Architectural ideation instrumented by GAI

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1. Introduction: Challenges and opportunities of Artificial Intelligence (AI) for architectural design and ideation

Recent developments in *generative artificial intelligence* (GAI), particularly through programs such as ChatGPT[1], Midjourney[2], DALL-E[3] or Stable Diffusion[4], are opening up new perspectives for ideation in architectural design. Indeed, these so-called *text-to-text, text-to-image* and *image-to-image* tools are capable of generating multiple representations that open up unprecedented opportunities for exploration, particularly significant for the ideation phase in architecture (Leach, 2023; Leach, 2022; Marsault & Nguyen, 2022).

Initial research results (Paananen et al. 2024; Yildirim 2022) suggest that these Artificial Intelligence-based image generators are promising tools for supporting designers' creativity. Indeed, GAIs are capable of producing unique and personalized visual representations, relatively aligned with the designer's initial intentions (Paananen et al., 2024). According to these studies, they can also do so more intuitively and rapidly than traditional design practices (Yildirim, 2022). This early research highlights that GAIs facilitate the rapid transformation of abstract ideas into visual forms, while enabling a diverse exploration of ideas through the use of textual descriptions to materialize imagined conceptions (Yıldırım, 2022). However, other authors and in particular Masure (2023) qualify these perspectives by highlighting their limiting technical natures. Masure argues that GAIs, unable to understand the complexity of human creativity, simply reproduce rather than produce original results (Masure, 2023), thereby limiting their alignment with a user designer's intentions.

[1] https://chatgpt.com/, consulted on March 4, 2025
[2] https://www.midjourney.com, consulted on March 4, 2025
[3] https://openai.com/index/dall-e-3/, consulted on March 4, 2025
[4] https://stability.ai/, consulted on March 4, 2025

Despite the potential of GAIs, we must question their impact on the ideation process. This is the question raised in this chapter. We focus particularly on the cognitive processes underlying the use of generative AIs in the ideation phase for architectural design, a field which is still very marginally studied. The aim of this contribution is to outline some initial considerations and perspectives on these cognitive processes. As AI tools and technologies are evolving at a very rapid pace, our aim here is to provide theoretical benchmarks and non-exhaustive "sounding boards" for questioning these practices.

To address the challenges of GAIs for architectural ideation, we draw on theoretical foundations from the field of *Design Cognition* as well as on several series of experiments we have conducted in various contexts (Yüksek and de Boissieu, 2025a, 2025b). These experiments, involving future architects, were analyzed in detail in order to better understand the cognitive processes involved in prompt design, image generation and idea emergence, while highlighting their specificities. By exploring the cognitive processes at play when using these tools, we aim to open up new perspectives on their impact on creativity and potential biases in the ideation phase.

Ideation is a founding stage of architectural design in which the architect generates the first main, structuring ideas for the project (Safin, 2011; Baudoux, 2023; Elsen, 2010). It plays a key role in linking the various facets of the problem with possible solutions (Dorst & Cross, 2001). Although the ideation process takes place mainly in the initial design phase, it also manifests itself in punctual episodes whenever a new problem emerges (Elsen et al., 2010). One of the hallmarks of the ideation process is the dialogue between the architect's so-called internal (mental) and external (materialized) representations (see Chapter 3).

The new modalities proposed by GAI shake up the traditional dynamics between internal and external representations. This chapter begins by introducing the multiple potentialities of GAI tools in order to situate their technological context and potential uses (section 2). We then explore the cognitive dynamics of instrumented ideation, examining how strategies of divergence and convergence foster the emergence or development of ideas (section 3). We also look at how the dynamics of internalization and externalization influence the design strategies and issues of prompts in creative processes (section 4).

2. Modes of interaction with GAIs

2.1 Introduction to GAIs and the specifics of prompts

Le Cun (2019) defines artificial intelligence as a set of techniques enabling machines to perform tasks that are mainly reserved for humans. These tasks range from recognizing objects in an image or planning robotic movements to more complex challenges, such as playing chess or translating texts. Current advances in AI enable developments as varied as autonomous cars or improved medical imaging analysis, sometimes surpassing human expertise (Le Cun, 2016; 2019).

Generative artificial intelligence (GAI) has been around for many years but gained momentum from the late 2010s, thanks to the rise of generative adversarial networks (GANs), introduced by Ian Goodfellow in 2014 (Le Cun, 2016; 2019). These models enabled GAI to develop and diversify, but it was above all with the release of publicly accessible tools, such as ChatGPT in late 2022, that the term “generative AI” gained massive recognition. Today, GAI is establishing itself as a key technology, defined as a system capable of producing new and diversified content in different formats and for various tasks (García-Peñalvo & Vázquez-Ingelmo, 2023).

The generation of new content, whether text or images, relies on the strategic use of prompts to guide the model in the creation of results adapted to the user's specific needs. A prompt is an instruction or request by which the user describes his or her needs to the GAI. It is therefore the main interface with which the user can guide and direct the GAI to obtain a production that meets his or her objectives. The writing of prompts is increasingly becoming a specific skill that needs to be adapted to different GAIs.

The prompt thus acts as a communication vector, guiding the AI model in the production of content aligned with the user's specific objectives. The quality of the prompt directly influences the relevance and richness of the responses generated by the AI. Therefore, mastering what is known as “prompt engineering” is becoming a skill for maximizing the effectiveness of interactions with an AI (Le Cun, 2016; Ekin, 2023). More specifically, a rigorous formulation of prompts makes it possible to establish more nuanced exchanges that are adapted to the specific needs of different applications (Ekin, 2023).

Ekin (2023) defines “prompt engineering” as the process of designing, refining and optimizing the instructions input to an AI model with the aim of conveying the user's intention clearly and precisely. This approach is fundamental to generating content that is accurate, relevant and consistent, thus guaranteeing an optimal match between the user's expectations and the responses generated by the model. Little research

focuses specifically on prompt engineering in general, and even less on prompt engineering for architectural design. However, architects with a passion for AIare exploring these technologies and proposing methods for designing effective prompts (Fu, cited in modulyss, 2024; Lucas, 2024).

Artificial intelligence image generators can be guided in different ways, depending on whether they are provided with textual or visual input, or a combination of both. When the user enters a textual description to guide image creation, this is referred to as a textual prompt. Some specialized tools enable image-to-image generation, with no text required. This is the case with templates that enhance the quality of existing images or apply the template's artistic style. Other tools offer image-based generation using parameters available in their interface. Finally, it is possible to use a hybrid prompt, combining both an image and a complementary text description, offering greater control over the final result.

2.2 Text-to-text: Text content generation

In the field of generative artificial intelligence, “text-to-text” generation models occupy a prominent place thanks to their ability to transform textual inputs into coherent textual responses. There are many text-to-text[5] artificial intelligences on the market today. One of the most representative models is ChatGPT, a language model developed by OpenAI that interacts in a conversational manner. This AI model is capable of answering questions, summarizing documents and translating automatically, all with a high degree of accuracy (Roumeliotis & Tselikas, 2023).

In the field of architectural design, a study by researchers Tan and Luke (2024) explores the use of text-to-text generative AI in the development of concepts for the built environment. The researchers postulate that text-to-text AI is emerging as a promising tool for transforming the architectural design process. They argue that text-to-text AI enables architects to explore new contexts and scenarios, such as visions of futuristic cities (Tan & Luke, 2024).

AI text-to-text can become an interesting tool for the ideation phase in architectural design. It can enrich the brainstorming process by helping architects to explore various conceptual approaches. From imagining the layout of a space, to defining a mood, contextualizing a project or experimenting with materials, these text-based GAIs offer

[5] Mistral AI, Microsoft Bing, Gemini from Google, Claude 2 from Anthropic, Llama 2 from Meta and DeepSeek

a dynamic and adaptive source of inspiration. Architects can interact with the AI by submitting precise queries, refining their ideas and opening up new perspectives according to the directions they wish to pursue. Moreover, as a conversational assistant, these AIs enable dynamic interaction that goes beyond the simple generation of one-off ideas. Thanks to its ability to maintain the thread of a discussion, it enables architects to progressively develop a thought process, refine concepts and explore different directions depending on the answers obtained. Nevertheless, these AIs remain dependent on the datasets used to train them. In addition to the ethical and intellectual property issues involved, we may wonder about the biases they induce, as well as the issues of reproduction of what already exists that they provoke (Ben Saci et al. 2024; Masure, 2023).

2.3 Text-and-image-to-image: Image generation

Following on from “text-to -text” models which transform textual descriptions into coherent texts, we are now looking at models that enable images to be generated or modified from a textual and/or visual (image) prompt. These so-called *text-and-image-to-image* models, such as DALL-E, Midjourney or Stable Diffusion, open up new perspectives for architectural design. Among them, at the time of writing this text, Midjourney is one of the most widely used tools for generating images from text descriptions (prompt text). The image generation process starts by entering the command “/imagine”, followed by a text prompt (a key request, see 2.1), which generates four images. It is then possible to create other variants from one of the generated images. It should be noted that executing the same prompt produces different results each time.

Midjourney is a general-purpose tool, which means it is trained on an indiscriminate database. However, architecture-specific tools are beginning to appear. For example, LookX AI is an artificial intelligence platform specially trained for architectural applications. This tool can be used to produce a variety of architectural images (see following sections) or video sequences, based on mainly text-based prompts. These prompts can be enriched with various visual elements, such as a reference image, a preliminary sketch or even a photograph of a physical model. The LookX AI interface stands out for its assistance in formulating prompts. The platform offers an interactive guide that facilitates the construction of descriptive text. Users can simply select predefined terms to suit their needs, guiding the generation of images according to the desired style, ambience or technical features (see Section 3). This simplified approach makes the tool easy to use, while delivering highly accurate visual results.

2.4 Image generation settings

Tools such as controlNet, or GAI features such as Midjourney v6, allow fine-tuned control of the desired distance between a visual prompt (photo, image, sketch) and the images generated. Figure 1, for example, shows how the same prompt, consisting of a text and a photograph of a mock-up, gives rise to very different generations as a function of different control settings. Figure 1.a remains relatively identical to the original image, resulting in a kind of strangeness. Figure 1.b, on the other hand, gives an impression of realism and completeness, although it establishes a great distance from the image provided (the composition of the openings is not respected, the overall scale of the building has been reinterpreted).

a b

Prompt: *A brutalist concrete building with bold geometric shapes, exposed structural elements, and a raw facade. The design emphasizes strong, angular forms, deep-set windows, and minimal ornamentation, creating a powerful, monolithic presence in the forest landscape. The building is like a huge cube with small openings.*

Figure 1.1. *Gap and control issues, generated by Stable Diffusion and ControlNet. (Author: Simon Baudru).*

The issue of control over the images generated is particularly important for uses requiring a mixed prompt: text and image, such as the production of renderings from images of white mock-ups or sketches. The difficulty of generating rendering images that are relevant to the designer without creating major deviations from the original design makes this use difficult.

Having reviewed the main modes of interaction of GAIS, the following section presents the uses and potential uses of image-generating AIs. It should be noted that the images generated are indeed visuals: colored pixels associated in two dimensions, and not definitive or complete architectural proposals (Jaruga-Rozdolska, 2022).

3. Uses and potential uses of GAIs

Generative artificial intelligences, beyond their ability to generate images, now offer new possibilities for supporting the ideation phases in architecture. Their use, which is still evolving, reveals a diversity of approaches and practices. This section presents an overview of some current uses and illustrates the potential of these tools for the ideation phase of architectural design.

3.1 Exploring architectural “styles”

Image generation tools give architects the opportunity to explore a wide range of architectural styles. As they modify prompts, they refine their intentions and instantly experiment with different aesthetics, historical influences or formal approaches.

As part of her research, Jaruga-Rozdolska (2022) experimented with the abilities of the AI platform Midjourney to produce an architectural idea with “Baroque style” as the criterion. To do this, she used prompts, which consist of keywords relating to styles, architects and works of the chosen architectural movement, such as “Baroque-style façade”, “Gian Lorenzo Bernini” or “technical drawing” to achieve an architectural drawing effect. The images generated by the GAI reflected the Baroque style without being replicas of existing works. The GAI thus enables architectural ideas to be generated from a specific historical style that the architect wishes to explore. In a similar vein, we have designed a prompt inspired by Mimar Sinan's classical Ottoman architecture for the design of a library (Fig.2). Thanks to this AI, the architect can generate visual proposals and, ultimately, explore imaginative variations based on probabilities identified by the GAI neural networks.

Prompt: *"A university library classical Ottoman style, inspired by Mimar Sinan, front view, featuring large imposing central domes, elegant arches, finely carved moucharabiehs, and intricate geometric patterns. Soft natural light creates a harmonious and majestic atmosphere. Materials include sculpted stone, marble, and finely crafted wood. The interior is illuminated by warm lighting, with figures, vegetation, and traditional furniture to bring the scene to life. --v 5 --ar 16:9"*

Figure 1.2. *Architectural concept generated by Midjourney inspired by the architectural style of Mimar Sinan. (Author: Gizem Yüksek).*

3.2 Exploring materials

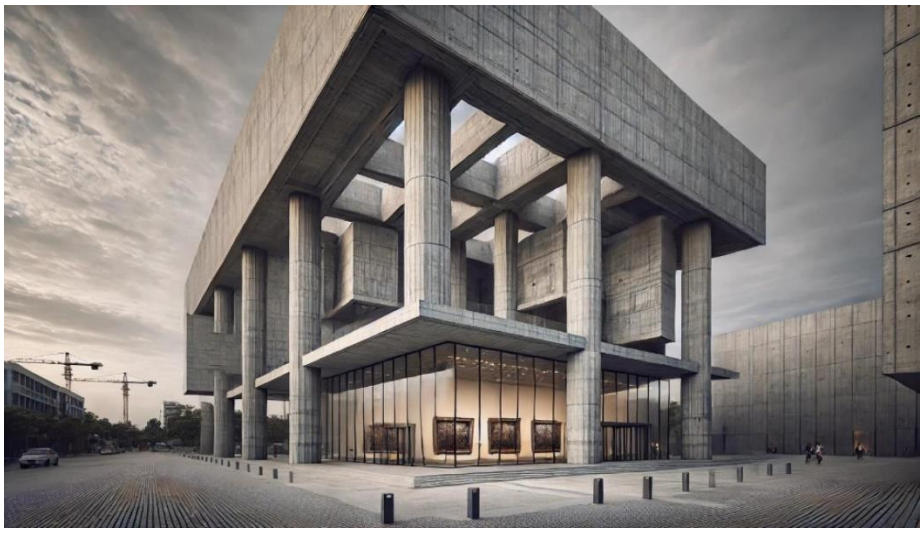
Recent research highlights the potential of generative artificial intelligence tools, such as DALLE-E and ChatGPT, to assist designers in the selection and texturing of materials in interior space design (Gallega & Sumi, 2024). These technologies can be used to generate ideas, simulate textures and propose novel combinations of materials, thus enriching the creative process. Depending on the prompt formulated, the GAI suggests original combinations with specific finishes, thereby opening up new perspectives on the use of materials in an architectural project.

The example below of a museum design illustrates the search for material configuration. An architect uses a GAI to explore a raw concrete assembly to ensure solidity and express a modern aesthetic, combined with perforated metal moucharabiehs to create a contrast between the industrial material and the artisanal

element. This combination emphasizes textures and the play of natural light filtered through the moucharabiehs. The use of different materials varies in different areas of the museum, creating unique experiences and different interactions with the outside world (Fig.3 and 4).

Prompt: *"As an architect working on a museum design, I wanted to generate an image of a modern museum facade in perspective. This façade combines a raw concrete structure and perforated metal moucharabiehs, with a modern architectural style influenced by Brutalism. It features geometric textures and the play of natural light filtered through the moucharabiehs, creating a contemporary, uncluttered ambience. The main materials are concrete and perforated metal, and the natural light should generate dynamic patterns to reinforce the overall aesthetic."*

Figure 1.3. *ChatGPT-generated façade for exploring material combinations and configurations. (Author: Gizem Yüksek).*



Prompt: *"Generate an image of a museum with a concrete structure and metal elements."*

Figure 1.4. *Façade generated by ChatGPT for exploring material combinations and configurations (version with reduced prompt). (Author: Gizem Yüksek).*

A difference can be seen between Figures 3 and 4: Figure 4 shows a less detailed result due to an insufficiently elaborated prompt. The limited of the information provided in the prompt leads to a representation that does not reflect the architect's initial intention, underlining the importance of a precise and detailed formulation to obtain results aligned with expectations.

3.3 Exploring combinations of ideas

Generative models also make it possible to combine seemingly incompatible architectural ideas, such as the integration of historically distinct architectural styles (Figure 5). This opens up the possibility of experimenting with new ideas and visual combinations (Yildirim, 2022).

Architects can use a GAI such as Gemini as a tool for exploring combinations of ideas for their architectural projects. This chatbot, developed by Google, can generate images associating architectural references. In the example in Figure 5, a designer uses a GAI to explore the hybridization between Baroque architecture and contemporary style. The generative AI model then generates an image proposing a

composition fusing the ornament and expressiveness of Baroque with the dynamic, fluid forms characteristic of Zaha Hadid's style. Depending on the prompt entered and the result obtained, the designer experiments and discovers solutions that enable him to enrich his ideation process and reflect on how to combine different contrasting ideas in a single project (Fig. 5). It is also possible to generate multiple images from a single prompt, thus opening up a wide range of visual interpretations.

Prompt: *Generate an image of a cultural center combining Baroque architecture and Zaha Hadid's architectural style, in perspective view. The design combines richly ornate and expressive Baroque elements with fluid, dynamic deconstructivist structures. Materials used include glass, metal and concrete for the modern structures, combined with Baroque-style carved stone decorations. Natural light highlights the contrasts between Baroque ornamentation and modern forms, creating an ambience that is both grandiose and futuristic. Soft, indirect interior lighting highlights the complex volumes and textures.*

Figure 1.5. *Combination of Baroque and deconstructivist architecture for a cultural center, generated by Gemini (Author: Gizem Yüksek).*

3.4 Exploring architectural morphology

AI also supports the exploration of non-standard architectural morphologies. For instance, the designer can test morphological configurations inspired by nature (biomimicry) or complex "parametric" structures (Fig. 6) without having to develop scripts that are demanding in terms of computing resources and geometric knowledge. Once again, the prompt plays a decisive role in the image generated, serving as a tool for refining the morphological exploration of the project.

Prompt: *A futuristic building inspired by coral formations, in perspective view, featuring fluid geometries and a transition from dense structural patterns to open frameworks. The design follows parametric principles, creating an organic and adaptive form. Materials include metal, glass, and composites with textured finishes mimicking coral patterns. Natural lighting highlights the gradient patterns and organic textures, with dynamic interior lighting emphasizing the fluid volumes.*

Figure 1.6. *Morphological exploration inspired by coral formations for a futuristic building, generated by Stable Diffusion. (Author: Gizem Yüksek).*

Another example of exploring architectural morphologies (Fig. 7) is the generation of images that explore architecture inspired by mountains and rock formations. This approach results in an architectural form where rough, massive surfaces gradually evolve into more fluid, open volumes, with harmonious transitions created by textures.

Prompt: *A futuristic building inspired by mountains and rock formations, in perspective view, transitioning from rough, massive surfaces to fluid, open volumes. The design features textured layers evoking geological striations, with natural textures such as rugged stone and smooth, flowing forms. Materials include textured stone, concrete, and glass, creating a contrast between rough and smooth surfaces. Natural lighting highlights the rugged textures and fluid forms, with dynamic interior lighting emphasizing the transitions.*

Figure 1.7. *Morphological exploration inspired by mountains and rock formations for a futuristic building, generated by Stable Diffusion. (Author: Gizem Yüksek).*

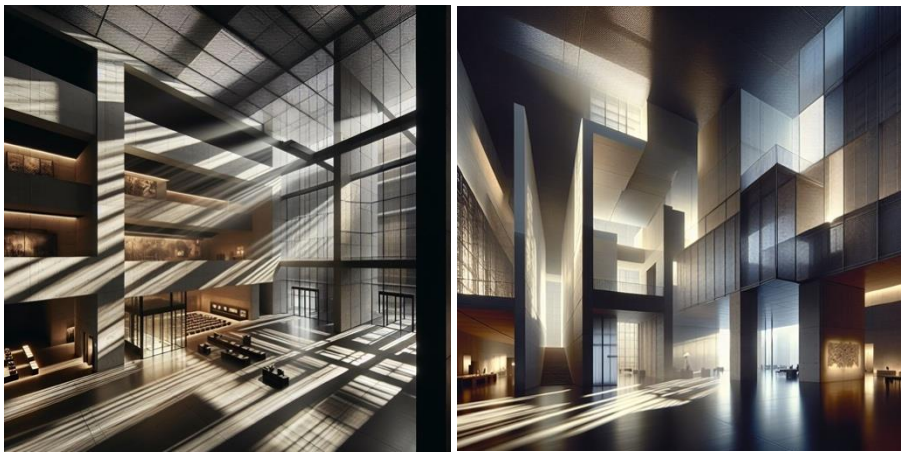
In addition to using a variety of references, such as those taken from nature (Fig. 6 and 7), a simple crumpled paper can become the starting point for an in-depth, innovative exploration of architectural forms (Fu, 2024). In this way, the GAI makes it possible to generate photo-realistic images (Fig. 8) from abstract images such as those of crumpled paper, offering varied visualizations of multiple ideas. For architects like Tim Fu, GAI opens up new perspectives by enabling rapid exploration and iteration of formal intentions through a fluid transition from creative abstraction to the precise materialization of concepts (Fu, 2023).

Prompt: *modern, public building, city centers, squares, urban landscape, cars, people, streets, reality.*

Figure 1.8. *From crumpled paper to realistic rendering (Author: Gizem Yüksek).*

3.5 Exploring ambiences

GAI is also used to explore ambiences and atmospheres, in particular the effects of light, shadow and material texture. For example, an architect can use Microsoft's Copilot to test multiple ambiences, such as the play of natural, artificial or filtered light through perforated or reflective materials in an interior space. The work carried out to design the prompt accentuates the lighting conditions or atmospheres that can create specific moods and impact the experience of the space. An example of this is the generation of an image showing an interior space in which light sculpts the volume and transforms the ambience of the architecture according to the season or time of day (Fig. 9).



Prompt: *Generate an interior space where light sculpts the volume and transforms the ambiance of the architecture, in interior view. The lighting varies according to different times of day or seasons, creating distinct atmospheres that impact the experience of the space. Natural and artificial light filters through materials like glass, metal, and textured fabrics, casting dynamic shadows and highlighting architectural forms.*

Figure 1.9. *Exploration of the impact of light on the ambience of an interior space, generated by Stable Diffusion. (Author: Gizem Yüksek).*

By exploiting the capabilities of LookX AI, for example, it is also possible to transform a rudimentary sketch into a detailed, realistic architectural rendering (Fig. 10). Here, GAI is used to visualize the overall ambience of a project, such as the surrounding context, the desired architectural style and specific materials. This approach gives access to the generation of representations aimed at facilitating the understanding and evaluation of design choices.

Prompt: *perspective, deconstructivist style, zaha hadid, parametric envelope, form, glass curtain wall, exposed concrete, horizontal frame, dawn, plaza, public building high Rise.*

Figure 1.10. *From sketch to realistic rendering, generated by LookX (Author: Gizem Yüksek).*

It should be noted that the hyper-realistic renderings often favored when using these GAIs are just one of the many graphical effects that can be generated with these tools. For example, watercolor rendering is possible (Fig. 11), despite the artificial nature of the tool, if properly described in the prompts and included in the training datasets.

Prompt: *An architectural floor plan rendered in a watercolor style, featuring soft, hand-painted textures and vibrant colors. The layout includes labeled rooms, furniture, and decorative details, with subtle gradients and delicate brushstrokes creating an artistic yet functional representation.*

Figure 1.11. *Watercolor rendering: alternatives to realistic rendering, generated by Midjourney v6 (Author: Simon Baudru).*

In view of the constant evolution of these generative tools and of architectural practices, the list of uses cannot be exhaustive. The avenues opened up here do, however, present a wide range of potential uses for architects.

4. Cognitive processes at work in AI-instrumented ideation

Having presented the main modes of interaction with GAIs (Section 2) as well as their usage opportunities for the architect (Section 3), we propose in the remainder of this chapter to question the cognitive processes underlying GAI-instrumented ideation. A number of experiments have recently been carried out along these lines (Yüksek, 2023; Yüksek & de Boissieu, 2025a, 2025b). This research has highlighted two main dynamics, which are presented in detail in this text:

- The dynamics of ideation itself, between periods of searching for new ideas, known as *divergence*, and periods of exploring and confirming specific ideas, known as *convergence* (Section 4);
- And the dynamics of thought involved in ideation: navigating between the designer's mental images and the elaboration of external representations (whether prompts, paper sketches or images produced by the GAI), these dynamics are referred to as *internalization* and *externalization* (Section 5).

4.1 Divergence strategies

In our research (Yüksek, 2023; Yüksek & de Boissieu, 2025a, 2025b), we have observed the implementation of divergence strategies to promote the emergence of new ideas. This approach relies on divergent thinking dynamics, a key process in cognitive psychology that involves exploring a wide range of solutions and ideas in a random, unorganized way (Aviña et al., 2018; Dorfman & Gassimova, 2017). We have observed how designers can initiate their design process by starting with a general idea, which they then refine and enrich through a series of adjusted prompts throughout an iterative process. During this process, the designers carry out extensive work on the formulation of the prompts, in particular to fine-tune the effectiveness of their communication with the GAI tool. Designers test different formulations, adjust the chosen terms and keywords, and carefully observe how each modification influences the results generated before iterating again. These successive adjustments

are one way in which designers can create a divergent dynamic by introducing new elements and exploring different avenues (Fig 12).

Figure 1.12. *Design 1 - Prompt iterations and key moments of **ideation** (framed in black: prompts as written by the designer; in purple: emergence of ideas while writing the prompt or viewing images; in red: images not retained by the designers).*

In this first case study from our experiments, the designer chose to work on a container project for urban agriculture. The designer's aim was to design a modular container, made up of several interlocking pockets, to be manufactured using 3D concrete printing. His approach began with a relatively simple initial prompt: *"High concrete strawberry pot in a little public park"* (Fig. 12). Although basic, this initial prompt served as a starting point for structuring an initial idea. Based on the results obtained, a new prompt was drawn up to enrich the initial idea by introducing a reference to parametric design, thereby opening the way to more complex morphologies. By integrating additional specifications with each iteration, the designer is able to widen the field of possibilities and explore new combinations of ideas. Figure 12 shows the succession of nine image generation iterations, with or without the emergence of an idea (marked in purple).

By generating images from these prompts, AI plays a crucial role in this dynamic. For example, one of the images generated with the prompt: *"High parametric concrete hydroponic pot"* proposes the integration of a spiral structure, an idea that was not initially considered. This new idea, emerging from the generated image, led to the development of a new prompt: *"High parametric concrete spiral hydroponic pot"*. Following the generation of images from this prompt, the designer observed that the term *"parametric"* seemed to be interpreted by the AI as evoking fractal-like structures. This interpretation led to the testing of a new formulation that removed the term *"parametric"*, resulting in the prompt: *"High concrete spiral hydroponic pot"*. However, the results generated by this simplified version of the prompt fell short of expectations, lacking complexity and visual richness. The designer therefore decided to reintegrate the term *"parametric"* into the prompt, returning to the formulation: *"Parametric concrete spiral hydroponic pot"*. This reintroduction gave rise to stimulating results, including the emergence of a texture reminiscent of coral, as well as new ideas relating to water retention and flow. Although these ideas had not been anticipated, they captured the designer's attention.

4.2 Convergence strategies

We can also observe here a convergence sequence in which the designer, starting from an initial idea, refines and evolves his idea through interaction with the GAI. By integrating new emerging ideas, such as the addition of a spiral structure or the exploration of textures (Fig.12), the designer gradually evolves the general idea into

a more precise and complete solution. This convergence phase illustrates how AI acts as a catalyst to deepen and enrich an initial idea while maintaining consistency with the project's objectives.

However, despite their best efforts, designers don't always get the results they expect. When they seek to generate a specific form, such as a structure inspired by a termite mound as in Fig. 12, the image produced may not correspond to the initial intention. Interestingly, however, these discrepancies between the designers' expectations and the actual production of the GAI can be beneficial, contributing to the dynamic of divergence that enriches an initial idea.

4.3 Meaningful indeterminacy and letting go

This phenomenon is similar to what Marin (2010) identifies as *meaningful indeterminacy*. It shows that the unexpected or random in a creative process is not a simple error or failure, but an opportunity for designers to find new meaning in an unexpected element. In the case of Designer 1, although the prompts were carefully crafted to generate specific shapes, it was often an unexpected texture, detail or visual feature that caught the designer's attention and stimulated his imagination. Rather than considering the gaps between intention and result as failures, the designer in Case Study 1 turned them into creative opportunities, giving them meaning, and thus ultimately turning them into *meaningful indeterminacies*. More than an *unexpected discovery* (Goldschmidt, 1990), these deviations are an indetermination of the generative system into which meaning is introduced through the designer's appropriation. This appropriation by the designer of the deviation made by the machine, comes close to the movement of *letting go* described by Bourbonnais (2017). Letting go is defined by the latter as *"the capacity for a designer to let, momentarily, the program take charge of transforming, modifying and varying the form thanks to a particular algorithm"*. This differs from an *inspiration* generated by serendipity, in the key role played by the algorithm, whether developed by the designer himself (Bourbonnais, 2017; de Boissieu, 2022) or by others, as in the case of the GAIs studied here (see Section 5.5).

Bourbonnais points to the difficulty and novelty of this trend, which he sees as part of a digital sensibility (Bourbonnais, 2017). Indeed, it is not always easy for designers to exploit the discrepancies produced by GAIs. This is what design number 2 (Fig. 13) shows us.

4.4 Fixation

In Case 2, the architect chose to work on the design of an urban furniture element for seating: a bench shape. During his exploration of the GAI for this work, the designer remains dissatisfied with the results generated by the AI tool, feeling that it doesn't "understand" his initial idea. The designer puts it this way: *"But it understands nothing"*, *"I said I don't want a flat thing and it just makes me flat things"*. After several iterations of similar prompts, the designer finds that the results remain largely off his expectations, with the exception of the prompt: *"3D printed concrete bench curves vegetation"* (negative: *"wood"*), which produces an image deemed aesthetically satisfying, but insufficient to stimulate further thought (Fig. 13.a).

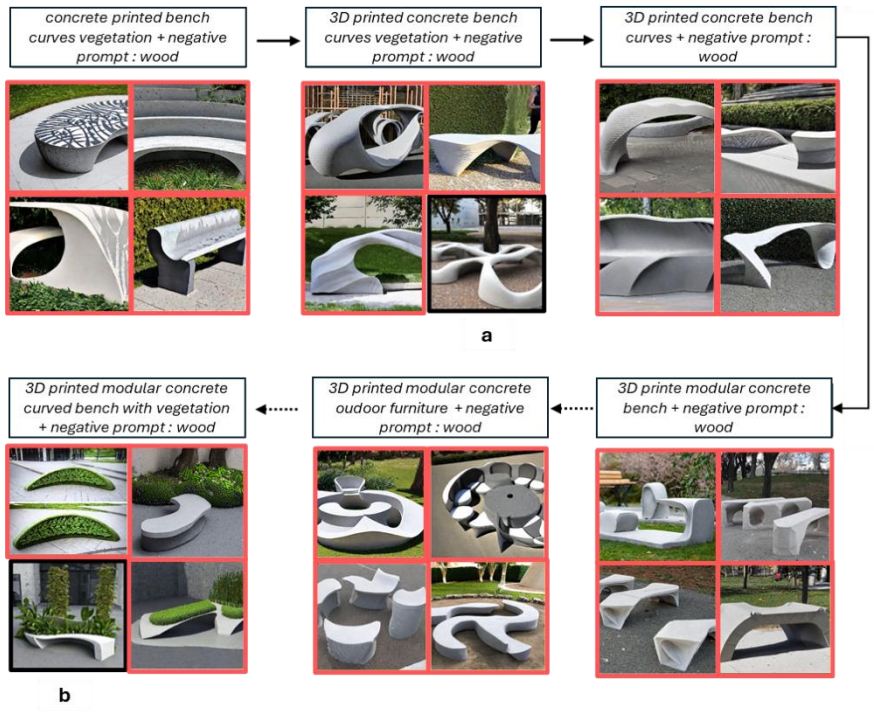


Figure 1.13. *Design 2 - Prompt iterations and key moments of **ideation** (texts framed in black: prompts as written by the designer; images framed in black: images retained/recorded by the designers; in red: images not retained by the designers).*

As the image generation did not meet his expectations, the designer was unable to use the results to generate new ideas. He then turned to Pinterest[6], where he found an image that matched his idea. He then modified his prompt based on the image description, adding the phrase *"modular outdoor furniture"*. However, this new formulation – *"3D printed modular concrete outdoor furniture curved"* (negative: *"wood"*) – still failed to deliver convincing results according to him. He then adjusted the prompt again, adding further elements, resulting in : *"3D printed modular concrete curved bench with vegetation "* (negative: *"wood"*). Although one of the images generated finally met his expectations, the designer did not reflect further on what it was about this image that appealed to him (Fig. 13.b). His analysis remained superficial, without exploring in detail the specific features that made this image more convincing than the previous ones for the current project.

This sequence (Fig.13) shows a fixation phenomenon (Condoor & LaVoie, 2007): manifested by the designer's tendency not to explore, or even be unable to consider, different approaches to defining and meeting a design need. This phenomenon considerably slows down ideation and often leads to unoriginal design solutions. The designer, dissatisfied with the AI results, repeats similar ideas without questioning whether they were really appropriate and relevant (see Chapter 4). The designer develops a loop of similar prompts, without being able to go beyond his initial idea. This fixation limits the creative potential of exploration and prevents the designer from questioning the prompt design, exploring new elements or letting go to exploit the tool's unexpected propositions. What we see here, then, is both a difficulty in prompt design and a barrier to the posture of letting go and serendipity necessary to the implementation of meaningful indeterminacy, which we have seen supports the divergence dynamics instrumented by the GAI.

4.5 Alternating convergence and divergence

Analysis of the prompts generated by Designer 3 reveals a cognitive sequence marked by alternating convergence and divergence. This dynamic illustrates how the designer has structured his thinking to explore a wide range of ideas while maintaining consistency in the approach. The designer deliberately adopts a strategy of formulating prompts based on recognizable and repetitive structures. Although both divergent and convergent modes of thinking play a role, it is convergence that seems to dominate, guiding systematic exploration around a central theme while allowing new and varied ideas to emerge (Fig. 14).

[6] https://fr.pinterest.com/

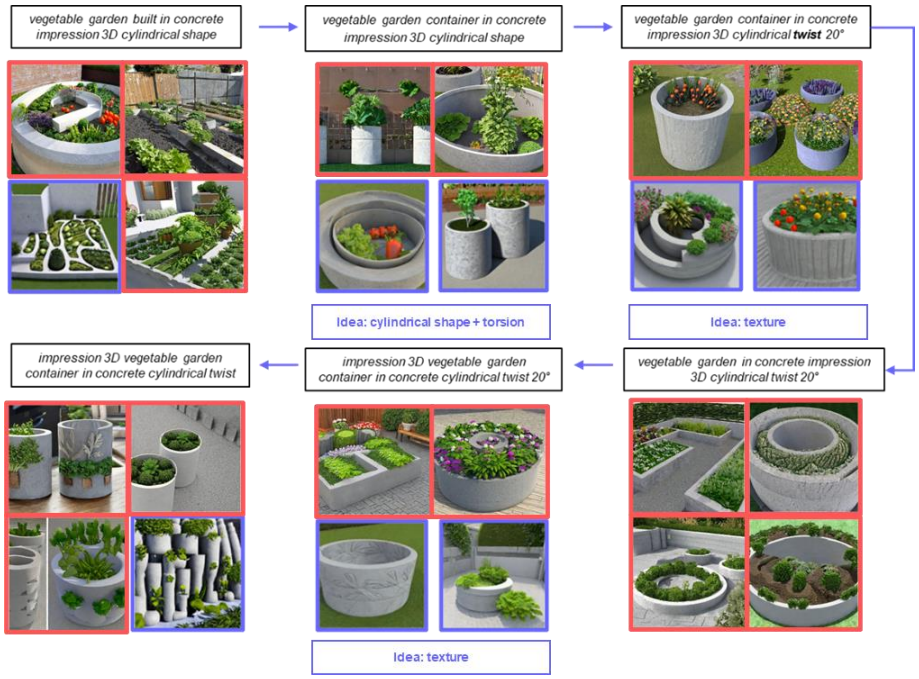


Figure 1.14. Design 3 *Prompt iterations (framed in black: prompts as written by the designer; in purple: emergence of ideas while writing the prompt or viewing images; in red: images not retained by the designers).*

In this third case study, on the one hand, convergence helped to structure and channel creativity around clear objectives, and on the other, divergence opened the way to unforeseen explorations, enriching the creative process with innovative and sometimes disruptive elements. This alternation between focus and openness instrumented by the GAI illustrates how the two modes of thinking complement each other to stimulate ideation. This alternation is the one most commonly observed in our research, and the one that gives rise to the highest level of designer satisfaction. Although ideation processes based mainly on divergence dynamics (as in the case of Designer 1, for example) also gave rise to a high level of perceived satisfaction, the GAI-instrumented ideations observed implementing exclusively convergence dynamics were not satisfactory for the designers. It therefore seems that ideation instrumented by GAIs is mainly divergence ideation, which can be explained by the central role of emergence and unpredictability of the algorithms (Marin 2010, de Boissieu, 2022) used in these AIs. We also observe the barrier to ideation represented by the phenomenon of fixation, as well as the difficulty of “letting go” and

appropriating the discrepancy. In these situations, the discrepancies between the images generated by the AI and the designer's intentions are read not as *meaningful indeterminacies* but as failures.

5. Internalization and externalization dynamics supported by GAIs

5.1 The central role of the prompt

We have seen in previous sections the central role of prompts in the ideation process instrumented by the GAI, whether these prompts are textual or pictorial. These prompts, as expressions of the ideation process in progress, participate in the dynamics of externalization and internalization. In Chapter 3, Safin explains that *"cognitive activity can be seen as divided between internal resources (cognitive, affective and perceptual processes), external resources present in the environment (external representations, tools, spatial arrangements, etc.) and social and cultural resources (socio-affective and collaborative processes)".* These resources interact constantly, creating a fertile dialogue between internalization and externalization, both fundamental processes in the genesis and maturation of ideas. This dynamic is particularly evident in the data analyzed in our research and is discussed in this section.

Design and ideation processes in architecture are eminently multimodal (Calixte, 2021; Baudoux, 2023). While the use of freehand sketches and physical models is well known, architects also often use various digital tools for 2D or 3D representation, as well as so-called computational digital tools (de Boissieu, 2022). However, we must also consider the role of language in design, in the form of words that are spoken or exchanged, oral or written (Boudon, 2004, Camus, 2016). The use of language as a design tool is not new, but the scope and role it takes on in the processes instrumented by GAIs is quite new and specific.

A prompt is a form of description of an idea. Its format is designed to be assimilated by a machine – the GAI algorithm – in the most efficient way possible. The vocabulary chosen, as well as the order of the words and the overall structure of the prompt, has an impact on its reading and interpretation by the algorithm, and an effect on the images chosen. The prompt is first and foremost a query in the computer sense of the term. It is not intended to be used to communicate an idea to human collaborators, nor is it a note taken by designers for themselves.

5.2 Iterations between text and image prompts

The main purpose of the prompt is to be transformed into images by the GAI. Text to image is a real transmutation: a transformation of textual matter into visual matter, operated by the GAI algorithm and supported by the datasets used for its training. Even in the most common use of GAIs, the specificity of the algorithms and datasets used are not known to the user. They are the property of private companies and are the subject of major political and ethical stakes (Masure, 2023). We shall not examine the issues involved in training GAIs here, but focus instead on the most common current uses of GAIs. While the prompt is primarily a tool for communicating with the GAI, it also acts as a tool for structuring the designers' ideas (see Section 3, Designs 1, 2 and 3). Indeed, one of the main characteristics of the prompt is that it is a text developed iteratively. The image-generation process itself requires multiple trial-and-error processes, from which the designer learns and through which his or her ideas evolve (Section 3). When the prompt is transmuted into an image by the GAI algorithms, this image in turn is internalized and integrated into the cognitive work (Section 3, Design 1 and 3). This process illustrates a constant to-and-for between internal and external resources, where the externalization of a starting idea (via the prompt) and the internalization of new ideas (via the generated image) feed each other. This cyclical dynamic encourages iterative exploration, with each stage enriching the previous one.

In the case of the designs studied (Fig 1.12 to 1.14, above), the designers used an image-to-image GAI combining textual and visual prompts (DreamStudio from Stability.ai). For example, the designer in case 1 entered the prompt *"add spiral for water retention"* together with an image (which had been generated by the GAI beforehand), this mixed prompt produced results that elicited very positive reactions (Fig.15).

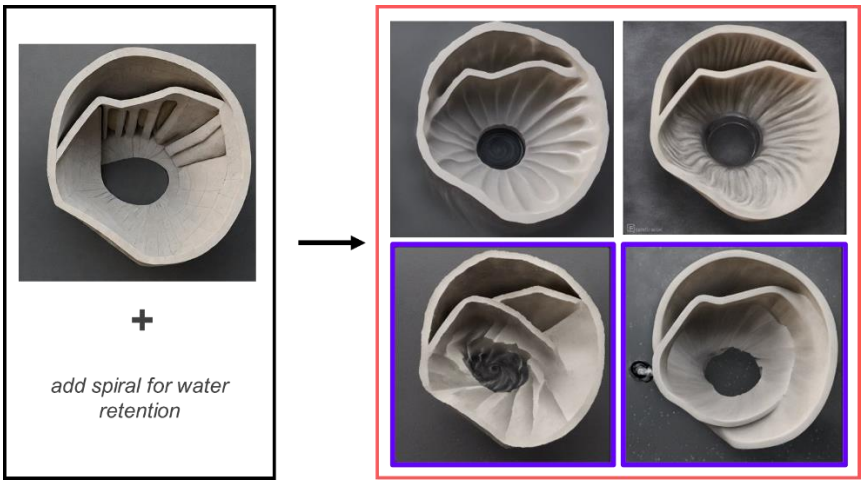


Figure 1.15. *Mixed prompt (image and text) transformed into images by the GAI. (Black box: mixed prompt; red box: images generated by IAG & purple boxes: mages selected by designers 1).*

Similarly, the designer in case study 2 generated images with this GAI parameter. Entering an image from Pinterest that looked interesting, and with the text prompt *"3D printed concrete modular bench curved planters with people relaxing on it*", the designer managed to generate two images, one of which was selected (Fig.16).

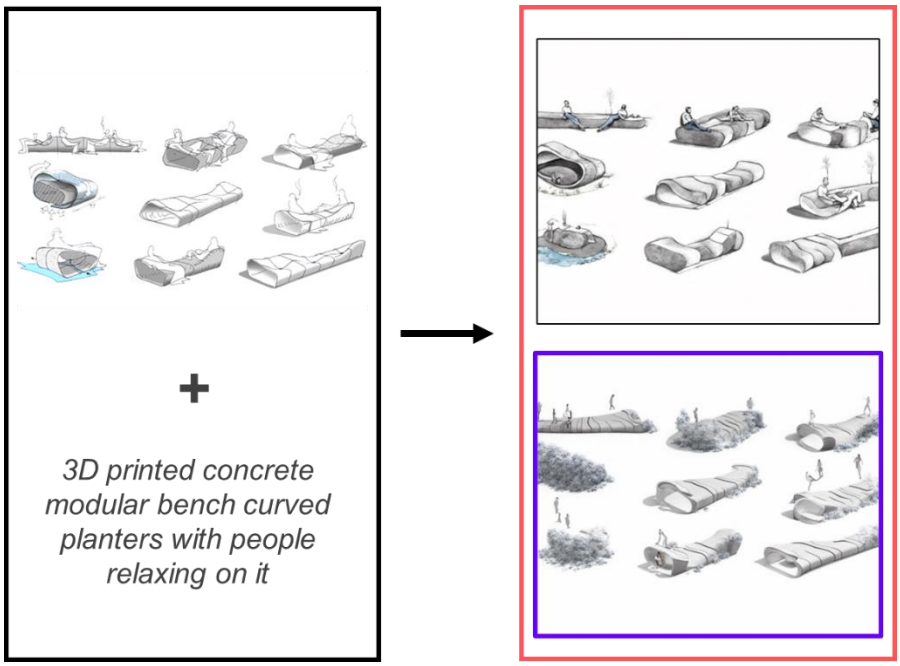


Figure 1.16. *Mixed prompts (image and text) transformed into images by the GAI. (Black box: mixed prompt; red box: images generated by the GAI & purple boxes: images selected by designers 2).*

The mixed image-text prompt is a key multidimensional medium in the interaction between GAIs and designers. It enables the textual and visual mediums to be exploited in a complementary way, making the designer's thoughts more explicit.

5.3 A dynamic process of internalization and externalization

Within the cognitive work of internalization, a profound process unfolds, relating to the maturation of the idea. After the GAI has generated images, the designer has to interpret them. After careful thought and maturation, this interpretation is transformed into a new, unmaterialized idea. This idea begins as a thought, then takes on a more concrete, tangible and explicit form when it is externalized again, for example in the form of a revised prompt, sketch or mock-up. In this way, the cycle of internalization and externalization continues, encouraging the evolution and refinement of ideas.

In this context, the prompt is more than just an instruction given to the AI. It becomes an active design mechanism, requiring careful drafting and progressive construction

to encourage the emergence of ideas. Adding or removing words allows designers to influence image generation and explore ideas that might not have been initially considered. For example, although the result generated may not always correspond to the initial intention expressed in the prompt, the general terms contained within it enable broader concepts to be reached which then serve as a starting point for new ideas.

In a nutshell, the prompt is at the heart of the dynamic between internalization and externalization. It enables us to externalize an idea in text form, generate an image that will be internalized, and extract information from this image that will in turn nourish the maturation of the idea. This iterative cycle, in which each stage enriches the previous one, is an essential pillar of the creative process in an RTI context. The strategies of divergence and convergence, as well as the ability to exploit letting go, illustrate how designers can navigate between open exploration and deep focus to develop innovative and successful ideas.

5.4 A cross-computational design

The computational capabilities of digital technology make it possible to model and manipulate complex systems in the form of algorithms and masses of data, which would be impossible to grasp without the tools and methods of computer science. These capabilities, but also this computational technicality, imply an approach based on algorithms called computational thinking or algorithmic thinking (Denning et al. 2019). In the field of architecture, Nicholas Negroponte distinguished as early as 1969 between “computer aided” practices, which accompany or automate existing practices, and new practices enabled by digital tools. Computational design in architecture represents a real paradigm shift (Carpo 2017, Terzidis 2004, de Boissieu 2022, Marin 2024). It focuses on the design of architecture-generating systems (algorithms) rather than the design of finite forms (de Boissieu 2022, see also Chapter 4). This involves the designer implementing a mode of thinking known as explicit thinking (Marin 2010), in order to tackle a specific problem through an effort of abstraction to provide a general solution (Kelly et al. 2021, Marin 2024).

Midjourney and other tools provide access to highly sophisticated generative AI algorithms in easy-to-use interfaces. Designers find themselves as simple users of these tools. They manipulate complex tools without having access to all the information needed to understand how the machine is trained and how the images produced emerge. The context here is very different from that of explicit

computational design with visual programming software such as Grasshopper[7]. These software packages provide access to function libraries that allow architects to code their own programs.

Two design approaches coexist: one focused on the definition of the GAI model itself, and the other on its use in the ideation phase of architectural design. Though distinct, they interact through the way the GAI model is conceived and deployed. This imbrication produces a dynamic with a dual nature: intimate (expression of personal reasoning) and collective (evolutionary reuse of shared designs). Deep learning models embody the cognitive patterns of the engineers who design them - on the one hand, through the training databases they choose, and on the other, in the design of the model architecture. These models are then deployed by practitioners - architects, designers, artists - as tools for exploration. Many artists are developing their own training databases and entering the details of GAI models. But this is still not widespread, nor is it the case for the uses presented in our text, which represent the most common current practices.

The suggestive nature of the images produced by GAIs also raises a number of questions. These images come from collective databases, and the large-scale harvesting of data by AI developers raises a number of ethical questions. Some authors speak of the emergence of an "artificial imaginary" (Ben Saci et al. 2024). For these authors, these artificial imaginaries relay stereotyped visions of the world, like filter bubbles that tend to erase the diversity of the arts (Ben Saci et al. 2024, Masure 2023).

6. Conclusion

Recent developments in generative artificial intelligence (GAI) are opening up new perspectives for ideation in architectural design. Tools such as Midjourney, DALL-E and Stable Diffusion, as well as text-based models like ChatGPT, have demonstrated their potential to support designers' creativity by facilitating the rapid transformation of vague, non-materialized ideas into concretized visual and textual representations.

However, the integration of GAI into the design process raises important questions about the cognitive processes it mobilizes. We have highlighted the complex cognitive dynamics underlying the use of these tools, in particular around the generation

[7] https://www.grasshopper3d.com/

(divergence) and maturation (convergence) of ideas (Section 3). These two phases alternate and cooperate: divergence opens up the field of possibilities by encouraging the generation of varied ideas, while convergence refocuses attention on more relevant ideas by structuring and deepening them. Both processes revolve around the prompt, which plays a central role as mediator between the designer's still fuzzy thoughts and their materialization.

Far from being a simple instruction given to the AI, the prompt is an active design medium. To take full advantage of GAI's potential, designers need to develop skills in prompt engineering so as to formulate clear, precise instructions that effectively guide the AI. The careful drafting and progressive construction of these instructions translates into image generation and, subject to an effort to interpret any deviations that may occur, enables unexpected ideas to be explored. The designers whose work has been analyzed here have demonstrated that adjusting prompts can lead to varied results, sometimes unforeseen, but often rich in opportunity. For example, unexpected textures or visual details in the images generated often inspired new project ideas, thus illustrating the phenomenon of serendipity and letting go. These unforeseen events, when not interpreted by the designer as failures, become catalysts for the emergence of new ideas and underline the importance of remaining open to indeterminacy in the design process.

The dynamics of internalization and externalization (Section 4) play a crucial role in this process. The externalization of an idea in the form of a prompt enables it to be transformed into an image by the AI, which can then be internalized and integrated into the cognitive work. This iterative cycle, in which each step enriches the previous one, encourages continuous, in-depth exploration. It leads designers to navigate between verbal (linear) and visual (spatial) thinking, enriching their ideation process with a multi-dimensional approach.

However, using GAI is also challenging. Designers often find it difficult to align AI-generated results with their initial intentions. This can lead to fixation phenomena, where they repeat similar ideas without exploring new avenues. This observation highlights the importance of cognitive flexibility and the ability to adapt to unexpected results.

To conclude, when used strategically and thoughtfully, GAI can significantly enrich the ideation process in architectural design. Generative tools don't simply reproduce existing ideas; they open up new avenues of exploration, enabling designers to navigate between divergence and convergence, between open exploration and deep focus. As an interface between human and machine, the prompt becomes a powerful

tool for externalizing, internalizing and refining ideas, while integrating the unexpected as a source of innovation.

These findings offer insights for the integration of AI into design practices. At the same time, they highlight the need to develop cognitive and technical skills to fully exploit these technologies. Managing indeterminacy, cognitive flexibility and mastering prompt engineering are emerging as essential skills for architects and designers in a landscape increasingly influenced by artificial intelligence. Last but not least, this research paves the way for future explorations into the long-term impacts of GAI on creativity, cognitive biases and collaborative practices in architecture – contributing to a deeper understanding of human-machine dynamics in the design process.

Today, the use of GAI in architecture is not a fully automated process. On the contrary, it requires in-depth expertise: the precise formulation of prompts, the interpretation and appropriation of images generated by the GAI, and the management of a constant dialogue between the designer and the machine. This expertise requires specific training that integrates these new design methods with the architect's traditional skills.

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