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MAE 207 Project Proposal

Introduction & Background

Multi-disciplinary optimization (MDO) is an invaluable tool to solving real world design problems. Engineering fields often overlap in design problems so accounting for the intersectionality of various disciplines is critical. In order to achieve this, MDO solutions revolve around an objective function that is minimized in relation to the design parameters, which are subject to various constraints. These formulations combine the equations across various fields. The calculation of derivatives (Jacobian & Hessian matrices) is critical to assure efficient convergence on the solution, especially in large design sub-spaces representing an object with 3 physical dimensions. Gradient-based topology optimization utilizes these derivatives to manipulate the shape of an object step-by-step. Thusly, the design of these MDO problems has a dominant role is assuring that the derivative calculation can be efficiently and accurately computed. The focus then falls on the back of how these 3-dimensional spaces are defined. B-spline surfaces appear to be a great candidate for this. Hwang and Martins showed that B-spline shapes can efficiently solve 1D shape and 3D free-form design problems using adaptive parameterization [1]. B-splines are also memory efficient and polynomial exact surface representations [3]. Adaptive refining commonly improves efficiency and decreases the achievable objective function value in topology optimization problems [1,3,4]. Additionally, B-spline shapes solve the issue of checkerboarding in the solutions to topology optimization [2,3].

Goals

The countless advantages of representing design spaces with B-splines drive further investigation into the utility of B-splines in optimization problems. The goal I have for this project is to investigate the methodologies used to convert 3-dimensional design problems into B-spline surfaces. More specifically, an arbitrarily defined volume, such as a human heart, which the sub-space is constrained to, can be represented by arbitrary outer walls defined by B-spline surfaces. B-spline surface boundary constraints may have similar potential to be scalable for performance purposes, at an expense to the resolution of the constrained volume. Should new prohibitive discoveries be made, further investigation can be pursued in investigating the performance of 3-dimensional B-splines defined on a drastically curvilinear surface, such as a curved tube. I can investigate how to define such design parameters in a B-spline space.

[1] Hwang, J. T. and Martins, J. R. R. A., “A Dynamic Parametrization Scheme for Shape Optimization Using Quasi-Newton Methods,” 50th AIAA Aerospace Sciences Meeting, Nashville, TN, January 2012.

[2] Qian, Xiaoping. “Topology Optimization in B-Spline Space.” Computer Methods in Applied Mechanics and Engineering 2013.

[3] Avinash Shukla, Anadi Misra, Sunil Kumar, “Checkerboard Problem in Finite Element Based Topology Optimization,” International Journal of Advances in Engineering & Technology, Sept. 2013.

[4] Andersong, G. R. (Dec 2015). *Shape optimization in adaptive search spaces* [Submitted Dissertation]. Stanford University.