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Programmatic Lattice Generation for Additive Manufacture

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Abstract

Advances in additive manufacturing hardware have enabled the creation of lattice structures for engineering purposes; however the use of standard CAD software for the design of lattice structures is grossly inefficient, time consuming, and can lead to processing issues. To assist designer engineers that intend to implement large lattice structures a highly customisable free open source method of generating periodic lattice structures directly to the generic STL format has been developed. Programmatic method also offers a significant advantage to designers seeking to optimise or conduct finite element simulations on lattice structures allowing a batch export of both STL parts and a geometrically equivalent FE beam models.

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1. Introduction

Additive Manufacturing (AM) enables the fabrication of novel, highly complex geometries such as three-dimensional lattice structures. Lattices, three-dimensional periodic cellular structures [1], have been proven in multiple engineering applications due to their high specific strength [2, 3], stiffness [4], thermal isolation capability [5, 6], impact absorption properties [4, 7, 8], and ability to replace support material [9, 10].

A lattice is a series of interconnected struts, analysed as representative volume elements [11] or unit cells tessellated in three dimensions. The unit cell encapsulates many of the basic lattice properties such as strut diameter

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and lattice type. While many examples of lattice configurations are available in literature [3, 12-16], this work focuses on periodic hexahedral (cubic) lattice types.

Given the current capability and availability of AM equipment, it has been observed that the widespread implementation of periodic lattice structures are hindered by their relative design complexity coupled with the unavailability of capable design for additive manufacture software (DFAM) [2, 17, 18]. Furthermore, traditional Computer Aided Design (CAD) and Computer Aided Engineering (CAE) packages are extremely demanding of computational resources [18] and are often not able to represent lattices with a large number of cells, further restricting the use of lattice structures.

Design for additive manufacture (DFAM) is the use of tools or rules that assist in the generation of robust structures suited to AM processes. DFAM tools are limited and research contributions that assist operators to engage with AM are required [18, 19]. Furthermore although commercial tools exist their cost [20] and licensing make them hard to access and customise to a designers specific requirements. The Programmatic Lattice Generator (PLG) method was developed as a free, open source, fully customisable piece of software that generates periodic lattices in an efficient method directly to STL without the use of CAD software. The PLG software is a standalone DFAM tool that addresses some of the limitations of existing CAD at generating large periodic structures. The open source nature of the code allows customisation to a designers specific engineering requirements, finite element (FE) beam models can be easily generated and the precise number of faces in on each strut of the lattice can be controlled which allows reduced file sizes.

Commercial CAD packages, while able to represent hundreds or thousands of design features effectively, are not computationally efficient when the number of features extends beyond the thousands due to the nature of geometry representation [7, 18, 21].

The implementation of tailored lattice structures of many hundreds of thousands of elements in parametric CAD is not a trivial problem. Overall modelling time is highly dependent on the available computational resources, the software used, and designer proficiency. Regardless of these factors, the nature of geometric calculations inside parametric CAD practically restricts the maximum complexity of a lattice that can be created [18].

Through experimentation it has been found that the minimum representative facet order (number of facets bounding a cylindrical strut) in traditional CAD is much higher than required for the AM production of small diameter struts, even at the minimum resolution settings [1].

Finer resolution settings create more accurate virtual representations; however the unintended consequence is a reduction in computational performance without improving the manufactured component. Instead, it is highly desirable to have direct control over the number of facets used to represent a cylindrical strut, minimising the memory footprint, and able to optimise cross-section based on the strut diameter and additive process used.

2. Programmatic Lattice Generator (PLG) method

Due to the considerable challenges in reliably implementing large periodic lattice structures, a programmatic method has been created. In place of a traditional parametric CAD approach, a programmatic approach has been found to be highly efficient at creating cellular structures, in terms of user time and computational resources.

Created using the MATLAB environment (although also able to run in Octave), the Programmatic Lattice Generator (PLG) is currently able to generate regular uniform, bounding region, and cylindrical lattices with various cell configurations. The method of solution is described below to omit the majority of the programing detail, however the full code is available online for a more detailed reference [22].

Similar to CAD, manually creating a lattice model for finite element (FE) software is an arduous task. To simplify the process of creating FE lattice models, the PLG can produce beam model meshes alongside or separate to the STL creation process.