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Enhancing projection multi-photon 3D printing with convolutional neural networks

Additive manufacturing at the micro-nanoscale has made significant advancements through multi-photon lithography techniques. The recently developed continuous layer-by-layer projection 3D printing process facilitates high-speed micro-manufacturing. Achieving precise 3D printing, however, requires optimizing process parameters for each 2D layer to mitigate imperfections, such as under-polymerization at structure perimeters caused by oxygen inhibition. Traditional trial-and-error optimization of sub-micron features often involves time-consuming experimentation and costly analysis methods, such as scanning electron microscopy. While machine learning (ML) techniques have previously been explored for classifying the printability of micro/nanostructures, limited efforts have focused on enhancing process accuracy. In this study, we propose a convolutional neural network-based ML approach to optimize 2D layer printing using a fast and cost-effective data collection method. Various shapes with systematically varied edge parameters and aspect ratios are projection printed and analyzed through optical microscopy on the same experimental setup. An autoencoder, utilizing both image-based input layer patterns and experimental results, is trained for forward prediction to visualize how printed layers will compare to target dimensions for any 3D model without requiring extensive experiments. The inverse prediction model is also explored to generate optimized 2D input layer patterns. This approach has the potential to streamline part optimization, significantly reducing the time and cost associated with achieving precise micro-nanoscale 3D printed structures.

Focus areas

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