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Optimal design of an Origami-inspired kinetic façade by balancing composite motion optimization for improving daylight performance and energy efficiency

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A B S T R A C T

This article presents a novel concept for an Origami-inspired shading device based on dynamic daylight that can be used to improve the daylight performance of a target building and reduce the energy consumption for the building. The daylight performance is evaluated based on the Leed v4 (Leadership in Energy and Environmental Design) daylight criterion. The proposed shading device is experimented in an office located in Ho Chi Minh City, Vietnam, where there is a tropical monsoon climate being hot and humid by the year. To investigate the effectiveness of the proposed design in acting as a sun shading system for the office, we consider eight cases corresponding to eight directions which are South, North, East, West, South-East, North-East, South-West, and North-West. An automatic simulation optimization procedure is developed by combining a daylight simulation tool called DIVA and an optimization method called Balancing Composite Motion Optimization (BCMO). BCMO is used to find the optimal design for the proposed kinetic shading device which will help the building to improve daylight performance. It must be noted that the proposed framework is not necessarily tied to any particular optimization tool or type of building. The results show that the proposed kinetic device has outstanding performance as it helps the building to achieve 2, 3 points in Leed v4 for four different directions, including North, North-East, South, North-West.

1. Introduction

Daylight can have significant influences on human physiology and psychology [28]. Due to urbanization, people need to spend more time indoors, about 86.9% time of their life [19]. It is believed that working in artificial lighting for a long time may negatively impact health while working in natural daylight may help reduce stress and discomfort [10]. Although natural daylight can provide sufficient conditions for good vision, it can also produce uncomfortable solar glare and unwanted reflections or overheating [10,28]. Designers always aim to design a sun shading system that can effectively utilize daylight while minimizing the discomfort caused by daylight and the energy consumption of the building [8,16,36]. To achieve this goal, choosing a suitable form of the building or the right amount of glazing-areas on the façade in specific directions may be an effective solution in the early design stage. If the building's form or direction is fixed, a good kinetic façade would be an effective solution.

A kinetic façade is defined as a structure installed on the outside of the building as an envelope, which includes kinetic shading devices that can change their forms in order to adapt to the surrounding environment [9,25,44]. The general design concept of a kinetic shading device is based on the four basic movements: translation, rotation, scaling, and movement via material deformation. They are illustrated in Fig. 1 [25]. The material deformation often comes from biomimetic inspirations, e.g., the Thematic

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