Design of Lattice Structures for Additive Manufacturing

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ABSTRACT: We have developed a method for creating a lattice structure in the input geometric domain. The method first creates a tetrahedral mesh of the input geometric domain and then creates a solid lattice structure by thickening the edges of the mesh. The density and anisotropy of the lattice structure can be controlled locally by using the Bubble Mesh method for creating a tetrahedral mesh in the first step. To avoid stress concentration at the joints, we have applied a method called Metaball for edge thickening, which makes smooth connection between beams. Since the second step relies only on the edges of the mesh, the same method can create a Voronoi lattice by converting a tetrahedral mesh to a Voronoi mesh, which is useful when a soft structure is necessary.

BIOGRAPHY: Dr. Soji Yamakawa received a BS in Faculty of Environmental Information of Keio University, MS from the Keio Graduate School of Media and Governance, and PhD in Mechanical Engineering from Carnegie Mellon University (CMU). He has been a researcher at CMU since completing his education in 2002. His research interests include numerical mesh generation, feature identification, computer graphics, and computer-aided geometric design. As a first author, he has published 11 journal articles, 12 conference papers with full-text peer review, and four books. He also has written four technical magazine articles. He received the Best Poster Award in the 9th International Meshing Roundtable conference in 2000 and Best Technical Poster Award in the 14th International Meshing Roundtable conference in 2005. He has been teaching C++ programming to the graduate students in the Department of Mechanical Engineering since 2010. His freeware, YS FLIGHT SIMULATOR, has been used in more than 30 countries and has received numerous awards including an Online Software Award from the Internet Association Japan and an Editor’s Choice Award from German company, PC Freunde. It has been downloaded over 1.5 million times. His work on preservation of historic computers is also highly recognized and he received a Best Retro Demo award by Demosplash 2017 and 2019 for his demonstration programs written in all assembly for 8-bit computers from 1982 and 1985.

ABSTRACT: Minimizing weight while maintaining strength in components is a continuous struggle within engineering related industries, especially in aerospace. The balance between weight and strength controls the cost of manufacturing and the safety of a given system. To decrease weight and maintain strength, methods such as topology optimization and lattice generation within components are used. However, highly optimized components may fail under unexpected loads and when considering lattices generated by commercial software that repeat unit cell patterns and do not allow for optimization of lattice geometric parameters to yield the best mechanical properties. This study explores how optimizing the geometric parameters of a lattice yields ideal mechanical properties for aerospace related applications. A computer program was developed to generate a novel type of tetrahedral lattice as it allows for the manipulation of the following parameters: cell size/density, strut diameter, and strut intersection rounding. To optimize the lattice for ideal strength and weight, multiple computational compression tests are performed on latticed cubes with varying parameters. The results showed that primarily altering strut diameter and strut intersection rounding best maintains strength and reduces weight. These results were then applied to optimize actual applications such as a jet engine bracket and airplane bearing bracket. By altering strut diameter and strut intersection rounding, the lattices reduced the weight of the jet engine bracket by 60% and the airplane bearing bracket by 25% and both withstand their required loading.

BIOGRAPHY: Uchechukwu (Uche) Agwu received a BS in Mechanical Engineering from Santa Clara University and is currently completing a Research MS in Mechanical Engineering at CMU. He will be entering the PhD program in Mechanical Engineering under Professor Kenji Shimada in Fall 2020. His active areas of research are structural mechanics and computational design and analysis, focusing on the generation of high-strength-low-weight lattices for additive manufacturing applications in the aerospace industry. He aims to define their mechanical properties and determine suitable applications based on their results. Currently his work is primarily computational, but he plans to move in an experimental direction to better understand the best methods and practices to additively manufacture the lattices he designs.