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Multi-objective Rationality Optimisation for Robotic-fabrication-oriented Free-form Timber Structure Morphology Design

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Abstract : The traditional construction industry is unable to meet the requirements for novel fabrication and construction. Automated construction and digital design have emerged as industry development trends that compensate for this shortcoming under the backdrop of Industrial Revolution 4.0. Benefitting from more flexible working space and more various end-effector tools compared to CNC methods, robot fabrication and construction techniques have been used in irregular architectural design. However, there is a lack of a systematic and comprehensive design and optimisation workflow considering geometric form, material, and fabrication methods. This paper aims to propose a design optimisation workflow for improving the rationality of a free-form timber structure fabricated by the robotic arm. Firstly, the free-form surface is described by NURBS, while its structure is calculated using the finite element analysis method. Then, by considering the characteristics and limiting factors of robotic timber fabrication, strain energy and robustness are set as optimisation objectives to optimise structural morphology by gradient descent method. As a result, an optimised structure with axial force as the main force and uniform stress distribution is generated after the structure morphology optimisation process. With the decreased strain energy and the improved robustness, the generated structure's bearing capacity and mechanical properties have been enhanced. The results prove the feasibility and effectiveness of the proposed optimisation workflow for free-form timber structure morphology design.

Keywords : robotic fabrication, free-form timber structure, Multi-objective optimisation, Structural morphology, rational design

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