Submission for an invited session, organized by Ana Cristina Casimiro & Paula Pascoal-Faria

Topology Optimization: Applications in Bioscaffold Design

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Bioscaffolds show a promising future in the field of Tissue Engineering. These 3D, porous, biodegradable, and biocompatible structures are implanted in the region of defect and allow tissue-regeneration whilst degrading so as not to remain in the patient's body after the regenerative process is complete. During this period of degradation, it is of great importance that the structure can withstand outer stresses in a similar manner to its surrounding tissue, while having adequate porosity to allow cell differentiation. Topology Optimization (TO), a modern field in structural optimization, is concerned with allocating material where structural compliance dominates and removing it where it is less needed. For TO problems, where the number of design variables is extremely large, global compliance is often used as a single measure of structural performance. This allows the development of efficient algorithms and cheap computation of derivatives for approximation schemes used to solve these large-scale problems.

In this work TO is used to generate new bone scaffold designs. A differential thickness of a scaffold was optimized using the solid isotropic material with penalization (SIMP) method [1]. The optimization problem is first formulated, which includes a volume constraint (maximum material to be used), and a perimeter constraint (measure of porosity of the structure). A sequential convex approximation scheme (MMA, the method of the moving asymptotes [2], an optimizer) is then used to solve the problem.

Results allow to manufacture scaffolds where both cortical and trabecular porosities are clearly identified. Constraints related to trabecular porosity and diameter are also included. A comparison of bone scaffold internal geometry obtained using TO algorithms and microCT analysis is also presented.

References

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Funding: This research was funded by the FCT and Centro2020 through the following Projects: UIDB/04044/2020, UIDP/04044/2020 and Stimuli2BioScaffold co-financed by COMPETE2020 under the PT2020 programme, Ref. PTDC/EME-SIS/32554/2017.