Automating Analogical Reasoning: A Wizard of Oz study on the benefits and pitfalls of a sketch-based AI image generator for design

Gaëlle Baudoux, Kosa Goucher-Lambert
University of California, Berkeley, United States
gbaudoux@berkeley.edu

Our research vision is to stimulate design ideation through the creative power of analogical reasoning with the automatic delivery of impactful stimuli; sending project-appropriate inspiration to automatically render images during the preliminary stages of design. Recent advances in artificial intelligence opens this up. However, many questions remain about how designers may engage with such interactions. This paper employs a Wizard of Oz protocol to immerse 9 architects for a 4 hours residential building design task. Collected data is analyzed to study questions such as: what elements are extracted, from which relevant images, with what need, and when and how are they reintegrated into design? Our results show that designers use the "AI generated" images for inspiration and to evaluate initial ideas. They extract general form related attributes and more detailed function related ones, which they reintegrate by direct transposition. Designers favor general ambiences images over design details or plans.

Introduction

The preliminary stages of the architectural design process are crucial to the success of the rest of the design and construction as they involve the majority of decisions and overall costs. However, existing studies dedicate little time to improving the initial phase of the design process [1]. On the other hand, previously conducted research has shown the potential of reflexive conversations between the designer and provided representations of their

Design Computing and Cognition DCC'24. J.S. Gero (ed), pp. xx-yy.

own project [2]. Among the main design assistance strategies (problem structuring, solution generation, solution evaluation, and decision traceability [3, 4]), this work will focus on assisting designers in generating better solutions and evaluating the most promising ones. To this extent, analogies have been found to play a key role in creative design [5, 6, 7, 8]. Therefore, we aim to stimulate design in the ideation phases by capitalizing on the creative power of analogical reasoning. The proposed instrumentation will automate the sending of project-appropriate inspiration and rendering images during the preliminary stages of design.

The purpose of this paper is to investigate how designers react to this new, yet-to-be-developed instrumentation principle using the Wizard of Oz technique to simulate it. This technique allows us to immerse several designers in the new tool and study their behavior and usage. It allows to simulate real-life tasks and capture all their complexity.

We thus examine how designers use the provided images through the following research questions:

- *What elements do they look for in received images and in response to which need?*
- *What are the most relevant and useful sent images?*
- *When and how do designers reintegrate extracted elements into the artifact?*

This paper will first introduce key concepts related to the topic. Next, it will present the method developed to simulate the proposed technology in order to study its benefits and challenges. Finally, it will discuss the observed behaviors of designers when faced with the simulated technology and how and why they utilized this resource.

Background

In this section we will raise two key-concept when addressing the potential of inspirational images for the design and leading to our research vision, which are: the analogical reasoning, and the current image generators. We will also synthesize our prior research work leading to the present paper.

Analogical reasoning

Before application of domain knowledge [9] or rediscovery of the project, ideation by analogy is a crucial activity in the design process to generate solutions [10]. An analogy is a resemblance established by the imagination between several objects of thought. This assimilative action transforms one object of thought under the influence of another. Reasoning by analogy is a form of inductive reasoning that concludes that objects of thought are similar. Analogical reasoning has been actively studied in the design research literature due to the ability of analogies to stimulate additional design concepts, as well as concepts with desirable properties (e.g., increased novelty or quality) [11, 12, 13, 14, 15].

Leclercq and Heylighen [16] suggest that reasoning by analogy can be a powerful design strategy in architecture and other design fields due to the ill-defined nature of design problems. Analogical reasoning can bring valuable knowledge from a known situation to the ill-defined design situation at hand. Visual analogy can improve design quality and proposed solutions [5, 6, 7, 8]. Reasoning by analogy plays two roles in design activities [5, 6, 7, 17]. On one hand, it is important to identify potential new solutions, such as drawing inspiration from the façade of a building to choose an exterior cladding material. On the other hand, it is crucial to validate the proposed solution, in this case, the choice of cladding material, by ensuring its successful implementation and durability over time, as demonstrated by the neighboring building. Analogies can facilitate the process of generating and evaluating solutions more efficiently. According to Le Coguiec [18], it is commonly utilized in the initial stages of design and persists throughout the entire process.

AI image generators

Recently, new tools have emerged to support creative activity: AI image generators, such as MidJourney or DALL-E. These software programs produce collage images based on a prompt, which is a succession of keywords describing the desired image [19]. AI image generators are a great aid for creativity because they unleash imagination by overcoming the limits of realism and physical constraints [20]. These unconventional stimuli enhance analogical reasoning and creative thinking [20]. As a result, they can speed up the creative phases of the design process [19]. However, the main limit of these text-to-image generators is that they operate based on textual prompts. Architects must therefore pause their design work to create the needed prompts to generate images, which can disrupt the subject's train of thought. Additionally, the adequacy of the images received depends largely on the architect's awareness of their own needs and their ability to accurately formulate the prompt [19, 21, 22] as well as on their level of expertise in the field [23].

Exploring the current landscape of AI creative tools, which includes generators, blenders, and editors, Hwang [24] concludes that AI creative tools can indeed generate inspiring alternatives enhancing human creativity and guide designers through decision-making processes. Further exploring the distribution of roles between humans and AI in design, Vinchon et al. [25] conclude that AI is proficient at generating a large number of alternative propositions, while humans have emerged as the managers of these AI tools and take on the higher-level decision-making role. But if AI is most conducive to new ideas, it is least inclined to let humans take the lead in the co-creation process [24].

Prior work on ideation instrumentation

Thus, our proposed instrumentation, discussed in a previous paper, retains the forms of design aids used by text-to-image tools like MidJourney, but goes beyond their limits. It is based on recognizing the characteristics of the current project, rather than asking the designer to encode a prompt, which is the main limitation of current tools. In this sense, it fosters creativity without interrupting the cognitive activity of design. The platform also provides additional images beyond the initial sketch concept proposed by MidJourney, including plans of similar buildings and photos of real environments related to the project's characteristics. The co-creation process is carried out by the architect sketching their ideas on a graphic table. The technological partner, our proposed instrumentation, captures these drawings and interprets them to extract the building's features and their semantic meaning. Based on this information, it searches for similar images or variants of the element being designed, such as zoning of first floor functions, an original staircase shape, or a kitchen layout, on architectural image databases. The designer receives these images and decides whether or not to integrate them into their sketches. They then modify their sketches accordingly while continuing to design. If necessary, the designer can also directly input search keywords, although this is not the primary function. As the exchange between the architect and the technological partner progresses, mutual understanding is refined, and the images become increasingly appropriate to the designer's personal style and the design object [26].

Method

The following experimental protocol [27] is developed as an evolving studying research tool built from the Wizard of Oz technique. This section introduces the Wizard of Oz standard technique and its benefits. It then outlines the experimental protocol, including the general structure of the experiment, the space set-up, the design task chosen, and the population studied. Finally, it specifies the data collected and the coding procedure.

Experimental protocol

Wizard of Oz method

The Wizard of Oz technique involves simulating the functions of an innovative technology by replacing them with equivalent human work, which is hidden and performed in real-time. This allows the subject under observation to believe they are using the technology, even though it is not yet operational [28, 29, 30].

Devices for interpreting ambiguous data, such as sketches, have the advantage of informing researchers about both human-machine interactions and interpretation processes. They provide a relatively easy-to-implement tool for simulating complex interpretations. The Wizard of Oz prototype evaluation effectively highlights user needs and expectations, as well as potential development issues [28, 29, 30, 31]. Additionally, it is the only method that can provide designers with external representations tailored to their architectural project at any stage of the design process.

Our aim with this project is to immerse design subjects in our technology, which has been replaced by a team of modeling « pixies », for the duration of a preliminary architectural design session. The pixies are a team of students with architectural design expertise who act as modeling agents replacing the technology's functionalities.

General principle of the experiment

Each experiment involves requesting an architect to design a family home in an urban environment on a sloping site. The program lists the various rooms required by the client, along with a plan of the site and accompanying photos to aid the designer's understanding of the site. The designer has an hour and a half to sketch out their project, equipped with a graphic table and digital pen, which serves as the input connected to the Interpreter. The Interpreter, represented by three modeling pixies in a separate room, provides the design subject with a rough 3D digital model of the project, plans, sections, and elevations (if applicable) in CAD format, and a board of inspirational or realistic rendering images of the project based on the sketches received. These elements are sent to the design subject every 5 minutes (approximately 17 visuals per design session). This brief and routine delay allows the modeler to update the progress of the model while achieving a response that is as close to real-time as possible. Additionally, the subject can request a specific point of view in the 3D model, a cross-section, or inspirational images based on three specified keywords at any time. The conversation between the subject designer and the interpreter continued in this manner until the end of the design process.

Experimental space

The experiment was conducted in two adjacent rooms. The first room, labeled as ‘Room 1’ in Figure 1, was occupied by designers and the researcher. The designer sat at a virtual desk, which consisted of a computer with three screens and a tablet with A2 size graphics embedded in the table. The graphics tablet served as a digital sketching interface through the digital annotation software SketSha [32] and as an input for the drawings. The three screens display, from left to right, the experiment's timer and the current board with inspirational images or a realistic representation of what the project will look like; the current CAD plan and section; and the current 3D model and interpreter control terminal (see Figure 1). Additionally, there are paper documents on the architect's desk containing information about the architectural plans and site. The researcher's role is to facilitate the use of the interpreter, pace the various stages of the experiment, and collect initial observational data. To record the experiment, several cameras are installed in the room. Participants are requested to utilize a trained think-aloud protocol to express their design reasoning and emotional responses towards the machine.

In Room 2 is a team of three modeling pixies and their coordinator (Figure 1 - ‘Room 2’). They are seated in front of a control screen enabling them to follow the design in the adjacent room (refer to Figure 1). This screen displays representations of image boards, 2D CAD documents, and 3D models from left to right and top to bottom. Additionally, it shows sketch development in real-time, the overall image of the design space transmitted from the camera, and the interpreter's control terminal (Figure 1). Modeling pixies work continuously, each performing a specific task. The project requires three main tasks: creating a board with inspirational images to provide a realistic representation, creating clear plans and sections, and developing a 3D model based on the designer's sketch. The inspirational images are selected by the ‘image pixie’ from Google Image and Pinterest databases according to the current focus of design (e.g. the kitchen layout, a stair design, the function repartition, etc.) to be as accurate as possible for the designer. These images are either projecting what the design would render in real life or divergent to inspire alternatives. The coordinator serves as the designer's intermediary through the control terminal and communicates the designer's requests to the modeling team. After the 5-minute period has elapsed, the coordinator sends expressions to the screens shown to the design subject. Finally, the coordinator provides their fourth opinion, which can aid in the interpretation of the received sketch. The coordinator can also maintain communication with researchers to report any technical issues.

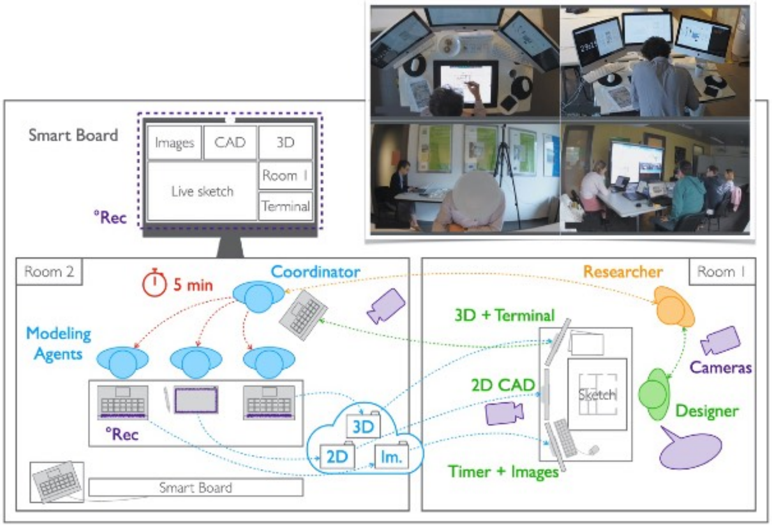

Fig. 1 Spatial and technical set-up of the experiment

Timeline of the experiment

The experiment involves three parts: (i) a design capsule (technology usage), (ii) a presentation to a fictitious client (project's resume), and (iii) interviews with designers and pixies (activity comprehension). The total time being 4 hours, only mobilize the participants for half a day.

Choice of design task

The chosen design task - in this case a 4 bedroom family housing on a slope site - is complex, which is a unique aspect of this research in the field of Human-Computer Interaction (HCI). The task aims to be realistic enough for participants to take it seriously and utilize design methods representative of their actual usage, while incorporating the proposed technology. The task also allows for a reasonably high level of project concretization within the given time. The architectural program is adjusted to accommodate the number of designers, in this case, one, as well as the duration of the experiment and the complexity of the task assigned to the modeling pixies.

The design time is set to 90 minutes. This duration allows for significant progress to be made on the project, leading to the creation of a first complete sketch (refer to Fig. 2). Additionally, it is short enough to prevent unproductive mental fatigue on the part of the designer and to ensure that the overall experiment does not require more than three hours of their time.

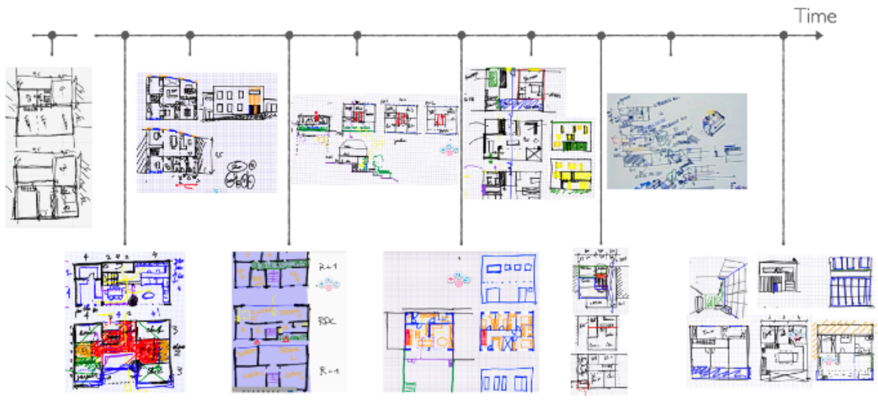

Fig. 2 Final sketched propositions of each designer.

Choice of studied population

The modellers behind the « software » are trained engineer-architects in their third or fourth year of a five-year training program. For logistical reasons, two teams of three modellers with specific tasks and a coordinator were formed.

Table 1 Studied population of designers [27, p.5].

Subject	1	2	3	4	5	6	7	8	9
Date -dd.mm	18.03	21.03	30.03	01.04	15.04	20.04	25.04	27.04	09.05
Gender	Man	Woman	Man	Woman	Woman	Man	Man	Man	Man
Age -years	52	24	25	34	30	30	48	30	28
Background	Eng. Archi	Eng. Archi	Eng. Archi	Archi	Eng. Archi	Eng. Archi	Eng. Archi	Archi	Eng. Archi
Activity	Agency	Agency / Research	Agency	Research	Agency	Agency	Agency	Research	Agency
Experience	Senior	Junior	Junior	Interm.	Interm.	Interm.	Senior	Junior	Junior

The design subjects come from varied backgrounds. The profiles were intentionally diversified to eliminate bias in terms of experience, digital sensitivity, or gender. The study population consisted of nine subjects, six men and three women, with diverse educational backgrounds and an average of 10±8 years of professional experience. The number of subjects was sufficient to reach an initial saturation stage in the observed behaviors.

Data collection

Data collected

We carry out non-participant observations based on the recording of the experiment and conducted with observation grid (see section « activity coding »). In parallel we collected the rationale of the design and the use of the proposed instrumentation through a think aloud protocol. Finally, the interviews enabled us to access explanations about some unique design moments and the overall satisfaction of use. We thus document 9*(90min+10min), or 15 hours, of commented design, we collect 9*40-min, or 6 hours of interviews explaining the activities carried out, as well as 9*3*17 + 9, or 468 design support documents. Moreover, as we made a paradigm shift by observing the design process through the project's attribute, we translated the 9 design capsules in a succession of 1259 project's attribute composition, for an average of 1.57 elements per minute of design.

Activity coding

Firstly, the possible characteristics and attributes of a building are described through a previously developed classification (Table 2).

This allows for the characterization of the designed elements as well as the elements extracted from the provided images. These elements are classified into three main families encountered in any design domain: *form, function,* and *technique* [33]. Form refers to the artifact's aesthetic and volumetric dimensions, which characterize its visual appearance and spatial scope. Function, composition details, and technique are the three main aspects of an artifact. Technique refers to the specific solutions implemented to ensure compliance with physical laws or administrative rules [33]. These three aspects are further subdivided into 11 specific classes [34]. As there was a lack of classifications in the literature. We therefore, in this previous study, applied a bottom-up methodology, proceeding by inductive labeling of the types of information stated by the designers during the 78 hours of design activity observed [34]. At the end of the process, we obtained the 11 classes - presented in table 2, organized from general to detailed within each of the three main families.

Table 2 Design element's typology [34].

Form		Function		Technique	
Concept	Leading concept, general idea.	Functional Distribution	Location of the functions and adjacency.	Structure	Type of structure, spans, dimensions.
Implantation	Object's position in the space.	Usage	Users' perceptions, views, flows.	Regulation	Regulation relative (fire, accessibility, …)
Volumetry	Volume, shape, height and size.	Material	Color, material, rendering.	Technical Solution	Concrete answer to technical point
Facade	Facades' elements, windows, doors.	Layout	Sub-rooms, furniture, details of layout.		

This enables us to code the design session by specifying the typology of each successive project's element drawn or mentioned over time (Fig. 3).

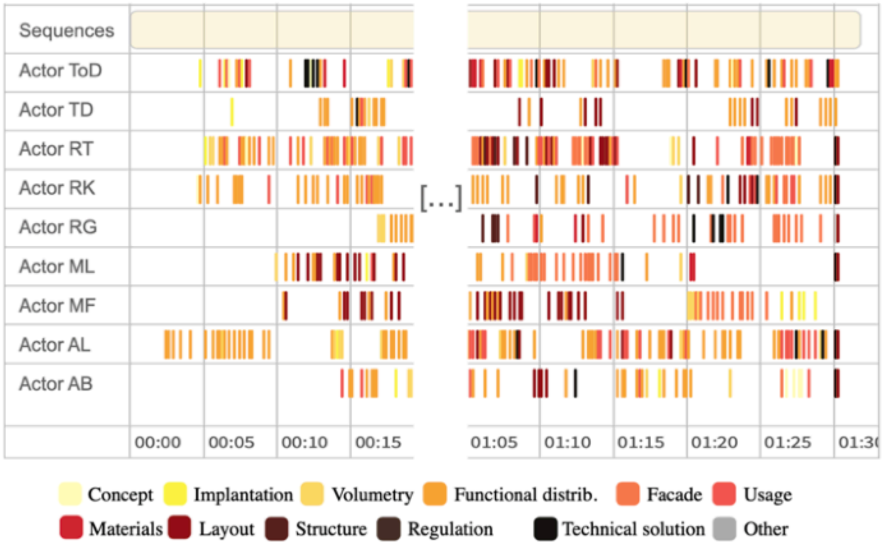

Fig. 3 Distribution of the nature of extracted features from the provided images, each row representing the successive elements extracted by each designer over time, color-coded to illustrate their nature.

Results

This paper focuses on the benefits of automatically provided project-appropriate inspiration and rendering images. It is important to note that only the usage of the images sent to the designer will be analyzed, and not the 2D CAD and 3D models. The results will be presented from more concrete to more general, each section corresponding to each research question: (i) features extraction from the images, (ii) images relevance, and (iii) roles of features re-injections in design.

Extraction of form related features to inspire and evaluate

Firstly, the type of information extracted by the designers from the images was analyzed by coding the elements they specifically looked at and mentioned during their think aloud. We saw that 23% of the 146 image sets provided were used for the design, and a total of 60 features were extracted from them. Classifying the mentioned elements, we obtain the pie chart in Fig. 4. It shows that designers are mainly extracting information related to volume (19%), concept (15%), layout (14%), facade (11%), and material (10%).

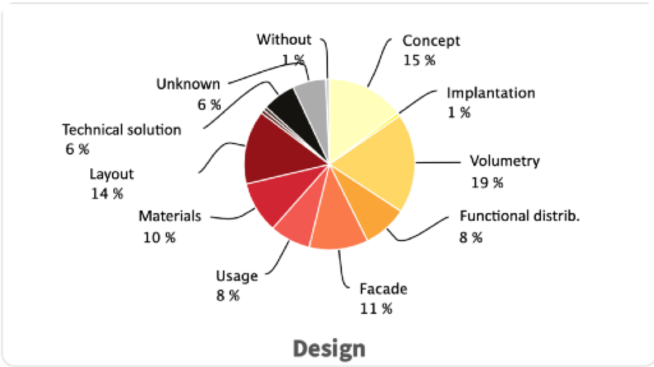

Fig. 4 Distribution of the nature of extracted features from the provided images.

When analyzing the three main domains (form, function, and technique) to which these categories belong, it becomes apparent that almost half of the extracted image features are **general form principles** (volume, concept, and facade), accounting for 45%. Another quarter of the features are **functional details** (layout and material), while the remaining quarter consists of a mix of various categories, but rarely technique. The subsequent analysis of these extracted features is qualitative in nature.

The think-aloud data enables us to identify the type of activity that prompts the consultation of the provided images and the extraction of features (refer to Table 3).

Table 3 Activity types triggering the images consultation and features extraction.

Type of activity	Percentage of occurrence (N=60)
Thinking about a topic that calls for inspiration	25%
Immediately following of another extraction	21%
Attention drawn by image change / Raises head to think and see new representations	17%
Project evaluation using software representations	12%
Consultation at the end of an action	8%
Check-up before or at the beginning of the next phase	7%
Search for additional information	5%
Check that the software understands properly	3%
Viewing requested representations	2%

The data indicates that the designer uses image extraction for two main purposes: seeking **inspiration** (25% of the time) and evaluating proposals (12% of the time). Evaluation can take the form of **projective or comparative (in)validation**. In projective evaluation, designers evaluate the feasibility of their ideas based on simulated images. For example, a designer might say, "*there, the living rooms [about provided images rendering his ideas] are nice. With this layout they won't have any privacy problem with the neighborhood*" or "*Ah… well [about provided images rendering his ideas] it's super roomy, it fits*"). In comparative evaluation, individuals may express a preference for their own design over the alternative shown in the image. For example, one individual stated ("*Yes, this kind of staircase is a nice idea (...) it gives inspiration. So, we could start with a staircase more like this one, that comes back... [implementing a L shaped staircase instead of the straight one firstly sketched]*"). Finally, feature extraction is often triggered by a visual change or a shift in attention, rather than a specific goal, accounting for 17% of the time. This highlights the opportunistic nature of design activity.

Preferential use of general overall perspectives images

This second section of results relates to the relevance and usefulness of the images. It was (qualitatively) observed that some images were examined for analogy-based design, while others were not used at all. All images provided were from the architectural domain and were aesthetically pleasing. The purpose of this study is to determine which type of image is most used in order to inform future use of the technology.

Figure 5 highlights the panel of images from which designers extracted features for their designs, while Figure 6 highlights the panel of images that were seen but not used by the designers. Upon comparison of the two panels, it appears that half of the used images represent **general realistic overall perspective** views of buildings (which is the type of object to be designed in this task), and another quarter of them show **detailed views related to volumetry or facade**. In contrast, the unused images are one-third **plans and sections** of other similar buildings and one-third **detailed images of interior design**.

Several hypotheses could explain these observations. Firstly, designers may require inspiration at a higher level of abstraction rather than focusing on details. They may also benefit from inspiration through ambiance pictures rather than concrete geometrical solutions. Additionally, they appear to require assistance with designing facades and finding inspiration for form-related aesthetics, which are two specific aspects of architectural design.

Fig. 5 Panel of the provided images from which design features were extracted.

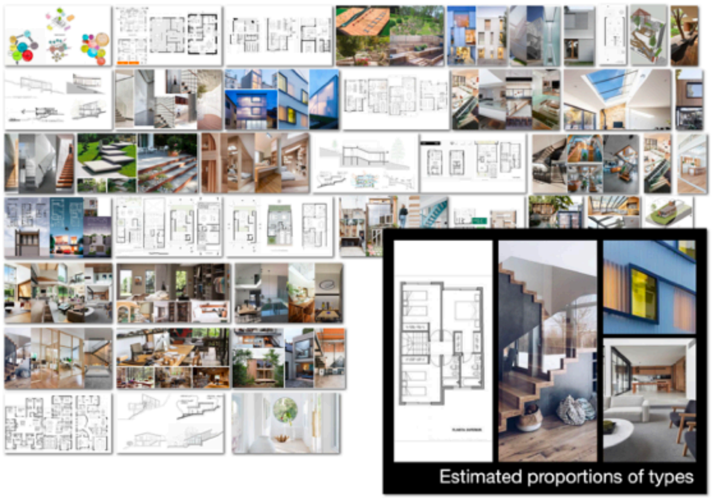

Fig. 6 Panel of the provided images seen but not used in the design.

Additional roles of analogy in design

The extracted elements are not only used to inspire or validate a design through analogical reasoning, but they are also concretely transposed and re-injected into the project with little to no modification. During the design process, we noted every instance where a building attribute was designed by analogy with an explicit reference to previously seen images. The design timeline (Figure 7) displays the extracted elements (green cross) and the moment they are utilized in the design (blue circle).

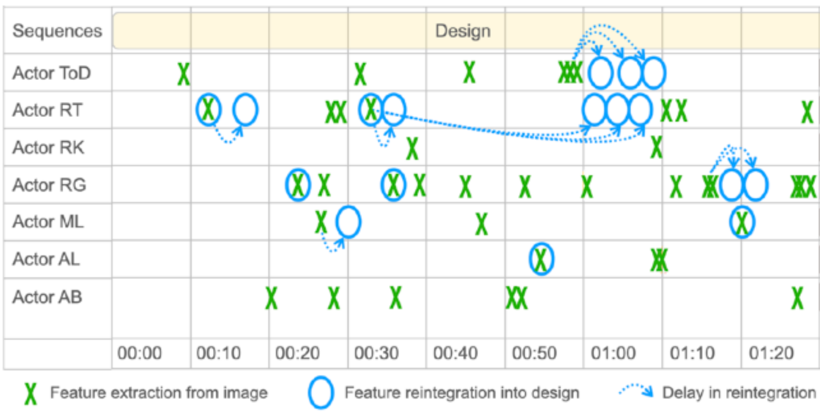

Fig. 7 Timeline of successive extracted elements [green cross] and the moment they are used in design [blue circle], immediately or with delay [dotted arrow].

Re-injection into the design was **immediate** in 53% of the cases, but the other 47% of the analogies were made a 12 minutes on average **delay** after having seen the corresponding inspiring feature (delayed-dotted arrow).

We then aim to determine the designers' needs that motivate the use of analogy in design, i.e. the re-injection of the seen images into the design. Qualitative analysis of the think aloud collected revealed seven needs (see Table 4).

Table 4 Need leading to analogical reasoning mobilization with verbatim examples and occurrence.

Need leading to analogical reasoning mobilization	**Percentage of occurrence (N=17)**
Evaluating the proposal by comparison or projection *"Earlier I drew a large glass box, and compared to the references I saw earlier, it's perhaps a little excessive. So I'll set windows for the part that overlaps the terrace."*	25%
Summarizing the project *"So, let's redraw all of this in a synthetic comprehensible perspective. And I'm going to integrate the wood and polycarbonate facade style it showed me before. It was cool."*	15%
Finding a solution to a composition's conflict *"Well this table... complicated. It gets in the way of the kitchen and if I put it there it's half in the lounge. Let's try what it suggests as a layout."*	15%
Seeking an inspiring alternative *"We could work with a bay window that's more vertical, or even roof-mounted... So, taking inspiration from the inspirational images: ..."*	15%
Seeking a concept to structure the composition *"Well... I need some facade logic. Oh, that's exactly what I was looking for, that's great. And this recess is exactly what I wanted. So now we're going to do this facade and recess which are really interesting..."*	15%
Considering another facet of architecture *"Now that's a nice image. It's a good representation of what I want to do with a full-height staircase on two levels. Except I didn't make a cover like they did. But it's true that the cover idea isn't bad. And it could prevent overheating. So we'd have a top part coming here..."*	10%
Better understanding the initial problem *"Ah yes, it's true that the terrain is sloping! [looking at the inspirational image] I'd forgotten. So I'm going to work on some stepped floors like in the picture."*	5%

Note that the 17 attributes designed by analogy, which consist of reintegrated elements previously extracted from the provided images, are explicit and conscious analogies as we have coded them. However, upon further examination of the common elements between the final project and the provided images, there are a total of 34 attributes created by analogy. This highlights a portion of design-by-analogy behavior that is actually unconscious.

Discussion

Literature knows analogical reasoning to have two roles in design (inspiration and evaluation). However, our results reveal a specific sub-activity of evaluation that is important to designers, which involves the need to evaluate the premises of ideas at an early stage. The evaluation is conducted using two methods: simulation and comparison. Simulation involves visualizing the idea and deciding whether to validate it, while comparison involves comparing it with alternatives to determine the best solution. Our observations also document new analogical reasoning activities and reveal that analogies can serve four additional roles: synthesizing, unblocking, structuring, and recalling forgotten aspects.

Regarding the nature of analogy, literature [16, 35, 36] usually characterize the analogy's focus according to a binary classification: component itself or relation between components. Going beyond that, we observe here that designers call on analogy for general elements relating to form, as well as, to a lesser extent, for details relating to the artifact's function. This allows us to pinpoint the aspects of design in which subjects need assistance.

We also surprisingly observed that subjects transfer the ideas extracted from the images to their project with little to no modification, both consciously and unconsciously. While unconscious analogies are a known fact, previous literature has documented analogical design activities that involve modifying and adapting the inspirational object before integrating it into the design [6, 16, 35, 36]. The integration without modification, specific to this observation context, may be a consequence of the source images being from the same design domain and relevant to the design subfocus in real time. This integration occurring both immediately or with delay also point that some design decisions were influenced by the received images, but were integrated into the project at a later stage. Additionally, some images were initially used to aid the design and later repurposed for new analogies during the process. That is an interesting founding.

Bonnardel [23] moreover stated that creative individuals develop « divergent thinking », i.e. vary their perspectives on the design object by integrating various domain knowledge and inspiration, which is a behavior we observed here is their appearance for divergent inspirational images.

Finally, our findings confirm that this approach of design stimulation by visuals is a valuable approach, as the image mobilization rate was 23%.

The types of extracted elements also indicate that this aid is particularly useful during ideation phases.

Implications for design research

This paper has several contributions. Firstly, it presents a complex and realistic task for architectural designers. Secondly, it offers a paradigm shift by examining the design process through the project's attributes. Finally, it introduces an experimental protocol that serves as an evolving research tool. The research provides insight into the potential of stimulating analogical reasoning through automatically generated images. The study reinforced the idea that AI image generators can be a successful tool for design assistance when they are based on the artifact under design and provide both divergent and convergent inspirational images.

This paper also contributes to our ongoing research on design instrumentation. We decided to capitalize on analogical reasoning and stimulate the design with images. We provided both inspirational and rendering images, and observed that these features were utilized during generation and evaluation activities. Finally, we decided to use project-specific images based on the design sketches. According to another analysis [26] of the interviews with the designers, the images we sent were deemed appropriate and non-disruptive, surpassing the main limitation of current AI image generators.

Additionally, the results section also provides some recommendations for further refining our technological proposal. Preferably, the images should provide a realistic perspective and show a global view of the object. The most useful topics to cover would be formal principles such as volume, elevation, and concept, as well as functional details.

Conclusion

The objective of this work is to stimulate design in the ideation phase by harnessing the creative power of AI-powered analogical reasoning. This will be achieved by automating the delivery of inspiration and rendering images that are suitable for the project. To investigate how designers respond to this type of aid, we conducted a Wizard of Oz experiment. Nine architects were immersed in a 90-minute house design capsule that included automatic and regular delivery of inspiration and projection images. We analyzed how the architects utilized these images, what specific elements they looked for, and how they integrated them into the design. Additionally, we identified the types of images that were considered most relevant and useful.

Our results indicate that designers primarily use the provided images for inspiration and to evaluate their initial ideas. The images were found to be appropriate and fulfilled the need those needs. They extract attributes related to the general form or, to a lesser extent, more detailed function, which they then reintegrate through direct transposition. This is mainly seen in the specification of the building's volumetry or facades. When presented with images, they tend to favor and use those that show general realist views. More detailed images or plans do not seem to meet their needs.

One limitation of the study is the relatively small number of participants due to the experience required to complete the design task. For further analysis, we plan to replicate the study with a larger population and diversify the domain source of the images by providing non-building inspirational images and comparing their usage and success.

References

1. Safin, S., Juchmes, R., & Leclercq, P. (2012). Use of graphical modality in a collaborative design distant setting. *Work, 41*(Supplement 1), 3484-3493.
2. Baudoux, G., & Safin, S. (in submission). Study of the multi-instrumented reflective conversation activity in preliminary design. In *Design Sciences*.
3. Falzon, P. (2004). *Ergonomie*. Paris : Presses Universitaires de France.
4. Safin, S. (2011). *Processus d'externalisation graphique dans les activités cognitives complexes : le cas de l'esquisse numérique en conception architecturale individuelle et collective.* PhD Thesis, University of Liège, Belgium.
5. Casakin, H. (1997). *The role of analogies and visual displays in architectural design*, unpublished doctoral dissertation, Technion, Haifa.
6. Casakin, H. & Goldschmidt, G. (1999). Expertise and the use of visual analogy: implications for design education. *Design Studies, 20*, 153–175.
7. Ball, L. J., & Christensen, B. T. (2009). Analogical reasoning and mental simulation in design: Two strategies linked to uncertainty resolution. *Design Studies, 30*, 169-186.
8. Ball, L. J., & Christensen, B. T. (2019). Advancing an understanding of design cognition and design metacognition: Progress and prospects. *Design Studies, 65*, 35-59.
9. Visser, W. (2001). *Conception individuelle et collective. Approche de l'ergonomie cognitive*. Le Chesnay, France: INRIA - Institut national de la Recherche en Informatique et Automatique.
10. Darses, F. (2004). *Processus psychologiques de résolution collective des problèmes de conception : contribution de la psychologie ergonomique*. Document de synthèse en vue d'obtenir une Habilitation à Diriger des Recherches. Paris: Université Paris V - René Descartes.

11.Jiang, S., Hu, J., Wood, K. L., & Luo, J. (2022). Data-driven design-by-analogy: state-of-the-art and future directions. *Journal of Mechanical Design*, *144*(2), 020801.
12. Ball, L. J., & Christensen, B. T. (2022). Analogical reasoning and mental simulation in design: two strategies linked to uncertainty resolution. In *About Designing* (pp. 137-152). CRC Press.
13.Jang, S. (2014). The effect of image stimulus on conceptual combination in the design idea generation process. *Archives of Design Research, 27*(4), 59-72.
14.Kwon, E., Rao, V., & Goucher-Lambert, K. (2023). Understanding inspiration: Insights into how designers discover inspirational stimuli using an AI-enabled platform. *Design Studies, 88*, 101202.
15.Goucher-Lambert, K., & Cagan, J. (2019). Crowdsourcing inspiration: Using crowd generated inspirational stimuli to support designer ideation. *Design Studies, 61*, 1-29.
16.Leclercq, P., & Heylighen, A. (2002). 5,8 Analogies per hour. A designer's view on analogical reasoning. Paper presented at the *AID'02 Artificial intelligence in design*
17.Bonnardel, N. (2000). Towards understanding and supporting creativity in design: analogies in a constrained cognitive environment. *Knowledge-Based Systems, 13*, 505-513.
18.Le Coguiec, É. (2012). *Pour une compréhension de la conception architecturale: étude réflexive de la conception du projet MN 12 et de ses références.* PhD Thesis, Université du Québec, Montréal, Canada.
19.Jaruga-Rozdolska, A. (2022). Artificial intelligence as part of future practices in the architect's work: MidJourney generative tool as part of a process of creating an architectural form. *Architectus, 3* (71).
20.Casakin, H., & Wodehouse, A. (2021). A systematic review of design creativity in the architectural design studio. *Buildings, 11*(1), 31.
21.Paananen, V., Oppenlaender, J., & Visuri, A. (2023). *Using Text-to-Image Generation for Architectural Design Ideation.* Preprint.
22.Beyan, E. V. P., & Rossy, A. G. C. (2023). A Review of AI Image Generator: Influences, Challenges, and Future Prospects for Architectural Field. *Journal of Artificial Intelligence in Architecture, 2*(1), 53-65.
23.Bonnardel, N. (2009). Activités de conception et créativité: de l'analyse des facteurs cognitifs à l'assistance aux activités de conception créatives. *Le travail humain, 72*(1), 5-22.
24.Angel Hsing-Chi Hwang. (2022). Too Late to be Creative? AI-Empowered Tools in Creative Processes. In Extended Abstracts of the 2022 CHI Conference on Human Factors in Computing Systems (CHI EA '22). Association for Computing Machinery, New York, NY, USA, Article 38, 1–9.
25.Vinchon, F., Lubart, T., Bartolotta, S., Gironnay, V., Botella, M., Bourgeois-Bougrine, S., Burkhardt, J.-M., Bonnardel, N., Corazza, G.E., Glăveanu, V., Hanchett Hanson, M., Ivcevic, Z., Karwowski, M., Kaufman, J.C., Okada, T., Reiter-Palmon, R. and Gaggioli, A. (2023), *Artificial Intelligence & Creativity: A Manifesto for Collaboration.* J Creat Behav.
26.Baudoux, G. (in press). The Benefits and Challenges of AI Image Generators for Architectural Ideation: Study of an alternative human-machine co-creation

exchange based on sketch recognition. In *International Journal of Architectural Computing.*

27. Baudoux, G., & Leclercq, P. (2023). Experimenting with a new proposal for digital design instrumentation: A Wizard of OZ method to study the impact on activity, *41th international conference on Education and research in Computer Aided Architectural Design in Europe*, Gratz, Austria.
28. Dahlbäck, N., Jönsson, A. & Ahrenberg, L. (1993). Wizard of Oz studies—why and how. *Knowledge-based systems, 6*(4), 258-266.
29. Browne, J. T. (2019). Wizard of oz prototyping for machine learning experiences. In *Extended Abstracts of the 2019 CHI Conference on Human Factors in Computing Systems* (pp. 1-6).
30. Rietz, F., Sutherland, A., Bensch, S., Wermter, S. & Hellström, T. (2021). WoZ4U: An Open-Source Wizard-of-Oz Interface for Easy, Efficient and Robust HRI Experiments. *Frontiers in Robotics and AI*, 8.
31. Anastassova, M., Mégard, C., & Burkhardt, J. M. (2007). Prototype evaluation and user-needs analysis in the early design of emerging technologies. In *Human-Computer Interaction. Interaction Design and Usability: 12th International Conference*, HCI International 2007, Beijing, China, July 22-27, 2007, Proceedings, Part I 12 (pp. 383-392). Springer Berlin Heidelberg.
32. Safin, S., Delfosse, V. and Leclercq, P. (2010). *Mixed-reality prototypes to support early creative design.* In E. Dubois, P. Gray and L. Nigay (Eds). The Engineering of Mixed Reality Systems, London, Springer.
33. A. Heylighen., G. Martin (2004). Design Computing and Cognition, That Elusive Concept of Concept in Architecture, 57-76.
34. Baudoux, G., & Leclercq, P. (2022). Collaborative design: Evolution of project's information and role of the graphic interactions, *10th International Conference on Design Computing and Cognition*, Glasgow, UK.
35. Gentner, D., & Kurtz, K. J. (2006). Relations, objects, and the composition of analogies. *Cognitive science, 30*(4), 609-642.
36. Goel, A. K. (1997). Design, analogy, and creativity. *IEEE expert, 12*(3), 62-70