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PARAMETRIC MODELING AS AN INNOVATIVE APPROACH IN GRAPHIC DESIGN

Purpose. *The article focuses on exploring the possibilities and strategies of innovative integration of parametricism into the field of graphic design and analyzing the main problems and potential solutions in using parametric design in creating graphic objects.*

Methodology. *According to the research topic, the methods employed include comparative study, theoretical analysis, and synthesis.*

Results. *The article discusses the definitions and characteristics of parametric design, examines its applications for optimizing design thinking and creating personalized objects. Various levels of innovative implementations are presented, offering several strategies for integrating parametric modeling into graphic design, including visual element generation, layout optimization, design interactivity enhancement, and data visualization in personalized design. Additionally, integration challenges related to the use of artificial intelligence technologies are discussed.*

Scientific novelty*. The article analyzes various levels and effective strategies for applying parametric modeling in the field of graphic design, exploring current aspects of interaction that are innovative and emphasizing the importance of utilizing parametric design methodology, artificial intelligence, and computational design in the paradigm of contemporary graphic design.*

Practical significance. *The materials presented in the article can be utilized for investigating the innovative application of digital design, parametric design, and artificial intelligence in the field of graphic design.*

Keywords: *parametric modeling, parametrism, parametric design, graphic design, artificial intelligence, digital design.*

Introduction. Parametric design works not only as a design tool but also as a modelling thinking method. Within the context of digital design processes, parametric design assumes a position of significance. Presently, parametric modelling is widely and deeply applied in the realm of architectural design, utilizing algorithms and logic to undertake tasks such as design generation, design simulation, and design optimization. Parametric modelling has the potential to revolutionize graphic design by significantly enhancing graphic generation, layout optimization, design functionality, interactivity, personalization, and customization. Exploring the integration mechanisms and strategies between these fields carries notable importance. Yet, relative challenges shouldn't be disregarded. This paper seeks to analyze and discuss these issues and explore the possibilities and strategies systematically for their integration.

Analysis of previous studies. In the context of the increasing emphasis on digitized and intelligent design, parametric design, as a revolutionary design technology, methodology, and design thinking methods, is exerting a robust influence on the field of design. Presently, a substantial portion of research and practice in parametric design is concentrated within the realm of architectural design. However, the diverse attributes of parametric design indicate the necessity to extend this advanced methodological approach to a broader array of design domains, thereby initiating an expansive revolution in digital design.

There are kinds of descriptive definitions for parametric design. Generally, Parametric design（PD）is an innovative approach to the design process that utilizes parameters, rules, and algorithms to reframe and express associative relationships of design elements

and design problems logically. The parametric design will automatically generate corresponding design alternatives by changing input parameters, such as variables, dimensions, or proportions, leading to a dynamic and iterative design process affecting shapes, proportions, and other attributes. Eltaweel A. and Yuehong S. U. provide a comprehensive literature review, tracing the origins and evolution of the term «parametric». They pointed out that the principle of parametric design is mathematics [6]. The review further outlines its extensive applications in urban planning, architectural design, interior decoration, fashion design, and structural engineering. As the application domains of parametric design expand, Kandikjan T. et al. suggested parametric design and additive manufacturing knowledge should be Integrated into industrial design education [9].

Parametric modelling can be applied to different kinds of design fields. All design is parametric design. The essence of parametrism lies in the process of redefining and logically reconstructing design challenges through the utilization of design parameters and algorithms. Subsequently, these challenges are transformed into design models amenable to computer processing and programming languages. From this perspective, opportunities for integration with parametric design exist across various domains of design.

Parametrism is commonly associated with computational tools and scripting languages. Computer-aided design (CAD) software with the function of parametric modeling is applied to create designs that can adapt and respond to various inputs and constraints. Caetano, I. et al. defined parametric, generative, and algorithmic design in the Computational design field [3].

Generation and form-finding are the core functionalities of parametric design. Through the utilization of parametric design tools, designers can construct pertinent algorithms to generate intricate and innovative design solutions. In the article, the author developed a generation algorithm for masonry arch bridges and viaducts models by using parametric software [8]. For the generation of 2D images, Zhang, J. et al. proposed a parametric approach to model and generate mandala thangka patterns to retain and digitize the heritage [16].

Interactivity is one of the excellent features of parametric design. Designers can interactively adjust design parameters while simultaneously observing and evaluating prompt feedback of the generated results. Through iterative refinement, optimal design solutions can be identified. Kwieciński K. et al. proposed an interactive generative system for house design allowing non-experts to obtain designs within limited time [11].

Design optimization is another core task of parametric design. By adjusting parameters, the optimal performance of certain design parameters can be achieved. These performance criteria may include factors such as strength, illumination, thermal properties, proportional relationships, etc. Such a design methodology is also referred to as performance-based design. Danhaive R. et al. pointed out that There is a need for methods that take advantage of computing intelligence to augment a designer's creativity while guiding not forcing their search for better-performing solutions [4].

Parametrism is a kind of highly logical design thinking method. Throughout history, design has been characterized by its inherent complexity and abstract nature. The investigation of design thinking has consistently remained a point in the design domain. By observing the progression of design history, it's clear that when design tools undergo revolutionary changes, it doesn't just affect the technical aspects. It also changes how designers work, which in turn deeply influences how design thinking evolves. An important paper by Oxman R. proposed the term «parametric design thinking (PDT)», analyzed the cognitive model of design knowledge in the parametric schema in PDT, and explored the

continuity and change within the evolution of design thinking [13].

Parametric design offers personalized and customized solutions. The design outcomes are generated based on specific parameter configurations. Designers can create more personalized and customized designs by addressing specific design requirements, dimensions, and data.

Graphic design is a specialized field of art and practice that focuses on conveying information, expressing concepts, and creating aesthetic experiences through visual elements such as images, text, and color in various graphic media. In this domain, designers employ combinations and arrangements of diverse visual elements to craft works that possess visual allure and communicative efficacy. Driven by the digital revolution and intelligent technologies, digitization and intelligence have emerged as pivotal research directions in contemporary and future graphic design practice. AI, as the most crucial intelligent design tool at present, holds significant implications for the future trajectories of graphic design. The paper by Gill, S. et al. s pointed out the future directions of AI generation. In the article the authors reviewed the basic issues of intelligent layout generation [7]. They pointed out that layout generation was a crucial stage in Artificial Intelligence-Generated Content (AIGC) task [12].

Statement of the problem. The integration of parametric design and graphic design has the potential to evoke great innovation. However, prior to achieving that, there are some problems that need to be considered. Graphic designers lack a comprehensive understanding of parameter design concepts and features. Researchers encounter confusion regarding the concepts of parametric design, algorithm-assisted design, and artificial intelligence (AI). Currently, there exist several notable practices of integrating parametric design into graphic design. Nevertheless, comprehensive analysis and systematic synthesis are absent. Strategies on how parametric design can revolutionize graphic design are not proposed. Additionally, potential challenges and difficulties haven`t been clarified. This paper aims to explore the levels and strategies of the integration and identifies potential challenges through investigating and analyzing relative literature.

Research results and discussion.

1. Parametric Design, Algorithm-Aided Design and AI

Parametric modelling is intricately linked with algorithm-assisted design. Within the realm of algorithm-assisted design, a dual approach becomes evident. On one hand, it involves the development of original algorithms in response to specific design issues, while on the other, it entails the direct integration of pre-existing exemplary algorithms into the design generation process. The knowledge stemming from diverse domains such as ecology, engineering, chemistry, and physics can be methodically organized and codified into algorithmic frameworks, subsequently applied within the domain of design. From this point, algorithm-assisted design emerges as a pivotal facilitator in promoting interdisciplinary design efforts.

Parametric design and artificial intelligence (AI) both serve distinct functions in design generation, yet their underlying principles diverge. Parametric design primarily focuses on describing generative problems and constructing algorithms from scratch, altering parameters to achieve diverse outcomes. In this process, designers themselves are responsible for constructing generative algorithms, without requiring extensive datasets for support. In contrast, AI necessitates learning before generating design solutions, relying heavily on abundant training data, like existing real-world design outcomes. Through techniques like machine learning and neural networks, AI can analyze this data and generate novel design outputs. Notably, a substantial corpus of existing design samples serves as a prerequisite for AI-driven design generation.

From the aforementioned perspectives, parametric design, relative to AI, exhibits a more intuitive stance in terms of algorithm construction and demonstration. It places emphasis on the manipulation of design parameters and the ensuing variations in design outcomes. AI, however, relies on the analysis of existing relevant designs. Although this process is often intricate and ambiguous, it involves designing based on extracted traits, patterns, and features to yield novel solutions. These solutions align with the characteristics previously identified through analysis.

2. The Levels of Integration Between Parametric Modelling and Graphic Design

By synthesizing parametric design features, principal design elements of graphic design, and digital design trends, four hierarchical levels for the integration between parametric have been found.

Integration of Design Tools

The design tools here referred to primarily encompass graphic design software, generative design software, and parametric design software. The integration of design tools represents the most direct and prominent way to seamlessly integrate parametric design into graphic design. Designers can directly utilize parametric design software to create graphic design works and elements, or they can combine parametric design software with graphic design software to collaboratively accomplish design tasks. As an example, designers can utilize parametric design software to formulate generative algorithms and fine-tune parameters, resulting in the generation of graphic elements that correspond to specific design criteria. Following this, these elements can be imported into graphic design applications like Adobe Photoshop or Adobe Illustrator for additional refinement. Currently, there is a greater emphasis on the collaborative application of these two design software categories. However, it is foreseeable that as integration deepens, there will emerge higher levels of integration and more targeted parametric graphic design software, which will more effectively support graphic designers in innovating their designs using parametric methodologies.

Integration of Design Process

Traditional graphic design processes typically follow a linear structure, including stages such as creative ideation, initial draft creation, detailed refinement, and the final design outcome. In contrast, the process of parametric modelling exhibits pronounced dissimilarity. It embodies a dynamic, non-static linear design process that doesn't yield a singular design outcome but rather an infinite array of design possibilities. Design outcomes continuously respond to alterations in parameters. By incorporating this dynamic design process into graphic design, the conventional linear structure is effectively disrupted. Designers' focus shifts from attaining a solitary final solution to iteratively adjusting parameters and selecting optimal solutions within an infinite design space. Consider graphic design as an example. Parametric design initially identifies the essential design parameters that dictate the shape of the graphic. By iteratively modifying these parameters, the generation of the graphic evolves. Throughout this process, designers evaluate and select patterns, ultimately attaining a satisfactory result. Through the integration of the parametric design process, the exploration of graphic design solutions is no longer confined to a linear trajectory but transforms into a dynamic process of experimentation.

Integration of Design Thinking Method

In the realm of graphic design, designers often embrace a mindset of uninhibited creativity characterized by its ambiguity and randomness. However, the paradigm of parametric design thinking demands the establishment of a logical framework prior to realization, not just considering the final outcome, but formulating the groundwork for it. This requires designers to contemplate the kind of logical structure that needs to be laid before achieving the end result. While graphic

designers are naturally inclined towards unfettered creativity, they might be hesitant or less practiced in employing a structured logical approach to dissect and articulate design issues, despite the fact that logical thinking is a crucial method for deconstructing complex design problems. To bridge this gap, graphic designers should selectively integrate logical thinking methods into their creative process. This entails infusing a more organized and rational perspective into their understanding and expression of design problems.

Integration of Knowledge Structure

The aforementioned levels of integration are intended to propose that graphic designers should embrace and comprehend the tools, processes, and thinking methods of parametric design. However, the learning curve for designers in mastering parametric design presents significant challenges. Learners must grasp concepts related to programming, algorithms, mathematics, computer vision, and more in order to effectively utilize parametric techniques in design work. Despite the potential value offered by parametric design, many designers relinquish its potential due to the mismatch between their existing knowledge structure and the demands of parametric design. Future graphic designers seeking to wield digital and intelligent design methods must not only possess essential design knowledge but also acquire proficiency in programming languages, algorithms, data structures, and related subjects. Through the organic integration of their knowledge structures, a genuine integration of parametric design and graphic design can be achieved at its core.

3. Strategies for the Integration

Graphic design encompasses fundamental aspects such as crafting visual elements, employing color schemes, and optimizing layouts. Concurrently, as digital design advances, an array of new design concepts has emerged, including interactive design, data visualization, as well as personalized and customized design. These ideas are gaining increasing prominence within the realm of graphic design. The integration and innovation of parametric design within graphic design can be conducted with these aspects.

The Generation of Visual Elements

One of the core functions of parametric design is generation. Various visual elements such as lines, shapes, patterns, textures, and fonts can be algorithmically constructed using computational capabilities. The resulting elements exhibit diversity and dynamism, enriching graphic design with distinctiveness and appeal. Parametric design facilitates the generation of unique icons and logos for personalized brand visual identities. In posters and illustrations, it enables captivating patterns and arrangements (Fig. 1). It also can be used for font generation, enhancing efficiency for designers while maintaining precision.

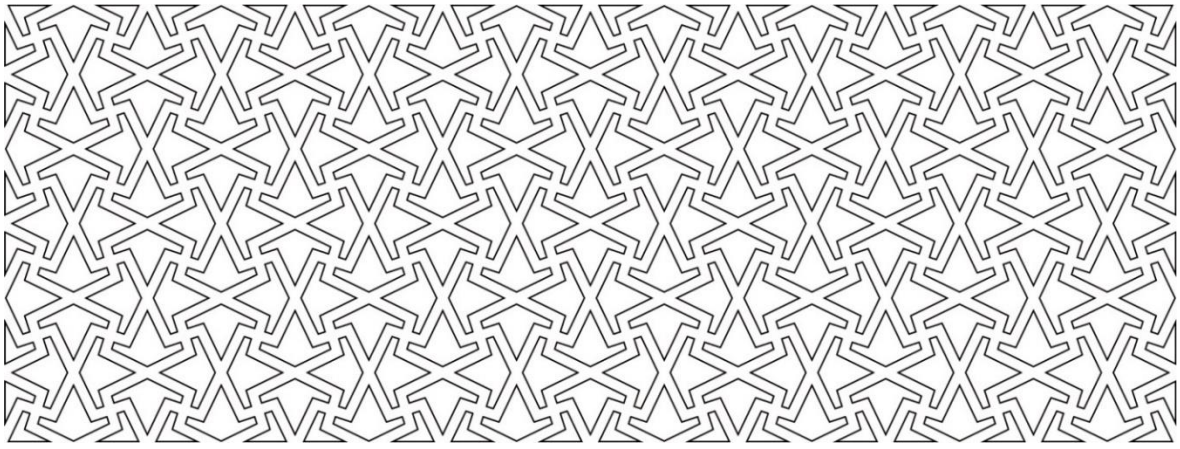

Fig. 1. Complex pattern generated with Grasshopper (a parametric software) by the author

By tightly integrating parametric design with layout design, designers are enabled to achieve a more precise presentation of aesthetics, functionality, and diversity in content. This kind of integration not only sparks greater creativity in the design process but also significantly enhances efficiency and adaptability. The application of parametric design enables the realization of adaptive layouts, dynamic typesetting, and precise control over visual hierarchy within layout design. Taking visual design for various screen sizes and devices as an example, the same design concept can flexibly adapt, providing a more exceptional user experience. The arrangement of textual and visual elements can be intelligently adjusted based on specific rules and parameters, thereby achieving a dynamic and elegant layout effect. Precise control over the size, spacing, and positioning of individual elements provides a richer potential for visual presentation hierarchy and balance. Furthermore, parametric design empowers the automatic generation of typesetting styles, greatly enhancing the efficiency of layout design. This innovative approach endows layout design with greater autonomy and creativity, achieving a dual benefit of design effectiveness and production efficiency.

Innovative Application of Color

In the contemporary realm of graphic design software, designers possess near-boundless possibilities to utilize colors of varying luminosity, hue, and saturation. The digitized mode of color presentation has ushered in substantial degrees of creative freedom in design. While this autonomy enhances the creative process, in practical scenarios, designers often grapple with the challenge of achieving extensive and precise control over color effects. For instance, consider an image composed of hundreds of grids; when seeking to meticulously adjust the color attributes of each individual grid, conventional design software frequently falls short in managing such intricate tasks. Conversely, the application of parametric design readily enables the facilitation of this level of control. By designating the color information of each grid as a design parameter, the realization of complex and precise color control becomes readily achievable (Fig. 2).

Enhancement of Interactivity

In the context of graphic design, it is imperative to acknowledge the growing need to address scenarios encompassing dynamic design elements. Simultaneously, the thriving evolution of the interactive design field presents fresh challenges and demands to the realm of graphic design. Against this backdrop of change, the evolutionary trajectory of graphic design is increasingly emphasizing design interactivity. This emerging trend aims to cater to the expanding scope of design and user expectations. Currently, the creative process in graphic design requires heightened interaction with users to achieve dynamic design element portrayal and interactive experiences. The unprecedented design paradigm of parametric design offers designers novel opportunities, holding significant potential to enhance design interactivity. Throughout the design process, designers continuously adjust parameters and receive feedback on design outcomes.

Application in Data Visualization

Data visualization is a method of presenting abstract data and information through visual elements such as charts, graphs, and images. Its objective is to make data more comprehensible, analyzable, and communicable through visual means. The essence of data visualization lies in transforming complex datasets into intuitive visual forms to assist in quickly identifying patterns, uncovering trends, gaining profound insights, and effectively conveying this information to the audience. In data visualization, the processing of data and the visual representation of information are core tasks. Parametric design, as a logical design approach, is also data-centric in nature and can precisely generate various types of charts based on data (Fig. 3).

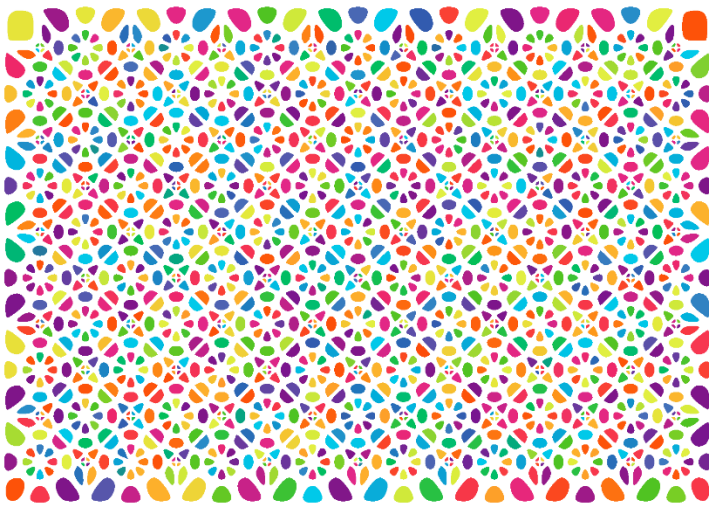

Fig. 2. Colour composition created with Grasshopper (a parametric software) by the author

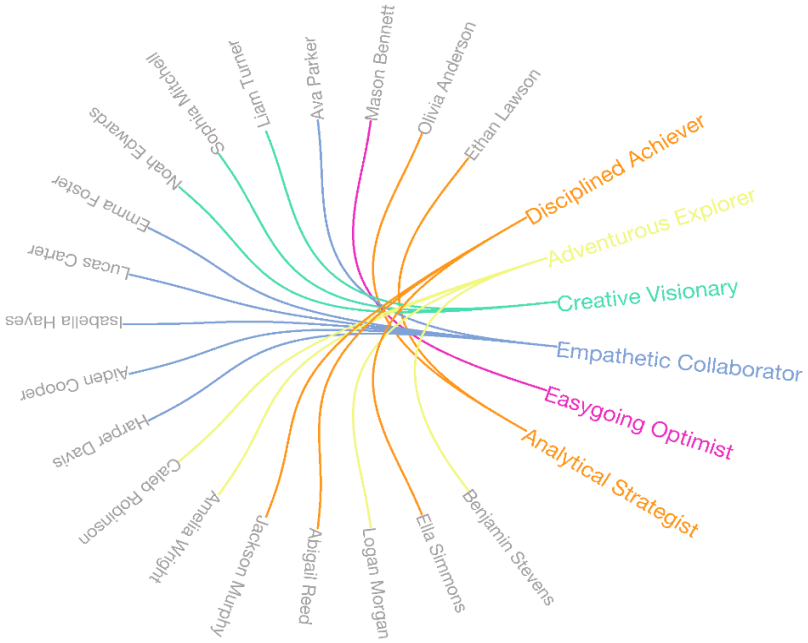

Fig. 3. Data visualization generated with Grasshopper (a parametric software) by the author

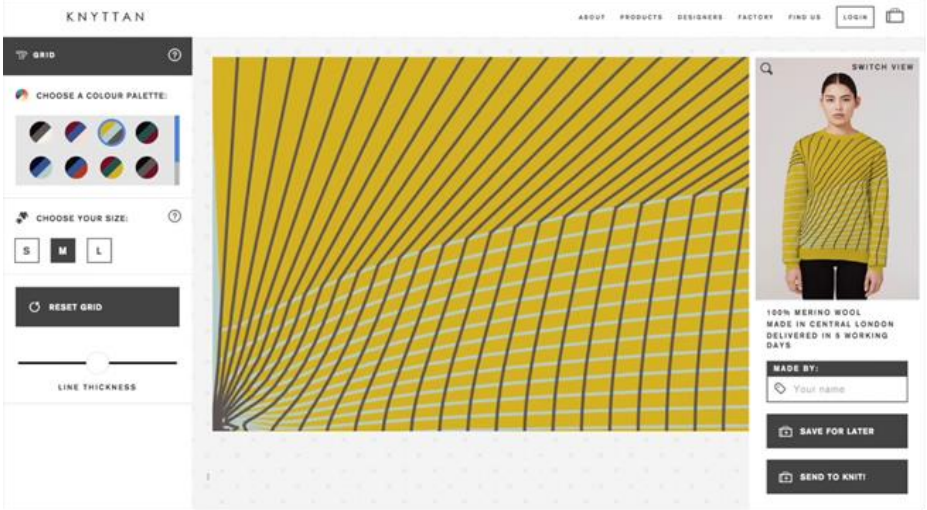

Fig. 4. KNYTTAN customized cloth brand

What's more, parametric design exhibits notable advantages in handling extensive and intricate data samples, generating diverse types of charts, and similar tasks. Its representation can dynamically change with slight parameter adjustments, further enhancing the effectiveness of data presentation.

Application in Personalized and Customized Design

In the contemporary society characterized by a pursuit of heightened personalization, graphic design assumes a paramount role in fulfilling the incessantly growing individualistic demands. Graphic design transcends its conventional role of mere information presentation, evolving into a pivotal medium for articulating individual personas, brand identities, and ideological stances. Through the incorporation of distinct visual elements and bespoke design strategies, it facilitates the cultivation of brand distinctiveness, accentuates individual self-expression, and provides tailored experiences for products, thereby encapsulating the mosaic of cultural diversity. Within this milieu, the integration of parametric design emerges as a sagacious paradigm. By leveraging parameter-driven customization within the graphic design workflow, a spectrum of distinct design propositions can be generated, thus manifesting design personalization. This strategic approach endows graphic design with augmented creativity and flexibility, positioning it as an instrumental tool for addressing the contemporary multitudinous requisites of personalized design. For example, KNYTTAN is a customized cloth brand that everyone can interactively customize the generative patterns. Then the patterns will be woven into the cloth so that people can customize their own designs (Fig.4).

Performance-based Optimization

The functionalities of graphic design extend far beyond visual aesthetics, encompassing the guidance of attention, effectiveness and accuracy of information delivery, as well as eliciting emotional feedback. The evaluation of these functional aspects involves numerous influencing factors and has long been a significant topic in design assessment. In this context, the application of parametric design holds value not only in optimizing visual forms but also in addressing these intricate functional issues to achieve scientifically sound design outcomes. For instance, the construction of parametric algorithms can establish a dynamic linkage between visual form parameters and visual attention parameters, thereby achieving the desired visual attention distribution through the configuration of form parameters. Such outcomes exhibit a high degree of accuracy and scientific rigor, providing a more objective approach for the functional evaluation of design outcomes. Through parametric design, it is possible not only to enhance visual effects but also to ensure the efficacy of information transmission and emotional resonance. This allows the design to exhibit a more comprehensive and far-reaching set of functionalities across various dimensions [1].

Materialization of Design Results

In practical applications, the outcomes of graphic design often need to be presented through materialization methods such as printing, creating displays, or designing related products. While designers engage in two-dimensional visual creations on computers, they must also consider how to materialize their design results. In this process, parametric design tools differ significantly from conventional design software, as they construct each design parameter and geometric element with precise mathematical and geometric definitions from the early stages of design. This precision grants design files greater potential for practical application. For example, lines and patterns generated through parametric design can be directly imported into computer numerical control (CNC) processing equipment like laser cutting machines for crafting tangible displays. This seamless connection streamlines the transition from design to production, enhancing efficiency and accuracy without the

need for additional conversion or adjustment steps. This approach provides designers with enhanced practicality and creative freedom, while also bolstering the feasibility and application scope of their designs.

Furthermore, due to the stochastic and intricate nature of its design forms, parametric design offers distinctive aesthetic styles with certain visual characteristics, contributing to the realm of design. The distinct «aesthetic styles» can serve as valuable references for designers when creating visual designs related to specific themes, inspiring creativity and providing fresh perspectives and inspiration.

In summary, it is evident that the innovative integration of parametric design into graphic design can be realized through a multitude of strategies. The integration not only demonstrates clear feasibility and necessity but also holds immense potential for innovation.

4. Challenges for the Integration

The integration of parametric design with graphic design indeed presents significant design opportunities and innovative potential. However, it also confronts a range of specific difficulties and challenges that necessitate a comprehensive consideration of how to address these issues to achieve the goals of innovative integration [18].

The first challenge to be addressed is the gap between knowledge structures. In traditional design education, the knowledge structure of graphic designers often lacks sufficient content in mathematics, programming, and computer-related fields. This results in significant difficulties for them when learning and grasping the concepts of parametric design. The absence of essential technical background makes designers struggle to master parametric design software and, consequently, may lead them to avoid its use in practical design work.

Another challenge lies in the extraction and determination of design parameters in graphic design. This involves abstracting and logically transforming graphic design issues, ultimately constructing algorithms for form generation based on specific parameters. Designers must translate design problems into parameter and algorithmic problems and validate the effectiveness and comprehensiveness of such conversions. This process is fraught with challenges and requires considerable time and effort from design professionals to accomplish. Clearly, this is not an efficient process.

A fundamental challenge stems from differing thinking approaches. Designers typically favor creative, free-thinking, viewing it as a reflection of individual originality. However, embracing parametric modeling necessitates logical thinking, rational consideration, and step-by-step algorithmic construction. This discrepancy in thinking methods can make designers feel confined, requiring time and training to overcome [10].

The last challenge involves the recognition of software tool precision. Although design software relies on a series of programming languages, a significant disparity often exists between users' perception of design precision and its actual application. Consider Adobe Photoshop, where users' geometric creations are subjective, as opposed to parametric design where each geometric object stems from precise parameters and mathematical formulas, ensuring consistent accuracy. This diverges significantly from conventional design software. A lack of awareness about this precision could impede designers from fully adopting parametric graphic design.

5. AI Empowering Parametric Design Integration

The rise of AI presents an effective avenue for addressing the challenges and difficulties arising from the integration of both aspects. AI's capabilities in data analysis and pattern recognition enable the extraction of valuable insights from extensive design data. It can assist designers in identifying potential parametric design opportunities, guiding them to incorporate more precise and innovative elements into their designs. Furthermore,

leveraging the foundational principles of parametric design, AI can recommend appropriate parameter combinations based on design objectives and requirements, thereby reducing the technical barriers for designers. This allows a greater number of designers to engage in the practice of parametric design actively.

AI also possesses the capability to assist designers in overcoming challenges in technology, processes, and thinking methods. By providing training, resources, and guidance, AI aids in accelerating designers' comprehension and application of parametric design, thereby advancing the realization of integrated innovation. This implies that designers can employ parametric design methods with greater confidence, leading to more efficient and precise outcomes in their designs.

Conclusions. By conducting a thorough investigation of literature and research, this paper expounds upon the concepts, features, and practices of parametric design proving the necessity and viability of integrating parametric modeling into the realm of graphic design. Strategies of integration are proposed, such as the generation of visual elements, optimization for layout, innovative application of color, enhancement of interactivity, application in data visualization, application in personalized and customized design, performance-based optimization, materialization of design results, application in data visualization, application in personalized and customized design, performance-based optimization, and materialization of design results. Finally, there are some potential challenges and AI could provide great advantages for the integration in future research.

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ПАРАМЕТРИЧНЕ МОДЕЛЮВАННЯ ЯК ІННОВАЦІЙНИЙ ПІДХІД У ГРАФІЧНОМУ ДИЗАЙНІ

Мета. *Стаття спрямована на дослідження можливостей і стратегій інноваційної інтеграції параметризму в сферу графічного дизайну та аналіз основних проблем і можливих рішень використання параметричного дизайну у створенні графічних об'єктів.*

Методологія. *Відповідно до теми дослідження використані методи включають порівняльне дослідження, теоретичний аналіз та синтез.*

Результати. *У статті розглядаються визначення та особливості параметричного дизайну, аналізуються особливості його застосування для оптимізації дизайн-мислення й створення персоналізованих об'єктів. Представлено різні рівні інноваційних реалізацій, які пропонують кілька стратегій для інтеграції параметричного моделювання у сферу графічного дизайну, включаючи генерацію візуальних елементів, оптимізацію макета, покращення інтерактивності дизайну та застосування візуалізації даних у персоналізованому дизайні. Крім того, обговорюються деякі проблеми інтеграції, пов'язані з використанням технологій штучного інтелекту.*

Наукова новизна. *У статті аналізуються різні рівні та ефективні стратегії застосування параметричного моделювання у сфері графічного дизайну, досліджуються актуальні аспекти взаємодії, які є інноваційними й підкреслюють вагомість використання методології параметричного проєктування, штучного інтелекту, обчислювального дизайну у парадигмі сучасного графічного дизайну.*

Практичне значення. *Матеріали статті можуть бути використані для дослідження інноваційного застосування цифрового дизайну, параметричного дизайну та штучного інтелекту в галузі графічного дизайну.*

Ключові слова: *параметричне моделювання, параметризм, параметричний дизайн, графічний дизайн, штучний інтелект, цифровий дизайн.*

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