Origami inspired engineering: Challenges and opportunities in portable and foldable mechanisms in solar-power generation

Daniel Lavayen-Farfán[1] & Enrique Pujada-Gamarra[1,2]

[1]Applied Mechanics, Machines and Mechanisms Group, Pontificia Universidad Católica del Perú, Universitaria Ave. 1801, 15088 Lima, Perú, {dlavayen@pucp.edu.pe}
[2]Fakultät Maschinenbau, Technische Universität Ilmenau, Ehrenbergstraße 29, 98693 Ilmenau, Germany,

ABSTRACT

Origami can be a source of inspiration for engineers and professionals in R&D, as complex figures can be obtained by folding a flat sheet of paper. Among the various applications of origami-inspired engineering, solar-power generation has emerged as a particularly promising field. Solar-powered systems are typically heavily constrained by the surface area they need to cover to produce electricity. The more power needed, the more surface area that requires to be covered. Foldable panels overcome this difficulty by folding the panels one on top of the other to temporarily reduce their footprint. However, to adequately design these products, several factors need to be accounted for, such as: the dynamics of the movement, the joint design, and the thickness of the panels, which might affect the Origami motion. These factors have a huge impact in the structural integrity, quality and performance of the panels. Thus, these factors also present themselves as challenges that must be overcome in a growing field with more and more applications. In this work, the authors present some of these challenges, as well as opportunities of research and development in this promising field.

1 Introduction

Origami, the ancient japanese art of folding paper, can be a limitless source of inspiration for engineers dedicated to research and development. By folding a flat sheet of paper, complex 3d shapes can be created. The hidden potential in origami lies precisely in these folds: a complex and compact and folded shape can be "unfolded" to occupy a larger footprint. This property has found several uses in different fields, including robotics [1, 2], space exploration [3, 4], solar-power generation [5], among others [6]. However, to fully exploit its potential, further study on the kinematics and design methodologies must be done [7, 8, 9].

2 Thick Origami: challenges and opportunities

One particular and often useful way of analyzing origami, is to consider that it is actually a 3d linkage mechanism. By this analogy, the kinematics of existing and even new Origami patterns can be studied as the kinematics of a 3d linkage. This analogy is also useful to determine the number of degrees of freedom of an Origami pattern, which is extremely useful since this information can be used to build the driver system and structure of the Origami.

Unlike paper Origami, otherwise known as thin Origami, most engineering applications require to account for panel thickness and stiffness. This applications lie in the field known as thick Origami. The inclusion of thickness makes flat foldability almost impossible unless the folds are redesigned using the so-called thickness-accommodation techniques [10]. Some of these techniques have been widely studies, whereas others have been neglected despite their advantages, because of limitations that have yet to be overcome. The challenge is to build a thick origami which can reliably achieve flat foldability, preserve Origami-like motion, with hinges that can be able to withstand continuous and repetitive use without breaking or collapsing.

3 Impact and possible applications

As mentioned, there are several possible applications for Origami-inspired foldable solar-panels. Even though they were initially conceived with space-exploration applications in mind, plenty other ground and maritime applications exist. For instance, foldable solar panels can be installed on naval vessels, with extreme space constraints and limited surface area; therefore increasing the energy efficiency of the vessel and significantly reducing the fuel costs [11]. On the other hand, mining facilities (typically located far away from the main cities or the electric grid) rely heavily on portable diesel generators for electricity for human use; thus, mobile and/or portable solar-power generation systems can not only reduce the fuel costs, but also contribute to a cleaner and greener environment [5].

Moreover, foldable solar panels can enhance agricultural photovoltaic systems (AgriPV), where the ability to adjust panel configurations dynamically can increase land productivity by optimizing energy output for different types of crops. These applications showcase not only the versatility of foldable solar panels but also their capacity to contribute to more sustainable, cost-efficient solutions across multiple sectors. As the technology matures, further innovations in the design and deployment of foldable solar panels promise to expand their impact in different applications.

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4 Conclusions

In conclusion, origami inspired engineering presents a large variety of opportunities in the development mechanisms for foldable and portable solar panels. While the challenges of joint design, panel thickness, and kinematics are still significant, they also offer important research lines. As the demand for sustainable and mobile energy solutions grow, advances in origami inspired design could play a major and critical role in solar-power generation.

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