Modeling Light Propagation in Skin for Visualization of Subcutaneous Veins

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Abstract

Vein visualization systems such as the VeinViewer are vein-contrast enhancement devices that use an infrared camera to highlight blood or the underlying vasculature and project the image in real time onto the skin[1]. Infrared light is used to illuminate a local area of the skin and contrast between light scattering/absorption in the skin and in the blood is projected for vein visualization. Understanding the light propagation in a realistic skin model is critical, but only a few computational models for vein visualization have been developed to account for this particular imaging system [2, 3]. We have developed a 3D computational skin model with embedded veins taking advantage of COMSOL Multiphysics® allowing importing complex geometry. The aim of this work is to aid in optimization and improvement of the device design and practices. The 3-D model consists of epidermis/dermis and subcutaneous vein branches of different diameters and depth as shown in Figure 1. The geometry was modified for simulations to have a curved skin surface and realistic morphology of veins. Factors affecting this model are location, wavelength, intensity of light sources, variation in optical properties of skins, and topology of veins.

Use of COMSOL Multiphysics:

The diffusion approximation of an RTE (radiation transfer equation) was used because the skin is a scatter dominated medium[4]. The RTE was expressed as Helmholtz equation in COMSOL Multiphysics and an LED light source was applied on the boundary. The 3-D vein geometry was imported from a SolidWorks model.

Results:

The initial results from the COMSOL 3D light propagation in the simplified skin model showed clear distinction between the skin and subcutaneous veins where optical properties are significantly different (Figure 2). The contrast depends on wavelength and location of the light source, skin variation such as melanin, and depth and size of the veins. These parameters can be modified to adjust to the personal and locational variations and to find optimal practice conditions. We present more complicated geometry and vein visualization.

Conclusion:

As the vein visualization device is under continuous improvement to visualize smaller capillaries as well as deeply embedded veins, a working computational skin model can play a critical role. The 3-D COMSOL® model effectively shows the contrast of the veins from the surrounding tissue. The advantage of the COMSOL model is that the topology of vasculature can be modified easily using 3-D CAD modeling software or a scanner. This model can effectively be used to advance the design and practices of vein visualization devices for projection and clinical assessment of dermal blood vessels.

Reference

[1] H. D. Zeman, G. Lovhoiden, C. Vrancken, and R. K. Danish, "Prototype vein contrast enhancer," Opt. Eng., vol. 44, p. 086401, 2005.
[2] I. Nishidate, T. Maeda, Y. Aizu, and K. Niizeki, "Visualizing depth and thickness of a local blood region in skin tissue using diffuse reflectance images.," J. Biomed. Opt., vol. 12, p. 054006, 2007.
[3] V. C. Paquit, F. Meriaudeau, J. R. Price, and K. W. Tobin, "Simulation of skin reflectance images using 3D tissue modeling and multispectral Monte Carlo light propagation," in Engineering in Medicine and Biology Society, 2008. EMBS 2008. 30th Annual International Conference of the IEEE, 2008, pp. 447-450.
[4] S. R. Arridge, "Optical tomography in medical imaging" Inverse Problems, vol. 15, p. R41, 1999.

Figures used in the abstract

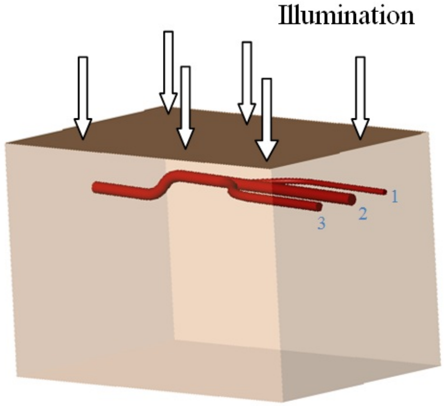

Figure 1: Schematics of the initial SolidWorks® model of the skin and subcutaneous veins. Vein vessel is 2.5mm under the skin surface. Numbers indicate different vein diameters: 1 is 0.5mm; 2, 1mm; and 3, 0.8mm.

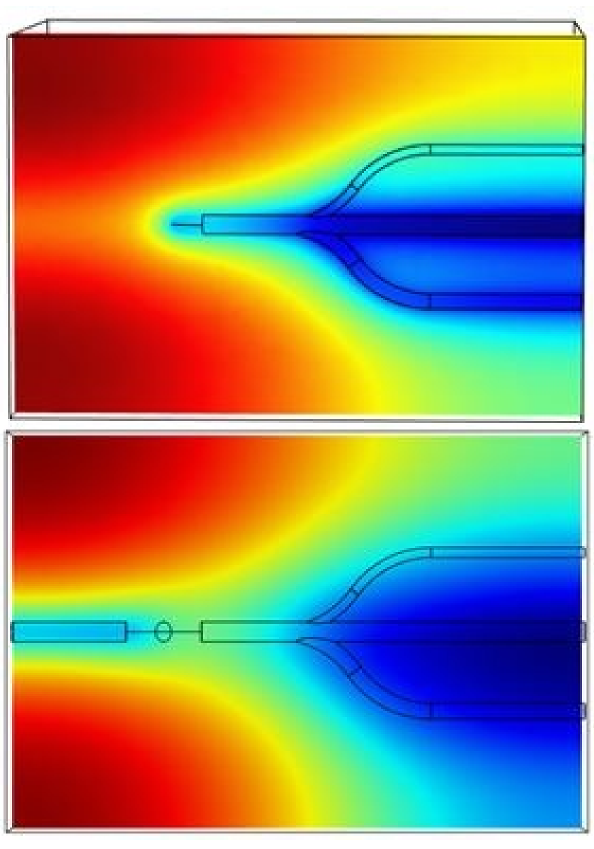

Figure 2: Simulated image of the light contrast in the slide of 2.5mm and 3 mm depth.