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ON THE LAYER-BY-LAYER IN-SITU DETECTION AND ANALYSIS OF FEATURES AND DEFECTS IN ADDITIVE MANUFACTURING

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Abstract

Additive Manufacturing (AM) has revolutionized the manufacturing industry by enabling the production of complex and customized components across a variety of applications. As the demand for complex and custom-designed parts grows, automated quality assurance processes are required to ensure that the final product meets the desired specifications. However, differences in dimensions and shapes of internal features and external geometries from design specifications can affect the functional performance of the printed components. Traditional methods for quality assurance are reactive rather than proactive and typically identify issues after manufacture. In-situ monitoring of each layer in real-time aims to provide immediate feedback on print quality, detecting potential defects and geometric differences. However, evaluating the geometric conformity of in-layer features remains a challenge due to low contrast between the features and the background, as well as textural variations in the background, imaging artifacts, and lighting conditions.
This research investigates into developing an in-situ vision-based framework for AM, taking advantage of a custom developed image acquisition and processing environment to identify in-layer geometry features and determine their shape and dimensions. An image processing pipeline was developed to reduce noise, improve contrast, and improve the overall quality of the image. A Region of Interest (ROI) is established to align the as-printed and as-processed layer masks. Calibration methodologies are developed to ensure accurate measurements of dimensions and positions of the segmented contours are obtained. The shape and dimensions of the as-printed layer are compared with the as-processed layer features to evaluate the geometrical differences between them to ensure that the manufactured part meets the required geometrical specifications. An important part of this framework is the segmentation process, and the effectiveness of the segmentation method used can significantly impact the accuracy and reliability of the feature recognition system. Several segmentation methods (simple thresholding, adaptive thresholding, Sobel edge detector, Canny edge detector, and watershed transform) are evaluated for their ability to detect high- and low-contrast in-layer features. While these methods are reliably able to segment high-contrast features, however their performance is limited when segmenting low-contrast features. Based on this evaluation, the framework introduces a composite approach to effectively segment features by combining simple thresholding methods for high-contrast external features with the Chan-Vese (C-V) active contour model to identify low-contrast internal features. The effects of the C-V parameters (initial level set, intensity weighting factor, contour smoothness, and number of iterations) are evaluated to segment low-contrast internal features.

The framework was evaluated on a customized Fused Deposition Modeling (FDM) printer. The control system software for printing and imaging (acquisition and processing) was custom developed in Python running on a Raspberry Pi. The segmentation performance of the composite method was compared with traditional methods with the results showing that the composite method scores higher in most metrics and to effectively segment high and low contrast features. The improved segmentation enabled the identification of feature geometric differences ranging from 1 to 10 pixels verifying the ability of the framework to detect differences at the pixel level (= 0.025 mm) on the evaluation platform. The results demonstrate the potential of the proposed framework to segment features under different contrast and texture conditions, providing confidence to ensure geometric conformity of the printed features. The research further explores reconstruction of 2D layers into 3D representation of the as-printed parts. The 3D model of the as-printed part can be used to perform functional assessments such as structural analysis to evaluate the performance of the part. This research was evaluated on a FDM AM platform, however with suitable image acquisition setup, the developed framework could be implemented on other AM processes.