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Deployable structures using non-singular rigid foldable patterns

Ruud van Knippenberg, Arjan Habraken, Patrick Teuffel*

Eindhoven University of Technology, Chair of Innovative Structural Design, 5600 MB, Eindhoven, The Netherlands

Abstract

The opportunities of fully foldable structures are well utilized in some industries, but are only rarely applied in the built environment. In the first part of this study, a number of folding typologies are investigated and their (un)favourable properties are related to the built environment. In the second part, the results of the first part are exploited in order to design an adaptable pavilion.

The conclusion of the first part of the study is that there are multiple folding typologies which can generate a wide variety of forms. However, there is especially one typology with a high potential to translate the folding patterns into real structures. This folding typology is called non-singular, rigid foldable. The advantage of this typology is that the individual surfaces do not bend during the folding motion, while the degrees of freedom (DOF) are only dependent on geometric characteristics of the folding patterns.

The second part of the study uses the results from the first part in order to design an adaptable pavilion. To design this pavilion a variant study is performed with folding patterns which belong to the stable adaptive typology. The variants are compared to each other with respect to their: structural performance, innovative appearance, effective floor space range and ease of transportation as well as deployability.

From this study the final variant is studied in more detail and a structural analysis is performed based on the Eurocode for temporary structures. In this non-linear structural analysis, the structure is modelled in various configurations. The resulting design leads to an innovative pavilion which is able to transform in multiple configurations by only moving the support points, while it is stable for every possible state.

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Keywords: Deployable structures, Textile Skins, Adaptive Systems, Foldable patterns, Temporary structures

* Corresponding author. Tel.: +31 40 247 2679
E-mail address: p.m.teuffel@tue.nl

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1. Introduction

1.1. Foldable structures in the Built Environment

The opportunities of fully foldable structures are well utilized in some industries, but are only rarely applied in the built environment. In the first part of this study, a number of folding typologies are investigated and their (un)favourable properties are related to the built environment. In the second part, the results of the first part are exploited in order to design an adaptable pavilion.

1.2. Folding typologies

The authors explored extensively various folding patterns, which show a potential for structural applications [1] and as a consequence these patterns were categorized based on their structural properties and potential for the built environment. This section lists the characteristics of these typologies and gives the individual conclusion [2], [3], [5].

Non-rigid foldable patterns
- Huge form freedom due to the deformation of the individual surfaces
- Stresses are introduced by deformation of the surface during the folding process and it is (almost) impossible to stabilize due to the flexibility of the surfaces

Rigid and non-rigid foldable patterns
- Rigid foldable for in-plane movement
- Only non-rigid foldable for out-of-plane movement and thus limited adaptability

Singular, rigid foldable patterns
- Can be easy realized with rigid panels and hinges
- Can be stabilized by “freezing” all hinges in the desired configuration

Non-singular, rigid foldable patterns
- Can be easy realized with rigid panels and hinges
- The structure can be stabilized by fixing the supports

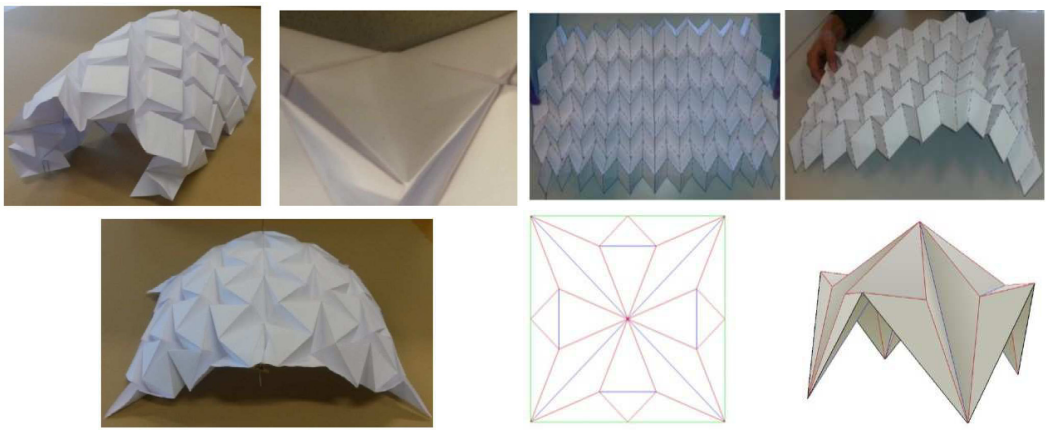

Figure 1: Top left (2x): Non-rigid foldable pattern; Top right (2x): Rigid and non-rigid foldable pattern; Bottom left (1x): Singular, rigid foldable pattern; Bottom right (2x): Non-singular, rigid foldable pattern