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INTEGRATED IMAGING AND FAST BOUNDARY ELEMENT COMPUTATION FOR COMPLEX FREEFORM OBJECTS

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ABSTRACT

Digital modeling by means of nondestructive imaging techniques such as laser scanning, computerized tomography or magnetic resonance imaging has been a fast growing research area leading to many practical applications. As an alternative to modeling objects with the aid of CAD software, digital modeling allows us to reconstruct geometric models from real or “as-built” objects. The acquired digital models are increasingly used in various reverse engineering applications [1]. In the field of industrial design and ergonomics for example, aesthetic and ergonomic freeform designs that are hard to model using standard CAD packages are captured from sculptured prototypes and used in product design phase. Digital models are also heavily used in medical and dental fields to capture complex geometry of the human body for downstream applications.

Computer simulation using reconstructed digital images can play an important role in evaluating and characterizing mechanical performance of complex physical objects. Efforts towards this end will enable real-time mechanical characterization of scanned complex objects, which may benefit the medical industry, e.g., to develop simulation-based diagnosis or surgery training systems using patient-specific scan models.

Many researchers have introduced reconstructed geometries into their standard finite element studies due to its wide popularity. When applied for reverse engineering simulation, domain computation presented an inefficient workflow. To eliminate time-consuming solid reconstruction, an image-based finite element method [2] was proposed to translate bitmap information from scan images into brick elements for FEM anaysis. The image-based FEM however would produce nonsmooth boundary representation in the translated voxel model. Computational cost has also become a serious challenge for domain method in simulating reconstructed realistic models, as the problem size becomes large. It was found in a recent FEM study [3] that approximately 6 weeks of wall-clock time were spent to obtain results from a human proximal femur microstructure bone model with over 96 million brick elements (using thirty processors of an SGI/Cray Origin 2000 with a total of 128 processors and 57 GB memory).

In this research, an efficient computational scheme was developed to integrate imaging

and fase boundary element computation. The proposed solution exploits the surface discretization nature of BEM, and eliminates time-consuming NURBS surface/solid reconstruction needed in a domain approach. In the developed BEM, unstructured as-scanned data can be directly imported and regularized into a BEM mesh. A simple mesh regularization procedure is implemented to ensure quality of the translated BEM mesh. The developed BEM achieves a near order *N* computational complexity, by coupling the conventional BEM (of order N^3) with the fast multipole acceleration [4, 5].

Numerical examples are presented to demonstrate the effectiveness and efficiency of the developed BEM. Preliminary results show that the developed BEM can be a promising tool for reverse engineering simulation applications involving highly complex organic shapes and large-scale models (Figure 1), e.g., the ones acquired from medical images.

The image-based BEM with FMM acceleration, though only developed for steady-sate thermal analysis in this study, can be readily extended for elasticity. Multiple material domains with interface effects can also be considered. With further development, more interesting numerical experiments can be conducted, e.g. virtual tensile, compressive or bending testing of realistic high-resolution digital objects. Modeling results of these studies can then be used for prediction and characterization, e.g., biomechanical behaviors from patient-specific scan images. The image-based BEM, once fully-developed, will have many promising applications in areas including material science, biomedical engineering, and traditional design.

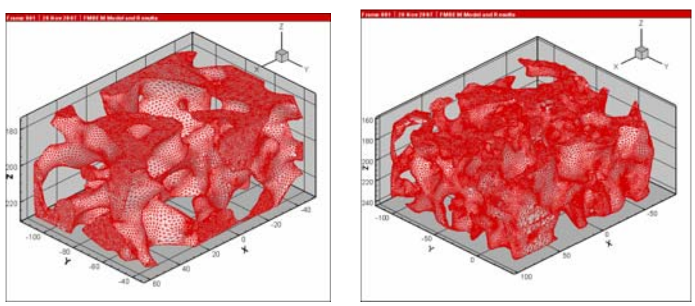

Figure 1. BEM models for healthy and weak trabecular bone microstructures

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