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Image-Based Mesh Generation and Volumetric T-Spline Modeling for Isogeometric Analysis with Engineering Applications

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Abstract: With finite element method (FEM) and scanning technology seeing increased use in many research areas, there is an emerging need for high-fidelity geometric modeling and mesh generation of spatially realistic domains. In this talk, I will highlight our research in three areas: image-based mesh generation for complicated domains, trivariate spline modeling for isogeometric analysis (IGA), as well as biomedical, material sciences and engineering applications. I will first present advances and challenges in image-based geometric modeling and meshing along with a comprehensive computational framework. Different from other methods, the presented framework supports five unique features: high-fidelity meshing for heterogeneous domains with topology ambiguity resolved; multiscale geometric modeling for biomolecular complexes; automatic all-hexahedral mesh generation with sharp feature preservation; robust quality improvement for non-manifold meshes; and guaranteed-quality meshing. Then, I will present our latest research on volumetric T-spline parameterization for IGA applications. For arbitrary-topology objects, we first build a polycube whose topology is equivalent to the input geometry. Boolean operations, geometry skeleton and centroidal Voronoi tessellation based surface segmentation are used to preserve surface features. A parametric mapping is then used to build a one-to-one correspondence between the input geometry and the polycube boundary. We make the T-mesh valid through pillowing, quality improvement, and applying templates or truncation schemes to handle extraordinary nodes. Weighted and truncated T-spline basis functions are derived to enable analysis-suitability, including partition of unity and linear independence. The developed pipelines have been incorporated into commercial software such as Rhino and Abaqus.

Biographical Sketch: Jessica Zhang is a Professor in Mechanical Engineering at Carnegie Mellon University (CMU) with a courtesy appointment in Biomedical Engineering. She received her B.Eng. in Automotive Engineering, and M.Eng. in Engineering Mechanics from Tsinghua University, China; and M.Eng. in Aerospace Engineering and Engineering Mechanics and Ph.D. in Computational Engineering and Sciences from The University of Texas at Austin. She joined CMU in 2007 as an assistant professor, and then was promoted to an associate professor in 2012 and a full professor in 2016. Her research interests include computational geometry, mesh generation, computer graphics, visualization, finite element method, isogeometric analysis and their application in computational biomedicine, material sciences and engineering. She is the recipient of Presidential Early Career Award for Scientists and Engineers, NSF CAREER Award, Office of Naval Research Young Investigator Award, USACM Gallagher Young Investigator Award, Clarence H. Adamson Career Faculty Fellow in Mechanical Engineering, George Tallman Ladd Research Award, and Donald L. & Rhonda Struminger Faculty Fellow.

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