TECHNOLOGY APPLICATIONS IN ARCHITECTURE -A BRIEF REVIEW

Shannaon Abraham [1], Sudhir Acharya [1], Jalumedi Babu [2]

[1] *Department of Architecture, IMPACT School of Architecture, Sahakaranagar south, Kodigenhali, Bangaluru 560092, Karnataka, India.*
[2]*Department of Mechanical Engineering, IMPACT college of Engineering & Applied Sciences, Sahakaranagar south, Kodigenhali, Bangaluru 560092, Karnataka, India*

Abstract: Considerable progress is being made in the field of architecture, particularly when it comes to visual displays. Digital technology is always evolving, affecting the technical side of visualisation that was previously accomplished through modelling, rendering, and sketching methods. This paper presents a brief review of technology applications in architecture. Technologies include, virtual reality (VR) and augmented reality (AR), 3D Printing, Artificial Intelligence (AI) and parameter modelling techniques. Challenges and future scope of research in these technologies for architecture were also presented. Various applications of 3D printing in architectures such as architecture education, design and construction were also presented in brief. The use of AI techniques like, Expert systems, Evolutionary algorithms, Machine learning, and multi-objective optimization in architecture were also presented.

Keywords; Virtual reality; Augmented reality; Artificial Intelligence; 3D Printing; Expert Systems; Evolutionary Algorithm.

1. INTRODUCTION

In this era of artificial intelligence, digitization has pervaded almost all areas of human enterprise. Theories have come up stating that in the next 50 years, robots will replace human beings in many fields, leading to widespread unemployment. Since architecture is a creative field, practitioners in the field will presumably be safe from professional displacement. That prompts the question, “What is creativity?” As Google would define it, “*creativity is the use of imagination or original ideas to create something*”. Creativity is very important as it helps solve problems in unique ways. This is because everybody has different modes and styles of thought, which promotes a diversity of ideas.

Globalisation has brought forth a global advancement in technology. Progress is sometimes seen as modernization, which facilitates human control over nature, science, welfare, and student performance through technical elements. Humans are now capable of unimaginable feats thanks to the advancement of IT. Buildings are works of art that, in addition to serving as places of habitation, have the power to define a nation's identity and promote nationalism. As such, the world of architecture is inextricably linked to the advancement of technology.

In contrast, the location may draw both domestic and international visitors for sightseeing, study, or other purposes. However, architecture is more than just construction; it is also social art. Now it is our duty to guarantee that architecture provides both practical and spiritual comfort. The community's demands must be met via architectural design, which must also be pertinent to the community. The civilization that gave rise to architecture is reflected in it. Form and composition have certain goals and philosophical principles [1].

"Green architecture" refers to a design approach that reduces its impact on both the environment and human health. Green architecture uses eco-friendly building materials to create sustainable structures that protect the air, water, and land [2]. One of the key elements that architects use to improve living in all spheres of human endeavour over a comparatively long period of time is eco-friendly design. This backdrop explains why the primary objective of thoughtfully designed modern architecture is green architecture [3]. Ten years ago, the majority of pupils at school became victims of pressure due to their numerous assignments, and these varied environmental difficulties were not effective enough to be remedied simple. Students' performance may suffer as a result, and their academic performance may even become stressful [4].

Is everything we create truly original? Is anything at all? That is debatable. As Mario Klingemann said, "*Humans are not original. We only reinvent and make connections between things we have seen*" which is true because what we create today is something we have seen before stored in the subconscious mind, which we merely reconfigure into other forms. Sometimes we are aware of this recreation, and sometimes we are not.

While digitalization will help architects come up with construction drawings and presentations at rapid rates in comparison to manual drafting, the entire work of coming up with a design cannot be fully left to machines, as they are merely drafting tools. No machine can automatically come up with an aesthetic and functional spatial design catering to every nuance of human interest. It is the architect's job to create a space where people can live and work in all their complex requirements and forms. However, no matter how much we detest it, to some extent, all architects do depend on technology**.** A machine can aid in the process, but it is my contention that it cannot do away with an architect completely.

Some people would say that the quality of design is better if technology is involved. It does seem that technology-driven designs are more precise and less time-consuming. There's no doubting that technology has made the architect's life easier because various software such as Revit, AutoCAD, and ArchiCAD enable architects to come up with 3D shell structures just by drawing the floor plan in 2D format. Why use a measuring or cutting tool when a machine can do that at a lesser time and cost? Clients are seldom happy with the first draft of a design; ~~r~~evisions become easier when digitally reproduced. A related effect may be that such rapid ability to edit and reproduce at a fraction of the cost will displace many people from routine tasks and cause unemployment.

Industrialization led to the generation of advanced construction methods, technologies and, in turn, to the mass production of iron and steel. The steam engines and spinning mills put craftsmen and weavers out of favour with consumers who preferred machine-made products. This resulted in people moving from agricultural lands to cities in search of better job opportunities. Architecturally, there was mass production of iron (cast and wrought), steel, and glass, which were more resistant to tension and bending moments. Buildings such as the Crystal Palace and the Eiffel Tower were built. Iron bridges like the New York's Brooklyn Bridge and the London's Tower Bridge were built.

The following are a few examples of technology applications making a difference to architecture.

2. VIRTUAL REALITY (VR) AND AUGMENTED REALITY (AR)

Technology has given us a variety of ways to review, understand, and 'live' our designs. Virtual reality is an example where technological advancement helps architects solve design problems. When a person puts on virtual reality goggles, it is as if the person is transported into the newly designed space, where he can almost experience what it would be like to feel and touch that space intimately before building. It helps understand spatial relations and massing better, and the design can be rendered at different levels of detail. So, if there's a particular detail of the design that the person doesn't like, then he can change the design without any waste of resources.

The built environments are inextricably linked with three-dimensional space, and working professionals in engineering, architecture, and construction industries significantly rely on imagery for communication, making virtual reality (VR) and augmented reality (AR) technologies of the greater importance for the AEC (architecture, engineering, and construction) sectors. Since the early 1990s, professionals working in the built environment have utilised AR, and VR albeit to a smaller extent, to aid in visualisation of design, building, and urban operations [5]. AR is a technology that modifies or enhances the user's contextual experience of their surroundings by superimposing data and computer-generated pictures on the actual world [6], [7]. A head-mounted display (HMD), tablet, or mobile device are used to visualise the augmentations. Conversely, virtual reality is a technology that builds virtual worlds that are fully computer-generated.

After researching how virtual reality and augmented reality are utilised in the architecture, engineering, and construction fields, Juan Manuel et al. [8] suggested an agenda for research to close the current gaps in necessary skills. 54 experts from 36 organisations in the business and academic sectors participated in a series of exploratory workshops and questionnaires that they conducted. They identified six use-cases for VR and AR based on the information gathered from the workshops, including

1. Stakeholder engagement,
2. Design review,
3. Design support,
4. Operations and management support,
5. Construction support
6. Training.

They also proposed three important research areas for future. They are,

1. Engineering-grade devices, which includes studies that lead to practical, reliable gadgets that may be utilised in challenging environments like building sites
2. Data management and workflow: to efficiently handle the data and procedures needed for VR and AR technologies; and
3. Advanced capabilities: such as the need for new research to add features that are essential for the demands of the particular building sector.

Using XML methods, Abdelhameed [9] created a micro-simulation feature that was included into the VR Studio software, a virtual reality environment. This feature of the VR programme in design studios was used in his research. The primary goal was to find out how and to what degree using this new VR function's potential will assist pupils. It was hypothesised that the function potential would help students comprehend the chosen structural system better, which would be advantageous for architectural design as well. When they were proposing and investigating the structural system during the design phase, the students used the virtual reality programme.

The programme in use aims to give the students a useful tool for choosing and visualising a structural system and the building process. The VR Studio project is employed by the research to bring new visualisation potentials beyond what is now available. The study comes to strong conclusions on the application of virtual reality in architecture design studios, and moves forward to establish new research locations.

2.1. Challenges and future scope of research

Organisational and financial issues predominate in the VR industry's challenges in architecture and, more broadly, the AEC sector. Managers usually think the technology is too costly and lack experience with virtual reality. Additionally, according to managers, the technology is still immature and not widely applicable in such sectors. VR deployment necessitates the purchase of new hardware and software because it is an emerging technology. This includes a computer strong enough to run virtual reality software in addition to the headset, controls, and tracker. Other issues include the need for staff to have VR training and the possibility of motion sickness.

Several technical obstacles need to be overcome before AR-enabled progress monitoring can be used. These include

1. Automatically reconstructing building components in three dimensions from point clouds, rather than just creating polygon meshes.
2. Achieving trustworthy object recognition.
3. Comparing and automatically updating as-built and also planned models.

It is challenging to integrate photogrammetry, BIM data, and VR platforms due to the lack of interoperability among data formats. One of the other issues with VR is the complexity of managing the several technology pipelines and data sources that are utilised for VR visualisations and on building sites.

2. Lack of an accuracy indicator and no means to verify the progress of monitoring data (i.e., does the VR environment accurately mirror reality).

3. 3D PRINTING

To drive the point home further, let’s take the example of 3D printed homes. Pre- fabricated modular panels of homes that are printed by huge machines that are then bought onto the site and assembled by fitting it around doors, windows and roofs. Such forms of construction are more efficient and faster since they can be built in just a matter ofdays. With no wastage of resources and no need of manual labour, the cost of the project also comes down to a large extent. 3D printed structures are a revolutionary concept that it has been proposed that if ever man moves into space, these structures will provide habitable spaces outside earth. These structures will be built by machines that are transported by rockets into space and assembled by 3D printers.

Exponential growth has been seen in the field of architecture in terms of clients being able to experience virtual and augmented reality and one example of a software that enables us to do so is the use of holographic software where the design is inputted from anyAutodesk product or any other 3D rendering (developing sounds like its being built in real life) software and the final product is seen on a 2D screen with a 3D effect when the screen is rotated. This can be developed at a faster rate compared to a physical model and is lighterin weight since the 2D screen can be just one plastic sheet. The display is done with the helpof a halogen bulb which is placed above the 2D screen or a 2D screen with an integrated light source which displays the street view as well as a bird’s eye view. This screen is available in different sizes with the smallest being 12’’ x12” and the largest being 24”x36” and the preferred scale can be inputted.

Following sections briefly explains the various applications of 3D printing or 3DP in architectural education, design and construction.

3.1. 3DP Technology in Education.

Compared to traditional teaching techniques, research have demonstrated that the use of 3DP technologies in design process that can stimulate creative thinking and result in sophisticated design solutions [10–12]. Prototyping with 3D technology was popular among students, and this resulted in designs that became more intricate. They were able to produce physical models which were geometrically complex and more conceptual thanks to 3DP as opposed to traditional methods [13, 14].

By allowing students to see the designs in real world and concentrate on overall design concepts, AM use improved students' spatial cognition, which is another advantage of this technique [15, 16]. Typically, this technology takes the shape of common desktop 3D printers that can produce small models that are useful for developing presentation models throughout the design phase [17]. However, as part of the ETH Zurich Master's design studio course, Anton et al. [18] show how to print concrete columns on a massive scale using 3DP technology.

3.2. 3DP Technology in Design.

Researchers are continuously investigating 3DP technology by examining its structural and geometric potentials because 3DP concrete is still a relatively new trend [19, 20]. Similarly, instead of using 3DP formworks [20,21], researchers are experimenting with various design and production techniques for 3DP, primarily directly printing of the structural material [18, 22]. In terms of the structural properties of printed forms and geometric complexity, each approach has specific benefits and drawbacks. The possibility for incorporating AM technologies into the design process is often the focus of this.

3.3. 3DP Technology in construction.

The majority of researchers concentrate on the advancement and uses of 3D printing technology in the building sector. The use of 3D printing for large-scale prototypes and construction-scale AM projects are the two primary research topics. Either complete buildings or prefabricated building components can be used in the construction scale projects. 3DP is currently employed for both in situ and also prefabricated elements in several construction projects, ranging from housing units [23,24] to bridges [19,25,26].

Although in situ fabrication techniques are frequently used for full 3DP construction projects, prefabrication of 3DP architectural pieces is preferred by research because it enables the creation of customised designs [20]. Typically, large-scale prototypes are test versions of architectural components that investigate novel materials or fabrication techniques but are not yet prepared for widespread use [18,27]. The applications of 3D printing technology or fabrication techniques in the construction sector is another popular study topic. A number of authors have presented new techniques in this area [28-32] or have reviewed and categorised current techniques [24,33, 34].

3.4. Challenges and scope for future research

Technical difficulties are frequently encountered while utilising 3DP technology, particularly when working on larger projects. Research on large-scale technological development has been steadily increasing since the late 1990s, when 3DP was first used in the building industry. Particularly acknowledged as a task with room for growth is the difficulty of on-site 3DP [35]. The requirement for appropriate structural qualities in materials that can be printed on a wide scale gives rise to the second category of technological difficulties. As a result, a lot of researchers concentrate their research on creating novel content [36,37].

To decrease labour costs, increase productivity, boost safety, and lower the ecological impact of the building sector, more research is needed [18]. It would be beneficial to focus research efforts on full automation in order to reduce labour costs and make the process more feasible. To determine the real potential of this technology and its use in the industry, research must also proceed towards large-scale building construction and experimentation [38]. Furthermore, reducing the resource intensity of construction could lead to lower labour and material costs as well as less environmental harm from things like trash and noise pollution [39].

4. AI IN ARCHITECTURE

Another area of expanding research interest in the AEC sector is artificial intelligence (AI)-based solutions. Still, the use of AI approaches is not keeping up with other industries' procedures. Thus, greater investigation is required into how systems based on 3DP and AI technologies may optimise the design and building processes. Further research areas that could support automation and intelligence in building include digital twins, blockchains, artificial intelligence of things (AIoT), smart robotics, and 4D printing or 4DP [40]. Accordingly, 4DP is an experimental technology that opens up new research avenues by allowing 3D printed objects to adapt over time to a changing environment in terms of both shape and behaviour [41, 42].

Artificial intelligence (AI) is defined in the literature as the ability to understand and learn from large amounts of data to achieve certain objectives and activities [43]. When McCulloch and Pitts presented their Boolean circuit model of the brain in 1943, artificial intelligence was just a concept. The theoretical foundation for computer science was established in 1950 by Turing's investigations into "information processing machines and intelligence" [44]. Numerous artificial intelligence techniques and subdisciplines have emerged from these disciplines.

1. Expert systems
2. Machine learning
3. Evolutionary algorithms
4. Multi-objective optimisation

4.1. Expert systems

In the world of architecture, these disciplines have also made numerous advancements possible. One of the first examples of artificial intelligence, expert systems, have been used in design to provide the best result possible by combining different inputs. In this field, the development of solutions to multi-layered design problems has been facilitated by expert systems. In the context of expert systems, the following are used to obtain utilitarian solutions: building energy-saving designs based on real-time simulations [45], life cycle assessment in architectural studies, holistic analyses of environmental performance, different emergency situations in constructing renovation systems to the construction portfolio designing build envelopes those adapt to the climate, also energy performance analysis of various facade systems.

4.2. Machine learning

A technology approach with transformational potential in architecture and many other industries is machine learning, a branch of artificial intelligence. Its adaptability has made it useful in a variety of applications, including energy savings estimation [46], city plan expansion prediction [47], and the development of architectural aesthetic variations [48].

4.3. Evolutionary algorithms

Evolutionary algorithms have significantly advanced the application of computational concepts in architectural design. To obtain the best answer, generative algorithm techniques were applied, carrying on the idea of evolutionary algorithms. These algorithms are applied to shape discovery [49], sustainable architectural approaches [50], and parametric design optimisation [51].

4.4. Multi-objective optimisation

Furthermore, multi-objective optimisation approaches have emerged from the development of artificial intelligence tools, allowing for the simultaneous solution of multilayer issues. Most of the simulations have found this strategy to be beneficial. Ultimately, one of the newest methods utilised in the production process is deep learning. taxonomy of urban textures, in addition to offering architectural options that other methods are unable to.

4.5. Challenges and scope for future research

Even though the research was done recently, recent studies employing artificial intelligence optimisation algorithms have not favoured contemporary algorithms. The outcome of optimisation is impacted by this situation.

AI-based methods have made it possible for architects to evaluate and improve complicated design issues that were previously hard to handle, which has aided in the development of multidisciplinary research in the area. Furthermore, multidisciplinary research is growing at an exponential rate. This pattern illustrates how cutting-edge technologies and computational approaches have the ability to transform architectural practise and research while creating new opportunities for creative and innovative architecture.

5. PARAMETRIC MODELLING

Another example of a technological breakthrough in the field of architecture is parametric modelling, which basically means the entire geometry of the model can be changed if we input different dimensions. This is more design-efficient and user-friendly because, while modifying the design, all three parameters, such as length, breadth, and height, can be changed with the help of parametric software. By changing only one of the three parameters with the input of real project conditions in the form of mathematical equations, the accuracy of the model built in the software is high. Advantages of these types of designs include the production of flexible designs and also the ability to visualise the product thoroughly. This ensures that parametric modelling is the next big thing in the field of technological usage in architecture.

The Oxford Dictionary defines the term "parametric" as referring to the parameter, which comes from the Greek word para, which means an assistant or subsidiary, and the metron, a term for measure. There are two methods of interpretation; the first is primarily mathematical and involves a quantity whose worth is chosen for the specific conditions and in connection with which other variable quantity that can be articulated, and secondly, a broad one, defining the limits and areas of a particular method or undertaking. If we were to define parametric as exact; in contrast, design is free-form and reckless behaviour. Despite the Latin origin of the word. The verb design are means to designate, and it is frequently suggesting a haphazard or unclear operation involving really vague issues.

The research suggests that parametric design can be combined with algorithmic thinking to create a design process that employs constraints in the form of rules and parameters [52]. The mathematical designs that display the corelation between the design elements as the parameters that can be reformulated to create complex geometries is known as parametric design. Geometries are depend on the parameters of the elements, by varying the parameters, new shapes can be simultaneously generated. Many researchers [53] believe that the digital paradigm has a significant impact on fields like engineering and architecture and, not just in the terms of creative process and design thinking but also in terms of manufacturing and production.

Ivan Sutherland [54] built the first parametric computer-aided design system using Sketchpad for his 1963 doctoral thesis. Professor Samuel Geisberg was a mathematician who established the Parametric Technology Corporation (PTC) in 1988 [55]. He also developed Pro/ENGINEER, the first parametric modelling software that is still in use today in many companies for mechanical design. Pro/ENGINEER is an integrated CAE/CAD/CAM solution.

Some researchers have asserted that architects have always created parametric models as all design, by the definition, comes from the parameters, despite the fact that many contend that architects have spent decades progressively using parametric modelling. These days, parametric models are created by architects using a variety of software programmes, such as visual scripts (Grasshopper, Generic Components, Houdini), history-based modellers (SolidWorks, Pro/Engineer, CATIA), and physical modelling.

5.1. Grasshopper

David Rutten created Grasshopper, a visual programming editor. Grasshopper is a plug-in for Rhino3D, which is a powerful and adaptable modelling environment used by creative professionals in a wide range of industries, such as environmental analysis, mechanical engineering, urban planning, architecture, and more. With an easy-to-use graphical interface, Grasshopper and Rhino give designers the power to specify exact parametric control over models, investigate generative design methods, and create higher-level programming logic [56].

5.2. When to use parametric design

These days, parametric design is employed in many industries, particularly in those where it is difficult to visualise anything with traditional tools or control an operation using only the mind. These sectors include creative forms, multiprocessing treatments, multidisciplinary work, and disciplines with complex algorithmic relations. There are various uses for parametric design outside of architecture, including urban planning, structural analysis, environmental studies, and more, thanks to the use and growth of digital design.

5.2.1. Urban Design

In addition to offering a variety of options for a broad range of designs, parametric design produces unique outcomes for the iterative design process that are difficult to achieve with traditional techniques. In urban design scenarios, the discrete technique of problem-solving may handle several levels by reducing time in formulating and coordinating amongst different layers. In one study [57], the pedestrian pathway was selected to ascertain the linkages among the project's region, with respect to the smaller buildings that obstruct the street's visual connection. The pedestrian circulation was split up into patterns by the divided terrain. Grasshopper developed the method used in this study with the goal of identifying the shortest pedestrian pathway.

5.2.2. Structural Design

In addition to manipulating intricate linkages and calculating algorithmic calculations, parametric design may establish relationships with a wide range of materials. A spiral building example was examined in the aforementioned study [57] in order to examine the structural system design. The Diagrid system's benefits led to the selection of this form for the structure. The deflections and material behaviour were specified using the parametric approach. It was determined by looking at the algorithm analysis of spiral columns which were no longer required. In addition, beam profiles may be smaller than typical ones or they may be swapped out for a spring beam system. This might result in considerable cost savings.

5.2.3. Environmental Study

As was done in certain research work [58,59], we would foresee and overcome design challenges in the very early stages of design by monitoring and analysing environmental and climate changes. The study's parametric controls included location, humidity, sun movement, light, wind speed, radiation, heat gain or loss, and shadows. Additionally, we could use the time component to create a simulation in the fourth dimension, which might further affect the building in real time, and see how time can alter the building's performance parametrically.

6. CONCLUSIONS

In conclusion, technological advancement is something that we cannot completely ignore. Computer-aided design helps us produce more accurate and detailed designs with less waste of resources and at a faster rate. There is a constant need for improvement, and we should embrace the changes happening every day in our society to be better and better with each passing day. As an architect, developing our technical skills with computational data-driven designs with the help of parametric modelling is one way to do so. With the invention of smart materials such as piezoelectric polymers, magneto strictive materials, or robotically fabricated facades, forms and façades that seemed impossible to build before can now be built with the new construction methods aided by technology.

Similarly, dilapidation, “*the state or process of falling into decay or being in disrepair,*” is something that can be prevented with technological advancements. For example, self-healing concrete is where cracks in a building developed after a few years due to wear and tear are mended by bacteria that were mixed into the concrete, which would excrete calcite and repair the crack. Another example would be the use of transparent aluminium, which looks the same as glass but is four times stronger and is not as brittle as glass.

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