A BETTER IMAGE DEGRADATION METHOD FOR CONVERTING HIGH RESOLUTION CT SCANS INTO FINITE ELEMENT MODELS

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INTRODUCTION

When performing finite element analysis of voxel-based images converted directly from CT scans, image degradation is often necessary to decrease the size of the finite element model when the model is too large to be solved due to time or memory constraints. The region average (RA, Figure 1: left) image degradation method is widely used. The degraded voxel is generated by combining a particular number of adjacent voxels of the original model and averaging their grayscale values. A voxel expansion (VE Figure 1: right) degradation method is proposed for which the degraded voxel is generated by directly expanding a single original voxel. A reliable method should render high fidelity for the degraded model in three areas: bone indices, image grayscale distribution, and biomechanics.

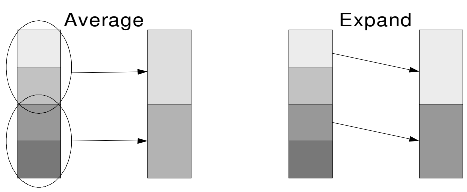

Figure 1: Left: Region average. Right: Voxel expansion

METHODS

Three New Zealand white rabbit distal femurs were scanned in a micro-CT system (ACTIS 150/225 FFi-HR CT, BIR Inc., Chicago, IL) with 14μm nominal resolution. A 3.5mm trabecular cube was generated from each of the three image stacks. Models at this size satisfied the continuum assumption for a porous material [1]. The voxel size of each model was then degraded by both methods to 28μm and 42μm which is smaller than 1/4 of the mean trabecular thickness (Tb.Th) as recommended for solution convergence [2]. The trabecular volume fraction, mean Tb.Th, grayscale distribution and apparent stiffness of the degraded models were compared to that of the original models to evaluate the performance.

RESULTS AND DISCUSSION

For the trabecular indices calculation, the Otsu method [3] was used to threshold the image stacks. The indices percentage errors for the two methods are shown in Figure 2. The volume fractions of the degraded models rendered by the VE method were essentially unchanged whereas the values from the RA method changed. The mean Tb.Th increased for both methods but significantly less for the VE method compared to RA.

The RA method affects the model grayscale distribution significantly. A distribution comparison between the two methods is shown in Figure 3. The grayscale distribution of the VE rendered model is similar to that of the original model whereas the distribution for the RA rendered model changed.

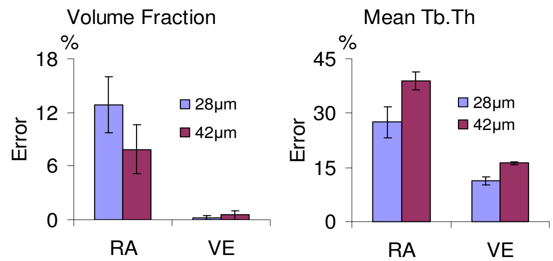

Figure 2: Trabecular indices comparison between two degradation methods

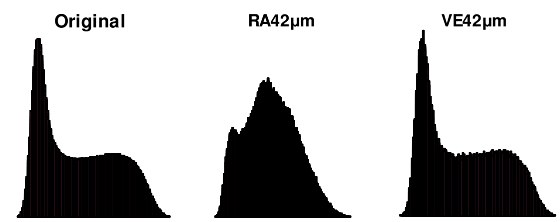

Figure 3: Grayscale distribution comparison between two degradation methods

Six finite element models created by two methods and two degraded levels were evaluated. Homogeneous material properties were assumed and tissue stiffness was set to 10GPa. All models were fixed at one end and a 0.2% axial strain was applied at the other end. Results for the degraded models were compared to the original models (Figure 4).

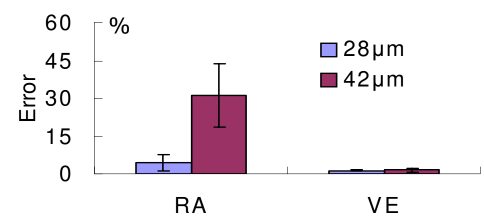

Figure 4: Finite Element Analysis apparent stiffness comparison between two degradation methods

All differences between the VE and RA methods (Vol. Frac., Tb. Th., App Stiff.) were statistically significant except the apparent stiffness for the 28μm voxel size.

CONCLUSION

The widely used RA degradation method produced less desirable results than the VE method. The reliability does not decrease significantly as the degraded voxel size increases for the VE method.

REFERENCE

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2. Guldberg et al. J Biomech 120, 289-295.
3. Otsu, N., 1979. IEEE Trans. Systems, Man, and Cybernetics, 9(1), 62-66.