UDC: 004.8:72
10.69899/limes-plus-en-24212-3073p
Original scientific work

# INTEGRATION OF ARTIFICIAL INTELLIGENCE IN PROFESSIONAL ARCHITECTURAL PRACTICE

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**Abstract:** *The research and application of Information and Communication Technologies (ICT) in various processes within the Architecture, Engineering, and Construction (AEC) industry have been present for decades. This practice continues with contemporary advancements in the field of Artificial Intelligence (AI), especially through software designed for widespread adoption and consumption by architects and other professionals in the AEC industry. The process of creating "digital twins" of buildings – computable models that simulate design, construction, building performance, and maintenance – requires very strict parametrization of different elements and procedures that constitute the composition of an architectural project as a whole. The concrete parametrization of building elements, in return, requires strict theoretical classifications, categorizations, structuring, and the composition of design methodology as a programmable, computable algorithm. Questions arise, such as: What is the logic behind automated decision-making? How much can we trust an automated computational model? What kind of tendencies or ideologies are embedded in the process of identifying parameters, their connections, and their relation to an architectural project? What is the underlying design methodology or design philosophy upon which an algorithm is created? The purpose of*

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*this paper is to question the integration of AI and ICT in the actual process of architectural design and to explore realistic possibilities for implementing emerging technologies in the architect's workflow that extend beyond research and experimentation into the domain of architectural practice.*

**Keywords**: *architecture, architectural design, architectural engineering, artificial intelligence, AI, AI tools, CAD, parametric design.*

## 1. THE CULTURE OF BUILDING DESIGN AND CONSTRUCTION

A building's purpose is to enable the use of spaces in a meaningful, comfortable, affordable, and secure way, and to endure and maintain desired conditions through years of weather changes, natural disasters, and many other unwanted and unexpected scenarios. The idea to design and build a building comes from the need for a durable, stable, functional shelter, storage, temple, or other archetype from the architectural language related to living and working culture. Longevity, durability, and stable existence over long periods of time are essential features that predefine the building design and construction process, making it a relatively expensive investment even in the case of a smaller housing unit or a simple hut. Reliable building materials, structural systems, and general requirements of interior spaces in terms of volume and functionality are some of the conditions for the enduring usability of a building, all of which are relatively costly in terms of resources, knowledge, skills, available machinery, and construction technology. Therefore, reducing costs by reducing time and resources used for design, manual labor, the consumption of building materials, and the resources needed for building operation is an ever-growing tendency in the construction industry, especially with the use of rapidly evolving and developing information and communication technologies. However, despite ongoing efforts and investments in cost reduction, the complexity of building design and construction—marked by the purpose of serving its users and maintaining functionality and security over long periods—makes optimizing the design, construction, operation, and maintenance process an extremely challenging task.

Since the earliest days of humanity, building various machines, instruments, and tools to further optimize, speed up, and enhance different parts of architectural and construction processes has been a common practice. The idea of achieving a goal in different, more efficient ways to produce higher-quality outputs is a consistent theme throughout the history of problem-solving. Measuring distances, and surfaces of regular and irregular land areas, measuring heights of different points on the terrain, recording precise geometry of lots and parcels for insurance purposes, and the creating of various plans and maps are some of the problems in building design and construction that are solved today with various mechanical and digital inventions.

"Indeed, when culture is introduced at all it is treated as a constraint to creativity. For instance: '[d]esigns that are based on known compositions of techniques (practices and styles) from within a culture will appear mundane.'" (Calvo M.C., 1993).

On the contrary, design itself may already include a drive for innovation, improvement, and change. The culture of architectural design, construction, and operation of buildings is embedded within the tendency to change, improve, reform, and transform the way things are thought or done – improvement in design and construction is always present. Reproduction, copying, and replication of existing designs may appear mundane, but every new architectural project has its own context and reality with unique features that affect design decisions and the final appearance of the building. Here again, it is the architect's responsibility to interpret the conditions and context for architectural design and apply skills and use accessible resources to create a unique architectural solution.

Everlasting optimization and innovation in architectural design and construction within the given environment may be the essential forces that drive and define the general culture, history, and tradition of architectural design and construction. Optimization of a building's life from the first conceptual designs to a usable constructed building is a continuous process in all cultures of architectural design. The ability to design and construct a building in a short period while preserving overall quality defines the art of architectural design and construction. Being practical and innovative in the use of accessible materials, experimenting with new building materials, using different tools, including various scientific and technological discoveries, reinventing and reusing existing technology – anything that could ease, improve, and speed up the design, construction, and operation process while maintaining building quality can be incorporated into the process of architectural design and construction.

The tendency to automate, ease, and transform the process or parts of the process of building design and construction to make the whole process more efficient is enhanced, especially within the capitalist market where form follows profit. Therefore, there are significant concerns regarding the automation of the design process to preserve the quality of building spaces that adhere to social, psychological, and ethical standards and norms. Automating the process or its parts and reducing the time needed for design does not mean there will be significant changes in the overall quality of the building and the quality of services the building should provide. On the other hand, problems of homelessness and the growing need for housing spaces due to the increase in global population and migrations to urban areas drive architects and other engineers to seek more efficient but also sustainable, long-term solutions.

"Digitization and AI require new machines (robots, automation technology), much higher data speeds (fiber optic cables, routers, higher performance microchips, sensors, data transfer infrastructure), and data storage with larger volumes such as significant higher data capacity (data clouds, IoT, AIoT)." (Weber Lewerenz, 2023). The development of new tools, faster communication, travel and transportation, the apparent ease of use, and mass adoption of technology additionally create new layers of archetypes, new types of buildings, structures, and infrastructure, which again are subjects of optimization and development (e.g., data centers, control rooms). Investing in research of new ideas to improve existing processes is available only to larger companies and institutions. Research conducted by the Fraunhofer Institute Austria in 2022 shows that a redesign of the educational system is also required since AI and other emerging technologies require “new qualifications, new knowledge, improved transfer of knowledge between research and practice, and a new corporate culture of thinking and openness towards innovation.” (Weber-Lewerenz, 2023). Even though the Architecture, Engineering, and Construction (AEC) industry is considered to be the least digitized industry, the AI valuation in the construction market was US$429.20 million in 2018 and is expected to grow to US$4.51 billion in 2026. (Rafasanjani, Nabizadeh, 2023).

## 2. ARCHITECTURAL DESIGN

> “Conceptual design continues into design phases, the construction phase, and throughout the life of the building.” (Pena M. L. C. et al, 2021).

In this paper, the focus is on the architectural design process as the initial phase towards the creation of the building, with building construction and building maintenance and operation as consequent stages of building life. The architect’s responsibility is to define in detail the future building and, in this way, determine how the building will be constructed and operated. In essence, architectural design must incorporate detailed information about how the building will be constructed and how it will be used and maintained. The architectural project contains information about all stages of the future building’s life and must provide instructions on how to build and equip an enduring and functional building that is also aesthetically pleasing.

The process of architectural design, therefore, involves projecting different future events and scenarios regarding construction, usage, and maintenance of the building and incorporating them into the initial design – architectural plan – architectural project – instructions for the construction of the building according to the specified function. In this way, the architectural building design process is heavily influenced by available and accessible construction, maintenance, and operational building technology. Accessibility and affordability of preferred structural systems and components, various devices and installation systems, insulation, and quality and durable building materials are also some of the conditions that shape the architectural design process.

The architectural design process can be represented as a finite linear vector representing time in the sense that there are consequent phases as the project develops. The architect first collects and organizes information relevant to the project – in the second step, the information model is translated into a geometrical, conceptual model. The conceptual model is then fine-tuned and eventually presented as a set of documents that prove its legality and also serve as an instruction for construction. However, the architectural design is not a linear process but has the form of a multidimensional, multilayered model – a virtual (cognitive) model where the architect from the very beginning deals with the totality of available information (constraints, access, resources) and defined requirements of future space to be designed.

Designing complex systems such as buildings is rarely done on the first try; rather, it is a process of exploring different solutions and incorporating feedback that, in return, becomes the base for new solutions and proposals. Architectural design is a process that goes back and forth between the architect (who proposes solutions according to known information) and different stakeholders (client, users of the space, neighbors) until a consensus is achieved. Based on the given information, the architect explores future possibilities to design the building by exploring different architectural solutions – different geometries – and how they interact with given constraints, potentials, and features of the given location.

Every architectural project starts with existing constraints that already predetermine possible building design outcomes. The exact geographical location, geometrical boundaries of the construction site and the terrain, specific user needs, and functional requirements are just some of the constraints that narrow the number of possible reasonable design outcomes from the very start of the design process.

The architect's trip to the building site, visiting the site, and understanding and comprehending the environment and context of the future building are some of the very important steps in the architectural design process. Physical presence at the location for which the building is to be designed provides the architect with unique insights into the existing qualities, issues, and potentials that should be incorporated into the project – sometimes the existing conditions might be the crucial force that actually shapes the design.

Designing building extensions or adding additional components to an existing building is yet another common challenge for architects. In these cases, there are many more constraints, and the architect has to adhere to the existing geometry, style, and functions in a strict way to design a functional building extension. This task is extremely challenging when renovation, reconstruction, or similar works are done on historical buildings.

In theory, instead of building the extension, removing a part of the building may solve the problem. There may be instances where not designing and not constructing the building may be a better solution than having a building designed and constructed. It may happen that a certain function does not fit a specific location because of socio-economic, urban, infrastructure, or other factors, and no design tool, optimization, or simulation software could eventually help produce a successful design if the more general urban conditions are not met.

The meaning of culture in the context of contemporary building design and construction is phantasmagoric in any sense beyond being practical, functional, sustainable, efficient, and durable – which is the essence of a building. Aesthetics in the domain of computation become a manifestation of the architect's ability to organize, manage, sort, shape, and combine different information into the geometry of architectural language – aesthetic value emerges from the overall composition of spaces and forms that anticipate, host, welcome, and perform given functions. With the use of different optimization software in the initial stages of design, especially in terms of optimizing natural daylight exposure, passive heating, and shadowing, beauty no longer belongs solely in the eye of the beholder. In this way, beauty appears as a surplus product of the specific management of various building elements and layers into a coherent, unifying physical structure, in a unique location, in a unique moment of time, combining past experiences, contemporary tendencies, and visions of the future.

## 3. BUILDING AS AN INFORMATION MODEL

"Development of computer-based assistants must be grounded in a larger philosophical discourse which places it in a framework for addressing social concerns and providing validation for daily life." (Calvo M.C., 1993).

A philosophical approach to architectural design, in the broadest sense, must incorporate a number of different dimensions, perceptions, and realities. It is a generic feature of every architectural project to include information from various users and participants affected by the act of architectural design, engineering, and construction. This also includes information about the location, legal situation, climate, context and neighborhood, living culture, building culture, and available building and construction technology.

Architectural design is partially a task of managing information coming from different disciplines such as psychology (needs of individuals in terms of mental health), sociology (spaces for human interaction, accommodation of different human relationships), physics (the movement of air through the building, sound transfers, structural capabilities of materials in different shapes), and chemistry (reaction of building materials in different conditions). The architect juggles all of this information (and much more) from different sources and transforms it into a meaningful geometrical shape that represents the building.

To produce meaningful geometry and successful building design, the architect first has to gather and manage information relevant to the design of the future building. The architect acts as an information manager, managing different information and producing geometry as a response to that information.

The information the architect has about the project in general before stepping into any sort of design is crucial for the design outcome. With access to new information, the design changes accordingly. It is the architect's responsibility to search, gather, explore, collect, manage, and sort information and determine its relevancy, as well as the information sources related to the project, to get the overall "picture" of the reality of the architectural challenge as accurately as possible.

The more information the architect has about the existing, present context, situation, location, social context, habits, and culture attached to a specific location, and the opinions of different stakeholders, as well as about the new building and its function, requirements, and intentions, the greater the chance for the building to be designed to last and endure for a long period. The more access the architect has to the "objective reality" of the context in which the architectural project will be developed, the greater the chance that the future building will be able to address real-life problems, challenges, and situations that it will encounter after being constructed.

The architect's task is also to collaborate with other engineers (mechanical, plumbing, HVAC, renewable energy, etc.) and incorporate related systems into the overall building design. With the support of a structural engineer, the architect defines and optimizes the structural system of the building, including the exact dimensions of building elements such as beams, columns, slabs, and foundations. Eventually, all related information is used to define and redefine the geometry of the building, incorporating what is required and fitting within the boundaries and constraints. The architect's responsibility is to invent a building, a geometrical shape with physical properties, that fits within legal, physical, and natural constraints, but also to fit the limited resources, time, accessibility to materials, and construction technology.

## 4. CONCEPT

In the face of a situation that eventually requires architectural intervention, the architect's actual response or output is a more or less geometrical model based on the assumed distribution of different functions, circulation, structural features, and costs of construction and maintenance. The overall geometry – dominant volumetric – representative, encapsulating shape of the building – the concept – is one of the infinite possible geometrical shapes as an answer to the given architectural challenge. It is a result of concurrent information about the project. With new information, different concepts may be found to be more appropriate, or new geometries can open different questions and perspectives that could then be used to reconfigure existing or create new concepts.

The conceptual phase of architectural design – referred to as the concept – this terminology is mostly used to describe the process of essentially brainstorming by an architect or a team of architects. The conceptual phase refers to the "play" of the architect to envision, imagine, and project a future state of a specific location and its context as a whole by "playing" with different information and geometries.

The conceptual phase is referred to as "The initial form," "Building's shape," "exploration of the requirements and possible solutions," and "finding a solution in a defined search space." (Pena M. L. C. et al, 2021).

By rule, the conceptual design phase ends when the geometry of the building is well established and going back to significant changes becomes impractical and uneconomical. At this point, details are already defined, and there is enough time to annotate, label, draft final drawings, prepare layouts, render, and prepare a final product form of the architectural project.

As changes to the design of the building form become less and less significant in terms of affecting the operation of the building, the building's effect on the environment, resource allocations, and possible structural systems to be used for the building's base frame – the conceptual stage of the design comes to an end. This continues until the point where making significant changes to the overall design is not economical and starting the design from scratch would not fit the given resources and deadlines.

The conceptual phase of architectural design is very vaguely defined, and in this phase "design requirements are not yet well defined." (Pena M. L. C. et al, 2021). Even though there is an obvious tendency to represent design as a pure information process – as the "production of a description of an artifact sufficient that the artifact may be manufactured" (Calvo M.C., 1993) – the transformation of (textual) information into (physical) geometry cannot be ignored and represents an essential part of the design process. This is exactly why the automated production of a concrete geometric description of the building is challenged by the fact that many important parameters are "often described quite vaguely" (Nourian, 2023).

It is with geometry that the architect operates, changes, transforms, and composes as the best possible solution is searched within the space of constraints (physical, legal, and economic) and the space of possibilities. The actuality of decision-making in architectural design refers to the process of transforming information into geometry – into exact geometrical boundaries, shapes, and forms. The transformation of available information into a three-dimensional geometrical structure represents the most important part of the conceptual stage of design. Exploration and production of different geometries in search of the most optimal one that best fits and exploits given constraints represent dynamic, multi-layered, multi-dimensional processes that make up the conceptual design phase. This means that even with the best insulation materials, the building will be damaged by underground water humidity if the geometry of the building and its structure are not properly positioned in the design phase. The cost of the construction work can be greatly reduced or increased with different architectural solutions on the given terrain.

## 5. ARCHITECTURAL INTELLIGENCE

"Following such reduction, the subject – the designer is separated from design, which may then be automated, and the designer is removed from his/her role as the active agent of design and positioned to control the process from without." (Calvo M.C., 1993). In a scenario where there is a program capable of generating building designs from "scratch" for a given location, function, and size (generating designs from initially inputted parameters or prompts), the role of the architect will be solely preserved within the actual architecture of the whole information process (of an algorithm). The architect will be designing the information model that operates with the input parameters in a specific way to produce meaningful building designs (and eventually construct and operate the building too). The architect's job will be to design the algorithm that processes the information in a specific way to generate meaningful architectural geometry.

What may be the most challenging issue in creating a general architectural intelligence – an autonomous system able to generate reasonable building designs – is the fact that every architectural project has many specificities and is unique in many ways, including the boundary shape of the location, climate, available resources, and priorities in terms of styles, functions, and building materials. Even with an autonomous system, it seems that the architect would still have a lot of work to do in terms of adjusting the system for a specific project and adjusting different parameters according to the unique qualities of the building site.

"As designers, we are valued for our individuality; we all 'see' the world in different ways, and our genius lies in the application of that vision." (Calvo M.C., 1993).

Architects may be different, but every project is different too. Every architectural project shares a larger part of the design process in terms of design phases and even tools, but each architectural project has a different location and context, which by rule has the greatest impact on the design outcome. The information about the terrain's geometry, shape, slopes, and different structures will be one of the predominant factors in the overall design of the building regardless of its function. For each function, the same terrain would be treated differently, but the specific terrain structure already predetermines many potential outcomes regarding available resources. In some cases, the possible design outcomes could be largely affected by available construction tools and machines, for example.

"Knowledge-based systems are likely to substantially change the manner in which knowledge is acquired, applied, and exchanged." (Calvo M.C., 1993).

Using computers as an aid in design means that the theoretical, conceptual idea of the building design, meaning, and representations need to be translated into "machine language." The building design process must be properly structured because it is the only way it can be used inside computer software. The translation of the building design process and the theory around it differs from project to project, and there has never been a standardized methodology for how a building should be designed – what the priorities and goals should be. In this way, the introduction of "knowledge-based systems" into building design through software development conforms with modern design theories that aim to replace architects' free interpretations with concrete data. The intense involvement of an architect's personal superstitions and presuppositions in the design process is not valued in the literature concerning design ontology. Problems such as an architect's "fixation" on ideas and solutions are reported to be common issues that prevent the development of meaningful solutions. (Restrepo, 2004). The architect must balance the actual reality of the project, constraints, dominant forces, and personal affinities, desires, and ideas. The architect should always try to ignore personal affinities and visions and focus on the actual, real information present in the context, basing solutions and proposals on information relevant to the project.

By automating the design process, the only thing remaining for the architect is to know (learn) how to use the system, software, or tool, and how to control the program or robot to make desired effects and adjustments to the digitally generated model. For a completely autonomous architectural design generator to work, it must be trained on a large set of architectural projects. It would first be shown how the architectural design process works for various locations, functions, and styles, from which architectural intelligence would emerge. From this perspective, creating a working, usable autonomous architectural intelligence able to generate reasonable architectural solutions seems to be an extremely expensive undertaking with little chance for significant success. In some works, architects or multidisciplinary teams can program and design software to fit the needs of specific tasks or research, but this is an extremely challenging task for architects and designers without professional coding experience. Even participation in such research and experimental projects requires architects and designers to have a deep insight and significant knowledge on a variety of topics within Information and Communication Technologies.

## 6. COMPUTER-AIDED DESIGN

In today's practice, architects use various tools and instruments throughout the design process. The use of notebooks and pencils to sketch ideas or record information, measuring devices, and various computer software are some of the many essential tools for the performance of the contemporary architectural office. In large projects operating with substantial amounts of information and data, efficient and fast communication between project stakeholders enabled through the internet and various software and hardware is crucial for meeting reasonable deadlines when delivering architectural projects.

In contemporary architectural practice, CAD (Computer-Aided Design) and BIM (Building Information Modeling) are the two most common digital interfaces that architects and other engineers use for different parts of project design and management. Architectural practice today is inseparable from the use of computers and various software. CAD (AutoCAD, SketchUp, etc.) and BIM (Archicad, Revit, etc.) software are commonly used in the AEC industry to draw final building plans and documents.

CAD refers to software that acts as 2D and 3D drawing tools, enabling engineers to more easily represent design ideas. Software such as AutoCAD or SketchUp are CAD software that ease the drawing of complex 2D drawings and 3D models by introducing the concept of different layers, grouping options, duplication, arrays, and all sorts of other tools that can make the actual production of representation in the form of drawings or 3D models more efficient.

From this point, the concept of BIM introduces dynamic relationships between different drawings (floorplans, sections, ceiling plans), information about building elements, and different design and building stages by combining information into one single 3D model. BIM software has preprogrammed basic and complex building elements (walls, windows, roofs), and these elements are then represented on any section, plan, or scale without the need to draw them over and over again.

According to Nourian (2023), "CAD and BIM are heavily focused on geometrically representing building elements and facilitating the process of construction management." Stojanovski (2021) reports that BIM denotes software for the design, construction, operation, and maintenance of buildings and infrastructures, while BIM software such as Revit and Archicad is "seldom used in construction, operation or maintenance." Hanafyl (2023) emphasizes the communication aspect of using BIM technology, which enables "exchanging design data with one another, allowing the many project participants in this system to efficiently interact and communicate, which helps to lower mistakes and boost efficiency."

In simple terms, the difference between the application of CAD and BIM in architectural design is such that if using 2D drawing software, the architect has to draw each building element, such as a column or wall, separately on each of the drawings where this element is represented—on every cross-section, plan, structural plan, etc. In BIM, by using predefined 3D objects that have the properties of columns, beams, and slabs, the actual drawings of the architectural project are automatically generated from the 3D model of the building. The architect rarely has to actually draw the building elements; instead, they are picked from a palette and positioned in space.

There are a lot of works and research efforts trying to expand the use of computer software beyond simply serving as a "drawing board" (Stojanovski, 2021) (Cudzik, Radziszewski, 2018). However, most experimental projects in this direction are done "through conventional mathematical or computational procedures," and using Artificial Intelligence is considered inefficient in terms of "resource-efficiency, interpretability, transparency and explainability" (Nourian, 2023). Such applications based on mathematical models include "performance evaluation, optimization of structural solutions and erection processes, and parametric design" (Jaruga-Rozdolska, 2022). Another example of a mathematical model is swarm intelligence, which can be leveraged to "optimize energy usage in building design, offering an approach that harmonizes design aesthetics with sustainability" (Zhang et al., 2023). In research done by Kong (2022), for example, the results are obtained based on a mathematical model and static input data to observe the fire accident situation in a single-person apartment. It is clear that there is a lot of space for AI technologies to be implemented into existing software and procedures related to design, but the complexity of building design, construction, maintenance, and operation makes this an extremely challenging task.

In eCAADe 2018, Computing for a Better Tomorrow, Volume 1, and many other scientific resources, there are numerous reports mentioning the use of Autodesk Revit in creating more advanced computations that can be integrated into building design. This is mostly the case because Revit is a globally used software that shares an underlying data structure – that is, all architectural projects done in Revit can be analyzed, studied, and examined through the same set of parameters. In this case, Revit offers a rare potential to have AI integrated into the actual decision-making process that could be available to a larger audience of architects, which would be trained on a very large data set coming directly from building information models.

## 7. INTEGRATION OF AI IN ARCHITECTURAL DESIGN

Definition of the actual meaning of the phrase "Artificial Intelligence" seems to be quite a challenge because there are different levels of depth and different discourses in which various aspects of AI are important and relevant. Calvo (1993) identifies two approaches to the integration of AI and knowledge-based systems into architectural design: systems that can produce designs on their own and systems that can assist designers. Based on the level of intelligence, Rafasnjani and Nabizadeh (2023) divide AI into three categories: "artificial narrow intelligence (ANI), (2) artificial general intelligence (AGI), and (3) artificial super intelligence (ASI)," sequentially representing higher levels of intelligence from semi-autonomous to fully autonomous AI. Hanafyl (2023) defines AI as "a machine that replicates human cognitive processes including problem-solving, pattern recognition, and learning." Mohammad (2019) reports that AI is a branch of computer science involving the development of "computer programs to complete tasks that require human intelligence," including algorithms for "learning, perception, problem-solving, language understanding, and logical reasoning." Jaruga-Rozdolska (2022) sees AI as a "computer's ability to mimic intelligent human behavior" such as "analyzing information, recognizing objects and sounds." "Learning, knowledge representation, perception, planning, action, and communication" are six major components of AI, as reported by Rafasnjani (2023).

Deep Neural Networks (DNN) (Harapan 2021), Generative Adversarial Networks (GANs), Latent Diffusion Models (LDMs), and Segment Anything Models (SAMs) (Zhang et.al) are some of the specific AI technologies focused on graphic approaches, generating conceptual designs, and the general application of AI in the architectural software domain.

On the other hand, architects and multidisciplinary teams are developing their own tools based on AI technology. In research done by Hussain (2024), Deep Convolutional Neural Networks (CNN) are used to train (teach) the system to predict potential floods based on 9000 selected digital images from different sources. Even though this research is not directly related to architectural design, it shows how AI technology can be used to collect, process, and use image data to potentially predict future floods.

Deep Convolutional Neural Networks (CNN) are also used in research for "classifying works belonging to 34 different architects" (Yoshimura). The proposed model reports satisfying accuracy and points to interesting outcomes, although there are limitations such as differences in the number of works representing different architects ("the maximum number is more than 1,400, the minimum one is only around 200"). The conclusion is that CNN can help "analyze visual similarities between types of architecture and create typologies and classifications of their design features."

In another example, AI technology is combined with swarm technology to propose ABM (Agent Based Modelling) as a tool to shape architectural spaces according to information from intelligent agents exploring the digital space of the building. Even though such experimental projects are always welcome and necessary for further development and correct implementation and integration of new technologies in the design process, there is much to be done to improve data quality and outcome precision. (Yi H).

"Based on the machine learning concept, diffusion models are trained by learning knowledge from a vast amount of data [11,12] to generate diverse designs based on text prompts [13]." (Chen 2023).

In recent years, there has been growing popularity of AI-based tools extensively used by architects, mostly including tools for generating images by pre-trained models that can generate visual information based on textual prompts inputted by the architect. Generated images can be further refined through different options, and these models are being improved daily with new features and control options being continuously added. There is already a large amount of literature that deals with tools such as MidJourney, DALL-E, NightCafe Studio, and similar AI image generators.

Zhang et al. (2023) reports an "empirical analysis using Gaudí's work as a reference to assess the potential of AI in replicating his style." The author explains the research to demonstrate the "possible direction of AI implementation in the field of architecture." Jaruga-Rozdolska (2022) used MidJourney to explore different ways it can be used by architects and proposes three different ideas: 1. Using the textual prompt "Project in the manner of…" to generate images of architectural projects based on the style of a specific architect. MidJourney can generate apparently completely new images of architectural projects as it uses existing image data labeled with architect's names. 2. Exploring different architectural designs by typing specific style references such as “Baroque-style façade.” 3. Using MidJourney to generate a “customized set of inspirations,” that is, conceptual design images, by typing different textual prompts such as “underwater modern restaurant concrete.”

In the next step of the evolution of AI tools, architects and multidisciplinary teams are expanding existing models such as Stable Diffusion, MidJourney, and DALL E2 to be more accurate for the purpose of architectural design, since they originally “have limited applications in architectural design due to their inability to embed specific design style and form in the generated architectural designs” (Chen 2023). The research paper by Chen (2023) “aims to enhance the controllability and usability of diffusion models to generate master-quality architectural designs of specified design styles.” The research concludes by underlining the limitations of the proposed idea: the “designer still needs to remodel the generated renderings into a 3D model in the construction stage,” and “only the design styles of eight master architects were collected for the training data,” which are common limitations in many similar explorations of the use of AI tools in architectural design.

## 8. CONCLUSION

Ongoing projects concerning the integration of new technologies to improve the design process are promising, but it seems that there are still basic questions that need to be answered before there will be results significantly applicable in everyday architectural practice. What could really improve the architectural design process in relation to construction and engineering-related industries? What should actually be computed? Which area of architectural design deserves specific attention? How could design tools be made to help improve the design of better buildings? What areas are most crucial to be researched to improve the automation of the design process – making it more efficient, faster, more economical, and communicative, while preserving and exploring possibilities of higher levels of comfort, durability, flexibility, and perseverance of the building? These are some of the many questions regarding "first principles" and require examination of critical theoretical foundations required for the successful use of computer aid in design.

Most of the results provided by research in the field of applying AI in architectural design are still at the level of recommendations and inspiration. For example, Weber-Lewerenz's (2023) study "provides concrete innovative approaches for the future of cities, working and living environments for today's society and all future generations." Nourian (2023) reports that even "what needs to be attained from buildings is rather absent in the literature" – there is no "structured discourse based on an explicit representation of decision variables and outcomes of interest." Stojanovski (2021) also reports that "despite recent advancements in Deep Learning (DL) and Artificial Neural Networks (ANN), AI has not yet been integrated into Computer-Aided Design (CAD), Building Information Modelling (BIM), or Geographic Information Systems (GIS) software" and that most of the work in this area is focused on "experimentation at the academy and with student projects." Yi (2020) suggests that "the existing tools and methods are not fully supportive of architectural practice."

Cudzik and Radziszewski (2018) recognize the results of many projects in the field of AI application in architectural design to be "rather conceptual geometries than architectural forms" and that "fully user-ready AI systems should be based on structured data, which in terms of architecture is provided by the Building Information Modelling process."

Zhang et al. (2023) report on the limitation of AI technology such as machine learning (ML) that "it requires customization for each project, with data collection, preprocessing, and computational power being crucial elements." In most, if not all, cases presented here and existing in many other places, an AI-generated image or result obtained using AI technology "represents no more than the initial stage of creation—it remains an architect's role to assess the feasibility of the building, make the necessary adjustments, determine the parameters of the building, and draw its functional plan" (Jaruga-Rozdolska, 2022).

Midjourney, Blockadelabs, Meshy, LumaAI – and many more AI-based tools – are already changing the way many jobs are being done or procedures within specific jobs. Even in the relatively early days of success, these tools are able to generate high-quality, detailed, realistic images, videos, animations, 360 panoramas, 3D environments, and models in seconds. Workflows that usually required many hours of work and very expensive equipment in terms of hardware and software are now available to an extremely large audience to use in creating multimedia using prompts written in natural language. With the rapid development of these tools for various media generation – 3D models, music, animation, computer code – whole industries are being transformed, such as the gaming industry or multimedia design in general. Even the skill of 3D modeling, texturing, and rigging 3D models, considered to be one of the most complex computer skills, is rapidly being undermined by the development of 3D model generators such as LumaAI and Meshy.

In this context, the question remains: How can architects benefit from contemporary trends in the development of Artificial Intelligence, especially from already massively adopted tools like various image and video generators – even 3D model generators? Or should the question be what will architects lose because of these tools?

In the shown examples, focused more on the visual part of the design process, there is not much applicable information on how AI could support contemporary architectural practice and real project design and management. There are examples of the use of AI on the level of conceptual design, but they are still very limited and require further exploration to be considered examples of good practice. On the other hand, the most famous AI tool that eventually started the AI craze – ChatGPT – may be extremely useful when it comes to architectural project design in general since architects operate with a lot of textual information.

NLP (Natural Language Processing) is a subfield of AI technology and is able to process and analyze information in the form of human language as a machine language by using "processing techniques such as dependency parsing and phrase-structure parsing." This opens the possibility to "extract and retrieve valuable information from human language in a variety of forms to facilitate work such as interpreting stakeholder opinion, checking the compliance of building designs with building codes, and automatically assigning workforce and arranging staff" (Rafasnjani, Nabizadeh, 2023).

ChatGPT is the most famous online AI tool that uses NLP technology. In a paper focusing on the use of ChatGPT in architectural design, Nitin Rane et al. (2023) mention a variety of different examples where this tool can be used to generate various textual information to help design and manage architectural projects. Topics such as "architectural theory, design documentation and explanation, user interaction, cultural research and sensitivity, building codes, multilingual support, marketing and presentation materials" are among many where text interpreters and generators could be useful. ChatGPT can analyze information "from diverse sources, including social media, to provide architects with a comprehensive understanding of public opinion on a design."

"Tools used by architects are constantly evolving. From sketches, two-dimensional drawings, and physical models to creating advanced design tools dedicated to particular solutions. Contemporary architects often use advanced computational systems to create complex forms and gain means to control and change them freely." (Cudzik, Radziszewski, 2018).

When it comes to tools in general, as well as the use of tools in architectural design, it is another dimension where creativity can be exercised. It is the architect's responsibility to first recognize something as a tool and recognize possibilities to use it to increase efficiency and quality of the design process. Inventing how different tools can be used and included in architectural design is also an area where the architect can exercise creativity. Even in the best BIM computer software (Building Information Modeling) such as ArchiCAD or Revit, which extremely speed up the overall project design process, architects always need to improvise with the use of otherwise limited tools to create more complex structures. It may be more the case that architects should exercise creativity to recognize, experiment, and develop ways to use various tools to increase their performance and the performance of their teams. There is already a common saying that jobs will not be taken by AI but by people who will be able to leverage the potentials given by AI technology.

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