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CONTENT

02.103 - THE ROLE OF ARTIFICIAL INTELLIGENCE IN ARCHITECTURAL DESIGN: CONVERSATION WITH DESIGNERS AND RESEARCHERS

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Abstract

The proliferation of data together with the increase of computing power in the last decade has triggered a new interest in artificial intelligence methods. Machine learning and in particular deep learning techniques, inspired by the topological structure of neurons network in brains, are omnipresent in the IT discourse, and generated new enthusiasms and fears in our society. These methods have already shown great effectiveness in fields far from architecture and have long been exploited in software that we use every day. Many computing libraries are available for anyone with some programming skills and allow them to "train" a neural network based on several types of data.

The world of architecture has not remained external to this phenomenon: many researchers are working on the applications of artificial intelligence to architectural design, a few design software allow exploiting machine learning algorithms, and some large architectural firms have begun to experiment with deep learning methods to put into practice data accumulated over years of profession, with special interest in environmental sustainability and building performance. If on the one hand, these techniques promise great results, on the other we are still in an exploratory phase. It is then necessary, in our opinion, to understand what the roles of this technology could be within the architectural design process, and with which scopes they can facilitate such a complex profession as that of the architect.

On this subject we made ten interviews with as many designers and researchers in the AEC industry, In the article we will report a summary of their testimonies, comparing and commenting on the responses of the designers, with the aim of understanding the potentials of using artificial intelligence methods within the design process, report their perceptions on how artificial intelligence techniques can affect the architect's approach to the project, concluding with some reflections on the critical issues identified during the interviews with the designers.

Keywords

Digital Architecture, Artificial intelligence, Machine Learning, Architectural Design, Computational Methods

1 What do we mean by artificial intelligence?

Since artificial intelligence methods have become of great interest in every scientific and commercial sphere, it is, however, necessary to point out the meaning of the term artificial intelligence, used commercially with different meanings.

If it is true that already in 1950 Alan Turing wondered if a machine could imitate human intelligence, it is also true that the term with the meaning we attribute to it today was coined in 1955 by John Mc Carthy, to describe a research field where "explore ways to make a machine that could reason like a human, was capable of abstract thought, problem-solving and self-improvement" [1].

Over 60 years, artificial intelligence has been enriched with sub-fields and related methods that vary from the simplest Rules-Based Systems, to Machine Learning, shallow and deep neural networks, natural language processing, speech processing, image recognition and many others. To define these different methods of artificial intelligence it is useful to differentiate them according to the need for human interaction during their learning process. In the case of supervised learning, the presence of a programmer, or better that of a data scientist, is required to organize the data in order to allow the software to create and therefore recognize the desired correlations between input and output. With active learning, the interaction required by the algorithm to direct its choices is minimal, and most of the data is unlabelled. There are then reinforced learning approaches, processes in which the data is collected in real-time and the software is able to gradually learn based on its own experiences. Finally, there are those methods that involve unsupervised learning, which implies total autonomy of software in generation of rules used to analyse the information collected and independently search for correlations that the machine will use to process the data [2]. Among these methods, the ones that have seen the greatest development in recent years are clustering algorithms, which measure the similarities between uncategorized data, organizing them into clusters, through which they distinguish the new data acquired, without the need for human interaction. Deep Leaning algorithms, which are based on the relatively old concept of Artificial Neural Networks, are now extremely popular and extensively applied in many fields. This is mainly due to the advent of fast graphics processing units (GPUs) the have significantly increased our computational capability and made now it possible to apply such novel Machine Learning techniques to an extremely large set of problems. The fundamental characteristic of neural networks, is the organization of the algorithm, a computer analogue of the brain neuronal interconnections. A deep neural network is therefore organized in different layers, even 100, each of which includes multiple neurons.

Through this complex structure, the algorithm can independently manage a huge complexity of data and extrapolate information previously unobtainable by any other type of algorithm[3]. To date, applications of these networks found large within numerous fields, from self-driving cars, the translation of texts or facial recognition, even managing to beat human champions in complex games such as Go [4].

Reactions towards these technologies have been as positive as negative, if on the one hand some read their enormous potential and have shown confidence in their wide adoption, others [5] warned us, saying that Artificial Intelligence could even decree the end of the human race. Even in the architectural field, there is a discussion about their role within the

practice, several researchers and architects have said that the introduction of the next artificial intelligence will bring modification to architecture [6]. In order to understand the topic, it is important to investigate how architectural firms have welcome artificial intelligence methods, and what are architects expectations about them.

2 Will artificial intelligence be useful in architecture?

From February to July 2019 we met and interviewed ten architectural designers and researchers with great experience in digital design: Daniel Davis, former Director of Research of WeWork, Aurélie de Boissieu, London Head of BIM Grimshaw Architects, Xavier de Kestelier, director of Hassell, Al Fisher, Head of computational development of Buro Happold engineering, Irene Gallou, Head of specialist modelling group of Foster+Partners, Harry Ibbs, Europe design technology director of Gensler, Andreas Klok Pedersen, partner at BIG – Bjarke Ingels Group, Arthur Mamou-Mani, director of Mamou-Mani studio, Edoardo Tibuzzi, director of AKTII and Pablo Zamorano, head of computational design of Heatherwick studio.

We asked all of them to order various of industry 4.0 enabling technologies and digital techniques characteristic of our sector based on the usefulness they will demonstrate in architecture. The interviewees, therefore, gave a vote from seven to one to the technologies of Internet of Things, Augmented Reality, Virtual Reality, Digital Manufacturing, Machine Learning, BIM and "Other computational methods" category which includes other possible methods not mentioned among others in the group. It is important to point out that the respondents were asked to make predictions over the next 10 years based on their impressions, taking for granted the benefits already demonstrated by these technologies in contemporary practice within their experiences, with obvious reference to Building Information Modeling.

Interviewee	BIM	Other Comp. Meth.	IOT	AR	VR	Machine Learning	Digital Manufact.
Arthur Mamou Mani	5	6	2	3	1	4	7
Al Fisher	6	7	2	4	1	3	5
Andreas Klok Pedersen	7	1	2	4	3	6	5
Aurélie de Boissieu	1	2	5	4	3	7	6
Daniel Davis	7	7	5	4	3	2	1
Edoardo Tibuzzi	2	7	5	3	3	4	6
Harry Ibbs	1	3	2	5	4	7	6
Irene Gallou	2	3	5	4	4	7	6
Pablo Zamorano	3	7	4	5	6	6	5
Xavier de Kestelier	3	4	6	1	2	7	4
Total	37	47	38	37	30	**53**	51

Fig.1: Results of the question “Order the following technologies for the usefulness they will have in Architecture over the next 10 years”. In green, first places for each personal ranking.

As is evident from figure 1, Machine Learning is the technology that obtained the highest score with a total of 53 out of 70 achievable points, followed by digital manufacturing with 51, third “other computational methods” with 47, then Internet of things with 38, BIM and Augmented Reality with 37, last Virtual Reality with 30. It is interesting to note that Machine Learning and "other computational methods" both obtained the first place in the personal rankings of the designers four times, as well as happened twice for BIM and once for Digital Manufacturing. It is therefore clear that based on the experiences and expectations of the interviewed designers, machine learning and its derivations are expected to play a role within the architectural practice, a role that, for many of the interviewees, will be decisive in ten years.

3 The approach to artificial intelligence in professional practice.

Despite expectations, all the designers interviewed acknowledged that the relationship between the most advanced machine learning techniques and architecture practices is still in an embryonic phase. What is happening is what Eduardo Tibuzzi, among others, recognizes as a moment of experimentation, characterized by a pioneering and empirical approach, in which the new techniques will be adopted to measure their potential. This has already happened with all the digital techniques previously applied in architecture, from the use of the digital curve to the parametric design, up to the evolutionary algorithms and swarm intelligence, well known within the architectural community today, systems which, outside our profession, are also exploited within machine learning and deep learning methods [7].

As Harry Ibbs states, there are substantial differences between these new methods and previous digital techniques adopted in Architecture. It is required, before applying them, to understand how they work, and master at least one programming language. We can also say with certainty, that to adopt these most advanced techniques we need significantly greater computing power compared to common computers and workstations. As an example, if we want to create a deep neural network, the faster strategy would probably include the use of Tensorflow or Pythorch, open-source computer libraries developed by Google and Facebook respectively, which allow, like several others, to develop machine learning and deep learning algorithms. Anyone wishing to try these methods can then count on extensive documentation, practical and theoretical lessons, tutorials, guides and on-line support based on large communities.

To work at their best, these libraries use parallel computing: the ability to simultaneously perform thousands of operations, thanks to high parallelism video cards, without which deep learning would not be possible in an accessible time. It is then possible the practice of remote parallel computing, in the form of cloud services offered by some of the web giants, who rent their powerful IT infrastructures with tariffs based on the machines' effective use.

To exploit the power of deep neural networks, specific skills and a computing power, significantly higher than that available within an ordinary architectural firm today, are therefore required. Deep Learning, unlike the most common machine learning algorithms, requires time in the order of hours or even weeks of CPU time, for training, so to acquire and process the huge amount of data required for its operation, after that neural networks can be interrogated quickly.

4 The role of Data

As underlined by almost all the interviewees, the topic of data is central in any machine learning application. Because data and their structure will strongly influence final outputs: a neural network, for example, will become very able to distinguish a cat, only after seeing thousands of photos of cats, examples from which it will autonomously extrapolate characteristics with which the AI will build his idea of the object cat. Leaving aside the ethical considerations related to artificial intelligence in general, it is necessary to reflect on the data we inject in these processes. The ways we collect and organize them can lead to biased output, and on more than one occasion artificial intelligence has shown discriminatory behaviours concerning ethnicity or gender [8].

An excellent example applied to architecture is provided by Xavier de Kestelier, who states that: "if you only show them modernist architecture, the AI will only be able to create modern architecture" this statement refers in particular to some applications of the deep learning, and testifies how the functioning of these methods can be influenced by the data we used to populate the algorithms. It is therefore important to ask ourselves what is the data that an architecture firm can use, suitable in quantity and quality, to develop artificial intelligence methods? And above all: What are the goals we want to achieve using them?

Despite the increasing role of data in contemporary society, in the fragmented world of architecture, only a few practices have fully embraced the use of data within the design process [9]. In the case of the latter, it is certainly possible for Architects to take advantage of a collection of data collected during the design, construction and use of the architectures already built over the years. As Aurelie de Boissieu and Pablo Zamorano point out, it is possible to base these methods on all the legacy knowledge that professional practices have built up over years of experience. The data can also be created based on purely geometric considerations, as it happens when you want to optimize the number of parking spots inside a parking lot, or the number of desks in a room.

For these purposes, machine learning has already been used, and it can provide as output a highly performing geometric configuration according to functional criteria previously established by the designers. Potentially all simulations, starting with physical and environmental models to human behaviours, represent a source of data, especially for deep learning. Ss they can be obtained with relative simplicity, and they are potentially consistent with the amount of information required from a deep neural network to learn something. This occurs, for example, with computational fluid dynamics simulations, as Irene Gallou testifies, who affirms how neural networks, thanks to the experience and data acquired on the subject for over ten years, adequately trained with billions of simulations, are capable, just by intuition, to quickly provide a building's wind behaviour model, immediately useful for Architecture choices.

Several architectural offices and companies have already started to collect data on how space is inhabited, through traceability systems and user feedback. With this information, it is possible, as an example, to obtain information on the effective use of spaces within a co-working, and remodel internal environments taking into account their actual use. Al Fisher told us that data collected inside a stadium during a football game was analysed with machine learning methods developed by his office to design a new stadium. The number of

computer data available is also growing: administrations and governments at different levels are increasingly collecting data to optimize processes and distributing them for free.

Limiting our view to architecture, it is easy to observe how those who surely have a stronger connection with data, in addition to large architectural firms, are software houses. Companies specialized in digital tools for Architectural design and a relationship of constant dialogue and collaboration with some of the most innovative architecture firms.

5 Current contributions and expectations

About the contribution and role that artificial intelligence will have within the architectural project, it is quite clear that it will be, at least initially, limited to those areas in which there is a well-defined set of rules as Xavier de Kestelier suggests. He cites, as an example, design of residential buildings in Asia, where there are specific rules to be respected, a theme on which AI will be able to make a large contribution in the future. Daniel Davis, author of numerous researches on machine learning applications to architecture [10], also states that, although it is certainly true that machine learning will have a role to play in architecture: "I don't think machine learning should be seen as a magic bullet, it's a difficult and complex technology to use, and only really works in certain situations".

Speaking about Deep Learning methods, Andreas Klok Pedersen confirms that we have just begun to know these systems. Underlining that, when applied in other fields, they showed great skills when used in a coordinative way instead of a prescriptive one: avoiding teaching what they should strictly do, defining instead game rules and success criteria and letting artificial intelligence find its answers independently.

If anyone expects Artificial Intelligence to report on architecture the disruptive influence they are demonstrating in areas such as autonomous driving, image recognition or other fields, it is clear that none of the designers interviewed currently sees the possibility of such a massive revolution in architecture. This is because, as Andreas Klok Petersen points out, architecture is certainly among the most complex professional practices, and any architectural choice involves countless aspects. It is not a question of carrying out a single operation correctly, but of finding in one move a solution capable of solving a vast collection of problems. Engineering constraints, human, environmental parameters, politics, social sciences, art, are just some of the parameters from which the design choices arise. Architecture is a complex practice. On the contrary, sectors where Artificial Intelligences are showing an important impact, have a more linear nature than that of our profession. The interviewee goes on saying that, by breaking up the architect's work into separate tasks, describing the process rigorously, it is easier to imagine an AI capable of solving these operations individually. It is therefore important to ask ourselves several questions: Are we able to manage these enormous potentials to generate new concepts and ideas? Can we describe this complexity so that a machine can process it? Maybe in the future.

It is therefore still too early to understand how much these technologies will erode from an architect's professional practice, and certainly nothing in terms of responsibility. In this sense, Arthur Mamou-Mani declares that even by using AI, designers retain the right to control the design process at any time, making choices and questioning answers provided by artificial intelligence.

Looking to the near future, with a realistic approach to the potential already shown by these methods within their first applications in the field of architecture, Irene Gallou potentially

sees in Artificial Intelligences some magnificent assistants, able to remember all the experience acquired through data properly structured, and quickly return feedback that is certainly useful for architects.

6 Conclusions

According to our respondents' answers and reflections there is confidence that, the most advanced artificial intelligence will be highly useful for professional practice over the next ten years. It is important to note that, the interviewees also see utility for architecture in technologies such as digital manufacturing or other computational methods, of which, among other things, artificial intelligence could become an engine. The relationship between Artificial Intelligence and professional practice is currently at a recognized pioneering status: few studies and companies with specific skills, especially computer skills, familiarity with data, experience, and parallel computing capabilities, are exploring the applications of advanced artificial intelligence within the architectural practice.

Within these offices, some of the most advanced methods of machine learning and deep learning have demonstrated great results in limited areas, in terms of data analysis and optimization, also proposing effective spatial configurations when the boundary conditions are duly defined.

The data, which plays a central role within each machine learning and deep learning strategy, must be structured consistently and be a lot. These algorithms use in fact, thousands or even billions of examples to learn autonomously, and the amount of data is decisive for the result's quality. So, among the first data used with these strategies, we may easily find those produced in years of professional experience. New data can be collected, created or acquired. That of data is certainly one of the most sensitive subjects from an ethical point of view: data is collected more and more often and by many actors, from technology giants to governments, and it is certainly important to question their validity upstream of any artificial intelligence process. Architect's responsibility is therefore enhanced: An architect can question the machine's outputs at any time but he must also be able to understand the quality of the inputs with which he trains the machine.

Given the complexity of architecture, our interviewees exclude that artificial intelligence will be able to have disruptive effects in our field in the short-term, the role that AI will probably assume in the immediate future will be that of an assistant, extremely specialized and able to solve very specific problems.

Even if it is not yet quantifiable how much the introduction of these hyper-specialized artificial colleagues will erode from the architect's practice. However, we can assume that profession, within some of the most innovative studies, will further approach computer science, statistics and science in general. Skills needed to be able to obtain information and solutions capable of speeding up the project and improving the final architectures. The contribution of software houses within the phenomenon of artificial intelligence in architecture remains to be investigated. It is probable, that in the case of proven usefulness and diffusion of AI within the most innovative architectural firms, software houses will probably be decisive in the dissemination of new tools developed ad hoc for our sector.

The full interview with the Architects will be published with Giuseppe Gallo's doctoral thesis.

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