# Lightweight Structural Design using frame-aligned hexahedral-dominant mesh

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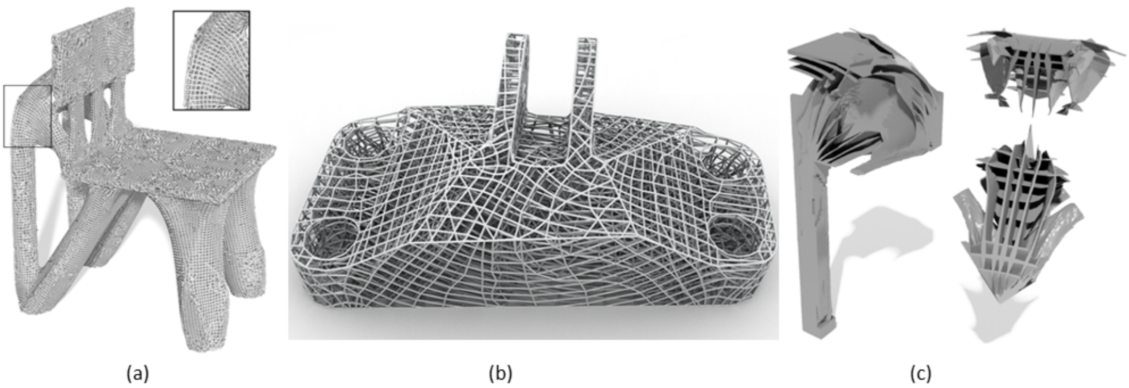


Figure 1: Exisitng works on using frame-aligned methods to design and optimize the 3D structures. (a) and (c) are the results de-homogenizing the homogenization-based topology results [10, 7]. (b) The extracted Michell's truss structure directly from the stress field simulated on the solid domain [1].

**Abstract**

**This is a thesis topic provided for master's students.**

## 1 Introduction

Homogenization-based topology optimization originally proposed in [2] is one of the popular solutions for lightweight structure design, which can generate a mathematical specification of theoretically optimal structures [9]. Homogenization-based topology optimization results are multi-scale, and thus, cannot be manufactured directly. To tackle the manufacturing limit, the focus of homogenization-based approaches has shifted to the post-process of translating the results of homogenization-based topology optimization into a manufacturable geometry. This post-process is now often referred to as *de-homogenization*. Given that the cells used in homogenization-based topology optimization can usually be described by a Fourier series [5, 6], the key advantage of such a methodology for structural design and optimization is the computational complexity. I.e., by combining the well-designed de-homogenization strategy with the homogenization-based topology optimization, it enables the possibility of deriving a near-optimal high-resolution design from the optimization result that is obtained from the coarse simulation resolution, thus, significantly saving processing time [3, 4].

We in [8] present a novel de-homogenization approach for the efficient design of high-resolution load-bearing structures. The proposed approach builds upon a streamline-based parametrization of the design domain, using a set of space-filling and evenly-spaced streamlines in the two mutually orthogonal direction fields that are obtained from homogenization-based topology optimization. Streamlines in these fields are converted into a graph, which is then used to construct a quad-dominant mesh whose edges follow the direction fields. In addition, the edge width is adjusted according to the density and anisotropy of the optimized orthotropic cells. In a number of numerical examples, we demonstrate the mechanical performance and regular appearance of the resulting structural designs and compare them with those from classic and contemporary approaches. However, this work restricts the discussion only to 2D, now we aim for extending it to 3D.

The major obstacle to such an extension is how to obtain the mesh. The streamlines in 3D space don't intersect necessarily, so we cannot duplicate the method in [8] to construct the parametrization. To this end, we plan to resort to a relaxed scheme, i.e., the frame-aligned parametrization and the hex-mesh generation built upon it [1, 10]. In specific, the design space will be parametrized with the frame-aligned hex-dominant mesh, then for each element, the deposition strategy in [8] will be used to achieve the de-homogenization, i.e., adjusting the thickness of element faces or hollowing the element. Compared to [10], where they achieved the anisotropy via element shape, the planned method will achieve the anisotropy via element deposition. In this way, we expect to see an improved mechanical performance. Compared to [7] which produces the wall-like designs, the planned method gives rise to the conforming lattice structure.

## 2 Methodology & Techniques

- homogenization-based topology optimization in 3D
- frame-aligned hex-dominant meshing
- Lattice deposition
- Visualization

## 3 Outlook

We want to investigate the de-homogenization of 3D homogenization-based topology optimization. In specific, we want to confirm whether such a structural design can be obtained: which is formed by a hex-dominant mesh composed of uniformly-sized elements, and shows better mechanical performance than the results in [10] and comparable mechanical performance with the results in [7].

## 4 Prerequisites

The student shall have some fundamental expertise in numerical simulation and computer graphics, e.g., finite element analysis (FEA), and numerical optimizer.

## 5 Available Resource

The datasets or code of frame-aligned hex-dominant meshing will be available to the student. A prototype of the 3D homogenization-based topology optimization code will be provided, but the student needs to adapt it to the context of this topic.

## References


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