11th World Congress on Structural and Multidisciplinary Optimisation
07th -12th, June 2015, Sydney Australia

Microstructure interpolation for macroscopic design with application to bone prosthetics

Andrew D. Cramer[1], Vivien J. Challis[1], and Anthony P. Roberts[1]

[1]The University of Queensland, Brisbane, Australia

Abstract

Recent advances in additive manufacturing now allow the physical construction of designs with features on the scale of tens of micrometres. This new manufacturing capability can be fully exploited using multi-scale structural optimisation to find the best high resolution design for a particular application. We present a novel method for structural optimisation over two length scales: Shape interpolation between optimised microstructures is used to produce a continuous set that smoothly varies in both geometry and mechanical properties. This smooth set is used for macroscopic optimisation via the material distribution method. Our approach trades the generality of existing methods for better physical interpretation: while the space of allowed microstructures is diminished compared to traditional hierarchical optimisation, the microstructures vary smoothly throughout the design. This smoothness makes it clear how the microstructures can be transitioned between neighbouring elements.

We apply the method to the problem of optimising porous bone prosthetics. For this application, the microstructures are optimised via a level set method to have high bulk modulus and be elastically isotropic while maintaining an open pore space. We formulate the macroscopic bone prosthetic optimisation problem to address two concerns: bone resorption from under-loaded bone; and failure of the interface between the prosthetic and the bone due to shear stresses. Our work demonstrates the usefulness of microstructure interpolation for macroscopic design of physically realisable scaffold structures.