A Finite Element Spine Model from VHD™ Male Data

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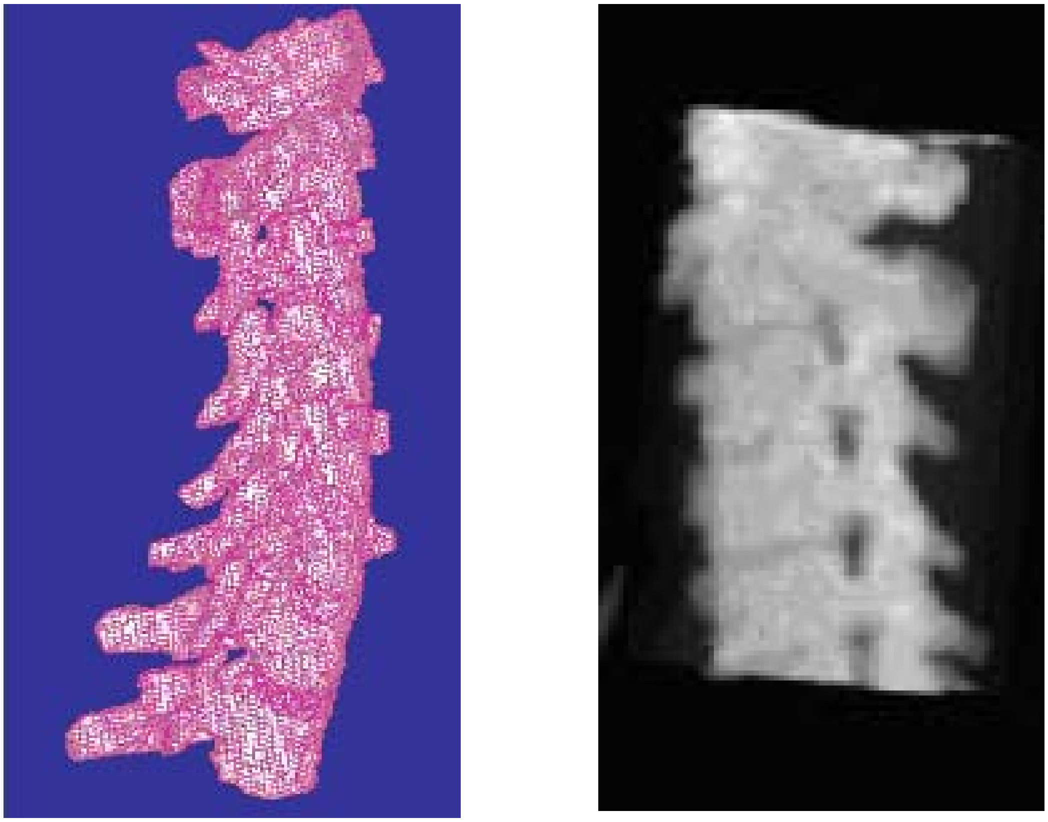
Abstracts

We are developing patient specific biomechanical model of human spine for the purpose of advanced surgical training and planning. Prior to using our first patient specific data acquired using high resolution CT scanner, we investigate our methods with the VHD™ Male Data. We are able to construct a discrete representation of the individual vertebrae using volumetric elements. These elements are employed to construct the finite elements for deformation analysis with the finite element method (FEM) and surface meshes for visualization. Figure 1(a) shows our finite element model of the VHD™ Male thoracic and lumbar spine. Figure 1(b) is a volume rendered image of the spine. Our earlier intention also includes studies of spinal injuries from high speed flying.



(a) Finite element model (b) Volume rendered images

Figure 1. VHD™ Male spine model

Since we intend to use this model as a reference in the construction of a patient specific spine, we pay particular emphasis to the accuracy of the model. We first identify, segment and label the target anatomy from VHD™ photo images using Adobe Photoshop. The identification of the structures of each of the thoracic vertebrae and the intervertebral discs was done with reference to the Atlas of the Visible Human Male. The naming of the contours is uses a specific naming nomenclature so that meshes can be obtained from our mesh generation software.

Using this software, which was developed in-house, we extract and display all the contours in 3D view for verification, construct the volumetric finite elements and then generate the surface meshes from these volumetric elements. Displacement of the contours from the original axis could happen on single or consecutive slices. These contours are manually aligned horizontally and vertically using the software. We can vary the number of meshes representing the spine by controlling the mesh resolution. The model in Figure 1(a) has a slice interval taken of 3.125 pixels which is approximately equal to the original cryosection images taken at 1.00 mm intervals. Instead of developing our own finite-element representation, we adopt the format of a commercial finite element package – ABAQUS. Figure 2 shows the rendered C2 of the spine model with and without overlaying of meshes.

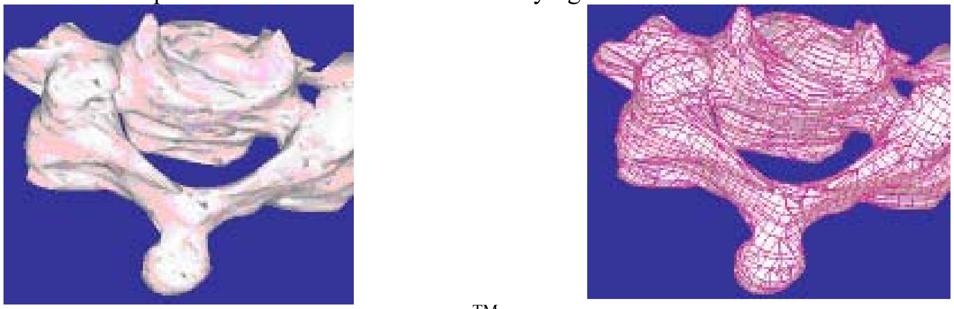
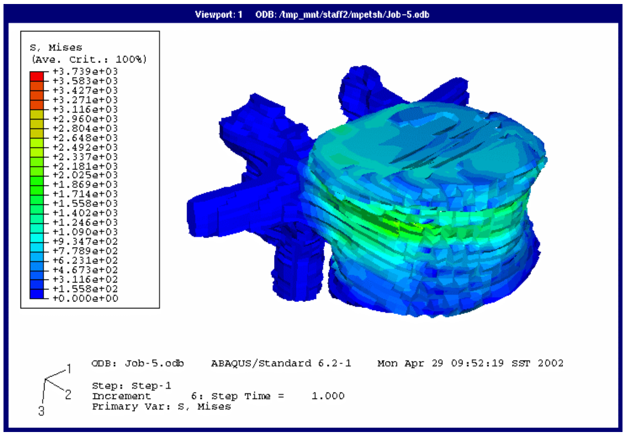


Figure 2. C2 of VHD^{TM} Male spine model.

Figure 3 shows the von Mises stress distribution of the L4 vertebra of our finite element spine model. There are 5700 elements and 5810 nodes. The model is tested using static deformation analysis in ABAQUS/CAE version 6.21 with a distributed load of 400N applied to the top of the vertebral body and a fixed bottom. The finite element model was assigned an elastic modulus of 16 GPa and a Poisson ratio of 0.3 based on existing literature. We also assume that the vertebral body is homogeneous and exhibits isotropy in our study.



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S, Mises
(Ave. Crit.: 100%)
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+3.583e+03
+3.427e+03
+3.271e+03
+3.116e+03
+2.960e+03
+2.804e+03
+2.648e+03
+2.492e+03
+2.337e+03
+2.181e+03
+2.025e+03
+1.869e+03
+1.714e+03
+1.558e+03
+1.402e+03
+1.246e+03
+1.090e+03
+9.347e+02
+7.789e+02
+6.231e+02
+4.673e+02
+3.116e+02
+1.558e+02
+0.000e+00

ODB: Job-5.odb    ABAQUS/Standard 6.2-1    Mon Apr 29 09:52:19 SST 2002

Step: Step-1
Increment      6: Step Time =    1.000
Primary Var: S, Mises
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Figure 3. The von Mises stress distribution of L4 vertebra.

In conclusion, we have developed a finite element model of the spine from the VHD^{TM} Male dataset. The computer graphics rendered model is compared with the volume rendered images for visual correctness. In addition to applying finite element analysis of the entire spine, we can perform stress analysis on individual vertebrae which is important for surgical simulation.