

From augmented reality for construction based on multiple sensory modalities to artificial intelligence within the design process. How does AI technology change the way we approach design?

School of Architecture, Built and Natural Environment

Course: BSc Architecture

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Module code: M6X01986

Word count: 10,010

Date: Monday 11th April 2022

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Abstract

Architects today should be knowledgeable about current legislation, ergonomics, and technology. Designing a space requires a keen appreciation of its quality and a high degree of creativity. As a result of the development of technology, it is a profession that has seen major changes in recent years. Computer algorithms are now capable of generating such complex designs that some designers are starting to wonder if they are more the work of computers than of humans. Furthermore, there is increasing speculation about the possibility of humans becoming redundant, as a result of the development of Artificial Intelligence.

A wide range of experts provide their opinions on the possibility that artificial intelligence may replace architects. This research explores, will computers eliminate the human factor in design? This study also considers the artificial intelligence and communication skills needed to achieve this goal, through the exploration of literature, case studies and an industry targeted questionnaire. In addition to determining the future of architecture, these questions will provide insight into the profession's current state. By examining the technologies that are enabling computers to replace many aspects of the human workforce, we will also gain a better understanding of how they work and draw conclusions on the future relationship between AI and Architecture.

Acknowledgements

I would like to acknowledge and give my thanks to my supervisor, Gavin Traylor, whose support allowed me to complete this research. Gavin's guidance and advice enabled me to complete most stages of my writing. I have been deeply inspired by his dynamism, vision, sincerity, and motivation.

The love, prayer, care, and sacrifices made by my parents to educate and prepare me for the future are deeply appreciated. Also, I would like to extend my sincere gratitude to my sisters, brothers, and friends for their support and prayers.

Last but not least, I would like to thank God for allowing me to survive all the challenges. Your guidance has become more apparent each day. Through your grace, I have pursued my degree. I will continue to trust you for my future.

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Introduction

From the infrastructure we use to examine workers, to the devices we use to communicate; our generation's technological growth is visible. Especially during COVID 19, digital tools have provided architects and designers with an amazing opportunity to communicate their work to a larger audience internationally. The utilisation of design technology has enabled architects to explore the possibilities of new design techniques and processes with a much wider group.

This study seeks to convey how advancements in digital technology for design and fabrication has influenced our work as architects. It is essential to remember the history of architecture and design, as well as the architects and philosophers who are always engaged in architectural research using digital design and production, to gain a better understanding of the state of digital design today and future trends.

Aims and objectives

Aim 1 – Investigate the history and background of Artificial Intelligence

Objective 1.1 – What was architecture before AI?

Objective 1.2 – What type of AI is used in architecture?

Objective 1.3 – Explore the progressive adaptation of technological solutions.

Aim 2 – Does Artificial Intelligence enhance or limit the design process in Architecture?

Objective 2.1 – Investigate the relationship between AI and architects?

Objective 2.2 – Can AI replace the creative factor in architecture?

Objective 2.3 – Explore case studies that use AI technology in their architectural firm, big and small practices.

Aim 3 – Is AI just a method that can solve technical problems, or can we foresee their potential to change the way we design architecture in the future?

Objective 3.1 – How will AI develop in the future, in terms of the systems gaining technical and ethnical knowledge and experiences of an architect?

Objective 3.2 – is AI seen as a threat, or an opportunity to explore new ideas, enhance creativity, and constantly optimising and pushing boundaries of our designs.

Objective 3.3 – Will it change the definition of architecture?

Methodology

Literature review – using literature to find out the history of AI technology and how it has evolved since technology has been introduced in the industry, using a mixture of primary and secondary research to support facts, as well as online research. In other words, how technology is revolutionising architectural design.

Case study – a primary research method to research of Foster + Partners and Frank Gehry work, which supports how AI technology define the terminology of architecture.

Questionnaire – A secondary research method includes a short questionnaire distributed to the industry about how they feel digital tools have changed the way we design and build as architects.

Chapter 1: History and background of artificial intelligence

Architecture can be described as the “built realisation of a particular concept”. This can be seen in “construction, or the way people will use a building, or how the building fits into a physical, or social environment. The balanced integration of artistic sensibility and scientific methodology applied to designing buildings and their environment, is essential to creating great architecture.”¹ Buildings have an impact on us both practically and emotionally based on their appearance in their context and their interior environment.

“But what is ‘Architecture’?”

As architecture definitions and career paths develop, this question has become increasingly more important for students seeking new perspectives on architecture. Architecture exists everywhere and at its roots to create the physical environment; it is also a part of our culture, representing how we see ourselves and how we see the world.

Before defining ‘architecture’, the term has a two-part definition of ‘designing’ (art) and ‘engineering’ (science), which must be made clear. ‘Designing’ allows us to provide platform for creative expression while also allowing society to view, develop, and modify their environment and living area in their own unique way. We respect it as architects because it is a lasting reflection of society values, desires, beliefs, and more at a specific time and place. Architecture requires creativity and imagination, as well as the ability to organise and convey ideas clearly and creatively. It also takes a great interest in human behaviour, our habitat, and the natural environment, as well as problem-solving abilities.

Regarding the terms science and engineering, it refers to our living space and environment, which provides us with both practical and comfortable living conditions. Buildings are developed using scientific methods that are considered numerous levels of research and development. As part of this process, users must also determine the programmed areas required for their specific needs, such as interior products, structure, mechanical, electrical, plumbing, fire protection, technological and security systems.

¹ Anon., *What is Architecture?* 2018

It is also possible for architecture to create miniature time capsules reflecting human thoughts and ideas, which can be seen in figure 1 and 2. Architecture shows where we are from, who we are, and how we like to live.

Figure 1: The Guggenheim Museum Bilbao, Frank Gehry.²



Figure 2: The Heydar Aliyev Centre, Zaha Hadid.³



² Jones, R., *AD Classics: Walt Disney Concert Hall / Gehry Partner*. 2013

³ Rhodes, M., *Tracing the legacy of Zaha Hadid, Architecture's Esteemed Anomaly*. 2016

Early adoption of technology

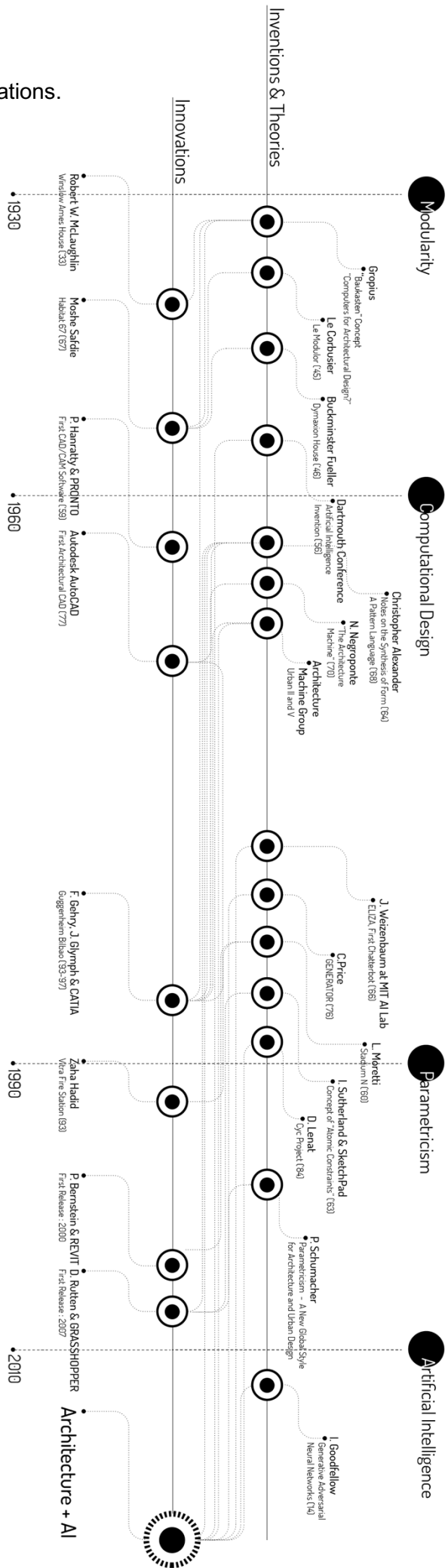
Goldsberry and Thomas (2020) notes that the use of technology in architecture is widely used to automate repetitive tasks and increase efficiency. One of the first means of conveying design between disciplines was to use blueprints to make copies of hand drawings (e.g., from architects to builders working on the construction site). They then describe the advancements in desktop computing have led to computer-aided software such as AutoCAD and Revit to become a viable production method in architecture offices, eventually replacing the process of physical hand drafting.⁴

Chaillou (2020) suggests that the advent of technology in architecture can be defined in four periods: modularity, computational design, parametricism, and artificial intelligence, as shown in figure 3. These reflect the chronology of the progress which has been shaping and refining architectural means and methods. Before introducing the Age of Architecture and Artificial intelligence, each period aims to demonstrate the deeply intertwined evolutions of the computational and architectural fields.⁵

⁴ Goldsberry, M. and Thomas, I.C., *Navigating the Growing Influence of Artificial Intelligence in Building Design*. 2020

⁵ Chillou, S., *A tour of AI in Architecture*. 2020

Figure 3: Inventions & Innovations.
(Chillou, 2020)



Modularity (1930s)

The term “modularity in design” can be used to describe a systematic architectural design process that began in the early 1930s. The modular construction brought both a language and an architectural grammar to the conception phase, simplifying and rationalising building design. Since its initiation, modularity in construction has proven to be a highly constraining system with limited options for potential designs.⁶ Nevertheless, such options quickly met construction feasibility criteria, and their architectural quality was questioned early on. Modularity in architecture, is a system is broken down into simpler sections called modules or skids that can be built separately and used in multiple systems using this design technique. Functional division into distinct, scalable, and reusable modules characterises a modular system, with a strict application of well-defined modular interfaces.

An example of this approach was shown in the 1920s and 1930s, during the Great Depression and the Inter-war period through the work of Buckminster Fuller. (Refer back to figure 3) Many lacked the money to invest in new homes. Fortunately, Fuller anticipated that the war would drive demands for his designs to become simpler, less expensive, and also more temporary. Fuller was determined to design a sustainable and inexpensive concept. He incorporates many inventive features into his pods, including a “compost-based methane heating system, a wind power generator, and a recirculating greywater plumbing system.”⁷ By applying a modular design approach, Fuller was able to keep costs down by creating an assembly line home. The triangular panels were used to construct the roof, floor, and walls. Aside from the central mast, every single piece of the kit was light enough to carry, which would be easily transported onto the site. (As shown in in figure 4 and 5)

⁶ Chillou, S., *A tour of AI in Architecture*. 2020

⁷ Kilson, K., *Forget Geodesic Domes, Buckminster Fuller's dymaxion house was his masterpiece*. 2019

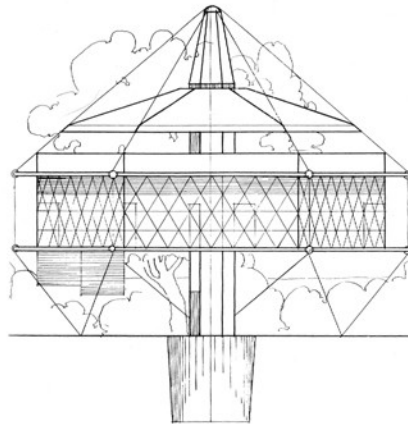


Figure 4: The prototype of the Dymaxion House by Buckminster Fuller.

Figure 5: Design concept drawing of the Dymaxion House.⁸

With modularity, you can achieve a variety of designs while achieving low development costs and cost-saving in the design and construction process. As a result, you find that modularity is “pushing out the productivity frontier in design creation” (McCluskey, 2000). However, modularity on the other hand, may result in excessive cost due to over-design, inefficient performance, and a loss of design identity due to the use of too many standard modules.⁹

⁸ Merin, G., *AD Classics: The Dymaxion House / Buckminster Fuller*. 2019

⁹ Alsane, A, and Nady, R., *Modular Architecture: When Beauty and Efficiency Meet*. 2015

Computational design (1960s)

As modular systems became more complex, the arrival of computation restored modular practicality and scalability. “Beyond the resurrection of the module, the systematicity of rule-based design was somehow rehabilitated.”¹⁰ Meaning that the designer can finally escape the grid’s rigidity to design feasible buildings with actual singularity with computational design. Furthermore, it enables the programme to solve such difficult shapes, lowering conceptual costs and allows for even more design iterations.

Computational design is a way of solving design problems by applying computational strategies.¹¹ While most designers make judgements based on intuition and experience, computational design enhances the performance by encoding the options in a computer language. A designer’s approach to solving problems is called design thinking, which is a human-centred, prototyping-driven, iterative problem-solving method. In order for computational tools to help enhance design thinking, it would need to go through the following modes: empathise, define, ideate, prototype and test. An architect, for example, might gain empathy with the client they are designing for in order to understand their latent needs, the redefines and scopes the problem, to develop many design ideas, and then create immersive prototypes for the client to test. As a result, new paths for iterating on solutions or the problems itself have opened up, through the use of computational design.

¹⁰ Chillou, S., *A tour of AI in Architecture*. 2020

¹¹ Kilkelly, M., *5 ways Computational design will change the way you work*. 2016

“Notes on the Synthesis of Form”

Christopher Alexander

This is a study based on how designs are formed and how those forms are adapted to real-world problems. (Refer back to figure 3) Design borrows elements from both art and science, but in reality, it is unique and distinct from both. The design output is neither a statement of truth nor a philosophical exercise in communication through aesthetics. Instead, design is a pursuit of what it could be. The common themes in design thinking are shown in figure 6.

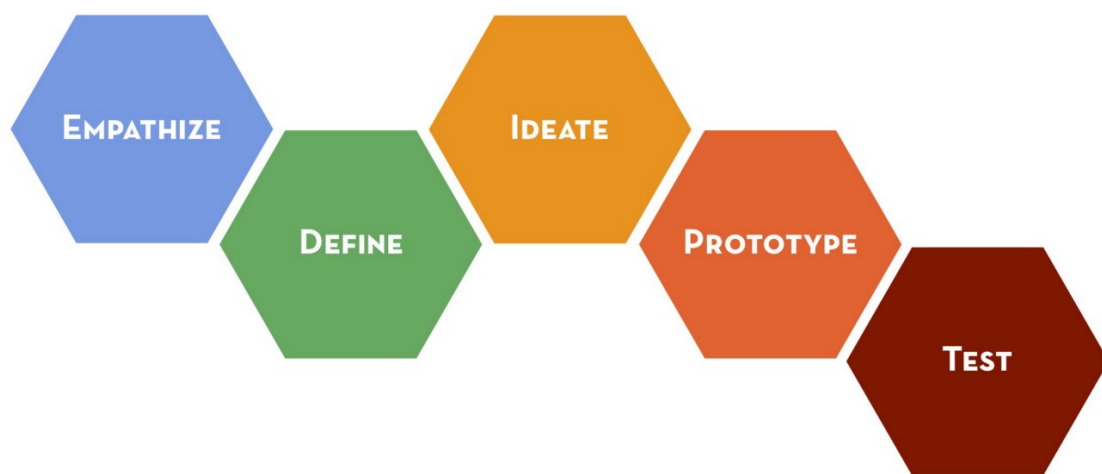


Figure 6: Design Thinking ideology.¹²

Alexander (1964) states that *“every design begins with an effort to achieve fitness between two entities: the form and its context. The form is the solution to the problem; the context defines the problem.”*

Architects are tasked designing buildings, and in doing so, they must consider the building as the ‘form’ and the environment where it will be used as the ‘context’. As Alexander describe how forms are shaped by forces in the context, he uses the analogy of iron filings in a magnetic field. Depending on the direction of the field; the context, the filings arrange themselves in a certain way, which results in the form.¹³ However, Alexander notes that it is not always straightforward because we do not know the direction of the field. In other words, a successful

¹² Geol, A., *Notes on Christopher Alexander's Notes on the Synthesis of Form and Design Thinking*. 2014

design depends on how well a form fits the context, not just the form itself. And when Alexander describes an ensemble as having a 'good fit' when it is working well.

"Good fit is a desired property of the ensemble which relates to some particular division of the ensemble into form and context." (Alexander, 1964)

When you consider the context, you'll notice that there are some anomalies in the system. For example, a designer may decide that using a kettle to heat water is ineffective, and then move onto another aspect of the ensemble. This occurs when a designer is trying to incorporate numerous parameters into an ensemble at the same time.

Alexander illustrated the failure of contemporary methods to consider the requirements and conditions that surround their development in design. He further argues that contemporary methods fail to produce products that meet the precise requirements placed upon them by individuals and society, meet user's needs, and respond to the basic requirement that design and engineering need to improve the human condition. Although architectural artefacts exemplify Alexander's arguments and methods, his concerns and methods apply just as well to software systems, subsystems, objects, etc. At this level of discussion, there are obvious differences between houses and software. For example: software entities engage in greater dynamic interaction (e.g., sending messages to each other). In some cases, describing software is the same as creating it (as with programming). Also, users are unaware of how a software is designed, this is because software is usually less physically constrained. Software requirements are allegedly more precise and explicit than building a house.¹⁴

Computational design tools enable designers to utilise the power of computation without having to learn complicated algorithms. In addition, these tools allow architects and designers to create their own tools. Computational design, for example, enables a more precise control of geometry, which improves the design's reliability, practicality, and cost. It also makes it easier for designers to collaborate. Finally, it allows for more design iterations than traditional hand sketching allows. As a result, more tests are conducted in order to improve designs, than through hand drawings.

¹⁴ Geol, A., *Notes on Christopher Alexander's Notes on the Synthesis of Form and Design Thinking*. 2014

Parametricism (1990s)

“What’s old is new again.”(Suzuki, 2020)¹⁵ This phrase has its place in ‘Architecture’. Algorithms are used in parametric tools to make complex designs easier to create. Before experimenting, design teams create a set of parameters, and when restricted to simple sets of rules, both repeated tasks and complex shapes could be addressed in parameters. By encoding the rules on the program, it would eliminate the time-consuming manual process.

“Parametricism: A new Global Style for Architecture and Urban Design”

Patrik Schumacher

Samuel Geisberg described the parametric ideal as *“the goal is to create a system that would be flexible enough to encourage the engineer to easily consider a variety of designs. And the cost of making designs. And the cost of making design changes to be as close to zero as possible.”*¹⁶

Architects were becoming more and more able to manipulate their design by utilising parameters, and the discipline “slowly converged” to parametricism, according to P. Schumacher. In his article in 2009, Schumacher highlights how Parametricism was inspired by a growing understanding of parameters within architecture. There are a few key individuals who have shaped the arrival of parametricism, from their invention to their translation into innovations throughout the industry. Zaha Hadid Architect’s work is the best example to start in terms of parametrisation. As an Iraqi architect with a background in mathematics, Hadid began her practice with the intention of using maths in architecture through parametric design. Using rules encoded in the program, Hadid was able to take control of the geometry of her buildings to an unprecedented degree. As a result, each architectural move corresponds to a particular tuning of the parameters, resulting in a certain building shape.

¹⁵ Suzuki, E., *What is Parametric design in Architecture, and how is it shaping the industry?* 2020

¹⁶ Davis, D., *Chapter 2 – The Challenges of Parametric Modelling.* 2013



Figure 7: Kartal Masterplan, Zaha Hadid Architects. The Kartal masterplan is a 2006 competition-winning project for a new civic, residential, commercial, and transportation hub located 25 kilometres southeast of the city.¹⁷

One of the examples that Schumacher uses to explain how Hadid used Parametricism in her designs is the Kartal Masterplan. A fabric study where both perimeter and cross towers make up the urban fabric. Figure 7 illustrates how the parameter blocks vary in morphology. And secondary pedestrian paths are created by dividing blocks into four quadrants. In addition, there are specific network crossing points where the block system becomes assimilated to the tower system: each block sponsors one quadrant around a crossing point to form a pseudo-tower.

¹⁷ Zaha Hadid Architects. "Kartal Masterplan". 2006

Through parametricism, we can manipulate organic shapes even further. Furthermore, the entire building could be discretised into buildable elements and resolved assembly systems by standardising their geometry. As a result, the parametric style became trivialised, leading to a more generic, repetitive patterns of space and poor architectural quality as some may say. This is because parametric has failed to consider the compound effect of multiple variables, the importance of spatial organisation and style over strict efficiency, the viability of scenarios, and the computational costs of simulation.¹⁸

¹⁸ Chillou, S., *A tour of AI in Architecture*. 2020

Artificial Intelligence (2010s)

In its simplest form, “artificial intelligence is a statistical approach to architecture”.¹⁹ By combining statistical principles with computations, artificial intelligence provides a new approach that overcomes the shortcomings of parametric architecture. In the end, artificial intelligence has become a viable alternative to parametricism legibility and generic style, while obtaining all of the benefits of previous generations, such as modularity and computational design. Its introduction marks the arrival of a new era in architecture and, to architects, a step towards a better quality and knowledge in design.

“What is Artificial Intelligence?”

A major technological breakthrough of the digital age is artificial intelligence, which aims to mimic human intelligence on machines to behave and think like humans. It refers to the ability of a computer or computer-controlled robot to perform tasks commonly associated with intelligent beings. For example, artificial intelligence could emulate human cognitive processes, such as reasoning, discovering meaning, generalising, or learning from experience.

As a result of the advent of modern technology in the 1940s, since the era of modularity and computational design, computers have demonstrated their ability to perform many complex tasks, such as discovering proofs or playing chess. Additionally, some software programs have attained the level of performance of human professionals or experts in performing a specific task.²⁰ Artificial intelligence can therefore be found in medical diagnostics, computer search engines, and speech recognition in this specific sense.

¹⁹ Chillou, S., *A tour of AI in Architecture*. 2020

²⁰ Copeland, B.J., “artificial intelligence”. 2021

The common themes in artificial intelligence

Research in artificial intelligence has focused on the following components of intelligence: learning, reasoning, problem solving, perception, and using language.

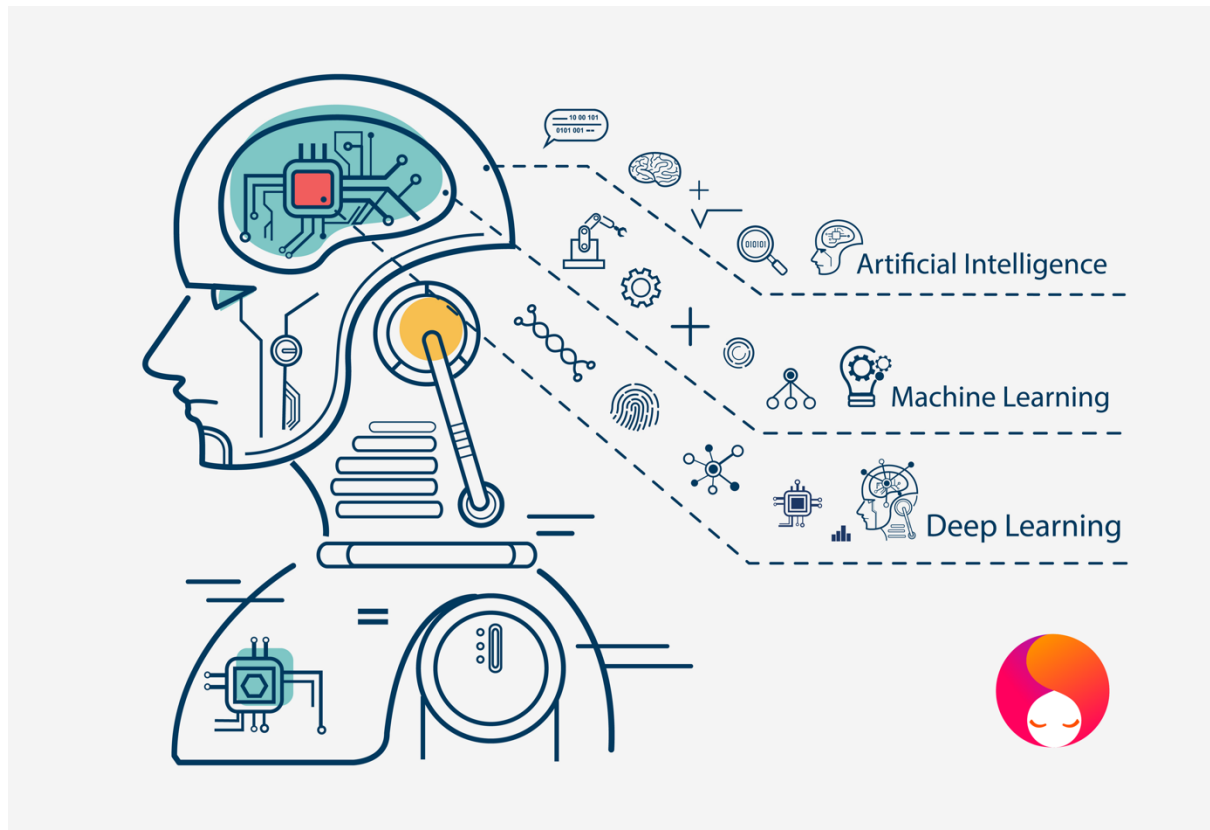


Figure 8: “Artificial Intelligence, which involves having a computer do something we assume only entities with human-like intelligence could do. Machine learning, which involves AI in which the computer learns how to perform a particular task. Deep learning in machine learning technique or algorithm for learning a pattern.”²¹

²¹ Signorelli, P., *Artificial Intelligence: Transforming the Nature of Work, Learning, and learning to Work*. 2018

Learning

When it comes to artificial intelligence, there are a few distinct characteristics of learning, like trial and error. For instance, a single computer program might look for a solution to a mate-in-one chess problem by playing moves at random. The program might then store a solution with the position. The next time the computer encountered the same position, it would recall the solution by memorising individual items and procedures known as rote learning, which is relatively easy to implement on a computer.²² In other words, artificial intelligence requires a learning process of trial and error. Furthermore, once taught, utilising a memorisation technique based on repetition, the machine should be able to complete tasks independently, without the need for instructions.

Implementing involves generalisation when applied to analogous new situations, which could be difficult. Copeland (2021) uses the example that if a program learns the past tense of a verb through rote learning, it will not produce the past tense of a word such as jump unless it has previously seen jumping. In contrast, a generalisation process can result in learning the “add ed”, so it forms the past tense of jump in light of previous experience with similar verbs.

Reasoning

It is drawn inferences relevant to the situation, that allows artificial intelligence to reason. The inferences are classified as either deductive or inductive. The conclusions are guaranteed to be accurate using deductive reasoning if the premises are true. In contrast, inductive reasoning means that the truth of the premise supports the conclusion but does not provide a guarantee. Copeland (2021) believed that a standard method of reasoning in science is inductive reasoning, which involves collecting data and developing models that describe and predict future behaviour until anomalous data force the model to be revised. Whereas deductive reasoning is based on the use of mathematics and logic to build intricate frameworks or irrefutable theorems from a limited collection of basic assumptions and principles.

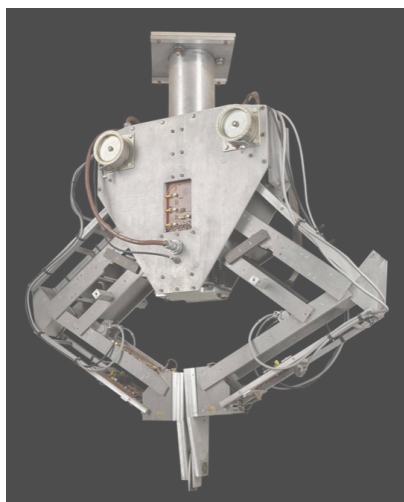
²² Copeland, B.J., “artificial intelligence”. 2021

Problem solving

It is defined as a systematic search through a set of options in order to reach a particular goal or solution. This method can be divided into specific purposes and general purposes. The special-purpose method exploits feature of the specific situation in which the problem occurs and is explicitly designed to solve it. Copeland (2021) describes one general-purpose technique used in artificial intelligence, which is a means-end analysis, in other words, a step-by-step or a reduction of the difference between the current state and the final goal. The program selects actions from a list of means: pick up, put down, move forward, move back, move left, and move right.

Perception

The environment is split into separate objects in various spatial relationships after being scanned by various sensory organs, natural or artificial. In this case, Copeland (2021) states that the analysis is complicated as the object may appear differently depending on the angle from which it is viewed, the direction and intensity of illumination in the scene, and how much the object contrasts with the surrounding area.



As a result of artificial perception, optical sensors can recognise individuals, autonomous vehicles can drive at moderate speeds on open road, and robots can go door to door collecting empty soda cans. FREDDY, a stationary robot constructed at the University of Edinburgh, in 1966 – 73, has a moveable television eye and a pincher hand. Using this robot, assembling products could be commanded from an assortment of components, such as assembling a toy car.²³ (shown in figure 9)

Figure 9: 'FREDDY' The original Freddy was created in the early 1970s by researchers at the University of Edinburgh's Department of Artificial Intelligence. Freddy the robot was the first robot to combine vision and touch through AI.²⁴

²³ Copeland, B.J., "artificial intelligence". 2021

²⁴ National Museums Scotland., *Freddy the Robot*. 2022

Language

There is no limit to the concept of language as it is a system of signs that have meaning by convention, which means that it is not restricted to the spoken word. Languages are characterised by meaning-by-convention linguistic units. “Linguistic meaning is very different from natural meaning, exemplified in statements such as “those clouds mean rain” and “the fall in pressure means the valve is malfunctioning.”²⁵

In contrast to birdcalls and traffic signs, an essential characteristic of human languages is their productivity, which means that a productive language can formulate an unlimited variety of sentences. Meaning that programmable computers can respond fluently to questions and statements in human languages in severely limited contexts. Despite the fact that none of these algorithms understands language, the principle reaches a point where their command of a language is indistinguishable from an average human. Even if a computer uses language as if it were a native speaker, can it be acknowledged that it understands?

²⁵ Copeland, B.J., “*artificial intelligence*”. 2021

Chapter 2: Artificial intelligence in architecture

Artificial intelligence has managed to impact most of the fields, but what about Architecture. Artificial intelligence has the potential to make the design process of the architects significantly easier, giving them access to countless amounts of data, creating models, interpreting the building environment, and creating cost estimates.²⁶ These days, every architect uses a computer, whether it's for 3D modelling or documentation. As a result, architects now need to know almost as much about the software as they do about structure, building regulations, and designs. That being said, not everyone has the time or the desire to learn how to use the software, as it is already time-consuming with projects to run, drawings to review, and buildings to design. Fortunately, there are tools available to enable programming to be executed with ease.

In a field that sways between art and engineering aspects, can AI replace the creative process in design?

Research

Artificial intelligence in the design process, acts as the foundation. And when researching, it tends to take as much time as 75% of the entire design process.²⁷ As AI software already knows everything about us, our interests, habits, likes, and dislikes, activities, friends, etc. AI is able to predict the growth of the population, prioritise projects, categorised streets according to their usage and so on, and then create plans that will satisfy everyone. In other words, AI supplements the architect's research by showing simplified and specific results. Architects can evaluate site conditions with minute precision using existing BIM tools, which tap into these data constellations. In addition, architects can conduct building and environmental analyses without ever leaving the office through software such as Ecodesigner Star and open-source plugins for Google Sketchup.

²⁶ Alexander, D., *5 ways Artificial Intelligence is changing Architecture*. 2020

²⁷ Wood, H., *The Architecture of Artificial Intelligence*. 2017

Experimentation

Artificial intelligence as the final juror means that the design's stability, strength, and performance could not be assessed earlier. And with the help of AI, we can test the design close enough to the site conditions and other parameters. And as a result, it enables the architect to experiment without affecting anybody and anything.

Also, artificial intelligence gives us the opportunity to help bring your vision to life through 'Augmented Reality' and 'Virtual Reality'. A technology evolved to the point where you can walk through a design. In augmented reality, it enables architects to interact with their projects by merging a digital model with physical space, generating a 3D model of the suggested model, and placing it over the project's environment and surroundings. On the other hand, with virtual reality becoming more accessible to consumers and firms alike, the architecture industry has noticed. Virtual reality is most commonly experienced by wearing a headset that fully covers the user's eyes and entirely immerses them in the virtual environment.

Empathy

However, artificial intelligence cannot currently deal with everything. Although AI can give us outputs from an asset of data and information stored previously it cannot curate one on its own. Although artificial intelligence has no knowledge of emotional aspect and decision making, AI can offer a set of viable options for an architect, which was mentioned on the 'Synthesis of Form' on design thinking.²⁸ For example, an architect puts themselves into their client's shoes and tries to figure out solutions that suit best for each scenario, giving an empathetic and emotive response, a human characteristic. Studies show that "most of the professions that were on the least likely side had human interaction as one of their cornerstones along with empathy and emotions."²⁹

²⁸ Alexander, C., *Notes on the synthesis of form*. 1964

²⁹ Raphy, R., *Can artificial intelligence replace Architects – A realist's perspective*. 2020

Creativity

Artificial intelligence can take over repetitive tasks. Obserste-Ufer (2019) stated that "software tools and programs can now make building calculations and environmental analysis a simple task."³⁰ Redrafting and revising drawings will be taken over by AI, which would help render precise and accurate drawings, meaning that the architect would be left with time in hand to focus more on the project.

"But can AI learn to be creative?"

With the advancements in artificial intelligence today, there is a possibility that computers can be taught on some parameters of creativity. However, studies point out that teaching computers to be creative, is inherently different from how humans learn to create. Therefore, many questions how AI can develop its sense of creativity.³¹

University of Sussex cognitive scientist, Margaret Boden, who also serves as an advisor at Stephen Hawking's Leverhulme Centre for the Future of Intelligence, explains that "many examples of creativity involve learning and exploring in a hierarchy style. For example, if you had a machine that generates random musical note combinations, a human with adequate understanding and time might be able to come up with a few ideas. Whereas a gifted artist might hear the same random compilation and come away with a completely novel idea, one that sparks a totally new form of composition."³² According to Boden (1973), 95% of what professional artists and scientists do is exploratory, with the remaining 5% being truly transforming creativity. There are numerous processes involved in creative thinking, and she feels that artificial intelligence plays a significant part.

³⁰ Oberste-Ufer, K., *7 ways artificial intelligence is revolutionising Architecture*. 2019

³¹ IBM., *The quest for AI creativity*. 2017

³² Boden, M., *What's next for AI*. 1973

Alan Turing

In 1935, Alan Turing described the computing machine “as a limitless memory and a scanner that moves back and forth through the memory, symbol by symbol, reading what it finds and writing further symbols.” The scanner operates on, modifies, or improves its program through a program of instructions. Later in 1947, Turing mentioned that the computer intelligence, saying “what we want is a machine that can learn from experience, and that the possibility of letting the machine alter its own instructions provides the mechanism for this.”³³

“*Can machines think?*” Turing (1950) states that “a computer deserves to be called intelligent if it could deceive a human into believing that it was human”. Turing claimed in 1950, that a machine may have artificial intelligence if it could mimic human behaviours under certain circumstances. In response, he created a practical test for computer intelligence named the Turing test, which involves three contestants: a computer, a human interrogator, and a human foil. In the test it starts by asking questions of the two other participants, the interrogator attempts to determine which participant is the computer.³⁴

The test is administered in a room under the supervision of a judge. A person and a computer program are hidden during the test. During the conversation, the judge attempts to tell which party is the human and which is the computer. If he or she cannot identify the party from its differences, as a result the computer has demonstrated human intelligence, proving that it can think. Using this simple method, it can be determined whether or not a machine can demonstrate human intelligence; if a machine engages in a conversation with a human, it has demonstrated human intelligence (as shown in figure 10)

³³ Copeland, B.J., “artificial intelligence”. 2021

³⁴ George, B. and Gillis, A.S., *Turing test*. 2021

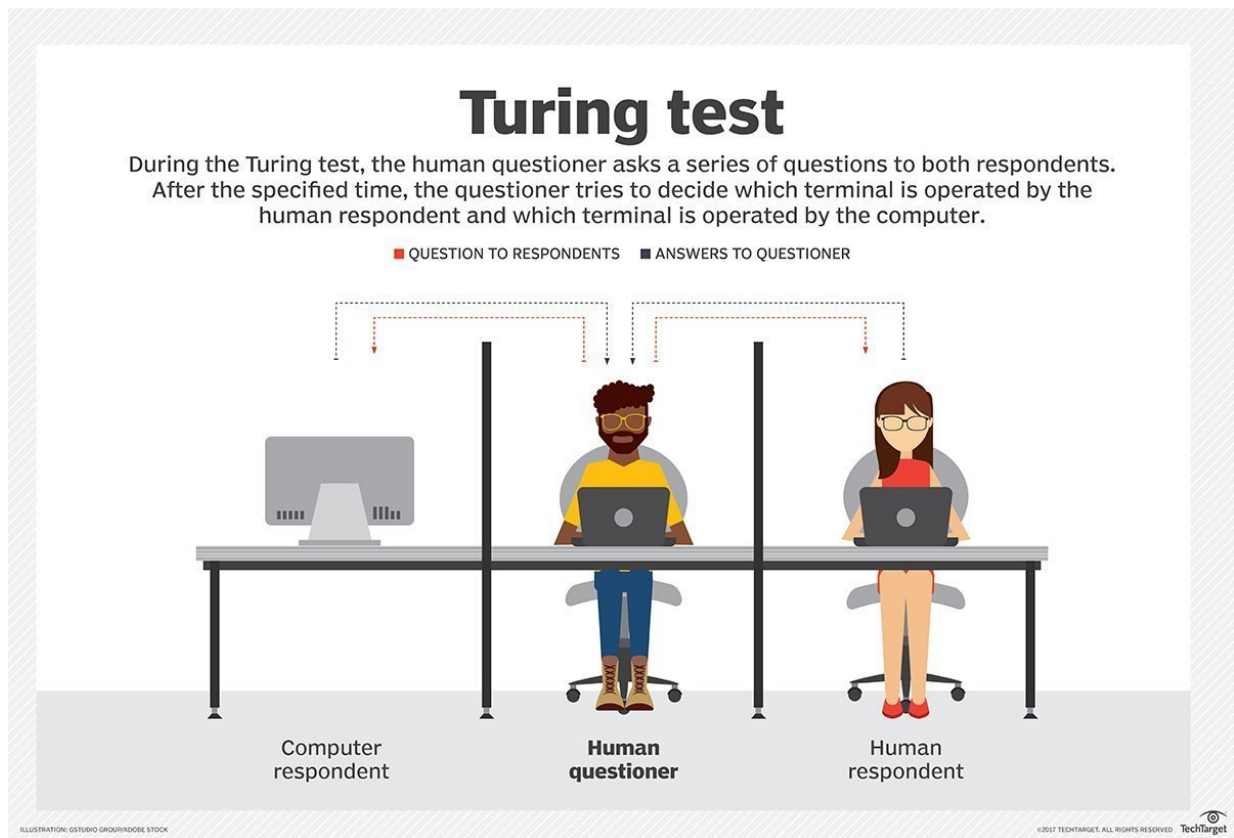


Figure 10: The Turing test in 1950.³⁵

The Turing test evaluates the computer's conversational abilities as a consequence of this test. "According to the test, a computer program can think if its responses can fool a human into believing it is human."³⁶ Many question the validity of the test, but padding it remains a significant challenge for artificial intelligence developers. Which raises the question, will artificial intelligence gain empathy and creativity through the improvements of AI thinking?

³⁵ George, B. and Gillis, A.S., *Turing Test*. 2021

³⁶ Frankenfield, J., *Turing test*. 2022

Artificial intelligence used in architecture practice

Rethinking the mindset of embracing machine learning, not replicating, or replacing architects, rather than embracing our knowledge, instincts, and sensitivities with them. In Foster & Partners they believe that with AI established in the 1950s through modularity, computational design and parametricism, the systems and processes must be perfected to mimic human intelligence accurately. An example would be the subset of AI known as machine learning, summarised by a computer scientist from Tom Mitchell (1951) as 'the study of computer algorithms that allow computer programs to automatically improve through experience.' (Foster & Partners, 2021)

Using machine learning, we can analyse designs quickly and at a reduced cost. The Foster + Partners ARD team has been looking at incorporating it into the design process, as well as some other exciting possibilities.

Surrogate modelling

An alternative to analytical engineering simulations (such as structural deformation, solar radiation, pedestrian movement) that may take days or even weeks to complete is surrogate modelling. In other words, the surrogate method interpolates a mathematical model based on the relationships between design parameters and performance criteria, therefore using this model, architects can explore the approximate impact of the changing design variables. Due to the time and work involved, it is nearly impossible to optimise designs based on their findings, therefore undermining these tools' benefits by helping through the research stage. Machine learning might enable architects to solve difficulties and find trends, depending on complex analytical simulations and programmes.

To address this issue, the ARD team have looked at surrogate models, in which a computationally 'cheaper' predictive model is built based on a set of carefully picked simulation results. The surrogate model's approximation of a simulation in real-time can then be used by the designer, allowing them to make a quick decision.³⁷

³⁷ Tsigkari, M. and Tarabishy, S. and Kosicki, M., *Towards Artificial Intelligence in Architecture: How machine learning can change the way we approach design*. 2021

Data: Original versus synthesised

“With machine learning, the input data is the key.”³⁸ The quality of data in Foster & Partners is provided by the system determines the success of the system. The data produced by architectural datasets is rich, complex, and often produced in large quantities; they contain many invaluable information and are ideal for training AI systems.



Figure 11: There are thousands of drawings, models, slides, photographs, publications, awards, and other practice-related materials in the Foster & Partners archive. Their digitalised image server contains over 600,00 files. (Foster & Partners, 2021)

It has become a necessity in both surrogate and design assistance models when it comes to data. There are two types of data; original or synthesized. At Foster + Partners, the practice has compiled an archive of drawings, models sketches, details, covering more than five decades of activity. In contrast, the synthesized data is automatically generated with the help of a generative design system.

³⁸ Tsigkari, M. and Tarabishy. and S. Kosicki, M., *Towards Artificial Intelligence in Architecture: How machine learning can change the way we approach design*. 2021

Currently, each of the data presents its own challenges. For example, in terms of original data, it takes time to sort through decades of digitally archived work in different file formats produced by many employee's projects to find the data relevant to their work. In addition, while synthesized data may not always be an option, developing generative models with the type of richness of data necessary may prove to be an impossible task.

Simulation of thermo-active laminates

It is the ability of materials to change their shape without the assistance of an external mechanical force. In other words, how smart, passively actuated materials react like living organisms, adapting to changes in their physical environment such as temperature, light, and humidity, which could result in great architectural potential. Foster & Partners (2021) used the example of a passively actuated façade might not have any mechanical shading devices like motor-controlled louvres. Instead, they would prefer to dilate under external light conditions, like an eye's iris, to provide shading, prevent overheating, or increase privacy.³⁹

Foster & Partners believed that this is achieved by mixing patterns of thermo-active materials around passive laminates (multi-layered materials). And as a result, contraction rates occurs where there is a difference in expansion. Therefore, if curated it can lead to specific deformations, which could help architects control and exploit designs.

The ARD team was interested in the material's morphological deformation, which involves a controlled transition between initial and end states. In contrast to a linear analysis, the laminate's internal forces and displacements have a non-linear relationship. Therefore, the changing input parameters will produce predictable results. The same cantilever beam under a constant force with its known dimensions coupled with a material that is permanently preformed in the same way will deform in a non-linear way during an earthquake. As a result, a non-linear analysis requires an elaborate and time-consuming simulation strategy. (Shown in figures 12 and 13)

It might be possible to repeatedly change the laminate's layering and analyse the results, adjusting at a steady yield to come closer to the target deformation. However, due to the complexity of the non-linear simulation, it goes through the process of trial and error to achieve the expected results.

³⁹ Tsigkari, M. and Tarabishy. and S. Kosicki, M., *Towards Artificial Intelligence in Architecture: How machine learning can change the way we approach design*. 2021

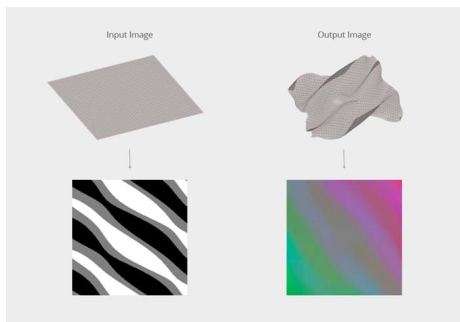


Figure 12: Below is a grey-scale image of the laminate as it appears in its initial state (on the left). A distorted image of this laminate is shown on the right (after completing a non-linear structural analysis) and its encoding to a depth map. Various colours represent the degree of deformation of each part of the laminate. (Foster & Partners, 2021)

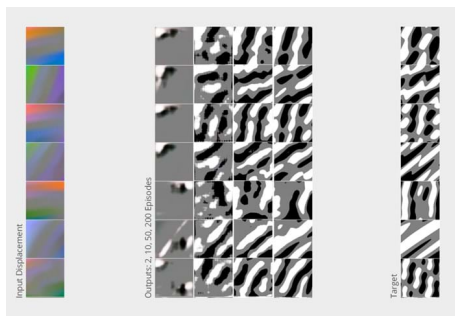


Figure 13: As you can see in the images, the system has learned to predict the material layering pattern that will produce each desired depth map (or material in its deformed state). You can see the required depth maps in the left column of the images. Below that is the necessary layering of the target layer. Between these layers, we can observe how the system moves towards the target. (Foster & Partners, 2021)

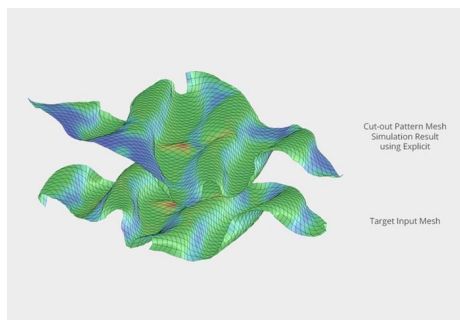


Figure 14: It demonstrates the difference between an arbitrary designed laminate in a set deformed state and the original non-linear analysis that was run on the laminate's initial state. Although the deformations are not identical, they are close enough to demonstrate the effectiveness of the approach and the system's ability to generalise. (Foster & Partners, 2021)

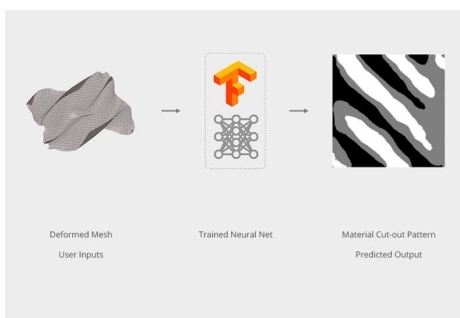


Figure 15: This still is taken from a custom design assistant application, which uses the trained neural network. (Foster & Partners, 2021)

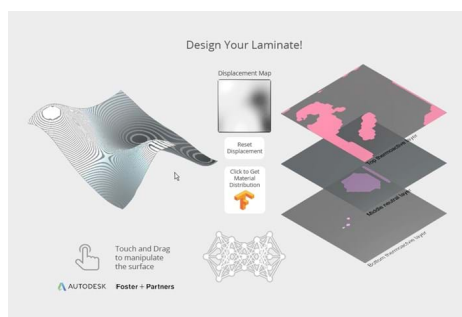


Figure 16: On the left, the desired deformed material state is fed into the trained neural network (centre) and on the right, the required material cut-out pattern is calculated. It shows how an inverse problem is solved after the training has finished, which is reverse of how the problem was initially conceived. (Foster & Partners, 2021)

Spatial and visual connectivity

When evaluating and experimenting with the function of a floorplan, for example, in an office, they consider issues such as visual navigation, walkability, the balance of private offices and shared spaces, and facilitating serendipitous collaboration. However, to achieve spatial and visual connectivity analysis, sometimes it can take a long time to compute for large-scale floor plans. Space and visual connectivity can provide valuable insights into the effectiveness of a floor plan early in the design process (shown in figure 17 and 18). On a grid, spatial connectivity measures the distance between two points. It allows for the examination of walking distances between locations of interest, as well as the analysis of escape routes. It can also be used to analyse visual distances instead of physical distances. The space configuration must be provided as an input for performing spatial analysis and visual analysis. Walls, partitions, and furniture are considered interior elements of an organisation. When analysing visual connectivity, you can conduct the analysis at knee height when walls and furniture are included as obstacles, or at eye level when only walls are included.⁴⁰

From the laminate study, ARD used machine learning and trained a surrogate model to mimic the analysis output. In Foster & Partners a parametric model was created to generate basic office plans that would include open-plan and compartmentalised workspaces, finished with walls, doors, and furniture. This results in the generative parametric model to allow us to construct a synthetic dataset of thousands of floor plans, each with their own set of visual and spatial results, indicating that the outputs from the ARD inputs accurately mirror the ARD inputs. This data can be utilised to train a machine learning system that will help analyse spatial and visual connection.

⁴⁰ Tsigkari, M. and Tarabishy, S. and Kosicki, M., *Towards Artificial Intelligence in Architecture: How machine learning can change the way we approach design*. 2021

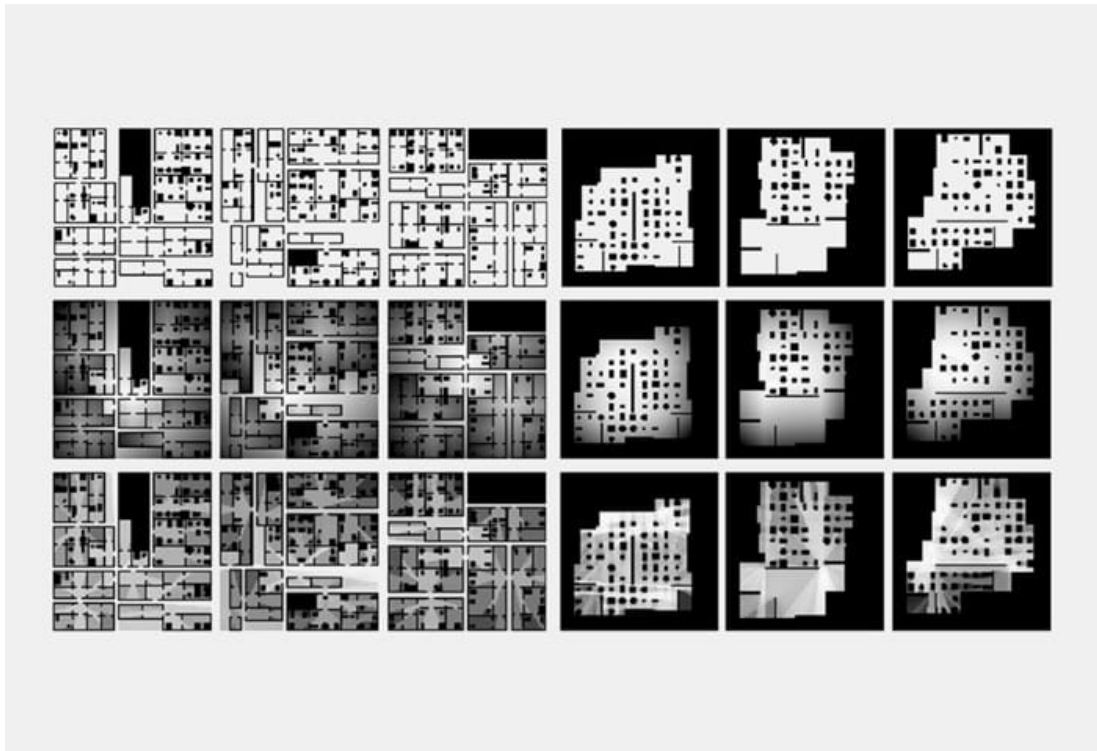


Figure 17: The image in the top row shows the output of the parametric model for floor plans, showing three computational space (left) and three open-plan workspaces (right). As shown in the middle row, the spatial connectivity analysis output appears, and the visual connectivity analysis output appears in the bottom row. (Fosters & Partners, 2021)

And as part of the machine ‘training’, it goes through trial and error, where it continues trying to improve itself by comparing the results. It goes through a phase in which it begins to show signs of inaccuracy, and as time passes, the artificial neural network receives feedback and begins to correct results. By the end, the models have discovered their own ‘recipe’ for mapping from the input of a floorplan to the output of a floor plan with the correct spatial and visual connectivity analysis, which was not the case at the start. ⁴¹

⁴¹ Tsigkari, M. and Tarabishy, S. and Kosicki, M., *Towards Artificial Intelligence in Architecture: How machine learning can change the way we approach design*. 2021

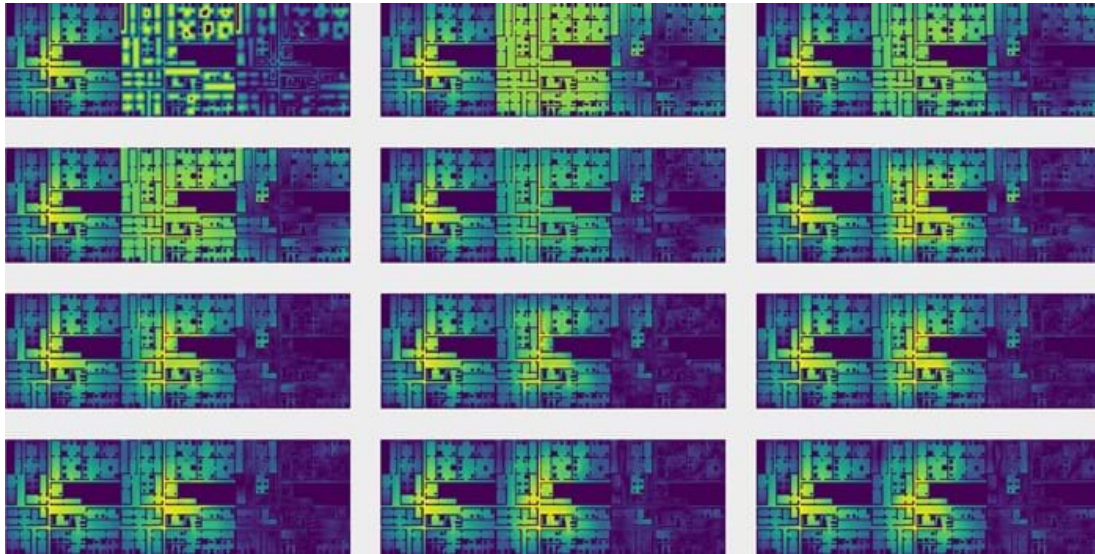


Figure 18: An analysis of the floorplan of the model with a series of stills. The left-hand floor plan displays the predicted (and correct) output of the connectivity analysis on the plan. As the model trains (showing the same floor plan), the central animation shows the model's steadily improving predictions. It matches the correct analysis in the left-hand plan at the end of the animation (bottom right). The right-hand plan darkens as the model's prediction gets closer to reality. (Foster & Partners, 2021)

Once the model has been trained, it can be put to work, which will run both the spatial and visual analysis on any architect's floor plan in less than 0.03 seconds. The ARD team begins to see the effectiveness of a change in office arrangement on screen as they adjust with such a powerful tool.⁴²

⁴² Tsigkari, M. Tarabishy, S. Kosicki, M., *Towards Artificial Intelligence in Architecture: How machine learning can change the way we approach design*. 2021

Case studies

The use of artificial intelligence in the industry represents a significant shift away from simply automating processes and toward guiding progressive design and constructability. There are other projects that define this transformation seen in projects through the technical solution to using artificial intelligence such as:

1. Yokohama Terminal, Foreign office architects (1995 – 2002)

Designed in 1995, it exemplifies a building design made possible by significant technological advancements in architecture modelling during the decades prior; personal computing, MicroStation, AutoCAD and Computer Numerical Control Milling.⁴³ Through its hyper-technological design, the project pushed the boundaries of architectural form and simultaneously provoked dialogue regarding the social responsibility of large-scale projects to enrich urban spaces. However, to achieve this striking appearance, a computer-aided design had to be used.

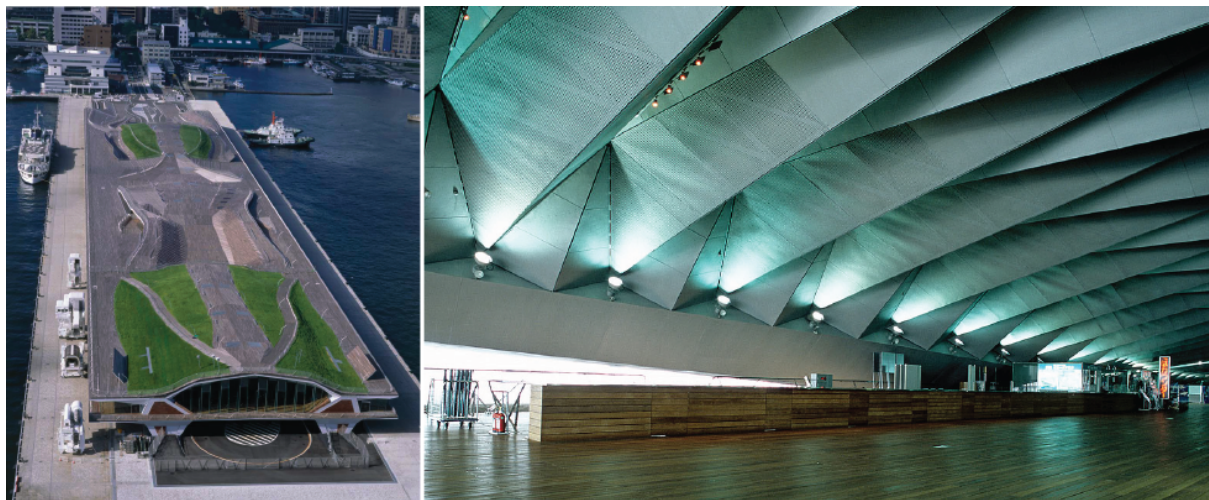


Figure 19: Yokohama International Port terminal.⁴⁴

The book “Drawing Architecture” (2018) by Helen Thomas describes FOA’s design process for Yokohama port terminal as one in which computer programmes were constantly mutated and multiplied. Rather than discrete, volumetric structure, these programmes produced undulating planes or new landscapes. By the early 1990s, personal computing advancements had enabled widespread adoption of MicroStation and AutoCAD. Then, after decades of

⁴³ Langdon, D., *AD Classics: Yokohama International Passenger terminal / Foreign Office Architects*. 2014

⁴⁴ Godsberry, M. and Thomas, I.C., *Navigating the Growing Influence of Artificial Intelligence in Building Design*. 2020

refinement, CNC Milling became more widely used. From this case study, AI was used as a tool to produce large scale projects through software such as AutoCAD and CNC milling. From collecting the data inputted by the humans, the artificial intelligence has worked through problem solving in terms of how the building can and cannot be constructed, while learning from this experience and inputting it for next large-scale projects.

2. Guggenheim Museum, Frank Gehry (1991 – 1997)

Foreign office architects utilise the same technology used when creating the Guggenheim Museum in Bilbao, Spain. In the book “Frank O. Gehry: The Complete Works,” (1998), he recalls that the software programs initially developed for designing airplane fuselages (CATIA), provided the matrix for shaping and refining every part and element in the Guggenheim’s design and construction.⁴⁵ Due to their mathematical complexity, these curves were designed using 3D design program called CATIA, which enables complex designs and calculations that were impossible years ago. Gehry’s hand-built models are digitalised by the software so that it can create on-screen animations based on edges, surfaces, and intersections of his models. For example, CATIA calculated the number of bars required in each location and the bars’ “positioning and orientation”.



Figure 20: Guggenheim Museum.⁴⁶

A common technological advancement was opened up to more creative uses through this software development by human ingenuity. The Complete Works book, Gehry (1998) notes that the Guggenheim at Bilbao set the trajectory for a productive capacity whereby a building could be conceived and executed into an uninterrupted loop rather than in separate and distinct phases. From this case study, it shows a similar process to Foster & Partners through

⁴⁵ Godsberry, M. and Thomas, I.C., *Navigating the Growing Influence of Artificial Intelligence in Building Design*. 2020

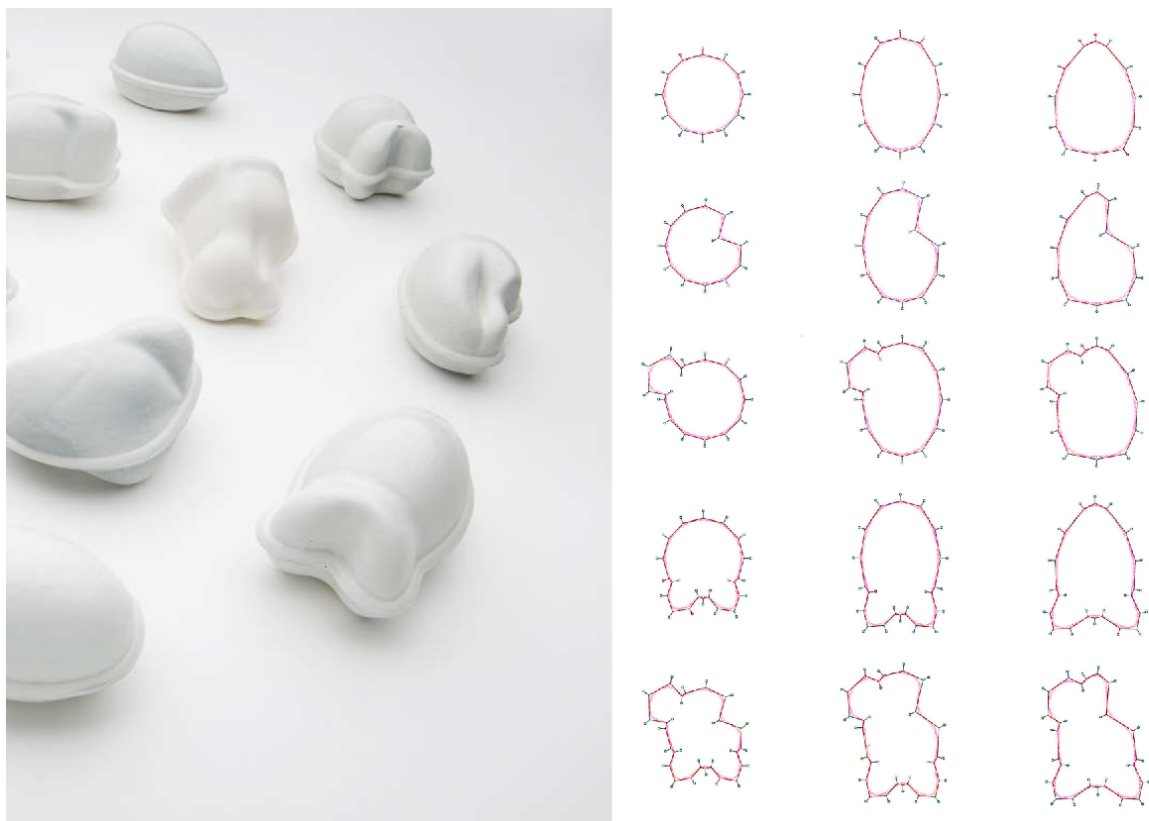
⁴⁶ Pagnotta, B., *AD Classic: The Guggenheim Museum Bilbao / Gehry partners*. 2013

the use of creating a model, from hand-built models to software created models, in order to use AI as a tool to find any problems and to solve it through what its learnt before. This helped to enhance the design process because it allows the architects to view their large-scale plans only from a 16-inch screen with all the tools needed.

3. Embryological House, Greg Lynn (1997 – 2001)

This case study in the preservation of digital architecture shows the dynamic forms of the house comprise flowing, and vector-based surfaces sometimes referred to as “blob” architecture, made possible through animation software.⁴⁷ Lynn anticipates that the new computer-aided design capabilities and computer numerically controlled manufacturing will aid in the design process. In architectural construction, the early adoption of software in creating and fabricating without following a prototypical journey demonstrates the early adoption of software.

Figure 21: Physical models for the Embryological House.⁴⁸



⁴⁷ Goldsberry, M. and Thomas, I.C., *Navigating the Growing Influence of Artificial Intelligence in Building Design*. 2020

⁴⁸ Lynn, G., “Greg Lynn’s Embryological House, “AD” Contemporary Processes in Architecture”. 2007

Testing the design's compatibility with the available manufacturing technology, prototypes for the Embryological House were made using prototyping technology. Embryological House prototypes were made of a variety of materials. The models, for example, was intentionally exposed to the manufacturing process by Lynn leaving traces of computer-controlled tools on its surfaces.

The concept was to create a family of architectural forms built from unrestricted iterations of a basic primitive, ultimately resulting in a similar yet unique construction. In addition, forms and houses would have "shared regulating principles" that would allow customisation and mass production of each component. In conjunction with CNC manufacturing, computers can use computer-controlled design tools to communicate directly with robotically controlled devices in the production process. For example, the 2D/3D drafting program MicroStation was transformed into an animation and visualisation program called MAYA by combining computer drafting and animation software.

"The Embryologic House employ a rigorous system of geometrical limits that liberate models of endless variations." (Lynn, 1997) Lynn's work with the Embryological House, is a postmodern, organisms styled inspired by evolutionary biology and the science of turbulence and made possible by the computer's ability to generate warped or fluid forms. And this was made possible through the use of AI, this case study differs from the previous studies as Lynn begins to explore within the creativity through AI, will AI seek the other creative possibilities that we are not seeing?

Chapter 3: Analysis and comparison of case studies

What will the future hold for architects, and what role will artificial intelligence play in shaping the future of the built environment? A global pandemic has dramatically accelerated the emergence and use of new design techniques as well as creative possibilities, but how is this reflected in practices. As secondary data, the author has decided to produce a questionnaire aimed primarily to architects working within practice. This questionnaire was aimed at ascertaining perceptions and experience of AI within the workplace. The questionnaire was sent on Friday 11th of February, to the ARB registered architects within UK through emails, and was posted on LinkedIn for more exposure to the research. The results were collected and analysed on Monday, 21st of February, meaning that there was a time limit of two weeks maximum to collect a decent size data. As a result, we had 22 respondents from within the architecture industry. Despite some limitations when analysing the data, it still provides an interesting insight into how the technologies and software have affected architects in the industry. (Full details of the questionnaire are included in Appendix A)

AI in Architectural Practice

Nowadays, 50% of those working in practice describe artificial intelligence as a machine used to analyse and solve problems with minimal human input. Many say artificial intelligence introduces a new design method by applying the software that mimics human-driven processes traditionally. However, it is also a method for eliminating human input from the design process. (Shown in figure 22) When using artificial intelligence in architecture, 45% believe that AI is another tool used to optimise resources, producing efficient and sustainable designs. However, according to 13% of architects, AI offers solutions in terms of space and practical considerations. In terms of aesthetics and sensitivity, it is less useful in the architectural field. (Shown in figure 24) With artificial intelligence in the design process, it should be able to utilise two systems, called “Expert Systems” and “Rule Based Systems”, that simplify and clarify all constraints, from client briefs to building regulations to planning and legal constraints. A designer or design team can easily explore multiple design options using neural networks and algorithmic exploration and select from a palette of available options. Neural networks should also be able to monitor construction in real-time to ensure it conforms to the design intent and adapt to the building’s usage in real-time, thus serving as a real-time monitor system. These systems are similarly done through Fosters + Partners, where they are able to explore the multiple design options using AI, through the common themes of learning, reasoning and problem solving during their research/ experimentation process.

Machine Digital Design Parametric design Intelligence Forms + processes A new concept



Figure 22: What do you understand by the term 'artificial intelligence' in architecture?

Phone Algorithms Softwares BIM Parametric design



Figure 23: What is your experience with artificial intelligence?

Design Solution Aesthetics Neural networks Future

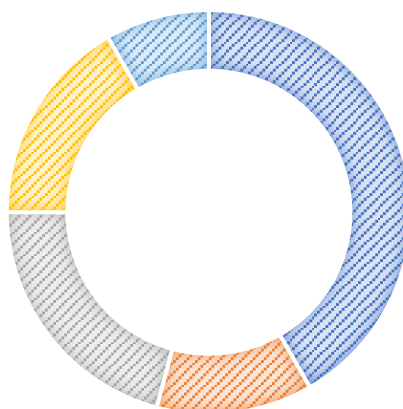


Figure 24: What is your opinion on using artificial intelligence in architecture?

Architecture and social values

During the 1950s and 1960s, through modularity and computational design, artificial intelligence was envisioned as a computer learning to perform cognitive tasks and operations like a human brain, until it was tested by Turing if machines can think. Today, artificial intelligence is shaping our aesthetics choices with algorithms that suggest what we should see, read, and listen to. We use it when making movies, music albums, product, and website designs, and to evaluate aesthetic choices.

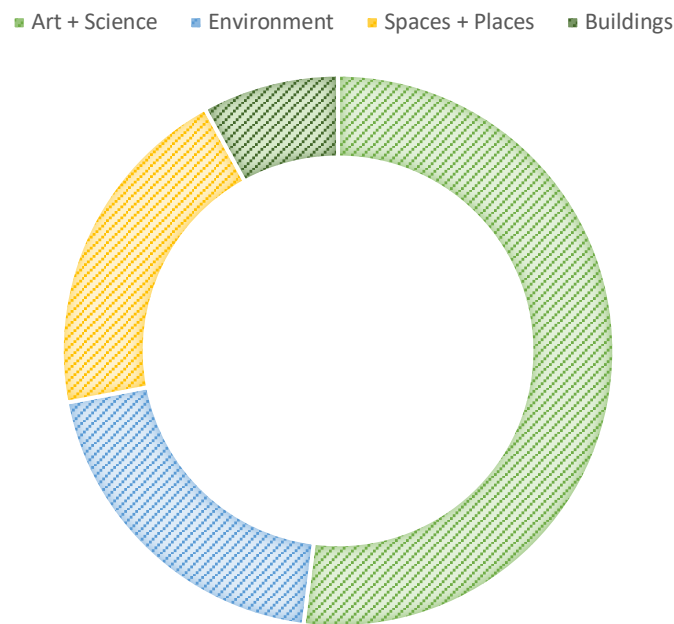


Figure 25: How would you define 'Architecture'?

59% of architects define 'architecture' as art and science, whereas 45% defined it as a built environment and space. (Shown in figure 25) The respondents believe that the built environment defines places and society numerous ways, reflecting the conditions and aspirations of the inhabitants of a specific location with its particularities. It influences how people live, meet, and congregate in the modern world. In other words, we are shaped and effected by the built environment. Architecture provides safe environments to provide comfort, security, warmth, and shelter for the people who live and work in them. As a result, they are a direct influence on our culture and society, and influence on our culture and society, and influences how we behave.

■ Value of beauty ■ Social value ■ Design ■ Opportunity

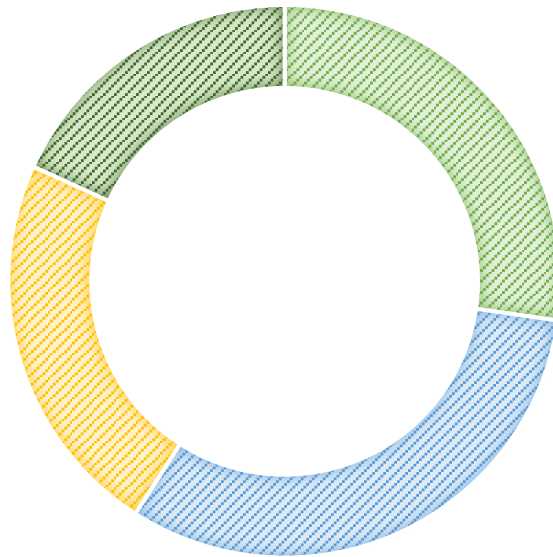


Figure 26: Do you think the social value in architecture is important? If so, why?

Architecture is also defined as social art. However, these days in 'Grand Designs', where the focus is mainly on enlisted projects. Creating the feeling that architecture is something reserved for the affluent, and everyone else should accept what they are given. On the contrary, architecture's role is to be more inclusive and should be seen to focus on the wants and needs of the vast majority rather than the elite few. (Shown in figure 26)

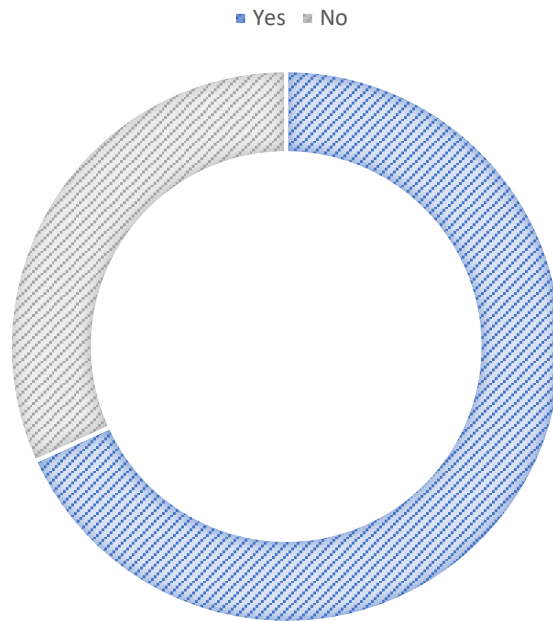


Figure 27: What do you understand by the role of architecture in today's society?

68% of those working in the architecture industry believe that the social value in architecture is important and should be shown while using artificial intelligence as a tool. There are many aspects of our existence that the world and contemporary society permit, including environmental responsibility, social responsibility; mental health and physical well-being; beauty and creativity as a positive stimulus to the society as a whole. (Shown in figure 27)

Future of artificial intelligence and architecture

Artificial Intelligence uses algorithms to create better buildings as it can help to refine, inform, and generate designs. In other words, artificial intelligence provides architects with a new tool to help them obtain their goals and enhance their ideas. It is a tool that can also reveal hidden patterns while proposing new and existing constructions. But what does this mean for the future of architects?

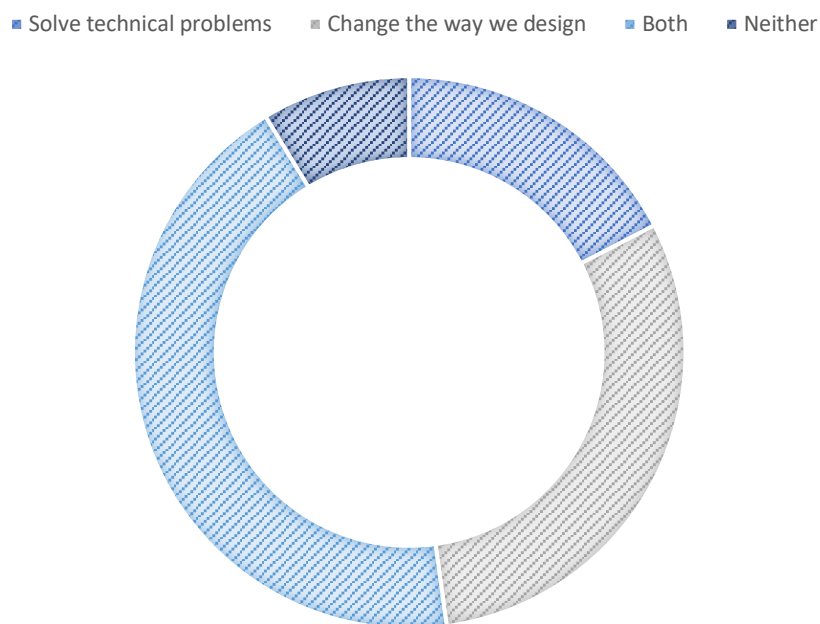


Figure 28: Is AI just a tool that can technical problems or a potential to change the way we design architecture in the near future?

18% of respondents believed that artificial intelligence could solve technical problems in architecture. This is because it acts as a tool that enhances the design and minimises the danger of a bad design, through the components of trial and error and minimum human input. For example, artificial intelligence acts as a tool that allows architects to explore design spaces in virtual reality. A third of respondents saw artificial intelligence as an opportunity to change how we design or improve our designs. As AI and its uses grow in complexity, they are likely to play a more significant role in the duties of the future architects in the 'Metaverse,' which is seeing vast investment, as one respondent stated. In the near future, 45% see it as a tool for solving technical problems as well as a tool for changing the way we design architecture. (Shown in figure 28)

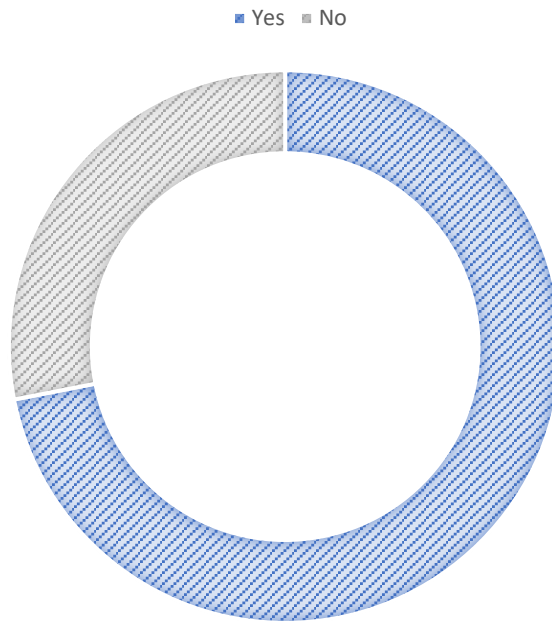


Figure 29: Do you think AI can replace in the near future?

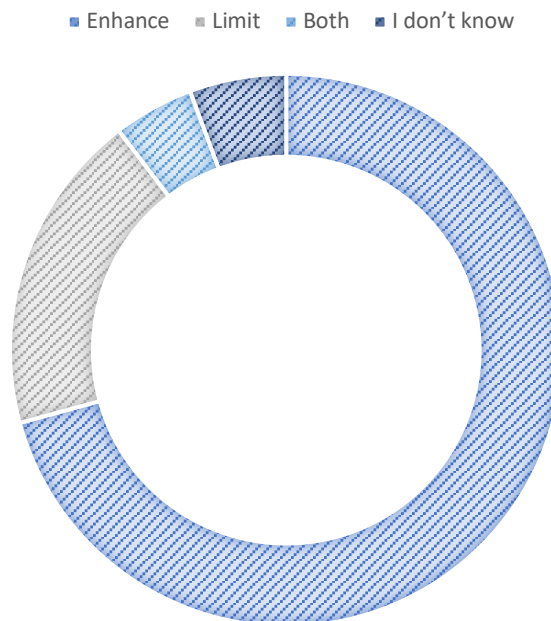


Figure 30: In terms of creative thinking, will AI enhance or limit the design process in architecture?

In the near future, technological advances could eliminate the need for architects such as taking over task during the research and experimentation process of the design. However, majority of architects perceive artificial intelligence as a tool and will have to adopt and use it to benefit society as a whole. 29% says it's highly unlikely and have not been proven that AI can replace humans, especially designers. For example, uber driverless cars has shown that Artificial intelligence is getting better at handling complex tasks, proving the unlikely possibility of AI replacing designers based on AI's limitations in cognitive capabilities such as judgement and emotions. This refers back to the fact that AI has no knowledge of emotional aspect and decision making when it comes to the design process. It will need the human input to be able to have the empathetic and emotive response after a client meeting to best suit a design for each scenario. Artificial intelligence can solve commodity and firmness; however, architects should limit their involvement to only the technical side of things and consider depending on AI with all its data, which means it may replace technicians. (Shown in figure 29)

68% say there is a possibility that artificial intelligence could enhance the architectural process as a tool, but potentially as a solution to improve the process if it is sufficiently advanced. (Shown in figure 30) Despite the fact that AI can think, the result will be a simple box solution, with more than four walls, a roof, and a floor. The process would enhance if the AI was utilised correctly. However, if AI is used incorrectly or overused, the result will be extremely repetitive. This would equate to building but does not mean that it creates Architecture. The ability of artificial intelligence to think creatively about space in relation to the human experience is questionable, for example would AI ever have the emotional response that humans have? Architects would also have an easier time demonstrating their proposals through AI. However, those new to using software designs may say otherwise, "My experience over the last 30 years has been that the digital age has increasingly removed control, reduced leisure time and increased stress throughout society – the opposite of all the things we were promised it would deliver."

Many did not have enough experience with artificial intelligence to answer this question in figure 30. As a result, this may be a reflection that for smaller practices, artificial intelligence is not used extensively. This raises the question that pioneered through AI is only currently used for large practices which is evidenced in the case studies of Foster & Partners, and Frank Gehry (which was discussed in the previous chapter). Nevertheless, AI can play a role in the development of a design and the function of a space, depending on what the input parameters are supposed to achieve. Assessing priority whether its cost, environmental control, material selection, sustainability, and adapting the outcome if those parameters change could increase the future potential. The idea of having design meetings with all key design and consulting parties present, using VR headsets in the space being designed, would make the design process more engaging and, therefore more informed. The ability to share things quickly and remotely, and send designs into VR headsets easily, would be helpful for multiple users at once.

Conclusion

Artificial intelligence has been developing and growing since the 1930s to become a tool that would potentially aid in the complexity of designs. These complex algorithms are generating such complex designs that some designers are beginning to wonder if they are more the work of computers than humans. Designing a space requires a keen appreciation of its quality and a high degree of creativity. By encoding the decisions in a computer language, artificial intelligence can simply enhance the designer's intuition and experience, acting as a tool in this industry.

Even if we don't believe artificial intelligence will replace architects, it has already changed the way architecture is practiced. The future of architecture involves exploring how AI will enhance aesthetics and how we can improve the design process. Artificial intelligence and machine learning will continue to play a significant role in shaping our future. When machines are capable of understanding and influencing our perception of beauty, then we must seek better ways to use these tools and processes in design. Even though most of an architect's role may be replaced by AI, it would never be able to completely replace an architect. For example, decision making, emotions, and conscience are a few of the parameters that AI is yet to explore and master.

Architecture provides safe environments to offer social values such as comfort, security, warmth, and shelter for the people who live and work in them. But if artificial intelligence improves in terms of gaining the knowledge necessary to meet these needs, will it keep these values or change them, as architecture still today has a direct influence on our culture and society. Some may say that the use of artificial intelligence can yield opportunities for future developments in architecture and the world, allowing for a better outcome, a faster design process, and appropriate solutions. But what does it mean when artificial intelligence gains the knowledge of human characteristics such as having the creativity and empathetic response to architectural design? Will it change the definition of architecture, or will AI simply form its way into a new form of architecture?

In conclusion, the findings remain uncertain since their effects have not yet been fully understood. Technology is developing at an exponential rate and what was science fiction is increasingly being realised as science fact. However, artificial intelligence will be less likely to replace architects in the long run, and in the context of architecture practice, it will continue to have an impact as we adapt to future demands and harness the power of new technology in combination with the creative human thought.

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Appendix A: Questionnaire

Friday 11th February – Monday 21st February 2022

AI and Architecture

Digital tools have enabled architects and designers greater opportunities to communicate their work to a larger audience. The use of digital tools has heightened during the global pandemic which has seen an accelerated emergence of new design techniques and creative possibilities. What will the future hold for architects and what role will AI play in shaping the future will AI play in shaping the future built environment?

1. How would you define 'architecture'?

2. Do you think the social value in architecture is important? If so why?

3. What do you understand by the role of architecture in today's society?

4. What do you understand by the term 'artificial intelligence' in architecture?

5. What is your experience with AI?

6. What is your opinion on using artificial intelligence in architecture?

7. Is AI just a tool that can solve technical problems or a potential to change the way we design architecture in the near future?

8. Do you think AI can replace architects in the near future?

9. In terms of creative thinking, will AI enhance or limit the design process in architecture?

10. How do you foresee the potential in AI to develop in the future?

11. In reflection to question 2, do you think AI will change the value of architecture?

Add new

Review: AI and Architecture

Respondent

1

Anonymous

09:56

Time to complete

1. How would you define 'architecture'?

Score / 0 pts

Designed buildings

2. Do you think the social value in architecture is important? If so why?

Score / 0 pts

Define social value

3. What do you understand by the role of architecture in today's society?

Score / 0 pts

?

4. What do you understand by the term 'artificial intelligence' in architecture?

Score / 0 pts

I don't

5. What is your experience with AI?

Score / 0 pts

Use of my iPhone

More options for Responses

6. What is your opinion on using artificial intelligence in architecture?

Score / 0 pts

Too broad a question

7. Is AI just a tool that can solve technical problems or a potential to change the way we design architecture in the near future?

Score / 0 pts

Probably both but we don't know yet.

8. Do you think AI can replace architects in the near future?

Score / 0 pts

No, but it might replace technicians

9. In terms of creative thinking, will AI enhance or limit the design process in architecture?

Score / 0 pts

Enhance

10. How do you foresee the potential in AI to develop in the future?

Score / 0 pts

POE feeding actionable data back to the Architect

11. In reflection to question 2, do you think AI will change the value of architecture?

Score / 0 pts

don't know

Review: AI and Architecture

Respondent

2

Anonymous

06:12

Time to complete

1. How would you define 'architecture'?

The functional and aesthetic qualities of buildings and structures

Score / 0 pts

2. Do you think the social value in architecture is important? If so why?

The quality of our surroundings directly impacts on the quality of our lives.

Score / 0 pts

3. What do you understand by the role of architecture in today's society?

To provide quality buildings and environments to improve society both socially and economically

Score / 0 pts

4. What do you understand by the term 'artificial intelligence' in architecture?

Where computers are used to analyse and solve problems with minimal human input.

Score / 0 pts

5. What is your experience with AI?

None.

Score / 0 pts

6. What is your opinion on using artificial intelligence in architecture?

I think there are possibilities in terms of solving spatial and practical considerations. I am sceptical about its use in the aesthetic design of buildings, although for repetative structures/buildings there may be opportunities.

Score / 0 pts

7. Is AI just a tool that can solve technical problems or a potential to change the way we design architecture in the near future?

It could be both

Score / 0 pts

8. Do you think AI can replace architects in the near future?

No

Score / 0 pts

9. In terms of creative thinking, will AI enhance or limit the design process in architecture?

It may help if it frees up designers to spend more time on creative thinking.

Score / 0 pts

10. How do you foresee the potential in AI to develop in the future?

Not sure at this stage as I don't have enough experience of the technology.

Score / 0 pts

11. In reflection to question 2, do you think AI will change the value of architecture?

No

Score / 0 pts

Review: AI and Architecture

Respondent

3

Anonymous

18:13

Time to complete

1. How would you define 'architecture'?

Score / 0 pts

the aesthetic accommodation of human activity with a particular focus on enhanced quality of life, and on enhanced sustainability

2. Do you think the social value in architecture is important? If so why?

Score / 0 pts

enhancing the quality of life in all aspects.

3. What do you understand by the role of architecture in today's society?

Score / 0 pts

enhancing the quality of life in all aspects, and enhancing sustainability

4. What do you understand by the term 'artificial intelligence' in architecture?

Score / 0 pts

1) since the 1980s there has been an effort to create "artificial intelligence" then referred to as the 5th Generation. However what has been successfully created are otherwise, either "Expert Systems" along the lines of an idiot savant, or neural networks. 2) Neither has had widespread adoption in architecture to date, because the former is too narrow in scope, and the latter too much of a blackbox (ie no clear explanation or reasoning behind the suggested solutions).

More options for Responses

5. What is your experience with AI?

Score / 0 pts

I have been researching AI in architecture and BIM since the early 1980s

6. What is your opinion on using artificial intelligence in architecture?

Score / 0 pts

I think there remains promise to speed many aspects of architectural design. "Expert Systems" or "Rule Based Systems" lend themselves to clarifying and simplifying all varieties of constraints, from client briefs to building regs, planning and legal constraints. Neural networks and algorithmic exploration offer the potential of affordably exploring multiple design solutions for faster selection of a palette of potential solutions by a designer or design team. Neural networks should enable real time site monitoring of the construction process to ensure the realisation is in accord with the design intent, and more adaptable building performance in use, a form of real time POE.

7. Is AI just a tool that can solve technical problems or a potential to change the way we design architecture in the near future?

Score / 0 pts

It has the potential to change, but so has BIM. I have been waiting for BIM to become mainstream since 1990. ie Don't hold your breath!

8. Do you think AI can replace architects in the near future?

Score / 0 pts

No (note that I think for all sorts of reasons, including legal, Designers will have to make the final choices).

9. In terms of creative thinking, will AI enhance or limit the design process in architecture?

Score / 0 pts

It should enhance by examining multiple potentially suitable design solutions.

10. How do you foresee the potential in AI to develop in the future?

Score / 0 pts

it will take a long time to become mainstream (note that BIM has been quite possible since the 1980's across distributed networks between hundreds of stakeholders).

11. In reflection to question 2, do you think AI will change the value of architecture?

Score / 0 pts

Only to the extent that it actually does enhance quality of life, affordability and sustainability (ie resources) and realtime optimisation leading to greater efficiency in use.

Review: AI and Architecture

Respondent

4

Anonymous

12:29

Time to complete

1. How would you define 'architecture'?

Score / 0 pts

For starts with a capital (A) Architecture. Have been taught its the Art and Science of constructing a vision

2. Do you think the social value in architecture is important? If so why?

Score / 0 pts

Yes, Architecture adds social value through the natural process of doing the development

3. What do you understand by the role of architecture in today's society?

Score / 0 pts

We are taught that it exists to create the physical environment in which people live. Reality, it is a commercial tool for making developers / stakeholders money

4. What do you understand by the term 'artificial intelligence' in architecture?

Score / 0 pts

I don't. Not seen it in my level of industry. At a guess, the AI doing 'Architecture'

5. What is your experience with AI?

Score / 0 pts

Non

More options for Responses

6. What is your opinion on using artificial intelligence in architecture?

Score / 0 pts

Naively, at the moment, can't see it replacing an Architect for providing a design solution.

7. Is AI just a tool that can solve technical problems or a potential to change the way we design architecture in the near future?

Score / 0 pts

AI for technical and process, yes. And a positive tool for this. And yes, to input into the design process.

8. Do you think AI can replace architects in the near future?

Score / 0 pts

Naively, at the moment, can't see it replacing an Architect for providing a design solution.

9. In terms of creative thinking, will AI enhance or limit the design process in architecture?

Score / 0 pts

Enhance. It provides another collaborative design tool to help inform constraints and design

10. How do you foresee the potential in AI to develop in the future?

Score / 0 pts

confirming site constraints and efficiency. Connectivity to knowledge

11. In reflection to question 2, do you think AI will change the value of architecture?

Score / 0 pts

Potentially

Review: AI and Architecture

Respondent

5

Anonymous

36:16

Time to complete

1. How would you define 'architecture'?

Score / 0 pts

Architecture is the art of building design to ameliorate climatic conditions within the social, environmental, economical and historical context

2. Do you think the social value in architecture is important? If so why?

Score / 0 pts

The built environment defines places and society in numerous ways, reflecting the conditions and aspirations of the inhabitants of a specific location with its particularities. The way that modern people live, meet and congregate is often done so with reference to the built environment or its absence. Therefore architecture must be valuable

3. What do you understand by the role of architecture in today's society?

Score / 0 pts

Architecture is a driver for change and innovation in society. Social value in architecture must be sought through the engagement and buy-in of local shareholders in the building design to engender pride of place where these innovations are concerned

4. What do you understand by the term 'artificial intelligence' in architecture?

Score / 0 pts

With specific reference to architecture, artificial intelligence must refer to a machine-driven process that emulates traditionally human-driven processes which require a level of critical discernment

More options for Responses

5. What is your experience with AI?

Score / 0 pts

User of navigation systems, identification, recommendation engines

6. What is your opinion on using artificial intelligence in architecture?

Score / 0 pts

Artificial intelligence in architecture currently is likely to be a layer of processing to identify and potentially resolve clear quantitative issues that occur during the design process

7. Is AI just a tool that can solve technical problems or a potential to change the way we design architecture in the near future?

Score / 0 pts

There is a distinction to be made between an artificial intelligence that can handle quantitative issues programmatically and a machine-learning process that may be able to be taught how to intervene in the qualitative aspect of design etc.

8. Do you think AI can replace architects in the near future?

Score / 0 pts

In the near-future, I believe that certain processes will be able to be offloaded to automation through AI, but the issue of the qualitative aspects of the profession involved with artistry and critique would not be a prospect for such a timescale

9. In terms of creative thinking, will AI enhance or limit the design process in architecture?

Score / 0 pts

Assuming that an AI is sophisticated enough to continually self-improve and generate layers of complexity, there is the possibility that AI can absolutely enhance the architectural process in the first instance as a design tool but potentially as a solution to the process

10. How do you foresee the potential in AI to develop in the future?

Score / 0 pts

Presently, AI is largely relegated to service-based processes. In the future, I expect that the technology will improve to the point where AI delivered product will become normalised

11. In reflection to question 2, do you think AI will change the value of architecture?

Score / 0 pts

AI has the potential to interpret far more data in terms what stakeholders in architect view as important than a human can. While this may allow something that is truly representative of the entire body of data in terms of what is valued, it may not be able to understand the nuance that often drives design. Resultantly, there is a risk that architecture will be a collective design-by-committee exercise rather than an crafted solution; evidently there are pros and cons to each approach.

Review: AI and Architecture

Respondent

6 Anonymous

07:43

Time to complete

1. How would you define 'architecture'?

Score / 0 pts

the discipline of coordinating design requirements, legal and technical restrictions, context and culture to create a design in 3 dimensions and to communicate that to others to enable it to be constructed on a specific site.

2. Do you think the social value in architecture is important? If so why?

Score / 0 pts

Define social value? As I understand it: the expression of aspiration, aesthetics and beliefs held by the client in that current context in society. This is an essential part of architecture: people appoint Architects to produce something that makes a statement about them and their values at that time of their lives.

3. What do you understand by the role of architecture in today's society?

Score / 0 pts

Achieving something more than the sum of the parts: a building that expresses values, culture, beliefs, and touches into the psyche and emotions of the viewer.

4. What do you understand by the term 'artificial intelligence' in architecture?

Score / 0 pts

Nothing: it is a new concept to me.

5. What is your experience with AI?

More options for Responses
Score / 0 pts

None.

6. What is your opinion on using artificial intelligence in architecture?

Score / 0 pts

I don't have an opinion.

7. Is AI just a tool that can solve technical problems or a potential to change the way we design architecture in the near future?

Score / 0 pts

I feel very sceptical about whether a computer will ever replace people in the design process. They certainly replace us in the production of information more efficiently than we could manage in some contexts.

8. Do you think AI can replace architects in the near future?

Score / 0 pts

No

9. In terms of creative thinking, will AI enhance or limit the design process in architecture?

Score / 0 pts

I don't know enough about AI to answer this question

10. How do you foresee the potential in AI to develop in the future?

Score / 0 pts

I don't know enough about AI to answer this question

Score / 0 pts

11. In reflection to question 2, do you think AI will change the value of architecture?

If AI does come into architecture then the spiritual, emotional and mental stimulation and complexity seems likely to depart and be replaced with formulaic solutions.

Review: AI and Architecture

Respondent

7 Anonymous

11:01

Time to complete

1. How would you define 'architecture'?

Score / 0 pts

A scientific art for good communicators.

2. Do you think the social value in architecture is important? If so why?

Score / 0 pts

Yes. All buildings are parts of the community and they should be good neighbours.

3. What do you understand by the role of architecture in today's society?

Score / 0 pts

Architecture creates character.

4. What do you understand by the term 'artificial intelligence' in architecture?

Score / 0 pts

Computer based intelligence created by humans.

5. What is your experience with AI?

Score / 0 pts

Minimal but could become essential.

6. What is your opinion on using artificial intelligence in architecture?

Score / 0 pts

It's the future.

7. Is AI just a tool that can solve technical problems or a potential to change the way we design architecture in the near future?

Score / 0 pts

It has the wonderful opportunity to immerse anyone in design proposals as they emerge. Especially when other sensory responses such as sound and touch are included.

8. Do you think AI can replace architects in the near future?

Score / 0 pts

No. Architects will use it, just as we do with all other computer based technology.

9. In terms of creative thinking, will AI enhance or limit the design process in architecture?

Score / 0 pts

It will enhance the architect's ability to demonstrate their proposals

10. How do you foresee the potential in AI to develop in the future?

Score / 0 pts

Upside is creating realism in design downside it'll discourage the genuine use of sketching. We should hold onto both.

11. In reflection to question 2, do you think AI will change the value of architecture?

Score / 0 pts

It will be a significant communicator of ideas

More options for Responses

Review: AI and Architecture

Respondent

8

Anonymous

09:27

Time to complete

1. How would you define 'architecture'?

The design of Buildings and Places

Score / 0 pts

2. Do you think the social value in architecture is important? If so why?

Yes - Architecture is a social art - social value is it's primary purpose.

Score / 0 pts

3. What do you understand by the role of architecture in today's society?

To enhance the quality of the environment and peoples living conditions.

Score / 0 pts

4. What do you understand by the term 'artificial intelligence' in architecture?

It is an adjunct to CAD particularly in parametric design.

Score / 0 pts

5. What is your experience with AI?

None

Score / 0 pts

More options for Responses

6. What is your opinion on using artificial intelligence in architecture?

I am not sufficiently familiar with possible applications to comment

Score / 0 pts

7. Is AI just a tool that can solve technical problems or a potential to change the way we design architecture in the near future?

Both

Score / 0 pts

8. Do you think AI can replace architects in the near future?

Possibly - for some building types.

Score / 0 pts

9. In terms of creative thinking, will AI enhance or limit the design process in architecture?

It will depend on it's application, as with any technology it is a tool that can be used to enhance creativity or displace creativity

Score / 0 pts

10. How do you foresee the potential in AI to develop in the future?

I think it will have a massive impact - particularly in displacing white collar jobs in the way robotics displaced blue collar jobs

Score / 0 pts

11. In reflection to question 2, do you think AI will change the value of architecture?

I hope not - but there is no doubt that it will involve significant social change - and architects will need to respond

Score / 0 pts

Review: AI and Architecture

Respondent

9 Anonymous

20:39

Time to complete

1. How would you define 'architecture'?

Score / 0 pts

The creation of environments.

2. Do you think the social value in architecture is important? If so why?

Score / 0 pts

Yes - it is important that good quality, appropriate and stimulating environments are available for all.

3. What do you understand by the role of architecture in today's society?

Score / 0 pts

Architects have an opportunity to undertake a central and influential role in the creation of environments.

4. What do you understand by the term 'artificial intelligence' in architecture?

Score / 0 pts

My understanding of how AI can play a role in Architecture is currently very vague.

5. What is your experience with AI?

Score / 0 pts

I have no direct experience of AI as yet.

6. What is your opinion on using artificial intelligence in architecture?

Score / 0 pts

I feel certain that it could have a positive role.

7. Is AI just a tool that can solve technical problems or a potential to change the way we design architecture in the near future?

Score / 0 pts

I feel that it could change the way that we design.

8. Do you think AI can replace architects in the near future?

Score / 0 pts

I feel certain that AI will be able to come up with design solutions and proposals. I would like to think that AI will be another powerful tool which Architects will be able to utilize during the design process.

9. In terms of creative thinking, will AI enhance or limit the design process in architecture?

Score / 0 pts

I feel that it is important that Architects do not lose the ability to create by over reliance on AI to design and solve problems.

10. How do you foresee the potential in AI to develop in the future?

Score / 0 pts

I feel that AI will be able to produce Architecture and Architectural solutions but I hope that the the human Architect will still have a valuable and pivotal contribution to make in the process.ion to make

Score / 0 pts

More options for Responses

11. In reflection to question 2, do you think AI will change the value of architecture?

The value of Architecture will, I hope remain, I feel that AI could be a very powerful tool in enhancing the Architecture produced by Architects.

Review: AI and Architecture

Respondent

10

Anonymous

19:17

Time to complete

1. How would you define 'architecture'?

Score / 0 pts

Architecture is many different things to different people but could be considered as the process by which art, to a greater or lesser extent, is introduced to the human need for shelter. Of course, this also requires a definition of art!

2. Do you think the social value in architecture is important? If so why?

Score / 0 pts

Yes. Because otherwise architecture is reduced to the level of a financial investment.

3. What do you understand by the role of architecture in today's society?

Score / 0 pts

It depends on the society but in the UK at least, architects (as opposed to architecture) have the opportunity to play a major role in reshaping our society for a low-carbon future.

4. What do you understand by the term 'artificial intelligence' in architecture?

Score / 0 pts

I don't understand it other than as a mechanism for removing human input into the design process.

5. What is your experience with AI?

Score / 0 pts

None.

More options for Responses

6. What is your opinion on using artificial intelligence in architecture?

Score / 0 pts

Based on my understanding, the only opinion I have is that in a world where human beings are increasingly frustrated by the unhelpful influence of algorithms in their daily lives, it isn't something I view favourably.

7. Is AI just a tool that can solve technical problems or a potential to change the way we design architecture in the near future?

Score / 0 pts

My opinion is that 'problems' in architecture don't tend to be so sophisticated that they are beyond the scope of the human mind.

8. Do you think AI can replace architects in the near future?

Score / 0 pts

No.

9. In terms of creative thinking, will AI enhance or limit the design process in architecture?

Score / 0 pts

My experience over the last 30 years has been that the digital age has increasingly removed control, reduced leisure time and increased stress throughout society - the opposite of all the things we were promised it would deliver.

10. How do you foresee the potential in AI to develop in the future?

Score / 0 pts

I am unsure of how it is applicable to architectural design.

11. In reflection to question 2, do you think AI will change the value of architecture?

Score / 0 pts

That will depend on the success of the architectural output delivered through AI.

Review: AI and Architecture

Respondent

11 Anonymous

27:33
Time to complete

1. How would you define 'architecture'?

An Intellectual construct related to the built environment

Score / 0 pts

2. Do you think the social value in architecture is important? If so why?

Social value is the best measure upon which the intellectual construct is examined

Score / 0 pts

3. What do you understand by the role of architecture in today's society?

To design and deliver safe, practical and environmentally responsible buildings for the required social context.

Score / 0 pts

4. What do you understand by the term 'artificial intelligence' in architecture?

Machines that think

Score / 0 pts

5. What is your experience with AI?

Movies, Siri?

Score / 0 pts

6. What is your opinion on using artificial intelligence in architecture?

I have none

Score / 0 pts

7. Is AI just a tool that can solve technical problems or a potential to change the way we design architecture in the near future?

It would be better if it helped refine and define a problem/ solution than design buildings.

Score / 0 pts

8. Do you think AI can replace architects in the near future?

Who interprets the cultural and social needs? This will be a human, afterwhich AI might be able to help. Who you call the architect is up to you

Score / 0 pts

9. In terms of creative thinking, will AI enhance or limit the design process in architecture?

To be seen

Score / 0 pts

10. How do you foresee the potential in AI to develop in the future?

To be seen

Score / 0 pts

11. In reflection to question 2, do you think AI will change the value of architecture?

Impossible to know

Score / 0 pts

Review: AI and Architecture

Respondent

12 Anonymous

20:15
Time to complete

1. How would you define 'architecture'?

Score / 0 pts

Building environment engineering + renders

2. Do you think the social value in architecture is important? If so why?

Score / 0 pts

We are shaped and effected by the built environment

3. What do you understand by the role of architecture in today's society?

Score / 0 pts

Building environment engineering + renders

4. What do you understand by the term 'artificial intelligence' in architecture?

Score / 0 pts

Machine learning for rapid iteration at early stages of detail

5. What is your experience with AI?

Score / 0 pts

MSc in computational methods in architecture, focusing on optimization routines

More options for Responses

6. What is your opinion on using artificial intelligence in architecture?

Score / 0 pts

80% of machine learning can be done by reliable statiscal methods.

7. Is AI just a tool that can solve technical problems or a potential to change the way we design architecture in the near future?

Score / 0 pts

Yes to both.btools change the way we do things by definition

8. Do you think AI can replace architects in the near future?

Score / 0 pts

Some tasks yes.

9. In terms of creative thinking, will AI enhance or limit the design process in architecture?

Score / 0 pts

Depends entirely on the software design. Revit is constraint and punishes creativity.

10. How do you foresee the potential in AI to develop in the future?

Score / 0 pts

Take over some tasks entirely. Create a whole bunch of new tasks and responsibilities as expectations of design and documentation increase.

11. In reflection to question 2, do you think AI will change the value of architecture?

Score / 0 pts

We already know how to design nice buildings. Clients and builders are unwilling to pay to benefit the end user.

Review: AI and Architecture

Respondent

13 Anonymous

11:14
Time to complete

1. How would you define 'architecture'?

Score / 0 pts

The art and science of creating places and spaces for current and future generations

2. Do you think the social value in architecture is important? If so why?

Score / 0 pts

Yes, though "why" depends on the definition of social value. Because a building effects more than just those who paid for it, so those effects should be considered and positive wherever possible.

3. What do you understand by the role of architecture in today's society?

Score / 0 pts

Architecture is both largely undervalued individually, yet significantly valued societally, and is poorly serviced by a profession failing to recognise its failings

4. What do you understand by the term 'artificial intelligence' in architecture?

Score / 0 pts

Use of ML and comparable in digital design

5. What is your experience with AI?

Score / 0 pts

Google ;-)

More options for Responses

6. What is your opinion on using artificial intelligence in architecture?

Score / 0 pts

Bring it on

7. Is AI just a tool that can solve technical problems or a potential to change the way we design architecture in the near future?

Score / 0 pts

These are mutually exclusive - tools change the way we design too

8. Do you think AI can replace architects in the near future?

Score / 0 pts

It can probably solve the commodity and firmness, but may struggle with delight. However, given 95% of buildings fail to deliver that bit anyway, that suggests AI is well placed to cover 95% of the market...

9. In terms of creative thinking, will AI enhance or limit the design process in architecture?

Score / 0 pts

Narrow AI is what you teach it, but ultimately a fresh perspective will always enhance the design process regardless of whether it is human or computer intelligence

10. How do you foresee the potential in AI to develop in the future?

Score / 0 pts

I'd guess extrapolation of human led principles initially though potentially some interesting optimisation on site analysis

Score / 0 pts

11. In reflection to question 2, do you think AI will change the value of architecture?

Yes, undoubtedly.

Review: AI and Architecture

Respondent

14

Anonymous

22:20

Time to complete

1. How would you define 'architecture'?

Score / 0 pts

Architecture the the creation of spaces and places through the use of skills embedded in science and the arts.

2. Do you think the social value in architecture is important? If so why?

Score / 0 pts

Architecture goes far beyond the bricks and mortar. The creation of spaces and places add huge social value. This is what separates building and architecture. Added social value.

3. What do you understand by the role of architecture in today's society?

Score / 0 pts

The Value of architecture is not truly appreciated fully in the UK. This is due to the focus on lowest cost in terms of value.

4. What do you understand by the term 'artificial intelligence' in architecture?

Score / 0 pts

AI has the ability to undertake tasks that would normally be undertaken by us. This is now more than just digital tools, but how computing can think and therefore create solutions.

5. What is your experience with AI?

More options for Responses

I utilise digital tools, but have not produced parametric design that use AI to determine the architectural language

6. What is your opinion on using artificial intelligence in architecture?

Score / 0 pts

There is a place for AI as it can be used to pushed to enhance creativity. However, there is also a risk that this could standardise processes.

7. Is AI just a tool that can solve technical problems or a potential to change the way we design architecture in the near future?

Score / 0 pts

It can do both, but I do believe there is a whole language we are yet to tap into in terms of architecture.

8. Do you think AI can replace architects in the near future?

Score / 0 pts

Not replace, but architects will have to evolve and utilise AI to the benefit of wider society.

9. In terms of creative thinking, will AI enhance or limit the design process in architecture?

Score / 0 pts

AI has the ability it think, but would this result in a simple box solution. Space is more than 4 walls a roof and a floor. It is questionable whether AI will be able to thinking creatively in terms of the human experience of space. Eg would AI understand the wonder of the space within a cathedral or mosque. Will AI ever have the emotional response that humans have.

10. How do you foresee the potential in AI to develop in the future?

Score / 0 pts

I can see AI being used immediate for emergency housing, off world space architecture and continuing to have an influence in parametric design.

11. In reflection to question 2, do you think AI will change the value of architecture?

Score / 0 pts

This could go two ways. AI solutions could reduce architecture to simple standard building solution, with limited social value. Counter to this, architects could harness the power of AI and create inspirational architecture that respond to their environment, and add social value to the local community.

Review: AI and Architecture

Respondent

15

Anonymous

21:06

Time to complete

1. How would you define 'architecture'?

The result of human need to provide shelter and conduct business

Score / 0 pts

2. Do you think the social value in architecture is important? If so why?

Yes. Provides safe environments for humans to exchange and share in their endeavours leading to balance and understanding of each others social needs.

Score / 0 pts

3. What do you understand by the role of architecture in today's society?

Raised ones spirits and inspires evolutionary change in evolving societys. Provides the tangible asset in which these changes can take place

Score / 0 pts

4. What do you understand by the term 'artificial intelligence' in architecture?

Machine learning of patterns and processes that can then be extrapolated and applied into architectural forms and processes.

Score / 0 pts

5. What is your experience with AI?

Aware of AI used in trading assets

More options for Responses

6. What is your opinion on using artificial intelligence in architecture?

AI in architecture is another `tool` for making the processes in architecture potentially more efficient, optimizing resources and creating more sustainable designs

Score / 0 pts

7. Is AI just a tool that can solve technical problems or a potential to change the way we design architecture in the near future?

Both

Score / 0 pts

8. Do you think AI can replace architects in the near future?

No but the nature of their job roles and the way they think will need to adapt to using this relatively new tool.

Score / 0 pts

9. In terms of creative thinking, will AI enhance or limit the design process in architecture?

Used correctly it should enhance the process. Used incorrectly or over reliance on AI as a `tool` will lead to very repetitive results. Humans prefer variations on balance.

Score / 0 pts

10. How do you foresee the potential in AI to develop in the future?

AI should provide the baseline for safe (E.g structurally) and resource efficient (sustainable standards E.g. Passivhaus) architecture.

Score / 0 pts

11. In reflection to question 2, do you think AI will change the value of architecture?

Score / 0 pts

Value or social value ? Yes in that it can enhance living standards (human need for shelter) and our ability to survive and socialise in better environments.

Review: AI and Architecture

Respondent

16 Anonymous

28:06
Time to complete

1. How would you define 'architecture'?

The crafting and defining of the internal and external environment to create a spaces in which people can live, interact, function in and function in a both pleasant and meaningful way as possible.

Score / 0 pts

2. Do you think the social value in architecture is important? If so why?

Everyone's life is of equal worth and architecture has a role to play in asserting this even when the funds to back it up aren't always there.

Score / 0 pts

3. What do you understand by the role of architecture in today's society?

In these days of 'Grand Designs' where the focus tends to be on elitist projects itcreates the idea that architecture is something only for the rich and that everyone else should just accept what they are given. Arcitecture's role is to be more inclusive and should be seen to put greater focus on the wants and needs of the vast majority rather then the elite few..

Score / 0 pts

4. What do you understand by the term 'artificial intelligence' in architecture?

This can range from the use of 'smart' CAD software in a 3D BIM environment where much of the donkey work in terms of clash detection, take off schedules, lifetime costings etc etc are done for us. Then there are smart buildings that can adapt to circumstances and tell us when things are wrong and need attention in much the same way as modern day cars will tell you that your nearside rear tyre needs some air.

Score / 0 pts

More options for Responses

5. What is your experience with AI?

Not a great deal personally as it's something I tend to leave to the experts.

Score / 0 pts

6. What is your opinion on using artificial intelligence in architecture?

It's inevitable and I suspect it will evolve exponentially over the next few years given the pressures on efficient energy use.To enable this it will need to be as wireless as possible as hard wired solutions can quickly become obsolete.

Score / 0 pts

7. Is AI just a tool that can solve technical problems or a potential to change the way we design architecture in the near future?

For now its just a tool. anything else will be for the future to decide

Score / 0 pts

8. Do you think AI can replace architects in the near future?

No. No more than a computer could conceive and then paint the Mona Lisa

Score / 0 pts

9. In terms of creative thinking, will AI enhance or limit the design process in architecture?

Enhance in that, as it the case at present, it will free up time and speed the design process

Score / 0 pts

Score / 0 pts

10. How do you foresee the potential in AI to develop in the future?

Given that mankind is able to enjoy a long and happy future then there no limits.

11. In reflection to question 2, do you think AI will change the value of architecture?

Score / 0 pts

No

Review: AI and Architecture

Respondent

17 Anonymous

29:55
Time to complete

1. How would you define 'architecture'?

Score / 0 pts

Created space that we can inhabit

2. Do you think the social value in architecture is important? If so why?

Score / 0 pts

Certainly. The space that we create has an impact on both the social order and social well being of individuals and groups of people. Understanding this impact and responsibility is crucial in all aspects of designing buildings and spaces.

3. What do you understand by the role of architecture in today's society?

Score / 0 pts

Since the advent of tools, humans have innovated for two reasons; for survival/protection and for the joy of creativity. Today, we do these things within the parameters that the world and today's society permit: environmental responsibility; social responsibility; mental health and physical well being; the value of beauty and creativity as a positive stimulus to society as a whole.

4. What do you understand by the term 'artificial intelligence' in architecture?

Score / 0 pts

Not a great deal, besides the use of VR headsets when presenting models of buildings at design stage

More options for Responses

5. What is your experience with AI?

Score / 0 pts

Nominal - I have played a few games with my wee lads Oculus!

6. What is your opinion on using artificial intelligence in architecture?

Score / 0 pts

I consider it a good thing, to help avoid the risk of building out defects or bad design.

7. Is AI just a tool that can solve technical problems or a potential to change the way we design architecture in the near future?

Score / 0 pts

To avoid the risk of building out defects or bad design, which may need changing later, AI can enable walk throughs of designed space to 'test out' responses prior to committing to a build..

8. Do you think AI can replace architects in the near future?

Score / 0 pts

Not a prayer. It is just another valuable feature or tool for designers.

9. In terms of creative thinking, will AI enhance or limit the design process in architecture?

Score / 0 pts

More information, tools or techniques are always useful in informing the design process. But also, lets not forget that being guided by creative instincts is still the most powerful tool we can provide this process as architects, even though it can at times be erratic or seemingly risky. We must know when to use tools and listen to new knowledge, or absorb input and information; but if we become ruled by it, we design as if by committee. History shows us that this seldom results in beautiful things. This is something we must never lose sight of.

Score / 0 pts

10. How do you foresee the potential in AI to develop in the future?

More readily available platforms and tools for VR, so that sending a design into a VR headset quickly and easily, sharing something quickly and remotely for the use of multiple people at a time would be useful. (Design meetings with all key design and consultant parties present, via VR headsets, in the space that is being designed, would be a major step forward to enabling the design process to become more engaging and thus more informed).

11. In reflection to question 2, do you think AI will change the value of architecture?

Score / 0 pts

Architecture will always be a valuable part of society. AI may enhance responsibilities and improve the accuracy of the design process, and maybe help buildings understand their users more too. But we can't flush out the 'artist' with AI and in so doing, flush away the impulsive, instinctive, sometimes crazy, but innately surprising and enriching human creative spirit. We will always need that!

Review: AI and Architecture

Respondent

18 Anonymous

13:02

Time to complete

1. How would you define 'architecture'?

Score / 0 pts

There are about 10,000 better definitions on the internet than I could ever manage!

2. Do you think the social value in architecture is important? If so why?

Score / 0 pts

Of course it is. It is the difference between building and architecture.

3. What do you understand by the role of architecture in today's society?

Score / 0 pts

No answer provided.

4. What do you understand by the term 'artificial intelligence' in architecture?

Score / 0 pts

Using machine learning to speed up certain activities that occur in the design process.

5. What is your experience with AI?

Score / 0 pts

None in architecture so far as I am aware.

6. What is your opinion on using artificial intelligence in architecture?

Score / 0 pts

It is inevitable, so the best thing is usually to remember it is only a tool. Learning how to deploy the tool is the best way to proceed.

More options for Responses

7. Is AI just a tool that can solve technical problems or a potential to change the way we design architecture in the near future?

Score / 0 pts

Both - in fact, it would be a massive disappointment if it did not change design processes.

8. Do you think AI can replace architects in the near future?

Score / 0 pts

Not in the near future, or any future as far as I can see. It is just a tool - even if it is a mind-boggling complex one.

9. In terms of creative thinking, will AI enhance or limit the design process in architecture?

Score / 0 pts

Enhance, as it will undoubtedly improve the speed with which iterations can be made, and this is the main method for progressing a design solution

10. How do you foresee the potential in AI to develop in the future?

Score / 0 pts

See above.

11. In reflection to question 2, do you think AI will change the value of architecture?

Score / 0 pts

No, it is the use of the building that gives it value, not the building as object alone, which means how it came to be is less relevant.

Review: AI and Architecture

Respondent

19 Anonymous

87:18

Time to complete

1. How would you define 'architecture'?

Score / 0 pts

A physical interpretation of art, culture and society, often subjective but always intertwined with the personal experience of place and space.

2. Do you think the social value in architecture is important? If so why?

Score / 0 pts

Absolutely, how people interact with and around buildings is what often makes successful architecture.

3. What do you understand by the role of architecture in today's society?

Score / 0 pts

Architecture offers an opportunity to celebrate and interpret local vernacular, not to settle for gentrification.

4. What do you understand by the term 'artificial intelligence' in architecture?

Score / 0 pts

A useful tool in making the design, modelling and visualisation of spaces a more efficient process.

5. What is your experience with AI?

Score / 0 pts

Relatively little and not in an architectural sense.

More options for Responses

6. What is your opinion on using artificial intelligence in architecture?

Score / 0 pts

We should be open to it's integration, it's important to adapt alongside advances in technology - whilst ensuring we don't lose the heart and soul of making human judgments.

7. Is AI just a tool that can solve technical problems or a potential to change the way we design architecture in the near future?

Score / 0 pts

AI and its use case will likely only grow and develop in complexity, possibly as one example, featuring heavily in the future architects' role in the 'Metaverse', which is seeing vast amounts of investment.

8. Do you think AI can replace architects in the near future?

Score / 0 pts

Replace - absolutely not, architecture at its core should be designed for humans, by humans.

9. In terms of creative thinking, will AI enhance or limit the design process in architecture?

Score / 0 pts

I hope the former, once it has time to develop and is understood.

10. How do you foresee the potential in AI to develop in the future?

Score / 0 pts

Technology and digitalisation keeps advancing, new use-cases may emerge which we don't even know are needed yet, but features ought not to be simply as a 'gimmick'.

Score / 0 pts

11. In reflection to question 2, do you think AI will change the value of architecture?

It has the potential to change it, but whether it's for better or worse will be judged in time.

Review: AI and Architecture

Respondent

20

Anonymous

51:03

Time to complete

1. How would you define 'architecture'?

Score / 0 pts

Modifying the natural environment to create spaces for human existence

2. Do you think the social value in architecture is important? If so why?

Score / 0 pts

Extremely important. Architecture contributes to creating and defining the context in which social interaction develops

3. What do you understand by the role of architecture in today's society?

Score / 0 pts

The role of architecture is to function as

4. What do you understand by the term 'artificial intelligence' in architecture?

Score / 0 pts

I consider AI in architecture is the development of architectural design from input of parameters defining intended use of the space. Control of the built environment by learning from the use of the space rather than through controls operated by the user.

5. What is your experience with AI?

Score / 0 pts

I have no direct experience with AI within my practice of architecture

More options for Responses

6. What is your opinion on using artificial intelligence in architecture?

Score / 0 pts

I consider AI could contribute to users adapting social interaction with other users

7. Is AI just a tool that can solve technical problems or a potential to change the way we design architecture in the near future?

Score / 0 pts

By using information gathered from use of a space AI could contribute to the development of future design.

8. Do you think AI can replace architects in the near future?

Score / 0 pts

No, AI would be a tool used by Architects but it could influence the design decisions made by the Architect

9. In terms of creative thinking, will AI enhance or limit the design process in architecture?

Score / 0 pts

AI could enhance the design process but it may be without the subjective perception of the beauty of the design .

10. How do you foresee the potential in AI to develop in the future?

Score / 0 pts

AI can assist in developing a design and the function of a space depending on the final outcome that input parameters are required to achieve. The need to assess priority, whether cost, environmental control, material selection, sustainability, etc. and adapting the outcome if those parameters change could increase the future potential.

11. In reflection to question 2, do you think AI will change the value of architecture?

Score / 0 pts

I consider the importance of social value of architecture to the user would remain the same although it could provide the end user with an incentive to be more aware of their architectural environment.

Review: AI and Architecture

Respondent

21 Anonymous

14:37

Time to complete

1. How would you define 'architecture'?

Creation of place

Score / 0 pts

2. Do you think the social value in architecture is important? If so why?

Yes. The built environment defines how we interact with each other.

Score / 0 pts

3. What do you understand by the role of architecture in today's society?

Helps bring people together to interact in spaces (public and private). It also helps people with acute conditions such as autism etc through creative forms, spaces and light.

Score / 0 pts

4. What do you understand by the term 'artificial intelligence' in architecture?

Very little. AI can create models, specifications, collate information such as the user's brief and design spaces tailored for them.

Score / 0 pts

5. What is your experience with AI?

None. The closest I've experienced is BIM.

Score / 0 pts

More options for Responses

6. What is your opinion on using artificial intelligence in architecture?

It can be beneficial in terms of being more efficient with time and accuracy, however, there is a danger that the creativity will be taken away from the architect, i.e. defeats the purpose of being an architect.

Score / 0 pts

7. Is AI just a tool that can solve technical problems or a potential to change the way we design architecture in the near future?

Both

Score / 0 pts

8. Do you think AI can replace architects in the near future?

Yes possibly. We should limit their involvement to only the technical side of things.

Score / 0 pts

9. In terms of creative thinking, will AI enhance or limit the design process in architecture?

That's impossible to predict.

Score / 0 pts

10. How do you foresee the potential in AI to develop in the future?

It depends where do we want to go with it and how far involved. As with my answer to Q8, AI should be limited to the technical side only or architecture in its purest form will eventually be lost!

Score / 0 pts

Score / 0 pts

11. In reflection to question 2, do you think AI will change the value of architecture?

Yes. It could become very expensive for clients therefore it may be limited to commercial projects only.

Review: AI and Architecture

Respondent

22

Anonymous

20:35

Time to complete

1. How would you define 'architecture'?

Score / 0 pts

Architecture is the art of building. It is what is left when all the technical, practical, legal and functional requirements are stripped away.

2. Do you think the social value in architecture is important? If so why?

Score / 0 pts

Yes. If you think of buildings as effectively 'products' they are the ones we spend most time interacting with., With live and work in them, and rely on them for comfort, protection, warmth and shelter. They define our culture and society, and are influenced by, and have a strong influence on how we behave.

3. What do you understand by the role of architecture in today's society?

Score / 0 pts

Architecture not only comprises the fabric of our society, it also acts as a social mirror for our individual and collective attitudes.

4. What do you understand by the term 'artificial intelligence' in architecture?

Score / 0 pts

There is no 'artificial intelligence' in architecture. Terminology and detail are important. There is no genuine intelligence in any system applied to architecture. All that is being done, is that a system of rules is being applied to a narrow, very tightly-defined range of architectural principles. It's not at all intelligent!

More options for Responses

5. What is your experience with AI?

Score / 0 pts

I use a number of technologies which are supposed to make use of AI. This includes banking antifraud algorithms, my phone and various smart devices I use every day.

6. What is your opinion on using artificial intelligence in architecture?

Score / 0 pts

It's bullshit. Being able to manipulate certain small elements according to a system of rules can't be applied to anything in a way that is genuinely meaningful. There are cool structures it can make, but that is not remotely architecture.

7. Is AI just a tool that can solve technical problems or a potential to change the way we design architecture in the near future?

Score / 0 pts

It can't change architecture. You have AI, ML, parametric design and algorithmic design. All these things mean different things, and you need to be precise about your definitions, or everything becomes meaningless. They are just tools. Smarter pencils.

8. Do you think AI can replace architects in the near future?

Score / 0 pts

Not ever, let alone the near future! They can't even autonomously design something as repetitive and as cheap as a car yet. With sustainable design, unless you want to reduce the design to fit a simplistic set of rules, you will not end up with anything of any real value.

Score / 0 pts

9. In terms of creative thinking, will AI enhance or limit the design process in architecture?

I don't think it will do either. It's complex to implement in any way other than something simplistic, and would take longer to implement than it would take to evaluate a design in a conventional manner.

10. How do you foresee the potential in AI to develop in the future?

Score / 0 pts

Stop using the term AI and define what you mean more carefully! I think it will be applied in narrowly-defined specialist areas like maybe timber framing. Even things like planning house layouts rely on things like response to views and space, and a creation of perception of sensations. Leave this to an algorithm and you may as well live in a shipping container.

11. In reflection to question 2, do you think AI will change the value of architecture?

Score / 0 pts

Not in the slightest. When my Google (a world leader in AI and ML) security camera can't tell the difference between a sheep and a dog or a human voice, and when the trees blow it thinks I have someone in my drive, the world is safe from the technology taking over. My camera is supposed to have face recognition! Supermarket checkouts still can't work reliably. They don't even apply age recognition for things like alcohol purchasing. This stuff will only get any good when it's affordable, and it won't be affordable until people buy it, and they won't buy it unless it adds any value. This is why it's limited to niches.