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ORIGAMI-INSPIRED MOBILE ROBOTS: STRUCTURES, LOCOMOTION AND RESEARCH TRENDS

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Abstract: *This paper presents an analysis of mobile robots based on origami-inspired structures. The study focuses on design principles, locomotion mechanisms and research trends in the field of origami robotics. A literature review was conducted using major scientific databases including Web of Science, Scopus, IEEE, ScienceDirect and SpringerLink. The analysis highlights the evolution of research in this field between 2013 and 2026 and identifies the main structural models and locomotion strategies used in origami-based mobile robots.*

Key words: *origami robots, mobile robots, reconfigurable structures, origami engineering*

1. INTRODUCTION

Origami-inspired mobile robots represent an emerging research field that combines the traditional principles of Japanese paper folding with modern robotic engineering. Origami-based structures allow flat surfaces to transform into complex three-dimensional mechanisms, enabling robotic systems to achieve high structural adaptability and reconfigurability [1], [2].

Mobile robots operating in complex environments often face limitations related to rigid structures, limited adaptability, and inefficient locomotion mechanisms. These limitations motivate the development of robotic systems capable of structural transformation and adaptive locomotion.

Recent research has explored several origami-based robotic designs, including robots equipped with variable geometry wheels, soft crawling robots inspired by biological locomotion, and modular robots capable of structural reconfiguration. Folding patterns such as Miura-Ori, Kresling, and Waterbomb have been widely used to develop robotic mechanisms with enhanced mobility and structural flexibility [3], [4], [6], [8].

Despite these developments, further research is required to better understand the design principles, locomotion strategies, and research trends associated with origami-inspired mobile robots. A systematic analysis of the existing scientific literature is necessary to identify the most relevant structural models, locomotion mechanisms, and technological directions in this field.

The remainder of this paper is organized as follows. Section 1.1 presents origami-inspired robotic structures and representative robotic systems. Section 1.2 discusses locomotion mechanisms used in origami mobile robots. Section 3 presents the statistical analysis of scientific publications and research trends identified in the analyzed databases.

1.1 Origami-Inspired Robotic Structures

Origami-inspired robotic structures have been widely investigated in recent years due to their ability to generate lightweight and reconfigurable mechanical systems.

These structures allow robotic platforms to change their geometry while maintaining compact configurations and structural efficiency. By exploiting folding patterns, flat materials can be transformed into complex three-dimensional mechanisms capable of structural transformation and geometric adaptation.

A major advantage of origami-inspired structures lies in their capability to perform

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significant shape changes without requiring complex mechanical joints.

Through carefully designed crease patterns, robotic systems can achieve both structural flexibility and mechanical stability, enabling them to adapt to different operational conditions. In addition, origami-based mechanisms often reduce the number of moving components compared to conventional robotic systems, which can simplify the overall mechanical design and improve reliability.

One representative example is the MORI robot, a modular origami robotic system composed of multiple triangular modules connected through rotational joints. This modular configuration enables structural reconfiguration and allows the robot to adapt its geometry according to different locomotion requirements [3] as ilustrate in Fig. 1.

Fig.1. MORI Robot [3]

Another example is the OrumBot robot, an origami-based deformable robot inspired by an umbrella-like structure. The robot uses origami mechanisms to modify the geometry of its wheels, enabling improved mobility and adaptability on different terrains [4] as shown in Fig. 2.

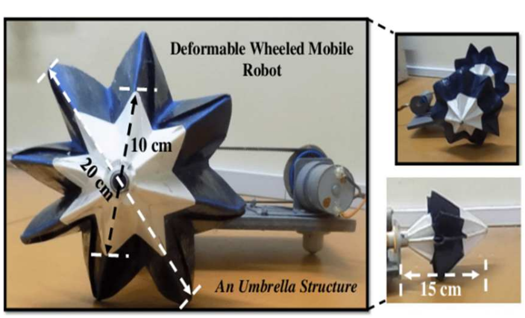

Fig. 2. Orumbot [4]

In addition, origami-inspired worm robots have been proposed to achieve peristaltic locomotion through sequential body deformation. Such robots exploit folding structures to generate wave-like movements that enable efficient crawling motion in confined or irregular environments [7], as illustrated in Fig. 3.

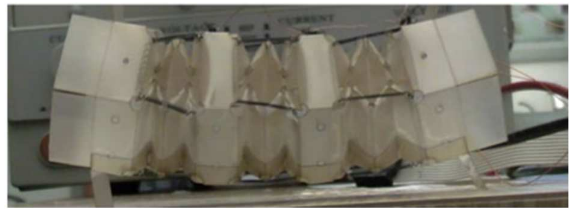

Fig. 3. Origami-inspired worm robot [7]

These examples highlight the diversity of origami-inspired robotic structures and demonstrate the potential of folding-based mechanisms for developing adaptable and reconfigurable robotic systems. The locomotion capabilities of these robots are further discussed in the following subsection.

1.2 Locomotion Mechanism in Origami Mobile Robots

Locomotion represents one of the most important aspects in the design of origami-inspired mobile robots. The geometric properties of folding structures allow the development of innovative locomotion mechanisms that can adapt to different environments and terrain conditions.

Several studies have investigated robots equipped with deformable origami wheels, capable of modifying their geometry to improve mobility and obstacle traversal [5], [8], as illustrated in Fig. 4.

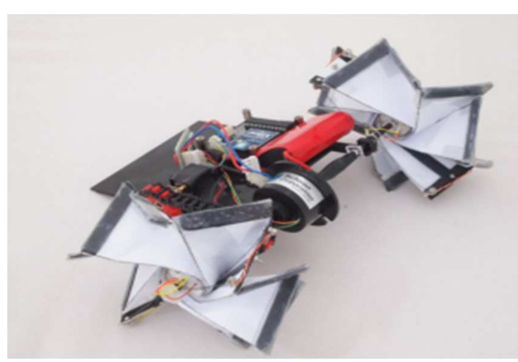

Fig. 4. Deformable wheel robot [5]

Bio-inspired locomotion has also been explored through origami-based robotic systems such as the OriSnake robot, which utilizes flexible folding structures to achieve snake-like motion and crawling locomotion. This type of locomotion enables robots to move through narrow or irregular environments where conventional wheeled robots may encounter limitations [6] as illustrated in Fig. 5.

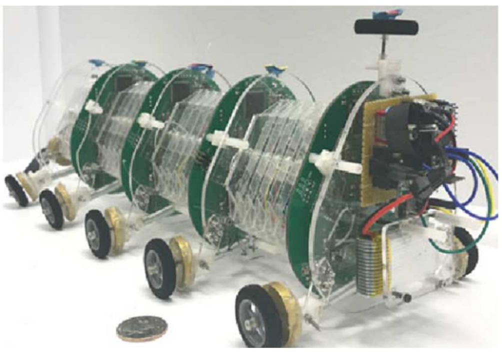

Fig. 5. OriSnake [6]

The aim of this paper is to analyze the current research trends in origami-based mobile robots through a literature review of scientific publications indexed in major databases such as Web of Science, Scopus, IEEE, ScienceDirect, and SpringerLink. The study investigates the evolution of research activity, identifies the main structural configurations and locomotion mechanisms, and highlights future research directions in the field of origami robotics.

2. METHODOLOGY

The methodology of this study is based on a systematic analysis of scientific literature related to origami-inspired mobile robots. The purpose of the analysis is to identify the main research directions, structural configurations, and locomotion mechanisms used in origami-based robotic systems.

The literature review was conducted using several major scientific databases, including Web of Science, Scopus, IEEE/IEL Electronic Library, ScienceDirect, and SpringerLink. The search was performed using the keyword "origami mobile robots", focusing on publications related to mobile robotics, origami structures, and reconfigurable robotic systems.

The analysis considered scientific articles published between 2013 and 2026, a period that reflects the most relevant developments and innovations in the field of origami robotics. Initially, a total number of articles were identified across the selected databases. After applying selection criteria and removing duplicate entries, a final set of relevant publications was obtained.

The selected articles were further analyzed according to several criteria, including year of publication, country of origin, continent, structural configuration, and locomotion strategy.

This classification allows the identification of research trends and the evaluation of the evolution of scientific interest in origami-inspired mobile robots.

The results of the literature analysis are presented through statistical graphs and comparative tables that highlight the distribution of publications across databases, the temporal evolution of research activity, and the geographical distribution of scientific contributions. The distribution of scientific publications identified in the analyzed databases is illustrated in Fig. 6.

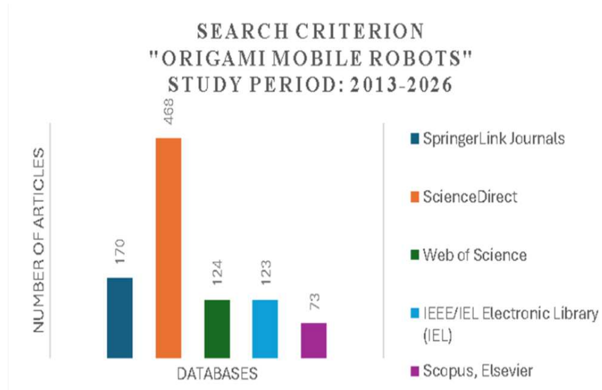

Fig. 6. Number of scientific publications identified in the analyzed databases using the keyword "origami mobile robots" for the period 2013–2026

3. RESULTS AND ANALYSIS

Following the literature search conducted across the selected scientific databases, many scientific publications related to origami-inspired mobile robots were initially identified.

After applying the selection criteria and analyzing the relevance of the publications, a subset of articles was selected for further analysis. During this process, duplicate entries appearing in multiple databases were also identified and removed to obtain a final set of unique publications used in the study.

The distribution of unique and duplicate publications identified during the analysis is presented in Fig. 7.

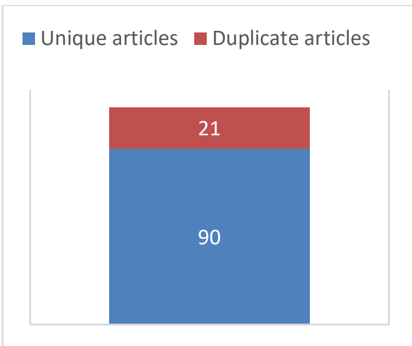

Fig 7. Distribution of unique and duplicate scientific publications identified in the analyzed databases

The temporal distribution of the selected publications according to the year of publication is presented in Fig. 8. This analysis allows the identification of research trends and the evolution of scientific interest in origami-inspired mobile robots over the analyzed period.

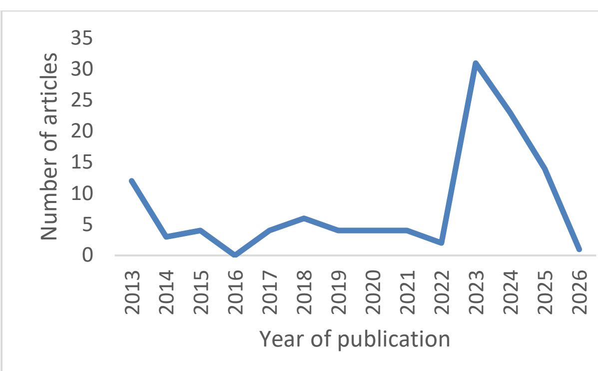

Fig. 8. Distribution of relevant publications according to the year of publication.

The results indicate a relatively low number of publications in the early years of the analyzed period, followed by a noticeable increase after 2020. A peak in the number of publications can be observed in 2023, reflecting the growing research interest in origami-inspired robotic systems and their applications in adaptive and reconfigurable robotic platforms.

In addition to the temporal analysis, the geographical distribution of the analyzed publications according to the country of origin was also investigated. The results are presented in Fig. 9.

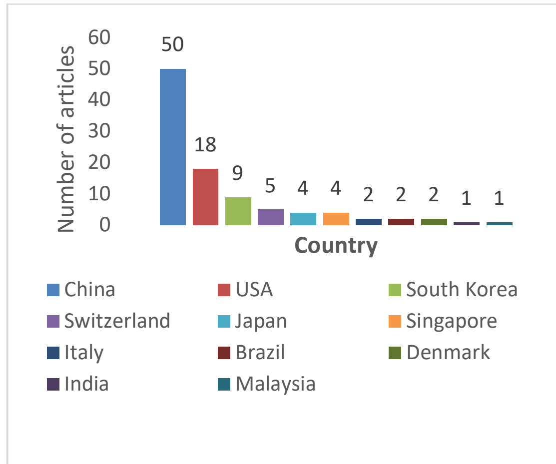

Fig. 9. Distribution of relevant publications according to the country of origin.

The results indicate that China represents the most active research region in the field of origami-inspired mobile robots, with a significantly higher number of publications compared to other countries. The United States represents the second most active research region, followed by several other countries such as Singapore, Switzerland and Italy.

A broader geographical analysis of the selected publications is presented in Fig. 10, which illustrates the distribution of scientific articles according to continent.

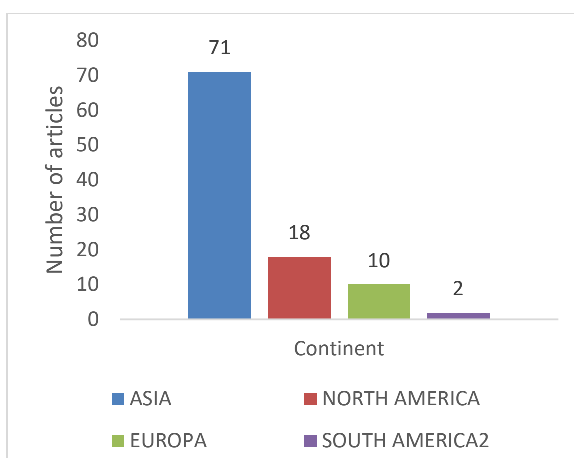

Fig.10. Distribution of relevant scientific publications according to continent

The results indicate that Asia concentrates the largest number of publications in the field of origami-inspired mobile robotics, followed by North America and Europe. This distribution highlights the strong research activity in Asian countries, particularly in China.

4.DISCUSSION

The results obtained from the literature analysis highlight several important trends in the field of origami-inspired mobile robotics.

The increasing number of publications in recent years reflects the growing interest in reconfigurable robotic systems capable of adapting to complex and dynamic environments [1], [7]. Origami-based structures offer significant advantages in terms of structural flexibility, compactness and multifunctionality, making them suitable for a wide range of robotic applications.

The geographical distribution of publications indicates that a significant part of the research activity is concentrated in Asian countries, particularly in China, where numerous studies related to origami-inspired robotic systems have been developed. This trend can be associated with the strong development of robotics research centers and the increasing investments in advanced robotic technologies.

In addition, the diversity of locomotion strategies identified in the analyzed publications highlights the versatility of origami-based robotic architectures [3], [4], [6]. These structures enable innovative locomotion mechanisms such as crawling, rolling, or multimodal locomotion, which can be adapted to different types of terrain and operational environments.

Overall, the analysis confirms that origami-inspired design principles represent a promising direction for the development of next-generation mobile robotic systems characterized by adaptability, modularity and structural efficiency

The results indicate a growing interest in origami-inspired robotic systems. Future research may focus on the development of more efficient locomotion mechanisms, improved structural designs, and the integration of advanced control strategies for autonomous origami robots.

5. CONCLUSION

This paper presented a literature analysis of scientific publications related to origami-inspired mobile robots. The study focused on identifying relevant research articles from several major scientific databases and analyzing their distribution according to publication year, country of origin and continent.

The results indicate a significant increase in scientific interest in origami-inspired robotic systems, particularly after 2020. The geographical analysis highlights that Asia represents the most active research region in this field, followed by North America and Europe.

The analysis also confirms that origami-inspired structures offer promising solutions for the development of mobile robots with enhanced adaptability, structural flexibility and efficient locomotion mechanisms.

Future research directions may include the development of new origami-based robotic architectures, advanced control strategies and experimental validation of innovative locomotion concepts.

6. REFERENCES

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Analiza roboților mobili inspirați din structuri origami și a tendințelor de cercetare

Rezumat: Lucrarea prezintă o analiză a roboților mobili inspirați din structuri origami, cu accent pe principiile de proiectare, mecanismele de locomoție și evoluția cercetărilor din acest domeniu. Analiza literaturii de specialitate a fost realizată utilizând mai multe baze de date științifice, inclusiv Web of Science, Scopus, IEEE, ScienceDirect și SpringerLink. Studiul evidențiază distribuția publicațiilor în funcție de anul apariției, țara de proveniență și continent, precum și principalele direcții de dezvoltare în domeniul roboticii inspirate din origami. Rezultatele indică o creștere semnificativă a interesului științific pentru aceste sisteme robotice în ultimii ani, datorită avantajelor oferite de structurile reconfigurabile și mecanismele de locomoție adaptative.

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