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ORIGINAL STUDY

Revolutionary Artificial Intelligence Architectural Design Solutions; Is It An Opportunity or a Threat?

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Abstract

Architectural design is uniquely complex, time-consuming work, so AI promises major benefits but also risks. Architectural design software programs have recently made an impressive development, especially those that use artificial intelligence. AI could transform design and construction with tools enabling generative design, parametric modeling, simulation, and optimization. However, AI’s impact remains unclear. Adoption depends on architects leveraging AI to augment judgment rather than replace it. Factors limiting AI include limited education/experience, threats to creative skills architects value, and unreliable AI design tools. While many see AI as an opportunity, not an endangerment, optimism and uncertainty prevail. AI may ultimately enhance design possibilities, not eliminate architects. With experimentation, benefits could include optimized performance, data insights, and offloading routine work. But this vision requires partnership, not replacement, of human design thinking. Barriers include job security concerns, lack of AI integration, and perception of automation threat instead of augmentation. But AI could catalyze new collaborative and sustainable solution-finding frontiers if progress is progressive rather than reactionary. This paper explores the Egyptian architects' points of view regarding the significant evolution of that type of software and foresees their readiness to adapt to this decisive variable. It also provides recommendations that will guide architectural education strategies in the near future.

Keywords: Architectural design, Artificial intelligence, Deep learning

1. Introduction

Artificial intelligence is the science of creating intelligent machines that can make accurate decisions. Researchers aim at human-level intelligence, and some seek to emulate all the human brain capabilities; they also believe that the AI System will be able to develop itself at some point (Al-zeiny, 2018). AI made great strides in many fields, which caused a heated argument. For instance, Bill Gates, the technology billionaire, is optimistic about the potential of AI to solve major world problems and transform various industries, such as healthcare, education, and agriculture. In his opinion, AI can improve healthcare outcomes, create personalized learning experiences for students, and increase crop yields, among other benefits. He highlighted the importance of responsible development, ethical use, and increased investment in AI research and development to realize its full potential (As et al., 2018). However, Elon Musk, the boundary-pushing entrepreneur, has expressed concerns about the potential dangers of uncontrolled AI development, particularly regarding the potential for job displacement and resulting economic crises. Musk believes that as AI systems become increasingly advanced, they will be capable of performing tasks previously carried out by humans, leading to widespread job losses and economic disruption. He also advocates for caution and regulation to prevent unintended consequences, such as the creation of fake news and deepfakes.
Musk’s stance reflects the broader conversation within the AI community about how best to harness the power of AI while minimizing its risks (Baldwin, 2021). AI has also greatly influenced architecture computer programs that shorten work time (Brady, 2021). Building information systems, BIM empowered the architects to model a fully detailed project with zero clash working drawings (Conix, 2023). Using AI in urban planning facilitated the decision-making process. Geographical information systems GIS give the planner various tools to know the city’s needs (Conix, 2022). It can also help the architect produce the conceptual design (Fahmy, 2017). Recently, the algorithm has developed different spatial configurations based on predefined variables and creates floor plans (Fluicell, 2023).

This incredible evolution, accompanied by predictions of machine superiority, made some architects afraid of changing the architecture profession with its well-known form (Brady, 2021). Some researchers estimated that 47% of total US employment will be replaced by robots before 2037. Architecture has one of the lowest replacement rates, probably 1.8% (Frey and Osborne, 2017). According to The National Council of Architectural Registration Boards, the number of resident architects in the USA is 113554 (Gates, 2023). Some estimate the number of architects worldwide by 2.7–3.8 million (Hadjzaman et al., 2016). And the number of registered architects in Egypt is 68000 (Index @ Jmc.Stanford.Edu). That means tens of thousands of architects worldwide will lose their jobs. What has doubled the architects’ fears is the media statement of the startup: It claims that 700 house was built by an online tool That customizes a whole house design without employing an architect (Narayan et al., 2023). This paper explores to what extent the Egyptian architect’s community is ready to accept the expected revolutionary development in artificial intelligence applications in generating architectural design incredibly shortly. It also aims to provide recommendations to guide professional and educational practice to deal with the imminent variable.

1.1. Emerging AI design software

Several software tools that use an AI-powered generative design approach are available, such as TestFit, Spacemaker, Archistar, Conix, GenieBelt, and Grasshopper. These tools allow architects, developers, and construction teams to input parameters such as site constraints, zoning requirements, programmatic needs, construction schedules, and costs and then generate multiple design and process options optimized across different factors. TestFit is a software tool that allows users to quickly create and test different design concepts for buildings. It uses algorithms and automation to streamline the design process, helping architects and developers save time and reduce errors. TestFit includes features such as 3D modeling, zoning analysis, and code compliance checks and can be used for various building types, including residential, commercial, and mixed-use. Overall, TestFit is designed to improve the efficiency and effectiveness of building design and development (Miller, 2017). Spacemaker is an AI-powered platform that helps architects, real estate developers, and city planners optimize and streamline the building design process. The platform uses algorithms and data analysis to create multiple design options for a site, considering factors such as zoning regulations, sunlight exposure, and building codes. This allows users to quickly test and compare different design concepts, saving time and reducing costs. Spacemaker also provides data visualization tools and analytics, allowing users to make informed decisions about building design. Spacemaker aims to improve cities’ sustainability, efficiency, and livability through unique building design (Minor, 2016). GenieBelt is a cloud-based construction management platform that improves project communication and collaboration between contractors, subcontractors, and clients. The platform offers tools for project scheduling, progress tracking, issue management, and reporting. It also includes file sharing, messaging, and notifications to keep all stakeholders informed and connected. GenieBelt aims to simplify and streamline the construction management process, reducing the risk of errors and delays. It can be used for various construction projects, including commercial, residential, and infrastructure (Minor, 2022). Archistar Archistar is a cloud-based software platform for architects, urban designers, and property developers. It uses artificial intelligence and machine learning to provide tools for building design, site analysis, and zoning compliance. The platform allows users to quickly generate 2D and 3D models of building designs, and to analyze the feasibility of those designs based on factors such as zoning regulations, sunlight exposure, and wind patterns. Archistar also offers features such as data visualization, collaboration tools, and project management capabilities. Overall, Archistar aims to improve the efficiency and effectiveness of the building design process, helping users to save time and reduce costs (Rizkiya et al., 2021). Grasshopper is a visual programming language and environment used for generative design and algorithmic modeling in architecture,
engineering, and other creative fields. It is a plugin for the 3D modeling software Rhinoceros and allows users to create and manipulate complex geometric forms and patterns through a graphical interface. Grasshopper uses a node-based system, where different nodes represent different operations or functions, and users can connect them together to create complex chains of commands. Grasshopper enables designers to explore and iterate design possibilities quickly and efficiently, creating complex forms and structures that may be difficult or time-consuming to create manually (Property Development Software, 2023).

Conix is another example, using AI-powered generative design as a cloud-based platform with machine learning algorithms to generate optimized building designs and construction plans. Users input requirements/constraints, and Conix develops multiple design options optimized for energy efficiency, daylighting, cost, and construction schedules, minimizing delays and optimizing resource allocation. Conix analyzes construction data to select the most cost-effective materials and methods. It also enables real-time collaboration, visualization, and accessible work sharing (Spacemaker, 2021).

Accordingly, emerging AI tools transform architectural design and construction by allowing designers and teams to quickly generate and analyze hundreds of optimized design and process options tailored to key objectives like performance, cost, schedule, and stakeholder needs. The AI-powered generative design provides a novel exploratory and data-driven approach to achieve high-performance, sustainable, and efficient building solutions.

2. Methodology

This research investigates the perception of AI usage in architectural design among Egyptian architects. In this regard, a survey was conducted for AI-using entities. The researcher scheduled virtual Zoom meetings with The CEO of one of the AI-using entities that started in Egypt. To ensure the inclusion of different opinions, the questionnaire was designed to investigate the views of Egyptian architects toward AI applications in architectural design. The questionnaire was created on Google Forms and was sent to a casual sample of architectural designers from different age groups, along with a short video showcasing the latest AI applications in architectural design. To improve the questionnaire, the researcher initially shared a limited number of questionnaires with an initial sample and gathered feedback, which was used to develop the form and language of the questionnaire.

Finally, the researcher shared the final version of the questionnaire with the last sample. The closed-ended questions were analyzed using SPSS software, while the open-ended questions were analyzed qualitatively.

The sample size was determined as a percentage of the total number of the Egyptian registered architects in the Egyptian syndicate as it was about 70,000 architects. SurveyMonkey (TestFit for Architects, 2023) a survey software tool was used to calculate the sample number the confidence level was assigned as 90%. And the sample number was 68. The questionnaire was sent to more than 300 Egyptian architect. The uncompleted forms were excluded the respondents who doesn't work in the architectural design were excluded to.

The study limits confined to study the Egyptian architectural designers. Thus the Egyptian architects who works in other engineering fields were excluded from the study.

2.1. An architectural design and artificial intelligence survey

This research investigates the use of artificial intelligence (AI) in architectural design. The questionnaire was constructed to gather data on the experiences and opinions of architects regarding the use of AI technology in their field. The questionnaire consists of 19 questions and can be categorized into several topics. Firstly, the questions focus on the respondents' background and experience in architectural design. These questions provide context to the respondents' answers to the following questions. Secondly, the questions focus on using drawing and presentation programs in architectural design and the respondents' familiarity with parametric design. Thirdly, the questions focus on using AI technology in architectural design. These questions aim to understand the respondents' awareness of AI technology in their field and their experience using AI technology for architectural design programs. Fourthly, the questions aim to gather opinions on the quality of designs produced by AI technology, whether AI design programs can replace human architects, and AI technology's impact on job opportunities in architectural design. Finally, the questionnaire includes questions on the respondents' knowledge of programming languages and their willingness to learn to use AI technology. It also consists of a question on the respondents' perspective on using AI technology in architectural work in Egypt and how it can be legalized and controlled.
2.2. Sample characteristics according to experience and using technological tools

The total number of the casual sample was 67, varied in years of experience. The experience level ranges from undergraduate students to those with more than 25 years of experience in the field, as shown in Fig. 1. The survey also indicates that most of the sample use drawing and presentation programs in architectural design, as shown in Fig. 2a, with some of the most commonly used software being AutoCAD, 3D Max, and Rivet. Other frequently mentioned software include Sketchup, Photoshop, Archicad, Lumion, Ecotect, Design Builder, Rhino and Grasshopper, and Maya. The used applications percentages are shown in Fig. 2b. Overall, the characteristics provided by the survey reflect the common trends in the architectural industry regarding software usage and experience levels.

2.3. Parametric design familiarity

From the survey responses, it appears that parametric design is a relatively well-known concept among architects, with most respondents (around 73%) having heard of it. However, using software that produces parametric design is much less common, with only around 19% of respondents using such software, as shown in Fig. 3a. This suggests there may be some barriers to adoption or challenges in learning to use this software effectively. The survey results indicate that architects are generally aware of the concept of parametric design, but there is a significant gap between awareness and usage of related software tools, as shown in Fig. 3b. Fig. 3c indicates some of the used applications.

2.4. Design AI familiarity

83% of the participants in the survey have heard of architectural design by AI technology, as shown in Fig. 4a. However, 91% of the participants have not personally used these programs Fig. 4b. It’s worth noting that most participants have not used any AI architectural design programs they have heard of, indicating that adopting these technologies in the field is still relatively limited. The programs mentioned by the respondents who have heard about AI technology in design are Spacemaker, Testfit, and Conix, and a small percentage of 7% that experienced the technology used Spacemaker and Testfit, as shown in Fig. 4c and d.

2.5. The opinion on using AI tools in architectural design

The industry’s use of AI tools in architectural design is debated. As shown in Fig. 5a, the few respondents who have experienced AI tools have mixed opinions about their impact on the quality of architectural products: two respondents claimed that the quality has improved, a respondent said that it has not, and two are unsure. Fig. 5b shows that 19% of the total sample believe that AI design programs can produce designs of equal quality to humans, while 17% doubt the rest are unsure, reflecting their ignorance of AI tools. On the other hand, 85% believe that AI tools will make their work more accessible and more efficient Fig. 4c. However, there are concerns about AI’s impact on architects’ job opportunities. 20% worry that AI design programs may eventually replace them, 50% believe AI will not reduce their jobs, and 26% are unsure, as shown in Fig. 4d.

Also, it seems that most respondents –88%– do not want to stop their development, as shown in Fig. 4e. This suggests that the respondents see the value in these programs and the benefits they bring. Additionally, Fig. 4f shows that 55% of the respondents intend to learn to use these tools, indicating a willingness to adapt and stay current in the ever-changing technological landscape. However,
there are a few respondents who would like to stop the development of these tools. They may have seen the evolution of technology and feel that the current direction of these programs is not aligned with their vision or principles. A few respondents are unsure whether they would like to learn to use these programs. This could be due to various reasons, such as a lack of interest or a preference for alternative tools. Most respondents think these programs have a high value and are willing to learn and adapt to their use. This is a positive sign for the continued development and innovation of technology.

2.6. Programming and architectural education

Based on the provided responses, there seems to be a growing trend toward understanding the need for architects to learn programming. 85% of the respondents answered ‘yes’ when asked if they believe learning programming has become

a. Do you use drawing and presentation Apps in design?  

b. What software apps do you use in design?

![Fig. 2. The responses to drawing and presentation usage questions in architectural design.](image1)

![Fig. 3. The responses to questions related to parametric design.](image2)

a. Have you heard about parametric design?  

b. Have you used parametric design software?

c. What software did you use for parametric design?

![Fig. 4. The responses to questions related to parametric design.](image3)
necessary for architects to deal with and develop these tools, as shown in Fig. 6b. But at the same time, Fig. 6a shows that 77% of the sample did not try to learn programming. This could be interpreted as they believe that the AI development speed will not be fast enough to be unable to work with their old techniques.

2.7. Statistical analysis for questioner responses

After extracting the results from the Google form, a statistical analysis was performed by the SPSS application. Chi-square, Pearson’s, and Spearman tests were performed to determine the correlation between the respondents’ answers (Wegener and Dm, 2019), and the correlation matrix was conducted, as shown in Fig. 7.

It is observed that there is a moderate inverse correlation between age and using computer-aided software. Architects that do not use computer software have over 20 years of experience. All the younger ones are good users. Although 74% of respondents claimed to know about parametric design, there was no correlation between the years of experience and the knowledge of parametric design. Similarly, 80% of respondents stated that they did not use parametric software, and there was no correlation between years of experience and the use of parametric software. It was found that most undergraduates and fresh graduates did not use parametric software.

On the other hand, 84% of respondents were familiar with the use of AI in architectural design, but there was no significant correlation between years of experience and knowledge of AI. However, there was a positive correlation between the use of drawing software and knowledge of AI design. Moreover, there was a correlation between the use of parametric software and AI software. Among the respondents, 78% were not familiar with any specific software, which raises the question of whether they understand the difference between using AI or computers generally in design. Only 7% of respondents used AI in design, and there was no
correlation with their years of experience. There was a significant correlation between the use of AI technology and the belief in its ability to produce human-like quality designs. Two-thirds of AI users believed that AI could not produce the same quality as humans and that the need for human architects...

Fig. 5. The responses to questions related to the opinion on AI technology usage in architecture.

a. If you used an AI program, did the quality of the architectural product differ?

b. Do you think AI design programs can produce designs with the same quality as humans?

c. Do you think these programs will facilitate the architect’s work?

d. Do you think AI programs will reduce the job opportunities of the architect and gradually replace him?

e. If you could stop the development of AI design software, would you do so?

f. Do you intend to learn to use such software?
would remain, while one-third were unsure. There was no correlation between the years of experience and learning a programming language, but there was a correlation between learning a programming language and using AI technologies. There was a negative correlation between the intention to learn AI Tools and the number of years of experience; the more experience a respondent had, the less desire they had to learn AI. Another correlation was found between knowledge of AI technology and the intention to learn it.

The results showed that although many respondents claimed to know about parametric design, most did not use parametric software. Conversely, many respondents were familiar with AI technology in architecture, but few used it in design. There was a significant correlation between the use of drawing software and knowledge of AI design. Moreover, there was a correlation between the use of parametric software and AI software. The study also revealed mixed opinions on the ability of AI to produce designs of human quality, with two-thirds of AI users believing that AI cannot replace human architects. Finally, the study found a negative correlation between the intention to learn AI technologies and the number of years of experience.

Fig. 6. The responses to questions related to the opinion on AI technology usage in architecture.

Fig. 7. Heatmap correlation for the different survey questions.
and a correlation between knowledge of AI technology and the intention to learn it. Overall, the study highlights the importance of keeping up-to-date with technological advancements in architecture.

2.8. Case study

Conex is one of the leading startups in using AI tools in the architectural design field in the Middle East. It was founded in 2017 by the CEO, Eng. Yusif Fahmy (Workshop for experimental products and G., 2022). The summary of the meeting between the researcher and Mr. Fahmy was as follows: Conix was established in January 2017 and got its first project in October of the same year. The business was growing gradually due to the COVID-19 crisis. The lockdown allowed the promotion of the business commercially and the tool codes. With the decline of the COVID-19 situation, the work began to come back gradually. Conix started using the Grasshopper application [https://grasshopper.app/], and adding customized plugins to the program code was the usual work for Conix. Whenever they face a design problem, they program a code to solve it. They produced tens of projects of different types in many countries. The tool produces tens of design alternatives; it ranks the best ten alternatives in zoning with areas. Here it comes the architect role to pick the most suitable one and uses codes commands one after one to finish an entire detailed villa project in about 15 min Mr. Fahmy describes Conix as a tool to help the architect, not replace him. He believes that both AI and human interventions produce the best design. AI gives humans new skills they would never have reached; it is more suitable for large-scale projects than small ones. It saves much time; the seven Conix teamwork members produced work equal to 20–30 usual architects’ teamwork. The Conix tool doesn’t cover all the human design sides, and the AI will always need a creative architect. Mr. Fahmy started his company with freshly graduated architects. He trained them to use the tool and to code using C sharp and JavaScript programming languages. Mr. Fahmy plans to make Conix an online platform or a cloud...
AI as a subscribed service for architects. He aimed at making Conix in the next five years like AutoCAD today. They emphasized that architecture students should learn to design in the bottom-up style. Change is inevitably coming, and we must hurry up to go along. Lately, Conix AI has raised $1.3 million in a pre-seed funding round led by BIM Ventures. The funds will expand the company's team and accelerate product development [https://www.wamda.com/2022/11/conixai-raises-1-3-million-preseed-round-led-bim-ventures]. Fig. 8 shows the Conix interface.

3. Discussion

The open-ended questionnaire provided a platform for participants to share their views on integrating AI in architectural practices in Egypt and its potential regulation. The feedback was categorized into three primary areas:

3.1. Role of architectural entities

(1) ‘AI’s Inevitability: Most respondents acknowledged that the evolution of AI in architecture is unavoidable and can offer significant advantages.

(2) Regulation and Control: There was a strong sentiment that architectural unions and engineering syndicates should actively regulate ‘AI’s growth. This is to ensure that the rapid advancements ‘do not adversely affect ‘architects’ employment opportunities.

(3) Licensing: A notable suggestion was to restrict the use of AI tools in architecture solely to licensed professionals, ensuring quality and expertise in its application.

3.2. Architectural education

(1) Balancing Graduates with AI: Some respondents felt that to counteract the jobs AI might replace, there might be a need to limit the number of architectural graduates.

(2) Curriculum Revamp: There was a consensus on modernizing the educational syllabus to incorporate AI and its related courses.

(3) Continuous Learning: The importance of workshops and training sessions was highlighted to keep current architects updated and well-versed with AI advancements.

3.3. Individual architects and AI

(1) Efficiency and Problem-solving: Respondents agreed that AI could significantly enhance design efficiency and streamline problem-solving processes.

(2) Human Touch in Architecture: Despite ‘AI’s capabilities, participants emphasized its limitations, particularly in understanding human emotions and cultural nuances vital for architectural designs. They stressed that architects should accentuate these humanistic elements, ensuring their indispensable role in the field.

(3) Future of Human Architects: A prevailing belief was that while AI will play a significant role, the demand for human architects will persist. The nuanced understanding and human touch they bring to projects are irreplaceable, and they will always be essential to guide and optimize AI applications.

In essence, while ‘AI’s integration into architecture is seen as a positive evolution, its regulation, the adaptation of educational systems, and the irreplaceable value of human architects were underscored as critical considerations.

3.4. Conclusion

After examining the survey data, it's evident that ‘AI’s role in architectural design needs thorough scrutiny. While many are acquainted with AI in design, ‘there's a gap in specific software and language knowledge. The insights suggest:

(1) Architectural Bodies: They should regulate ‘AI’s architectural use to protect ‘architects’ roles. This includes setting rules against non-architects using AI for architectural tasks and raising awareness about ‘AI’s pros and cons.

(2) Educational Institutions: Architectural curriculums should integrate AI technology. This involves updating courses to cover AI and organizing workshops to equip architects with AI skills.

(3) Architects Individually: While AI can enhance efficiency, architects should prioritize the human touch in design, emphasizing cultural and humanistic elements that AI lacks.

In summary, ‘AI’s integration into architecture demands a balanced approach, ensuring its benefits are harnessed without sidelining human architects.

Author credit statement

This research paper, ‘Revolutionary Artificial Intelligence Architectural Design Solutions: Is It an Opportunity or a Threat?’ is a collaborative effort by three authors, who contributed in the following
capacities: 1. Mahmoud Desouki - As the lead author, Mr. Desouki made significant contributions to this research work. He was instrumental in the conception and design of the study, developing the research methodology, including the creation of the questionnaire used for the survey. He conducted the literature review, providing the necessary context and foundation for this paper. In addition, Mr. Desouki organized scheduled meetings to maintain the project timeline and to foster effective team communication. He was also responsible for the qualitative analysis of the data, ensuring the interpretation aligns with the study objectives. 2. Taghreed El-Haddad - Ms. El-Haddad played a crucial role in conducting the statistical analysis of the survey data. Her expertise in quantitative analysis greatly enhanced the precision and accuracy of the study's results, and her contributions were pivotal in understanding the patterns and trends relevant to the research question. 3. Bahaa El-Boshey - As the senior author, Mr. El-Boshey provided oversight for the entire project. His supervisory role ensured the adherence of the team to research ethics and quality standards. He offered valuable input and guidance throughout the process, which helped shape the final outcome of this research paper.

All authors have read and approved the final manuscript. They have agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Conflicts of interest

All authors declare that they have no conflicts of interest.

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