A Non-parametric Form-Finding Method for Designing Membrane Structure

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In this paper, we present a non-parametric form-finding method for designing the minimal surface, or the uniformly tensioned surface of a membrane structure with arbitrary specified boundaries. The area minimization problems are formulated as distributed-parameter shape optimization problems. The internal volume and/or the perimeter are added as the constraints according to the type of a structure such as pneumatic or suspended membranes. It is assumed that the membrane is varied in the normal and/or the tangential direction to the surface. The shape sensitivity functions for the problems set up are derived using the material derivative method. The minimal surface is numerically determined without the shape parameterization by the free-form optimization method, a gradient method in the Hilbert space, where the shape is varied by the traction force in proportion to the sensitivity function. The calculated results show the effectiveness of the proposed method for the optimal form-finding of membrane structures.

Keywords: Membrane structure, Form finding, Shape optimization, Minimal surface, Free form