

Origami in Architecture

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Article Information

ABSTRACT

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In a society where people rely on phone swiping and computer keyboards, the opportunities to develop fine motor skills are limited. However, origami presents a unique avenue for enhancing hand-eye coordination, temporal/spatial abilities, and engaging both the mind and body. By practicing origami, individuals can improve their hand-eye coordination, fine motor skills, and mental focus.

To create intricate designs, simple origami folds can be combined in various ways. While traditional Japanese origami has been practiced for centuries, there have been instances where the strict adherence to guidelines has been relaxed, allowing for cutting the paper or starting with unconventional shapes. Origami finds applications beyond its traditional roots, being used in architecture, product design, packaging, and even as a fresh approach to designing deployable structures.

Due to its versatility and potential in numerous fields, origami has garnered significant attention within the design and engineering research community. Its ability to fold itself and save space makes it an innovative approach applicable in various domains, ranging from education to designing and beyond.

KEYWORDS: Innovation, design, education, paper folding

INTRODUCTION

Origami offers a captivating experience where you can fold, spin, and twist paper to create an enchanting environment. Rooted in the traditions of Japanese paper folding, origami aims to construct intricate sculptures using flat sheets of paper, without relying on glue or cutting tools. However, it encompasses more than mere paper manipulation. It is a technique that nurtures awareness and attentiveness, enabling better control over thoughts and fostering qualities such as tranquility, clarity, and focus. In essence, origami embodies a form of "meditation."

The field of design and engineering research is increasingly focusing on origami due to its immense potential in various applications. From self-folding structures to space-saving approaches, origami is

capturing rapid attention and sparking innovative exploration.

ORIGAMI IN ART FORM

The objective of origami, a traditional Japanese art of paper folding, is to create intricate sculptures using flat sheets of paper, without relying on glue or cutting tools. However, it encompasses more than mere folding. It is a technique that emphasizes the cultivation of awareness and attention, enabling individuals to gain better control over their thoughts and cultivate qualities such as serenity, clarity, and focus. In many ways, origami can be seen as a form of "meditation" that encompasses these aspects.

In the design and engineering research community, origami has gained significant attention due to its vast potential in a wide range of applications.

From self-folding structures to space-saving approaches, origami offers promising possibilities. Learning and practicing origami fosters patience, precision, memory, discipline, geometry, and problem-solving abilities. It also plays a crucial role in developing precision and hand-eye coordination, which are essential skills for every learner. By engaging both the visual and practical aspects, origami helps students grasp the principles of two- and three-dimensional geometry.

ORIGAMI FORM IN ARCHITECTURE

Origami, beyond being an art form, has found its way into numerous academic disciplines, encompassing architecture, engineering, education, mathematics, fashion, computing, psychology, biology, and many others.

Within the realm of architecture, origami has manifested in two distinct forms: static and non-static structures. Non-static origami structures offer a wide range of possibilities, encompassing shapes such as roofs and kinetic building components. On the other hand, static structures are commonly associated with folded plate structures.



Figure 1 Folded plate structure in origami

The residential dwelling challenges the conventional concept of cubic spaces by drawing inspiration from a unique surface developed by topological mathematicians. This approach empowers architects to create captivating and innovative environments that are both engaging and aesthetically pleasing.



Figure 2 Pink pavilion inspired from origami

Studio Morison, known for their artistic prowess, has constructed a vibrant pink pavilion resembling an origami pineapple. This unique structure now stands proudly in the walled garden of the Berrington Hall country estate in Herefordshire, England, adding a touch of whimsy to the surroundings. By breaking free from the constraints of traditional box-like designs, the pavilion showcases intriguing and unconventional interior layouts that exude a dynamic energy. Through the strategic use of cuts and inward folds, windows, balconies, and terraces are intricately carved out, adding further visual interest. This is just one example of the many inventive buildings that take inspiration from the art of origami, pushing the boundaries of architectural creativity.



Figure 3 Nestle chocolate museum



Figure 4 Origami House by Office of Architecture in Barcelona, Sant Cugat, Spain

The escalating climate crisis has led to an alarming increase in natural disasters worldwide, ranging from devastating wildfires in Turkey to catastrophic floods in Germany.

Providing shelter is a crucial aspect of humanitarian response, yet it is often a complex endeavor. While tents and tarps offer temporary solutions, the construction of more durable buildings is often delayed during crisis situations. Furthermore, ensuring the privacy and dignity of displaced individuals becomes a significant challenge due to the chaotic and unstable nature of humanitarian emergencies.

In response to these concerns, there has been conceptual inspiration drawn from the art of origami to address these issues. The development of shelter pods, influenced by origami principles, aims to offer solutions that are easy to assemble, cost-effective, and environmentally friendly. These innovative designs seek to provide efficient and sustainable shelter options for those affected by humanitarian catastrophes.



Figure 5 origami inspired emergency quarters.

Researchers have proposed that an origami-based design could enhance the structural performance of a dynamic façade system. To explore this concept, they utilized the Hearst Tower in New York as a basis for creating an adjustable diagrid façade (ADF) employing origami principles and powered by linear actuators. Computational fluid dynamics (CFD) simulations were conducted to analyze the behavior of three different ADF designs when subjected to significant wind loads.

The results of the simulations demonstrated that the origami based ADF effectively reduced wind loads exerted on the structure in all three configurations. In comparison to a shoebox model of the same size, the three ADF configurations exhibited a decrease in wind loads ranging from 16.9% to 43.8%, according to the simulation outcomes. This suggested origami-based model, though still in its early research stages, showcases the potential of origami-based systems with structural capabilities. However, further research is necessary before its practical application in real-life scenarios can be considered.

ORIGAMI FORM IN FURNITURE

Origami's influence extends beyond architecture and into the furniture sector as well. Utilizing plywood and piano hinges, prototype items have been created that fold flat and are effortlessly supported by a steel frame. These innovative designs not only inspire awe but also showcase how something accessible and affordable can be transformed into something extraordinary through folding techniques. Moreover, the folding mechanism enhances the practicality of origami for everyday use by minimizing creases and making it more functional and compact. These advancements in origami-based furniture design highlight its versatility and potential for creating

unique and efficient living spaces.



Origami, the ancient art of paper folding, stands as a renowned representative of this craft and has found its place in cultures worldwide, serving both decorative and practical purposes. In recent times, origami designs have garnered heightened attention across diverse disciplines such as mathematics, natural sciences, engineering, and architecture.

The appeal of origami lies in its ability to inspire innovative concepts for reconfigurable and multifunctional materials and structures. Researchers and practitioners in these fields are exploring origami-inspired approaches to develop novel solutions that can adapt, transform, and serve multiple functions. The principles derived from origami are paving the way for advancements in material science, structural engineering, and architectural design, opening up new avenues for creative problem-solving and efficient utilization of resources.

Origami's influence in these sectors reflects its enduring relevance and the untapped potential it holds for driving innovation and pushing the boundaries of what is possible in diverse fields of study and application.

CONCLUSION

The present study focused on exploring the engineering applications of origami-based designs across various sectors such as biomedical, architectural, robotic, space, biomimetic, as well as the examination of met materials and fold-core structures. It was discovered that origami-based solutions offer potential for solving diverse engineering challenges. However, several common issues were identified, including the complexity of design procedures, the lack of optimized design tools, and limitations related to fabrication processes.

A thorough analysis of numerous research findings revealed the absence of established design approaches within the origami community. Additionally, the study considered the potential of recent advancements in software interfaces to enhance design processes. Although there is a wide range of design and simulation tools currently available, many of them have been developed independently and do not seamlessly integrate into design workflows.

Despite the rapid expansion of origami-based applications, there remain several challenges that need to be addressed and resolved.

- **Elastic folding:** While rigid folding motions have been predominantly utilized in origami-based designs, there is a need for further exploration of distinctive elastic foldable crease patterns to generate innovative design concepts. A deeper understanding of the relationship between folding actions and material properties could lead to the development of a new generation of origami designs, including curved creases, unlocking new applications and enhancing folding actions and actuation systems.

- **Curved-fold origami:** The potential applications of curved-fold origami are largely unexplored. Recently, mechanical models that accurately mimic the behavior of curved-crease structures have emerged, but there is a scarcity of simulation tools capable of supporting the design of such models. The development of structures with curved creases inspired by origami can leverage material characteristics more effectively,

potentially leading to more efficient folding actions and actuation systems.

- **New materials:** The advancement of curved-creased origami and elastic-folding geometries relies on the utilization of new materials capable of withstanding folding stresses without failure. Given the uniqueness of origami-based designs, no single material can be universally applicable without thorough experimental testing. The exploration of new hybrid systems could drive the emergence of unexplored design possibilities. Incorporating material selection into the design phase, possibly through a database linking crease patterns and material specifications, could provide valuable insights for designers seeking optimal material combinations for specific crease patterns and design solutions.

- **Lack of a standard design process:** A generic and integrated design strategy is currently absent from origami designs across various sectors. Establishing such a strategy would be highly beneficial in generating optimal solutions and cross-disciplinary ideas. While the Direct Design methodology is commonly employed, the use of the Inverse Design technique, which has been applied to only a limited number of target geometries and origami designs, remains challenging. Utilizing optimization algorithms, such as interactive evolutionary algorithms, could enable exploration of larger design spaces without specific configurations. Subsequently, the selected design outcomes could be further improved using single- or multi-objective optimization methods.

Addressing these challenges and incorporating advancements in elastic folding, curved-fold origami, new materials, and a standardized design process would contribute to the advancement and broader application of origami-based designs in various sectors.

Origami-inspired designs have demonstrated their versatility in implementing cutting-edge technological advancements. Recent research findings

have further enhanced the potential and quality of these applications. The aim of this extensive review on origami-based applications, design approaches, and tools is to foster interdisciplinary thinking and stimulate new ideas.

By examining the wide range of origami-based applications across various fields, this review highlights the adaptability and effectiveness of origami-inspired designs in practical contexts. It also explores the evolving design approaches and methodologies employed in origami-based projects, shedding light on the potential for innovative problem-solving and solution generation.

Furthermore, the review focuses on the development of specialized tools and software interfaces that support origami design processes. These advancements aim to streamline the design workflow, enhance simulation capabilities, and facilitate the integration of origami-based designs into real-world applications.

By synthesizing and presenting these findings, the comprehensive review aims to inspire cross-disciplinary collaboration and encourage further exploration of origami-based approaches in diverse fields. The increasing scope and quality of origami-inspired applications hold promise for addressing complex challenges and driving technological advancements in various domains.

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