An Early Look at Applications for Artificial Intelligence Visualization Software in Landscape Architecture

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Abstract: Digital design technologies are currently dominating visual communications in the field of landscape architecture. Due to rapid technological changes, artificial intelligence (AI) graphic software appears to be the next frontier in creating digital imagery, though little is known on the potential of artificial intelligence for rendering landscape architecture graphics. The objective of this study is to determine the effectiveness and efficiencies of current Adobe-based rendering techniques, such as digital collaging in Photoshop, compared with the two major types of AI visualization software: text-based image generation (DALL-E 2) and sketch-based image refinement (NVIDIA GauGAN2). Images produced by current methods and AI software were evaluated by landscape architecture professionals. Professionals were also surveyed on their attitudes toward and adoption of AI programs. This study aims to determine whether AI-based software can compete with visualization methods currently taught to landscape architecture students and used by landscape architecture professionals. Understanding and adoption of AI-based visualization techniques may lead to significant changes in landscape architectural practice and education.

Keywords: Digital landscapes, visual communications, text-to-image, landscape software

1 Introduction

Digital design technologies have been of interest to researchers and practitioners of landscape architecture since the mainstream adoption of computers in the late 1990s (DEUSSEN et al. 1998, DEUSSEN 2003). The widespread adoption of computers and computer-based software led the rise of digital methods for rendering landscapes and architectural structures more efficiently than analogue methods, such as digital representation, 3D modelling, algorithmic design, parametric design, and geospatial modelling (PEDERSEN 2020, HOCHSCHILD et al. 2021). Artificial intelligence (AI) is the next frontier in digital design technology with the emergence of programs which can produce high quality graphics and renders with less time and skill required than previous computer design programs (CURETON 2016, XIAO 2021).

In addition, most practitioners and students have little familiarity with digital design techniques beyond CAD-based plans and sections (e. g. AutoCAD, Vectorworks), digital collage-based renders (e. g. Adobe Photoshop) and non-parametric 3D modelling (e. g. Rhinoceros 3D, SketchUp). It is possible that the skillset of today's landscape architect may be vastly different from the landscape architect of tomorrow as artificial intelligence technologies transform workflows. The impacts of new technologies on landscape architecture practice should be explored to help the field transition in the face of rapid technological change.

Artificial intelligence is still an emerging technology in landscape architecture as its practical applications are not yet solidly established (CURETON 2016, JAAKKOLA et al. 2019). There is currently limited research on the potential uses for artificial intelligence software in landscape

Journal of Digital Landscape Architecture, 8-2023, pp. 543-553. © Wichmann Verlag, VDE VERLAG GMBH · Berlin · Offenbach. ISBN 978-3-87907-740-3, ISSN 2367-4253, e-ISSN 2511-624X, doi:10.14627/537740057.

architecture. ZHANG & BOWES (2018) trained an AI program to model and predict groundwater levels for more effective stormwater management and ecological design outcomes. LEACH (2018) and CANTRELL & ZHANG (2018) emphasize that as artificial intelligence advances, there will be a need to redefine the role of the landscape architect from designer to curator, as machines will execute certain tasks far more efficiently than humans.

Nevertheless, AI-based landscape and urban design will require human intervention to varying degrees, as concepts related to the human world will need to be taught to AI, and ultimately humans must select and refine the most viable AI outputs (LEACH 2018), as seen in AI technology applied to architectural works (PENA et al. 2021). FERNBERG et al. (2021) created a framework for AI programs to learn the concept of landscape, which they define as an example of "AI ontology". FERNBERG et al. (2021) ordered landscape elements from Fresh Kills Park into increasingly simplified categories, creating a hierarchy that started from the largest concept of habitat type (morainal oak woodland) to the categories of plants (tree, shrub), to specific species. A thorough understanding of AI in landscapes has not yet been accomplished by any program due to the complexity of landscapes, but the current generation of AI visualization may already have utility for landscape architecture.

This study explored whether the current generation of artificial intelligence technology can be effectively used as a design tool for visualizing landscapes. The larger research question to be answered is: "Can artificial intelligence software be used to visualize designed landscapes as an alternative to current rendering methods?" or "Are AI visualizing methods more effective and efficient than current Photoshop digital collaging?" 'Effective and efficient' refer to faster image generation with similar visual quality compared to Photoshop-based rendering.

Beyond answering the larger research question, other objectives will be addressed:

1) Compare the quality (accuracy, realism, communicativeness) and efficiencies (time and complexity) of AI visualization with current popular rendering techniques.
2) Determine the capabilities and limitations of the current generation of AI visualization software.
3) Determine which parts of the design process would benefit from utilizing AI visualization.
4) Obtain feedback from landscape architecture professionals on the quality and viability of AI renders in practice and education.

2 Determining Effectiveness and Efficiencies of AI Visualization in Landscape Architecture

2.1 Generation of Images

First, various leading AI visualization software were examined, leading to the identification of two major types of AI visualization: "sketch-based" and "text-based" software. Sketch-based visualization requires a base image made up of rudimentary shapes and outlines, which provide a 'guide' for the AI to apply textures and forms from its database, resulting in semi- or photorealistic renders. Text-based visualization AI uses text prompts to generate images of varying styles, which can then be edited further with the addition of more text. Exploring effective sentence structure and use of keywords for text-based AI image visualization is a new area of research (KONARIEVA et al. 2019, LEE et al. 2021). Two programs capable of each type of AI image were selected for use in this study. NVIDIA GauGAN2 (released in 2021, free to use) was selected as the sketch-based option. GauGAN2 claims realistic landscape generation using a base sketch called a "segmentation map" in coded colours which can be combined with text prompts, though a sketch-only approach will be used for the purposes of this study. DALL-E 2 (released 2022) was selected as the text-based AI option, due to its low cost (~10 cents per image iteration) and versatility.

The effectiveness and efficiencies of these two AI programs were compared to rendering methods currently taught in landscape architecture programs and used by landscape architecture professionals. Five images produced using traditional digital collage methods in Adobe Photoshop were selected for re-creation in DALL-E 2 and GauGAN2, resulting in a total of 10 AI-generated renders (Fig. 1). These five renders covered a range of environmental conditions: terrestrial versus aquatic, urbanized versus naturalized, as well as including various outdoor structures and taking place in different seasons.

On average, producing the Photoshop collage renders required anywhere from 3 hours to over 10 hours, depending on complexity and availability of digital assets. In contrast, the DALL-E 2 text-based renders required roughly 1 minute to generate 4 square images at a time, and an additional roughly 5 minutes to edit the images if necessary. If none of the 4 generated images were satisfactory, then further images could be generated from the best image of the four. For example, image (C) in Figure 1, was produced in DALL-E 2 using the text prompt "A beach landscape, on the right side is a lake with a sandy shore, on the left are dunes with tall grasses and a sand pathway cutting through the dunes that leads to the sandy shoreline. Farther on the horizon line is a row of trees that disappears into the distance beyond the lake. The weather is sunny, with a pale blue sky and fluffy white clouds". The text prompt was written based on the composition of the original Photoshopped render (A) to try to recreate it. One generated image was then selected but needed to be edited from a square into a landscape aspect ratio like the original image. Images can then be edited in DALL-E 2 by adding a "generation frame", which can extend the image in any direction. DALL-E 2's editing feature also allows the addition of elements into specific parts of the image using a brush tool and additional text (e. g., woman walking holding hands with a child).

The sketch-based render method in GauGAN2 required a longer time commitment (10 to 20 minutes) due to the software needing a segmentation map with the landscape elements translated into simpler forms (Fig. 2). The segmentation map can be produced in the NVIDIA program directly, or produced in an external program (e. g., Adobe Illustrator) and uploaded into the software, given that correct colours corresponding to landscape elements are used. To produce image (B) in Figure 1, a segmentation map (Fig. 2), was produced in Adobe Illustrator and then uploaded into NVIDIA GauGAN2. The segmentation map was created by tracing the original image (A), resulting in a map of coloured vectors which could be read by the software to produce a landscape. Like DALL-E 2, GauGAN2 is limited to producing square images; to produce a landscape orientation image the segmentation map was divided into two squares which were rendered separately and pieced back together into one image.

Fig. 1: Example of rendering comparison undertaken by the study. Semi-realistic rendering of a shoreline dune landscape produced in Photoshop from Nadia Amoroso Studio for Brook/McIlroy Architects (A), process and results to be compared with attempts to reproduce the same scene in GauGAN2 (B) and DALL-E 2 (C).

Fig. 2: Example of segmentation map used to generate a landscape render in NVIDIA GauGAN. The map was divided into two square halves which had to be rendered separately.

2.2 Survey of Landscape Architecture Professionals

The images produced by DALL-E 2 and GauGAN2 were then used as part of a 5-minute anonymous questionnaire produced in Qualtrics sent out to key informants in the landscape architecture profession. In addition to the comparison images already produced, other AI-generated images were evaluated using the survey. The aim of the questionnaire was to obtain an answer to the research question of whether AI visualization programs can produce quality landscape architecture renders, as well as meet the other research objectives relating to the current applications for this generation of AI in the landscape architecture practice. An overall image of the value of AI to the field of landscape architecture could thus be obtained.

Key informants surveyed were selected based on the following criteria: 1) must be a landscape architect, urban designer, and/or academic in the profession of landscape architecture; and 2) must have knowledge and experience with digital design techniques, as well as an interest in emerging design technologies. A list of 20 professionals were selected and invited via email to complete the anonymous questionnaire. 17 out of 20 informants completed the survey. However, out of the 17 responses, only 12 responses were correct and complete, resulting in a 60 per cent response rate.

The first set of questions involved seven text-based questions. These text-based questions were used to determine practitioner's level of interest and use of AI programs, including the specific programs used, what stage of the design process they are used in, and the efficiencies and effectiveness of these programs compared to traditional methods.

Overall, responses indicated interest in AI for generating landscape visuals (11 out of 12 respondents), though less than half of respondents (5 out of 12) currently use AI in their projects. As a result, AI does not yet impact most firm's approaches to design, nor does AI play a key role in the design process (8 out of 12 answered No or Not Applicable). However, most respondents believe that AI will change the field of landscape architecture by altering design processes (11 out of 12, or 91.67%). This indicates a gap between the potential of AI for landscape architecture and its current implementation, which was confirmed by 11 out of 12 respondents. To address this gap, some early adopters of AI as a digital design tool are promoting AI in their educational or professional work (6 out of 12).

Out of the leading artificial intelligence visualization software, respondents favoured Midjourney (7 out of 12), followed by DALL-E 2 (5), Stable Diffusion (2) NVIDIA Canvas/ GauGAN2 (2) (Fig. 2). No respondents reported using an AI program that was not listed. One respondent reported not using AI software at all. Those who do use AI as part of the design process overwhelmingly use it for Ideation, followed by Concept Development (Fig. 3).

Further insight on the value of AI to the field was obtained via statements on AI visualization that were voted on using a 5-point Likert scale (Fig. 4). These statements received largely mixed responses without a clear consensus. The approachability and ease of use of AI visualization software was mixed, with 1 Strongly Disagree (SD) rating, 2 Disagree (D), 4 Neutral (N), 2 Agree (A) and 3 Strongly Agree (SA). For AI performance on landscape designs, Neutral and Agree both received 5 votes each, while 2 respondents Disagreed, and no respondents Strongly Agreed nor Disagreed. Architectural designs received a similar response (0 SD, 2 D, 5 N, 4 A, and 1 SA). Most professionals surveyed do not strongly view AI visualization as a more efficient alternative to non-AI design software (1 D, 7, 4 A, 0 SA or SD).

However, more respondents appear to anticipate that AI will replace certain tasks in the design process (1 SD, 1 D, 2 N, 6 A, 3 SA), and that AI may be used to enhance the design process (0 SD, 1 D, 2 N, 6 A, 3 SA). Respondents as a neutral to positive leaning response to whether AI will improve efficiency and time management are as follows (0 SD, 2 D, 5 N, 4 A, 0 SA), or results in more innovative design (2 SD, 1 D, 5 N, 4, A, 0 SA).

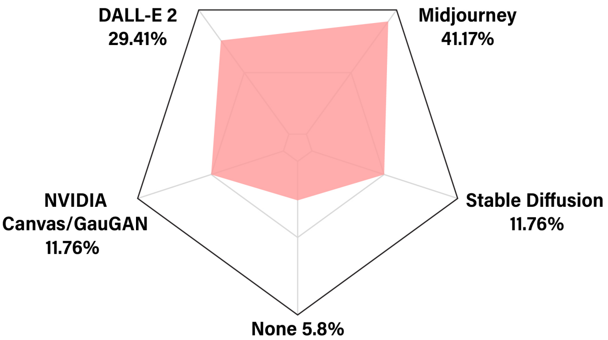

Fig. 3:
Radar chart of the different AI visualization programs used by landscape architecture professionals surveyed in this study

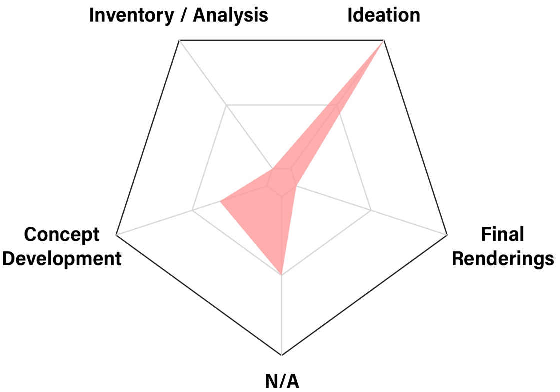

Fig. 4:
Radar chart visualizing the stages of the design process where AI programs are used by landscape architecture professionals

Following the text-based questions were image-based questions. First, informants were asked to rate four AI-generated images using a 5-point Likert scale (Very Poor, Poor, Fair, Good, Excellent). These images were generated using DALL-E 2 as an attempt to re-create deliverables from landscape architectural projects and included two perspective renders and two plan-view renders. Section elevations could not be produced by the AI program and thus were not included. Each image was accompanied by a brief text description of what the image was intended to communicate. The distinctive coloured square watermark in the bottom right corner of DALL-E 2 renders was cropped out to ensure objectivity.

For all four images, responses were also mixed (Fig. 5). The design perspectives received more positive responses compared to the two plan view images. The master plan view render for a biodiversity-focused public park was rated by most participants as Poor (5 out of 12) to Fair (5 out of 12). A render of part of an Italian formal garden received more mixed results (Very Poor and Poor received 1 vote each, whereas 5 respondents voted Fair, 2 voted Good and 3 rated the image as Excellent). The English cottage garden received similarly mixed responses but with a positive bent, with 1 Very Poor rating, 5 Fair ratings, 2 Good, and 1

Excellent. Lastly, the mixed-used neighbourhood plan in a hand drawn rendering style received the most negative response, with 4 Very Poor votes, 2 Poor votes, 6 Fair votes and 0 Good or Excellent ratings.

The final section of the survey asked respondents to compare of the AI-generated renders from section 2.1 with traditional Adobe Photoshop collage renderings. Five questions asked informants to pick between three images, one produced traditionally and two produced by DALL-E 2 and GauGAN2, without being told how the image was produced. Like the previous image-based questions, each set of three images was accompanied by a text description of the desired scene that the renders are in intended to convey.

The five comparisons revealed that the renders produced by DALL-E 2 were considered effective by respondents and were largely comparable to the human-led Photoshop renders (Fig. 6). In contrast, renders produced by GauGAN2 were not received as positively. For one scene (producing a pond in an ecological park), the human-made and AI-generated methods all tied for effectiveness (4 votes each) (Fig. 7). DALL-E 2 and traditional methods tied again for producing a small urban park with outdoor seating in winter (6 votes each, 0 for GauGAN2), and platform seating in an urban park (5 votes for both DALL-E 2 and Human/Photoshop, with the 2 remaining votes for GauGAN2). For the scene of a dune landscape with walkway (Fig. 1), the traditional Photoshop method was voted more effective than the AI visuals (6 votes), though DALL-E 2 received 5 votes and GauGAN2 with 1 vote. AI, specifically DALL-E 2, had the preferred render for the designed wetland comparison, with 9 votes versus 1 (Human) and 2 (GauGAN2). When segmented in total number of votes, DALL-E 2 received the most (29), followed by the Photoshop collage (21) and GauGAN2 (9).

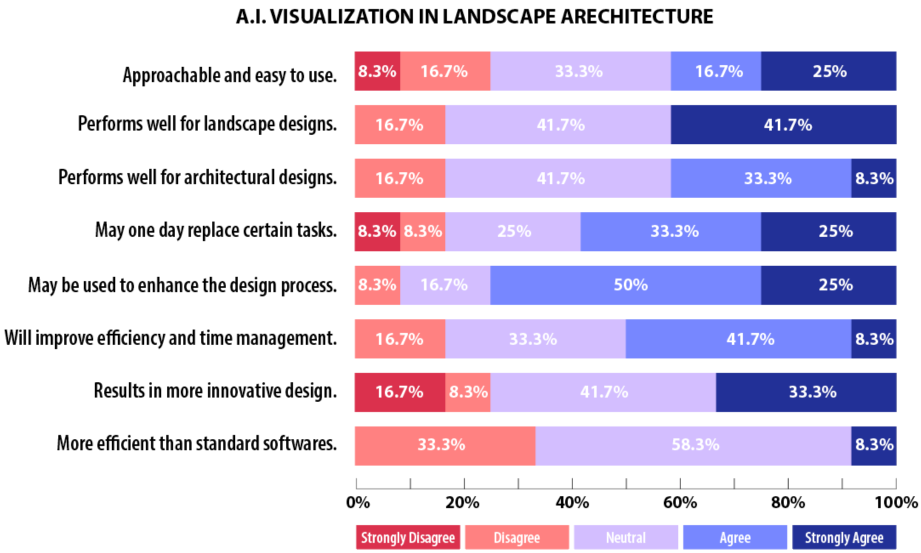

Fig. 5: Stacked bar chart illustrating Likert scale ratings of statements about AI visualization software. Reponses to statements revealed attitudes of landscape architecture professionals towards AI used in practice.

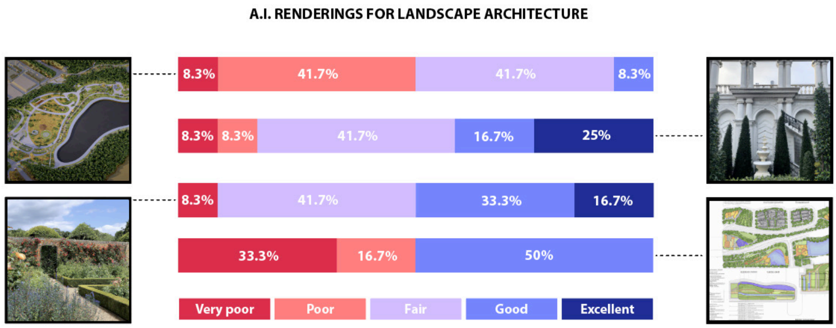

Fig. 6: Landscape architecture professionals' responses to AI-generated renders intended to mimic final renders or deliverables from projects

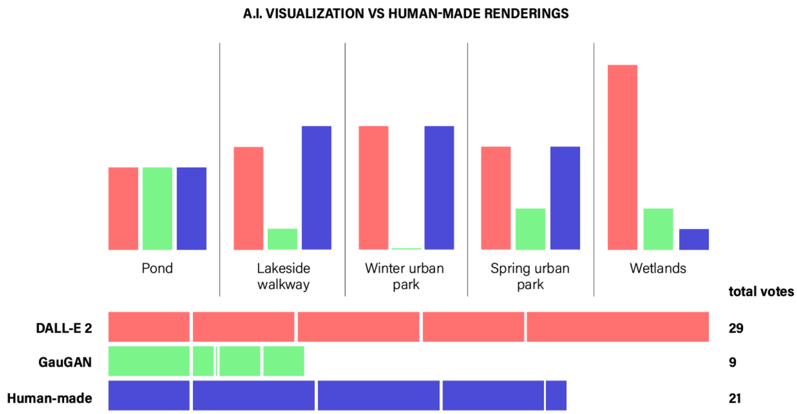

Fig. 7: Comparison of render quality/effectiveness between two AI visualization programs and traditional Photoshop collage renders. The most effective image was selected by landscape architecture professionals who were not told how the images were made.

Fig. 8: Image comparison question where all three rendering methods were considered equally effective by respondents. Left image was produced by DALL-E2, middle image was produced by GauGAN2, and right was produced by a human (Nadia Amoroso Studio) in Photoshop.

3 Discussion

Overall, the AI programs DALL-E 2 and GauGAN2 were able to generate renders more efficiently (i. e., less time required per image) than Photoshop collage methods. Images produced by GauGAN2 were not considered effective final renders by landscape architecture professionals. DALL-E 2 could not synthesize effective plans for a park or a neighbourhood, though the garden designs were rated higher. This result may be due to how the current generation of AI currently functions, as the garden designs were given descriptors tied to specific styles and eras in landscape architecture, rather than concepts like "biodiversity" and "mixed-use development" which are known to landscape architects and related professions but cannot be properly understood by the current AI programs, which is consistent with recent research with DALL-E 2 and urban design (SENEVIRATNE et al. 2022). Professional respondents typically limit their use of AI visualization for stages in the design process like ideation and concept development rather than final renderings, or inventory and analysis.

When comparing traditional human-led Photoshop renders with AI-generated renders, the text-based DALL-E 2 renders were preferred over both the Photoshopped renders and the sketch-based GauGAN2 renders. Despite the higher control in re-producing the shapes and composition of the Photoshop scenes, GauGAN2 failed to integrate landscape elements using the segmentation map in a way that looked realistic. DALL-E 2 excelled at creating high quality, attractive images of landscapes, though there was less control over where the landscape elements, people, and structures would be placed. Improved sketch-based GAN AI would be ideal for producing landscape renders with a high level of specificity without the time commitment of finding and placing digital assets in Photoshop. While text-based AI visualization currently dominates in the research and in practice, there is interest in improving GAN-based segmentation map technologies and techniques for image synthesis (LEE et al. 2022).

Currently, there are early adopters of AI technology in the field of landscape architecture. The efficiency and effectiveness of text-based AI appears to have value for the field. Though respondents were attracted to the DALL-E 2 renders during image comparison, practitioners and educators that were surveyed do not indicate a preference for AI over non-AI software. The prevalence of neutral responses when determining attitudes towards AI may be due to AI software having not yet established its utility for design professions, thus a lack of knowledge may result in fewer strong opinions. Overall, there is uncertainty with how the current generation of AI visualization will be integrated into the design process and whether the use of AI can result in more efficient, innovative, or efficient design. Landscape architecture professionals from this study believe there is currently a large gap between education/training and the potential of AI in practice, and as this gap closes a clearer image of the value of AI to the field will likely emerge.

4 Conclusion and Outlook

Overall, the research objectives stated in this research were met. The current generation of artificial intelligence can produce attractive images but is still too limited to produce final deliverables, though some landscape architects are beginning to experiment with using AI visualization for ideation and concept development. Typically, rendering requires some background image or context and understanding of detailed design elements and the specific layout of the design. These components are difficult to achieve at via AI visualizations due to software limitations. For example, the integration of human and animal subjects in AI images is a key limitation. Landscape renders often include humans and/or animals to create scenes that are more sympathetic and dynamic. This is especially important for designed landscapes intended for programmed activities or ecological restoration. NVIDIA rendering programs, including GauGAN2 used in this study, does not have a way to include humans or animals in the segmentation map. DALL-E 2 is able to produce images with humans and animals, though often with incorrect anatomical details (e. g. unnatural-looking faces, correct number of appendages). Thus, DALL-E 2 may be limited to producing humanoid figures that can be looked at from behind or at a distance. Another limitation includes the lack of species-specific plant, animal or insect knowledge that may be necessary to produce convincing renders. As a result, until AI programs improve, it may be more effective to take hybrid human-AI approach to rendering, where an image is produced by AI software and then added to or adjusted by the designer in Photoshop. Human intervention is still required in the rendering process, such as for specific customization in the visualizations, which can be achieved using current digital design approaches.

By exploring the capabilities of AI in landscape visualization, we aim to delineate between "machine work" and "human work" as suggested by LEACH (2018), as well as identify new skillsets and workflows of tomorrow's landscape architect. The delineation between the designer and the machine will become more and more imperative as artificial intelligence continues to advance exponentially and becomes more accessible to the public. Understanding the advantages and limitations of AI in various applications, as well as direct comparisons between AI rendering and human-only digital rendering are necessary to solidify the current advantages and limitations for AI visualization in landscape architecture.

New efficiencies in digital design techniques may have profound impacts on landscape architecture workflows due to the time-billed nature of private practice, which comprises the largest proportion of work in the field (TAYLOR 2006). New approaches to design may emerge as aspects of the design process are simplified, accelerated, or rendered obsolete by AI programs. Indeed, time taken from calculations, modelling, and rendering by AI may leave more human resources for the iterative, creative, and conceptual brainstorming in landscape architecture (YU 2018). More research is required to determine specific hybrid approaches for AI in landscape architecture. Rather than replacing the designer, the potential of AI programs may be used to strengthen the role of landscape architecture in designing the open spaces of tomorrow.

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