Modeling the Human Touch: A FEM Model of the Human Hand Fingertips for Haptic Applications

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Abstract

Sensation of touch, pressure, temperature and vibration are included in the tactile senses; without the sense of touch, it would be very hard to exploit the world. Humans use their fingertips as first approach when touching an object. Haptics technology aims at recreating the sense of touch by applying forces, vibrations, or motions to the user. To develop this type of technology it is extremely important to understand how the human skin, and in particular the hand fingers, react, in terms of tactile sensation and sensory thresholds, when it is in contact with a specific surface.

The goal of this study is to simulate the mechanism of tactile sensation of a fingertip using a multi-layered model. COMSOL Multiphysics® is used to simulate the multi-layered finite element model (FEM), which represents the biomechanics of tactile sensation of fingertip.

The fingertip is assumed to be composed of skin layers, comprising both epidermis and dermis, subcutaneous tissue, nail and arterial bone, as depicted in Figure 1.

The biomechanical properties of the skin and the subcutaneous tissue clearly influence the transmission of stress and strain through the tissue, and play an important role in the tactile sensation. The fingertip detail dimensions were considered as an index finger of a male subjects [2].
The model is clearly nonlinear and inhomogeneous. Characteristics of the contact pressure distribution, strain energy density distribution, stress and strain distribution are analyzed for a finger while touching a flat plate.

The obtained results show that skin deformations are highly dependent on the object contact surface. The obtained results were compared with other skin deformation models and experimental measures in order to validate the model.
The proposed multi-layered structural finite element model can predict the response of the fingertip skin to stimuli in tactile exploration and the effect of the object features on mechanoreceptors. The model will be adopted in the analysis and in the design of new haptic devices in which the cutaneous stimuli and the wearability aspects are fundamental [3].

This work is intended as an important basement for further and more detailed investigations with different objects; the intention is to create a predictive model to be used in the design and optimization process of new cutaneous haptic interfaces.

Reference

[1] www.cnx.org
[2] Clemente CD. Anatomy: a regional atlas of the human body, 2nd ed. Baltimore, Munich: Urban and Achwarzengerg, 1981.
[3] D. Prattichizzo, F. Chinello, C. Pacchierotti, M. Malvezzi. Towards wearability in fingertip haptics: a 3-DoF wearable device for cutaneous force feedback. IEEE Transactions on Haptics, 6(4):506-516, 2013.

Figures used in the abstract

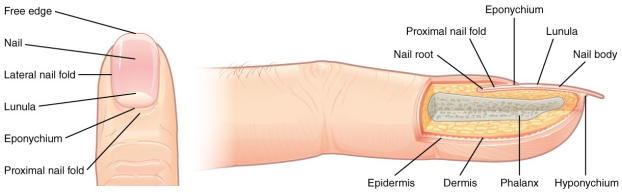

Figure 1: Detailed physiological structure of fingertip [1].