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Domain-Informed Machine Learning of Surface Manifold Data and Its Application in 3D Printing

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Abstract

Surface manifold data are widely collected to capture the topological and geometric structures of three-dimensional (3D) objects, such as 3D-printed products, anatomical structures, and terrain. Characterizing, modeling, and learning surface manifold data present fundamental challenges. First, manifold data are high-dimensional with a large variety of complex geometric structures. Second, the characterization of manifold data depends not only on geometry but also on physical domains. Third, the lack of the right data and physical knowledge limits the applicability of common machine learning approaches.

To address these challenges, we propose a domain-informed surface manifold data learning methodology. This talk presents key elements of this methodology: domain-informed surface manifold characterization, dimension reduction, and feature extraction for product qualification in 3D printing. Current surface manifold qualification methods are often labor-intensive, as they must accommodate an infinite variety of design geometries and domain constraints. To enable automated product qualification, we leverage domain knowledge of product geometric quality in surface manifold learning. Specifically, the dimension of surface manifolds is reduced by defining finite types of surface patches based on patch deviation patterns. The characterization of these surface patches is automated by utilizing the Laplace-Beltrami (LB) operator and critical points that are indicative of patch deviation patterns. Incorporating the impact of printing covariates on deviation patterns, we automate patch extraction through active landmark selection for patch centers and changepoint detection for optimal patch sizes. This talk will also briefly introduce our efforts in developing domain-informed surface manifold learning for automated product registration and a prototype digital twin system for autonomous product qualification and quality control in 3D printing.

About the Speaker

Weizhi Lin is a Ph.D. candidate in the Daniel J. Epstein Department of Industrial and Systems Engineering at the University of Southern California. She earned her Bachelor of Science in Statistics from Beihang University in 2019. Her research focuses on domain-informed machine learning of surface manifold data, with applications in 3D printing. The methodologies are also enabling digital twin systems for smart manufacturing and healthcare. Weizhi has received multiple awards in recognition of her work, including the Best Poster Winner at the 2024 and 2022 INFORMS QSR Student Poster Competitions and the Best Track Paper Award at the IISE Annual Conference in 2022.

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