# Normal Modes of Variation of Segmented CT Femur Scans

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Statistical models are extremely powerful tools which may incorporate anatomical information from various populations. Assuming a mathematical representation of a particular anatomical structure is available from subjects within a population, it is possible to analyze these structures in order to create a statistical model and ascertain it's modes of variation.

We hypothesized that the 3D anthropometric variation of male proximal femurs can be adequately explained by a limited number of normal modes. Sixty-two Caucasian male femurs were acquired with multi-slice CT (1 $mm^3$ resolution) and segmented to separate bone and soft tissue. To model the data, a tetrahedral mesh (2.5 mm between vertices) with associated density functions for each tetrahedron was derived. A slice through one of the CT volumes is shown in **Figure 1**, along with a slice through it's corresponding tetrahedral mesh. Principal component analysis (PCA) was then performed on this set of meshes to obtain a statistical model, consisting of a "mean-shape" (**Figure 3**), with associated eigen-vectors (modes of variation) and eigen-values. A plot of the eigen-values of the modes is shown in **Figure 2**.

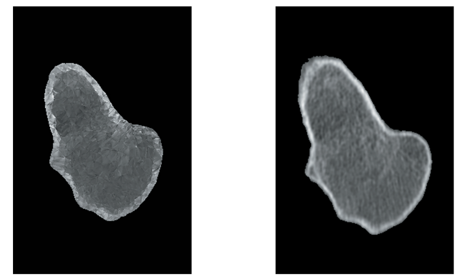

Figure 1

The left image is a slice of a tetrahedral mesh model approximation of a CT volume whose corresponding slice is shown on the right.

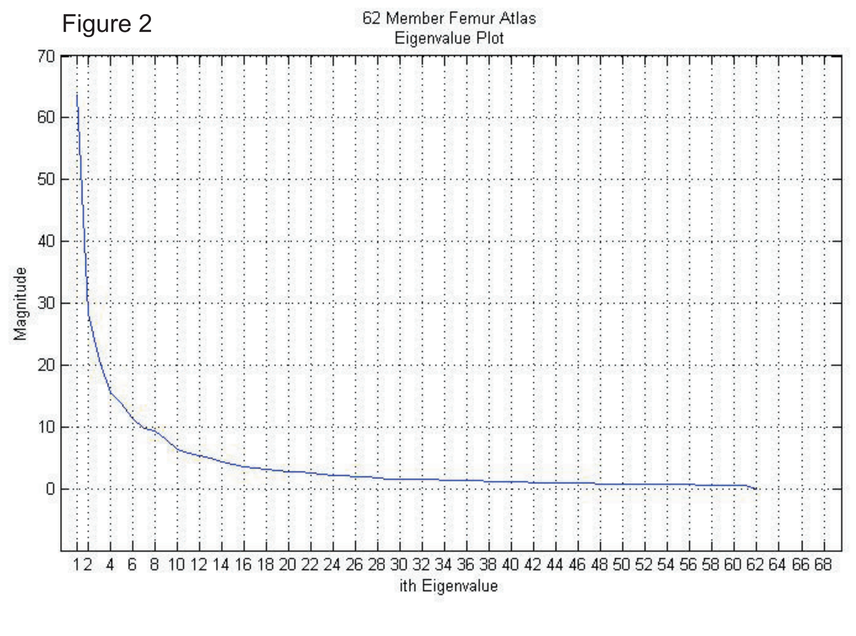


Figure 2

Statistical
Femur Model Mean
(Tetrahedral mesh derived from many patient CT volumes)

+

*n*-Modes of Variation

≈

Subject
Model
(Tetrahedral mesh derived from a different patient CT volume)

Figure 3

Another tetrahedral mesh with associated density functions was derived from a single subject CT of another Caucasian male femur which was not included in the statistical model (**Figure 3**, right). A linear combination of the eigen-modes (eigen-vectors) of our statistical model was then ascertained, which when added to the mean shape, minimized the vertex error magnitude between the statistical model mesh and the subject mesh. A plot of the mean vertex error magnitude vs. number of modes used to minimize the error is shown in **Figure 4**.

**Figure 5** shows the surface edges of the tetrahedral mesh for the statistical model and the subject. Most of the variation with regards to this particular subject appears to be covered by the first 20 modes of our 62 member statistical model.

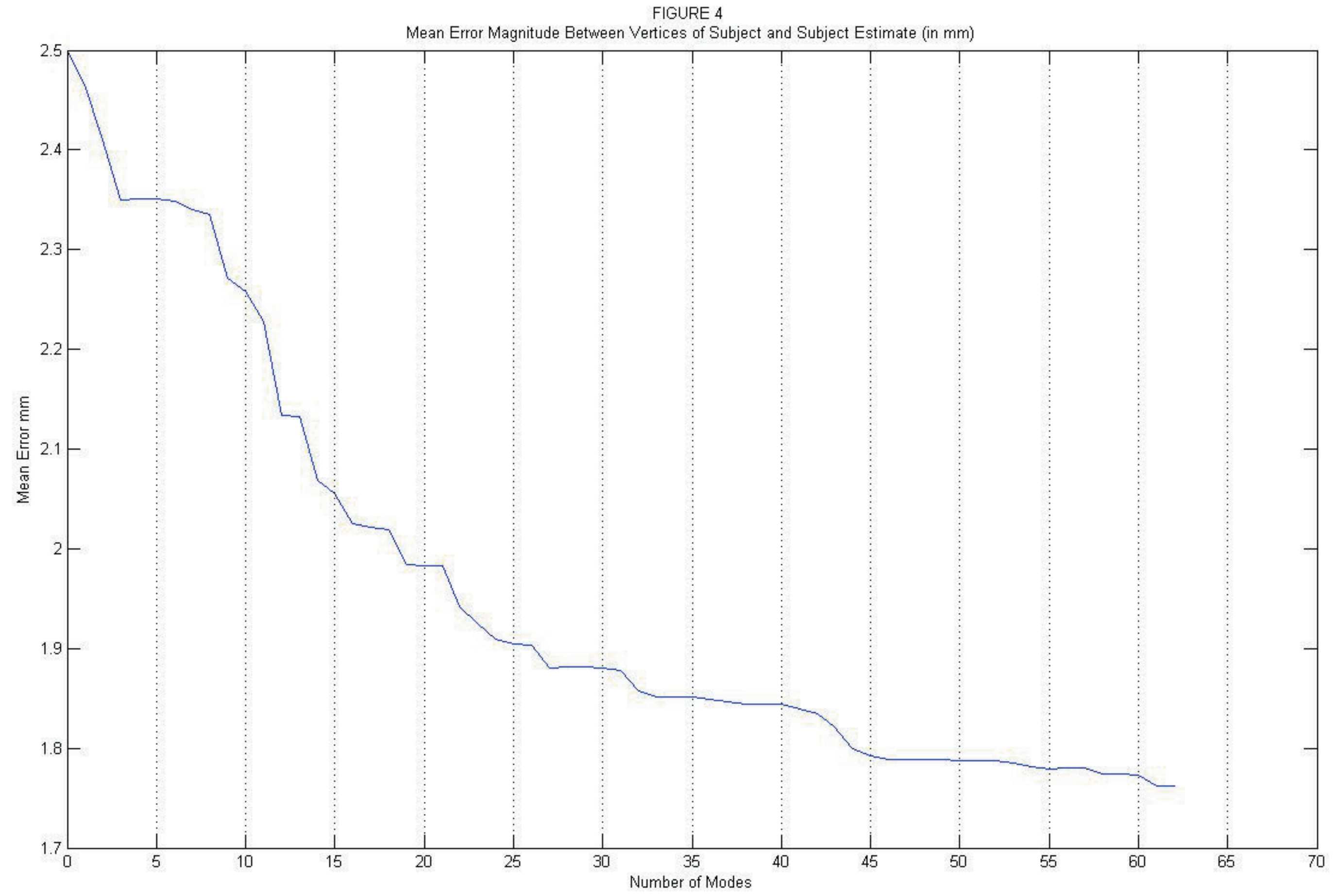



**Figure 5** Tetrahedral Mesh Surface Comparison
The Red Model is an Estimate of the Blue Subject