4DMDA Conference 2024

4D PRINTING SOCIETY

Deep Learning Powered 4D Printing Design of Hierarchical Architecture with Non-Rectangular Shapes

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Abstract

In recent years, inverse design has revolutionized 4D printing, particularly in achieving shape-shifting responses through the use of active hierarchical architecture. However, existing research predominantly focuses on rectangular shapes, posing challenges for non-rectangular shapes due to the diverse input sizes required for deep learning model training. This presentation introduces a novel approach leveraging deep learning for both forward prediction and inverse optimization of 4D-printed hierarchical architecture with non-rectangular shapes, extending beyond the limitations of rectangular designs. For forward prediction, we employ the Residual Network (ResNet) to model the behavior of 4D-printed parts with non-rectangular shapes. The training and validation losses can be achieved below 0.01. Additionally, an evolutionary algorithm is utilized for inverse optimization of the material allocation so that hierarchical architectures with non-rectangular shapes can reach the desired behavior. The root mean squared error between the designed performance and the desired behavior is demonstrated to be less than 1 mm. Our work addresses the gap in the 4D printing design of hierarchical architecture with non-rectangular shapes. The presented approach showcases its potential in expanding the design space for 4D printing applications, opening avenues for innovative and complex architecture.

Keywords: *4D printing, machine learning, inverse design, additive manufacturing, finite element methods*