

Research on Architectural Design Workflow Exploration Based on Stable Diffusion

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Abstract:

With the rapid development of AI technology, its integration into the architectural design process has become particularly important. Taking Stable Diffusion as an example, this paper summarizes its principle and control method, proposes a set of AIGC application processes in architectural design, and applies it to the project by means of practical exercises. Finally, the design process and results are analyzed, and it is concluded that Stable Diffusion has the advantages of high efficiency, controllability, and high quality, etc., but there are still limitations such as randomness of content and insufficient control of details.

Keywords:

Artificial Intelligence, Architectural Design, Stable Diffusion, AIGC

1. Introduction

Currently, due to the linear and phased workflow of architectural design, cumbersome and complex data processing and calculations, and limitations in technology applications, there are challenges in terms of innovation, collaboration, and sustainability. These problems and challenges may lead to significant time and resource consumption in architectural projects [1]. In recent years, artificial intelligence (AI) has achieved major breakthroughs through data-driven approaches [2]. These advancements in AI provide new opportunities for transforming architectural design workflows, as AI can assist designers in improving both design proposals and their evaluation [3]. Stable Diffusion, as a representative AI technology, holds significant potential for enhancing design efficiency and reducing costs, making research on its integration into architectural design workflows particularly meaningful.

1.1. Introduction to Stable Diffusion

Stable Diffusion (Figure 1, hereinafter referred to as the SD model) is an AI-based image generation model developed by the CompVis team and released as an open-source project on GitHub. The SD model can rapidly create high-quality digital artwork based on textual descriptions. The SD model is a generative model based on

the diffusion process, with its fundamental principle involving the progressive generation of a target image through the diffusion of noise in the input image. It is characterized by stable generation and high sample quality [4]. The SD model comprises a Variational Autoencoder (VAE), a U-Net, and an optional text encoder. These components work together to transform an original image into a noisy representation and subsequently remove the noise step by step, producing the final realistic artwork [5].

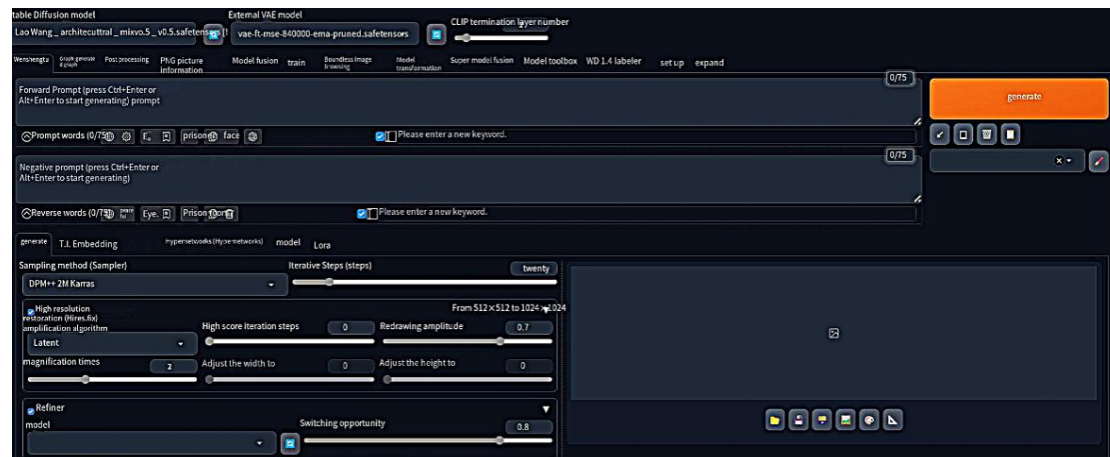


Figure 1. User Interface of the SD Model.

2. Control Methods of the SD Model

The SD model can generate conceptual images through either text or image inputs. Its control methods are primarily carried out via the user interface (UI), as illustrated in Figure 2. Users can select specific models to determine styles and input text prompts to guide the AI in generating targeted images. These text prompts may include positive descriptions (desired image features) and negative descriptions (undesired elements or effects).

The SD model supports the use of the ControlNet plugin, which allows for additional control conditions, such as guiding the image generation process through edge detection, line art extraction, or the application of specific styles. Users can fine-tune the output by adjusting various parameters, including image size, generation steps, and configuration profiles. These control methods make the SD model a flexible and customizable AI-based image generation tool [6].

3. Design Process

The design process is shown in Figure 2. Designers need to collect and organize a large amount of data and similar architectural design cases to determine factors such as architectural style, structure, materials, and environmental considerations. This data will serve as the foundation for utilizing the SD model.

Designers can then interact with the SD model by selecting the underlying model (i.e., choosing the architectural style), inputting design requirements (prompts and sample images), and setting parameters. The SD model will use its algorithms to generate a series of design proposals. After the SD model generates these design proposals, designers must evaluate and select the best options for further refinement and optimization. Designers can continuously provide feedback on design adjustments

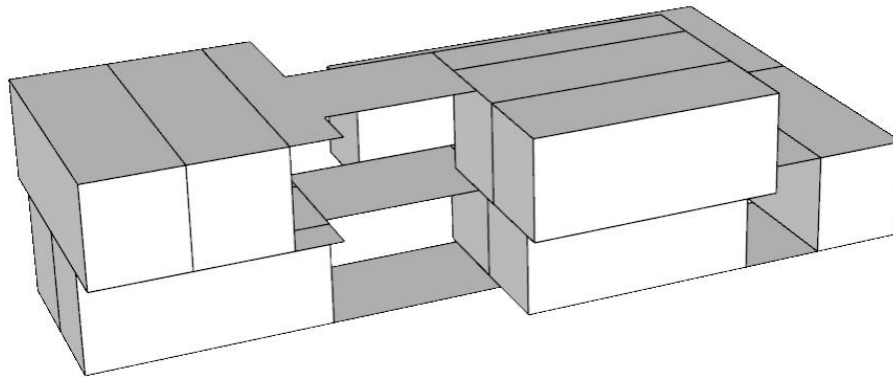


Figure 3. General massing of the target design.

4.2. Task Analysis and Prompt Extraction

Prompt is the text input that users provide when interacting with the SD model, guiding it to generate specific outputs. As shown in Figure 4, in this study, when constructing the prompts, we first analyze the basic characteristics of the building, including its style, function, and materials. Then, based on the project requirements (such as container architecture, alumni house, etc.), and in combination with specific design guidelines, we formulate the prompts. These prompts include descriptions of architectural style, materials, environment, and specific design elements or concepts. The SD model analyzes these inputs to generate highly creative and visually appealing design drafts.

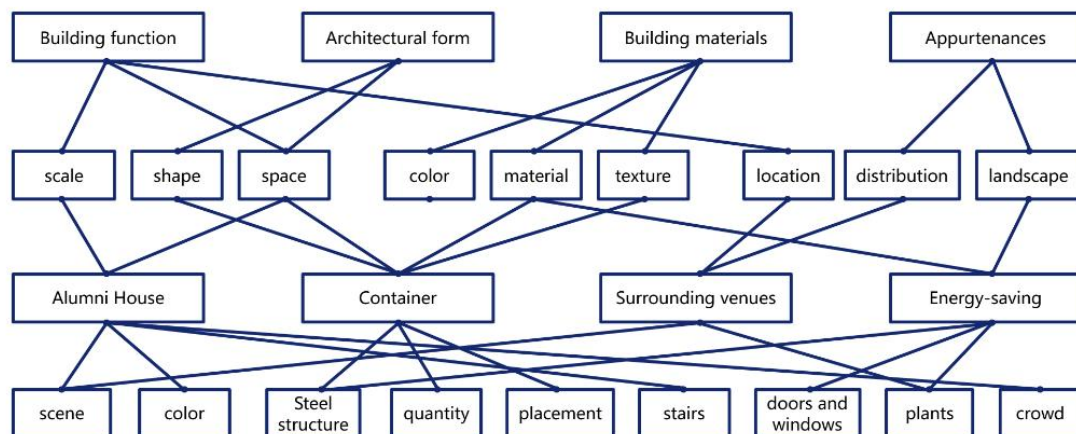


Figure 4. Prompt Extraction Diagram.

The prompt used in this case: A container with windows, indoor, color container, steel stairs, tree, outdoor scene, high definition image quality, high quality, rendering, 16k, Campus Home, natural light.

Subsequently, this study attempts to input the keywords into the SD model platform to initiate the image generation process. The AI analyzes these keywords and creates an initial design draft, with the output results shown in Figure 5.



Figure 5. Prompt Output Results.

4.3. ControlNet Control

This study utilizes the ControlNet plugin of the SD model for more refined control, extracting structural lines from sketches or existing designs and further developing the design based on them. After determining the general massing of the target design and performing basic massing modeling (Figure 3), the model is imported into the ControlNet plugin in the SD model. In the ControlNet1 preprocessor, MLSD (line) is selected for preprocessing.

ControlNet generates a contour drawing of the sample image, and through the control of ControlNet (Figure 6), the architectural spatial structure of the image is consistent with the sketch previously uploaded in this study.

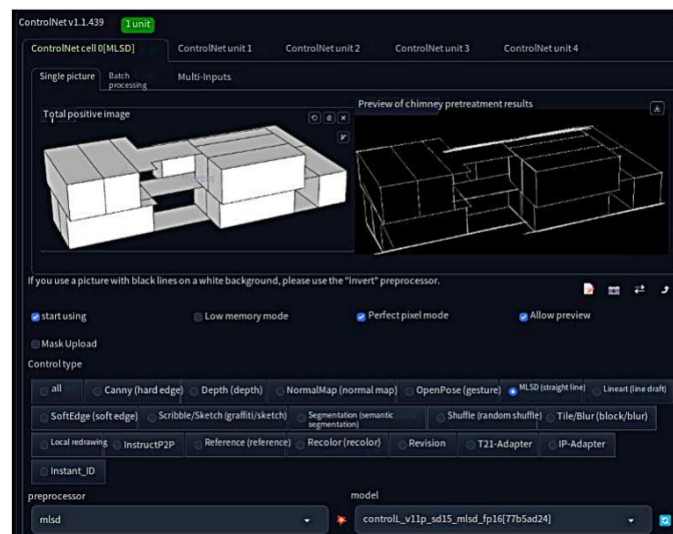


Figure 6. ControlNet Control in the SD Model.

4.4. Result Generation

In this study, prompts related to image quality were selected from the pre-organized text library, along with negative prompts, to generate images. By adjusting relevant parameters, six initial renderings were generated (Figure 7). These images demonstrate how the SD model generates images based on the contour drawing uploaded to ControlNet. The images (Figure 7) enhance the architectural mass generated by ControlNet with details such as the texture, material, and details of the container, while also adding depth and reinforcing the contours [8]. Multiple attempts were made to modify the prompts and continuously adjust them using the SD model

until multiple renderings were generated that closely matched the desired outcome. Various facade modification styles can then be selected for the designer's choice.



Figure 7. ControlNet Control in the SD Model.

4.5. Adjustment and Optimization

After the SD model generates an image, the resulting image may require further adjustments and optimization to better reflect the designer's vision. A relatively satisfactory rendering (see Figure 7) is selected and sent to the "image-to-image" option, with multiple attempts made to modify the prompts. By evaluating the generated image, the designer modifies the text and inputs it into the AI. The designer can extract inspiring elements from multiple generated images (Figure 8) for the design.

In addition, by adjusting the iteration steps and sampling methods, the designer can explore different levels of detail and visual effects. Finally, through the high-definition refinement function, the selected design proposal is refined into a high-quality architectural facade drawing, providing visual reference and guidance for further architectural design and construction.



Figure 8. Modified text and iterated design results in this study.

5. Result Analysis

Through the combined use of the SD model and ControlNet, designers are able to maintain creative freedom while achieving precise control over architectural design, thus accelerating the entire design process from conceptualization to final presentation [9]. The application of this technology not only enhances the efficiency of architectural design but also brings unprecedented innovative possibilities to the field of architecture.

5.1. Design Process Analysis

The input consists of low-information content such as sketches or text, while the output is high-information content, such as images. Although users provide simple descriptions or sketches, these serve as a starting point for AI creativity. The SD model, through deep learning, can understand these basic input details and generate highly detailed and visually rich images, completing the transformation from low-information to high-information content. This saves designers a significant amount of time and lowers the entry barrier.

Furthermore, in the field of architectural design, the model's powerful modification and iteration capabilities greatly expand design possibilities. Through the SD model, designers can easily explore various design options, from simple shape changes to complex spatial layouts, all of which can be instantly presented. The use of such a tool not only accelerates the design process but also enhances design flexibility and creativity.

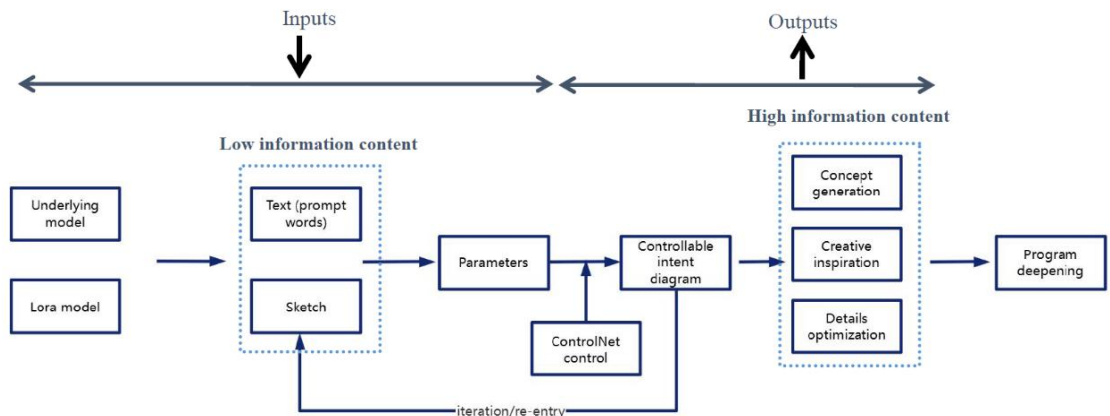


Figure 9. SD model design process analysis.

5.2. Design Results Analysis

By conducting a vertical comparative analysis of the design results generated by the SD model (Table 1), it can be concluded that: The SD model can quickly generate images in different styles, providing design inspiration and improving efficiency. Through the use of ControlNet scripts, more precise and personalized architectural form control is achieved, while also contributing to the deepening and derivation of design proposals. The SD model can generate high-quality and content-rich images. It not only accelerates the iteration of design concepts but also provides designers with the freedom to experiment and explore different design directions, thereby promoting the application of innovative thinking in architectural design.

Table 1. Effect diagrams generated by the SD model under different conditions.

Category	Effect Images Generated Without Direct Use of ControlNet	Effect Images Generated Using ControlNet in the SD Model	Effect Images Derived and Iterated by the SD Model
Input	Prompt	Prompt + Sample Image (ControlNet)	Prompt + Image
Result			

However, the SD model may have limitations in terms of detail handling and accuracy, especially when dealing with complex scenes or specific styles. The images generated each time may vary significantly and lack consistency, which could pose a problem for applications that require serialized or standardized output.

6. Result Analysis

This study explores an architect-led AI architectural design process using the SD model as an example.

The project design results demonstrate that the SD model's efficient image generation capabilities enable designers to quickly create design proposals, significantly shortening the cycle from concept to visualization. At the same time, the SD model provides a variety of plugins (such as ControlNet) and model support, achieving more precise and personalized architectural form control. The ease of use and user-friendly interface design of the SD model lower the technical barrier, allowing designers to explore and realize their architectural ideas. This process not only accelerates the iteration of design concepts but also offers designers the freedom to experiment and explore different design directions, thereby promoting the application of innovative thinking in architectural design [10].

However, during the design process, certain limitations of artificial intelligence were also identified. For example, when generating complex information, the produced images may contain noise and artifacts, affecting image quality. Additionally, the consistency of the output content may sometimes be insufficient, leading to results that do not align with the original text descriptions. In more complex spatial relationships and detailed aspects, the involvement of architects is still required [11]. Therefore, a potential solution is to break down complex architectural tasks and use AI to handle fragmentary tasks, with architects performing the final integration, decision-making, and optimization.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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