PROSPECTS FOR THE DEVELOPMENT OF THE USE OF ARTIFICIAL INTELLIGENCE IN DESIGN AND CONSTRUCTION

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Abstract. Tools and methods used by architects always had an impact on the way buildings were designed. With the change in design methods and new approaches towards creation process, they became more than ever before crucial elements of the creation process. The automation of architects' work has started with computational functions that were introduced to traditional computer-aided design tools. While these high-tech computers aren't good enough for some ideas, you'll have to rely on human intelligence. However, they can be used to save a lot of time by completing some time-consuming tasks and we can use that time to create some other designs. The geometry and efficient use of the space, building material amounts, wind patterns, load bearing weights, and even foot traffic are all areas ripe for AI.

Keywords: artificial intelligence, mechanical system, design, 3D printing, simulate, architecture, robots.

Introduction. The automation of architects' work began with the computational functions provided by traditional automated design tools. Although these high-tech computers are good enough for some ideas, you still have to rely on human intelligence. However, they can be used to save a lot of time by completing some time-consuming tasks, and the architect can use this time to create other designs. This article considers the possibilities of using artificial intelligence in architecture and construction. There are many ways to involve AI, and we have analyzed a few of them. This is the use of 3D printing in the construction of houses, the development of plans according to the given requirements, and the quality control of construction execution using an iPhone or iPad.

Analysis of the latest sources of research and publications. The article is based on the theoretical provisions set forth in the works of S. O. Khan-Magomedova, A. I. Kapluna, A. G. Rappaporta, I. A. Azizyan, A. V. Ikonnikova, A. V. Ryabushyna, O. M. Shukurova, V. L. Hayta. Along with general theoretical works, research related to the search for «project thinking matrices», «project language», development of programs for «automated means of designing construction objects», «automated design systems», presented in the work of L.M. Avdotyina, L.D. Broner, E.P. Grigorieva, A.E. Gutnova, N.M. Notkina, E.P. Kostogarova, V.I. Retinsky, A.P. Roma, D.M. Yablonsky. Some researchers (for example, Neil Leach, Roland Snooks) are engaged in the implementation of artificial intelligence, which will allow teaching a computer to solve the task of obtaining an architectural form based on spatial composition.

Formulation of the task. The main tasks of the article are:

1. To consider the use of artificial intelligence in architecture and construction, using the example of world experience.
2. To analyze the main methods of designing with the involvement of artificial intelligence.
3. To identify further prospects for the development of the use of innovative technologies in the process of designing and constructing modern buildings and structures.
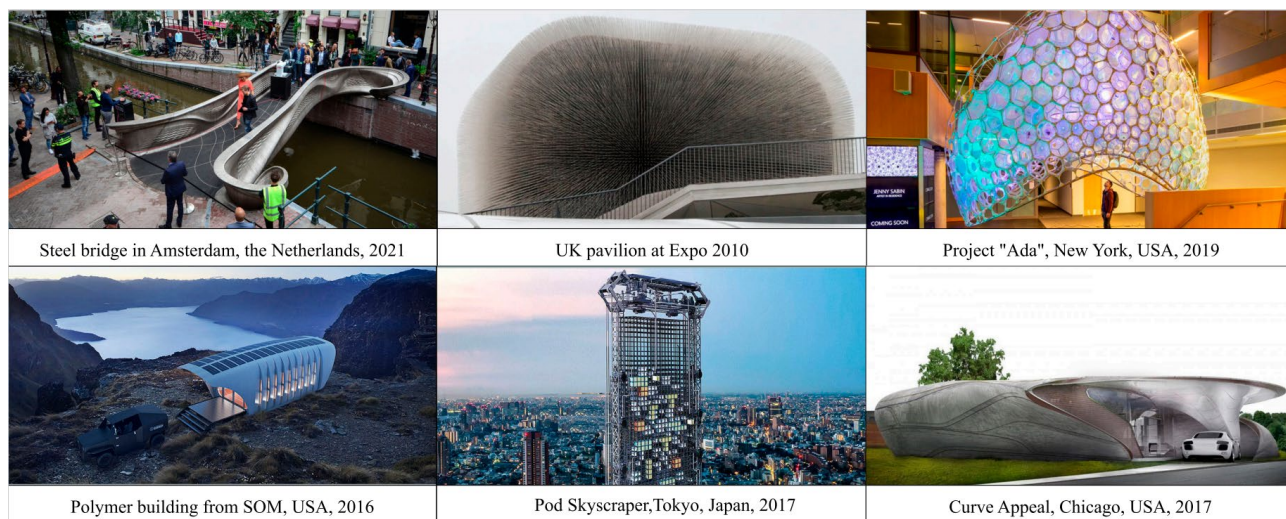
The basic material and results. Nowadays architects tend to use specified tools that suit their specific needs. In some cases, they use artificial intelligence. Despite many similarities, they have different advantages and disadvantages. Therefore, the change in the design process is more visible and unseen before solution are brought in the discipline. The article presents methods of applying the selected artificial intelligence algorithms.

Artificial Intelligence (hereinafter – AI) is a high technology mechanical system that can perform any task but needs a few human efforts like visual interpretation or design-making etc. AI works and gives the best results possible by analyzing tons of data, and that's how it can excel in architecture [1].

Artificial intelligence and robots are, first and foremost, terrific helpers. Automation tools are an extraordinary helping hand on the small scale, able to speed up the research and design process at the personal level. For example, one of the biggest challenges of an architectural design process is the information gathering step, taking pictures, measuring, and sketching. However, there's a lot of information that is already available online that allows the professional to tap into it and simulate almost perfectly the surrounding site without being physically there. And all this information is passively collected by the IoT every day. Smart tools can harvest this info and help the architects generate a believable environment with minute precision without having to leave their offices. There's no need to explain how useful this computational power can be in the creative process.

New tools now allow the architect to just input their project parameters and the software will then suggest a range of solutions that fulfill these criteria. For example, the Dreamcatcher software has been designed to integrate optimized parametric design with Revit and Dynamo. CAD models of the surrounding site and other data are collected from huge cloud databases, and then a machine-learning algorithm suggests optimized 3D design solutions ready to render. The results are amazing, as the software often imitates structural rules found in nature to generate fluid and potent forms that have been used, for example, to develop MX3D's steel bridge in Amsterdam [2].

The concept Pod Skyscraper was inspired by the avant-garde capsule structures proposed by the Metabolist Movement of Japan in the sixties. Skyscraper that would mass construct homes on site through methods of 3D Printing. Architecture practice SOM has created a 3D-printed structure that generates its own power and shares energy with a companion vehicle, providing a model for off-grid living, reports Dezeen. Branch Technology's innovation in the 3D-printing process opens the door for the creation of more complex design forms. The arching form provides structural rigidity to the residence, using various spring points throughout the floor plan, allowing the structure to carry roof loads and provide large open-plan living spaces, shaping structures in new ways without any restrictions (pic. 1).

Steel bridge in Amsterdam, the Netherlands, 2021	UK pavilion at Expo 2010	Project "Ada", New York, USA, 2019
Polymer building from SOM, USA, 2016	Pod Skyscraper,Tokyo, Japan, 2017	Curve Appeal, Chicago, USA, 2017

Pic. 1. Delta printers

Having considered the use of artificial intelligence in architecture and construction, using the example of world experience, it is possible to distinguish 3 ways of involving artificial intelligence in the design and construction process:

1. Full-stage construction thanks to AI.
2. The contribution of AI in building and creating designs.
3. Using AI to analyze quality levels and security risks.

Full-stage construction thanks to AI. One of the most authentically amazing uses of AI in architecture is the implementation of fully automated robots and drones that could build entire cities. Thanks to the possibilities provided by machine learning, autonomous drones can now collaborate to build architectural structures by working together as a team.

But machines can do more than just pile up a couple of bricks. Integration between 3D printing technology and AI software has the potential to give birth to a new generation of «robot crafters» that can craft every component of a building from scratch. They can even arrange complex structures, print building-scale rooms from sandstone, or even repair ancient statues with amazing precision (pic. 2).


Pic. 2. Delta printers

Eventually, they will also help in construction job sites, dealing with almost every task, from welding, to concrete dispensing, and optimizing logistics and human resources. They can be used to prevent risks and improve safety, for example, by identifying missing elements and mistakes in the construction process in real time.

The contribution of AI in building and creating designs. Machines and Softwares have previously impacted the architecture and engineering industry tremendously before, the Introduction of CAD design tools is described as "the greatest advance in construction history" has improved the entire industry. The role of an architect today to illustrate where artificial intelligence can be beneficial. The first fact is that: the contribution of AI in building and creating designs in which data is based on previous agendas and precedents, as well as create a new platform of designing according to the constantly changing needs of the people and the project requirements [3].

The project developed by the Harvard school of design, that illustrates how Artificial intelligence machines can generate and implement plans that fit the requirements of a given style (pic. 3). After an initial study in the potential of AI-generated floor plans, Chaillou's project developed into training and tuning an array of models on specific architectural styles: Baroque, Row House, Victorian Suburban House, & Manhattan Unit. The study reveals how style carries a fundamental set of functional rules that define mechanics of space and control the internal organization of the plan (pic. 4) [4].
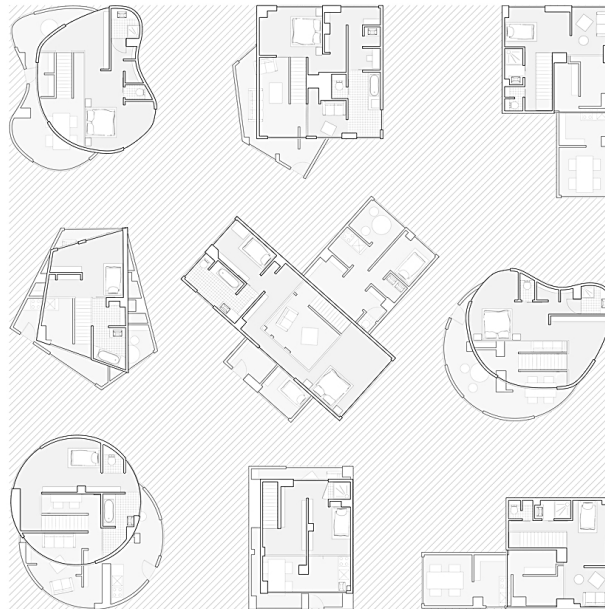
Pic. 3. Converting floor plans from one style to another by GAN

Original Plan   Segmented Plan   Baroque Translation
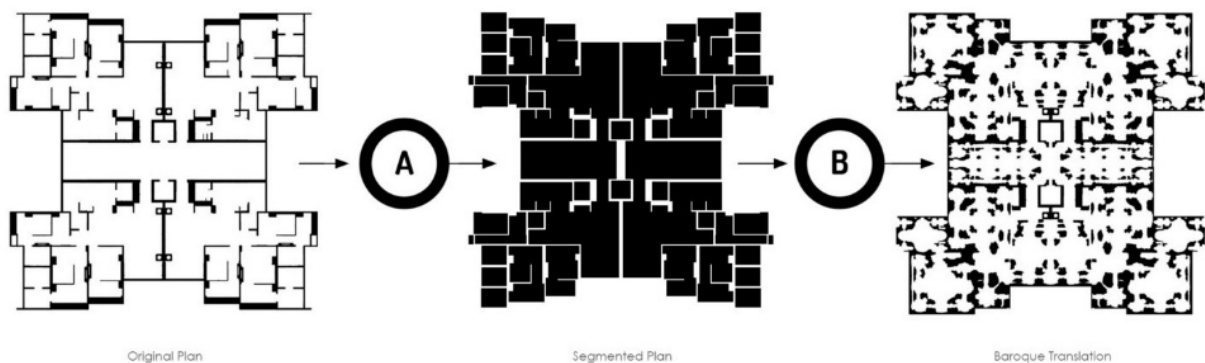
Pic. 4. Chaillou applied this technology to floorplan design, using image representations of plans as data format for both GAN-models' inputs, and outputs

Another example of generative design is Delve, a real estate development tool from Google's Sidewalk Labs. Delve can generate hundreds of designs in minutes. Each design considers various requirements such as retail, residential, parking, and public spaces. The designs also have a detailed cost model to show estimates of what a given design should cost [5].

Another reference was from the why factory explains the development of the block maker tool which is an algorithmic tool to how AI can power buildings according to users' needs. As well as a reference from Spaceform, which include a virtual reality tool that can showcase how design decisions affect the overall experience and the building itself, to clients and architects together by the given data. This allows for adjustments and improved design outcomes. The second fact is that: AI machines are currently developing into machines that can produce creative designs, created under certain industries like Google's Deepdream machine that produced a classical composition painting, which can be in comparison with paintings done by a human.

Using AI to analyze quality levels and security risks. The BAM Ireland company implemented the Construction IQ solution, in which machine learning algorithms are used to process the data of a construction project from BIM 360, automatically determine the level of quality and safety risks.

The solution works as follows: the site foreman uses an iPhone or iPad to review checklists and fix problems on the site in BIM 360 (pic. 5). Construction IQ applies machine learning models to automatically analyze such data and predict problems that are associated with maximum risk. Problems with a high priority are displayed on the Insight control panel in the form of simple and understandable emergency notifications.
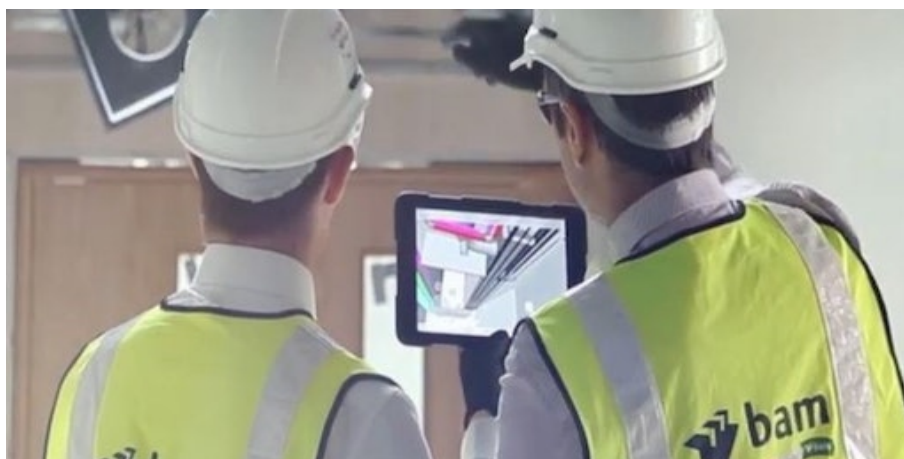
Pic. 5. BAM Ireland reviewing models in BIM 360

For example, in one of the BAM projects there were several unresolved problems, which is typical for the current project. Several such errors, discovered in the process of quality control, were associated with the absence of a moisture-proof sealant in the joints of the windows. Construction IQ classified such problems as related to the risk of moisture ingress and marked them as «high risk». "The beauty of this system is that it looks across all our projects," Tritschler says. "It's learning what we consider a risk to be. The more important ones will be pushed up the list for immediate action, and the less important ones will be pushed down the list" [6].
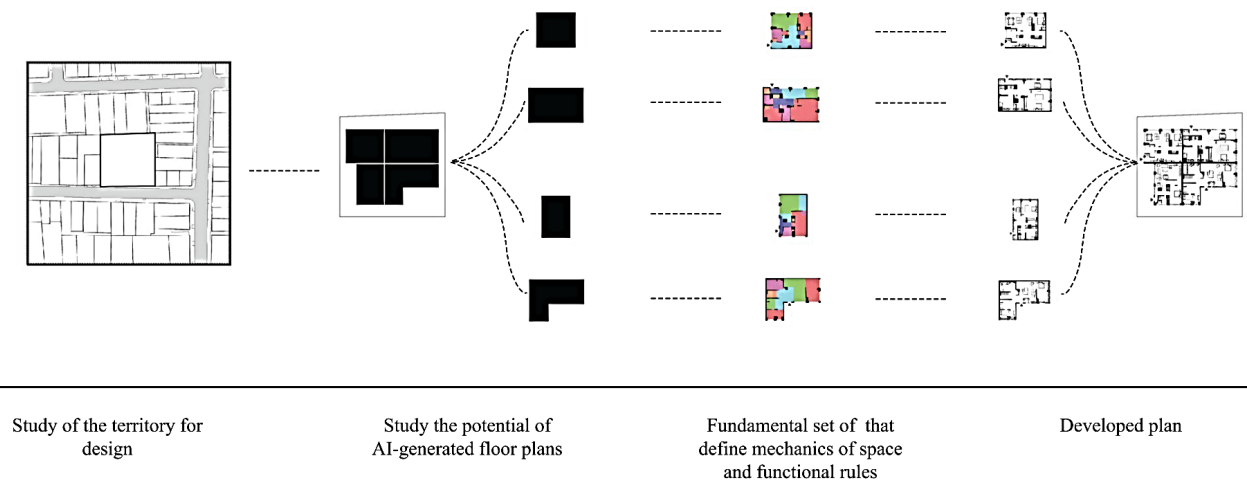
Directions of development and classification of digital methods of architectural design. Two main directions of digital architectural methods can be distinguished: parametric and generative. Parametric design methods stimulate the development and implementation of computer tools for performing certain tasks, for example, for modeling a complex shape, creating an automated model with variable parameters. That is, the architect creates a form according to his aesthetic ideas, and the computer decides the further technical points, keeping the architect's initial idea. In this case, computer tools help to make a flexible parametric model that can be changed at any level of the geometric code (point, line, surface, volume). On the other hand, there are generative methods that help solve architectural tasks by creating a large number of design options. Thus, the digital model is

subject to computer generation, and the architect controls the correctness of the initial data (technical task), the direct relevance of the computer code and chooses the most optimal one from the many options offered by the computer, including from an aesthetic point of view (pic. 6).

After considering ways to involve artificial intelligence, we concluded that innovative technologies can be divided into two groups, according to the time of application in the design process.

Classification of the use of tools at different stages of design:

▪ at the concept stage, architects use a wide range of different generative design tools for pre-project analysis and form finding;

▪ at the stages of design and work documentation, generative methods are narrowed down to tools that contribute to the optimization of the digital model and help with the release of drawings, reducing routine processes.

| Study of the territory for design | Study the potential of AI-generated floor plans | Fundamental set of that define mechanics of space and functional rules | Developed plan |

Pic. 6. Scheme of the stages of design with the help of AI based on GAN technology

Conclusions. The effects of artificial intelligence on the architecture profession are yet to be defined since the topic is highly current and is still under development. The advantages of AI are attracting people and companies to adopt them, though the consequences of their rise on people's lives, industries, and jobs remain unknown. In the case of architecture, AI will increase efficiency in the design and construction of buildings as well as create multiple solutions that will push boundaries of architectural developments and it is an opportunity to discover what ways the world could be improved through AI.

Having considered the use of artificial intelligence in architecture and construction, we can say about their strong integration into construction specialties today, and the incredible interest of specialists in greater possibilities of applying innovative technologies. AI works and gives the best results possible by analyzing tons of data, and that's how it can excel in architecture.

Having analyzed the main ways of involving AI, as stated in the research objectives, it can be concluded that AI can be applied in all stages of design. Artificial intelligence is already being used in the development of building plans and concepts, in construction itself using 3D printers, and in quality control of construction using BIM technologies.

Having identified the prospects for the development of innovative technologies, it can be assumed that the spread of computers and cybernetic devices, their use in human needs will determine the standard of living in the next century. All the considered factors speak only about one thing, that is, future architects will devote less effort to drawing and more to satisfying all user requirements with the help of Artificial Intelligence.

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ПЕРСПЕКТИВИ РОЗВИТКУ ВИКОРИСТАННЯ ЗАСОБІВ ШТУЧНОГО ІНТЕЛЕКТУ В ПРОЕКТУВАННІ ТА БУДІВНИЦТВІ

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Анотація. Інструменти та методи, які використовуються архітекторами, завжди впливали на те, як проектувалися будівлі. Зі зміною методів проектування та новими підходами до процесу створення вони стали більш ніж будь-коли важливими елементами процесу проектування. Автоматизація роботи архітекторів почалася з обчислювальних функцій, представлених традиційним інструментам автоматизованого проектування. Хоча ці високотехнологічні комп'ютери достатньо хороші для деяких ідей, все одно доведеться покладатися на людський інтелект. Однак їх можна використовувати, щоб заощадити багато часу, виконавши деякі трудомісткі завдання, і архітектор може використовувати цей час для створення іншого дизайна. Геометрія та ефективне використання простору, кількість будівельних матеріалів, характер вітру, несуча маса і навіть пішохідний рух – це сфери, дозріли для штучного інтелекту (ШІ).

Штучний інтелект – це високотехнологічна механічна система, яка може виконувати будь-яке завдання, але потребує деяких людських зусиль, таких як візуальна інтерпретація, створення дизайну і т. д. в архітектурі. «Штучний інтелект – це не просто імітація чи повторення вже існуючих рішень, – зазначив Джонатан Каган, професор Університету Карнегі – Меллона – це вивчення того, як люди вирішують конкретні проблеми та створюють нові дизайнерські рішення. Наскільки гарним може бути штучний інтелект у цьому?».

Штучний інтелект – дуже перспективна сфера досліджень, розвиток якої зумовлено досягненнями у комп'ютерній сфері. Можна вважати, що поширення комп'ютерів та кібернетичних приладів, їх застосування в людських потребах визначатиме рівень життя у наступному столітті.

Ключові слова: штучний інтелект, механічна система, проектування, 3D-друк, моделювання, архітектура, роботи.