11th. World Congress on Computational Mechanics (WCCM XI)
5th. European Conference on Computational Mechanics (ECCM V)
6th. European Conference on Computational Fluid Dynamics (ECFD VI)
July 20 - 25, 2014, Barcelona, Spain

ON THE IMPACT OF GEOMETRY ON GLOBAL MECHANICAL RESPONSE OF AN ISOTROPIC HYPERELASTIC FINGERTIP MODEL

J. Dallard[1,2*], X. Merlhiot[1], S. Duprey[2], X. Wang[2], A. Micaelli[1]

[1] CEA, LIST, Interactive Simulation Laboratory, Gif-sur-Yvette, F-91191, France, {jeremy.dallard, xavier.merlhiot, alain.micaelli}@cea.fr
[2] Université de Lyon, F-69622, Lyon ; IFSTTAR, LBMC, UMR_T9406 ; Université Lyon 1, France, {sonia.duprey, xuguang.wang}@inrets.fr

Key words: *Biomechanical Hand Model, Fingertip Model, Soft Tissue Modeling.*

Computational models of the human hand are key elements in the mechanical analysis of grasping and manipulation tasks, with applications in the ergonomics of industrial processes and products. This includes the modeling of soft tissues involved in the contact with objects, starting with the case of the fingertips. Although the influence of material properties in the modeling of fingertip soft tissues has been studied (either in the framework of linear elasticity as in [2] and [3] or hyperelasticity as in [1] and [4]), the influence of the geometry of these tissues is not well known. To model the shape of fingertips, two approaches are encountered: while the first one relies on segmentations from CT or MR scans ([2], [3]), the second one consists in the construction of an idealized geometry based on simple primitives like portions of spheres, ellipsoids and elliptic cylinders ([4]). Based on finite element simulations, we present a study which quantifies the impact of variations in the geometry of the fingertip on its global response to contact against a plane surface.

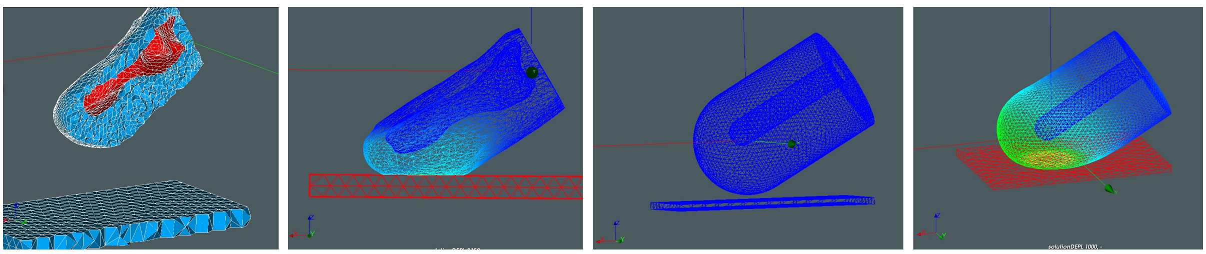

Figure 1: Geometry from the Visible Human (left) and idealized (right) and simulation of compression.

Our fingertip model is composed of two domains (figure 1): the first one is the distal phalanx considered as a rigid body while the second one groups all the soft tissues and is assigned an averaged homogeneous hyperelastic behavior law of Neo-Hookean type. The fingertip is pressed against a flat rigid surface, with fixed angle and prescribed displacement of the phalanx with respect to the contact plane. In order to be compared with the experimental data obtained by Shimawaki [3] on 17 healthy adult males, the response of the fingertip is measured in terms of the principal dimensions of the area of effective contact. In a first step, we used a realistic geometry extracted from the Visible Human dataset to calibrate the hyperelastic constants of our model against Shimawaki's data. In a second step, we kept these constants and used an idealized fingertip geometry with an ellipsoid tip on which we applied variations (figure 2) of the ratios between its principal radii.

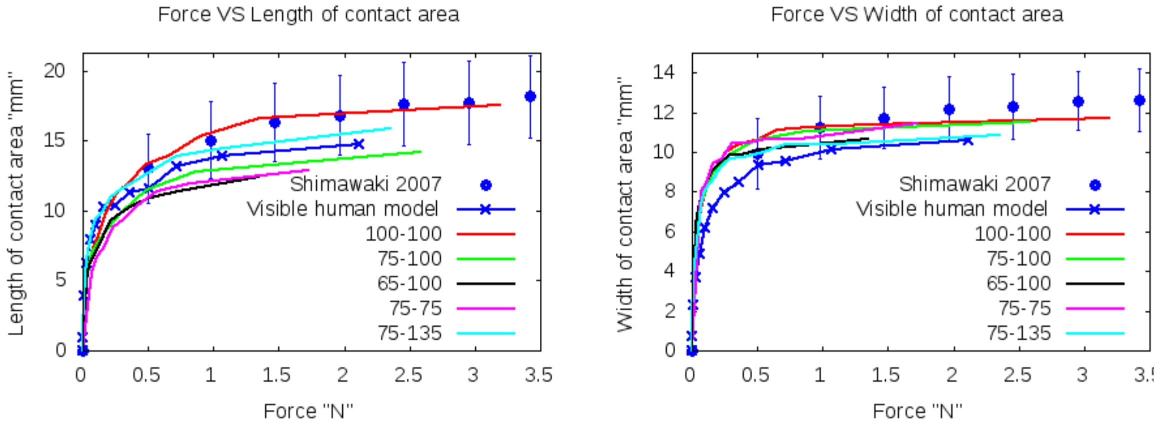

Figure 2: Dimensions of contact area along the phalanx axis (left) and finger width (right) directions, for our idealized geometry with various aspect ratios of the ellipsoid tip.

We observe that the curves obtained with the realistic and idealized geometries all have the same allure, most of the results lying inside the standard deviation of the experimental data of [3]. This study tends to prove that using idealized geometries when adding soft tissues to ergonomics-oriented virtual hand models is a reasonable approach to predict fingertip response during interaction with objects being manipulated. The authors wish to thank Dr. S. Shimawaki who shared his experimental data with them, and the National Library of Medicine for giving them access to the Visible Human Project dataset.

REFERENCES

[1] D. Chamoret, S. Roth, Z. Q. Feng, X. T. Yan, S. Gomes and F. Peyraut. A novel approach to modelling and simulating the contact behaviour between a human hand model and a deformable object. *Computer Methods in Biomechanics and Biomedical Engineering*, Vol. **16**, 130–140, 2013.

[2] M. A. Srinivasan. 3-D Finite-Element Models of Human and Monkey Fingertips to Investigate the Mechanics of Tactile Sense. *Transactions of the ASME*, Vol. **125**, 682–691, 2003.

[3] S. Shimawaki and N. Sakai. Derivation of thin plate bending elements with one degree of freedom per node. *Journal of Environment and Engineering*, Vol. **2**, 56–63, 2007.

[4] J. Z. Wu, R. G. Dong, S. Rakheja and A. W. Schopper. Simulation of mechanical responses of fingertip to dynamic loading. *Medical Engineering & Physics*, Vol. **24**, 253–264, 2002.