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Utilization of Image-generating AI in the Architectural Design Process: Focusing on the Comprehension and Expressiveness of 'Sketch-to-image' Input-based Image-generating AI

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In this study, we explore the role of image-generating AI in architectural design, focusing on sketch-to-image AI tools and their ability to interpret hand-drawn sketches. Five AI tools, namely, fabrie, LookX AI, PromeAI, mnml.ai, and Rerender AI, were analyzed for their comprehension and expressiveness in architectural contexts. To evaluate the effectiveness of these AI tools, architectural experts were surveyed to identify key architectural features present in sketches. These expert insights were then compared with AI-generated outputs to assess their accuracy in spatial perception, material expression, and spatial context awareness. Fabrie excelled in spatial interpretation and material representation, efficiently converting conceptual sketches into detailed visualizations. PromeAI demonstrated strong creative flexibility, supporting iterative design processes with diverse customization options. However, some contextual inconsistencies and missing environmental elements were noted. Importantly, in this study, we discuss how AI-generated imagery can be integrated with sensor-based feedback loops and material-aware simulation tools to enhance the design process. By combining AI visualization with sensor-informed environmental data and performance metrics, architects can more effectively evaluate spatial quality and environmental responsiveness in early-stage design. The study highlights AI's potential as a complementary tool in early-stage design, enhancing rapid ideation, visualization, and design automation. By integrating AI into workflows, architects can expand creativity and efficiency while exploring a wider range of design possibilities. Furthermore, advancements in AI learning models, prompt engineering, and collaborative design processes particularly those that incorporate sensor-derived data are emphasized to strengthen AI's role in bridging digital tools with human-driven creativity in architectural practice.

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1. Introduction

1.1 Background and objectives

In 2022, the artwork Theatre D'opera Spatial, created using the image-generating AI MidJourney, won the grand prize at the Colorado State Fair Fine Arts Competition, sparking widespread controversy.[1,2] Additionally, in 2024, OpenAI, a leading AI company, introduced Sora, an AI designed for video production. Its realistic and expressive results became a global topic of discussion.[3] AI, by leveraging vast datasets and computational processes, generates novel outputs in a fraction of the time it would take a human.[4] Given that both AI and humans engage in creative processes by building on existing knowledge, it is increasingly challenging to draw a clear boundary between the two.[5]

MidJourney, a prominent example of image-generating AI, is renowned for its ability to produce creative and artistic images. The platform generates images on the basis of textual prompts, allowing the AI to interpret the user's intent and produce related imagery.[6] Such applications of image-generating AI have transcended traditional visual domains such as design, fashion, and film, and are now expanding into a wide range of creative industries.[7]

In the field of architecture, where visual outputs are the primary deliverables, discussions on the use of image-generating AI are actively underway. Beyond merely generating images, these tools are being increasingly utilized for tasks such as architectural design automation, generation of design alternatives, and improvement of design solutions.[8]

MidJourney operates on the Discord platform, which may present a learning curve for first-time users.[9] To address this, various web-based image-generating AI tools such as PromeAI, fabrie, and LookX AI have been developed, offering user-friendly interfaces. These tools allow users to access them through web browsers, providing intuitive interfaces and templates that facilitate the creation of high-quality outputs in a short period, either through direct image inputs or textual prompts.

The aim of this study is to analyze and compare the outputs of these emerging web-based image-generating AI tools, identifying their respective strengths and unique characteristics. Furthermore, we seek to explore their potential applications in the architectural design process in this study. By evaluating the performance of various AIs and conducting empirical case studies, we aim to concretize their practical utility in architectural practice. Such findings can significantly contribute to the digital transformation of architectural design and the expansion of creative possibilities.

1.2 Research methods and scope

This study is composed of five sections. In Sect. 2, we examine the trends in relevant prior studies through a theoretical review and compare the characteristics of representative web-based image-generating AIs currently in service. Section 3 is dedicated to a survey of architectural design experts to identify and summarize the architectural features they perceive in architectural drawings (sketches). In Sect. 4, we describe how these same architectural drawings (sketches) are input into web-based image-generating AIs using prompts to generate images and analyze the results. Finally, the implications and limitations of using image-generating AIs in the architectural design process are discussed in Sect. 5.

The core parts of this study lie in Sects. 3 and 4, which are explained in more detail as follows. First, architectural design experts are presented with architectural drawings (sketches) and asked to describe and interpret the content they recognize and understand. The key points derived from their responses are then summarized. Second, the same architectural drawings (sketches) are input into five web-based image-generating AIs to produce outputs that are subsequently compared and analyzed. Finally, the level of understanding and the quality of expression of the outputs are evaluated in terms of how closely they resemble the interpretations provided by the experts. This interpretation can be better understood by referring to Fig. 1.

Through this process, we aim to determine which AI achieves the most humanlike level of understanding and produces the most complete outputs. Using these findings, we identify the optimal AI for use in architectural design and discuss strategies for its practical application in the architectural design process.

2. Literature Review

2.1 Previous studies on image-generating AI

Image-generating AI has been actively researched not only in architectural design but also in various visual art fields, including design, fashion, and film.[10] Recent studies on exploring its applicability in the architectural design process have focused on topics such as the utilization of AI in architectural design, the integration of sketch- and text-based generation methods, AI-

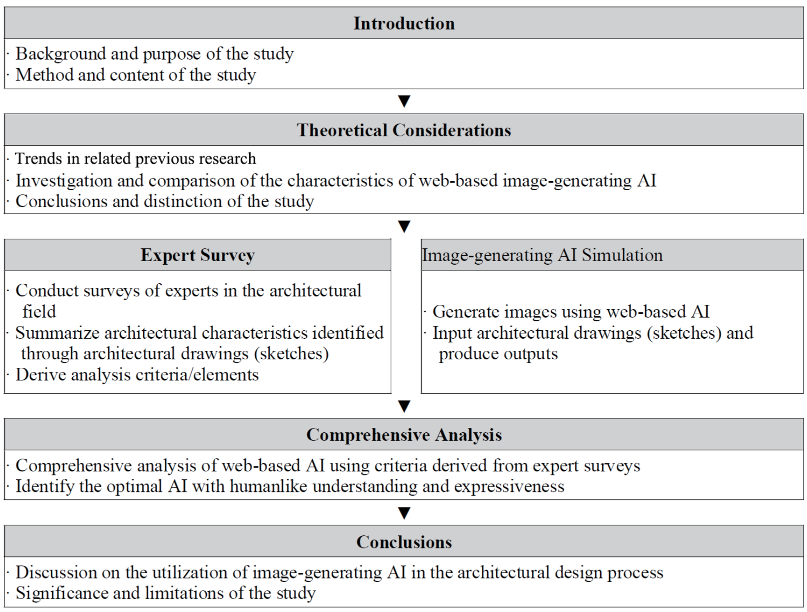

Fig. 1. Research flow and structure.

based building facade and elevation design, and the performance evaluation of image-generating AI tools.[11]

Regarding the exploration of AI's applicability in architectural design stages, Ville proposed using text-to-image generators to discover creative ideas and visualize concepts during the early stages of architectural design.[12] They emphasized AI's potential to stimulate designers' imagination and enhance communication with clients. Similarly, Lee analyzed the impact of generative AI tools on projects through case studies of their application in architectural design studios. Such studies provide foundational insights into how AI can revolutionize the design process.[13]

In studies on the integration of sketch- and text-based generation methods, Park *et al.* compared image-generation methods that utilize sketches with those based on textual prompts.[14] Their research included an analysis of the advantages and limitations of each approach in the architectural design process, highlighting the diverse potential applications ranging from initial conceptual design to detailed rendering tasks.

Research on AI-based building facade and elevation design was conducted by Heo and Cho[15] and Yoo.[16] These groups utilized AI tools such as Stable Diffusion and LoRA to generate floor plans and elevation designs. They evaluated the spatial characteristics reflected in the generated images and proposed potential applications in actual design processes.[15] Additionally, a method for efficiently visualizing facade designs using AI models trained on the styles of individual architects was suggested. This approach contributes to harmonizing clients' needs with designers' intentions.[16]

Ploennigs and Berger explored the architectural applicability of AI platforms, leveraging tools such as MidJourney, DALL-E 2, and Stable Diffusion to evaluate their potential in architectural design.[17] These platforms were found to be particularly effective in enhancing conceptual design and creative approaches. Seol conducted a study on the performance evaluation of AI tools, comparing various platforms such as PromeAI, Stable Diffusion, and MidJourney.[18] He examined the efficiency and limitations of these tools in architectural rendering tasks, and identified the appropriate design stages and applications for each tool while assessing their practical usability in the architectural field.

As such, recent studies on the application of image-generating AI in architecture have been progressing actively. The results of these studies suggest that image-generating AI has significant potential as a creative tool in the early stages of architectural design. Furthermore, they demonstrate that sketch- and text-based image-generation methods can complement and innovate design processes.

2.2 Image-generating AI and MidJourney (https://www.midjourney.com/home)

Image-generating AI can be broadly classified into two types: Discord-based[19] and web-based platforms. MidJourney is a representative example of Discord-based image-generating AI.[20] Discord is a real-time communication platform that facilitates interaction among users through voice chat, text messaging, video calls, and file sharing.[21] Initially designed as a voice chat tool for gamers engaged in team play, Discord has since expanded its user base to include a wide variety of communities and groups.

MidJourney has gained significant attention for its exceptional image-generation performance. It operates primarily through a text-to-model approach, where users input text prompts to guide the generation of models.(22) While this method is highly effective for certain architectural design tasks, it also imposes limitations, as it is only suitable for specific applications. Additionally, the process of generating images on the Discord platform requires users to input commands, which may pose a steep learning curve for beginners, particularly when fine-tuning prompts for detailed adjustments.(23) For a visual reference of this analysis, please see Fig. 2.

As a result, Discord-based image-generating AIs such as MidJourney are particularly useful for deriving highly imaginative conceptual images during the early stages of design, especially when there are no site constraints or design regulations to consider. However, they lack the capability to generate images based on sketches, which limits their ability to rapidly test specific alternatives, technical solutions, or varied conditional requirements in the early phases of architectural design.

2.3 Web-based image-generating AI

In September 2024, a study was conducted to identify the most frequently mentioned and widely used AI tools. In the selection process, multiple factors were considered including web-based accessibility, the presence of dedicated features for architectural applications, and the availability of free usage options. On the basis of the results of this comprehensive evaluation, five prominent image-generating AI tools were identified as key solutions gaining attention in the field. These tools—fabrie, Rerender AI, mnml.ai, LookX AI, and PromeAI(24)—are known for their unique functionalities and performance and are employed in architectural design and simulation tasks.

2.3.1 fabrie (https://www.fabrie.com/)

fabrie is a generative AI tool that supports image generation in various fields, including fashion, presentation design, and industrial design.(25) It is particularly noteworthy for its

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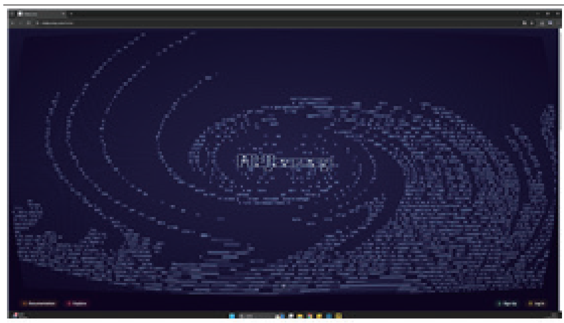

Interspace

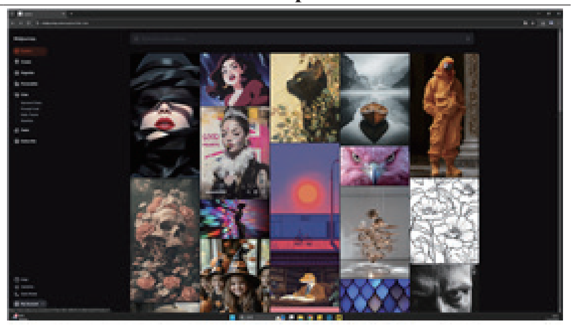

Fig. 2. (Color online) Web page of MidJourney.

dedicated menu for architectural rendering, making it highly applicable in the architectural field. fabrie allows users to input sketches, photographs, or 3D models as data sources for generating high-quality rendered images.[26]

This tool offers options to select various rendering styles and optimizes results in accordance with the architectural design purposes. It excels in interpreting sketches and accurately converting them into detailed images, making it useful for tasks ranging from initial design conceptualization to detailed rendering. New users receive 300 free credits upon registration, with each image generation consuming 40 credits. Additional credits can be purchased, offering flexibility based on usage needs.

2.3.2 Rerender AI (https://rerenderai.com/)

Rerender AI is an AI tool specialized for architectural rendering. However, its outputs often lack refinement or a modern aesthetic, limiting its use to simple visualization tasks. It generates images using image or 3D model file input and provides options to select various architectural types, including residential, commercial, educational, and cultural facilities.[27]

The rendering process takes approximately 40 s, making it relatively fast. Users receive three free trials upon registration. Each rendering session generates four images, but only one can be viewed in high resolution for free. The other three images are blurred, and a payment is required to access detailed versions. For a visual reference of this analysis, please see Figs. 3 and 4.

2.3.3 mnml.ai (https://www.mnml.ai/)

mnml.ai is an AI tool designed specifically for the architectural field.[28] It supports various functions, such as exterior rendering, interior design, and masterplan creation, offering tailored image generation options. mnml.ai is highly versatile, making it suitable for use in multiple stages of architectural design.[29]

Its rendering quality is excellent, making it ideal for projects requiring high-end visualization. New users are provided with 30 free credits upon registration, with each image generation costing 10 credits. This allows users to create up to three images during the trial period. Each rendering process takes about 35 s and produces one image. The generated images are automatically uploaded to a community platform, enabling users to view and reference others' renderings in real time.

2.3.4 LookX AI (https://www.lookx.ai/)

LookX AI is an AI tool specialized for architectural applications and is known for its exceptional ability to represent surrounding environments.[30] It includes features for generating or modifying prompts and supports rendering styles tailored for architecture, interior design, and universal aesthetics.[31]

LookX AI delivers high-quality results with a simple and intuitive interface, offering excellent usability for users. Upon registration, users can generate up to 100 images for free, making it beneficial for first-time users. Each image rendering takes approximately one minute.

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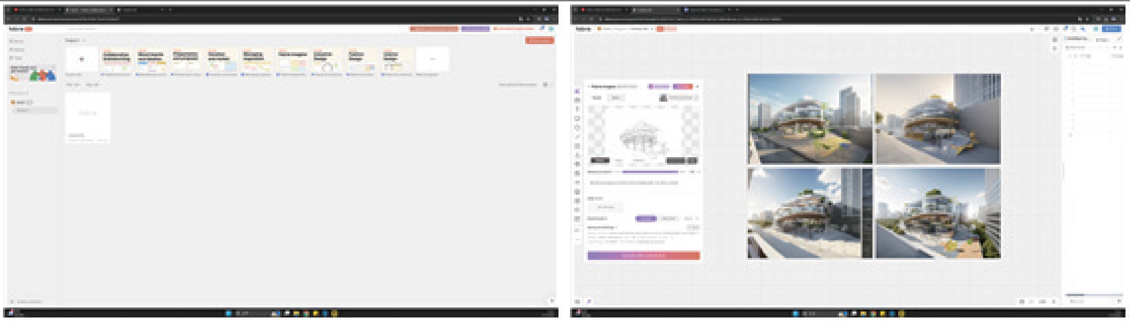

Fig. 3. (Color online) Web page of fabrie.

Start screen	Interspace and work space

Fig. 4. (Color online) Web page of Rerener AI.

2.3.5 PromeAI (https://www.promeai.pro/)

PromeAI is an AI tool with outstanding image-generation capabilities, offering various generative menus and rendering style customization options.(18) It specializes in creating diverse conceptual images, with results that vary significantly depending on prompt details and creativity settings.(32) For a visual reference of this analysis, please see Fig. 5.

PromeAI provides an extensive range of rendering modes and detailed customization menus, enhancing its applicability. However, a significant learning curve is required for users to become proficient with the tool. It allows overlapping of multiple styles and supports easy modifications. New users can use the tool without limitation for seven days upon registration, making it highly accessible initially. However, occasional technical errors, such as page freezes during rendering, have been reported. For a visual reference of this analysis, please see Fig. 6.

2.4 Distinction of this study

In the field of architectural design, prior studies on the application of web-based image-generating AI remain relatively underdeveloped compared with other fields. Most research has

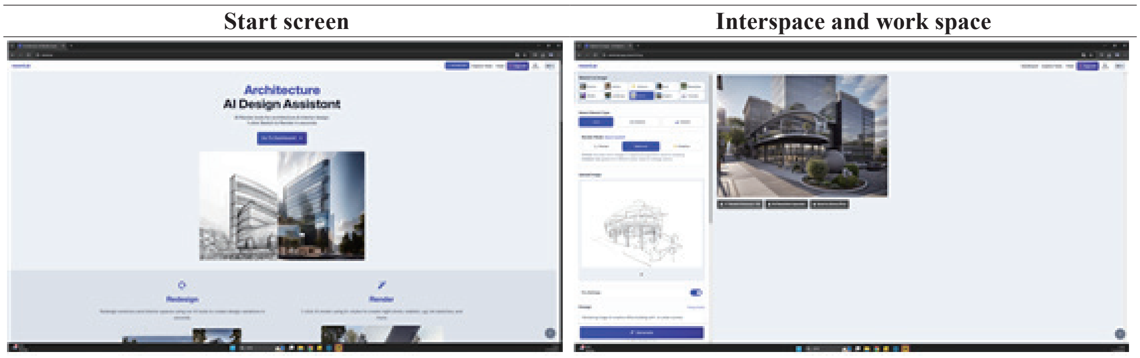

Fig. 5. (Color online) Web page of mnml.ai.

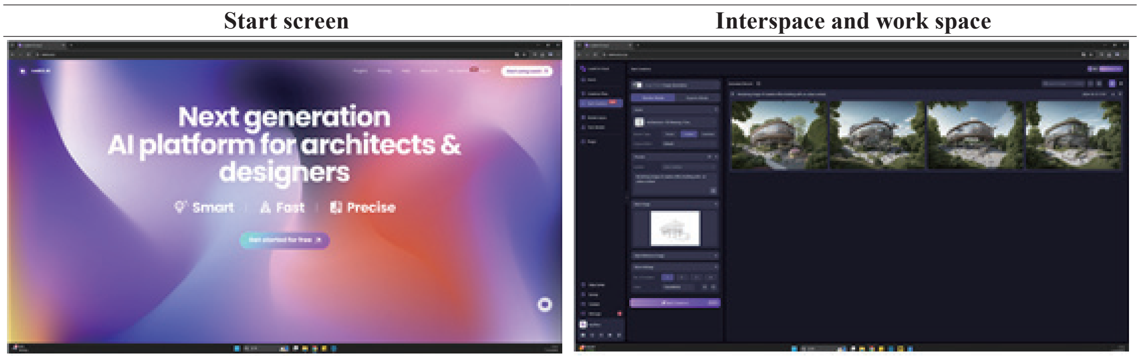

Fig. 6. (Color online) Web page of LookX AI.

centered around text-to-model approaches, which tend to be limited to specific stages or purposes. Furthermore, there is a notiable lack of analysis and validation regarding the performance and potential applications of newly introduced web-based AI tools.

Currently, prominent image-generating AI tools used in architectural design include fabrie, Rerender AI, mnml.ai, LookX AI, and PromeAI. Each of these tools possesses unique strengths and limitations and can be utilized for a wide range of purposes, from early conceptual design stages to detailed rendering tasks. For instance, fabrie excels at generating refined images based on sketches, while LookX AI and mnml.ai are well suited to high-quality rendering in advanced visualization projects. On the other hand, Rerender AI exhibits limitations in rendering quality, and PromeAI offers flexible customization and creative outputs but faces occasional technical issues. By comparing and analyzing these tools, architectural designers and related professionals can gain a better understanding of their characteristics and select the most suitable AI tools for their project requirements, thereby maximizing design process efficiency. For a visual reference of this analysis, please see Fig. 7.

A synthesis of prior research and analyses of image-generating AI reveals that studies focusing on web-based image-generating AI are generally insufficient. Specifically, there is a lack of concrete approaches to harmonizing the unique features and functionalities of each AI

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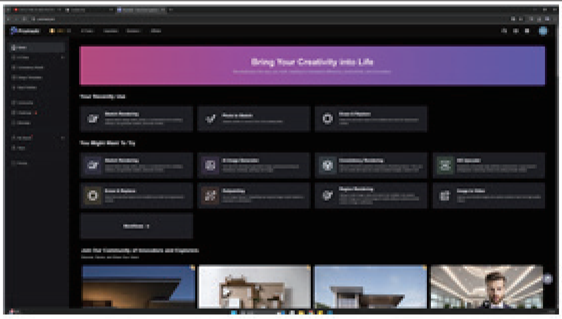
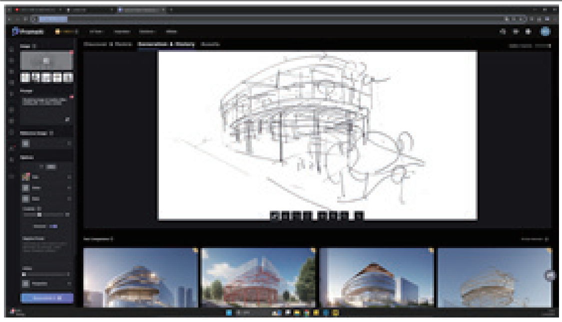
	

Fig. 7. (Color online) Web page of PromeAI.

tool within the architectural design process. The “sketch-to-image” approach, which involves generating images based on sketch inputs, offers groundbreaking possibilities for early-stage conceptualization and idea visualization. However, the lack of related research and validation has limited its practical application.

Therefore, in this study, we aim to explore the applicability of sketch-based image-generation methods in the architectural design process, distinguishing this study from previous research that primarily focused on text-to-image approaches. We will first analyze the content that architectural design experts perceive from architectural drawings (sketches) through a survey. Simultaneously, these findings will be compared with images generated using AI tools. By doing so, we seek to evaluate the performance of major AI tools and identify the most suitable AI for architectural design applications. The architectural features derived from expert surveys will serve as the analytical framework for comparing AI-generated design outputs. This comparative analysis will provide empirical insights into the applicability and limitations of AI in architectural design.

In particular, we will investigate methods for effectively visualizing designers’ creative ideas during the early design stages. By expanding the usability of image-generating AI in architectural design, we aim to concretize the integration of digital tools and design processes.

In summary, in this research, we explore the potential of AI-based image generation technology as a creative and practical tool in the architectural design process. By quantitatively and qualitatively analyzing the characteristics and strengths of various web-based image-generating AIs, we aim to propose effective strategies for their application in future architectural design processes, thereby establishing the distinct contribution of our study to the field.

3. Expert Survey

3.1 Survey overview

To identify the architectural characteristics embedded in architectural drawing sketches, a survey was conducted with experts in the architectural field. The survey was carried out over five days, from September 2 to September 6, 2024, in a written format. Participants were provided with architectural drawings (sketches) and asked to submit their responses in the form of opinion sheets. This interpretation can be better understood by referring to Table 1.

The survey was conducted with a total of 12 experts in the field of architecture, all of whom have 15 to 30 years of professional experience in architectural design. Among them, nine,

Table 1
(Color online) Key features of web-based image-generating AI tools.

Category	fabrie	Rerender AI	mnml.ai	LookX AI	PromeAI
Primary usage	Industrial, animation, graphics, 3D character, fashion, interior, architecture	Architecture	Architecture, interior, landscape, master planning	Architecture	Architecture, interior, landscape, games, fashion, furniture, jewelry, shoes, cars, electronics, packaging
Input data	Sketch, image, 3D model image	Image, 3D model file	Image	Image	Image, screen capture
Prompt additions	○	×	○	○	○
Negative prompt	×	×	○	×	○
Automatic prompt enhancement	×	×	○	×	○
Reference image input	×	×	×	×	○
Rendering/Mode Types	2 quality modes	Time/season/sky/ landscape/material	exact render, creative render	precise, balance, creative	3 quality modes:
Styles	44 styles	44 architectural types, 54 styles, 4 views	9 render styles	architecture, interior, universal	8 styles
Rendering time	30 s	40 s	35 s	60 s	25 s
Creativity adjustment	—	Detail preservation, creative mode, dream mode	Adjustable (1 to 100) Precise – creative	—	Artistry 1–100
Consistency control	×	×	×	seed -1	×
Result modification	○	×	×	×	○
Cost	- Basic: $9 (300 credits) - Professional: $48 (unlimited)	- $45 per month	- Basic: $19 (1000 credits, 10 credits per use) - Pro: $39 (5000 credits) - Expert: $79 (unlimited)	- Annual $199 - Monthly $20	- Base $16/month (500 coins, 1 coin per use) - Standard: $29 (2000 coins) Pro: $59 (6000 coins)
Free version	300 credits (40 credits per use)	3 renders per day	30 credits (10 credits per use)	100 credits	Unlimited use for 7 days with registration
Logo	fabrie	ReRender AI	mnml.ai	lookX.ai	PromeAI /promeai

including five university professors, hold an architect license. Additionally, one participant is a licensed landscape architect, while the remaining two are university professors with doctoral degrees. The participants were given architectural sketches and asked to identify at least three architectural features under three categories: architectural imagery, building form, and architecture and context. The responses were consolidated to analyze and summarize the architectural characteristics reflected in the sketches.

The sketches provided were freehand drawings created by the researcher, with specific purposes, functions, and contexts intentionally defined to guide the analysis.

3.2 Survey results

The survey results were summarized as follows. On the basis of the three categories mentioned—architectural imagery, building form, and architecture and context—relevant opinions were consolidated. Responses that were frequently mentioned by at least three experts were emphasized, while redundant or irrelevant content was excluded. For a visual reference of this analysis, please see Fig. 8.

3.2.1 Architectural imagery

Regarding the architectural imagery expressed in the sketches, various keywords with positive connotations were identified. Most experts interpreted the sketches as representing

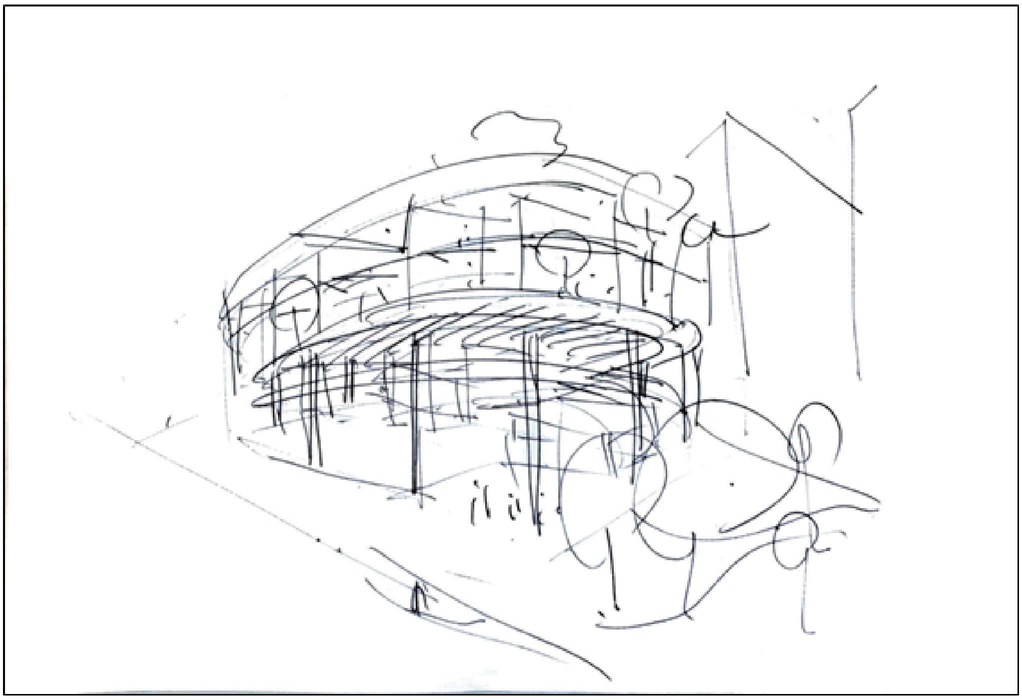


Fig. 8. (Color online) Architectural drawing sketch (created by the researcher).

creative and open architectural designs. The primary keywords related to imagery were as follows: independent, creative, floating, open, transparent, bright, glass-heavy, vibrant, cosmic, rounded, overcast weather, nonlinear, interconnected interior and exterior, environmental, and people resting on terraces.

3.2.2 Building form

Numerous opinions were provided regarding building form, including observations that were beyond the researcher's initial considerations. Nonlinear building shapes and elevated forms with open pilotis were consistently emphasized by multiple respondents, indicating these features to be easily understood through sketches. Some responses also described detailed characteristics, such as horizontal white bands and contrasts between exterior and interior spaces. Key terms related to building form include curves, rounded shapes, ring-shaped building masses, floating forms, open structures with large openings, masses elevated on pilotis, spaceship-like flying structures, exceptionally high floor heights, buildings with terraces or rooftop gardens, tree gardens, rounded and transparent buildings, facades emphasized by horizontal white bands, rectangular interior layouts contrasting with circular building shapes, and plazas connected to the lower levels of buildings.

3.2.3 Architecture and context

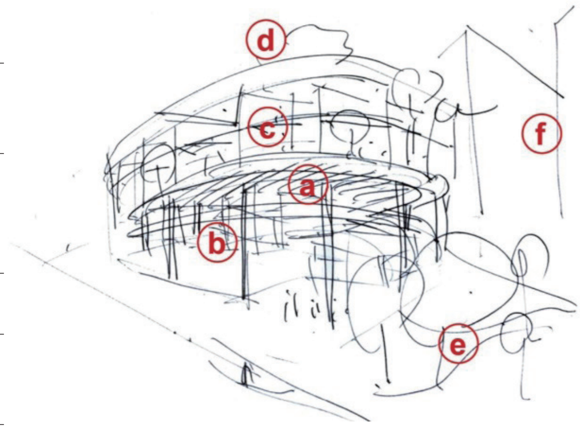
Opinions related to architectural context were relatively consistent. Commonly identified features included plazas extending into the building interior, surrounding high-rise buildings, uneven terrain, and green plazas. Additional features, such as courtyards and roads adjacent to the site, were mentioned by a smaller number of respondents. These results highlight a consensus on urban contexts featuring high-rise buildings and plazas in front of the structures. Key terms related to context include plazas with vegetation, uneven (nonflat) terrain, urban dense areas, green plazas, playgrounds, exterior-connected courtyard spaces, and roads adjacent to the site.

3.3 Summary

The survey results from architectural planning and design experts indicated that the architectural sketches were interpreted as depicting creative, bright architectural designs with unconventional, rounded forms elevated on pilotis. The designs were also described as being situated in urban environments with plazas at the forefront.

To facilitate a comparison between the survey results and the outputs of image-generating AI tools, the architectural features derived from the sketches were organized into six key elements, as summarized in Table 2. These features will serve as a benchmark for analyzing the compatibility and performance of AI-generated outputs with respect to architectural characteristics.

Table 2
(Color online) Architectural features and expressive elements represented in the architectural drawing.

Category	Architectural features	Expressive elements	Architectural drawing
ⓐ	Floating architectural form	Separation of 1st and 2nd floors, cantilever, underside finishes	
ⓑ	Pilotis space	Columns, open spaces, interior activities, people	
ⓒ	Nonlinear (circular) mass	Curved shapes, distinction of two levels, railings, interior spaces	
ⓓ	Empty upper space	Sky, clouds, rooftop gardens	
ⓔ	Exterior space	Slopes, vegetation, people, street facilities	
ⓕ	Surrounding context	Buildings, roads	

4. Web-based Image-generating AI Simulation

4.1 Simulation overview

In this study, a simulation using web-based image-generating AI tools was conducted to explore their applicability in architectural design. The image-to-model image-generation method was employed, where architectural drawings (sketches) created by the researcher were input as JPEG files. To enhance the AI's understanding of the architect's design intent, a simple prompt was added alongside the sketches. The prompt used was uniformly set as "Rendering of creative office building in an urban context."

The simulation utilized five major web-based AI tools: fabrie, Renderer AI, mnml.ai, LookX AI, and PromeAI. While these tools offer a variety of rendering modes, settings, and editing features, the simulation was conducted using default settings to enable a comparative analysis of each AI's core capabilities. Additionally, alternative simulations were performed to test the variety of modes and features provided by the tools.

For result analysis, the original architectural sketch and the rendered images generated by the AIs were compared to examine the expressive elements. By this analysis, we assessed how well each AI understood the input sketches and translated them into visual outputs. Furthermore, the overall rendering quality and architectural details were comprehensively analyzed to determine the optimal AI tool for architectural design applications.

4.2 Simulation results

4.2.1 Images generated by fabrie

The comparison between the architectural sketches and the images rendered by fabrie revealed the following characteristics.

The floating mass of the building was accurately depicted, with the cantilevered underside rendered in a detailed wooden louver finish (a). Despite the sketch not clearly defining the interior spaces of the lower floors, the AI interpreted and visualized a variety of interior spaces and programs. However, resolution limitations hindered a detailed inspection of the rendered images, though the columns were accurately represented (b). The nonlinear massing of the upper floors, including the two-story volume indicated in the sketch, was faithfully rendered. The terrace with people and vegetation was naturally integrated into the design. Additionally, the terrace spaces formed by the perpendicular relationship between the interior walls and the irregular exterior massing were exceptionally well rendered (c). Ambiguities in the upper building areas in the sketch were creatively interpreted by fabrie, with some parts represented as clouds and others as vegetation in alternative renderings (d). The exterior spaces were realistically represented, maintaining the relationship between the terrain and the building. Elements such as landscaping, street furniture, paving, and human figures were harmoniously arranged with the building. Notably, the free curves drawn on the ground in the sketch were creatively interpreted as shadows, showcasing a unique approach (e). The urban context of the image was effectively portrayed through distant high-rise buildings that accentuated the prominence of the architectural structure. The background effectively conveyed an urban atmosphere, with additional details such as roads, traffic lanes, and pedestrians visible in the lower-left corner (f).

The results of this analysis confirms fabrie's ability to interpret architectural sketches creatively and accurately, demonstrating exceptional performance in visualizing complex masses and effectively integrating contextual elements while considering spatial relationships. Its ability to cohesively integrate various elements highlights fabrie's potential as a valuable tool for architectural design.

4.2.2 Images generated by Rerender AI

The comparison between the architectural sketches and the images rendered by Rerender AI revealed the following characteristics.

The separation between the upper and lower masses was not clearly depicted. While the front view exposed the ceiling of the first floor, using color to highlight the ceiling plane, the side view inconsistently presented the structure as a two-story building (a). The lower-level space was rendered with glass façades, but the interior layout was indistinct, making it challenging to discern the internal composition (b). The upper-level structure was represented as a single-story volume, similar to the lower level, enclosed entirely with glass. This made the interior configuration difficult to interpret. The terrace space was minimally expressed, with no visible representations of vegetation or human figures (ⓒ). On the rooftop, a garden was included, but its color and design were inconsistent with the overall building, resulting in a lack of cohesion (ⓓ). The exterior space was surrounded by vegetation, but the connection between the landscape and the building was poorly integrated, resulting in a disjointed representation. This outcome indicates a failure to interpret the spatial relationship between the terrain and the building three-dimensionally (ⓔ). The urban context was not effectively incorporated into the rendering. The absence of a generated background or urban elements in additional renderings made it difficult to identify any contextual relationship with the surrounding city (ⓕ). For a visual reference of this analysis, please see Fig. 9.

Overall, the images generated by Rerender AI demonstrated a lack of consistency and integration in representing both architectural and contextual elements. While some aspects of the building and its environment were depicted, the AI's inability to interpret and visualize the three-dimensional relationships and urban context highlights significant limitations for architectural design applications. For a visual reference of this analysis, please see Fig. 10.

Image Generated by fabrie **Chart Analysis**

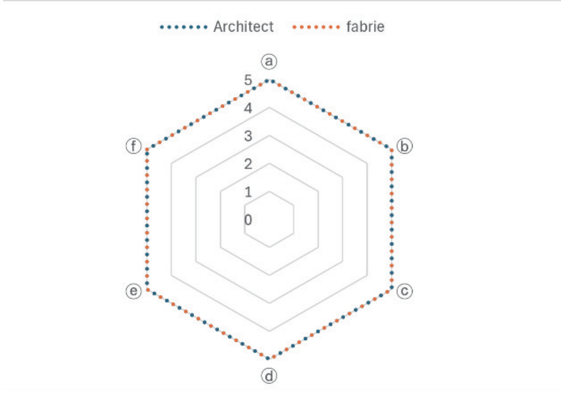


Fig. 9. (Color online) Analysis of rendering image generated by fabrie.

Extra image 1 **Extra image 2** **Extra image 3**

Fig. 10. (Color online) Additional images generated by fabrie.

4.2.3 Images generated by mnml.ai

The comparison between the architectural sketches and the images rendered by mnml.ai revealed the following characteristics.

The lower and upper masses were distinctly separated, with the upper ceiling finish and shadows of the lower level prominently rendered, effectively conveying a sense of mass (a). The lower level was finished with glass, and its interior functions and lighting were visible, allowing a clearer understanding of the space's specific configuration (b). The upper level was rendered as a single-story structure, with vegetation and rest areas included on the terrace. However, the interior space of the upper level was not as clearly depicted as the lower level, and its walls appeared ambiguously rendered. Additionally, some facades were represented with decorative elements, resulting in a lack of detail and completion (c). The upper building reflected vegetation from the background buildings, but this did not contribute to achieving harmony between the building and its surroundings (d). The landscape design utilized elements such as vegetation, sculptures, and landscaping stones based on the nonlinear sketch. However, the freeform aspect of the sketch was not properly implemented, with the landscaping being simplified into circular forms (e). The urban background was generated, but the background buildings appeared excessively close to the sketch building, overly emphasizing the surroundings and disrupting balance. The sketch building seemed to be part of the background buildings, losing its independence and appearing passively represented. A pedestrian street was generated on the left side of the image, but the absence of human activity rendered the space static and lacking vitality. In additional images, the building continued to lack independence and was portrayed as part of another structure, reducing the architectural emphasis (f). For a visual reference of this analysis, please see Fig. 11.

mnml.ai demonstrated competence in separating architectural masses and visualizing lower-level interiors. However, limitations in harmonizing the building with its background, a lack of detailed facade rendering, and passive contextual integration highlight areas for improvement.

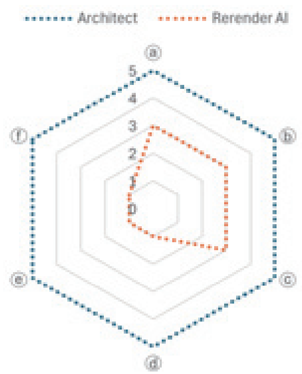
Image Generated by Rerender AI	Chart Analysis
	

Fig. 11. (Color online) Analysis of rendering image generated by Rerender AI.

The tool showed promise in rendering basic spatial configurations but fell short in achieving a cohesive architectural and contextual representation. For a visual reference of this analysis, please see Fig. 12.

4.2.4 Images generated by LookX AI

The comparison between the architectural sketches and the images rendered by LookX AI revealed the following characteristics.

The upper mass was clearly depicted as a floating structure, while the lower mass was rendered with a taller height, effectively conveying the design concept. The masses and designs of the lower and upper levels were distinctly differentiated, highlighting the overall design intent (a). The lower level pilotis was generated as an open space, incorporating a central courtyard, a significant sense of verticality, outdoor stairs, pedestrian movement, and artificial green terrain. These features showcased diverse possibilities for spatial utilization (b). The upper mass was rendered as fully floating, with its top and bottom finished in a woodlike material, emphasizing detailed finishes. The slender columns in the pilotis further accentuated the floating upper mass. However, the representation of the interior spaces and terraces was insufficient, leaving some of the design intent unexpressed (c). The upper space included greenery and people, emphasizing its potential for spatial use. This approach highlighted the usability of the upper-level space (d). The exterior spaces were effectively represented, with gentle slopes extending toward the inner courtyard and the terrain differences being well expressed. While the representation of people was appropriate, the vegetation appeared as decorative elements along the streets, detracting from the natural composition of the exterior spaces (e). The urban background was inaccurately generated, portraying the building as being located in the middle of natural greenery. This contradicted the intended design context. The issue persisted across additional renderings, with the urban context consistently failing to be adequately reflected (f). For a visual reference of this analysis, please see Fig. 13.

Extra image 1	Extra image 2

Fig. 12. (Color online) Additional images generated by Rerender AI.

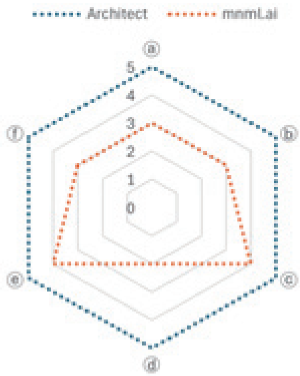
Image Generated by mnml.ai	Chart Analysis
	

Fig. 13. (Color online) Analysis of rendering image generated by mnml.ai.

LookX AI demonstrated strong performance in distinguishing between architectural masses and effectively expressing pilotis spaces with diverse spatial configurations. However, its misrepresentation of urban context and limited interior and terrace details presented significant challenges in fully capturing the design intent. Despite these limitations, its ability to visualize spatial elements and material details suggests potential for certain architectural design applications. For a visual reference of this analysis, please see Fig. 14.

4.2.5 Images generated by PromeAI

The comparison between the architectural sketches and the images rendered by PromeAI revealed the following characteristics.

The upper and lower masses were distinctly differentiated in design, with the upper mass rendered in a nonlinear form and the lower mass as a setback rectangular shape. The cantilevered underside of the upper mass prominently displayed interior spaces, emphasizing finishing details (ⓐ). The lower mass was depicted as a bright, open, and spacious area; however, interior environments and representations of people were omitted. The lower mass was rendered as a solid structure supporting the upper floors, effectively conveying spatial openness but lacking detailed representation (ⓑ). The upper mass was rendered as a transparent, nonlinear form with a two-story scale. Horizontal bands were delineated on the exterior, but vegetation and people on the terraces were absent, making it difficult to evaluate the usability of the space (ⓒ). The top of the building featured a unique canopy design, which diverged from the vegetation or cloud representations seen in other AI-generated images. While this could be considered a creative interpretation, it deviated from the original intent of the sketch (ⓓ). The exterior spaces included artificial terrain, with the building positioned atop this form. PromeAI accurately reflected the sloping terrain depicted in the sketch, where the road in front of the building rises toward the rear. However, the representation of vegetation, people, and plazas was either omitted or insufficiently detailed (ⓔ). The urban context was incorporated into the rendering, with the massing, height, and positioning of the generated building adjusted to enhance its visibility.

Extra image 1	Extra image 2	Extra image 3
		

Fig. 14. (Color online) Additional images generated by mnml.ai.

Additional images showcased creative interpretations of the sketch and urban context, such as portraying the building as part of a public urban structure or integrating it into a high-rise setting. While these interpretations demonstrated creative potential, they lacked consistency with the design intent of the original sketch (f). For a visual reference of this analysis, please see Fig. 15.

PromeAI demonstrated creative interpretations and effectively distinguished architectural masses, particularly in emphasizing spatial openness and terrain relationships. However, its deviations from the sketch's intent, omissions of spatial usability elements such as terraces and plazas, and inconsistencies in context alignment highlight areas for improvement. Despite these limitations, PromeAI's creative flexibility and adaptability show promise for exploring conceptual and innovative architectural applications. For a visual reference of this analysis, please see Fig. 16.

4.3 Analysis and discussion

We analyzed the characteristics of image-generating AI tools through simulations, demonstrating their practical and effective application in the architectural design process. By doing so, we sought to provide meaningful insights into the integration of digital tools and design workflows.

The five image-generating AIs tested in this study demonstrated distinct functionalities and features, resulting in varied output quality. Specifically, in the image-to-model approach, certain AIs showed specialization in understanding hand-drawn sketches and generating architectural design outputs, highlighting their potential for architectural applications.

On the basis of the simulation and analysis results, fabrie, LookX AI, and PromeAI emerged as the top-performing AIs in terms of understanding architectural sketches and generating architectural expressions. Among these, fabrie was identified as the optimal image-generating AI for architectural design applications. For a visual reference of this analysis, please see Figs. 17 and 18.

fabrie comprehensively understood the detailed aspects of sketches and effectively captured the atmosphere and spatial intent even with minimal prompts. It accurately interpreted the researcher's design intent and produced high-quality rendered outputs, making it particularly well suited for transitioning initial ideas into finalized results.

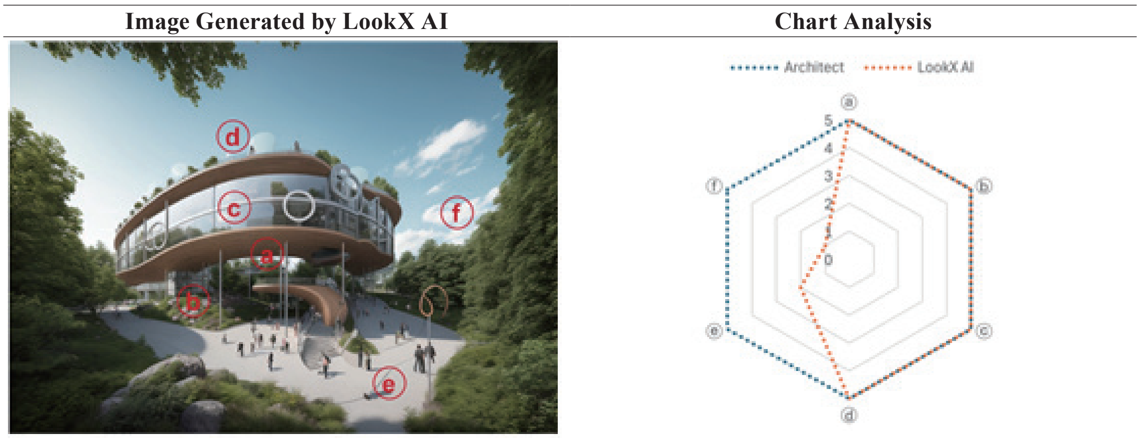


Fig. 15. (Color online) Analysis of rendering image generated by LookX AI.

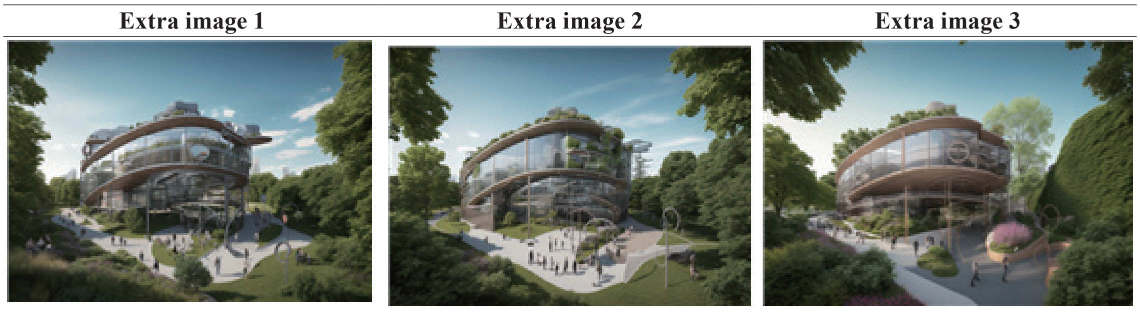


Fig. 16. (Color online) Additional images generated by LookX AI.

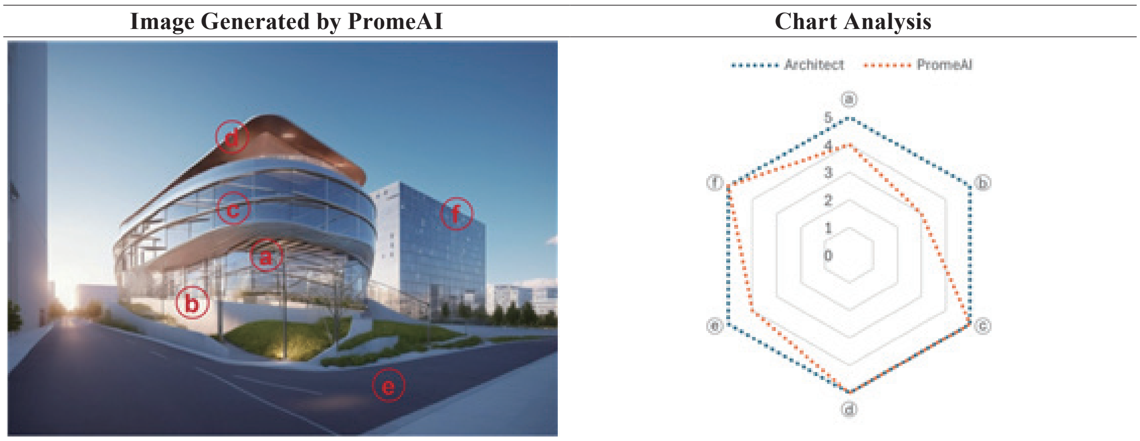
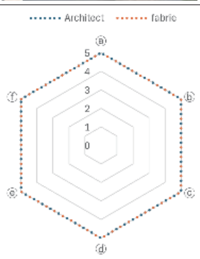
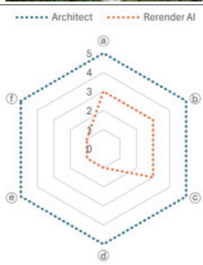
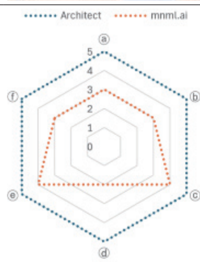
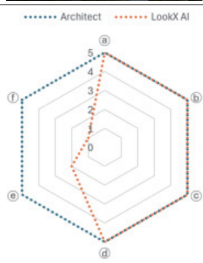
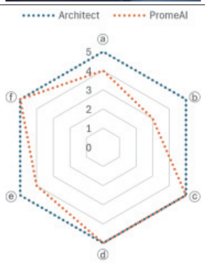


Fig. 17. (Color online) Analysis of rendering image generated by PromeAI.

Extra image 1	Extra image 2	Extra image 3

Fig. 18. (Color online) Additional images generated by PromeAI.

Table 3
(color online) Comprehension and expressiveness of rendering AI tools.

Category	fabrie	Rerender AI	mnml.ai	LookX AI	PromeAI
Floating architectural form	●●●●●	●●●○○	●●●○○	●●●●●	●●●●○
Pilotis space	●●●●●	●●●○○	●●●○○	●●●●●	●●●○○
Nonlinear (circular) mass	●●●●●	●●●○○	●●●●○	●●●●●	●●●●●
Empty upper space	●●●●●	●○○○○	●●○○○	●●●●●	●●●●●
Exterior space	●●●●●	●●○○○	●●●●○	●●●●○	●●●●○
Surrounding context	●●●●●	●○○○○	●●●○○	●○○○○	●●●●●
Evaluation	Beyond Excellent	Insufficient	Average	Excellent	Excellent
Rendering Image					
Chart Analysis					

*The comprehension and expressiveness of each AI tool in interpreting architectural sketches were evaluated and categorized into five levels, followed by a comprehensive analysis.

LookX AI demonstrated a strong ability to accurately interpret sketch content and creatively generate architectural designs by incorporating imaginative elements. However, its representations of exterior spaces and surrounding environments diverged significantly from the researcher's intent, limiting its effectiveness in certain contexts.

PromeAI excelled in creative interpretations and generating diverse designs. Its extensive customization menus and editing features allowed for broad testing in the design process.

Nevertheless, its representations of exterior spaces were sometimes omitted or oversimplified, though this limitation could potentially be mitigated by providing more detailed prompts.

Given these findings, fabrie was evaluated as the most versatile and suitable AI for use across all stages of the architectural design process. Its ability to accurately interpret sketches and produce refined outputs makes it a valuable tool for architectural professionals, particularly in the early conceptual stages of design. Meanwhile, LookX AI and PromeAI also demonstrated significant strengths in specific areas, indicating their potential for targeted applications within architectural design. This interpretation can be better understood by referring to Table 3.

5. Conclusions

In this study, we analyzed the characteristics and performance of web-based image-generating AI tools and explored their potential applications in the architectural design process. An expert survey was first conducted to identify key architectural features in hand-drawn sketches. They were then used as evaluation criteria. Simulations were performed using five AI tools—Fabrie, LookX AI, PromeAI, Mnml.ai, and Rerender AI—to compare and analyze the quality of their generated outputs.

The results revealed that each AI tool had its strengths and limitations, with Fabrie, LookX AI, and PromeAI demonstrating superior performance in interpreting architectural sketches and reflecting design intent. These AI tools effectively comprehended the intricate details of hand-drawn sketches and accurately conveyed architectural details and spatial ambiance with minimal input. This suggests that AI can serve as a valuable tool throughout the entire architectural design process, from initial concept development to the production of refined outputs.

The results of this study establish that AI technology in architectural design extends beyond simple rendering functions, enhancing both architectural creativity and efficiency. In particular, the sketch-to-image approach has the potential to revolutionize the early design ideation phase. AI tools not only serve as visualization aids but also supplement designers' creative thinking and enhance visual communication with clients. The findings further highlight the integration of digital tools with design workflows, proposing a new direction for AI-assisted architectural design.

Future research should focus on understanding and utilizing the detailed functionalities of image-generating AI tools, improving prompt-writing techniques to enhance precision in representations, evaluating the suitability of AI tools for different stages of the design process, and exploring the dynamics of collaboration between AI and designers. Through continued research, image-generating AI is expected to establish itself as a practical and creative tool across the entire spectrum of architectural design, contributing significantly to the evolution of design practices.

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