided on in collaboration with Boid and created the foundation for the prompting process. The specifications were derived from currently existing cameras on the market, along with the combined experiences in photography by the author and Boid.
It was decided that that the trial product should be a camera for Sony. The specifications are presented in table 1.

It was also decided that this project would utilize all three models created for this thesis, which means that HGTRTEST1, HUID1 and HUID2 were all used, with HUID2 seeing the most utilization throughout the process.

Table 1, Concept Specifications.

Full Frame 35mm sensor	Rear Screen	Rear Main Dial
Rear Thumb Dial	Shutter Button	Ergonomic Grip
Function Buttons	Custom Setting Buttons	Thread Mount
Solid Metal Frame	Medium size form-factor	Thin Body
Sony FE Mount	Interchangeable Lenses	SD Card Slot
Flash	Built in AI filters	LIDAR Sensor

4.6.2 Prompt

The process for finding the prompt is described in 4.3.3 along with some variations. The prompts used are presented in table 2.

Table 2, Stable Diffusion Prompt

"((A modern camera with lens attached)), with shutter button, with charging dock for file transfer and charging of the device, sony, compact and lightweight,HUID2, matte, (HUID2), product render, 8k, <lora:HUID2:0.8>, sharp focus, white background"
"((A modern camera with lens attached)), sony, compact and lightweight,HUID2, black aluminium, led, device (HUID2), product render, 8k, <lora:HUID2:0.8>, sharp focus, white background"

In conjunction with these, the set of negative prompts previously defined were also utilized.

Table 3, Negative prompts.

"deformed, bad proportions, unrealistic, fantasy, out of frame, out of focus, cropped, bad product, not centered, incomplete, sketch, drawing, ugly, overexposed, underexposed, unrealistic, wood"

4.6.3 Evaluate I

In the first evaluate stage, images were generated with and without sketches, using the prompts detailed in the previous section. The sketches ranged from rough outlines to fully defined sketches. Example of these sketches are presented in figure 13 and 14. The idea behind this was to test how ControlNet handles varying levels of detail in sketches, and how fast the process could potentially be by using rudimentary sketches to generate ideas. The generated images were then categorized based on their relevancy to their project, as there was a fair amount of unintelligible images produced by the AI. These have been excluded from the report. The chosen images for this stage are shown in figure 15 and 16.

Figure 13, Sketches Example

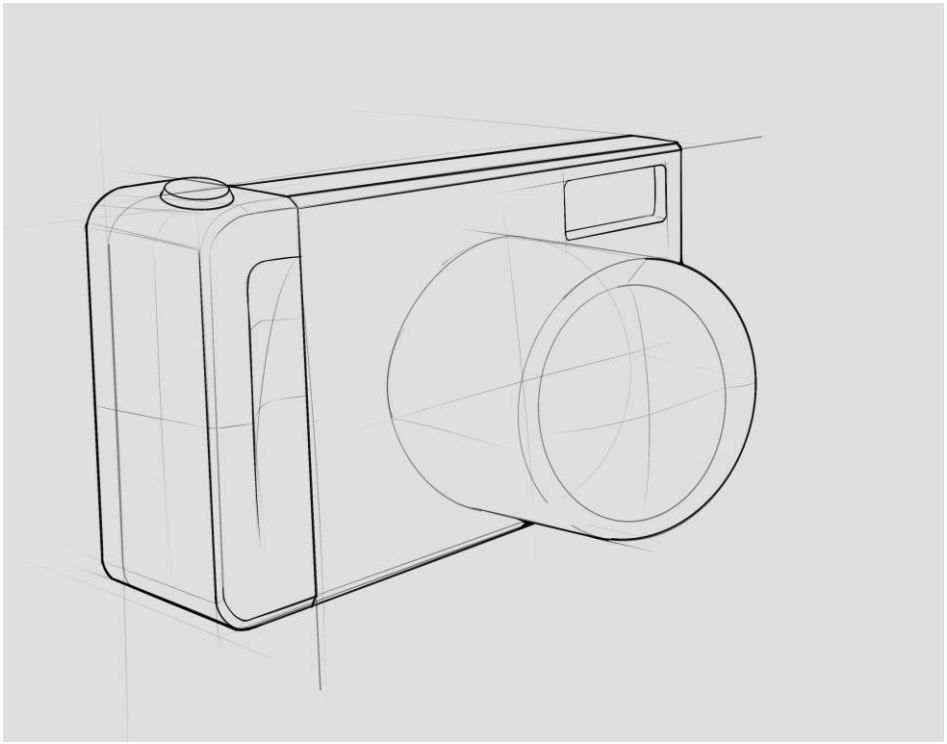

Figure 14, Sketch Example 2

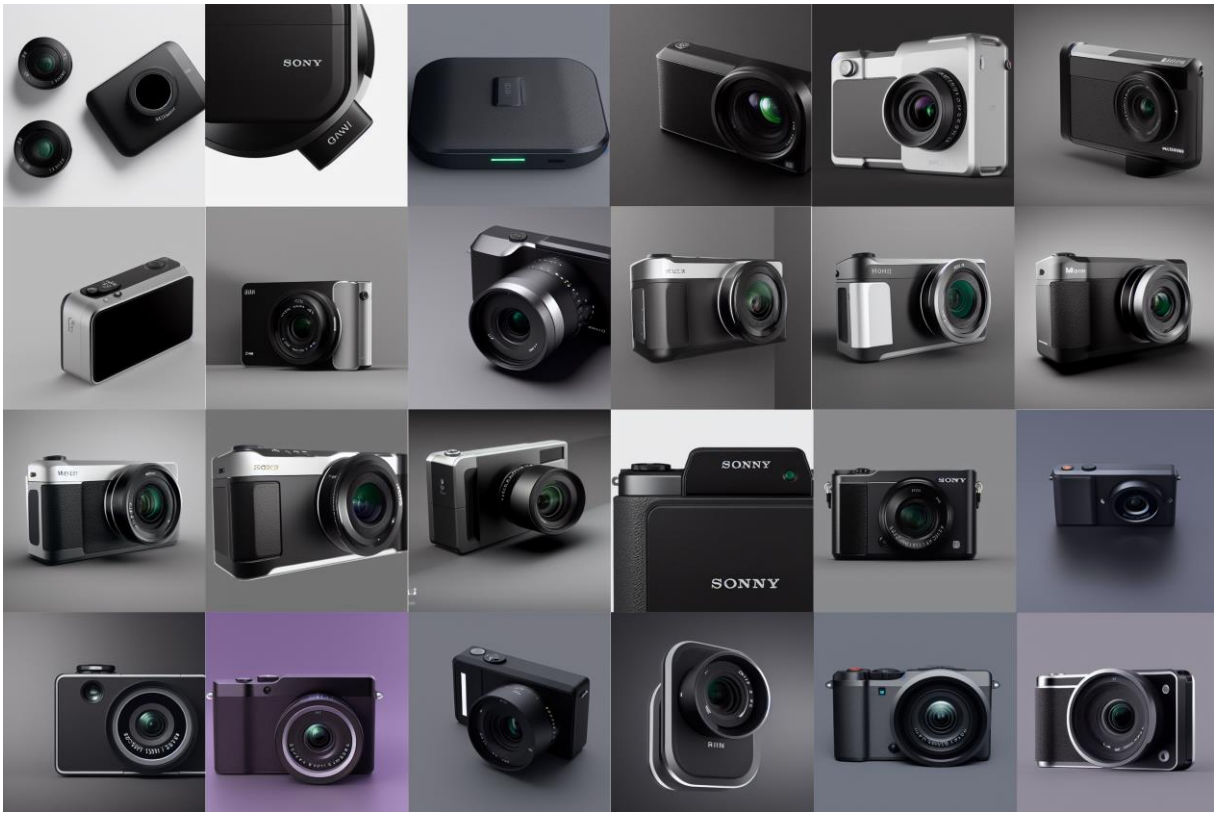

Figure 15, Evaluate 1, Generated Images

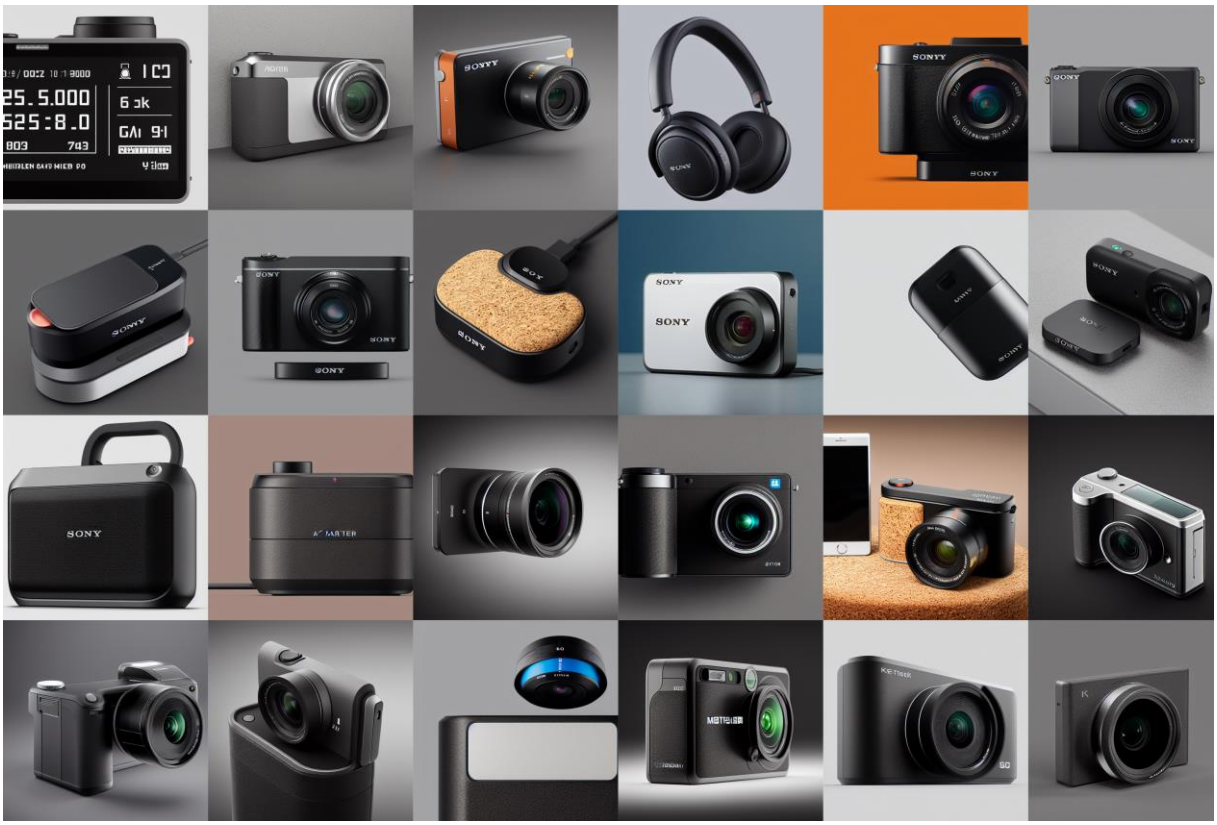

Figure 16, Evealuate 1, Generated Images 2

4.6.4 Iterate

The sketches and generated images were shown to the designers at Boid, who provided useful feedback to the project. While the generated images and sketches did utilize the AI, they believed that the product itself could take on a less conventional approach in order to emphasize the fact that it has been designed in collaboration with AI, rather than looking like a more standard camera. With this feedback in mind the work continued by finding more uncommon form-factors and functionality, which would be fed back into the AI to generate more inspiration for the next iteration of the camera.

While the AI did produce a lot of images that could provide the project with a lot of design inspiration, it became quite clear early on that the AI is often unable to take the functionality of the function into account. Which in this case refers to ergonomics, button layout and placement, and dials. In order to make up for this shortcoming of the AI, a “function-board” was created to ease the process of keeping track of all the functionality that needed to be included along with examples on how it could be implemented. This board can be seen in figure 17.

Figure 17, Function Board

4.6.5 Evaluate 2

Show chosen images along with the sketches. Show images inspiration was taken from.

With the feedback from Boid in mind along with the functions needed for the product, work continued with exploration of different shapes, design elements and form factors. By creating a number of loose sketches that represented these ideas, ControlNET could be utilized to generate images from the sketches. These sketches are shown in figure 18 and 19. From there the process of evaluating the generations, creating sketches and feeding them back into the AI once again continued until a loose idea of the final concept had been settled on. The AI generations selected for this stage can be seen in figure 20.

Figure 18, Concept Sketches for ControlNet

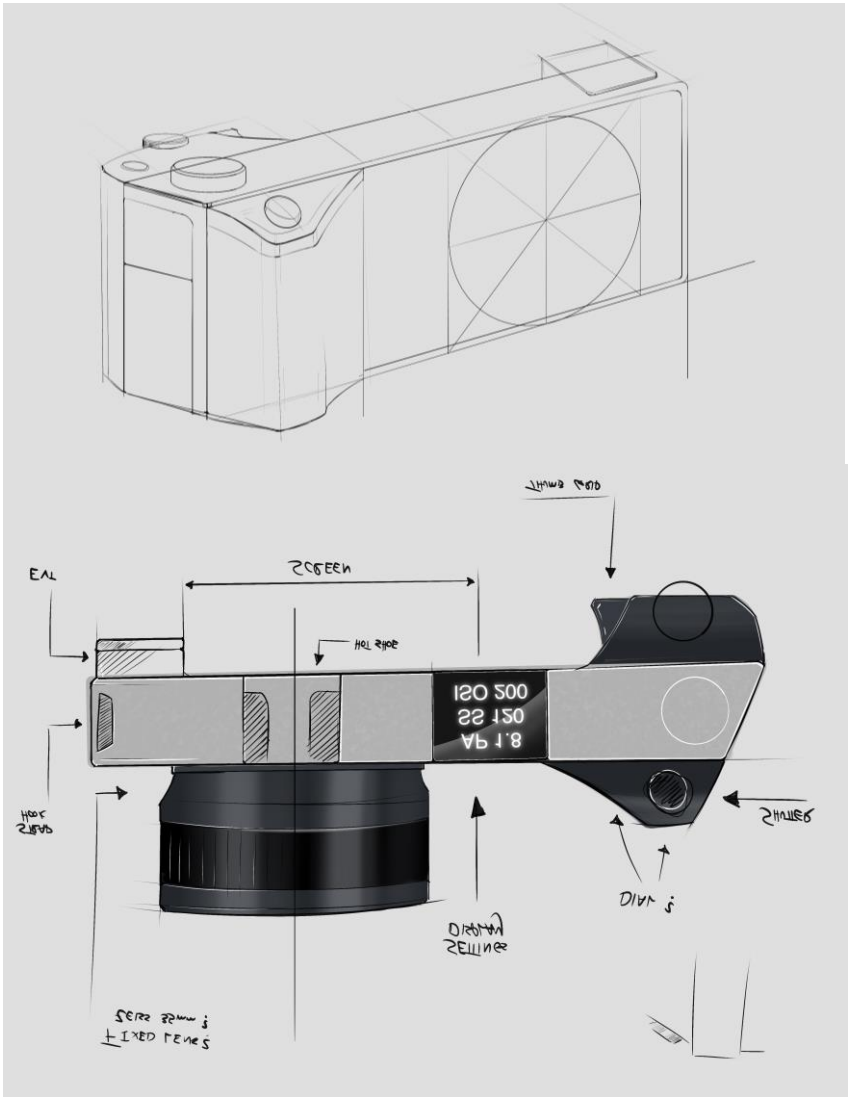

Figure 19, Concept Sketches for ControlNet 2

Figure 20, Selected AI generations, Evaluate 2

4.6.6 Refine

These ideas were then presented to Boid, and in collaboration with their industrial designer, the idea of the final concept was settled on. This was done by selecting design elements from the generated images and combining these. The selected inspiration and design elements can be seen in figure 21 and 22. These were then combined with the form factor and shape that was decided on in Evaluate 2. It was decided that this concept would be refined and realized in CAD, rather than through a final sketch. 3D prints were also created to verify the shape and ergonomics of the concept, which can be seen in figure 23.

Figure 21, Refine Chosen Elements

Figure 22, Refine Chosen Elements 2

Figure 23, Refine Ergonomic Evaluation Prints

4.6.7 Clarify

By utilizing the design elements and functions that were chosen with the help of Boid along with the information gleaned from the ergonomic testing and verification, work started on creating a 3D representation of a concept camera in CAD. The chosen tool for this stage of the process was Rhino 7, and the final model of the concept is presented in figure 24 below.

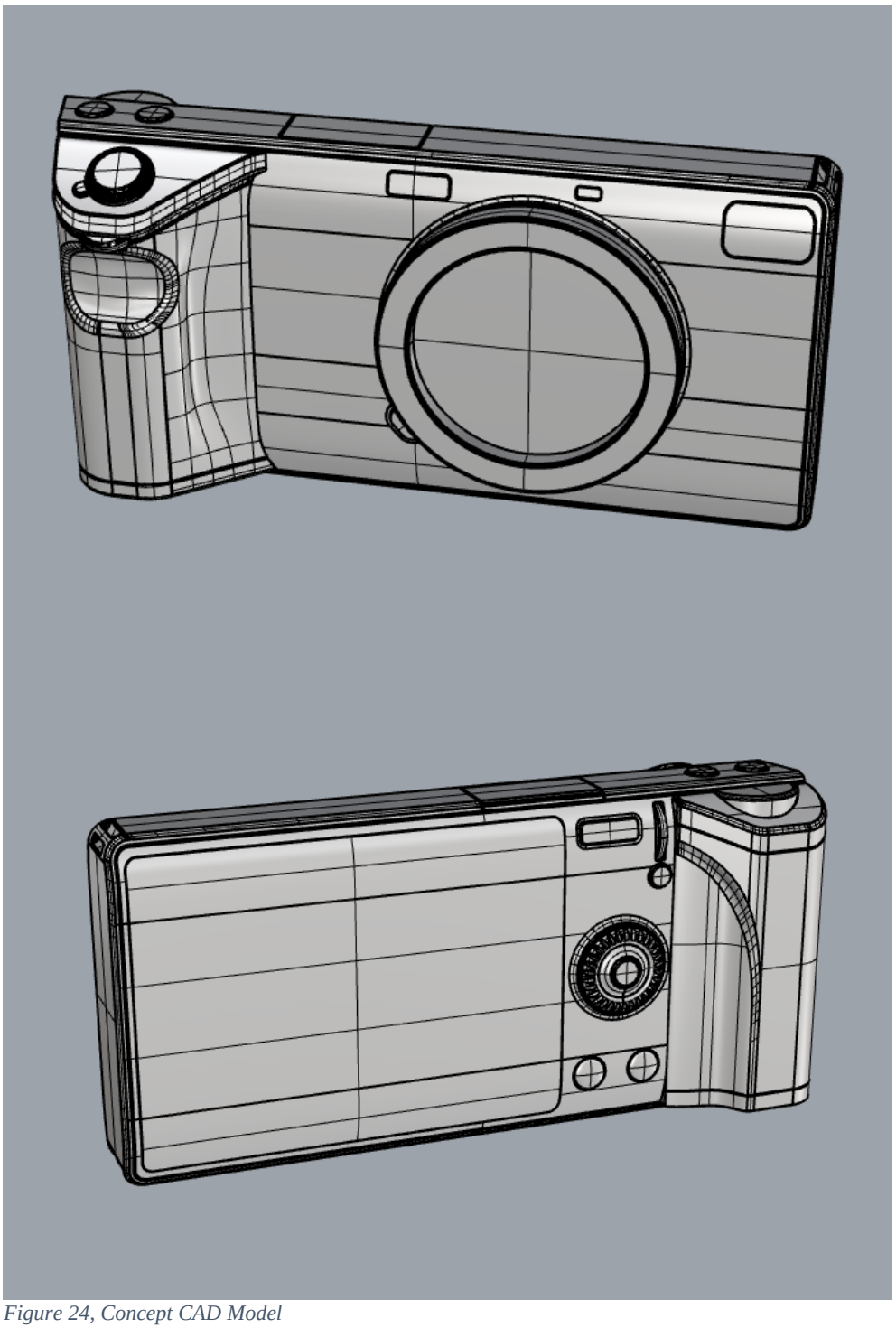

Figure 24, Concept CAD Model

4.6.8 Finalize

In order to fully represent the chosen materials, finish and functionality, renders and animations. were done in Keyshot. The goal of these is to accurately represent the concept in a realistic manner. The final renders are presented in figures 25 to 29.

Figure 25, Final Render 1

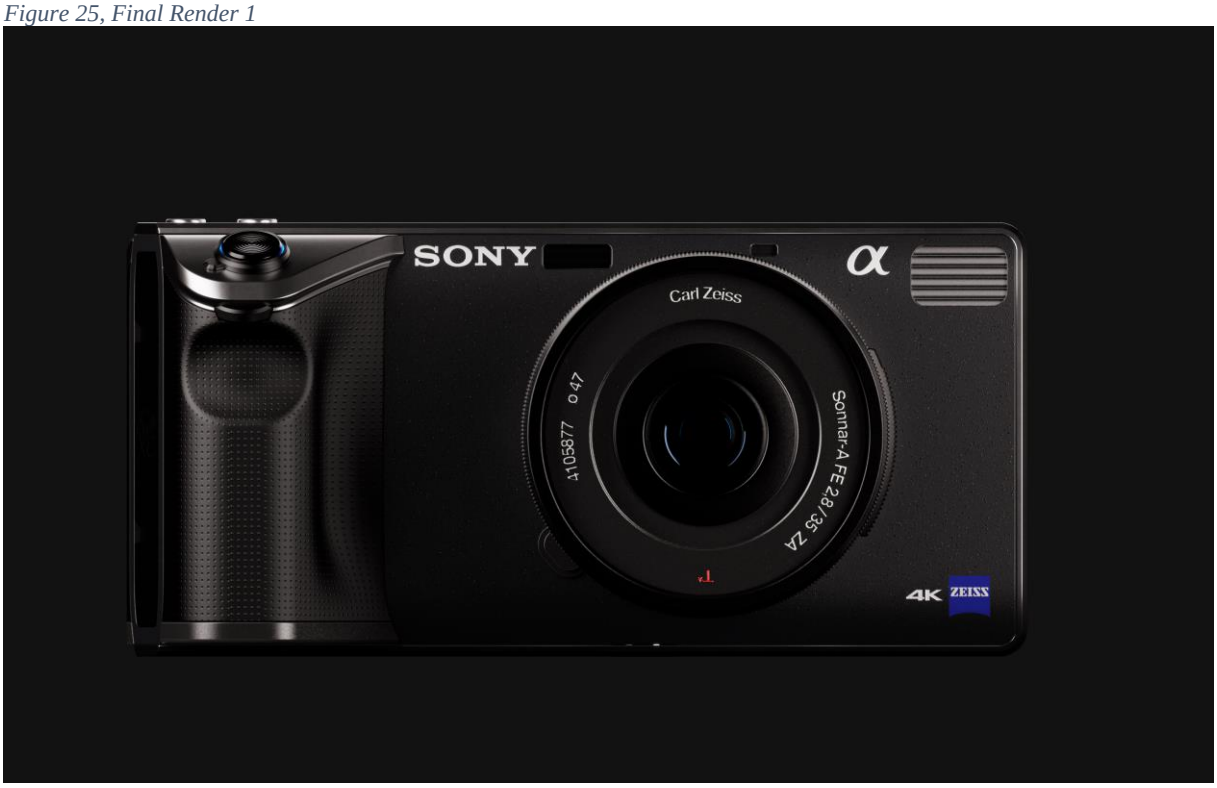

Figure 26, Final Render 2

Figure 27, Final Render 3

Figure 28, Final Render 4

Figure 29, Final Render 5

5 Conclusion and discussion

5.1 Further Process Development

The processes created during the course of this thesis is specifically focused on the tools that have been selected, which means that it does not take into consideration the further developments that have happened during the course of the project. Generative artificial intelligence is a rapidly expanding and developing field, which means that as this project has progressed, more and more potential tools have become available and not been considered. A good example at the time of writing is the release of ChatGPT 4 and the updated Midjourney 4, which boasts incredible image generation capabilities with high levels of fidelity and detail in comparison to the Stable Diffusion model utilized in this thesis. While this was an acknowledged risk of the thesis from the beginning, it also means that the processes created here will have to adapt and be updated in the future in order to stay relevant with regards to the releases of new and superior tools.

The trial of the process is also very condensed due to the time limitations of the thesis, which means that it has not been tested on a fully realistic project which can span months or even years. The time devoted to each of the stages are reduced dramatically in this trial, which means that the full effects of the process cannot be evaluated to its full potential. The stages that would benefit particularly from more time in this case are the Define and Clarify stages. In order to lend full legitimacy to the proposed process, it would have to be tested in a full project where the time is available to fully conduct each individual stage to its full extent.

A potential limitation on the process is the fact that it relies on the fact that the designer has to be relatively well-versed in prompt creation, as the results of the prompt and subsequent stages rely heavily on the relevance and quality of the generated images. Another potential problem stemming from generated images is the sheer volume of images produced. During the course of this thesis just over 3000 images were produced for the design process. Managing all of these images, even with dedicated tools, could prove an issue in more expansive and longer projects.

5.2 Further Product Development

The product developed as part of the trial of the process in this thesis is purely conceptual. Which means that it would have to undergo significant further development in order to become a viable product. While attention has been paid to the functionality and ergonomics of the concept, it does not consider manufacturing and cost constraints that would need to be taken into account.

5.3 Ethics and Artificial Intelligence

During the course of this report, I've become familiar with AI tools and the controversies that surround them currently. A clear problem with current AI models is the lack of transparency. There is no way to see what material was used to train an AI model, which applies in this case as well. I do not intend to use the model developed for this specific thesis for any financial gain, but the way that the material used to train it was gathered might be seen as a moral grey area. Since all material of the thesis were collected without the consent of their creators I feel like it would be ethically wrong to try to derive any sort of financial gain from any AI models.

This does not however stop other actors in the AI space from doing it, as legally there is nothing preventing them from doing so. This calls into the question of the future of AI generated imagery, and only time will tell how society and its laws evolve to meet the development of AI tools.

Another area which I feel warrants further exploration is how Ai tools affect human creativity. While AI is able to generate an infinite number of variations of a design, I feel like it lacks the ability to truly innovate within a given space. During the course of the concept development phase I found myself feeling stifled and restricted by the AI at times as I tunnel-visioned on the images that were generated by the AI, which locked me out of exploring concepts that were outside of the generated material.

5.4 Review of Goals and Research Questions

The report set out a number of goals in the beginning of the process, all of which have been achieved to varying degrees. The only objective which has only been lightly touched on is the ethical complications of using AI tools in the research process.

The first research question was *"How can the design process be altered to take benefit from the use of AI?"* which has been answered through developing a new process that takes advantage of the chosen AI tools. It is worth noting that the specific process developed in this report is only one answer to that question, as I would imagine there are near infinite ways to approach the way AI is used in the process not touched upon in this report.

The second research question was "*What changes must a human make to an AI generated concept in order to create a viable product?*" which has been answered through the trial of the process. To summarize, it was found that AI does not take into functionality and human factors such as usability and ergonomics. Therefore, the human designer still needs to do significant work on the product in order to fully realize it into a functional product fit for human use.

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7 Attachments

7.1 Final Renders

SONY
Carl Zeiss
Sonnar T* FE 2.8/35 ZA
SD XC
FULL-FRAME Exmor CMOS IMAGE SENSOR

SONY
FE 28/35
MENU

SONY

SONY
Carl Zeiss
SAMYANG AF 2.8/35 2A