

REDUCED BASIS METHODS FOR FAST EVALUATION OF ILIAC CREST TRABECULAR BONE ELASTIC PROPERTIES

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INTRODUCTION

Finite element analysis (FEA) is generally used for indirect evaluation of mechanical properties of trabecular specimens which is vital for fracture risk prediction. However, the finite element methods (FEM) can be computationally expensive. In this study, we propose the reduced basis (RB) methods, which correlate well with the typical finite element (FE) results, despite a considerable gain in overall computational speed.

METHODS

Three cylindrical iliac crest specimens (diameter: 8mm, length: 7mm) were obtained from healthy subjects (20 year, 24 year old females and 40 year old male) and scanned using micro-CT. Cubic samples of dimensions 1.5 mm x 1.5 mm x 1.5 mm were extracted from the cylindrical specimens for FE analysis. A validated in-house linear elastic FEM code based on four node tetrahedron elements was used to perform the analysis.

Subsequently, a FEM solution library (test space) was constructed for each of the specimens by varying the material property parameters such as Poisson's ratio. Consequently, the library was utilized to develop fast RB algorithms. The average computational speed gain obtained by the RB methods for the samples and their accuracy relative to the FEA was evaluated.

RESULTS AND DISCUSSION

Finite element CPU runtimes for samples A, B and C were 1 hour 50 minutes, 1 hour 23 minutes and 1 hour 30 minutes respectively. Online computational speed gains greater than 2000 were obtained for the specimens for a compromise of less than 1% accuracy in the maximum value of von-Mises stress (Table 1), assuming the FE solution to be the standard for comparison. The computational times were reduced from more than 1 hour to less than 3 seconds. For a fixed set of

material properties, it was observed that the spatial distribution of von-Mises stresses (Figure 1) and strains was as expected from the physics and symmetry of the problem.

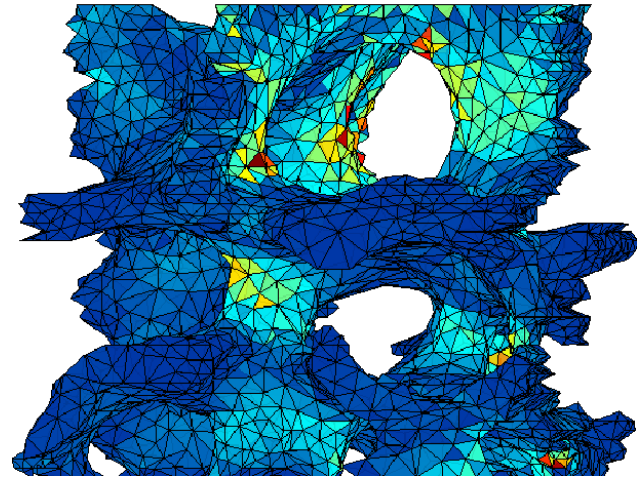


Figure 1: Contours of von-Mises stress (MPa) for male, Tissue Young's modulus = 100MPa, Poisson's ratio = 0.3.

CONCLUSIONS

The RB solution converged rapidly over the chosen test space, comprising of selected basis vectors. The hypothesis that the methods can be used as a tool for rapid indirect estimation of material properties has been proven in this study.

REFERENCES

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Number of Basis Vectors	Poisson's Ratios used in creating library (Young's modulus = 100 Mpa)	Percentage of error in maximum von-Mises stress (Sample A)	Percentage of error in maximum von-Mises stress (Sample B)	Percentage of error in maximum von-Mises stress (Sample C)	CPU run time for Sample A (sec)	CPU run time for Sample B (sec)	CPU run time for Sample C (sec)
4	{0.15,0.25,0.35,0.45}	3.987×10^{-3}	1.621×10^{-3}	1.056×10^{-4}	1.96	2.05	2.15
5	{0.15,0.20,0.30,0.40,0.45}	1.552×10^{-5}	9.361×10^{-6}	6.001×10^{-5}	2.02	2.14	2.21
6	{0.15,0.20,0.25,0.35,0.40,0.45}	9.653×10^{-6}	2.413×10^{-7}	8.515×10^{-6}	2.13	2.32	2.45

Table 1: The convergence of reduced basis solution with respect to the FEM solution with increase in the size of the library.