CREATION OF THE GEOMETRY FOR A FINITE ELEMENT MODEL OF THE WRIST UNDER LOADED AND UNLOADED CONDITIONS

Charlotte Curtis[1], Robert Dony[1], Michele Oliver[1], Anne Agur[2], David Salonen[2], and Vincent Lo[1]
[1]School of Engineering, University of Guelph, Guelph, ON, Canada,
{curtisc,rdony,moliver}@uoguelph.ca
[2]University of Toronto, Toronto, ON, Canada

INTRODUCTION

Repetitive strain injuries to the wrist are common in occupations ranging from office work to mobile machine operation (Grieco et al. 1998). In order to avoid such injuries, ergonomic considerations should be made when designing work stations and equipment. However, the biomechanics of the wrist joint are not well understood (Oliver et al. 2007).

The development and validation of a finite element (FE) model of the wrist will provide insight into the loading conditions that may result in wrist injuries. Specific challenges presented by the wrist joint such as the complex interactions between bone and soft tissue make creation of the basic geometry a difficult task (Carrigan et al. 2003). In this work, geometry of the wrist in loaded and unloaded positions were created through manual segmentation and image registration.

METHODS AND PROCEDURES

Computed tomography (CT) scans with a resolution of 0.337 mm in the coronal and saggital directions and 0.5 mm in the axial direction were acquired of a cadaveric hand and forearm in an unloaded position and under a 54.3 N axially compressive load. Each bone of the loaded image was segmented using the medical visualization software MeVisLab (MeVis Research, Bremen, Germany). The radius, ulna, and phalanges could be automatically outlined with a threshold of 250 HU. However, due to close spacing and poor definition between individual bones, segmentation of the carpal bones could not be automated. For these bones, contour splines were drawn by hand on each slice. The splines of the previous slices were displayed as increasingly faded lines to ensure continuity, and each of the three orthogonal views was examined to ensure accuracy (Figure 1).

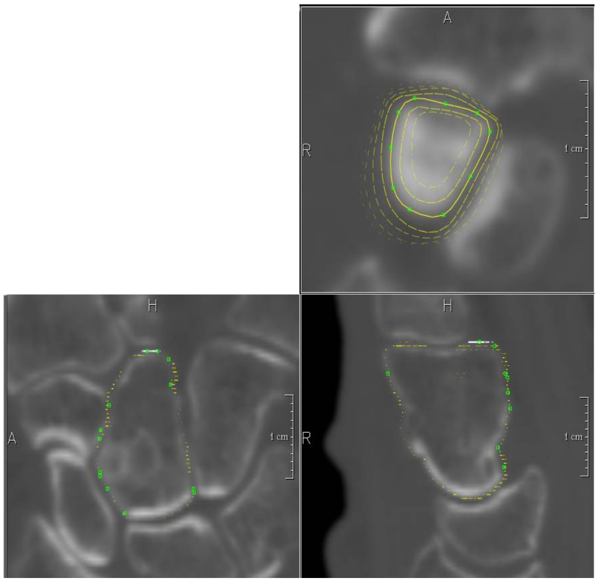

Figure 1: Manually segmenting the carpal bones of the wrist

The manually and automatically drawn contour splines were rasterized and filled to create binary segmentation objects which were then smoothed and triangulated to created individual surface mesh objects. A custom program to rigidly register the unloaded scan to the loaded scan was written in C++ using the open-source Insight Toolkit. The registration was confined to the bounding box containing each bone, and a least squares metric was used to find the optimal fit. The resulting 3D rigid transformation matrices were applied to the manual segmentations to create the geometry of the unloaded wrist.

RESULTS

Two sets of surface meshes were created to represent the geometry of the wrist under loaded and unloaded conditions (Figure 2).

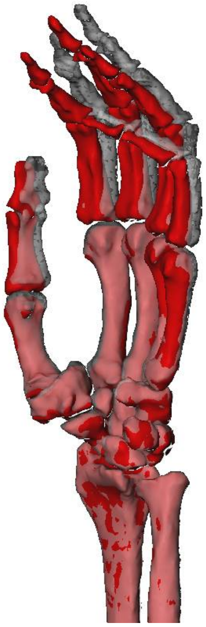

Figure 2: The final geometry (loaded in red, unloaded in grey)

DISCUSSION

The method of registering the unloaded and loaded images to create the second segmentation has several advantages over the more conventional approach of creating two separate models. The rigid transformation matrix provides a quantitative measure of the deformation between the two positions that can be used to fine-tune finite element model parameters such as material properties and interactions between bones. In addition, this method has the advantage of maintaining the same geometry for each bone, reducing the impact of errors introduced during the segmentation process. Finally, the registration process is significantly faster than the manual segmentation process, allowing for more loading scenario models of the same sample to be generated quickly and easily.

For a validated finite element model, future work is required to ensure that the segmentations are accurate. Due to the discrete nature of the CT images and the reliance on manual segmentation, it is likely that the geometry created differs slightly from the cadaveric sample. Also, a single reference point is insufficient for fine-tuning of model parameters; therefore, future work will be required to create the geometry of additional loading scenarios.

SUMMARY

Computed tomography images of a cadaveric wrist in two different loading scenarios were acquired. Each bone of the loaded wrist was manually segmented and meshed to generate surface mesh objects. The unloaded scan was rigidly registered to the loaded scan and the segmentations were transformed accordingly to create the geometry of the unloaded scan.

REFERENCES

Grieco, A. et al. (1998). *Ergonomics.* Vol. 41 (9); pp. 1253–1260.

Oliver, M. L. et al. (2007). *Ergonomics.* Vol. 49 (3); pp. 249–268.

Carrigan, S. et al. (2003). *Annals of Biomedical Engineering.* Vol. 31 (6); pp. 718-725.