

Statement of Relevance to PHD Project

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A key aim of this PhD research project is to demonstrate that the internal trabecular bone structure can be considered an optimal structure through the application of topology optimization to Finite Element models of bones. Topology Optimization defines the most efficient distribution of material within a structure under load by removing material from regions of the structure that are experiencing the least strain and reinforcing heavily strained regions of the structure. It is an iterative procedure that uses finite element analysis to calculate optimization sensitivities, for example the elemental strain energy density; these results are then used by an optimization algorithm to determine a more optimal structure. This process is repeated for the new until the process converges to the optimal solution. Hence multiple runs of both the FEA modelling and optimization algorithm are required making topology a very time consuming procedure. In this PhD project we have been developing a level set form of topology optimization programmed in C with some matrix calculation procedures performed in Fortran.

For topology optimization to be able to create a meaningful representation of the internal bone structure a fine mesh is required. In 2D, models with over 30 000 design variables are required. It can take over 15 hours to optimize these models. However the method is currently being extended to work on 3D models. The number of the design variables required to obtain a meaningful structure will significantly increase, upwards of 1000 000 design variables is possible. This will dramatically increase the computational cost and run times of the optimization procedure to impractical lengths reducing the number and scope of investigations that can be performed during the project. Obviously any reduction in this run time would be advantageous as it would allow us to run more models and perform more numerical experiments.

Parallelizing the program to make better use of the computational resources and reduce the run time. In particular parallel versions of the Fortran matrix calculation solvers could be used as and I hope it will also be possible to use parallel programming to speed up loops in the C program. I also believe that a better understanding of the factors that effect code performance would also allow the efficacy of the program to be further improved.

As I have no previous experience of HPC or parallel programming the Autumn Academy would be an ideal introduction to the concept. I hope that the course will allow me to understand and apply these methods to computer models giving me the skills I need to begin working on significantly increase the efficacy of the Topology Optimization program.