From Design Patterns to Design Machines, How can AI empower architect and architecture?

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Abstract. Could a robot compose Vivaldi's Four Seasons or paint Van Gogh's Starry Night? Could any design-machine curate the divine holiness of Hagia Sophia or Blue Mosque in Istanbul? Incredible façades of Sagra da Famiglia by Gaudi? The magic of the light comes through the oculus of the dome of the Pantheon in Rome? Not quite possible. Artistic or architectural, in all forms of outstanding masterpieces of humankind kneaded with wisdom and emotions fueled by the social, political and ideological archipelago of human creativity distilled through the motives of civilizations throughout the history. This is not only an invaluable wealth inherited from the past but also the very knowledge of the body & mind spirit of the human being and his/her creative genius to pass to the future. However, architectural design practices have been evolved and rely on AI, e.g., design machines with deep learning, more than ever. This is where the questions arise; Can AI take over the architecture and replace the architect or empower? The discussion in this paper suggests that design machines with machine learning abilities are offering highly sophisticated and cutting-edge design automation methods for architecture and several other design and art fields; however computers are still not good at open-ended creative solutions, and that is still reserved for humans.

Keywords: Architecture, design, AI, pattern language, design machines

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1. Introduction: Design Languages vs. Complexity of Space

Human environment is highly dynamic so does the overall information it transmits from generations to the generations. It responds to the needs of human life in its most stable and volatile states and carries its very own script along. The built environment is not static but an adaptive process. It is an embodied form of adaptation to the conflicts, negotiations, exchanges & interactions, protocols, flows and most importantly to the cultures and ideologies. Hence, there is always an invisible exchange and constant feedback within and between the place and its makers. Place in this sense, cannot be fully understood without recognition of the processes, experiences, and identities that create and recreate it. There is a robust hidden contract between space and its makers that articulate the principles established throughout ages. As place-makers, no matter what discipline, the more well-articulated guidelines we create, the more internalized and robust spaces we can design using the means of intelligent design tools. Not easy, but we can learn from these established principles, apply and verify them in our design proposals. The question is whether or not we can code them as self-evolving design patterns to solve complex design problems in time and scale.

This paper attempts to discuss and seek answers to the question of whether or not AI can fully take over design through self-learning and self-evolving robotic methods eliminating the failures reasoning from not only lack of considering physical, climatic and environmental factors but also the steady state human feedback. Historic cities are an excellent example of such adaptation of design patterns with perfect fitness criteria remains the same throughout ages that transmits the genius loci. A historic city is a form of accumulation of what we inherited from the past, and thus what we will pass on to the future. Furthermore, with all her layers, and all the interactions between human beings and their environment, the historic city is a cosmos within herself. As a cosmos, she consists of elements at different scales. These elements have their spatial and literal manifestations making up the image and the signs of the city (Ekinoglu, 2008).

C. Alexander (1977) with his collaborators introduced the systematic thinking of "A Pattern Language" for architects and designers as a series of place-making rules for some 253 particular spatial design cases of architecture, landscape, and urban planning & design. However, through the advances in technology and architectural practice, our conception of patterns have changed. Starting from C.Alexander's (1977) "A Pattern Language" and ending up with smart design machines with deep learning abilities have sneakily taken over several jobs in architectural production as in many other disciplines. However, space is a great complexity with an immense amount of inner and outer dynamics and connections across scales. Such complexity is constantly awakening up to new developments here and there especially in the cities. How can such complexity go beyond a patterned language, being a collection of things like Lego to assemble, to a life-phase that grows like a biologic organism? The problem is that when we consider patterns as elements, then we find ourselves playing games via creating different scenarios of this and that sort of formations. The scenarios are limited, and they are far from broadening new paths of thinking towards an embryo-like growth and embodiment fluid and continuous in every cycle of time and scale. Such fluidity can allow a great capacity to form morphological structures, much more than anything remotely resembling tinker toys, so it is just not similar. This was one of the core topics that Alexander, even years after publishing the "Nature of Order" (2002-2005), hoped to have few more years to work and be more precise about it since he wanted to develop correct analogies from biology that architecture can benefit.

This paper discusses whether or not design machines are capable of solving today's complex design problems and what the AI is offering to architects and designers. It can be useful to ask specific questions here; how can we let the design patterns evolve themselves from being static and generic to adaptive and differentiating which also allows the designers' broaden their views and enhance towards new discussions? How can data-based design lead to self-evolving and self-learning design machines for new patterns of thinking? Specifically, from the evolution of design patterns perspective, this paper aims to discuss along this stream to articulate a frame emphasizes that AI is not threatening architectural creativity but empower it.

1.1 Design via Pattern Languages

The debate of design through design machines that use the design patterns of generic libraries vs. evolutionary or adaptive design is an ongoing hot topic. Before diving deep into this debate, one should go through a brief annotative perspective on the core of the debate with contrasting views from different scholars for "why, while pattern language is a milestone work in systematic design in architecture, it was also defined as imperfect in making of spaces with existing built contexts by scholars and especially by C. Alexander himself who was the first scholar developed pattern languages.

Alexander, rather than mathematical methods as the basis of better design, utilized empirical research to create patterns and interested in what made certain places work both spatially and psychologically. As the created forms of "fit," the patterns in Alexander's understanding are good ways of creating successful places that blended application of logic with collective experiences. Embodied in the books "A Pattern Language"(1977) and "The Oregon Experiment"(1975), pattern theory inspired many but also failed to lead to beautiful buildings consistently. In the late 1980s, Alexander started to develop a further theoretical basis for good design based on a careful definition of "wholeness," or a deep and abiding beauty.

In his own words in below, Alexander (2010) explains this as his “biggest failure” and explains why “A Pattern Language” does not serve to the generative design process as if it prescribes a biological evolution (which it does not actually). *Alexander* says; he did not know how those generative sequences work coherently at that time, so he wrote the book and early 2000s he had a paradigm shift what also paved his way to “Nature of Order” (2002-2005).

"It is not so simple because the canons of Pattern Language, like the book ‘A Pattern Language,’ are sort of multipurpose. You're trying to achieve many, many different things with this one book of patterns. These traditional ones aren't like that at all, the biological ones aren't like that. With the biological ones, there's no fooling around – this is how this one works. You want an embryo for a locust, there's only one way to do it! So that was, I would say, my biggest failure. Incredibly, so many years later, I have not solved that problem to my satisfaction. Part of my trouble is I have so much work so…."

In architecture, Patterns and Pattern Languages are the ways to describe best practices, functional designs, and capture experience in a way that it is possible for others to reuse this experience. Fundamental to any science or engineering discipline is a common vocabulary for expressing its concepts, and a language for relating them together. The goal of patterns within the software community is to create a body of literature to help software developers resolve recurring problems encountered throughout all of the software development. Patterns help create a shared language for communicating insight and experience about these problems and their solutions. Formally codifying these solutions and their relationships lets us successfully capture the body of knowledge which defines our understanding of good architectures that meet the needs of their users. Forming a common pattern language for conveying the structures and mechanisms of our architectures allows us to intelligibly reason about them.

However, in place making, patterns do not always work as they do in automated design tools. A design pattern systematically names, motivates and explains a general design that addresses a recurring design problem in object-oriented systems. A computerized design tool might be compiled through various design patterns and targeted functions somewhat work. However, they are content-free, and they do not guide the user in any qualitative or in an adaptive sequential way. Enormous numbers of costly errors of adaptation might easily occur only because the design decisions are not prompted to take into account all interacting decisions. Space, contrary to that, is culturally and biologically adaptive process and the patterns that work in some contexts mostly do not work in other contexts. So, the patterns happen to be mechanical and generic solutions to design problems when we try to apply them in different contexts.

2. Alexander’s Transition from Pattern Languages to the Theory of Wholeness

This also describes Alexander’s transition from patterned language to beyond patterned language which is like a fluid entity that knows where it goes and what happens as it grows and matures. Alexander calls it “wholeness” or “the quality that has no name.” “Nature of Order” (2002-2005) in this sense is one of the most important documents in this century. Alexander's central thesis is that there is something fundamentally wrong with twentieth-century architectural design methods and practices. Despite many other books on architecture which are mainly 'mechanical' in a sense, these books seem to concern a more holistic perspective on design. Besides, it is not only considered as guidelines for architecture design but also defines a new kind of philosophy (for a new age). In a provoking way, it breaks with the overly exaggerated rationalistic movements of the last century and puts meta-physical aspects balanced with scientific reasoning into focus. Through experiments, he shows that this holistic approach to design works, that objectivity exists, and that people should strive for this to have a life with the order. Alexander establishes his thesis of wholeness & life duality upon a firm basis of completeness emerges through the order. The wholeness of a system is not about the quality and behavior of every single entity what he calls "center," but the way they come together and make each other strong across scales (Ekinoglu & Kubat, 2017). Jiang (2017) states, the wholeness emerges through a life-giving order or a living structure.

Even so, unlike a living organism, the space in various scales may be incomplete or imperfect and yet can have a life. The question might be posed as: how whole or how complete is a space or an area based on the information conveyed through its various, multi-scalar, morphologic possibilities? Ekinoglu & Kubat (2017) employed Shannon's entropy (1948), (2001) as a measure of uncertainty for conveyed morphologic information in measuring morphologic wholeness in the built environment.

Design machines that benefit from pattern languages offer practicality and agility in various forms. Although the agility that comes with design tools saves from time and workload when we need to alter the design at some point, this does not seem to give us hints on how patterns can achieve self-development to handle design problems never been experienced before. To be precise, we need self-learning and self-generating design machines in a world of complex design problems with a vast amount of evolving issues. From this point of view, the aforementioned metaphysical aspects that Alexander points in the "Nature of Order" balanced with scientific reasoning reminds the following questions when we are discussing the critical role of the pattern languages for the future of design. Can the design patterns set up the rules of transitions in form generations and adaptations of a good fit? Can we apply them as the rules of the morphogenesis probed and justified by particular fitness criteria in the built environment so that it is coherent and 'whole' at any point in time and scale, e.g., the embryo-child-adult, in its step by step differentiating development?

2.1 Patterns vs. Reality of Spatial Change

The critical issue is about understanding how the patterns can create self-regenerating codes so that proper morphogenesis can be possible. The question comes up with this how the code writers and designers, architects, urban planners & urban designers, should be properly situated in the development of such capacity. However, Alexander in his below quotation, states such morphogenesis excluding the architects and planners cannot be transmitted through the methods of the computer scientists and software engineers as the form-makers who use coding and the digital technics. This paper attempts to discuss it through a proper scientific frame.

"…..I want you to realize that the problem of generating living structure is not being handled well by architectural planners or developers or construction people now, and the Earth is suffering because of it. I believe there may be no way that they are ever going to be able to do it because the methods they use are not capable of it."

In short, he notes that the problem of making living structures is in the wrong hands. Here, it seems the idea of fitness criteria is highly controversial since it excludes the human factor in the evolution and adaptation of space. There is no simple math to apply in order to create the human-made built spaces with healing effects in a single attempt that addresses both the body and mind positively. Salingaros states that ..." the greatest healing effects come from man-made environments of traditional and vernacular character" (Kellert et al., 2008; Mehaffy & Salingaros, 2015; Salingaros, 2016). In other word, the complexity that emerges through human-creativity is beyond prescribed guidelines but principles established throughout ages. Bottom-up historic cities are entirely built upon such complexity constituting a dynamic system of in-situ information. This is a generic failure that dense metropolitan cities in need of affordable housing in urban fringe or suburb in developing countries experience. Figure 1. shows two situations summarizing this struggle. Left photo is from Porto urban core area, and the right photo shows an example from an urban regeneration experience from the Doğanbey district of Bursa urban core which ignores and disregards all the contextual information.

Figure 1: Beautiful morphologic and architectural grammar in Porto urban core area in Portugal (left) & urban regeneration experience that leads to large massive blocks in the heart of historic city of Bursa in Turkey (right). (credits: left: Sojatova-2018, right: Milliyet-2017)

The grammar of shapes, forms, and scales constitute a beautiful narrative in harmony with geography, climate, and culture. Much of Alexander's effort was to construct an understanding of what is beautiful through the right order of places or any sub-constituents that make a greater whole. The idea of right order is strong yet highly relational in addressing to and provoking our senses when we develop our spatial cognition. Alexander emphasizes that the concept of right order is incremental and everything has the potential to affect the whole system across scales through the way parts interact with each other. Alexander (Katarxis, 2004) in an interview with Mehaffy says that we can make a building or parts of a building through such resonance by avoiding weird geometries and non-fitting sizes. Learning how the geometry and order of nature do not necessarily mean mimicking nature but how the adaptation works in such a big and complex world of scales, shapes, and geometries.

Salingaros (2018), draws a full frame as a set of principles to rely on to create adaptive design through a step by step responsive process that channels emergent complexity instead of denying or eliminating it. Such set of principles, as the antithesis of the standard top-down "design" emphasizing the most massive scale, creates a design oasis through an intelligent rhythm of synthesis that creates -while instantly controlling the quality of each- design proposals based on the prescribed principles, parameters and highly specific field conditions.

(i) *Connect the parts of a system or structure through various geometrical means, most often with multiple and redundant connections.*

(ii) *Align adjoining flows, so they reinforce each other and define their natural paths (but do not force them to a rigid axis or grid).*

(iii) *Create many linked symmetries of different types as a response to activities on distinct scales (but do not impose a global overall symmetry).*

Implement approximate spatial correlations using similarities at a distance and scaling symmetries (i.e., similarity under magnification).

(iv) *Only repeat things adaptively, i.e., adapt the prototype to the new situation, which makes the units vary with each repetition. Monotonous repetition without variety, on the other hand, lacks adaptation.*

(v) *Build up a system or structure using a sequence of adaptive steps, where organized complexity arises from an evolutionary process with feedback. Do not build layers from a pre-determined blueprint.*

(vi) *Implement organized complexity as the result of adaptive dynamic processes rather than as the result of a conventional static appliqué of "art."*

This kind of well-articulated rules can be coded to establish the base of the algorithms that will generate forms and propose design solutions with a certain quality of adaptation. Adaptation in specific terms requires paying attention to all scales, and our emotional/psychological reactions on each scale (Salingaros, 2018). Through such sensitiveness, the rules directly help to develop the design proposal via learning from the specific conditions of the context to step by step evolve the design patterns through skipping the useless speculation and benefitting instant feedback. However, beyond adaptation, this kind of approach seeks answers to something more profound that considers the patterns as organic iterations. The question is how to differentiate the design patterns in the built environment with immense drivers of change? Built environments constantly change in different size and portions and different rhythms. This change inevitably affects the scaling hierarchy of cities which makes everything work in balance (Ekinoglu, 2018). How can AI help to go through this inevitable change and succeed to create needed adaptation and differentiation?

3. Can Algorithms Learn and Manage Spatial Adaptation and Differentiation?

Most of the current design tools are top-down that offer generic layouts and materials ready to use in creating space in a recursive fashion of form generation. This kind of form generation method is entirely mechanized and ad hoc without any preliminary R&D for a case-specific solution. This kind of tools performs within the limits what their form generation scripts enable and use the materials their libraries offer. Such routine draws the baseline for design tools that the designer has to work within certain limits, and they have nothing to do when it comes to adaptation and differentiation, as in biology and embryology, unless the rule sets are scripted detailed enough in development and definition of the patterns.

Design Machines with profound learning abilities can learn from the data of tens of thousands of different spatial parameters that affect the form and shape grammar of the constituents specific to a place and through such kind of machine learning and optimization the computer simulation can help to generate design and perform a digital fabrication as applied in the differential growth of a flora form in a sequence of a multitude of operations in Figure 2.

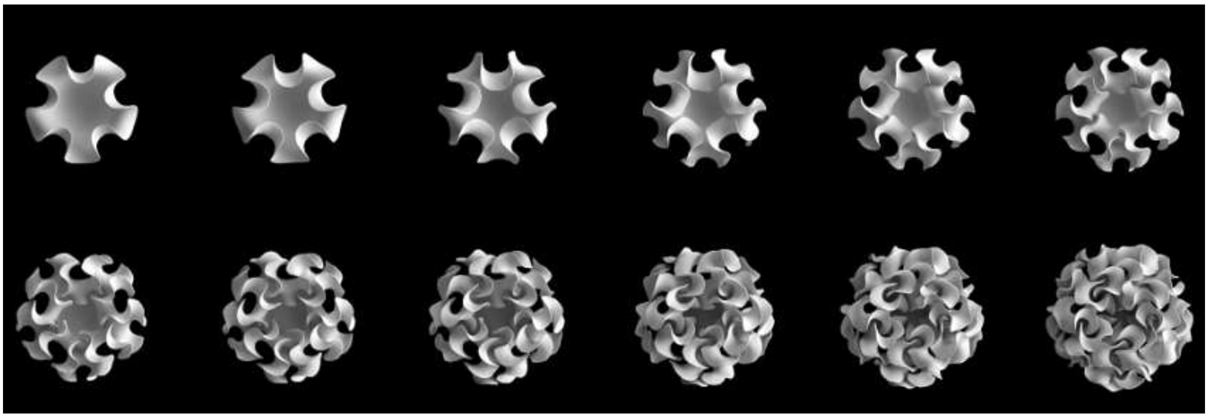

Figure 2: Digital fabrication of organic growth through design machine iterations (nervous systems project)

AI through learning from a vast amount of place-specific data of various parameters can re-code the algorithm that will lead to such kind of differential growth evolving the forms through digital fabrication to generate infinite possibilities of design solutions. There is no definitive, final product; instead, many design solutions created to allow for mass customization.

Both Alexander and Salingaros (2006) state that we need “form languages” that will step by step guide us when we start from the pattern languages. A “form language” flexible enough to show us rights & wrongs in various cases of adaptation and differentiation to suit new spatial requirements. Ekinoglu and Kubat (2017), in order to visualize the way spatial constituents make a topologic co-affect in mathematical terms, developed Entopic Interaction way of data visualization using Shannon's entropy. An interpolation algorithm directly generates a deformed grid that allows making an evidence-based comparison of how morphologic occurrences relatively interact and possibly affect each other in various built environment scenarios. Changing forms and positions of the vertices and the heat map color tones in each cell translate the intensity of change to the deformed grid.

Design as a wholeness-seeking and life-extending process in the built environment requires inspecting and questioning the relational nature of spatial context across scales (Ekinoglu et al., 2017). Having Alexander’s particular patterns as the case study, Postle (2013) developed an adaptive computational approach to residential design. The built environment is not tabula rasa. As the designers, we have to consider all possible eventualities that shape the place. Alexander’s patterns do not provide methods to design but methods to evaluate the iterations of small incremental improvements in a generative way. In order to do that, the algorithm has to first; run the iterations and generate the geometric improvements and second; evaluate the generated models based on the fitness criteria that Pattern Language provides. To operationalize his approach, Postle (2013) described certain specific spatial elements such as the plan of habitable spaces, boundaries between spaces, and the arrangement of boundaries depending on the nature of the selected pattern to run the iterations and evaluate them. The equilibrium among the use of the elements in each design proposal changes and there is no most complete and perfect but most adaptive design responding to the fitness criteria scripted by the selected pattern. In the final round, the architect has to decide on the design solutions that also need to respond to several other non-coded parameters specific to space. Still, Postle’s work is innovative and a remarkable contribution to the field.

Alexander (1964), in the foreword of his “Notes on the Synthesis of the Form, emphasizes that the core of the matter is to understand the script that we use to define the design pattern but not the method that tells how to use them. He thinks that so many people only care about the method itself or how to use it rather than getting the core idea and principles in creating the pattern so that using AI we can also create new patterns with specific scripts for new and never-experienced-before situations. The critical point to learn from Alexander’s views in below quote from the 1970s still did not change much and stands as an issue in the agenda of today’s spatial design theory & practice although we are more than ever using design automation and design machines in several ways at today’s architectural industry.

“...I think it is absurd to separate the study of design from the practice of design. In fact, people who study design methods without also practicing design are almost always frustrated designers who have no sap in them, who have lost, or never had, the urge to shape things. Such a person will never be able to say anything sensible about "how" to shape things either.”

Design patterns are expected to be responsive to all the environmental and psychological context, and all the interacting forces should affect the step by step learning and decision making processes by the AI. The more complex scripts we define, the more sophisticated and accurate design decisions can be made. This is still a limited ability compared to human creativity that can consider particular factors affecting the design. The patterns can be mobilized to learn from precise self-generating systems in nature and from creative complexities of organic contexts in historic cities to self-evolve to new hybrid algorithms for new spatial analogies. The intelligence of the pattern should manage this complex learning process towards a successful adaptation and differentiation that fits the nature of the design problem. This is still a question of how to mimic the wonders of biologic complexity along with human creativity towards an ability that will broaden the limits of self-learning design machines. So the central idea of new generation patterns will inevitably contribute to design towards robotic craftsmanship broadening human creativity via opening up never-experienced-before complexity, limits, and potentials in design.

4. What is next for design?

It is not new that humans have been concerned that machines are going to take over their professions and jobs. To some extent, this fear had no ground in the 80s and 90s. From the early 2000s, deep learning or machine learning in architecture has started allowing the architects to enjoy less workload while the computers are handling data-intense tasks. However, the real challenge, and stressful design practice, is still on the shoulders of the designer from architecture to engineering or manufacturing. In today's architecture industry in different weights, some architects keep embracing the traditional practice while some use the freedom offered by the design machines. This paper aims to discuss whether or not self-learning design machines impose some other kind of obstacle while breaking down the constraints and limitations of traditional design practice.

Automation and design are two different things. We want to and tend to use one instead of the other. It is because of the growing amount of data we use to design and run the multitasking process through supercomputers and such complex multitasking is far behind the ability the architect can perform. According to Simon (1988), "To design is to devise courses of action aimed at changing existing situations into preferred ones." Such a process of change from the existing into the preferred situation has shifted to a multitasking level of creating while controlling & learning from a vast amount of data to plot desired outcomes swiftly. Hence, the automated process was always and currently is an integral part of the design process. If we are designing something in Revit, it automatically produces all the necessary detailed and coordinated drawings to construct the structure. This is automation that does all the work we used to do manually and saves from time, labor and energy and allows the designer to use it for the design.

Today's advanced technology is pushing the borders beyond and seeking for a shift towards the question of whether we can solve design problems through artificial intelligence (AI). AI in the broad definition is an area of computer science that turns computers into machines with human intelligence and cognition. Science fiction imagines and presents the AI as robots with human-like features. However, the AI, from narrow to general, can perform many different activities, e.g. from Google's search algorithms to IBM's autonomous weapons. We have been mostly introduced the narrow AI that is coded to fulfill a particular task (pattern recognition, autonomous cars, wearables for treatment and so on). Long term goal of the scientists, through deep learning, is to create General AI, or Strong AI, which can perform any needed task from playing chess to making puzzles and writing codes. AI, in another word, is going towards fulfilling the tasks that require human cognition. This is where it starts to pose a danger for the future of design. AI in this respect is augmenting design and the way how architects and designers are responding to and working with these technological developments dramatically matters. The question is what kind of innovation AI is generating for the architecture and creative sectors. With recent innovations such as that of Nvidia's microchip in April 2016, a shift is now being seen towards what we might understand as 'deep learning,' where a system can, in effect, train and adapt itself.

In a high speed, the design is being a big-data-dependent activity. The evergrowing speed of microprocessors is accelerating to gather and use a multitude of redundant data relevant to the design problems. The online platforms of sharing and clouding the data are not only enabling to use but also virtually recreate for several other purposes in the design development. In addition to that, Virtual reality (VR) and Augmented Reality technologies allow project developers to virtually build and test design proposals. This is quite useful in several ends from saving time, money and human resources to test architectural qualities quantitatively and several inherent qualities qualitatively. It is hard to measure the architectural quality based on the user feedback before the construction since it is way too individualistic assessments that we cannot validate. However, VR technology allows designers to collect data about the users' reactions or attitudes in the virtual space until the data starts to draw meaningful conclusions to support the design decisions. Technology can make way better than humans at data collecting and learning from the data, but the challenge comes up when we have to trust technology about making design decisions based on the data that it created. How can we approve that AI can make design the same quality humans make or even better than humans? Is it all about validation? The question is how to validate non-human creativity vs. human creativity. AI can show us new things. Not the things that we already know but to explore the alternative ways of doing things that we have never thought before. This can be nothing but a great deal of brainstorming about the endless possibilities of design.

5. Conclusion

Briefly, AI in architectural and spatial design is offering us more than we can imagine. Such robotic craftsmanship that AI offers will not only alter the way we design but also the way we construct and monitor the structure in the consecutive stages. The robotic fabrication might introduce a whole new aesthetic language towards unimaginable forms and details provoking and speculating new sensational co-occurrences that conventional construction technics remain inadequate but 3D printing-like construction technics. The architects of the 21st century in this sense are at the dawn of a new architectural design and construction era that even the decline of traditional or vernacular craftsmanship in architecture can be over and shifted to a whole new paradigm.

Briefly, to the question of whether the robots are coming to get our jobs, the answer depends on the job we are doing. Yes, because the AI will have a high capability to fulfill what most of us are doing in most jobs that we do not need to use creativity but generally apply routine procedures. No, because creativity will remain in the realm of the human mind and machines with deep learning ability cannot compete with such competence which is a great mixture of emotions, culture, ideology, religion, societal gender and so on in profound details. In other word, a design fully automated and rationalized by computers are still blind to the context and facing hard times in decision making unless we human beings do not intervene. Significant research labs, such as MIT Media Lab, are working on designing more responsive design machines with complex deep learning abilities. However, at the same time, the intelligence that AI presents allows us to redefine the game and let machines deal with more complex problems in design process what will enhance the vision of designer in various terms. Machines, thanks to AI, through a great capability will stay as human's most prominent assistants & partners in our struggles and attempts to design and make the world a better place we want to live in and leave the annoying work to the machines.

With great power comes not only great responsibility but also great risk especially when the stake is the design. The capability and strengths of AI remind us of the pros and cons for the future of design. We need to clarify the terms and the specific practice to use such capability properly within the overall architectural production process for the benefit of design. In other word, such capability, through a hybrid approach is an excellent opportunity to decrease the workload and increase the time and focus devoted to design and creativity. Advanced computational developments are offering highly sophisticated and cutting-edge design automation methods for architecture, urban design, and industrial design that helps to save time from doing repetitive tasks. However, computers are still not good at open-ended creative solutions; and that is still reserved for humans.

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