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A Registration-free Approach for Shape and Color Monitoring of Functionally Graded Materials via 4D Point Clouds

Recent advances in additive manufacturing enable the fabrication of complex parts with intricate geometries and spatially-varying material composition. Data fusion integrates point cloud data with chromatic attributes, yielding 4D point clouds, a rich representation that jointly encodes shape and material information. We introduce a registration-free framework for jointly monitoring shape and surface color via 4D point clouds. The proposed approach leverages the Laplace-Beltrami operator to capture intrinsic spectral features. A combined monitoring scheme is developed to detect shape deformations and color anomalies, complemented by a spatially-aware post-signal diagnostic procedure to determine the source of change and localize color anomalies. Crucially, neither component requires point cloud registration or mesh reconstruction, thereby eliminating error-prone and computationally expensive pre-processing steps. The performance of the proposed framework is assessed through a Monte Carlo simulation study and a case study.

Special/ Invited session

Young Statisticians

Classification

Both methodology and application

Keywords

Statistical Process Monitoring; Post-signal diagnostic; Laplace-Beltrami operator

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Track Classification: Other/special session/invited session