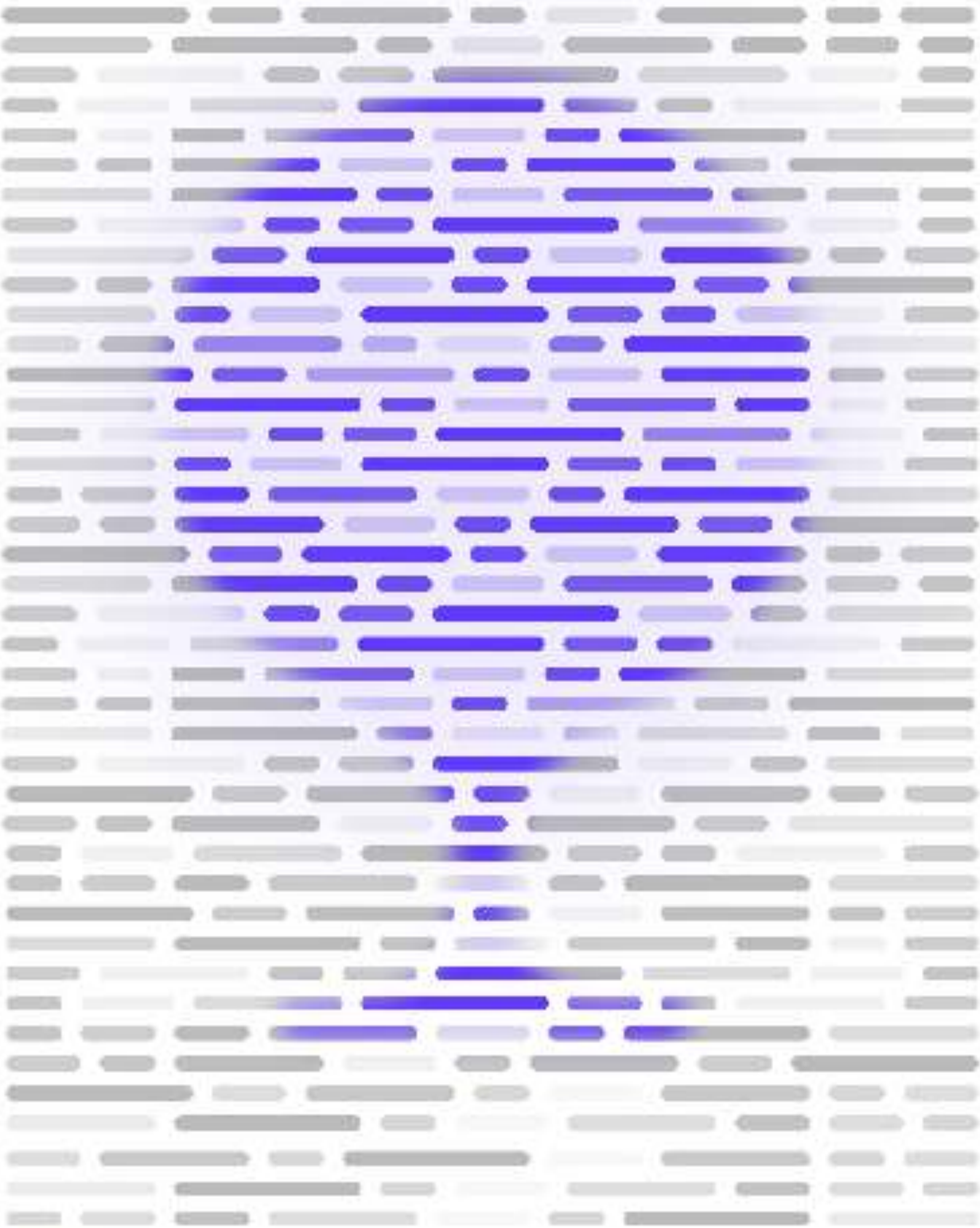


Dinuo Liao 02/2023 - 07/2023 TU Delft Design for Interaction

Generative AI & Tangible Products

Human-AI Design of 3D-printed Lamps

Welcome to the Journey from Text Descriptions to Functional Devices.

Chair Derek Lomas
Mentor Cehao Yu

Author Dinuo Liao

Figure 1. From texts to functional devices

"a symmetric opal glass lamp with very smooth curvatures suitable for 3D printing."

Generated Image

Real Image

Figure 2. From texts to functional devices

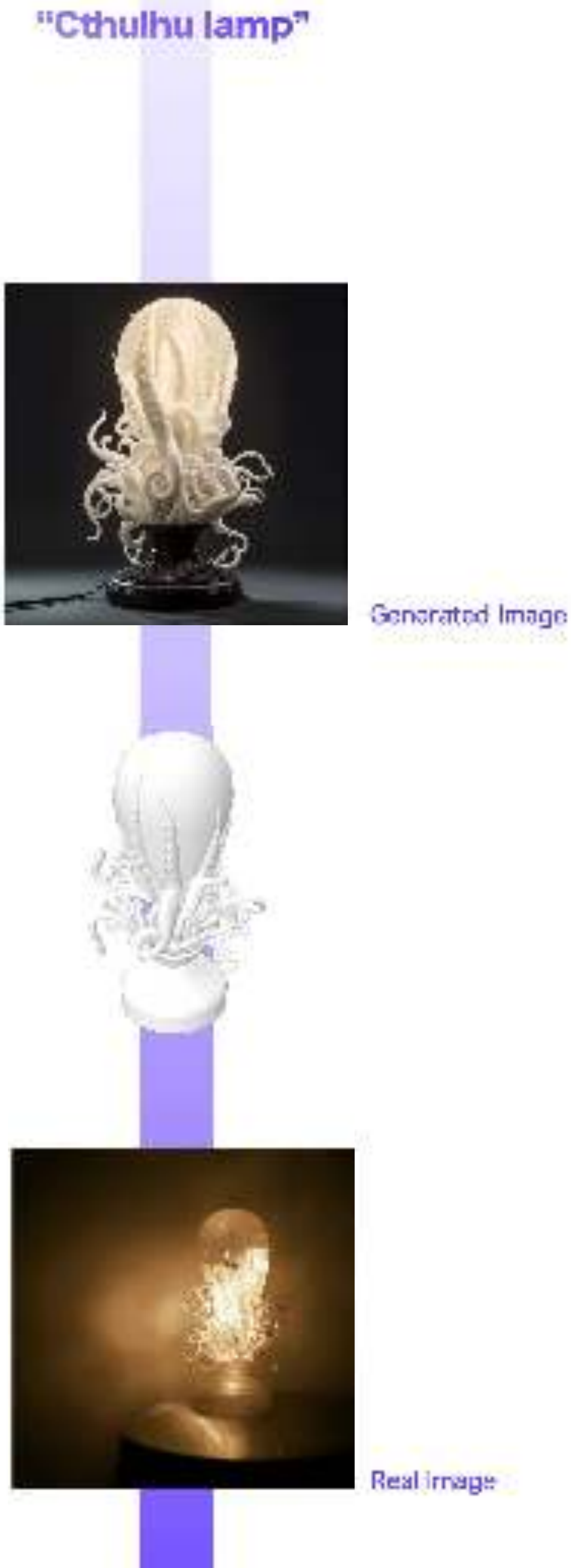


Figure 3. From texts to functional devices

"lamp, modular design, different ways to assemble"

Generated Image

Real Image

Preface

Arthur C. Clarke once observed, "Any sufficiently advanced technology is indistinguishable from magic." As a designer working at the intersection of human behavior, cutting-edge technology, and design, I've embraced this wisdom wholeheartedly.

The exponential development of AI in the past year has underscored the relevance of this perspective, prompting me to reconsider the future roles of designers and explore how AI could streamline the design process. Throughout this journey, I've had the opportunity to integrate my learnings from design and technology into the AI domain, creating AI tools for designers and constructing tangible product prototypes through an AI-driven workflow.

Despite the challenges and pressures, the thrill of actualizing concepts that might have seemed impossible just a year ago has been an exhilarating experience. In line with Clarke's quote, I genuinely feel as though I've been wielding magic in this project.

Fueled by this spirit, I was fortunate to find my Chair, Dr. Lomas, whose adventurous mindset and unwavering support allowed me to delve into how AI could transform traditional 3D printed product design. When we decided to focus on lamp design as our principal subject, I was again lucky to have Cohen, a specialist in lighting design, as my mentor. Their guidance enabled me to conduct my studies and experiments, all while granting me the freedom to explore my genuine interests. I cannot express enough appreciation to my supervisory team.

In addition, I want to extend my deepest gratitude to those who have assisted me during this project, particularly Adrian, who provided invaluable help during the 3D printing phase. The knowledge I've gained from him will undoubtedly serve me well in my future career. To every tester of my project, your contribution was integral to its success, and I cannot thank you enough.

I am sincerely grateful to my friends and family for their constant support. Their faith in me fueled the resilience to surmount numerous obstacles and continue following my passion. My utmost appreciation goes to my parents, my aunt's family, and grandparents for their unwavering love and support. I hope my achievements bring them pride. To my friends who offered comfort during challenging times and those who ensured I was nourished during my hectic schedule, I extend my heartfelt thanks.

After two years of study here, I've become adept at applying the knowledge I've gained both prior to and during this period to explore the areas that pique my curiosity and align with my beliefs. As I venture forward, my hope is to maintain my adventurous and inquisitive mindset in the realm of future technology, and to courageously explore the untrodden paths of future design.

Dinuo LIAO 廖迪诺

Executive Summary

Why is Now the Time to Integrate AI in Design?

As we entered 2022, the potential for artificial intelligence to impact the design industry was still largely uncertain. However, as the year progressed, the landscape started to shift dramatically with AI technology advancing at an unprecedented pace. We witnessed the rise of AI models like MusicLM(Agostinelli, 2023) and Riffusion(Huang, 2023), capable of generating music from text. Similarly, models like Stable Diffusion and Midjourney showed their potential in creating images and concepts from descriptions. By the end of 2022, we even had ChatGPT - an AI model that could generate text and code based on human instructions. The rapid evolution of AI didn't stop there - by 2023, AI models were generating videos and 3D models (Figure 4). This quick progress served as a wake up call, emphasizing why we should pay attention to AI now, especially in the design industry.

Figure 4. A series of AI tools and platforms that emerged in 2022 and 2023

Can Generative AI be Harnessed to Help Designers 3D Print Functional Product Designs?

Amidst these advancements, however, the application of these AI models to the creation of functional, physical products was an area yet to be fully explored. This gap became the driving force behind our project: to investigate whether generative AI could be harnessed to assist designers in creating 3D printable, functional, and aesthetically pleasing lamp designs. Driven by the belief that this novel application of generative AI held significant potential, we embarked on this journey to explore the untapped possibilities of AI in the realm of design.

Can GPT-4 Effectively Optimize Generative AI Outputs to Align with Human Preferences?

Two central studies were executed to investigate the efficacy of AI in enhancing the design process. The first study evaluated four AI generative models - Stable Diffusion, Open Journey, Dall-E 2, and Midjourney - in terms of their ability to create desirable and well-aligned lamp image concepts when used in conjunction with the GPT4 model as a prompt optimizer.

Can human preference data train AI to generate measurably improved human experiences?

The second study employed the LoRA model to fine-tune the Stable Diffusion based on the output from the four models, which served as the training data. The output from the four models consisted of images and their corresponding prompts. The study successfully established that this approach significantly improved the quality of concepts generated by Stable Diffusion, specifically in terms of desirability and aesthetic appeal.

How does the Developed Tool and User Interface Assist Designers?

Guided by insights from user testing and project studies, a user interface was developed and iteratively refined. This interface assists designers in generating images more effectively. It comprises three core components: an AI function, a chat interface with GPT4, and a generative AI tool. The interface simplifies communication of design preferences and enables the generation of lamp concept images, thereby fostering an iterative exploration of AI-assisted design.

How is the Conversion from 2D Images to 3D Models and Prototyping Achieved?

The project further delved into the conversion of 2D images into 3D models. This investigation employed commercial tools like Kaedim and other open source models to understand how AI could enhance the 3D modelling workflow. However, it was found that human intervention is currently still necessary in the 3D modelling process to ensure outcomes align closely with designer expectations.

What Insights Were Gained from the Exploration of 3D Printing Technologies?

The experimental phase examined various 3D printing technologies such as Stereolithography (SLA), Fused Deposition Modeling (FDM), and Selective Laser Sintering (SLS) for metal printing. A series of prototypes were developed using these technologies, effectively showcasing AI's potential in converting design ideas into tangible physical products. This realization of 3D objects from 2D concepts through 3D printing brings the process closer to real product production and prototyping, thereby meeting designers' expectations for the product.

Limitations and Future Outlook

This exploration of AI in design workflows, specifically in lamp production, reveals the potential and challenges of AI integration. While AI can simplify and expedite the design process, limitations emerge with complex physical structures, such as furniture or electronic devices. Additionally, the translation of 2D concepts to 3D models, facilitated by AI, requires significant human involvement for usability. While 3D printing is employed for prototypes, adapting AI-assisted designs for mass production methods might demand further adjustments. Despite these limitations, the future outlook is promising, with the expectation of overcoming current hurdles due to AI advancements. This project encourages designers to acquire new skills, embrace emerging technologies, and integrate AI with traditional design processes, signalling a transformative future for the design industry.

Project Introduction

In the swiftly developing domain of Artificial Intelligence (AI), this graduation project presents a novel interpretation of AI's role in design. Rather than viewing AI as a substitute for human creativity, it is seen as a collaborative ally in the design process. The project's aim is to establish a comprehensive toolkit or exploratory framework to enable designers to effectively harness AI in the creation of tangible products, with a specific focus on form-giving in the realm of 3D printed lamps.

Drawing from significant developments in generative AI technologies, such as OpenAI's ChatGPT and Dall-E which have demonstrated remarkable capabilities in generating human-like text and visusl content, the project also gains inspiration from AI tools like Stable Diffusion and DallE-2. These tools have opened new doors in the creative process, transforming text prompts into visual images and creating unique music pieces.

The project is organized around three central inquiries and anticipated outcomes(Figure5):

Figure 5. Project Scope

(User Interface) Examining how AI can cooperate with designers

This component investigates the potential interactions between AI and designers. It examines how the integration of AI can enrich the design process, making it more inclusive, creative, and efficient.

(AI Design Studies) Using AI to produce aesthetic, consumer-desirable, and 3D printable lamp designs

This objective seeks to harness the potential of generative AI in product design. It explores the ways AI can aid in producing innovative and aesthetically appealing products, with a special focus on form giving.

(3D Realization) Illustrating how AI-generated designs can be realized using 3D printing technology

This aspect underscores the practical implementation of AI-assisted designs, demonstrating the feasibility of AI-driven product creation through the application of 3D printing technology(Shahrubudin et al., 2019).

In addition, the project will scrutinize the growing trend of AI integration in the workplace, such as AI-powered virtual assistants, to understand the potential of collaborative AI and humans working together to achieve superior results.

By delving into these questions and objectives, this graduation project aims to shed light on the promising possibilities of AI-assisted design and its transformative potential for the design industry.

This graduation project investigates the journey from idea conception to the creation of a 3D model, utilizing the power of artificial intelligence. The target group for this project is product designers. The exploration journey is divided into two main phases: the Ideation Phase and the Crafting Phase.

Ideation Phase

The Ideation Phase consists of two steps(Figure6):

1. **From Zero to Prompts (AI-assisted):** The process begins with the generation of ideas and design concepts. Using AI models like GPT-3, designers can create unique prompts that capture their design vision. This is a crucial first step in form giving, where designers articulate the intended form, function, and aesthetic of the product.
2. **From Prompts to Images (AI-assisted):** The next step involves transforming the textual prompts into visual content. AI tools like Dall-E 2 and Stable Diffusion are used to create images based on the prompts. This stage solidifies the design concept and gives the first visual representation of the intended form.

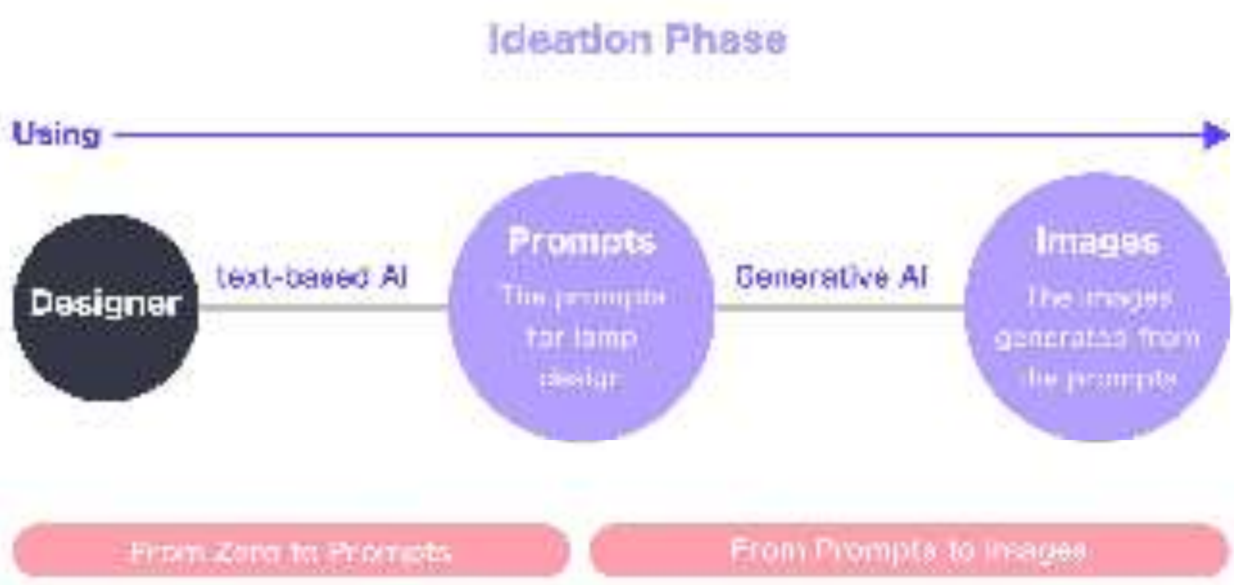


Figure 6. Ideation Phase Workflow

Crafting Phase

The Crafting Phase also consists of two steps(Figure7):

1. **Images to 3D Digital Models (Human-driven or AI-assisted):** The generated images are then used as a basis for creating precise digital 3D models. Here, the form is defined in three dimensions, and the design's structural and aesthetic details are refined. Depending on the complexity of the design and the available tools, this step may be performed by a human designer or assisted by AI.
2. **Digital Models to 3D Printing (Human-driven):** Finally, the digital 3D models are brought to life through 3D printing. This stage realizes the form-giving process, as the digital model takes on a physical form that can be touched and experienced in the real world.

At its core, this graduation project strives to highlight the transformative potential of AI-assisted design for the design industry, specifically in the context of form-giving. It aspires to understand the evolving role of designers in an AI-assisted future and provide insights into the forthcoming landscape of design and the designer's position within it. This project, therefore, stands at the crossroads of design and AI, offering a pioneering vision of a future where designers and AI work collaboratively to push the boundaries of creativity.

Figure 7. Crafting Phase Workflow

Motivation

The inspiration for this project stems from my future career goals and personal interests. As a designer specializing in the burgeoning fields of Internet of Things (IoT) and Artificial Intelligence (AI), I am captivated by the transformative potential these technologies hold for redefining design. My passion lies in fusing AI into the design process and investigating novel ways to exploit its capabilities for creating unique and captivating designs.

In the initial exploration stage of this project (Figure6), I dedicated significant efforts to create a multitude of lamp design concepts. Each design served as a testament to the limitless creative potential of AI, each showcasing a different aspect of AI's design capabilities. As you can see in the following images, the range of designs AI can generate is truly astounding. These designs are made at the initial stage of the project. With every new design, it became increasingly evident that this project was paving a path less traveled, pushing the boundaries of traditional design processes.

Real Images

Figure 6. My initial exploration on 3d printing prototype

In my role as a User Experience (UX) designer, I strive to stay abreast of technological progress and continuously adapt to new tools and methodologies. This philosophy is not confined to my professional life; it is a lifestyle that, in my perspective, is essential for fostering human advancement and technological progression. It centers on nurturing constant curiosity, openness to novel possibilities, and ceaselessly stretching the limits of the conceivable.

However, I've observed a sense of fear or 'technological phobia' in some designers when it comes to embracing advanced technologies, especially those involving coding. I believe that this apprehension can hamper innovation and impede the evolution of design practices. Consequently, I was inspired to develop a tool that could help assuage these fears and make cutting-edge technology more approachable and user-friendly for designers.

Figure 9. The initial AI-generated lamp design example

My journey with AI has been a profound enlightenment(Figure9). The potential for swift design iterations using AI tools struck me significantly. In one instance, I managed to conceptualize and produce an AI-assisted lamp design within the span of just 12 hours(Figure10). This experience ignited a desire within me to further refine and optimize this process, with the ultimate goal of rendering it more accessible and efficient for designers worldwide. By setting a personal example, I hope to inspire other designers to overcome their apprehensions, embrace technological advancements, and discover how these tools can significantly contribute to their design processes and outputs.

Tasks (from beginning to end)	Tools Used	Time Cost
Determine what needs to be included (electronic components)	No special tools used	2h total
Use prompts to generate design ideas	DALL·E, Midjourney	2h total (most time spent waiting for generation)
Optimize prompts in Midjourney and iterate	Midjourney, ChatGPT	2h total (most time spent waiting for generation)
Optimize the generated images	Photoshop	1h total
Generate 3D models from images	Kaedim	1h total
Manually optimize 3D models for 3D [illegible]	C4D Core	2h total
Set up the electronics and program	Arduino	2h total
Total Design Process Time		**12h total**

Figure 15. The tasks and time cost for the initial AI-generation process

Reader Guide

Chapter 1: Exploration in User Interface

In this chapter, I share the motivation and design principles behind the user interface, emphasizing its role in facilitating AI-assisted design. I introduce the initial AI models used in the early stages of the interface development, and show how user interaction and designer input helped refine those models. The chapter concludes with a discussion on how the collaborative process and the development of the interface set the stage for more advanced AI-assisted design (Figure [illegible]).

Chapter 2: Exploration in AI Design Studies

This chapter delves deeper into the AI models and their role in the design process, keeping a clear link to their integration within the collaborative interface. I start with an in-depth examination of the AI models and their specific roles in the design process, referring back to their implementation in the UI from Chapter 1. The chapter discusses how feedback and data from the collaborative interface were used to optimize AI models and improve design outcomes. It concludes with a look at how the AI-assisted design process feeds into the 3D realization stage, setting the stage for the next chapter (Figure [illegible]).

Chapter 3: Exploration in 3D Realization

In this chapter, I explore the methods of converting AI-generated designs into 3D models, emphasizing the role of the collaborative interface and AI models in this process. I highlight how designers can edit the AI models during the 3D realization stage and how this interplay contributes to the final product. The chapter discusses the various 3D printing technologies and their roles in realizing the designs, referencing how the AI-assisted design informed the choice of technology. The chapter concludes with reflections on the entire process, from collaborative interface design to AI-assisted design to 3D realization, demonstrating how these interconnected components contributed to the final 3D printed products (Figure [illegible]).

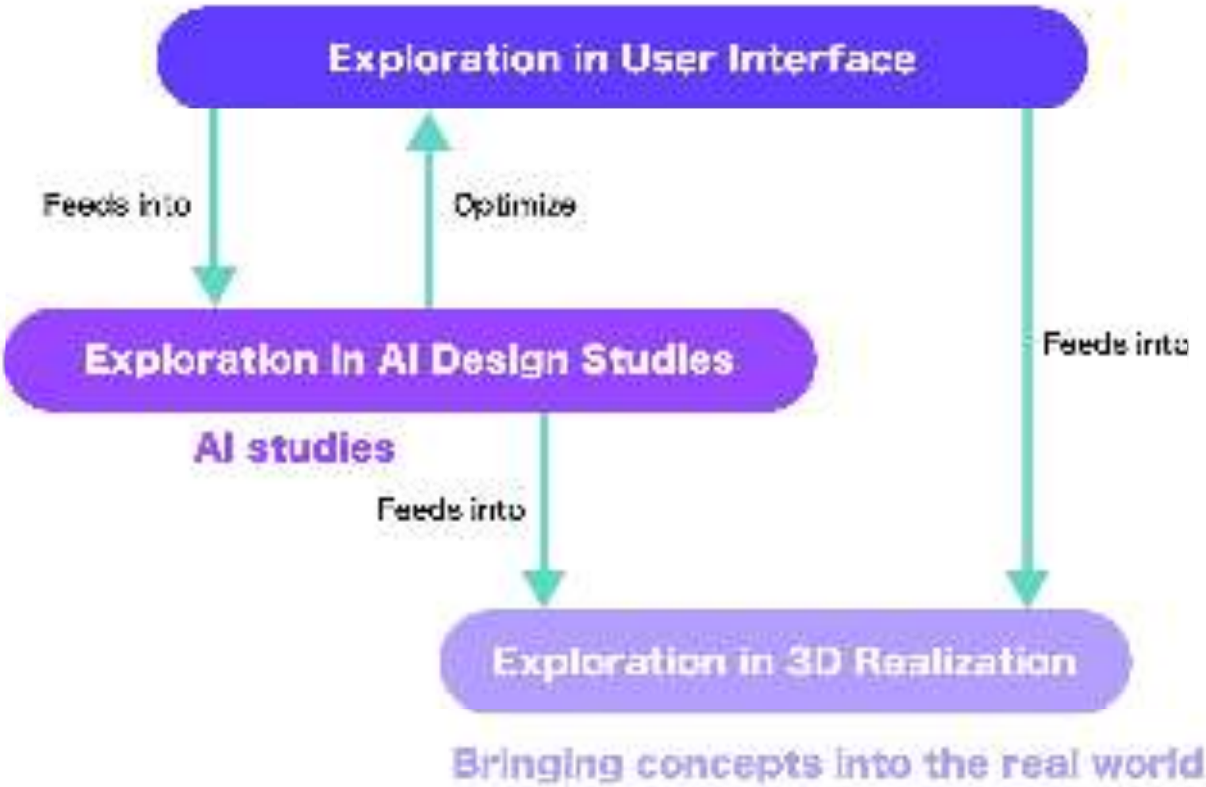


Figure 11. The Project Framework

Exploration in
UI Interface

Chapter Introduction

In this first chapter, we explore in detail the evolution and development of a unique **AI-driven platform designed to bridge the gap between artificial intelligence (AI)** and human creativity in the field of design.

Our initial task was the creation of a simple, yet functional, user interface (UI). This was aimed at facilitating image collection from users and providing a foundation for our platform. This basic interface, although rudimentary in its initial stages, was instrumental as the springboard from which we launched into more advanced aspects of our platform development.

(Figure 2)From this starting point, we introduced a significant advancement that marked a turning point in our journey – the integration of AI-assisted design. This innovation substantially expanded the platform's capabilities, unlocking a plethora of new possibilities that transcended the constraints of traditional design tools. At this stage, we dove into a comprehensive brainstorming and experimentation phase. We trialed various AI technologies, constantly evaluating how effectively they supplemented and enhanced human creativity. We also began to see the immense potential of AI in assisting the design process, hinting at the exciting prospects that lay ahead.

We then embarked on an exploratory journey, diving deep into various AI models, such as GPT-3, GPT-4, generative AI, and ControlNet. Our goal was to create an innovative interactive design process, which was not only assisted by AI, but also introduced a novel form of interaction – chatting. This form of interaction adds a unique dynamic to the design process, enabling a seamless blend of human and AI inputs. The development and iteration of the user interface were deeply influenced by user testing. Each round of user feedback was carefully evaluated, providing crucial insights that shaped the subsequent design revisions. Our primary focus was to ensure the interface was intuitive, user-friendly, and could effectively facilitate the AI-assisted design process.

The chapter delves into the specifics of the selected AI models, offering a detailed analysis of how these models enhanced the AI-assisted design process. We discussed the benefits and challenges associated with each model, explaining how they were integrated and how they added value to the overall design experience. We also provided an overview of the iterative development of the user interface, showcasing how user feedback was invaluable in refining the interface and improving its usability.

The culmination of this iterative, user-centered design process is the user-friendly website dinuoliao.com. Beneath its sleek and simple interface, a suite of AI models operates in harmony with user inputs, fostering a unique blend of human and machine creativity. The ultimate aim of this platform is to support users during the crucial ideation phase, empowering them with a set of innovative tools to bring their creative ideas to life.

In this chapter, we highlight the pivotal role of the ideation phase in shaping the final product. We emphasize the transformative potential of AI technology in augmenting the design process and enhancing creative outputs. At the same time, we address important ethical considerations in the deployment of AI, contributing to a broader discussion about the responsible use of AI in design.

By providing an in-depth look into the iterative, user-centered design process, this narrative serves as a testament to the dynamic and transformative power of AI in the design world. It invites readers to reflect on the future trajectory of design, particularly in an era where AI is becoming increasingly integrated into our daily lives.

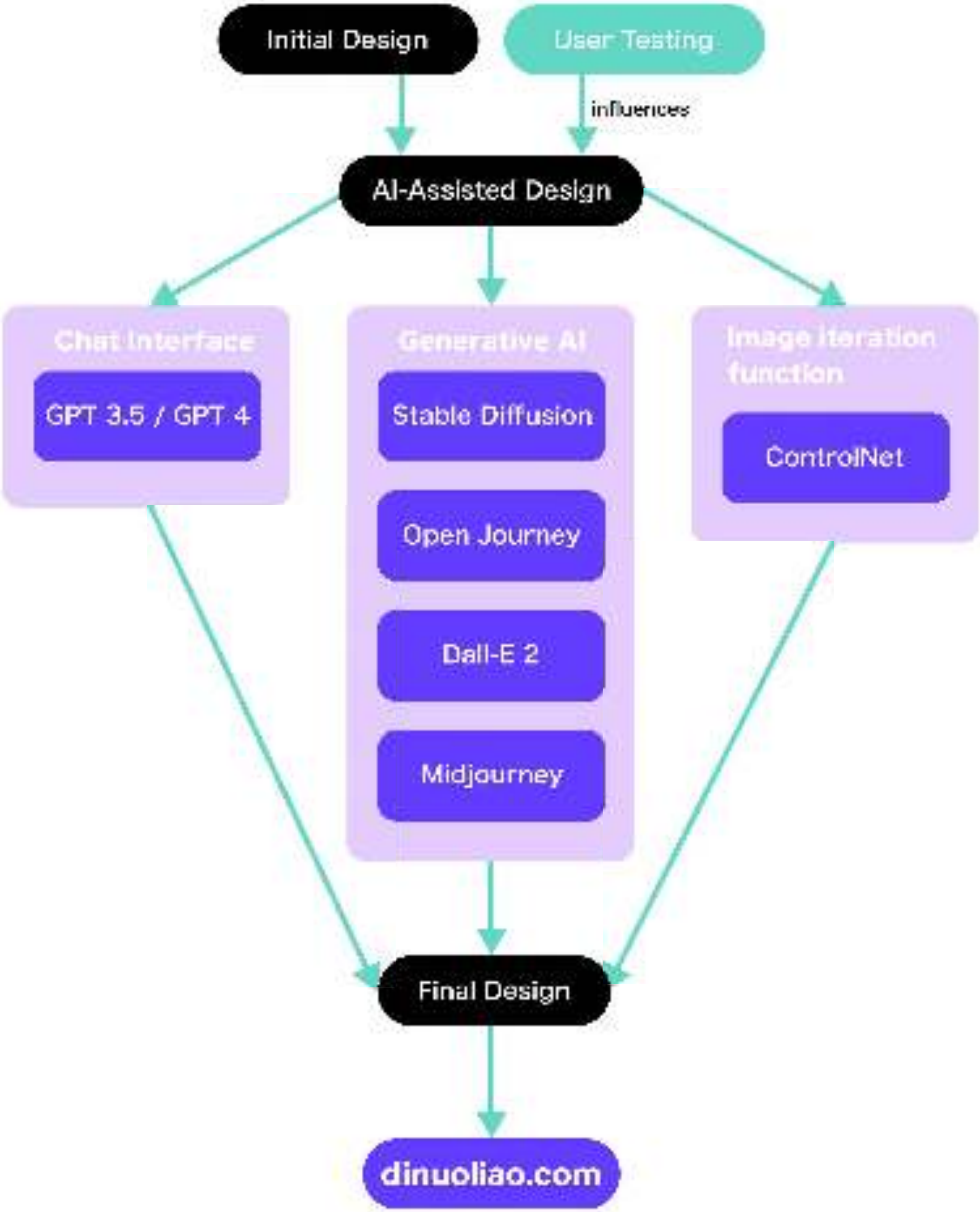


Figure 12. UI interface development structure

AI Models Deployed

Generative AI Models

What are the generative models we deployed?

Midjourney, Stable Diffusion, OpenJourney and DALL-E-2 are AI models that have shown impressive capabilities in generating high-quality images from textual descriptions.

1. **Stable Diffusion:**Stable Diffusion is a generative model that uses a diffusion process to generate images. It is known for its stability and the ability to generate high-quality images. It's part of a creative pipeline that can be used to generate initial sketches, which can then be further refined using other tools.
2. **OpenJourney:** OpenJourney is a variant of the Stable Diffusion model, trained with mid-journey images. It is capable of generating high-quality images and has shown similar level results to other models.
3. **DALL-E-2:** DALL-E-2 is an extension of the original DALL-E model by OpenAI, designed to generate images from textual descriptions. It has improved capabilities in terms of generating high-quality images that closely match the provided textual descriptions.
4. **Midjourney:** Midjourney is a generative artificial intelligence program developed by Midjourney, Inc. This tool generates images from natural language descriptions or "prompts", exhibiting similarities to OpenAI's DALL-E and Stable Diffusion. The company has been dedicated to enhancing its algorithms, leading to the release of new model versions every few months. The 5.1 model is more 'opinionated' than its predecessor, applying more of its own stylization to images. The 5.1 RAW model, on the other hand, offers improvements and works better with more literal prompts.

Why do designers need these models?

These AI generative models can be incredibly beneficial in the context of tangible product design for several reasons:

1. **Rapid Prototyping:** These models can generate images based on textual descriptions, which can be used to quickly create visual prototypes for user interfaces.
2. **Form-giving Customization:** The high degree of customization offered by these models allows for unique form-giving. The output is dependent on the input description enabling the creation of unique and personalized designs that align with the designer's vision.
3. **Efficiency in Visualization:** These models can generate complex images in a matter of seconds, significantly speeding up the design process. This quick visualization capability allows designers to see their ideas come to life promptly, aiding in decision making and design adjustments(Ali et al., 2023).
4. **Ideation:** These models can serve as a source of inspiration for designers. By generating a variety of images based on a given description, they can help stimulate creative thinking and ideation (Liao et al., 2023).

How can designers use these models?

Designers can harness the power of these AI models to stimulate their creative process. By inputting textual descriptions, they can generate a variety of lamp designs, including different shapes, sizes, and styles. These generated images serve not only as a visual guide but also as a source of inspiration, enabling designers to explore new design possibilities and visualize their ideas more concretely.

Once the AI models generate the images, they can be used as a reference for further design development. This could involve transforming these visual concepts into tangible 3D printed models, thereby bringing the designers' creative visions to life.

Incorporating these AI models as a function within the UI interface of our design application allows designers to seamlessly integrate this powerful tool into their workflow. This not only enhances the design process but also fosters a more innovative and efficient design environment.

GPT Model

What is the GPT model, including GPT-3.5 and GPT-4?

Generative Pre-training Transformer (GPT) is a type of AI model developed by OpenAI for natural language processing tasks. It operates by analyzing a large amount of text data and learning to predict the next word in a sentence based on the words that precede it. This allows the model to generate coherent, human-like text that can intelligently respond to a variety of prompts. The versions GPT-3.5 and GPT-4 are more recent iterations of this model, as of my knowledge cutoff in September 2021, each with enhancements and improvements over their predecessors.

Why do we need GPT in the UI interface for this project?

The GPT model brings several key benefits to the UI interface of a design application:

- **Natural Language Understanding and Generation:** The GPT model's ability to understand and generate natural language makes the user interface more intuitive and engaging. Users can interact with the system conversationally, expressing their design ideas and receiving responses in a language they understand.
- **Creativity and Innovation:** The GPT model is capable of generating new design ideas based on user specifications. This feature can stimulate the creative process and lead to the production of unique designs that may not have been conceived without AI assistance.
-

- **Automation and Efficiency:** The GPT model can take over routine tasks, freeing designers to focus on more complex and creative aspects of the design process. This increases the overall efficiency of the design process and can lead to higher quality outcomes.
- **Personalization:** The GPT model can learn from user interactions and generate output tailored to the specific needs or preferences of individual users. This level of personalization enhances the user experience and can lead to more satisfying design outcomes.
- **Collaborative Design:** The GPT model can facilitate collaboration by allowing multiple users to input their ideas and receive AI-generated suggestions. This can lead to a more diverse range of design ideas and a more inclusive design process.

How can designers use the GPT model?

Designers can interact with the GPT model through the chat interface, which provides a user-friendly and intuitive way to communicate with the AI. They can use natural language commands or queries to request the AI to generate design ideas, automate routine tasks, or provide creative suggestions. The GPT model can also facilitate collaborative design by allowing multiple users to input their ideas and receive AI-generated responses. By leveraging the power of GPT models, designers can streamline their workflow, enhance creativity, and improve the efficiency of the design process.

ControlNet

What is ControlNet?

ControlNet(Zhang, 2023) is a powerful tool in the realm of AI image generation. It is a neural network structure that adds extra conditions to control diffusion models. This unique capability allows ControlNet to guide the diffusion model in recognizing and implementing the designer's ideas, providing an unprecedented level of control over the image generation process.

Why do we need ControlNet in the UI interface?

ControlNet is particularly beneficial in the UI interface for the following reason:

- **Design Iteration:** ControlNet stands out from other generative AI models by enabling a more interactive design process. It allows designers to iterate on their existing designs or ideas. They can specify certain aspects or features they want to change in an existing design, and ControlNet will adjust the design accordingly. This interactive process allows designers to experiment with different design variations swiftly and effectively.

How can designers use ControlNet?

Designers can use ControlNet to modify existing images based on specific prompts or conditions. In the context of lamp design, they can specify which parts of the design to keep and which parts to change, and ControlNet will adjust the design accordingly. This process allows designers to quickly visualize their ideas and create unique, customized designs that align with their specific requirements. The integration of ControlNet into the UI interface facilitates a more efficient and creative design iteration process, enhancing the overall design experience.

User Interface Evolution

Why we built the user interface?

The initial development of the UI interface was primarily aimed at gathering image prompts and image data from experienced product designers. The primary goal was to facilitate further analysis for aesthetic optimization of lamp design images. However, during the testing phase, we discovered that the UI could serve as an effective toolkit for designers, aiding them in formulating their ideas.

The UI interface and the toolkit are connected to a database, to collect the generation prompts and image properties enabling comprehensive data analysis. Ultimately, the evolution of the UI interface from a simple data collection tool to a comprehensive design toolkit illustrates the potential of AI in enhancing the design process, fostering creativity, and driving innovation.(Figure 13)

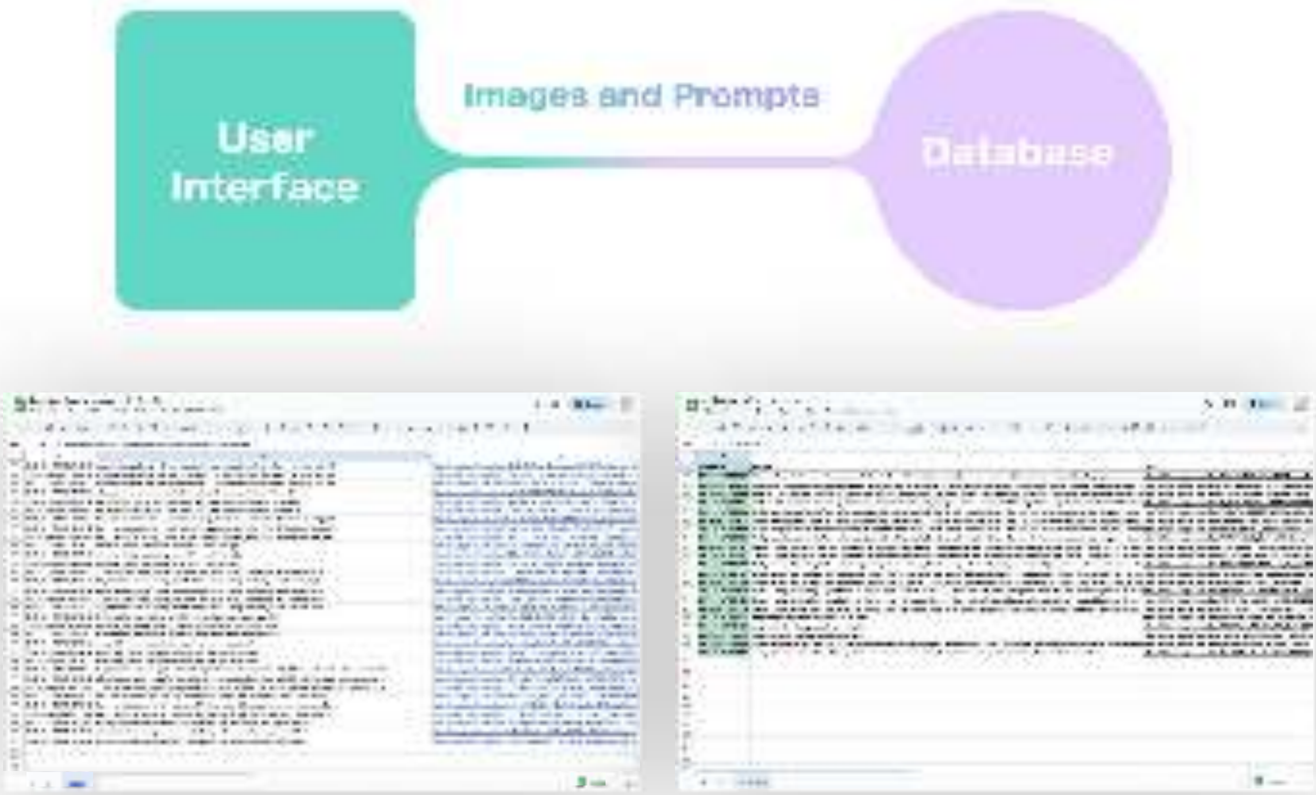


Figure 13. User Interface sending images and prompts to databases

Our UI interface, hosted at https://dinudian.com, has evolved from a simple data collection tool to a comprehensive platform that enhances the interaction between designers and AI. It incorporates GPT-4, four generative AI models, and ControlNet, streamlining the process of generating and iterating design ideas and enabling the system to evaluate the generated images for further AI model optimization in tangible design.

Beyond its functionality, the UI interface serves as a guide for designers, aiding them in their interaction with generative AI models. It provides a structured environment for exploration, experimentation, and creation, fostering effective communication of design ideas to the AI.

Looking ahead, the UI interface holds the potential for further development to provide more guidance, customization options, and deeper interaction between designers and AI. This could enhance the design process and contribute to the evolution of AI-assisted design. The UI interface is not just a functional tool, but a meaningful guide in the journey of generative AI design.

Development Process

Throughout the development process, we adhered to key principles of UI design. Usability was a primary focus, ensuring that the interface was easy to navigate and intuitive to use. We also prioritized consistency, maintaining a uniform design across different parts of the interface to provide a seamless user experience. Feedback was another crucial element, with the interface designed to provide clear

The development of the user interface (UI) for our generative AI design tool was a journey marked by iterative improvements, user feedback, and the evolving needs of designers. This journey can be divided into several key stages, each representing a significant milestone in the evolution of the tool.

Stage 1: Initial Design and Data Collection

(Figure 4)User interface sending images and prompts to databases The journey began with the creation of the initial series of UI interfaces. These were designed with a primary goal in mind: to facilitate the collection of images from designers. At this stage, we employed DallE 2, an AI model, to generate images.

As the project progressed and the needs of the designers became clearer, we saw the need to incorporate more AI generative models into the tool. We initially planned to include Stable Diffusion, Midjourney, and OpenJourney. However, due to technical constraints, Midjourney was not added at this stage. The inclusion of these models aimed to enhance the diversity and quality of the generated images, thus providing a broader range of creative possibilities for the designers.

The designers, who were our testers at this stage, were given the task of generating lamp designs that were both desirable to consumers and suitable for 3D printing. Through user interviews conducted during this phase, we identified the need for a more interactive and intuitive tool. This feedback was instrumental in guiding the subsequent stages of the UI interface development.

Figure 14. Initial UI development from single AI model to multiple AI models

Stage 2: Incorporation of GPT-based Chatbot

(Figure 15) The feedback from the initial testing phase led to the first significant iteration of the interface. Many designers reported difficulties in generating ideas for lamp designs within a short timeframe. To address this, we introduced a chatbot based on the GPT3.5 and GPT4 model. Initially, this chatbot was a separate feature, but based on further user interviews and feedback, it was later embedded into the main interface to provide a more seamless user experience(Kocaballi, 2023a).

Figure 15. Chatbot embedded in interface

Stage 3: Enhancement of Chatbot Functionality

(Figure 16)Despite the introduction of the chatbot, user interviews revealed that it was not meeting the needs of the designers effectively. They had to manually copy and paste their ideas, and initiating a conversation with the chatbot was not intuitive(Amershi et al., 2019). To address these issues, we enhanced the chatbot's functionality. We integrated the generative AI models directly into the chat interface and added features(Figure17, Figure18) to help users fetch example prompts and improve their prompts with the GPT-based system. This made the image generation process more intuitive and accessible(Makokha, 2022), a significant improvement highlighted by the designers during subsequent user interviews.

Figure 16. Chat-based UI interface

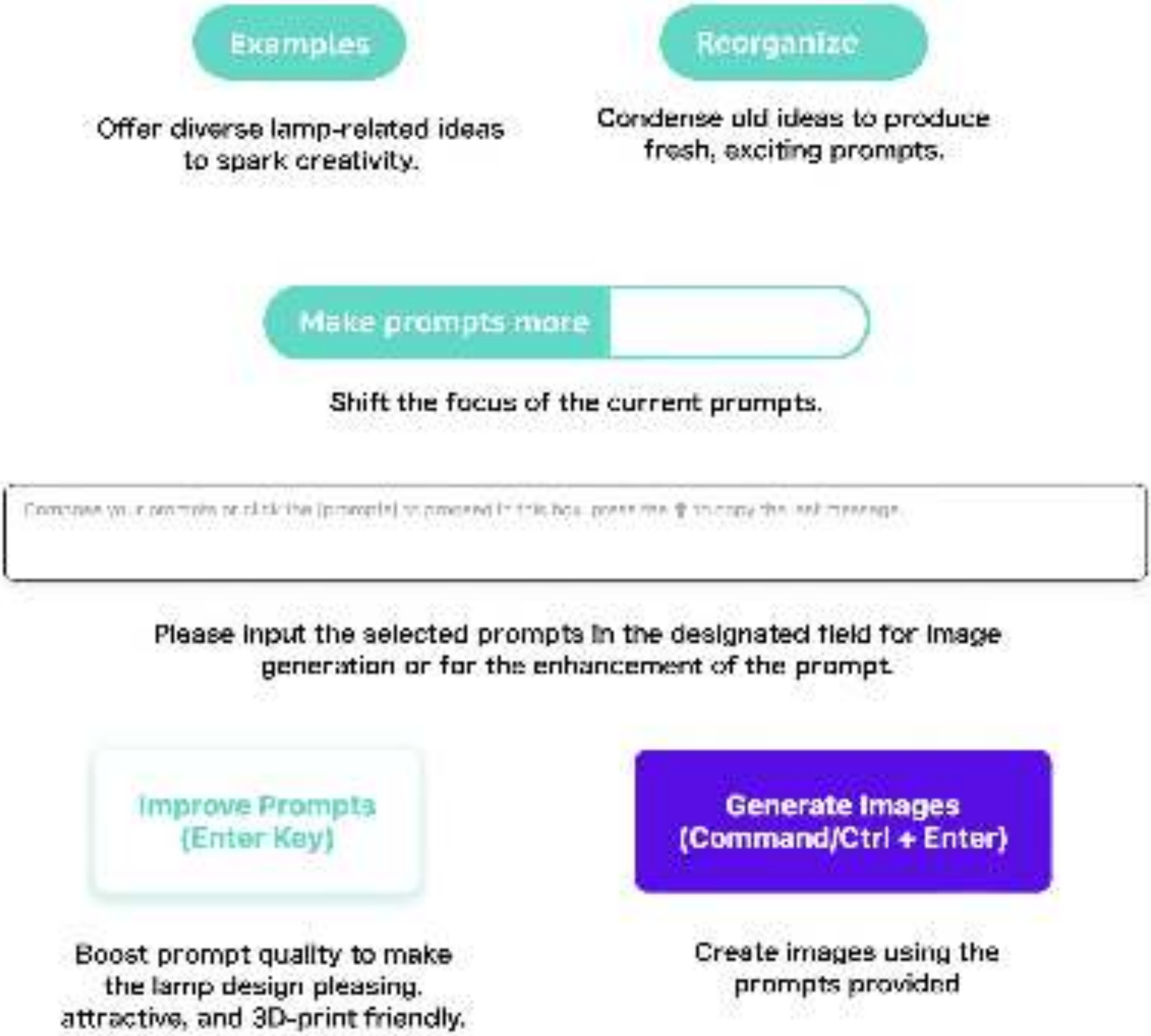


Figure 17. Features of the Text-based generation UI interface.

Figure 18. Features of the Chat based generation UI interface

Stage 4: Introduction of Image Iteration Function

As the project progressed, user interviews revealed a new need among designers: the ability to iterate on their ideas based on existing images rather than continually generating new ones. To meet this need, we introduced a new generative model, ControlNet. This model allows users to modify existing images based on specific prompts(Figure19, Figure20), with the resulting images heavily influenced by the original image(Figure21). This allowed for a more nuanced and iterative design process, a feature that was well-received by the designers

Figure 17. Clicking generated images can trigger the iteration function

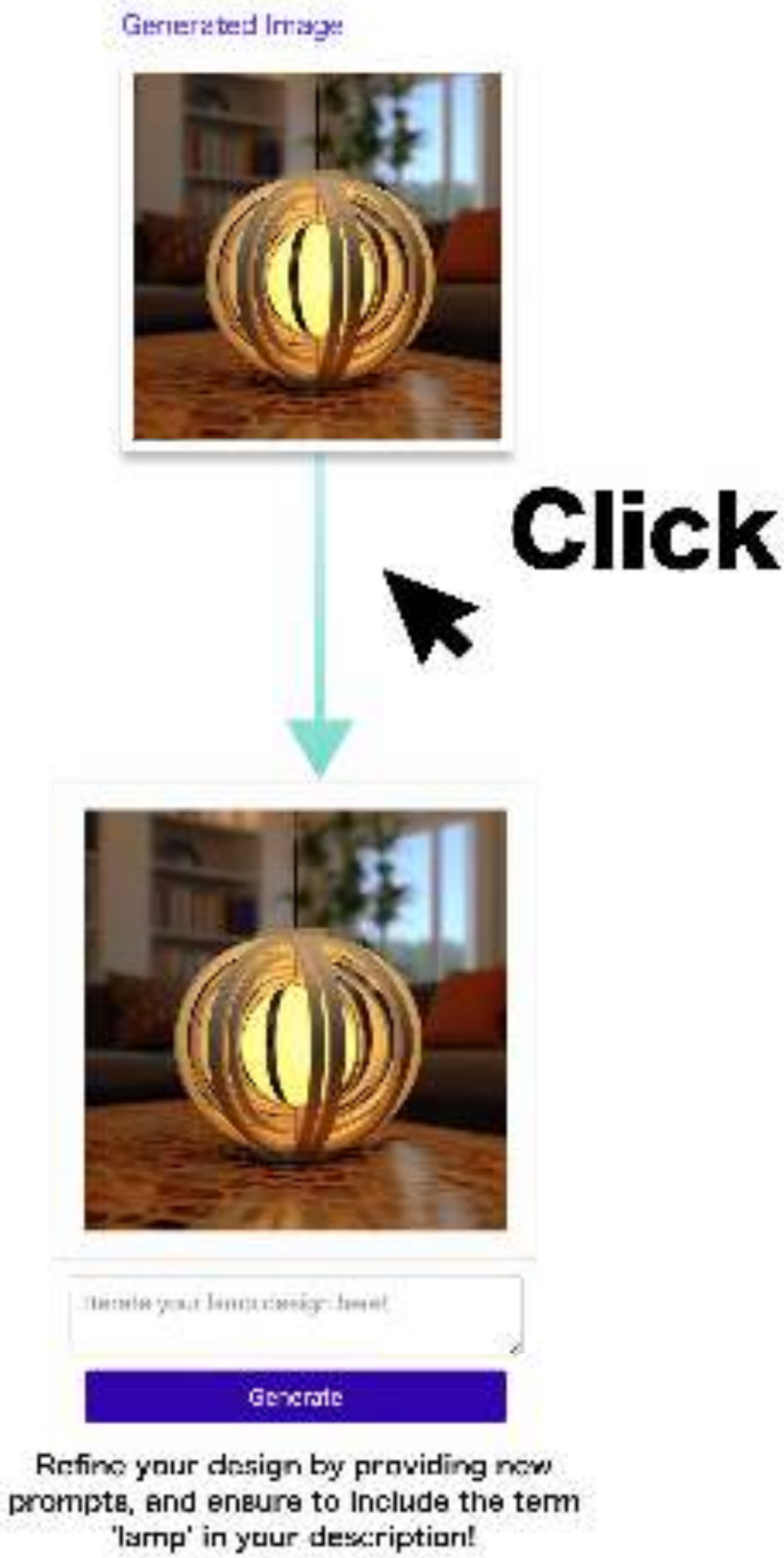


Figure 20. Clicking generated images can trigger the iteration function

Figure 21. Original pictures and the variants through ControlNet

Generated Images

3d printed lamp, big bulb, simple design

Ocean-inspired lamp design, clear background

glass lamp design, wireless

modern cubic lamp design, solid white background

metal lamp, minimalistic, art deco

big bulb, rustic wood log lamp design

Stage 5: Final Design and Simplification

The final stage of the journey involved refining the design of the UI interface and integrating user feedback mechanisms. We included a gallery page to showcase the capabilities of the tool and to provide inspiration for new users. We also simplified the process of generating examples and improving prompts, making it easier for designers to quickly generate lamp design ideas.

In response to user feedback, we added a feature that allows users to indicate whether they like or dislike the images they generate. This feedback mechanism facilitates our data analysis process and helps us train the AI model more effectively towards our design goal - creating more desirable and 3D printable lamp concepts(Amershi et al., 2019).

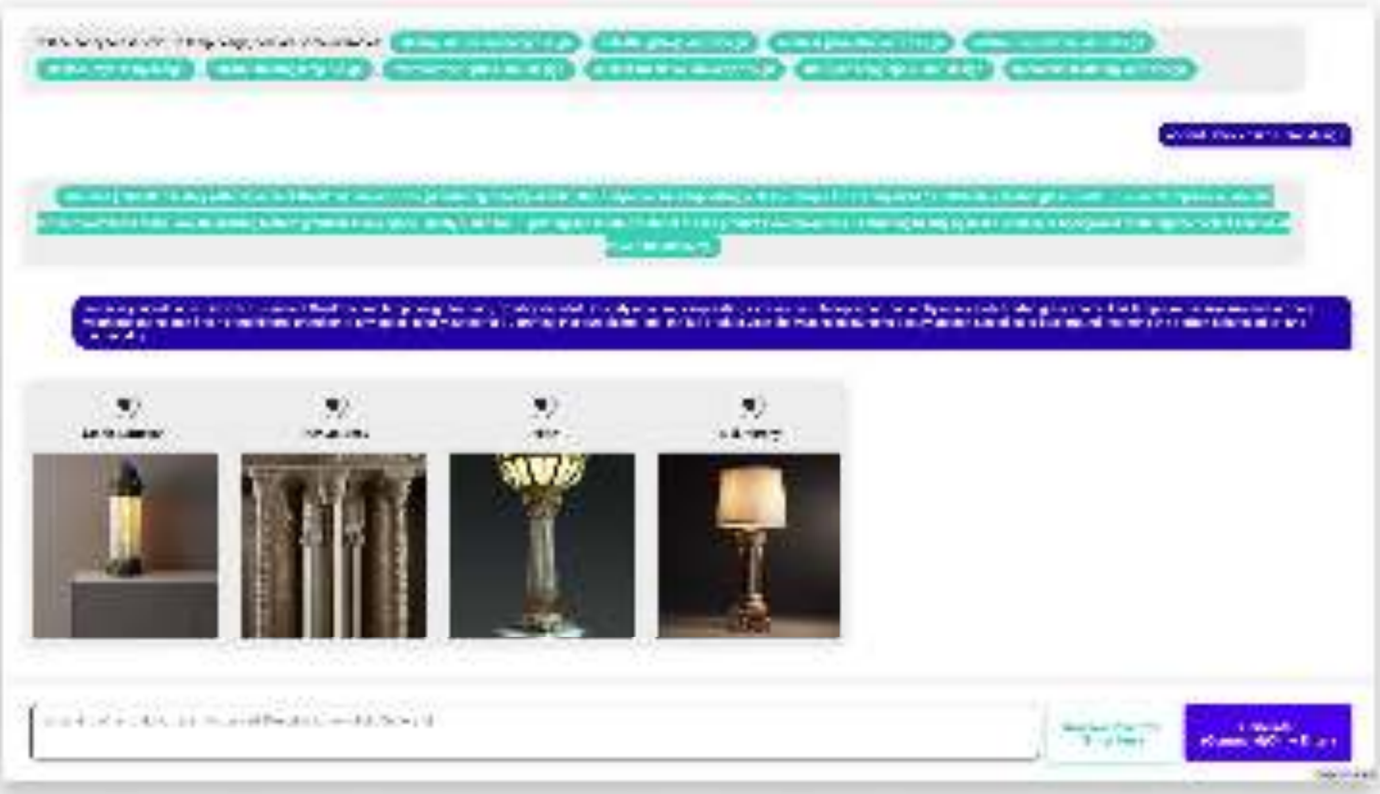


Figure 22. Final simplified UI interface

Moreover, the final UI interface now incorporates four generative models - Stable Diffusion, Dall-E 2, Open Journey, and Midjourney. These models enhance the diversity and quality of the generated designs, offering a broader range of creative possibilities for the designers. (Figure??)

The final UI interface, as it stands today, is not just a tool, but a comprehensive platform that enhances the interaction between designers and AI, facilitating the creation of unique and innovative lamp designs. This final design, as confirmed by our latest round of user interviews, effectively meets the needs of the designers and represents the culmination of a journey marked by user-centered design and iterative improvements.

Conclusion

The journey of the UI interface development exemplifies the pivotal role that user-centered design and constant iteration play in building an efficient and intuitive tool. By embracing an evolving design process and incorporating user feedback at each stage, we ensured the resulting interface met the real needs and preferences of designers.

One of the major advantages of our UI interface, currently hosted at dinuollab.com(Figure23), is its use of online resources to run the AI models. This cloud based approach means that designers don't need to possess high-end, powerful computers to harness the capabilities of AI. The heavy computational tasks are handled remotely, thereby providing cost-efficiency and accessibility. Designers can focus on the creative process rather than worry about the technical aspects of running the AI models.

This platform serves as a comprehensive and user-friendly environment for designers to interact with several generative AI models, thereby facilitating the generation and iteration of design concepts with unprecedented efficiency. The interface effectively streamlines the design process, integrating multiple AI tools into one unified platform. This avoids the time-consuming and complex task of juggling multiple AI tools separately. Designers can interact with a variety of AI models including GPT 4, DALL-E 2, Stable Diffusion, OpenJourney, Midjourney, and ControlNet, all within the same interface. By encapsulating these models in a user-friendly environment, we have significantly reduced the time required to generate and iterate design concepts.

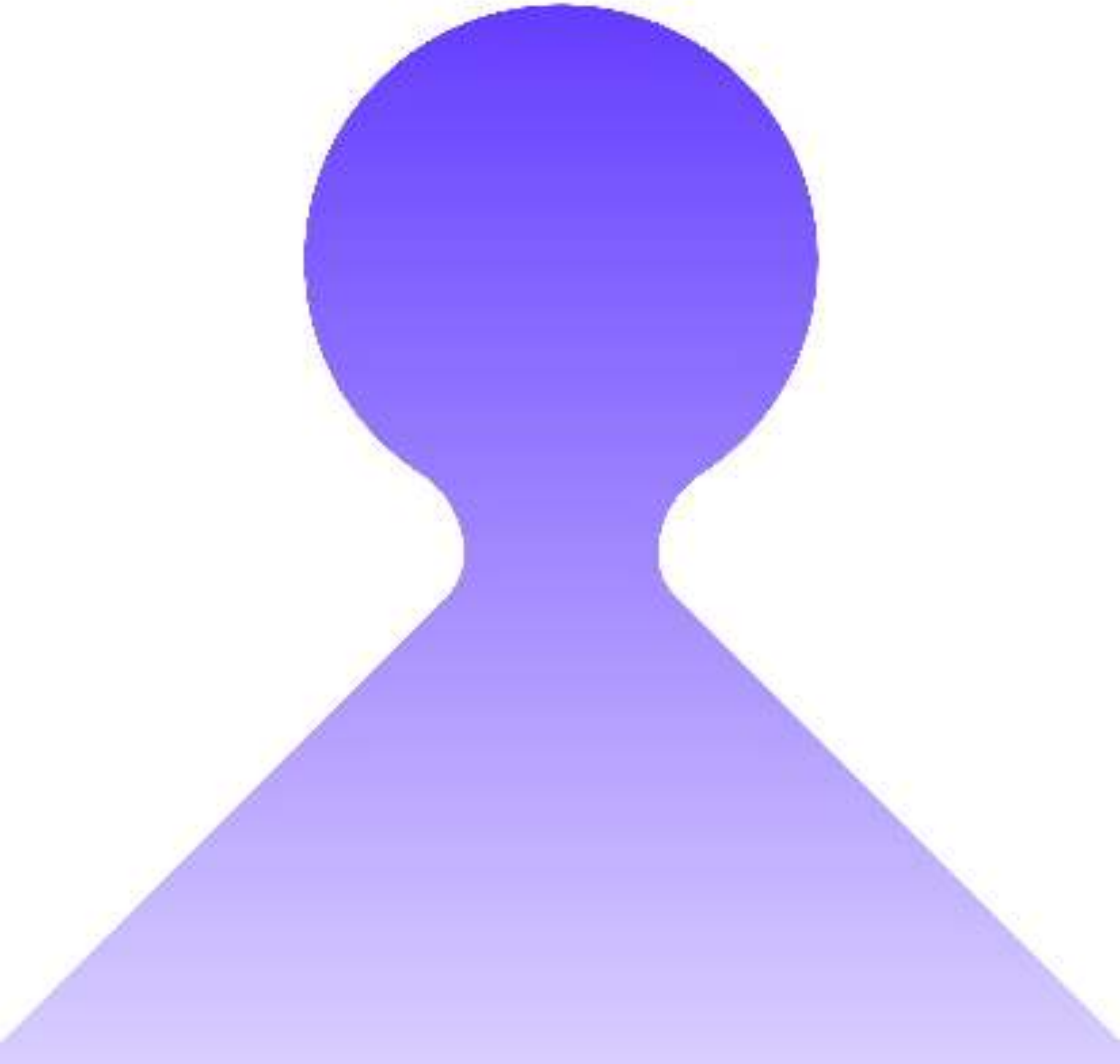
In conclusion, our UI interface represents a significant step forward in leveraging AI for design. It makes powerful AI tools accessible and intuitive, fostering a synergy between human creativity and AI capabilities. By reducing both the technical barriers and time investment needed to harness these AI tools, the UI interface democratizes the benefits of AI-enhanced design. As we continue to refine and develop this tool, we envision a future where the blend of human ingenuity and AI possibilities can realize truly innovative and remarkable designs.

Gallery page

dinuoliao.com

Figure 23: Final generation website with gallery page

Exploration in
AI Design Studies



Chapter Introduction

AI-assisted design is a journey of discovery, a narrative unfolding through the confluence of technology and creativity. The integration of artificial intelligence (AI) into our design process was a complex, transformative process. This chapter unravels the empirical studies we undertook along this journey, which led to a deeper understanding of our design choices and their subsequent implications. We developed innovative testing and evaluation tools and methodologies unique to our project that played a pivotal role in refining our user interface and enhancing the overall design process.

Can We Utilize GPT-4 to Optimize Image Generative AI for Developing Aesthetically Pleasing, 3D Printable, and Well-Aligned Lamp Concepts?

Study 1: Optimizing Image Generative AI in Tangible Lamp Concepts: Aesthetics, 3D Printability, and Alignment using GPT-4

Our first study embarked on an exploration into the influence of prompt optimization, employing the advanced GPT-4 large language model from OpenAI, on the performance of four generative AI models - Stable Diffusion, Open Journey, DALL-E 2, and Midjourney. Their performance was scrutinized under the lens of generating lamp design images along three key dimensions: aesthetic desirability, 3D printability, and alignment with the design concept. Participants were invited into a field of experimentation, where they generated lamp images using these AI models, before and after the application of prompt optimization with GPT-4. Post image generation, participants stepped into the shoes of evaluators, assessing the resultant lamp design concepts based on their desirability, printability, and adherence to the original design concept.

The quest of this study was to measure the reach of prompt optimization in influencing the performance of AI models, in terms of generating tangible, aesthetically pleasing, and 3D printable designs. The insights harvested from this study illuminated the path of AI in supporting designers, revealing its potential to create more effective and efficient design solutions.

The findings from this study underscored the criticality of prompt optimization in bolstering the performance of generative AI models. These insights were instrumental in refining the user interface, infusing it with greater intuitiveness and efficacy. The prompt improvement function was critically reevaluated and strengthened, based on these insights, rendering it more robust and logical. This evolution improved user engagement, and enriched the overall effectiveness of the design process, paving the way for subsequent studies.

Can we use human preference data to train AI to generate more desirable product designs?

Study 2: Utilizing Human Ratings to Augment the Quality of AI-Generated Designs: A Two-Dimensional Investigation of Desirability and Aesthetics

The second empirical study utilized a unique strategy to augment the quality of AI-created lamp designs, paying specific attention to their desirability and visual appeal. The method blended participant ratings of image aesthetics with the Low-Rank Adaptation (LoRA) technique, a strategy known for its efficiency in fine-tuning the Stable Diffusion model.

Participants were shown a series of lamp images, generated by four advanced AI models: Stable Diffusion, Open Journey, DALL-E 2, and Midjourney. Their task was to rate these images on the basis of desirability and visual appeal, thereby providing a standard for the quality of AI-produced designs. This feedback was instrumental for future design adjustments.

Next, images with high ratings in terms of desirability and visual appeal were isolated. The corresponding prompts for these highly-rated images were analyzed to identify common themes and patterns that contributed to their success. This analysis enriched our understanding of the potential impact human ratings can have on helping an AI model grasp design goals and human needs more effectively.

With this understanding, we utilized the LoRA technique to train two new models using these high-rated images and their corresponding prompts. This process facilitated the fine-tuning of these models, making them more efficient while using less memory. The aim was to evolve a model capable of consistently creating superior lamp designs that are both desirable and visually appealing, thereby closing the gap between human preferences and AI capabilities.

Significant improvements in the AI models' performance after fine-tuning confirmed the effectiveness of our participant feedback-driven design process. This study not only enhanced our design procedure but also extended our understanding of human design preferences. It culminated in a clearer vision of the symbiotic relationship between AI and human-led design, lighting the path in the intricate domain of AI-aided design and setting the stage for the next phase of our ongoing exploration.

Optimizing Image Generative AI in Tangible Lamp Concepts: Aesthetics, 3D Printability, and Alignment using GPT-4

This study explores the impact of prompt optimization, utilizing the GPT-4 large language model, on the performance of four generative AI models: Stable Diffusion, Open Journey, DALL-E 2 (Ramesh, 2022), and Midjourney. The models were evaluated in the context of generating lamp designs. Participants used these models to generate designs, both before and after the application of prompt optimization (Oppenlaender, 2022a) with GPT-4 (OpenAI, 2023). The designs were then evaluated based on their alignment with the design goals. The objective of the study was to investigate the influence of prompt optimization on the ability of AI models to generate designs that effectively meet the established goals.

Methodology

The Delft University of Technology's Human Research Ethics Committee (HREC) granted approval for data collection, ensuring strict adherence to the ethical principles outlined in the Declaration of Helsinki.

This study was meticulously structured to maintain logic and coherence throughout the process. Participants (n=10, for Midjourney n=8) engaged in 4-5 rounds of lamp design generation, each round incorporating both optimized and unoptimized prompts.

Initially, participants were asked to provide their own prompts for generating lamp designs. These prompts were then optimized using a custom GPT-4 model, leading to a set of optimized prompts. For each round, the AI system used both the original unoptimized prompts and the newly optimized ones to generate two distinct designs per participant (Hao, 2022).

Figure 24: testing UI interface for generating random images

To ensure impartiality, two designs—one derived from an optimized prompt and the other from an unoptimized prompt—were randomly exhibited for each model to participants via the user interface(Figure24). Participants remained unaware of which design corresponded to an optimized prompt. Due to certain biases making it challenging to integrate the Midjourney model within the testing system at the time, images from this model were manually generated in Discord and then added to the scoring database along with the prompts and optimized prompts.

After the completion of all generation rounds, participants were asked to evaluate each design. They assigned scores on a scale of zero to 100 to every design. Again, to avoid bias, all designs were randomized in the evaluation interface(Figure25).

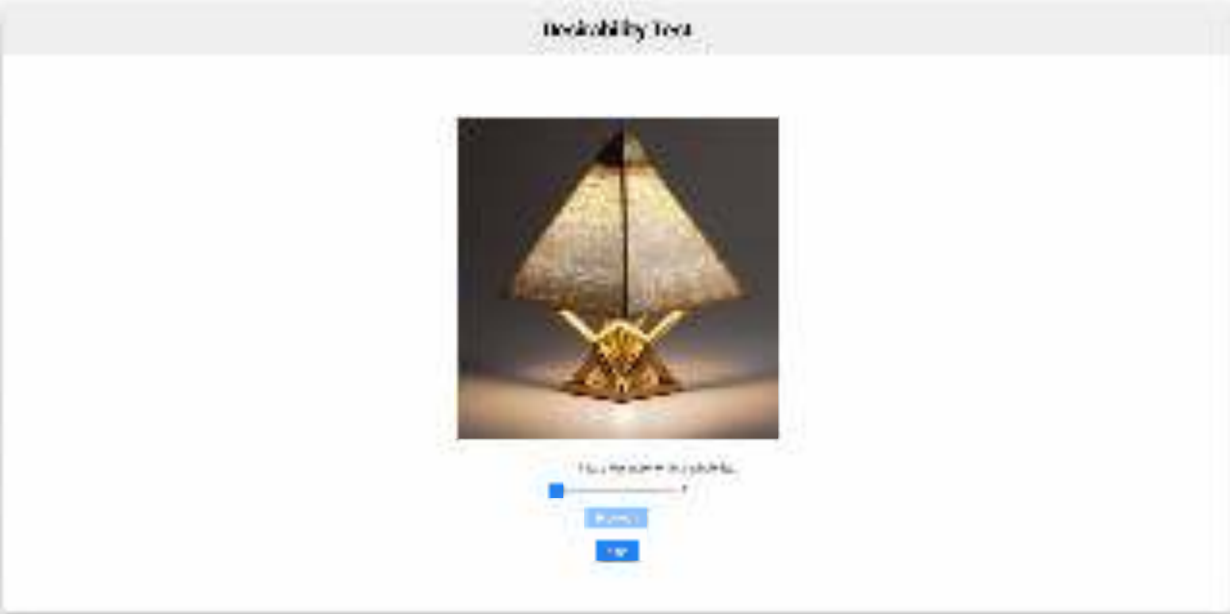


Figure 25. evaluation system

The study collected data on whether each design was based on an optimized or unoptimized prompt, which allowed a comparison of the scores between optimized and unoptimized designs.

Tools specifically designed for this study were employed to ensure the impartiality of the evaluation stage. These tools included imaging collection systems that kept participants in the dark about the optimization status of the designs. An evaluation interface uniquely built for this study and connected to our database was used to facilitate both design generation and evaluation processes.

Three key dimensions were used for assessment—**desirability, alignment, and printability. Desirability** referred to the attractiveness of a lamp design, influenced by individual preferences and the desire to own it, often shaped by personal tastes and cultural norms. **Alignment** was the degree to which the produced lamp design matched the user's original intention or prompt. **Printability** reflected the 3D printability of the design, taking into account factors like material compatibility, structural integrity, and design complexity. Participants were asked to rate each design on these dimensions based on their knowledge and experience with 3D printing(Figure26).

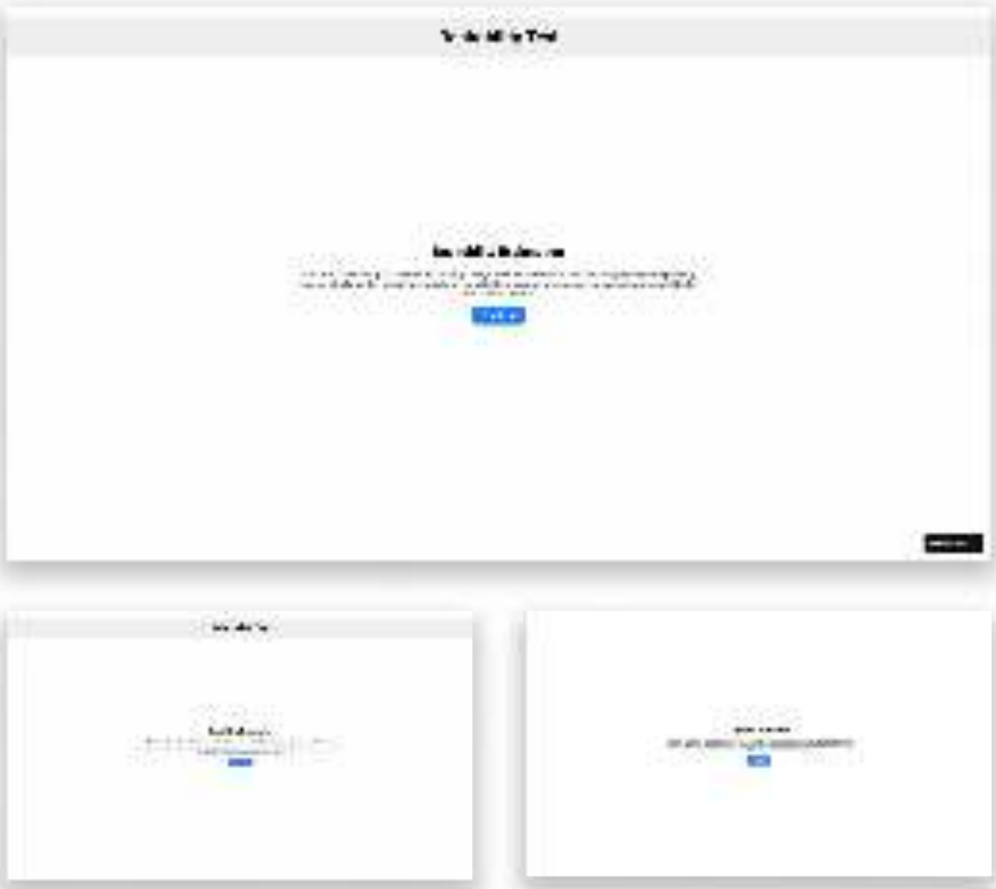


Figure 26. Evaluation system for three dimensions

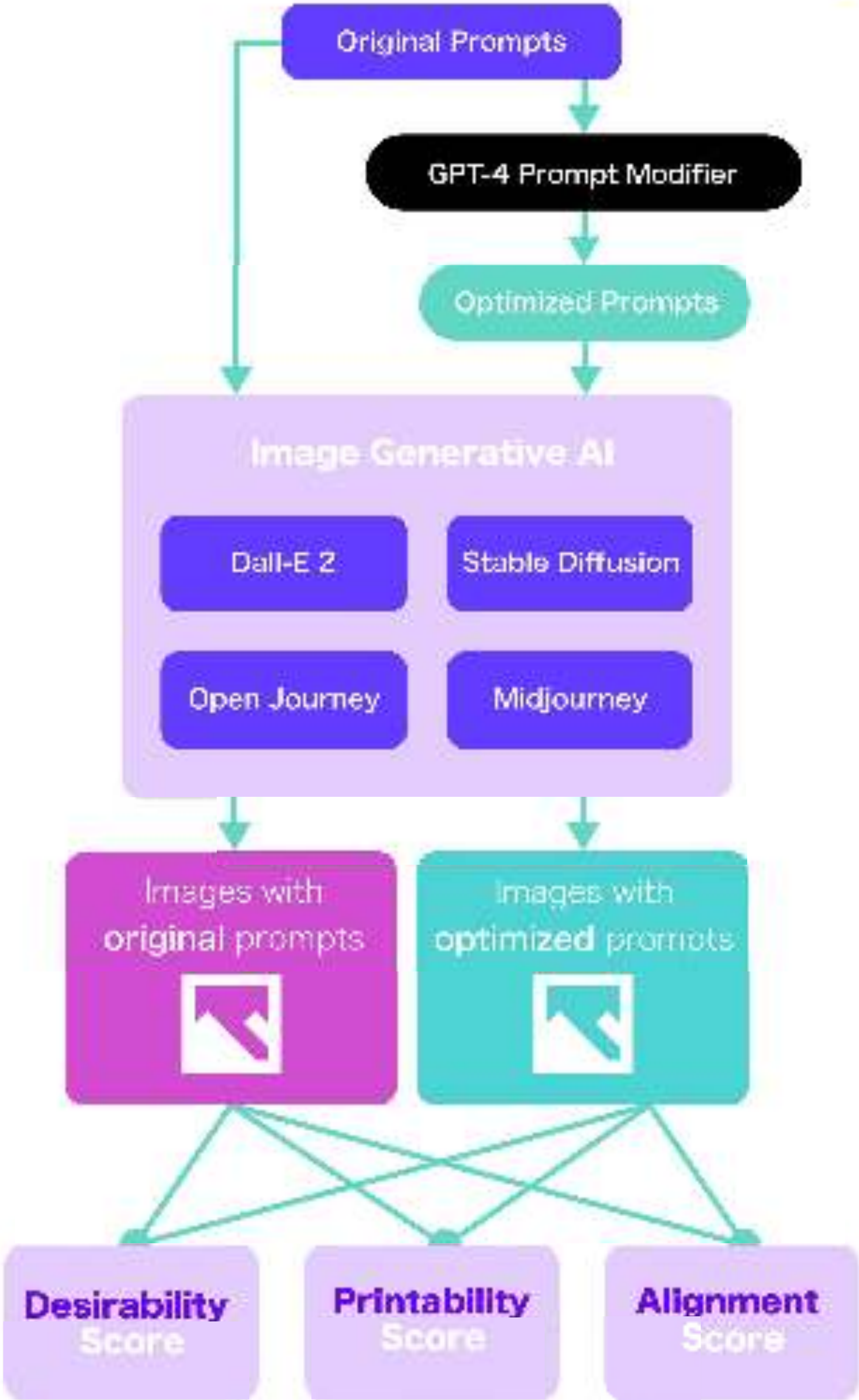


Figure 27. The framework of the study

Findings

Overall Findings

In the evaluation of GPT-4 prompt optimization, we analyzed three aspects: Desirability, Printability, and Alignment (Figure28).

The Desirability ratings improved significantly across all models after applying GPT-4 prompt optimization, as evidenced by a p-value of 3.37e-05***. Detailed statistical results will be available upon data accessibility.

In contrast, the Printability (p-value: 0.17) and Alignment (p-value: 0.20) ratings showed no significant changes after optimization. The full statistical findings for these measures will be supplied when the necessary data is obtained. These results suggest GPT-4 optimization had a limited impact on the printability and alignment of the design outputs.

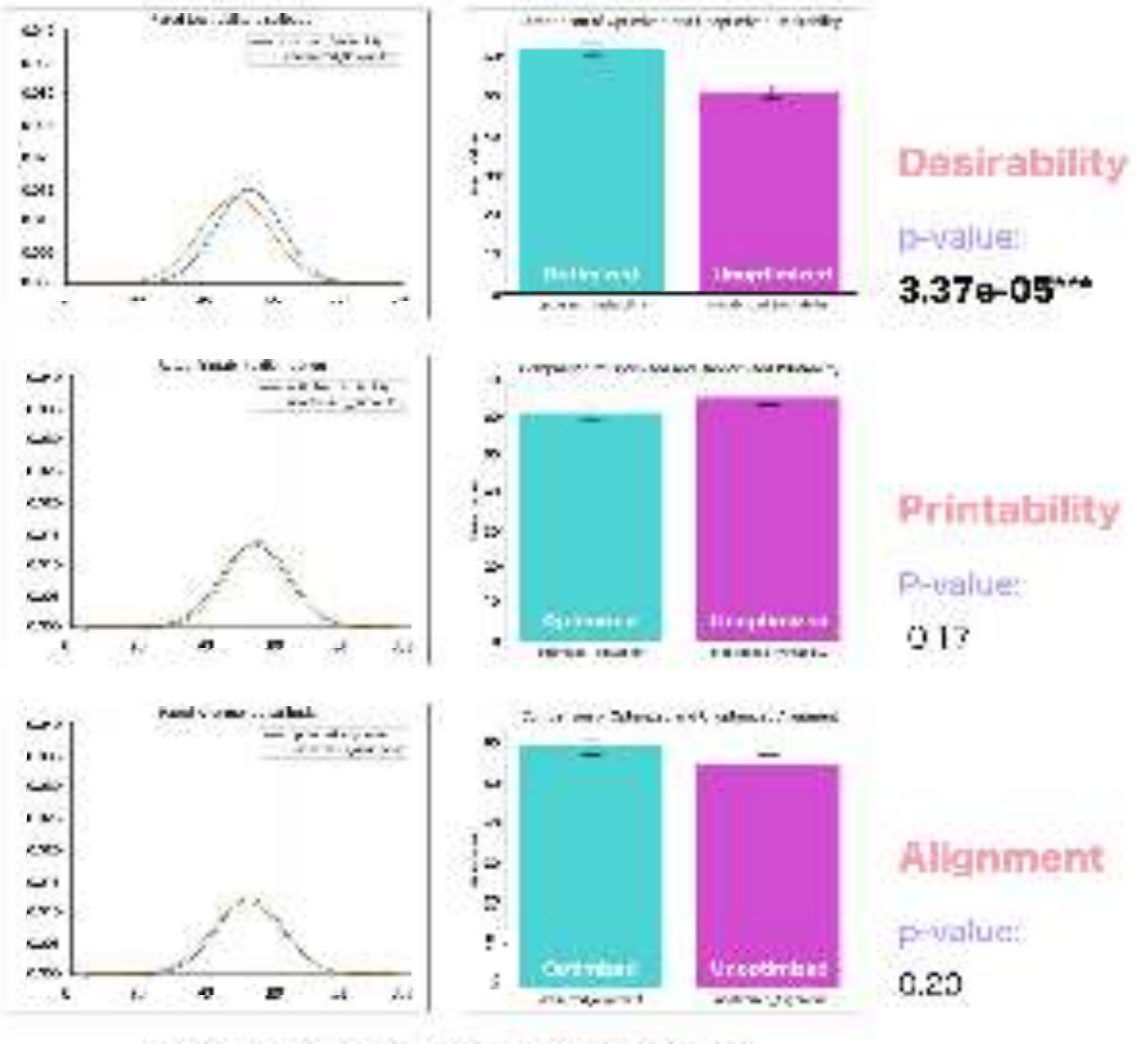
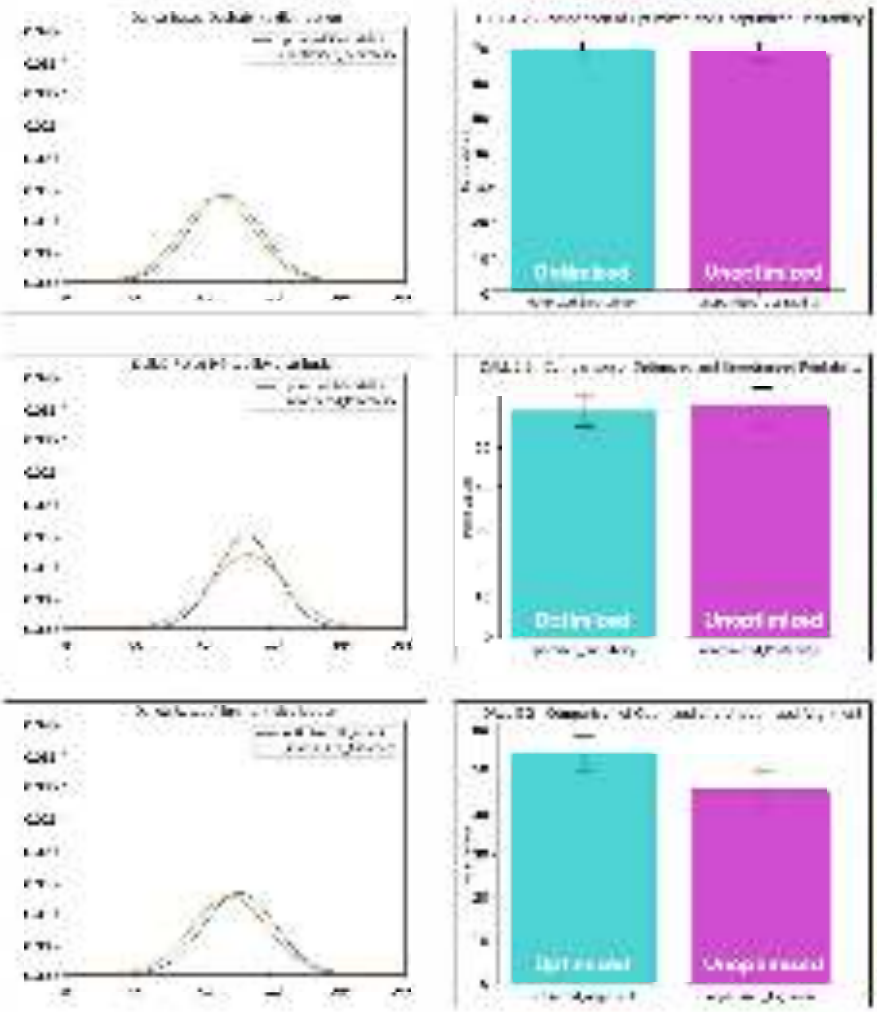


Figure 28. Overall Distribution plot and Bar plot

Individual Model Findings

DALL-E 2: This model didn't show any statistically significant difference in rated desirability, printability, or alignment after GPT-4 optimization (p-values of 0.24, 0.46, and 0.15, respectively)(Figure29).



Desirability

p-value:

0.24

Printability

p-value:

0.46

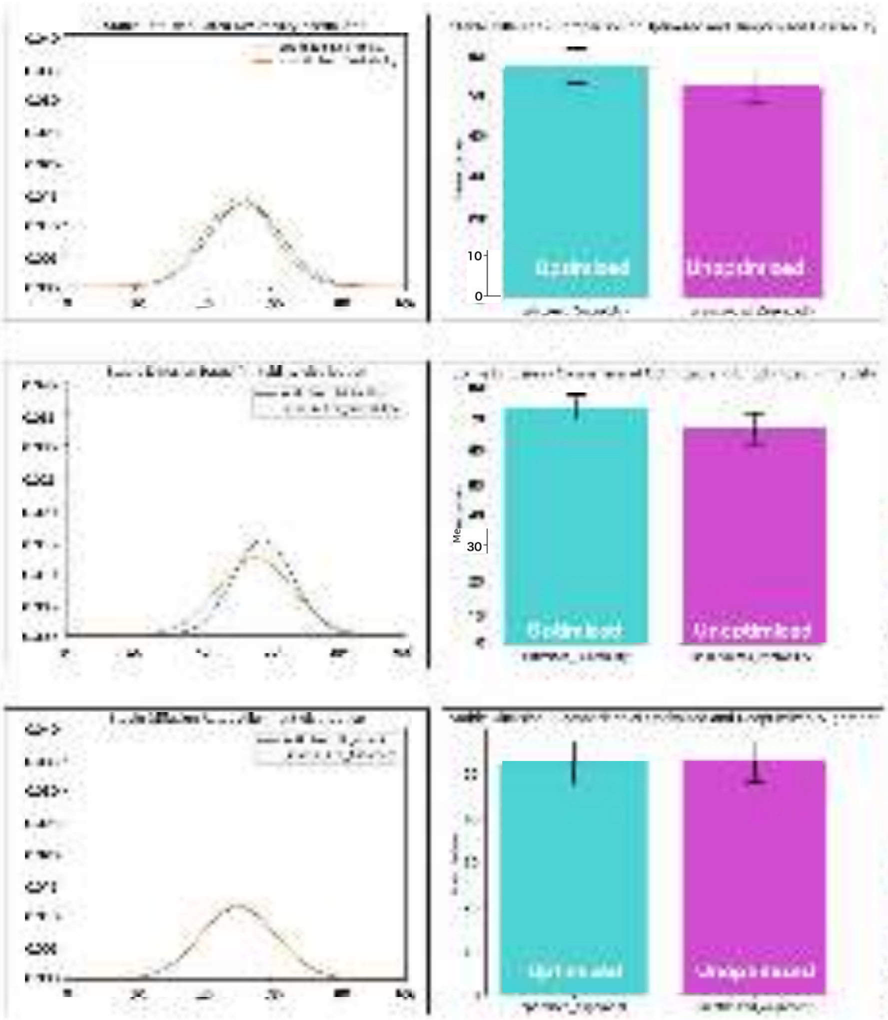
Alignment

p-value:

0.15

Figure 29. DALL-E 2 distribution plot and bar plot

Stable Diffusion: Similar to DALL-E 2, Stable Diffusion also didn't show any significant differences in rated desirability, printability, or alignment after the optimization (p-values of 0.35, 0.38, and 0.92, respectively)(Figure 30).



Desirability

p-value:

0.35

Printability

p-value:

0.38

Alignment

p-value:

0.92

Figure 30. Stable Diffusion Distribution plot and bar plot

Open Journey: This model showed a significant improvement in rated desirability after the optimization, with a p-value of 3.16e-05. However, there were no significant differences observed in printability or alignment (p-values of 0.37 and 0.037, respectively)(Figure31).

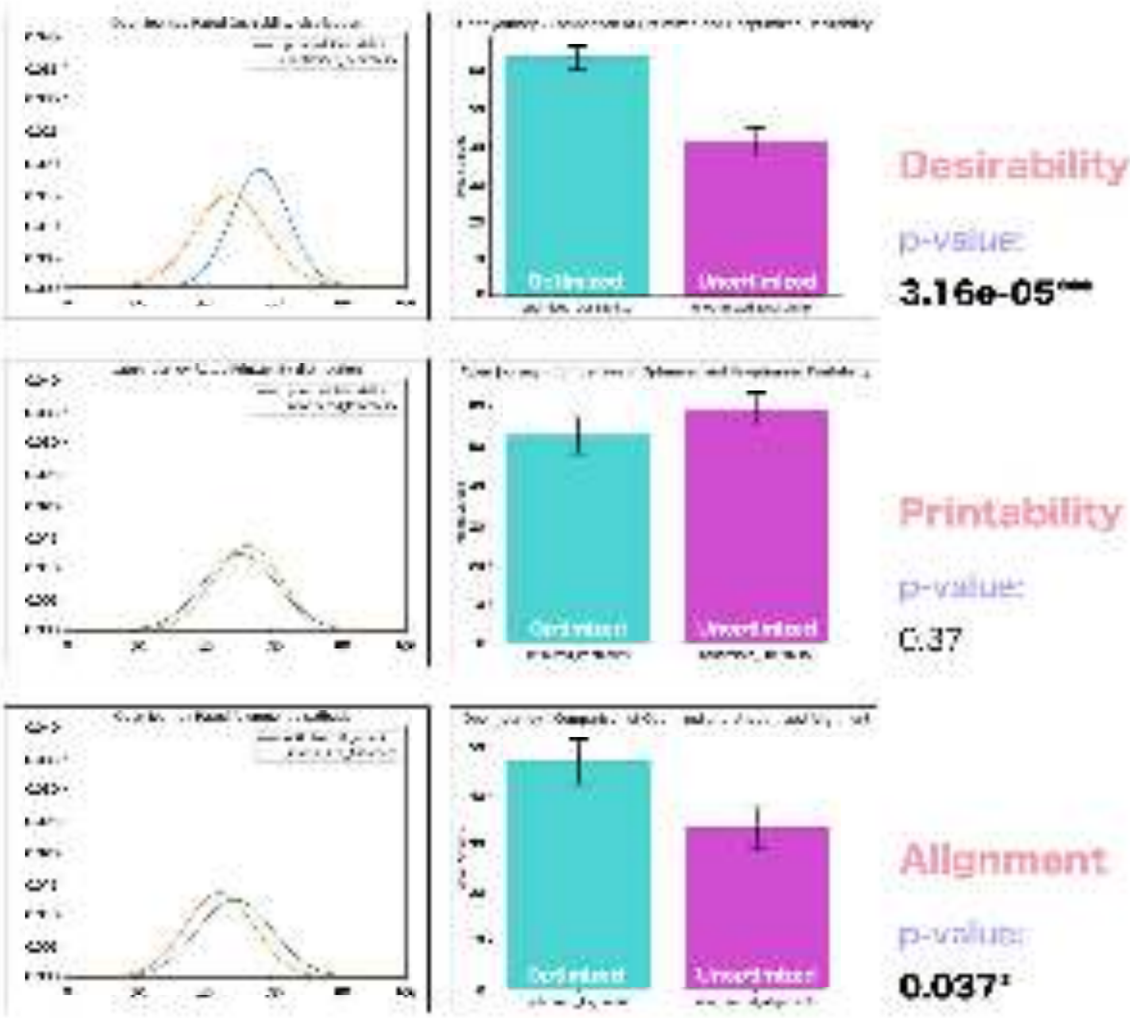
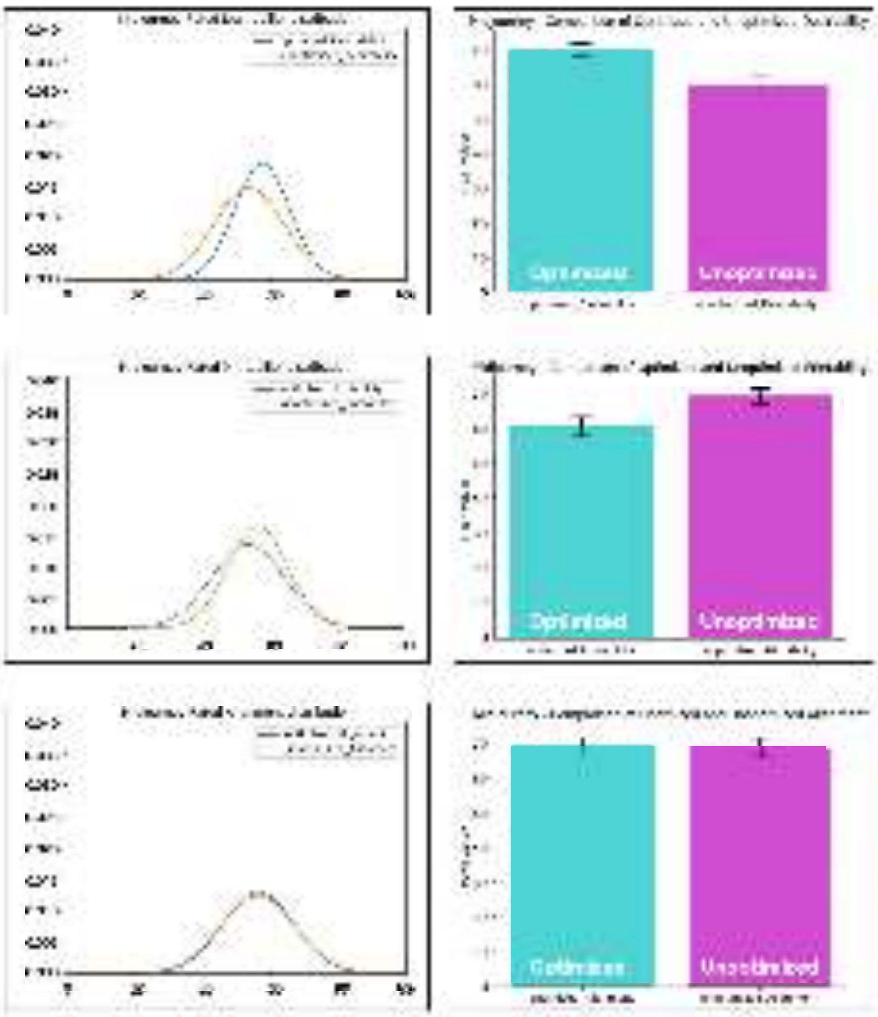


Figure 31. Open Journey Distribution plot and bar plot

Midjourney: After applying GPT-4 optimization, this model exhibited significant improvements in rated desirability, as confirmed by a Mann-Whitney U test with a p-value of 0.005. However, while there was an observable decrease in printability, the difference was not statistically significant (p-value of 0.07). Regarding the alignment with the original concept, no significant alteration was noted post-optimization (p-value of 0.84). These results indicate that while desirability improved significantly with GPT-4 optimization, printability and concept alignment remained largely unaffected(Figure32).



Desirability

p-value:

0.005**

Printability

p-value:

0.07

Alignment

p-value:

0.84

Figure 32. Midjourney Distribution plot and bar plot

The asterisk (*) and text in **purple** font are used to indicate a statistically significant increase.

The table(Figure33) encapsulates the key statistical results from the study, highlighting areas where notable differences were identified. The collective findings point to a significant difference in desirability across models, although the results for individual models differ. The Open Journey model demonstrated significant differences in both desirability and alignment, whereas the Midjourney model revealed significant differences in desirability. The DALL-E 2 and Stable Diffusion models, on the other hand, did not exhibit any significant differences across the evaluated parameters.

Model/ Category	Rated Desirability (U-statistic, p-value)	Rated Printability (U-statistic, p-value)	Rated Alignment (U-statistic, p-value)	Significant Difference
Midjourney	6620, 0.006*	9262.5, 0.07	8314, 0.84	Desirability
Open Journey	646, 3.16e-05*	1280, 0.37	946.5 0.036*	Desirability, Alignment
Stable Diffusion	1115, 0.25	1122.5, 0.38	1234.5, 0.92	None
DALL-E 2	1080, 0.24	1357, 0.46	1036.5, 0.15	None
Overall	30789.5, 3.37e-05*	41200.5, 0.17	36227.5, 0.20	Desirability

Figure 33. Mann-Whitney U-Test Results and Corresponding P-Values for Each Model Across Different Dimensions

Utilizing Human Ratings to Augment the Quality of AI-Generated Designs: A Two-Dimensional Investigation of Desirability and Aesthetics

This study focused on a unique strategy to elevate the quality of AI-created lamp designs. The objective of the study was to investigate the influence and integration of human ratings into AI systems to enable them to achieve design goals more effectively. Concentrating on two fundamental dimensions of design, desirability and aesthetics, the study harnessed participant ratings to set a benchmark for the quality of AI-generated designs. This feedback yielded valuable insights that guided future design iterations and the fine-tuning of models using the Low-Rank Adaptation (LoRA)(Hu, 2021) technique.

Methodology

The Delft University of Technology's Human Research Ethics Committee (HREC) granted approval for data collection, ensuring strict adherence to the ethical principles outlined in the Declaration of Helsinki.

Our methodology began with approximately 1800 lamp images generated by four different AI models - Stable Diffusion, Open Journey, DALL-E 2, and Midjourney. Out of these, we carefully selected 405 images with the best clarity and accurate perspective, considering their suitability for 3D model conversion(Burnap et al., 2019).

Participants were invited to rate a subset of these 100 images using a 'like' or 'dislike' (Figure34) scale along two dimensions. The first, 'desirability', measured whether users were attracted by the design to the extent that they would consider purchasing it. The second, 'visual appeal (aesthetics)', assessed the image's aesthetic quality independent of the design's suitability for the participants' personal needs. We concentrated on images that were rated between 5 to 15 times to ensure robust and reliable data.

Figure 34. Rating screen for desirability dimension.

This rating process enabled us to calculate the "like rate"(Figure35) for each image, defined as the number of "like" responses received divided by the total number of times the image was rated. A higher "like rate" suggests higher approval from the participants.

$$\text{"like rate"} = \frac{\text{like responses}}{\text{total responses}}$$

Figure 35. How the "like rate" is calculated

This rating process helped us identify 40 high-rated images for the desirability dimension and 34 for the visual appeal dimension. These high-rated images and their corresponding prompts served as the basis for training two separate models - one for desirability and another for visual appeal - using the Low-Rank Adaptation (LoRA) technique. LoRA(Figure36), built specifically for Stable Diffusion, allowed us to optimize these models with reduced memory usage and accelerated training times.

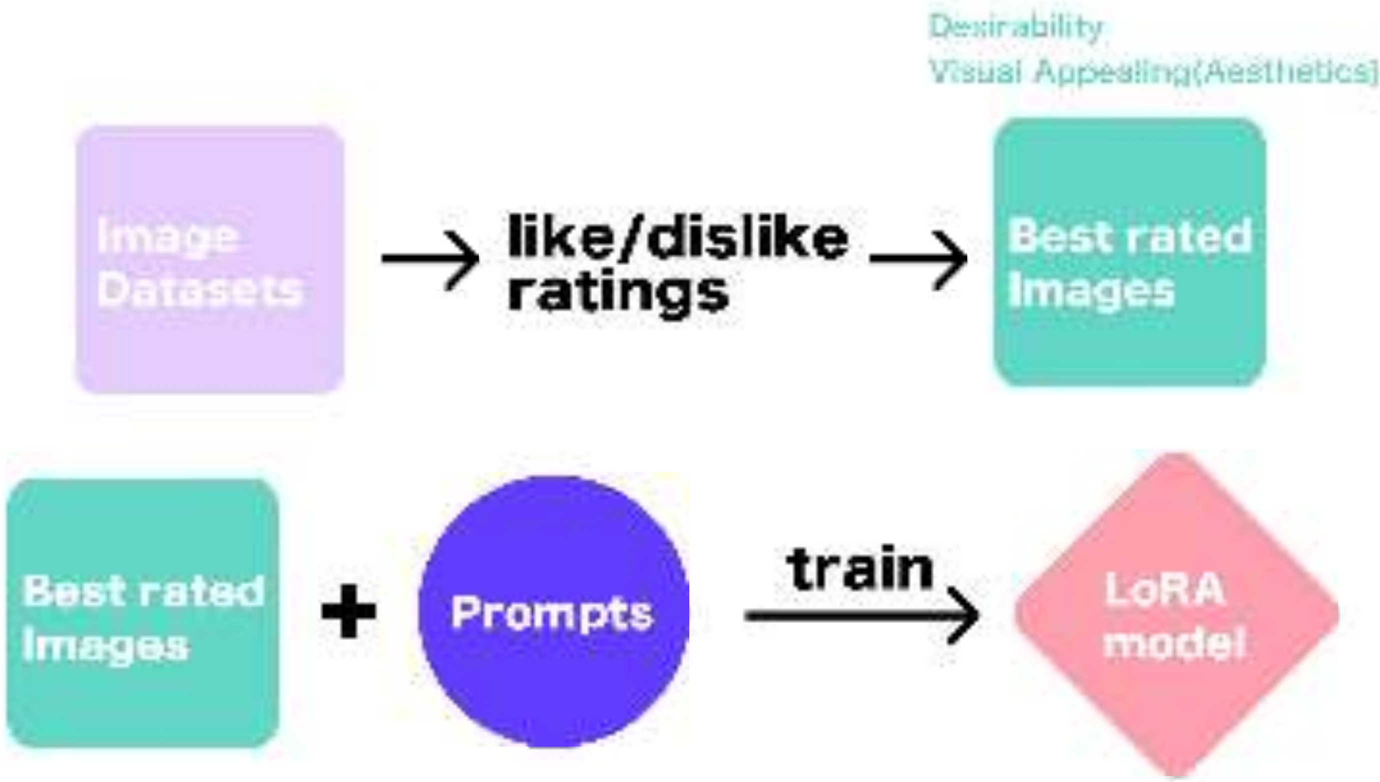


Figure 36. How we trained the LoRA model

Once trained, each model generated 100 images using 50 different prompts for evaluation. Of these, 50 images were produced directly through the original Stable Diffusion model, and the remaining 50 were generated by the Stable Diffusion model fine-tuned with the newly trained LoRA models.(Figure37)

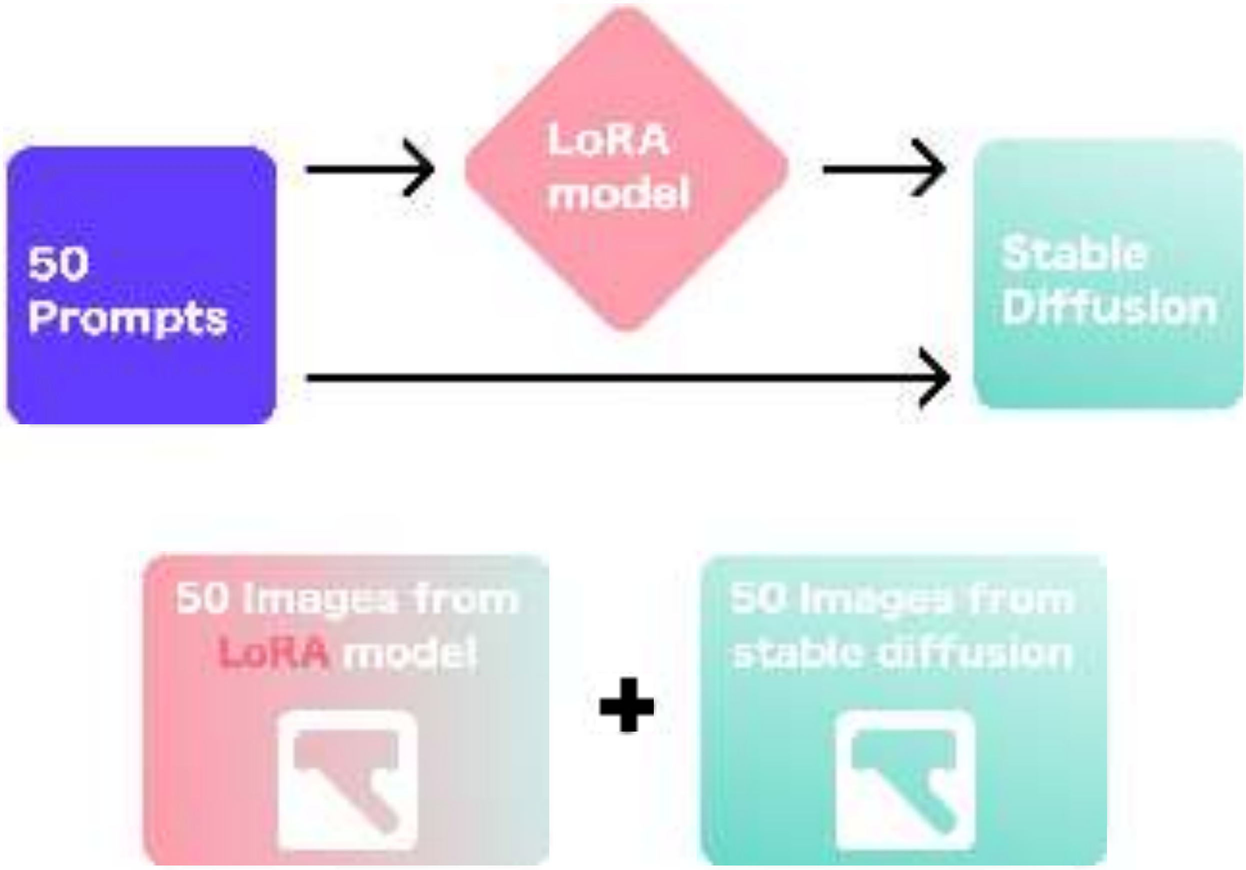


Figure 37. How the LoRA model is applied

We followed this up by separately conducting the "like" or "dislike" rating process again on these 100 images for both the desirability and visual appeal dimensions. We then compared the like rates between the images generated by the original Stable Diffusion model and those produced by the LoRA enhanced Stable Diffusion model. The objective was to assess the effectiveness of the human ratings integrated into the AI models and to evaluate if the AI models were better aligning with the design goals through this approach.

Findings

Desirability

For the dimension of desirability, defined as whether a user is attracted by the design to the extent of considering a purchase, we evaluated a total of 100 images. These images were equally divided between those produced by the LoRA enhanced Stable Diffusion model and those generated directly from the original Stable Diffusion model. Each image underwent 28 to 35 rounds of "like" or "dislike" ratings.

Our analysis revealed a substantial improvement in the desirability of lamp designs created by the LoRA enhanced model compared to those from the original Stable Diffusion model. A highly significant p-value of 0.0001(Figure38) was observed between the unoptimized and optimized image sets, indicating a statistically significant enhancement.

This data suggests that by using the LoRA technique, which integrates human ratings into the AI model training process, we can effectively steer the AI system towards generating lamp design images that more closely align with human notions of desirability. It underscores the effectiveness of the LoRA technique in augmenting the performance of generative AI models to produce more desirable design outputs.

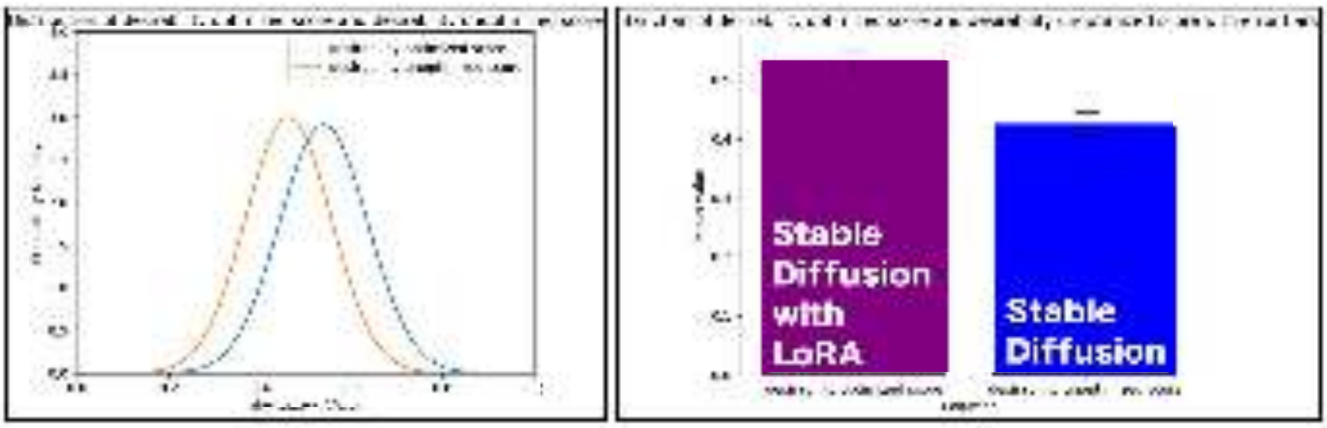


Figure 38. Desirability Distribution plot and bar plot

Significantly improved

p-value: 0.0001

Visual appealing(Aesthetics)

Turning to the visual appeal dimension, which evaluates the aesthetic quality of a design without considering its suitability for the user's personal needs, we assessed another set of 100 images. These were equally divided between those generated by the LoRA-enhanced Stable Diffusion model and those produced directly by the original Stable Diffusion model. Each image underwent the same 25 to 30 rounds of "like" or "dislike" ratings.

Our analysis revealed a significant improvement in the visual appeal of the lamp designs created by the LoRA-enhanced model compared to those from the original Stable Diffusion model. An extremely significant p-value of 9.8*10^-8(Figure39) was observed between the unoptimized and optimized image sets, indicating a highly statistically significant enhancement.

These findings suggest that the integration of human ratings in the training of the AI model using the LoRA technique can effectively guide the AI system towards generating lamp design images that more closely align with human notions of aesthetic appeal. This underscores the effectiveness of the LoRA technique in enhancing the performance of generative AI models to produce visually appealing design outputs.

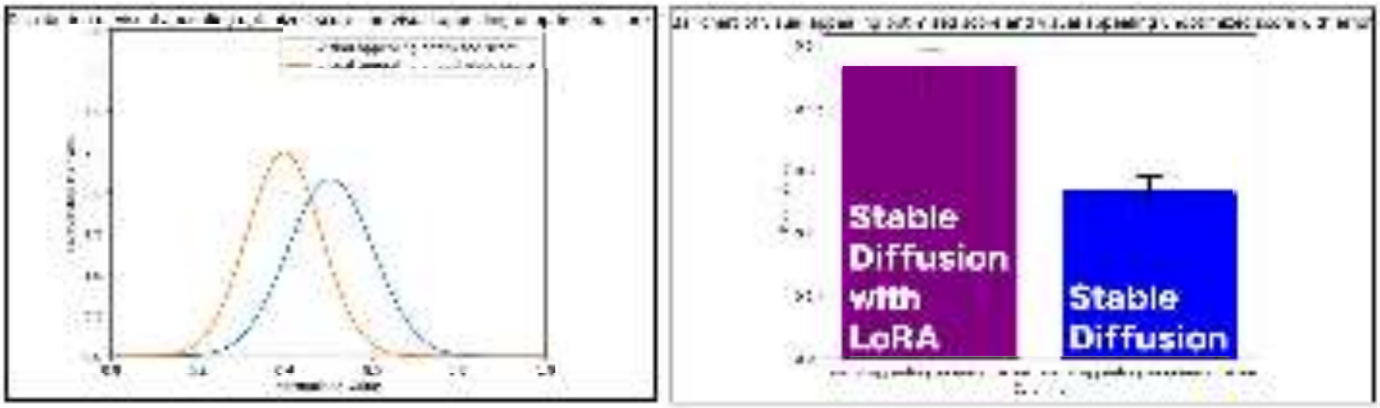


Figure 39. Visual appealing(Aesthetics) Distribution plot and bar plot

Significantly Improved
p-value: 9.8*10^-08

Conclusion

In our comprehensive empirical research comprising two main studies, we've gained essential insights into the potential of artificial intelligence as a tool to augment and enhance the design process. Specifically, our findings illustrate the promise of both a GPT-4 based prompt optimizer and a LoRA-enhanced Stable Diffusion model, in guiding AI systems closer to human preferences in design. This synthesis of evidence further cements the role of AI as a vital asset for designers.

The first study demonstrated notable improvements in the **desirability** and **alignment** of designs, proving the effectiveness of prompt optimization. Yet, when it came to **printability**, the results were more nuanced. We did not observe a significant improvement, and there were even instances of a negative trend. This discrepancy suggests that while AI has made strides in some aspects of the design process, its impact on physical elements like printability is still an area that warrants further investigation.

Our second study, embodying human ratings in the AI model's training process, led to significant enhancements in both **desirability** and **aesthetic** aspect of AI-generated designs. This not only reinforced the role of AI in achieving high-quality designs but also underscored the transformative potential of user-centric feedback in refining AI models.

Even in situations where statistical differences weren't as pronounced, a general trend towards improvement after optimization was apparent. This suggests that AI's value extends beyond tangible improvements—it can subtly enhance the design process in ways that may not be immediately quantifiable(Figure40).

Armed with these insights, we made strides in enhancing our chatbot's functionality, integrating it into our design tool's chat interface. By streamlining the optimization process and reducing manual tasks, we've made the AI-assisted design process more intuitive and accessible for designers. Subsequent user interviews confirmed the effectiveness of these changes, with designers appreciating the increased intuitiveness and efficacy of the tool, reflecting our successful efforts to synchronize AI-assisted design benefits with their requirements.

Still, our journey is far from over. The potential of AI in design is expansive, and the understanding of physical aspects like printability still has room for deeper exploration. As we proceed, our goal remains to broaden the scope of AI-assisted design, delving deeper into the crossroads of AI capabilities and human design preferences, driving us towards the exciting future of design.

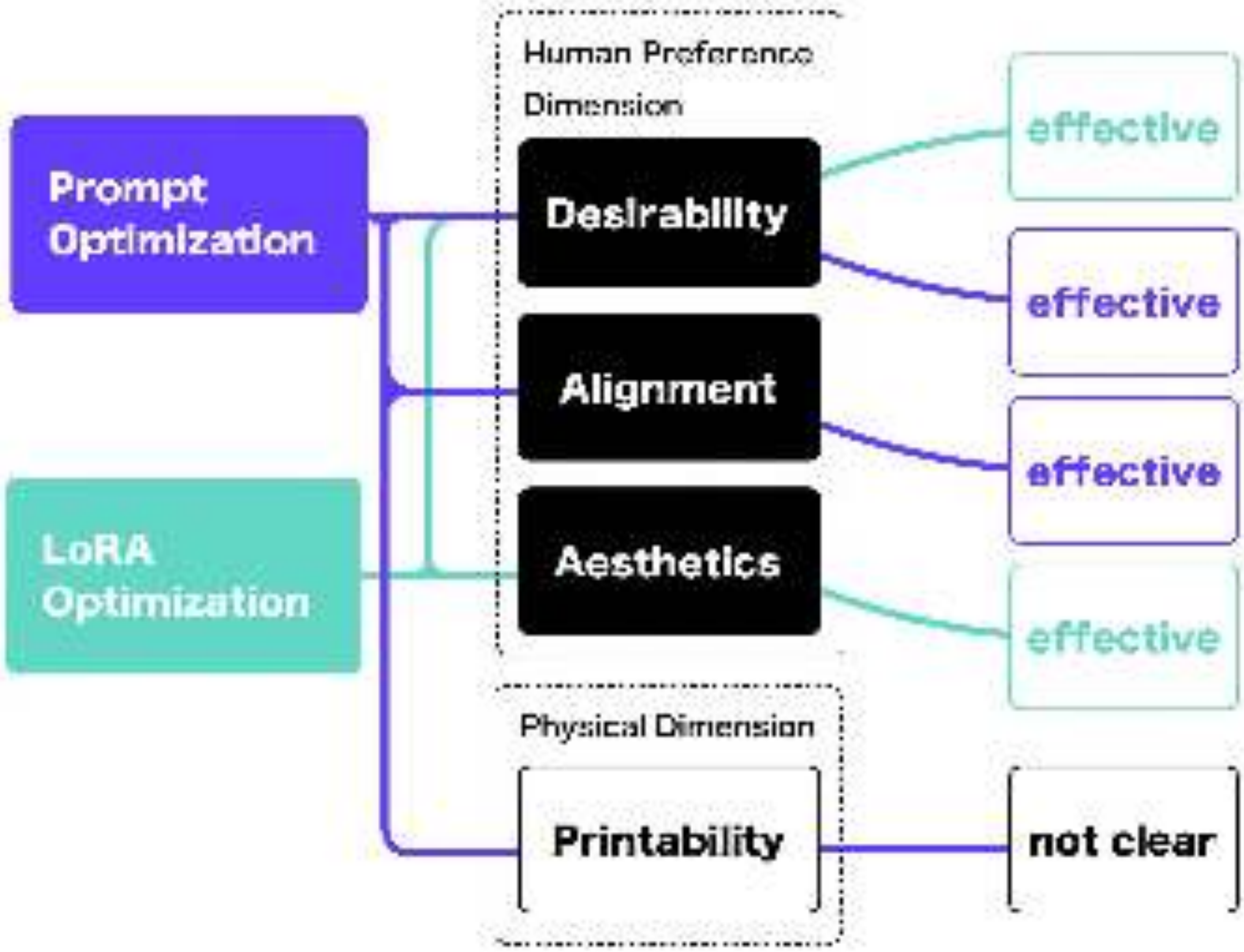
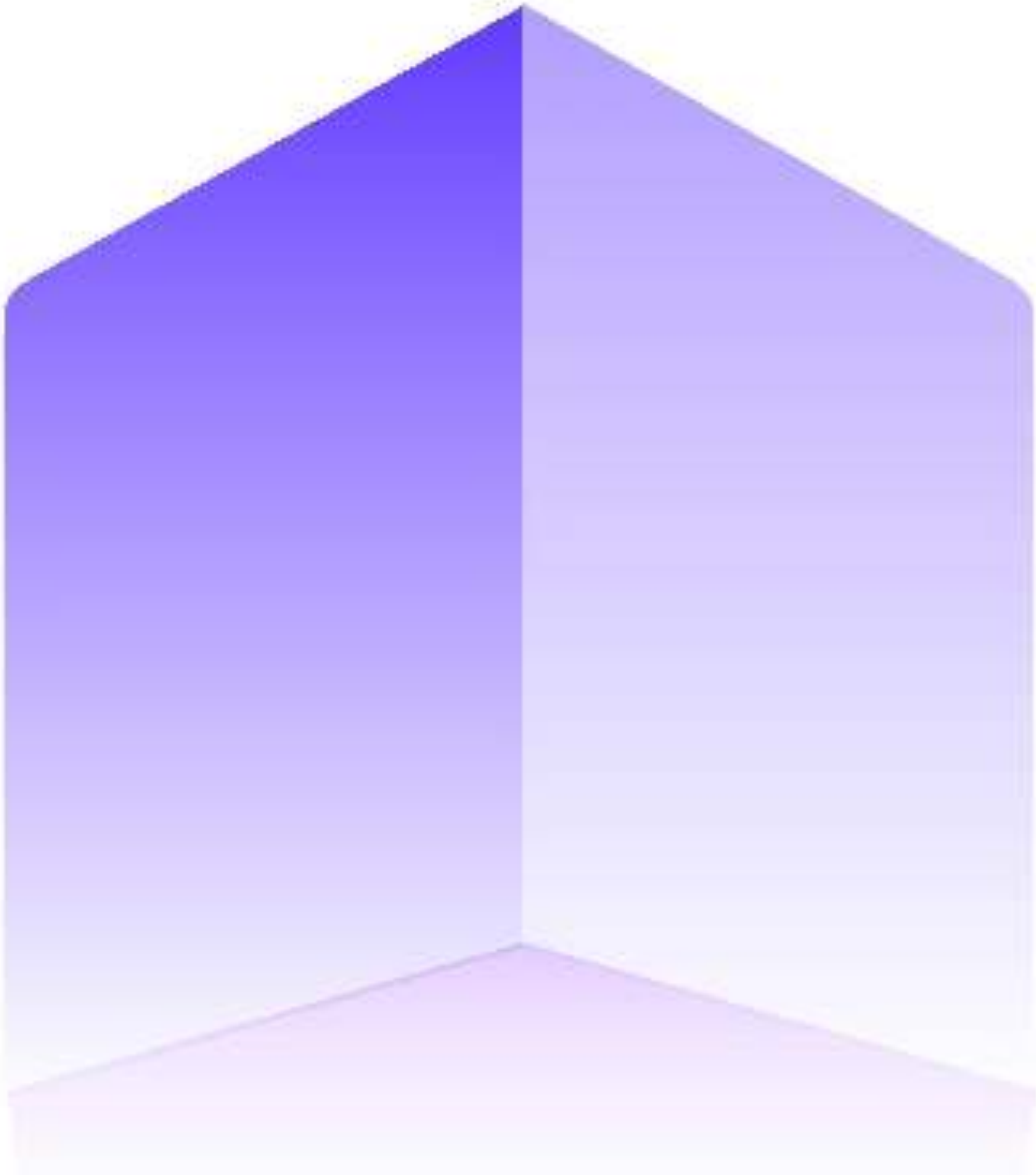


Figure 40: Exploring the Various Dimensions in the AI Approach and Their Results

Exploration in
3D Realization



Chapter Introduction

In the third chapter, 3D Realization, the focus is on the practical aspects of turning AI generated 2D images into 3D models, and the subsequent printing of these models. The chapter begins with an in-depth look at the tools and methods used for transforming 2D designs into 3D. This includes showcasing different software and techniques, and discussing the merits and limitations of each.

Following this, the exploration shifts to the 3D printing stage, where various methods of 3D printing are examined. This examination provides a detailed understanding of the different results each printing method can achieve, complete with accompanying images to illustrate these effects.

Throughout the chapter, the essential role of the designer in the 3D realization of the model is emphasized. Despite the assistance of AI and advanced tools, the designer's skills, intuition, and judgment remain crucial in successfully bringing the model to life.

The chapter concludes by reflecting on the entire journey from text prompts to tangible design works. It celebrates the magic of this transformative process and the groundbreaking potential it holds for the future of design. In its entirety, this chapter is an exploration of the final, crucial stage in the AI-assisted design process, revealing the intricacies of turning AI-generated designs into physical, 3D printed objects.

AI-Assisted 3D Modeling

The transformation of 2D designs into 3D models is a pivotal step in the 3D realization process. This is where the AI-generated designs take on a new dimension, both literally and figuratively. The primary technical challenge lies in transforming a single image into a 3D model.

Kaedim 3D

In our project, we primarily used Kaedim 3D(Figure41), an AI-powered tool that can convert single images into 3D models. While the quality of the output model can vary significantly, Kaedim 3D provides a valuable starting point for the 3D modeling process.

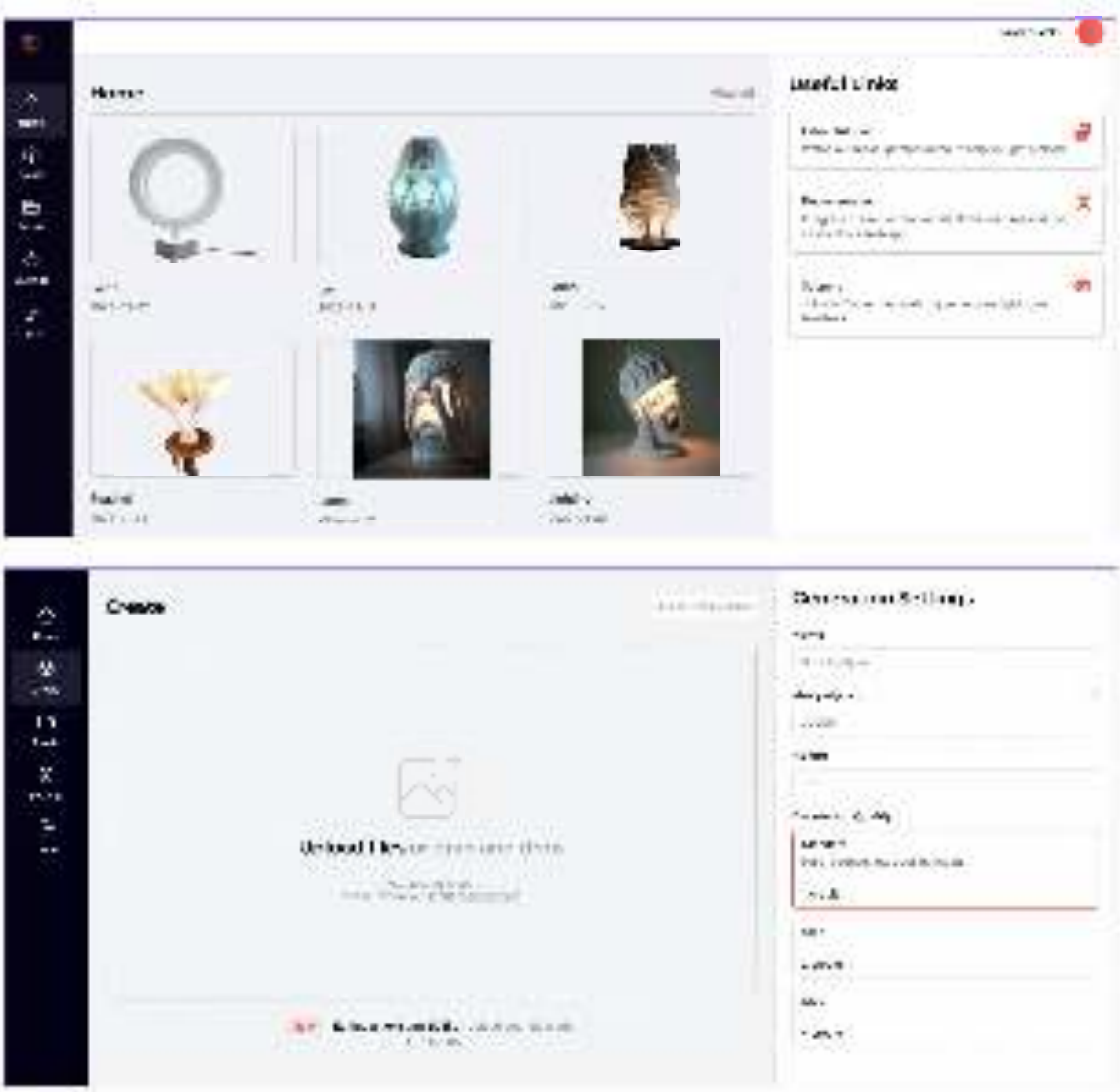


Figure 41. User Interface of Kaedim 3D

Kaedim is an AI-driven platform that enables the conversion of 2D images into 3D models. In this project, it was utilized to transform 2D lamp design concepts into initial 3D models. The platform allows users to upload images, which are then processed by its AI algorithms to generate corresponding 3D models. Despite the varying quality of the output(Figure42), Kaedim served as a valuable starting point for the 3D realization process. The generated models were further refined using other tools, highlighting the importance of designer input in achieving the desired final product.

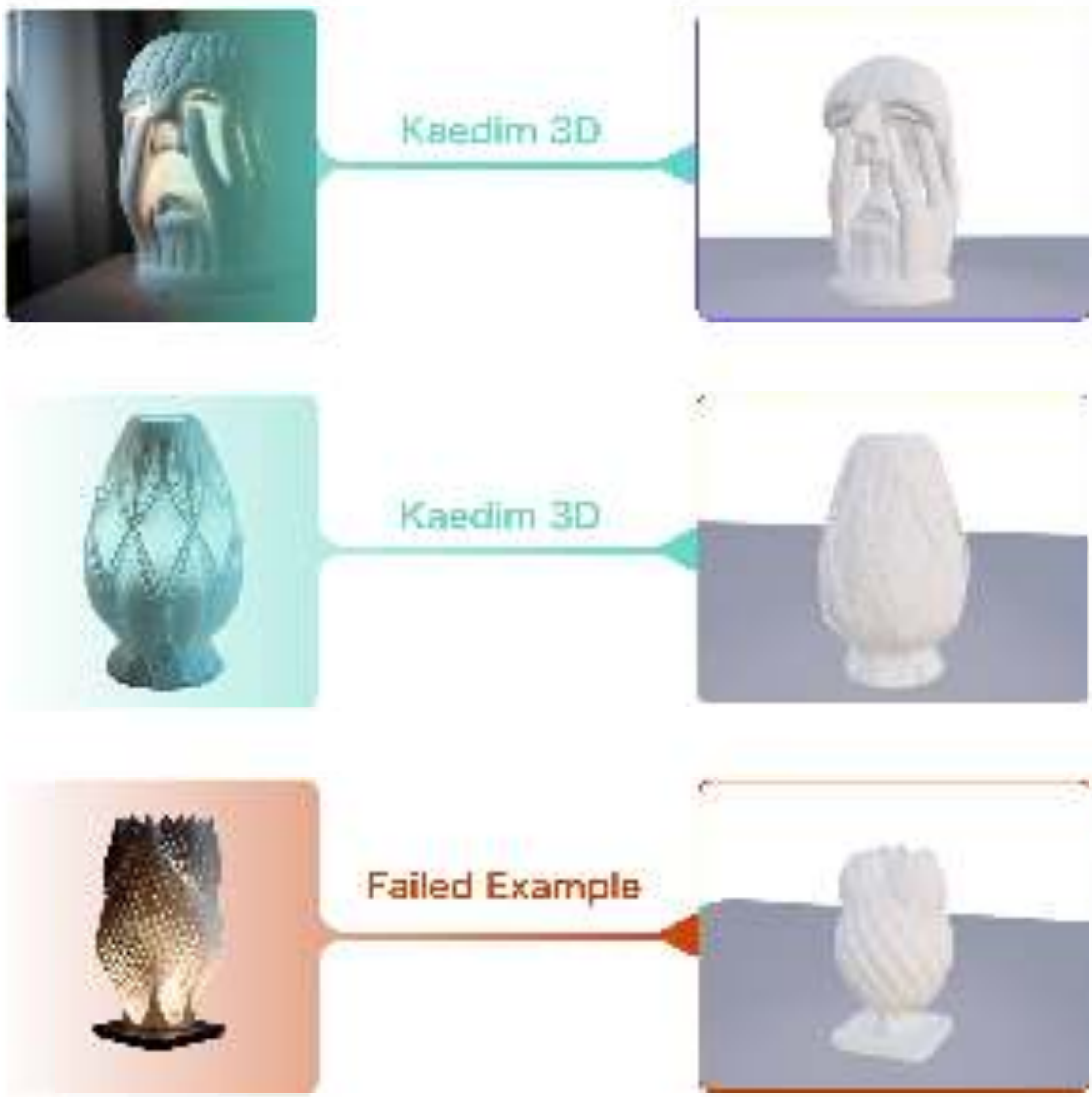


Figure 42. The AI-assisted modelling through Kaedim 3D

Manual Editing

However, the AI-generated models often required further refinement to meet our specific design goals. This is where the designer's expertise came into play. Using 3D modeling software such as Cinema 4D (C4D) and SolidWorks, we were able to modify and enhance the AI-generated models, tailoring them to our needs.

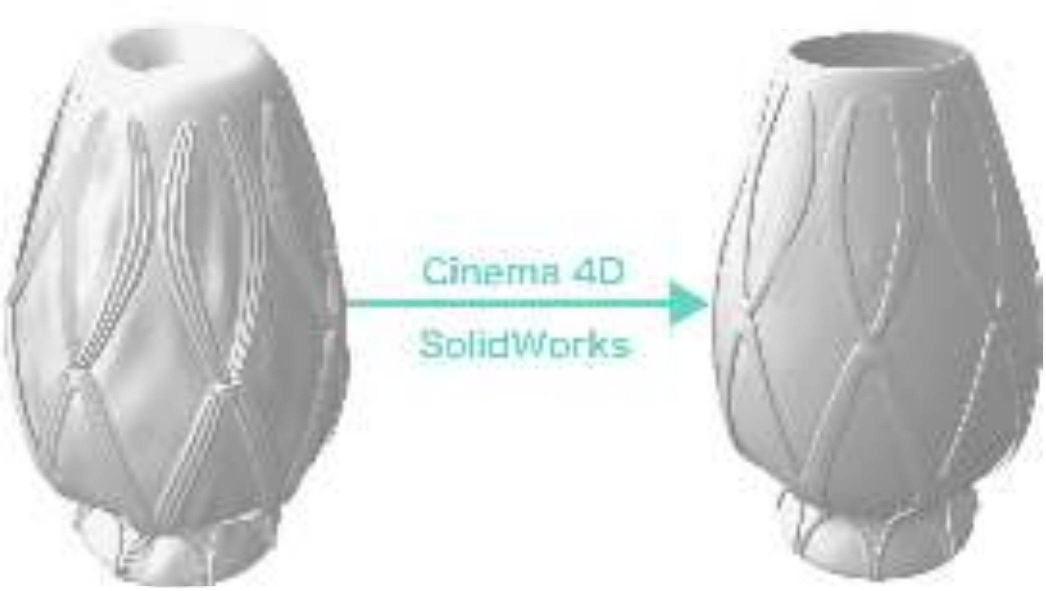


Figure 43: Modifying the AI-generated models manually to make it fit the design goals

For example(Figure43), adjustments were made to hollow out the models, creating the necessary space to accommodate lighting components. The models were also re-meshed to optimize their structure for 3D printing. This process involved adjusting the distribution of polygons in the model to ensure a smooth surface and structural integrity.

These adjustments were crucial in preparing the models for the next stage of the process - 3D printing. They ensured that the models were not only aesthetically pleasing but also functional as actual lamps. This highlights the importance of the designer's role in refining and optimizing the AI-generated models for real-world application.

In summary, the manual editing process for transforming AI-generated 2D images into tangible lamp designs involves several crucial considerations:

1. **Electronics and Lighting Accommodation:** The 3D model must have sufficient space to house the necessary electronic components and lighting elements.
2. **Optimization for 3D Printing:** The model should be prepared for 3D printing, which could involve thickening walls for structural integrity and ensuring the model is watertight.
3. **Structural Reasonability:** The design must be structurally sound and practical as a real product, considering factors such as balance, weight distribution, and durability.
4. **Aesthetic Refinement:** The aesthetic appeal of the lamp must be maintained. Designers may need to refine and adjust the model to ensure it aligns with the initial design vision and is visually appealing.

Other 2D to 3D exploration

In addition to Kaedim 3D, we also explored several open-source AI projects that offer potential for converting single images into 3D models. These included Shape-E, Point-E and Zero-1-to-3. While these tools offer exciting possibilities, they also have their limitations, and the quality of the resulting 3D models can vary.

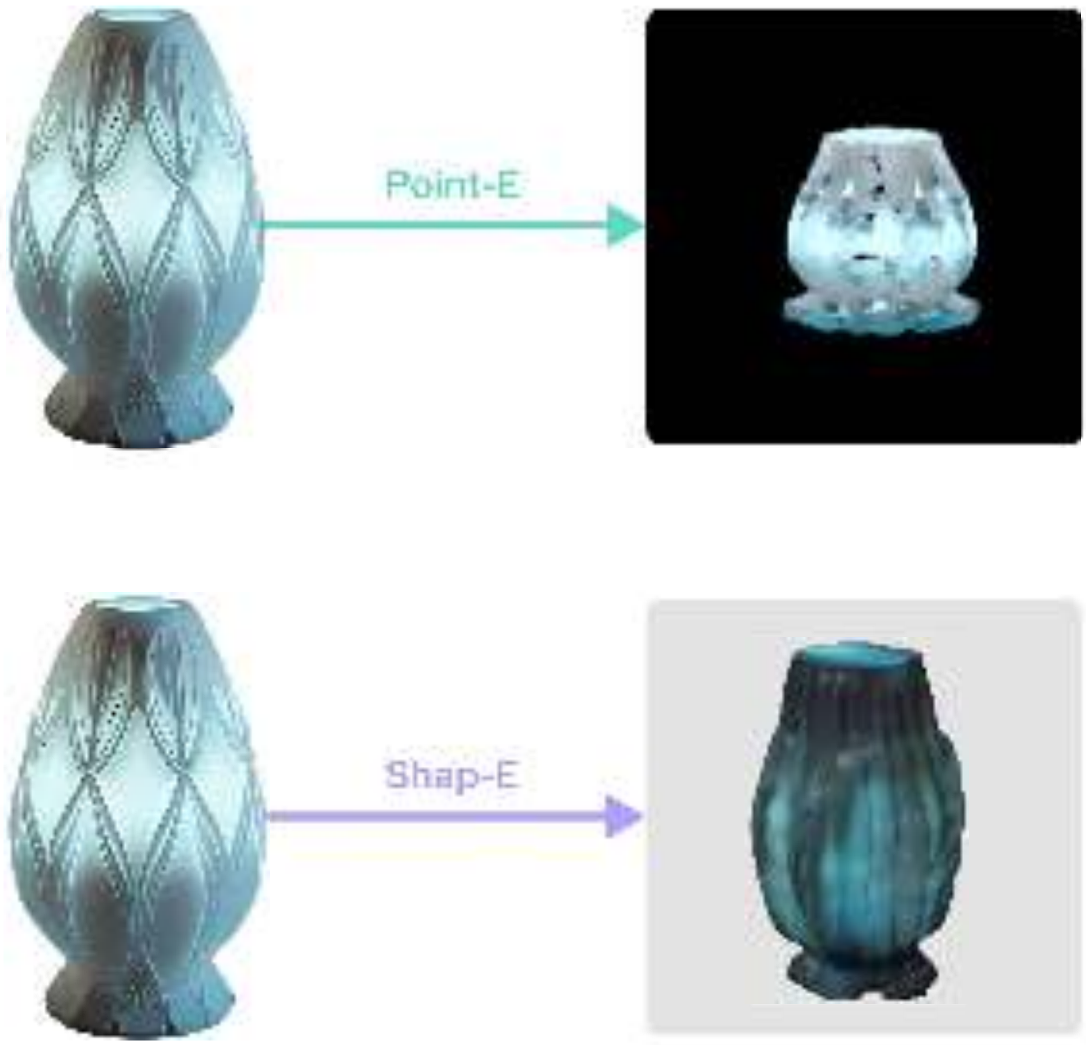


Figure 44. Open-source model Point-E and Shap-E can generate 3d models from single 2D images.

Point-E and Shap-E:

they are AI models developed by OpenAI, each offering unique capabilities for generating 3D representations(Figure44).

Point-E(Nichol, 2022), is designed to create 3D point clouds from complex prompts or single images providing a rough 3D structure of the design.

Shap-E(Jun, 2023), on the other hand, is aimed at generating more detailed and accurate 3D objects. It employs a feature called neural radiance fields (NeRFs) to enhance the clarity of the generated model.

Shap-E and Point-E represent the forefront of open source AI technology for converting single 2D images into 3D models. Their advanced capabilities and unique approaches have set new standards in the field, pushing the boundaries of what is currently possible in AI-assisted 3D modeling.

Zero-1-to-3

Zero-1-to-3 is an AI model that can generate novel views and reconstruct 3D objects from a single image. These capabilities can aid in manual model building by providing different perspectives of a design concept, which can be particularly useful when creating a 3D model of a lamp design concept.(Figure45)

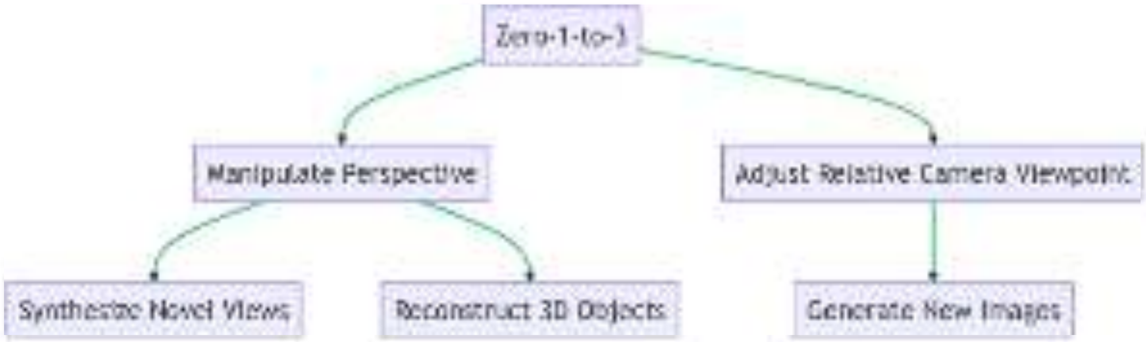


Figure 45. The structure of Zero-1-to-3

In the context of this project, **Zero-1-to-3** could potentially be used to generate different viewpoints(Figure46) of a lamp design concept. This could assist designers in visualizing the design from various angles, thereby aiding in the manual construction of the 3D model

Figure 46. Zero-1-to-3 can generate different views from single 2d images

Constraints of Open-Source Models

Despite the advanced capabilities of the open-source models: Shap-e, Point-E, and Zero-1-to-3, they are not without limitations. These models perform well with simple and clear images, but when it comes to more complex and asymmetrical structures, their performance can be less reliable.

The quality of the resulting 3D models can vary, and in some cases, significant manual editing may be required to achieve the desired result. This highlights an area for future development and improvement in the field of AI-assisted 3D modeling.

Design Guide

When leveraging AI models to convert single images into 3D models, designers should adhere to the following guidelines to ensure a smooth and successful transformation process:

1. **Background Removal:** It is advisable to generate images with prompts such as "solid color background" or "clear background". This can enhance the transformation process and increase the success rate.
2. **Accurate Perspective:** Maintaining a clean and accurate perspective in the image is crucial. An accurate perspective can yield a more precise output. Prompts like "orthographic view" or "three views" can be used when generating the design.
3. **Brightness:** Images that are too dark may pose challenges for the transformation process. It is recommended to keep the image bright. This can also be achieved with specific prompts.
4. **Geometry Complexity:** If you are using open-source models like Point-E and Shap-E, ensure that the geometry of your lamp design concepts is not overly complex. These models may struggle with complex geometries, leading to suboptimal results.

3D Printing

In the final stage of our project, we bring our AI assisted designs to life through 3D printing. This crucial phase transforms our digital concepts into physical, tangible products, allowing us to assess their real-world feasibility and aesthetic appeal. Any necessary modifications for practicality and visual attractiveness are made at this stage.

Our project employs a range of 3D printing technologies, each contributing unique capabilities that shape the final product. These technologies include Fused Deposition Modeling (FDM), Stereolithography Apparatus (SLA), and Selective Laser Sintering (SLS). We also anticipate the potential use of future technologies, such as ceramic printing.

This section will delve into the role of each technology in the form-giving process and present case studies demonstrating their application in the realization of our AI assisted designs. A variety of lamps printed using different methods will be showcased in this section, serving as visual representations of our work (Shahrubudin et. al. 2019).

Which Methodologies Have We Experimented With for 3D Modelling and Prototyping in This Project?

FDM printing

Fused Deposition Modeling (FDM) is a prevalent 3D printing method. It is an additive manufacturing technology where a thermoplastic material is heated and extruded layer by layer to construct a three-dimensional object. The material, in filament form, is supplied from a large coil through a moving, heated printer extruder head.

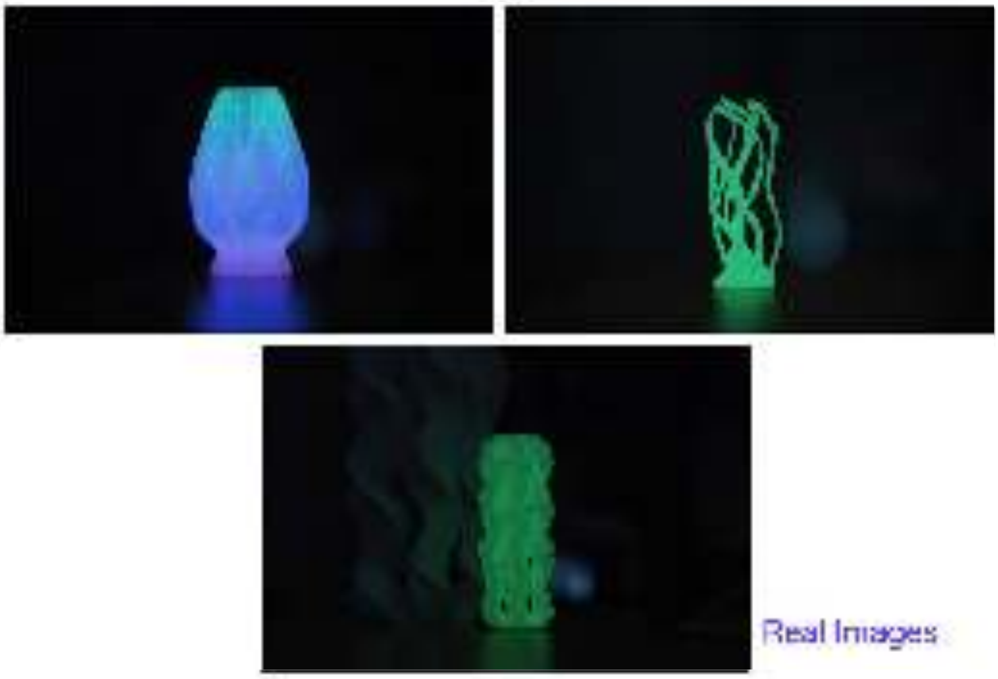
In our project, we utilized this method to print with various materials, including standard PLA (Polylactic Acid), fluorescent PLA, and PETG (Polyethylene Terephthalate Glycol). Each of these materials introduces unique properties to our 3D prints.

The standard PLA(Figure47) is a popular choice due to its ease of use and good detail representation. It's a versatile material that can be used for a wide range of prints.

Real Images

Figure 47. Normal PLA FDM printing

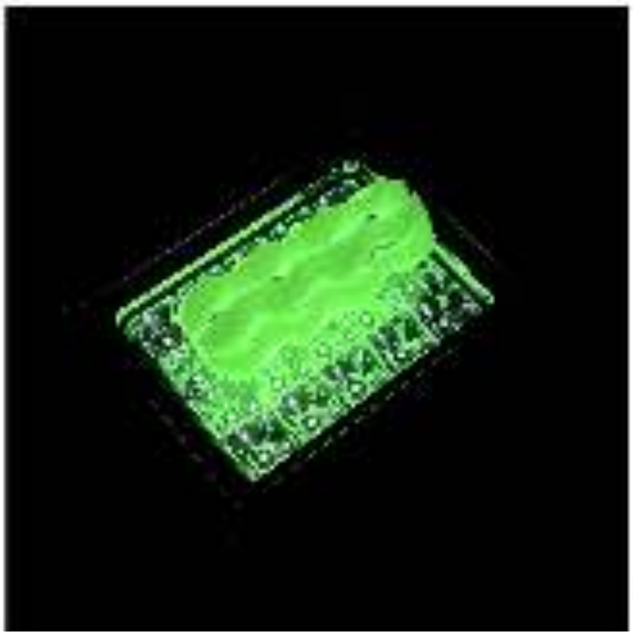
Phosphorescent PLA(Figure48), on the other hand, brings an intriguing twist to our designs. This material has the ability to glow in the dark, which we leveraged to create unique lighting effects in our AI lamp design. This feature can be seen as a form of "form giving", where the material itself contributes to the overall aesthetic and function of the design.



Real Images

Figure 48. PLA with phosphorescent material that can glow in the dark.

These materials have the ability to absorb light energy, particularly ultraviolet (UV) light(Figure49), and then slowly release that energy in the form of visible light. This is what gives the material its glow-in-the-dark property.



Real image

Figure 49. Phosphorescent material that can absorb the UV light and emit light

Lastly, we experimented with PETG to create transparent models. PETG is known for its strength and clarity, making it a suitable choice for applications that require some degree of transparency. Through careful calibration and experimentation, we've been able to push the boundaries of FDM printing to create models that are as transparent as possible.

In conclusion, FDM printing has allowed us to explore a wide range of materials and effects, contributing to the versatility and creativity of our designs.

Lastly, we experimented with PETG to create transparent models. PETG is known for its strength and clarity, making it a suitable choice for applications that require some degree of transparency(Figure50). Through careful calibration and experimentation, we've been able to push the boundaries of FDM printing to create models that are as transparent as possible. In conclusion, FDM printing has allowed us to explore a wide range of materials and effects contributing to the versatility and creativity of our designs.

In our experimentation with PETG(Figure51), we adjusted several printing parameters to achieve the best possible transparency. We changed the printing infill to 100% and experimented with different infill patterns. We found that a wall flow around 101 and a concentric infill pattern gave the best results in terms of transparency. Additionally, we found that a lower printing speed resulted in better transparency.

Real Images

Setting	Profile	Unit
Walls		
Wall Thickness	0.4	mm
Top/Bottom		
Top Layers	6	
Bottom Layers	6	
Infill		
Infill Density	[illegible]	%
Infill Pattern	concentr...	
Infill Line Directions	[illegible]	
Material		
Wall Flow	102	%
Top/Bottom Flow	101	%
Infill Flow	102	%
Skirt/Brim Flow	102	%
Prime Tower Flow	102	%
Initial Layer Flow	102	%
Speed		
Print Speed	5	mm/s
Outer Wall Speed	5	mm/s
Inner Wall Speed	5	mm/s
Cooling		
Enable Print Cooling	true	
Fan Speed	10.0	%
Support		
Support Overhang A...	70	°

Figure 50. PETG printing test to get transparent lamp

Figure 51. The Cura settings for printing transparent PETG material

SLA printing

Stereolithography (SLA) printing is another technology we employed in our project, which offers distinct advantages for lamp design. SLA printing is a form of 3D printing technology that uses a laser to cure liquid resin into hardened plastic (Figure52). This method is known for its high resolution and precision, which allows for the creation of intricate details and smooth surfaces that are often challenging to achieve with FDM printing.

Real Images

Figure 52. SLA printed lamp concepts with white resin

Moreover, the transparency offered by SLA printing can play a crucial role in the realization of AI-driven designs. AI can assist designers to create forms that exploit the properties of transparent materials in novel and unexpected ways. For instance, an AI might generate a design that uses the transparency of the material to create optical illusions, manipulate the perception of depth, or produce unique lighting effects. With SLA printing, these innovative design concepts can be faithfully translated into physical models.

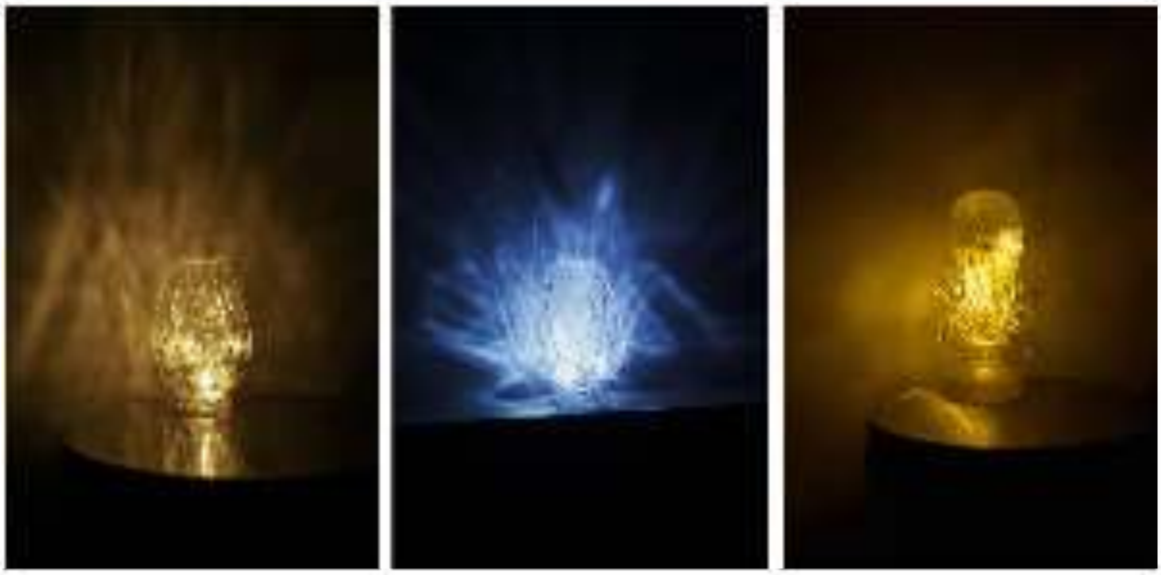


Figure 53. SLA printed lamp concepts with transparent resin

In addition, the ability to print highly transparent models(Figure53) can influence the AI's form-giving process. When the AI is trained with a dataset that includes examples of transparent objects, it can learn to incorporate transparency into its designs in creative ways. The AI might generate designs that use transparency to highlight certain aspects of the form, create visual depth, or manipulate the distribution and quality of light.

SLS printing

Selective Laser Sintering (SLS) is another 3D printing technology we utilized in our project. Unlike FDM and SLA, which are more common in plastic-based printing, SLS is particularly advantageous when working with metal materials. In our case, we used SLS to print a lamp made of aluminum (Figure54).

Real Images

Figure 54. SLS printed lamp concepts with aluminium powder

The SLS process involves the use of a high-power laser to fuse small particles of plastic, metal, ceramic, or glass powders into a mass that has the desired three-dimensional shape. The laser selectively fuses the powdered material by scanning the cross-sections (or layers) generated by the 3D modeling program on the surface of a powder bed. After each cross-section is scanned, the powder bed is lowered to add a new layer of material for the subsequent pass.

In the context of materialization and form giving, Selective Laser Sintering (SLS) presents unique advantages. Its ability to manipulate a variety of materials, most notably metal, gives way to new possibilities in design and functionality of products like lamps.

The metal materials utilized in SLS include a broad range, from steel to aluminum and titanium. These provide not only a distinct aesthetic departure from traditional plastic but also offer enhanced durability. Metal, being robust and resistant to physical impact, ensures that products like lamps have a longer lifespan.

Another defining feature of metal materials, and one particularly pertinent to lamp design, is their excellent heat resistance. A lamp, in its function, must withstand the heat emitted by the light source. Metals, being superior conductors of heat, effectively dissipate the thermal energy generated, thereby maintaining the structural integrity and safety of the lamp.

In addition to metal, SLS is also compatible with ceramics, another group of materials that exhibit unique aesthetic and functional properties. Ceramics can lend an upscale, refined appearance to lamp designs while also being sturdy and heat-resistant.

In conclusion, the versatility of SLS in accommodating diverse materials, ranging from metals to ceramics, paves the way for innovative design possibilities that perfectly harmonize aesthetics, form, and functionality.

Conclusion and Future

In conclusion, the 3D printing methodologies we utilized, including Fused Deposition Modeling (FDM), Stereolithography (SLA), and Selective Laser Sintering (SLS), have each significantly contributed to the materialization process of our AI-guided designs. FDM's extensive range of material options enabled us to experiment with diverse visual and tactile characteristics, such as phosphorescence and transparency. SLA, owing to its superior resolution and precision, facilitated the production of intricate details and seamless surfaces, thereby extending the limits of form and aesthetics. Meanwhile, SLS's capability to manipulate metal materials has unlocked new avenues in terms of resilience, heat tolerance, and visual allure.

As we envision the future, we anticipate the potential incorporation of other emergent 3D printing techniques such as ceramic printing, which could provide a fresh platform for lamp design, imbuing unique aesthetic and tactile elements. Beyond this, other technologies may significantly broaden the horizon concerning material selection and structural intricacy.

In a broader societal context, this evolution in product design and manufacturing holds transformative potential. As we continue to refine our methodologies, the ability to rapidly prototype and diversify designs using AI and advanced 3D printing techniques may democratize design, breaking down barriers to entry and fostering a more inclusive, creative society. Beyond lamps, these methodologies can be transposed onto a myriad of products, extending their influence across various sectors.

Moreover, as AI-generated designs become more mainstream, they may also begin to influence the broader cultural and aesthetic trends. This iterative feedback process between technology, society, and design could result in a new era of dynamic, AI-informed design aesthetics. Additionally, as these methodologies become more efficient and environmentally friendly, they could potentially influence sustainability practices within the manufacturing industry.

The future of product design and manufacturing is being reshaped by AI and advanced 3D printing techniques. By seamlessly integrating these technologies into our design processes, we can continue to push the boundaries of form, function, and sustainability.

Project
Summary

Evaluation and Self-reflection

Throughout the testing phase, it was evident that the AI-assisted design workflow significantly enhances the efficiency of the ideation process for designers. The capacity to rapidly visualize ideas from text rather than through traditional sketching, coupled with the large language model's understanding of design context, streamlines communication with clients. Moreover, AI assistance in the 3D modeling stage can alleviate the workload, and in certain instances, entirely manage this process.

Figure 55. Tester is using the workflow before 3d printing

This shift allows designers to devote more time to problem discovery, prototype creation, and product testing. The use of AI reduces the time spent on context comprehension, ideation, and even assists in creating authentic and convincing prototypes. Tests(Figure55) showed that users found the AI tools efficient, able to swiftly visualize their ideas and even inspire further design innovation.

exploration of various 3D printing technologies that align with AI design processes demonstrated that common lamp design materials and textures, including solid, transparent, and reflective surfaces, can be achieved effectively.

However, the need for further development in AI-assisted modeling processes was noted. Despite image enhancement techniques and accurate prompt descriptions, the translation of concepts into 3D models is still a challenge. Current AI technologies often require significant human intervention to refine the output. This necessitates that designers maintain their digital and physical prototyping skills to ensure final product authenticity.

The exact time savings when using AI-assisted processes in the design cycle can vary significantly based on the specific design problem, the designers involved, and the complexity of the design. However, for a rough estimate, let's break down the potential time savings in the three steps of the Stanford Design Thinking Process(Figure58) where AI can play a significant role:

1. **Define:** AI can process and analyze vast amounts of data far more quickly than a human can. By automating data analysis and trend discovery, AI could potentially reduce the time spent in this phase by up to 50%.
2. **Ideate:** In the ideation phase, AI tools like GPT-3 can quickly generate numerous ideas based on provided prompts. Instead of spending hours brainstorming, designers can generate a wealth of ideas in a matter of minutes. Again, an estimate of time saved could be around 70%.
3. **Prototype:** The process of creating initial prototypes could be expedited with the help of AI that can turn 2D designs into 3D models. However, due to the current limitations in this technology, substantial manual intervention might still be required. Assuming a moderate level of assistance from AI, we might estimate a time reduction of about 30%.

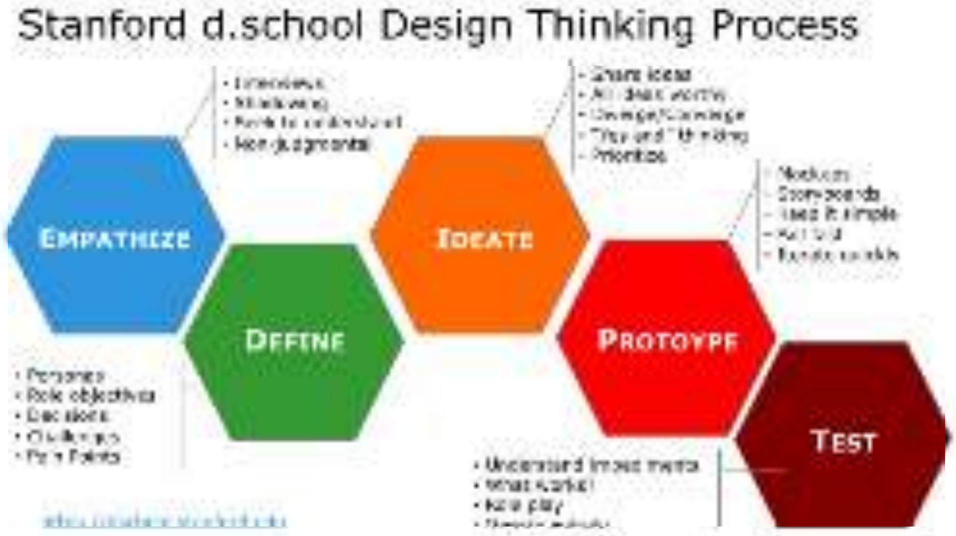


Figure 56. Stanford d.school Design Thinking Process (Schmarzo, 2017)

If we consider a traditional design process, without AI, to last around 100 hours as a baseline (this is a hypothetical number for calculation's sake), the time saved by using AI could look something like this:

1. **Define:** AI could reduce time spent by approximately 40%, saving about 10 hours.
2. **Ideate:** AI might reduce ideation time by 70%, saving about 21 hours.
3. **Prototype:** With current technology, AI may assist in reducing time by about 30%, equal to 7.5 hours saved.

In total, using AI could potentially save around 38.5 hours, shortening a 100-hour design process to roughly 61.5 hours, representing around 40% reduction in time.

However, the stages of Empathize and Test remain predominantly human-driven, demonstrating the necessity of human empathy and nuanced understanding in successful design processes.

In conclusion, the journey into AI-assisted design highlighted both its potential to transform design efficiency and the ongoing need for human skills in empathizing, interpreting, and refining design outputs. This intersection of AI technology and human creativity forms an exciting frontier in design methodology.

Limitations and Future Outlook

What is the limitation of this project?

This project embarks on an exploration of AI integration in the design process, focusing on tangible lamps. The methodologies and workflows implemented provide a path to incorporating AI into design workflows across the tangible product industry. However, the choice of lamp as the product brings certain limitations.

Lamps, with their simple physical functions and minimal structural requirements, allow for easier application of AI. Yet, applying AI becomes more challenging when complex physical structures are involved. Furniture like chairs or tables that need to bear weight require more human intervention to ensure the viability of AI-generated concepts. The complexity increases for products with intricate functionalities, such as electronic devices, making the transition from concept to reality more challenging.

Additionally, current AI-assisted modeling techniques, while promising, have limitations. The translation from 2D images to 3D models, facilitated by AI, often needs significant human involvement to ensure the usability of the output. Presently, open-source models available for image-to-3D model transformations may not meet required standards. Nonetheless, AI's potential to significantly reduce time in the design process is evident, and the continued development and improvement of these AI models is a promising prospect.

The project primarily uses 3D printing technology to produce tangible prototypes and products, which might pose limitations when considering mass production. Other production methods, such as injection molding, die casting, or CNC machining, which are typically used for mass production, may require further human intervention to adapt the AI-generated designs to fit these methodologies. Despite these challenges, AI's promise for creating more user-centered designs and efficient workflows is undeniable. The continued refinement and development of these methodologies heralds a future where AI becomes an integral part of the design process.

What is the role for human designers in the future of generative AI?

The profound impact of AI technologies on design mandates a reevaluation of existing design methodologies. As AI permeates the field, it has the potential to reshape traditional design practices, integrating with conventional methods to create more efficient workflows. This project showcases an exploration into the integration of AI tools, such as ChatGPT, in the creation of tangible products. The development of various tools and user interfaces, all assisted by AI, provides a case study for designers. The emergence of AI should be seen as an opportunity to acquire and utilize new tools in a more accessible and efficient manner. The AI-assisted design process demonstrated here could serve as a beacon for others in the field, helping them navigate the fusion of design and technology without fear, but with curiosity and creativity.

The Convergence of Design and AI Technology

The profound impact of AI technologies on design mandates a reevaluation of existing design methodologies. As AI permeates the field, it has the potential to reshape traditional design practices, integrating with conventional methods to create more efficient workflows. This project showcases an exploration into the integration of AI tools, such as ChatGPT, in the creation of tangible products. The development of various tools and user interfaces, all assisted by AI, provides a case study for designers. The emergence of AI should be seen as an opportunity to acquire and utilize new tools in a more accessible and efficient manner. The AI-assisted design process demonstrated here could serve as a beacon for others in the field, helping them navigate the fusion of design and technology without fear, but with curiosity and creativity.

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Appendix

Generative AI & Tangible Products

Human-AI Design of **3D-printed lamps**

Dinuo Liao

DESIGN FOR our future

TU Delft

IDE Master Graduation

Project team, Procedural checks and personal Project brief

This document contains the agreements made between student and supervisory team about the student's IDE Master Graduation Project. This document can also include the involvement of an external organisation, however, it does not cover any legal employment relationship that the student and the client (might) agree upon. Next to that, this document facilitates the required procedural checks. In this document:

- The student defines the team, what he/she is going to do/deliver and how that will come about.
- SSC E&SA (Shared Service Center, Education & Student Affairs) reports on the student's registration and study progress.
- IDE's Board of Examiners confirms if the student is allowed to start the Graduation Project.

USE ADOBE ACROBAT READER TO OPEN, EDIT AND SAVE THIS DOCUMENT

[illegible]

STUDENT DATA & MASTER PROGRAMME

[illegible]

family name	LIAO
initials	D.L.
given name	Dinuo
student number	[redacted]
street & no.	
zipcode & city	
country	
phone	
email	

Your master programme (only select the options that apply to you):

IDE master(s): ( ) IPD (X) DfI ( ) SPD

2nd non-IDE master:

individual programme: (give date of approval)

honours programme: ( ) Honours Programme Master

specialisation / annotation: ( ) Medisign ( ) Tech. in Sustainable Design ( ) Entrepreneurship

SUPERVISORY TEAM **

[illegible]

** chair	Derek Lomas	dept. / section:	HCD, DA
** mentor	Cehao Yu	dept. / section:	HCD, HCD
2nd mentor			
	organisation:		
	city:	country:	

comments (optional)

Chair should request the IDE Board of Examiners for approval of a non-IDE mentor, including a motivation letter and c.v.

Second mentor only applies in case the assignment is hosted by an external organisation.

Ensure a heterogeneous team. In case you wish to include two team members from the same section, please explain why.

APPROVAL PROJECT BRIEF

To be filled in by the chair of the supervisory team.

chair: Derek Lomas — date: 10 - 02 - 2025 — signature: [signature]

CHECK STUDY PROGRESS

To be filled in by the SSC E&SA (Shared Service Center, Education & Student Affairs), after approval of the project brief by the Chair.
The study progress will be checked for a 2nd time just before the green light meeting.

Master electives no. of EC accumulated in total: 21 EC

Of which, taking the conditional requirements into account, can be part of the exam programme: 21 EC

List of electives obtained before the third semester without approval of the BoE:

(x) YES — all 1st year master courses passed

( ) NO — missing 1st year master courses are:

name: Robin den Braber — date: 19 - 02 - 2025 — signature: Robin den Braber (Digitally signed by Robin den Braber, 2025.02.19)

FORMAL APPROVAL GRADUATION PROJECT

To be filled in by the Board of Examiners of IDE TU Delft. Please check the supervisory team and study the parts of the brief marked **.
Next, please assess, (dis)approve and sign this Project Brief, by using the criteria below.

- Does the project fit within the (MSc)-programme of the student (taking into account, if described, the activities done next to the obligatory MSc specific courses)?
- Is the level of the project challenging enough for a MSc IDE graduating student?
- Is the project expected to be doable within 100 working days/20 weeks ?
- Does the composition of the supervisory team comply with the regulations and fit the assignment ?

Content: (x) APPROVED ( ) NOT APPROVED

Procedure: (x) APPROVED ( ) NOT APPROVED

comments

name: Monique von Morgen — date: 21 - 02 - 2025 — signature:

Generative AI & Tangible Products: Human-AI Design of 3D-printed lamps project title

Please state the title of your graduation project (above) and the start date and end date (below). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

start date 15 - 02 - 2023 05 - 07 - 2023 end date

INTRODUCTION **

Please describe, the context of your project, and address the main stakeholders (interests) within this context in a concise yet complete manner. Who are involved, what do they value and how do they currently operate within the given context? What are the main opportunities and limitations you are currently aware of (cultural- and social norms, resources (time, money,...), technology, ...).

The applications of artificial intelligence have been ever-growing over the past few months in varied areas. The design industry has also adopted AI generative tools, such as DALL-E 2 [1], Midjourney [2], and Stable Diffusion [3], to enable artists and designers to produce high-quality images. The integration of AI generative tools allows designers to seamlessly iterate and explore the creation of tangible 3D designs, enhancing their design capabilities and potential for innovation.

This project will focus on a specific area of tangible design - 3d-printed lamps at a product level - to explore the possibility of using AI to produce tangible product design works that are aesthetically pleasing and functional for customers. The form-giving of lighting design is connected with the properties of light, the luminous environment and the perception of human beings [4]. This project will be prototype oriented and involve generative sessions and user studies to identify the obstacles and advantages of different AI-aided design approaches. Our objective is to distinguish the interplay between human and AI involvement in the creation of tangible products and to investigate how AI can augment creativity in shaping aesthetically pleasing and printable 3D designs.

To achieve this, we will focus on:

1. uncover the Design Possibilities of AI-Assisted 3D Printed Lighting: Exploring the impact of emotions, materials, lighting effects, and other factors on printability and desirability.

2. stream the AI-to-3D Printing Workflow for Designers: Making the process of using generative AI tools more accessible and user-friendly for designers.

3. improve the AI-to-3D Printing Process: Documenting the current challenges and opportunities and seeking ways to improve the workflow for better results.

4. examine the Impact of AI2Object on Society and Beyond: Assessing the impact of AI-assisted tangible design on fields such as education, the economy, and society as a whole.

5. empower Designers with AI Generation Skills: Identifying the skills and knowledge that designers need to effectively collaborate with AI in the creation of 3D printed objects.

space available for images / figures on next page introduction (continued): space for images

image / figure 1: the practical applications of using AI generative tools to produce lamp design concepts

image / figure 2: the practical applications from 2D AI images to 3D printed lamp models

PROBLEM DEFINITION **

Limit and define the scope and solution space of your project to one that is manageable within one Master Graduation Project of 30 EC (= 20 full time weeks or 100 working days) and clearly indicate what issue(s) should be addressed in this project.

This graduation project will focus on building a toolkit or a framework for designers to use AI as an assister to make and design the tangible design, specifically in the 3D-printed lamp designs. The key outcomes and questions are:

1. What do humans/designers need to stay within the AI-assisting tangible design process, and what aspects the humans/designers could use the AI for? What skills designers can/should bring to AI generation?

2. How can we use AI to explore and generate forms of tangible design and embed them into the form-giving design process and create desirable and printable designs? What are the limitations, and how can the process be improved?

3. What is the potential impact of AI-assisted tangible design on fields of education, the economy, and society?

ASSIGNMENT **

State in 2 or 3 sentences what you are going to research, design, create and / or generate, that will solve (part of) the issue(s) pointed out in "problem definition". Then illustrate this assignment by indicating what kind of solution you expect and / or aim to deliver, for instance: a product, a product-service combination, a strategy illustrated through product or product-service combination ideas, ... In case of a Specialisation and/or Annotation, make sure the assignment reflects this/these.

My graduation project focuses on developing a toolkit or framework that enables designers to leverage AI in the creation of tangible products, specifically in the realm of lamp design. I will validate its use through prototyping, generative sessions, and user research. Ultimately, my aim is to simplify the use of AI for designers in the creation of tangible products and to demonstrate its potential as a valuable tool in the design process.

Within the scope of exploring the form of lamps, the possible directions of this project are:

Self-validate the process of using AI approaches to build tangible lamp designs and conduct the survey for people to evaluate the result of the AI-assisting design process with an aesthetic lens, and massive prototypes are expected to be built.

Using the survey results to frame the advantages and disadvantages of different prompts in text-to-image AI and the limitations of different AI models and characterizing the design space of AI-3D printed lighting.

Interviewing the novel and trained designers to research their design process. Conducting generative sessions with them to validate and iterate the framework of AI-driven design workflow to make it more and more accessible to designers, comparing and rating the AI-driven workflow to other workflows.

A possible service-involved framework for letting people use prompts to customize their own design works and how the AI-to-Object mechanism could impact society, the economy, and other issues.

PLANNING AND APPROACH **

Include a Gantt Chart (replace the example below - more examples can be found in Manual 2) that shows the different phases of your project, deliverables you have in mind, meetings, and how you plan to spend your time. Please note that all activities should fit within the given net time of 30 EC = 20 full time weeks or 100 working days, and your planning should include a kick-off meeting, mid-term meeting, green light meeting and graduation ceremony. Illustrate your Gantt Chart by, for instance, explaining your approach, and please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any, for instance because of holidays or parallel activities.

start date 15 - 2 - 2023 | 5 - 7 - 2023 end date

In the initial stage, I will conduct a survey and study of current AI-based tools for lamp design generation. I will use these tools to produce lamp design images, and then gather both qualitative and quantitative data via a survey to evaluate the generated designs. My analysis will focus on the prompts and factors affecting the visual appeal and printability of the designs, to comprehend their impact on the final product, and to self-assess their feasibility and desirability.

The second phase is to research how to improve AI system performance through applicable procedures such as literature reviews, interviews and generative sessions to test with designers to use the AI system. Then build an AI system-based workflow that could allow designers to construct tangible 3D lamp structures, documenting the opportunities and challenges in current AI-to-3D-Print and reflecting on how to improve the process, and figure out the limitations and barriers of different AI models regarding the tangible design process. More prototypes from testers and us will be made to test and iterate the workflows to make it easier to produce desirable and producible designs.

The third phase is to conclude the framework and identify the skills and knowledge that designers need for effectively collaborating with AI systems in a way that can produce more desirable and producible tangible products. We will benchmark the AI-assisted workflow against other workflows and use quantitative and qualitative data from ratings for the design output to identify factors and develop measurements to compare different AI systems. We will state the strengths and weaknesses of the AI-assisted framework and assess the impact of AI-assisted tangible design on fields such as education, the economy, and society as a whole.

MOTIVATION AND PERSONAL AMBITIONS

Explain why you set up this project, what competences you want to prove and learn. For example: acquired competences from your MSc programme, the elective semester, extra-curricular activities (etc.) and point out the competences you have yet developed. Optionally, describe which personal learning ambitions you explicitly want to address in this project, on top of the learning objectives of the Graduation Project, such as: in depth knowledge a on specific subject, broadening your competences or experimenting with a specific tool and/or methodology, ... Stick to no more than five ambitions.

As a designer, I am a technology and experience-oriented designer. I enjoy learning how to apply technology to help people get better life experiences through the lens of design, which was the main reason that I chose to become a designer.

In my first-semester course, Project Exploring Interaction, I used machine learning to help me to complete the interaction structure of my final concepts, and I chose the topic of designing car AI in my second-semester project. These decisions show my strong intention to learn technology and AI skills quickly and my intense interest in AI-related design.

In the last six months, AI technology has developed so rapidly quickly, and I sincerely believe this is a game-changing tool in almost every industry in the upcoming future. As a result, I am keen to get involved in this trend of building AI, learning AI and implementing AI, and exploring how I can put AI and frame AI for design works.

With the lens of a product designer and interaction designer, using AI to help designers and human beings to improve the breadth and depth of tangible design could be an irreplaceable chance for me to explore the limitations and advantages of using AI as a creative source in the area of tangible design. In this project, I hope I could learn more about how to implement generative AI in a way that supports designers to design tangible works for the real world, broadening my competencies in design with technology.

[1] A. Ramesh, P. Dhariwal, A. Nichol, C. Chu, and M. Chen, "Hierarchical text-conditional image generation with clip latents," arXiv.org, 13 Apr 2022. [Online]. Available: https://doi.org/10.48550/arXiv.2204.06125. [Accessed: 07 Feb 2023].
[2] "Midjourney," [Online]. Available: https://www.midjourney.com/. [Accessed: 05 Feb 2023].
[3] R. Rombach, A. Blattmann, D. Lorenz, P. Esser, and B. Ommer, "High-resolution image synthesis with Latent Diffusion Models," 2022 IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR), 2022.
[4] S. C. Pont, "Spatial and form-giving qualities of light," Handbook of Experimental Phenomenology, pp. 205–222, 2013.

FINAL COMMENTS

In case your project brief needs final comments, please add any information you think is relevant.

User Interfaces and Image datasets

These are the versions of the functional interface repository, encompassing the code, images, and prompts data amassed from all generative AI models utilized throughout this project.

UI interface repository versions:

Without Midjourney:
https://4cgcb1.csb.app/(The most stable one)

With Midjourney:
https://www.dinuoliao.com
https://tclf6o.csb.app/
https://6zldcb.csb.app/

Image and prompt datasets from Stable Diffusion, Dall-E 2, Open Journey and Midjourney:

https://docs.google.com/spreadsheets/d/1CSiCyFA3We22DPWVcLAbbCehpw5MmGWj3xamLKrlWeO/edit?usp=sharing

Prompt optimization study datasets

This encompasses the data, the analysis program complete with its Python code, the testing platform, and the generation interface, all used for the prompt optimization study employing GPT-4.

[*]Prompt Optimization datasets (Images, prompts, score)

https://docs.google.com/spreadsheets/d/1-dpwTBF2XbIIVw57kridlQ3jmMoOUPlg0YWLMjm0TTI/edit?usp=sharing

Prompt Optimization analysis program code

https://colab.research.google.com/drive/1tY3ATMOcNfbXwmgBE8Nk9Ac83Ct3-ID?usp=sharing

Prompt Optimization image generation UI

https://0i2mki.csb.app

Prompt Optimization rating system UI(scale of 0-100)

Desirability: https://dugzo.csb.app/
Printability: https://68fnev.csb.app/
Alignment: https://9iug51.csb.app/

*The GPT-4 model we used in this study specifically refers GPT-4-0314

LoRA optimization study datasets

These include the testing platform (such as the like and dislike test) along with its code, the chosen images based on human (tester) ratings in terms of desirability and aesthetics, and the images accompanied by the prompts we used to train the LoRA models. We also present the final results of the LoRA model and the stable diffusion utilized in the ultimate human rating phase, where we examined whether the LoRA model could produce significant differences.

LoRA training pictures before rated(405 images)

https://drive.google.com/drive/
folders/1ytKYrYreUKyXBsnd_Mgnkm55JNZiN7o?usp=sharing

"like/dislike" test for 405 images datasets (1/0 result)

Desirability:https://docs.google.com/spreadsheets/
d/12SgwdKwt9CYGT_6G5Tc_uwXUauSuQX3Is2J6Gp5cA/edit?usp=sharing

Visual Appealing:https://docs.google.com/spreadsheets/
d/1cm6wvRayOxD5FqGaxWOMFxtxyhhTbFFJvCV79Gtcwg/edit?usp=sharing

LoRA test "like/dislike" test

Desirability:https://m4tjos.csb.app
Visual Appealing:https://pxsrdx.csb.app

LoRA training pictures and prompts for desirability

https://drive.google.com/drive/
folders/1Hu5JX99JSTs_7nlxMQLwSd4TqwFDX_02?usp=sharing

LoRA training pictures and prompts for visual appealing

https://drive.google.com/drive/
folders/1MH5Rwd_il0gjJa55snJkw1c-0V9X_axw?usp=sharing

LoRA examination test "like/dislike" test result (1/0 result)

*Desirability (100 images):https://docs.google.com/spreadsheets/
d/1dotIpyGM29uC8SwL_ECoQJOjIMpSiDvBKXIZoQJWY/edit?usp=sharing

*Visual Appealing(100images):https://docs.google.com/spreadsheets/
d/1u0JbX7hcNdDvrwwhrSGlx9KUes7JJWO4jkzm_3W6KvY/edit?usp=sharing

LoRA test "like/dislike" test result (like rate for unoptimized and optimized design concepts)

Desirability:https://docs.google.com/spreadsheets/
d/1zZjNbdg5ffBR6CoTU3rhD2z8xelqzA0lyC8FiKJ8xRA/edit?usp=sharing

Visual Appealing:https://docs.google.com/spreadsheets/
d/1ncKna8f6P5e1WO7-iHemFcXKM_33leM3C8ILCQFFu6c/
edit#gid=1559953478

***Image 1-50 are optimized with LoRA, and image 51 -100 are directly from Stable Diffusion 1.5**

LoRA test "like/dislike" test result (like rate for unoptimized and optimized design concepts)

Desirability:https://drive.google.com/drive/folders/1CUf_Lk2MrrcAd9-KwRw5z7I1LrLWi7nc5?usp=drive_link

Visual Appealing:https://drive.google.com/drive/folders/1olFjyard0CDU0yKJyxFS-_Uo_0eCd1z?usp=drive_link

LoRA test "like/dislike" test result analysis program code

Desirability:https://colab.research.google.com/drive/1q32ZqKYvn14wouY-1CO7CI1RM6zy0z1?usp=sharing

Visual Appealing:https://docs.google.com/spreadsheets/d/1noKna8f6P5e1W07-iHemFcXKM_S3leM3C3IL0OFFu6c/edit#gid=1559953478

LoRA training & LoRA generation settings

This is the set of training configurations we applied to the LoRA model, as well as the settings employed in stable diffusion to activate the LoRA model.

LoRA training settings

Train batch size: 4
Gradient accumulation steps: 1
Epoch: 10
Regulatization factor: 1
Pretrained model=runwayml/stable-diffusion-v1-5
Resolution: 512,512
Learning Rate: 0.0001
Mixed Precision: fp16
Save Precision: fp16
Shuffle Caption: False
Keep Tokens: 0
Caption Dropout Rate: 0.0
Caption Dropout Every n Epoches: 0
Caption Tag Dropout Rate: 0.0
Color Aug: False
Flip Aug: False
Face Crop Aug Range: None
Random Crop: False
Token Warmup Min: 1,
Token Warmup Step: 0,
Is Reg: False
Caption Extension: .txt
Image Num Repeats(Steps per Images): 500
(Figure57:

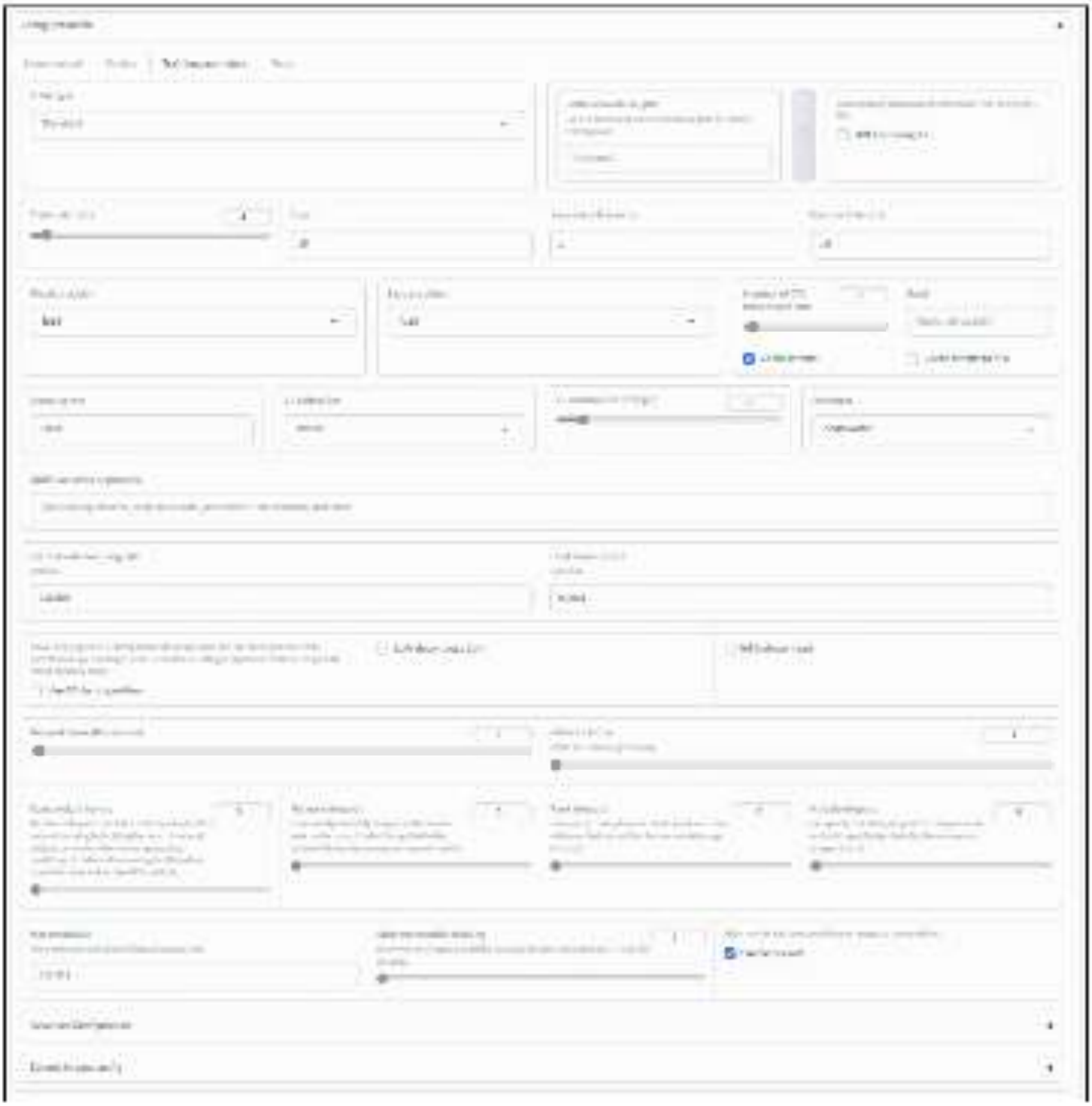
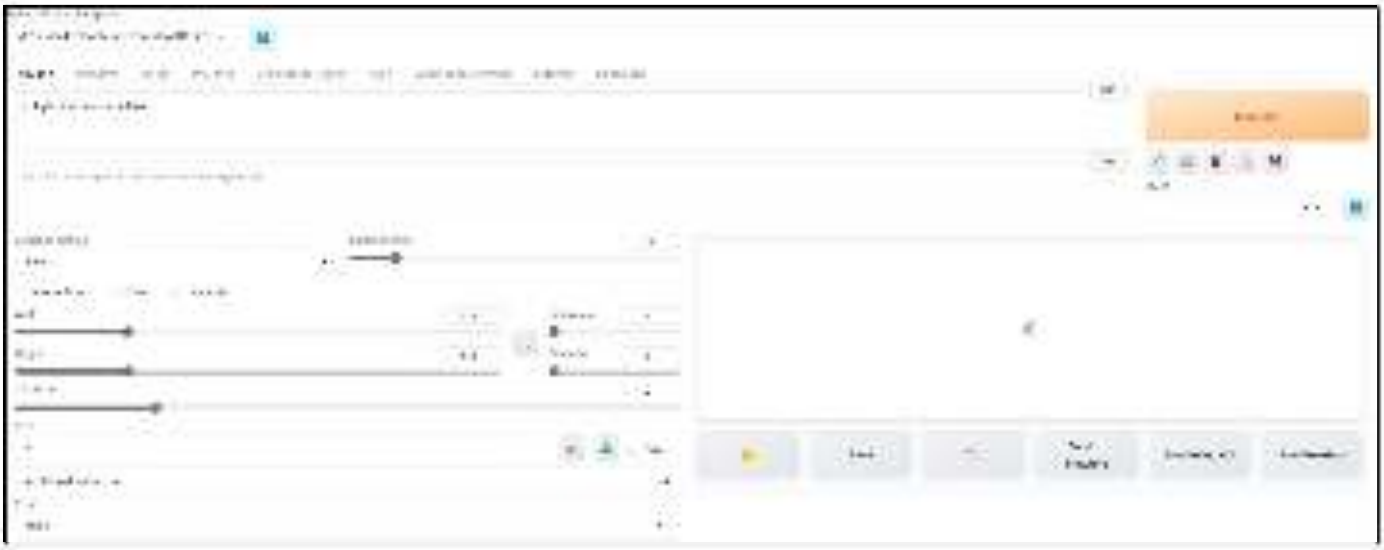


Figure 57: LoRA training settings UI interface

LoRA generation settings

LoRA weight: 0.6
Sampling method: Euler a
Size: 512x512
Sampling steps: 20
Stable Diffusion Model: v1.5
(Figure58)



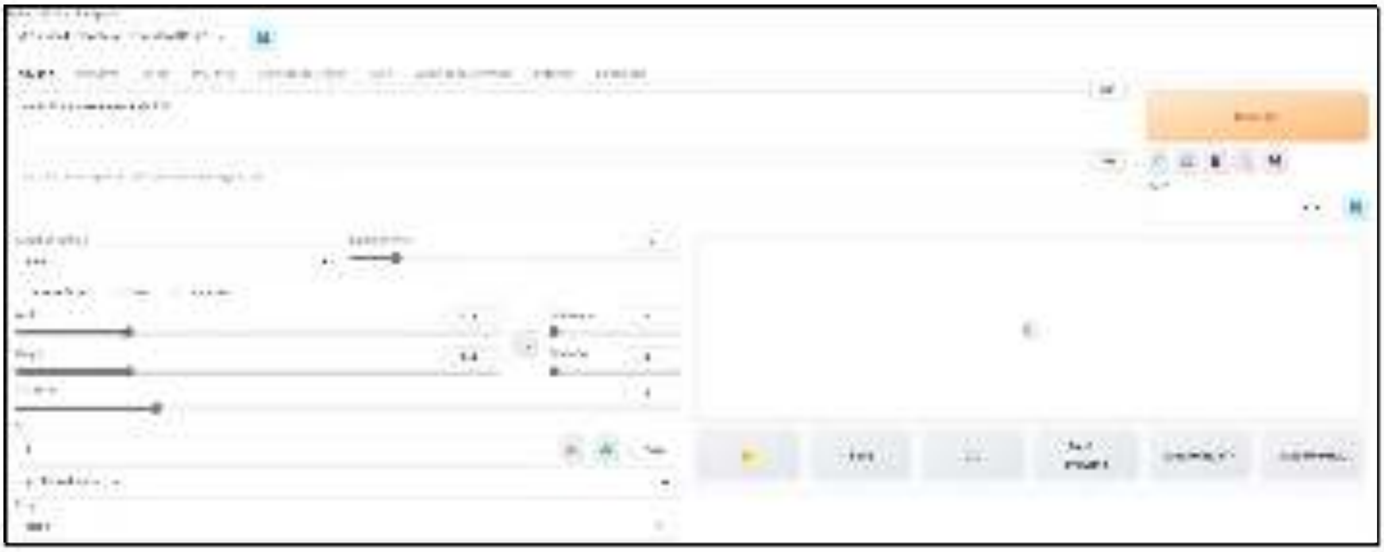


Figure 58. Stable Diffusion Generation Interface with LoRA