Computer Designed Architecture and Architects

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The designs generated by computer algorithms are becoming such a serious part of designers' work that some are beginning to question whether they are more the work of computers than humans. There are also increasing suggestions that software development will eventually lead to a situation where humans in the profession will become redundant. This review article aims to present the currently used, implemented, and planned computer technologies employed in the design and consider how they affect and will affect the work of architects in the future.

decline of architects | future of designing | computers control | algorithms | artificial intelligence

1. Introduction

This is a scoping review article. It aims to present current, implemented, and planned computer technologies used in the design and discuss how they affect and will affect architects' work in the future. Due to the nature of this article, a research query was conducted on the opinions of a wide range of experts. The selection of statements was based on the occupational criteria of the commentators. These include architects, scientists, developers of computer aided design software, but also writers, journalists, and even philosophers. The authors wanted to select opinions that represent different approaches to the possibility of replacing architects by computer algorithms. These comments, due to their different attitudes towards the aforementioned possibility are presented in the "Yes" and "No" subsections of this paper. The selection of opinions was also based on the different reasons that guided the commentators in forming their judgements, e.g., the development of particular technologies or limitations affecting computers and algorithms. The selection was not limited to the most recent commentaries, but the older ones from early computer development were also cited. The selection of opinion makers was focused on their experience and prestige. As a result, among representatives of scientists dealing with the described problem in their research work, opinions of professors predominate. Architects are mostly represented by a group of recognised and awarded designers, including those from well-known design studios. Design aid software manufacturers are dominated by representatives of leading companies from all over the world. This manuscript also contains statements of less known professionals. However, in the opinion of the authors, they contain important information on the described subject, which shows other, sometimes not obvious, points of view and enables a look at the described topic from a different perspective.

In the following part of the article, the obtained data are synthesised and an attempt is made to identify the patterns appearing in them. This will help to define the skills that computer algorithms would need to acquire in order to theoretically be able to replace architects.

The ultimate goal of the manuscript is an attempt to answer the question: will computers eliminate the human factor in the design of the future?

The answers to questions posed in this manuscript will contribute not only to determining the future of architecture but will also indicate the current condition of the profession. They will also help us to understand the technologies that are making computers capable of increasingly replacing human professions. Therefore, the problem described is multifaceted, and its complex character touches upon IT issues and sociological and even philosophical matters presented in this article.

2. Current Capabilities of Computers in Architectural Design

The initial use of the computer in architectural design was limited to replacing the drawing board, as exemplified by the widely used AutoCAD software. Dedicated CAD (computer-aided design) software was undoubtedly a great improvement on tedious manual work. Nowadays, there are more advanced programs such as ArchiCAD, which allow block design using predefined building components such as walls and ceilings. The design software continues to improve. Autodesk's Dreamcatcher is supposed to be the next generation of CAD. It is "a generative design system that enables designers to craft a definition of their design problem through goals and constraints. The system generates thousands of design options that meet specified goals, allowing designers to explore trade-offs between many alternative approaches and select design solutions for manufacture" [1]. The MaRS Innovation District office and research building in Toronto was designed using Dreamcatcher software. The design of the building was generated based on the needs and wishes of future users. "Software made it possible to take all of these factors into consideration to find a set of optimal options that satisfied as many criteria as possible" [2]. The benefits of generative design and examples of building forms created with this technology in Kiruna, Sweden, were presented among others by Jani Mukkavaara and Marcus Sandberg [3] (pp. 8–16).

System extensions and the introduction of the third dimension into CAD software have made it possible to integrate the various elements of a project into one thing. In recent years, BIM software, which uses "a modelling technology and associated set of processes to produce, communicate and analyse building models"[4] (p. 13) have been gaining popularity. Denis Neely noted that "design professionals are moving to BIM three times faster than the transition from hand drawing to CAD"[5], and in 2011 "BIM use reached the 50% mark among design professionals"[6] (p. 6) These programs significantly improve the work of architects, but professors Wojciech Bonenberg and Oleg Kaplinski also noted that BIM unexpectedly raises an architect's professional prestige [7] (p. 9). For instance, "the Sichuan Provincial Architectural Design and Research Institute used AECOsim Building Designer's BIM advancements to enhance information exchange among disciplines and ensure timely collection, update, management, and data application. The software enabled the institute to shorten the project period by 60%, reduced design errors by 80%, and increased design depth by 50%" [8]. Professors Oleg Kapliński and Wojciech Bonenberg consider the implementation of BIM technology (especially BIM as a process) and integrated project delivery (IPD) as "important elements conducive to the integration of architectural and engineering activities" [9] (p. 5), fundamentally affecting the work of architects in the future.

At the same time, parametric design programs are appearing, which enable the creation of ready-made structures based on parameters proposed by architects. They treat “the geometric properties of the design as variables”, resulting in a design that consists of “relationships that are maintained between the various elements of the composition” [10] (p. 1). “By far the most widely used parametric design software is “Grasshopper” developed by the David Rutten for Robert McNeel Associates and first released in 2008” [11] (p. 5). Grasshopper is a platform closely integrated with Rhinoceros— McNeel’s 3-D modeling tool, “to deal with this generative algorithms and associative modelling” [12] (p. 4). It also enables integration with sensors and software based on machine learning and artificial intelligence technologies. [13] (pp. 6–7). Therefore, it should come as no surprise that an increasing number of projects are based on this technology, which can be seen, for example, in the design of offices by Frank O. Gehry or Zaha Hadid. In 2021, a building design was presented by a Japanese architectural studio called Laboratory for Explorative Architecture and Design (LEAD) that was entirely generated by a computer program based on an algorithm prepared by the studio [14]. In addition to improving the work of designers and facilitating the design of complex, sculptural building forms, parametric design has had a significant impact on the architecture of cities such as Dubai, Doha, and Bilbao.

When it comes to AI, “in 2016, Google in the US developed the artificial intelligence (AI) applied in the field of graphic design” [15] (p. 2) called Alpha GD, which Wu Shan perceives as “a great threat to people engaged in graphic design” [15] (p. 2). Professor Duc Truong Pham notes “that there is a wide range of techniques which are capable of enhancing traditional CAD systems with advanced reasoning abilities thus increasing their prospect of being tools for intelligent design” [16] (p. 24). These include, among others: deep knowledge, non-monotonic, qualitative and geometric reasoning, uncertainty handling, and object-oriented representation [17] (pp. 15–24). Despite the increasing use of artificial intelligence in the construction industry [18][19]and design, as well as the aforementioned concerns about the future role of AI programs in design process, so far “it can only imitate the existing board, but cannot achieve independent innovation.”[15] (p. 2).

3. Will Computers Replace Architects?

People who express their opinions on the future of the architectural profession are undoubtedly aware of the continuous and unstoppable development of computer technologies, which will have an increasing impact on the design process. At the same time, they very often exclude the complete takeover of the architect’s tasks, postulating that computers will be an increasingly effective complement to the architect’s skills, allowing for more efficient, faster, and more accurate work. Dale Sinclair, Director, Architecture, Technical Practice, AECOM, agrees that “by automating aspects of the design process, such as creating multidisciplinary digital libraries that contain fabrication-ready information, more time can be spent on the design effort that makes a building unique in response to the client’s brief and relevant to its environment”[8]. He compares the art of design to music, in which “musicians have embraced new instruments from the electric guitar to synthesisers and onwards to automated composing tools, as delivery of their outputs has shifted from albums to streaming. Yet the role of the composer remains unaltered”[1]. There are also claims that despite the significant developments in computer technology and artificial intelligence, “it doesn’t have to mean that it causes job losses. As with any new technology, it’s likely that A.I. will create just as many jobs as it displaces”[20].

There is another indication that the rise of computer technology will not result in the end of the architectural profession. As reported in the National Council of Architectural Registration Boards' annual survey, the number of licensed architects has grown in the USA by 1% from 2018 and by 10% from 2010 [21]. "While the number of architects licensed in the United States has risen over 13% in the last decade, the total U.S. population has risen just 7%, according to data from the U.S. Census Bureau"[22]. There is even more significant growth in the number of architects in Europe. Between 2008 and 2018 "the total number of architects has grown by 24%" and "reached in 2018 the number of 562,000"[23] (p. 4). Although the above data does not cover the whole world, it shows that in highly developed countries, where e.g., the use of BIM technology is mandatory in a large proportion of projects and the percentage of construction companies that use BIM ranges from 20% (Austria) to 73% (United Kingdom) [24], the number of architects is increasing. This is despite the fact that in recent years there has been a rapid development of design support technologies like BIM [25], which originated in the 1980s [24].

Despite the turbulent history of building design, the architectural profession continues to exist and, despite the onslaught of information technology, it seems safe for the time being. Nevertheless, some architects like Krzysztof Ingarden believe that "further technological development, in particular the automation of design and construction processes, may go so far that it will be possible in the near future to replace man by machines, both at the design and construction stage" [26] (p. 23).

Ian Keough, CEO of HYPAR in his foreword to Randy Deutsch's book Superusers: Design Technology Specialists and the Future of Practice links the future of the architecture profession to so-called superusers, who believe that "much of what we do in architectural practice can and should be automated, but they work in a profession which has its roots in an artistic tradition spanning hundreds of years. This tradition assumes […] erroneously, that the act of 'design' is irreducibly human" [27] (pp. xi–xii). Admittedly, Keough does not say that computers will be able to completely replace humans, but he doesn't rule it out either. Randy Deutsch agrees with him and says "that the architecture profession and design industry will look radically different by 2030; and design technology specialists—a particular high-performing, high-functioning, highly connected, and highly motivated vocal minority here called Superusers—represent the near future of our industry" [27] (pp. xix–xx).

4. Theoretical Requirements for Computers to Replace Architects

According to Frey and Osborne, computers that are to replace humans in the future must be able to perform tasks that include simulating human perceptivity, human movements (manipulation tasks), must be able to handle creative intelligence tasks and social intelligence tasks [28] (pp. 24–26). While the ability to simulate human movements is not necessary to replace architects in design, the other skills seem essential. The senses enable architects to feel their surroundings. Without the senses, the concept of genius loci would not exist, i.e., the idea of the spirit of a place, which is expressed by "giving individual quality to particular places—objects, houses and complexes, cities, gardens and whole landscapes" [29] (p. 228). The senses are also essential to be able to experience beauty which is an indispensable component of architecture. Computers, that have no senses, could be capable of designing buildings but it is unlikely that they would ever be able to consciously design works of architecture.

This also raises the question, which coincides with the concerns of architects Peter Zumthor or Juhani Pallasma, expressed in previous chapters, that “if there is no initial intention to express a feeling, an aesthetical point of view, or any personal statement per se, can we still mention the existence of an artistic creativity” [30] (p. 72)? This is an important question, because even when computers will be able to design buildings on their own, there may be voices saying that this is still not architecture, since it was created without emotions. However, Deniz E. Kurt believes that “despite the absence of an initiative emotional expression of the maker, the flow of affect will occur through a bottom-up perspective, and the ‘feeling’ of an artwork will be shaped through the emotional attachment of the human spectator”[31] (p. 73). Thus, in such a case, “AI is the actor who generates the artworks by using its own interpretation”[32] (p. 74). “Hence, for AI artworks to be recognised as artistically creative, they should correspond to the human taste of aesthetics and human emotions. The absence of human emotions in a machine is an intrinsic feature that gives the aura to the artwork of that machine” [33] (pp. 75–76).

Questions also arise about the copyright of designs created by computer programs [34] (p. 58). However, it must be acknowledged, that controversy is also associated with projects created by people. Peggy Deamer in her works points out many problems concerning employment in architectural firms. She also notes that architects are responsible for an important, but limited, part of a building’s design. “In architecture, unlike the other arts no one person actually makes the object. Not only is there the significant distinction between designer and builder, or the multi-layered group of designers in an office, but the designers/manufacturers of the myriad of products used for a project bring the history of their own making with them” [35] (p. 17). Another issue is the multi-discipline nature of building design, where only part of the process falls to architects, but there are also structural engineers, installation designers, road engineers, etc. This contributes to the complexity of design and makes it difficult for computer algorithms to take over all of their skills. Nevertheless, design is a process that requires social intelligence. In this case, it is used, among other things, during the usually lengthy arrangements and negotiations with the client. They take place not only before the design work begins. Instruction changes occur even at an advanced design stage and are often necessary even during construction. Assuming that a computer algorithm would be responsible for the entire design process, which would eliminate the experts, technologists, and collaborators working with architects, social intelligence would still be indispensable for the reasons above. This view is supported by Frey and Osborne, who noted that computers that would design buildings must be able to talk to clients, have negotiation skills, and perhaps manage human resources [36] (p. 27). Andy Smith, Director of Product Management, Building Solutions, Bentley Systems, agrees with this sentiment, saying that the architect, after all, “needs to communicate the design intent to the client, explain why he or she chose certain things, and then evaluate the responses of the client’s emotions and business sense to the design. That is a human interaction that needs to happen” [1]. In addition to negotiation skills, human social intelligence includes skills such as persuasion and caring [37] (p. 26). While computers “can now reproduce some aspects of human social interaction, the real-time recognition of natural human emotion remains a challenging problem, and the ability to respond intelligently to such inputs is even more difficult. Even simplified versions of typical social tasks prove difficult for computers” [38] (pp. 26–27).

As with creative intelligence, the greatest hopes for developing this technology are specifically related to the development of artificial intelligence. However, current estimates suggest that full human brain emulations should be

possible before mid-century [39] (p. 81). The development of computer-aided design tools, as well as technologies that are likely to be developed in the future, are shown in **Table 1** .

Table 1. Development of software and technology for computer design.

Timeline	Type of Software/Technology	Software/Technology Capabilities
Past	2D Designing Software	drafting software to replace freehand drawing
	3D Designing Software	software enabling the creation of spatial structures used to generate particular parts of a design study
Present	Parametric Design	designing 3D structures and patterns following given parameters
	Generative Design	results-oriented design
	Building Information Modeling	3d modeling related to building model production, communication and analysis kit
	Building Life Cycling Modeling	modelling various aspects related to the life cycle of a building
	Augmented Reality	transferring virtual projects into real space using dedicated tools
	Neural Networks	forecasting phenomena based on initial data
	Machine Learning (ML)	collecting data and learning to use it under human supervision
	Artificial Intelligence (AI)	advanced machines and software based on neural networks and machine learning capable of solving complex problems
Future	Active Augmented Reality	real-time creation of spatial models in augmented reality
	Artificial General Intelligence (AGI)/ Strong Artificial Intelligence (SAI)	advanced machines and software based on neural networks and machine learning capable of solving complex problems
	Artificial Super Intelligence	highest form of computer intelligence that will enable the replacement of humans by machines, including architecture

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