A FEA model generation method for irregular-shaped and nonhomogeneous structures

Ming-Hsiao Lee*

National Center for High-performance Computing, Hsinchu, Taiwan

Abstract. This study proposes a FEA model generation method to handle biomedical objects which are highly irregular-shaped and nonhomogeneous, i.e., highly nonlinear structures. The method is based on the sectioned medical scanning data, e.g., CT scan, which has included bone density data, to generate analysis models according to the irregular shapes and randomly distributed bone densities, so that the analysis models can match the irregular shapes and randomly-distributed stiffness of the real bones. Using these more realistic models to simulate the dynamic characteristics, such as natural frequencies, of the objects, better results can be obtained.

Introduction

The finite element method, although widely being used in various fields, has difficulty to model some special applications in which extremely irregular shapes and uneven distribution of materials are treated, such as the cases in biomedical engineering, where the objects to be treated are extremely irregular-shaped, and the materials are completely nonhomogeneous in nature. For example, the bone shape of the human body is extremely irregular and varies from person to person, so it becomes very difficult to generate the geometry models with traditional CAD systems. Moreover, the bone density which affects the stiffness [1] is randomly nonhomogeneous, even the bone densities of the same person are different at different portions and vary over time. This situation makes it very difficult to generate the analysis models with traditional pre-processing systems. Such problems, if they are analysed in the traditional finite element modelling, most of the time adopt the assumption that the material is homogeneous. In this approach, the real stiffness of the bones cannot be accurately modelled, so do the natural frequencies, which are important during certain medical operations.

This study proposes a model generation method which is based on the sectioned medical scanning data, e.g., Computerized Tomography (CT scan), which includes bone density data, to generate analysis models according to the irregular shapes and randomly distributed bone densities, so that the analysis models can match the irregular shapes and randomly-distributed stiffness of the real bones. With these realistic models, better results can be achieved. For example, for a bone of the same person, the bone stiffness changes over time can also be effectively simulated to evaluate the effects of the age or therapy. The dynamic characteristics of the objects can also be accurately obtained, such as natural frequencies.

Results

The case shown in Fig. 1 is a certain person's mandible. Originally, it was found too weak because of the loss of bone density due to aging. After the therapy, the bone density is increased and improved. Although the mandible shape of the same person is still the same, the bone density distribution has changed. With the proposed modelling method, two FEA models which have the same shapes but with different bone density distribution were generated and used to simulation to evaluate the stiffness and natural frequencies of the same mandible at different time. If the stiffness is weakened, the natural frequencies decrease, so it may encounter the resonance problem during using electric ultrasonic toothbrushes and tooth drills. The results can tell the improvement of the therapy as thrown in Fig. 2. The natural frequencies also increase as well.

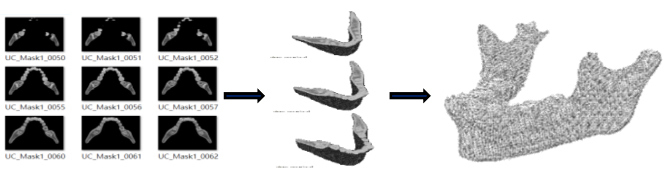

Figure 1: FEA model based on CT scan data and include the bone density data

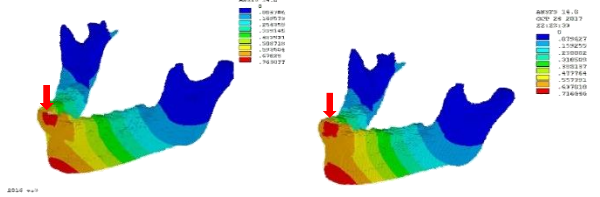

Figure 2: The results of the 'before' model (left) and 'after' model (right), the stiffness is increased after therapy

References

[1] Kostas, T. et al (2005): Dose reduction in maxillofacial imaging using low dose Cone Beam CT. European Journal of Radiology, Vol. 56, pp.413–417