International Journal of Information, Engineering & Technology

Volume 12, Issue 3, PP 25-31, ISSN: 2360-9194, May, 2023
DOI: 42721454381233
Double Blind Peer Reviewed International Research Journal
https://arcnjournals.org
arcnjournals@gmail.com
Journal Series: Global Academic Research Consortium (garc)

A Review of Interdisciplinary Approach to Parametric Design

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Abstract: *As urbanization continues to evolve, the demands of clients to implement unique edifice continued to augment, these demands has led to a transition from the conventional rectilinear designs to a more complicated structures. This phenomena has brought about the emergence of a new style known as parametricism. The parametric design movement has a significant impact in the fields of Architecture and Engineering by giving professionals a potent tool for producing elaborate, complicated geometrical patterns. Although, using parametric design software has its own set of difficulties, such as a steep learning curve, software complexity, and the possibility of producing designs that are difficult to build. The success of parametric design initiatives depends largely on interdisciplinary collaboration since these projects must integrate knowledge and experience from several fields. This study hence adopted the theoretical Framework as the methodology to examine the difficulties in utilizing parametric design tools in teamwork and possible solutions to them.*

Key words: *Architecture, collaboration, Design, Engineering, Parametricism*

I. INTRODUCTION

The continuos evolution and standards in the life of man have brought about high demands from clients, these challenges pushed programming experts to come up with strategies to satisfy their clients' needs, thus resulting to the advancement in the conventional ways to the use of more complex software. Parametric design software has gained popularity in recent years in various fields, such as architecture, engineering, and product design. It allows designers to create complex designs that can be modified easily and efficiently. These new modeling softwares use algorithms to model creative forms, such as shapes inspired from the nature. Although the term is more widely used in the construction industries nowadays, it originates from mathematics [1]. According to [2], the first computer-aided design system was parametric, programmed by Ivan Sutherland for his PhD thesis on Sketchpad5 in 1963.

Parametric design has numerous advantages such as providing the user with flexibility and alternative designs of a project; however the users of these softwares face challenges such as lack of providing a comprehensive method of implementation of the project which might be as a result of inadequate knowledge of that field from the side of the software developers or programmers. Despite continues effort

from the developers to address and update design requirements, there are still shortcomings experienced by the users.
Interdisciplinary collaboration approach is therefore essential for the success of parametric design projects, as it requires integration of knowledge and expertise from multiple disciplines. This paper hence discusses the challenges of paramtric design software and the interdisciplinary nature of parametric design and its benefits, as well as the challenges of collaboration and the potential solutions to overcome them.

II. LITERATURE REVIEW

II.1 Principles of parameteric design

II.1.1 Generative Design
Generative design is a principle of parametric design software that allows designers to create and explore multiple design options using algorithmic procedures. [3] discusses the potential of generative design to create innovative and efficient design solutions. In architecture, generative design has been used to create complex building forms and façade systems, as discussed by [4].

II.1.2 Parameterization
Parameterization involves defining design elements as variables, or parameters, that can be adjusted in response to changing design requirements. [2] emphasized the importance of parameterization in creating flexible and adaptable design solutions. In industrial and product design, parameterization has been used to create customizable and modular products.

II.1.3 Optimization
Optimization involves using mathematical algorithms to find the best design solution based on a set of predefined criteria. [5] highlights the potential of optimization in creating efficient and lightweight structures. In architecture, optimization has been used to create sustainable building designs, as discussed by [6].

II.1.4 Simulation
Simulation allows designers to test and analyze the performance of their designs under various conditions. Simulation can aid in creating safe and durable structures. In product design, simulation has been used to test and optimize the performance of complex systems, such as automotive components and aircraft engines, as discussed by [7].

II.1.5 Integration
Integration involves integrating diverse design elements, such as geometry, material properties, and performance criteria, into a single design model. [8] highlights the potential of integration in creating complex and adaptive design solutions. Integration has been used in various fields, including architecture, product design, and engineering, to create innovative and efficient design solutions, as discussed by [9].

II.2 Applications of parametric design software in various disciplines.

II.2.1 Architecture
Parametric design software has revolutionized the field of architecture, enabling architects to create complex and innovative designs quickly and efficiently [10]. This technology has been used in a variety of contexts, including digital fabrication, mass customization, and responsive architecture [3].
One example of the use of parametric design software in architecture is the Autodesk Revit platform, which allows for intuitive and precise parametric modeling [11]. This software has had a significant impact on the building industry, enabling Architects to create more sophisticated and complex designs than ever before.
Although the benefits of parametric design software are numerous, there are some limitations to its use. One concern is the potential for over-reliance on software-generated solutions, which can limit creativity and innovation [12]. Additionally, there can be a steep learning curve associated with using this technology, which may require significant investment in training and education.
Despite these challenges, the importance of parametric design software in architecture outweigh the drawbacks. For example, it has enabled architects to create large-scale 3D printed structures with robots, such as the fillet structure created by Peters and de Kestelier.

II.2.2 Urban Planning

Parametric design can offer numerous possibilities in a wide variety of design, giving distinct results during the iterative design process. These results are difficult to achieve using conventional methods. By reducing time on formula drafting and coordination between various layers, the discrete technique of problem solving may handle several layers in urban planning [13]. For instance, parametric approaches can quickly calculate pedestrian paths in the project area while taking into account the smaller buildings that obstruct street views. Grasshopper can figure out which pedestrian path is the shortest. Another example in the same area, investigated by [14] using parametrical approach analyses comfort values, such as wind study, solar envelop and daylight availability.

II.2.3 Structural study

The behavior of materials can be calculated using parametric design. In a prior study, a spiral building example was examined to explore the design of the structural system. This investigation was conducted using a running algorithm, and the results showed that spiral columns were no longer necessary. Also, beam sections could be thinner than usual, and a spring beam system could take their place [13]. Parametric design is also used to calculate algorithmic formulas and manipulate complex connections of a diagrid system and create complex relations with many kinds of materials.

II.2.4 Environmental study

Parametric program is used in the early stage of design simulating the climatic and environmental conditions of a building. It can analyze and parametrically adjust elements including daylighting, set dates, location identification, sun movement, humidity, illumination, radiation, wind speed, heat gain, shadows, and shades.

II.3 Challenges of using parametric design software

II.3.1. Complexity of Software:

Parametric design software is typically complex, and it requires specialized knowledge to use. According to [15], parametric design software requires a specific type of expertise, and designers may require additional training to use the software effectively. This complexity can also lead to difficulties in collaboration between team members with different levels of expertise. Parametric design software can hardly tell the difference between a little and a large project and handles all projects in the same manner. According [11], parametric modeling may increase the complexity of design decisions. The software creates complex designs since the designer is unable to determine how the 3D version would appear; it makes this assumption and approaches all projects with complexity. This implies that a straightforward two-bedroom bungalow model might be created in an odd, unconventional way.

Steep Learning Curve Parametric design software is notoriously difficult to learn, with a steep learning curve. Unlike traditional CAD software, which is relatively easy to learn and use, parametric design software requires a high degree of mathematical and computational knowledge.

II.3.2. Data Management

Another challenge associated with the use of parametric design software is data management. According to [16], parametric design software generates large amounts of data, which can be difficult to manage. This can lead to difficulties in data transfer, storage, and retrieval, which can affect the efficiency of the design process.

II.3.3. Integration with other Software

Many parametric design software programs are proprietary and do not easily integrate with other software tools. This can limit the ability of designers to collaborate and share data with others. Parametric design software is often used in conjunction with other software programs, such as CAD software, rendering software, and analysis software. However, integration between different software programs can be challenging. According to [17], integration between different software programs can lead to compatibility issues, which can affect the accuracy of the design.

II.3.4. Computational Performance

Parametric design software relies heavily on computational performance. According to [18], large-scale parametric models can require significant computing resources, which can affect the performance of the software. This can lead to slow rendering times, long computation times, and other performance issues.

II.3.5. Flexibility

Parametric design software allows for greater flexibility in design, but this can also be a challenge. According to [19], parametric design software can lead to overdesign, as designers may be tempted to explore every possible design option. This can lead to excessive complexity, which can make the design process more challenging.

II.3.6. Lack of standardization

There is currently no standardization in the parametric design software industry, with different software programs using different terminology and workflows. This can make it difficult for designers to switch between different software tools.

II.3.7. Learning and Training Difficulties.

Parametric design Softwares are hard to master. According to [11], in order to utilize these softwares effectively, a user must be a combination of a designer, computer scientist, and mathematician, this could be the reasons why it is still not widely used by many people in today's world due to its complexity and learning needs.

II.3.8. Constraining Creativity with a Reactive Structure

The designer's inventiveness is constrained or limited by the user's inability to interact with the software. Meaning that once the parameters have been entered into the software, the machine takes over management of the design and develops whatever shape is appropriate based on the data entered. Designers will eventually need to create algorithms to create the designs they have in mind. Since machines are calculating how a design will look without outside intervention or help from the designer's side, parametric design could consequently pose a threat to architecture as a profession. The lack of Architect's involvement can also give rise to the problem of design authorship.

II.4 Constraints of using parametric design software in an interdisciplinary context

Parametric design software has enabled the creation of complex and innovative designs. However, the use of parametric design software in an interdisciplinary context presents several challenges.

II.4.1 Communication

Effective communication is critical in interdisciplinary collaborations. In parametric design, interdisciplinary teams often include professionals from various fields, each with their own expertise and technical jargon. This can create communication barriers, leading to misunderstandings, delays, and errors. As [20] state, "effective communication is a significant challenge, particularly when the team comprises professionals with diverse training and experience".

II.4.2 Technical Compatibility

Different disciplines may use different software programs or tools, which may not be compatible with each other. This can cause issues when trying to share files or collaborate on a design project. According to [21] et al., "the use of different software platforms is a significant challenge to interdisciplinary collaborations in parametric design".

II.4.3 Lack of Understanding

Interdisciplinary teams may not have a full understanding of each other's fields, which can lead to misunderstandings or incorrect assumptions about the design requirements or limitations. As [22] state, "Designers need to be aware of the perspectives and methods of the other disciplines and understand how they fit into the overall design project".

II.4.4 Design Complexity

Interdisciplinary designs can be more complex than designs created by a single discipline, as they must take into account multiple factors and constraints from different fields. This complexity can be challenging to manage and can lead to design errors or inefficiencies.

II.4.5 Time and Resource Constraints

Interdisciplinary projects may require more time and resources than single-discipline projects, as the team must take into account multiple factors and constraints. This can make it challenging to meet project timelines or budgets. As [23] state, "Interdisciplinary projects require more resources and time due to the increased complexity, which can be a challenge to manage within the constraints of the project".

II.5 Benefits of interdisciplinary approach to parametric design software

Interdisciplinary approaches to parametric design have become increasingly popular in recent years. This approach involves bringing together professionals from different fields such as architecture, engineering, and computer science to collaborate on design projects using parametric modeling tools. The benefits of this approach are numerous, and some of them are outlined below:

II.5.1 Improved problem-solving

An interdisciplinary approach to parametric design allows for a wider range of perspectives and expertise to be brought to bear on a problem. This can lead to more creative solutions and a better understanding of the underlying issues [24].

II.5.2 Enhanced communication

Collaborating with professionals from different fields allows for better communication and understanding of complex ideas. This can lead to more efficient and effective teamwork, ultimately resulting in a better end product [25].

II.5.3 Increased efficiency

The use of parametric modeling tools can help streamline the design process, allowing for faster iteration and prototyping. This can help save time and money in the long run [26].

II.5.4 Improved sustainability

An interdisciplinary approach to parametric design can help address sustainability issues by incorporating knowledge from fields such as environmental science and materials science. This can lead to more sustainable and environmentally friendly design solutions [27].

II.5.5 Better integration of technology

An interdisciplinary approach to parametric design can help bridge the gap between different technologies and software programs. This can lead to a more seamless workflow and better integration of different tools [28].

Overall, an interdisciplinary approach to parametric design can lead to better outcomes in terms of creativity, efficiency, communication, sustainability, and technology integration.

IV. RESULTS AND DISCUSSIONS

The use of parametric design software in interdisciplinary contexts presents several challenges; including communication, technical compatibility, lack of understanding, design complexity, time and resource constraints etc. Effective communication, collaboration, and understanding of each other's fields are essential to overcoming these challenges, thereby creating successful interdisciplinary designs. Below are some of the suggestions on how to achieve effective interdisciplinary approach to parametric design

1. Organising Training and workshops

To mitigate the steep learning curve associated with parametric design software, it is important to provide designers with the necessary training and education. This can include workshops, online tutorials, and formal training programs.

2. Simplification of software to address the issue of complexity software developers can work to simplify the user interface and make it more intuitive. This can involve streamlining the number of features and tools or developing more user-friendly interfaces.

3. Collaboration and Communication:

To avoid constructability issues, it is important for designers to collaborate with construction professionals and communicate the design intent throughout the design process. This can help ensure that the design is both aesthetically pleasing and constructible.

4. Improving curriculum

Creating some programming and scripting courses in the architectural pedagogy curriculum can help the architects in becoming more familiar with these softwares.

5. Creating a field of specialization that deals with programming and developing parametric design softwares by Architects for Architectural designs can help in removing design constraints in developing the

softwares because the programmers have backgrounds in Architecture and the softwares could be more flexible and user friendly.

IV. CONCLUSIONS

Parametric design software has revolutionized the field of architecture and engineering, allowing designers to create complex, intricately detailed designs that were previously impossible to achieve. However, the use of parametric design software comes with its own set of challenges, including the steep learning curve, the complexity of the software, and the risk of generating designs that are not easily constructible. These challenges can be mitigated, allowing designers to fully harness the power of parametric design software by providing designers with the necessary training and education, simplifying the software, promoting collaboration and communication, introduction of some programming and scripting courses in the architectural pedagogy curriculum, or better yet, creating a field of specialization that deals with programming and developing parametric design softwares by Architects for Architectural designs. This can help to remove the design constraints in developing the softwares because the programmers have backgrounds in Architecture and the softwares would be more flexible and user friendly

VII. ACKNOWLEDGMENTS

VIII. REFERENCES

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