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# Simulation of Light Propagation in Skin and Subcutaneous Blood Vessels

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# Simulation of light propagation in skin and subcutaneous blood vessels

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## Abstract

The VeinViewer, produced by the Luminetx Corporation, projects an image of subcutaneous veins onto the surface of the skin by using the discovery that near-infrared (NIR) light passes through and transmits back out of the skin tissue except at the blood vessels as a result of the presence of hemoglobin[1]. We aim to improve the function of the VeinViewer by using computational models to interpret changes in properties of the subject, such as skin pigmentation, and settings on the device, such as light frequency. We also look to decrease error, as a result of the geometry of veins and the multiple layers of skin. A finite-element model implementing the diffusion approximation of the radiation transfer equation fulfills the role in part, but questions of boundary conditions and the description of the source need clarification.

## The Model

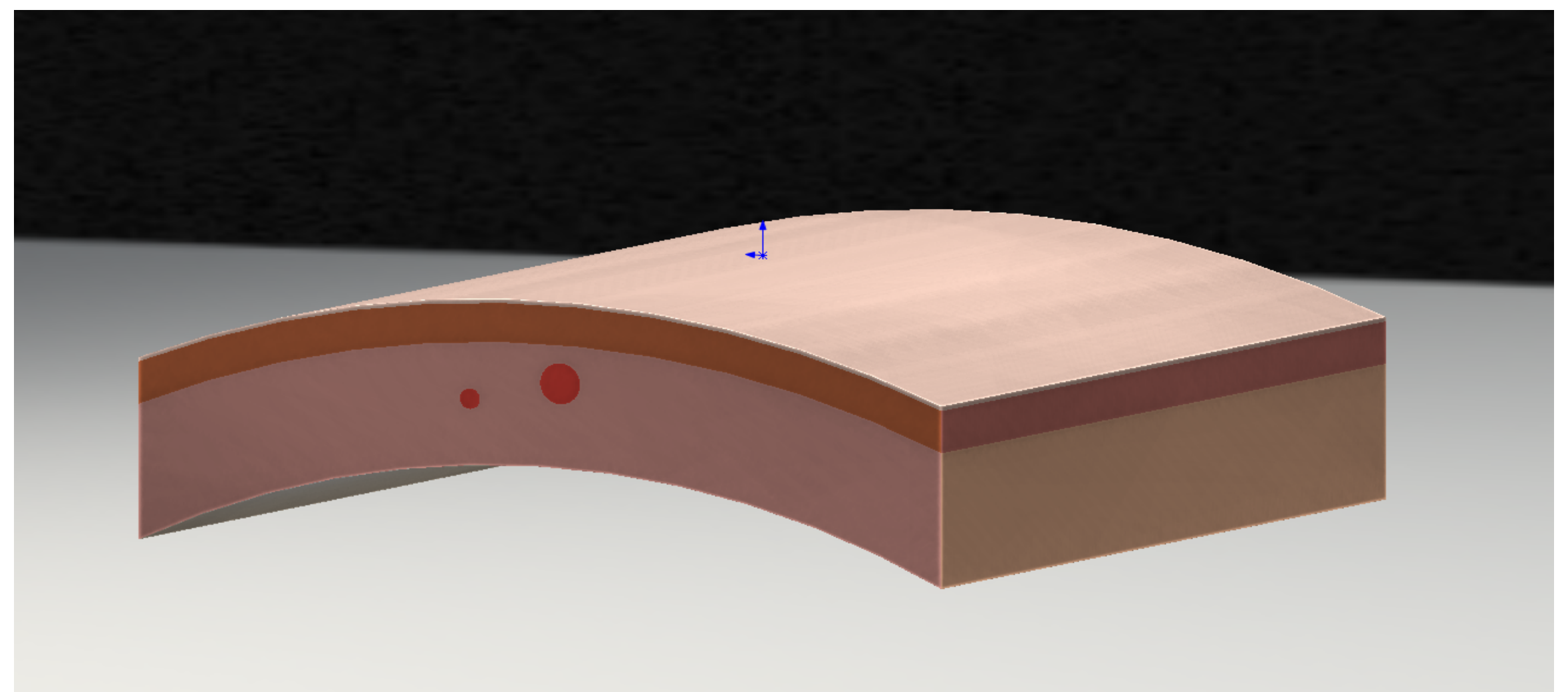

Figure 1: Model of the three layers of skin and the two blood vessels located in the hypodermis, made in SolidWorks

The skin model, in Figure 1, consists of three layers, the epidermis, dermis, and the hypodermis, each with their corresponding coefficients of absorption and diffusion coefficients, given in Table 1. One vessel is 1 mm in diameter and the other is 2 mm in diameter. Both of the vessels are located in the hypodermis, or subcutaneous, tissue.

| Wavelength (nm) | Epidermis | | Dermis | | Hypodermis | | Whole Blood | |
|---|---|---|---|---|---|---|---|---|
| | $\mu_a$ | $D$ | $\mu_a$ | $D$ | $\mu_a$ | $D$ | $\mu_a$ | $D$ |
| 650 | 8.9 | 2.87 | .033 | 12.1 | .013 | 26.2 | 4.3 | 2.33 |
| 760 | 7.8 | 3.30 | .018 | 14.3 | .008 | 27.6 | 5.3 | 2.82 |
| 880 | 6.9 | 3.91 | .013 | 20.3 | .012 | 30.5 | 8.5 | 2.28 |

Table 1: Absorption coefficients (in $cm^{-1}$) and diffusion coefficients (in $cm^2s^{-1}$) of tissue and blood[1]

## Governing Equations

The diffusion approximation to the radiation transfer equation was used to approximate a steady-state solution to the light transfer problem[2].

$$\nabla \cdot (-D\nabla\Phi) + \mu_a\Phi = q_0$$

Where $\Phi$ is the fluence rate of light, $D$ is the diffusion coefficient of the tissue, $\mu_a$ is the absorption coefficient of the tissue, and $q_0$ is the light irradiance of the light source incident on the top surface of the skin, which was set to 0.01 W/$m^2$.

## Results

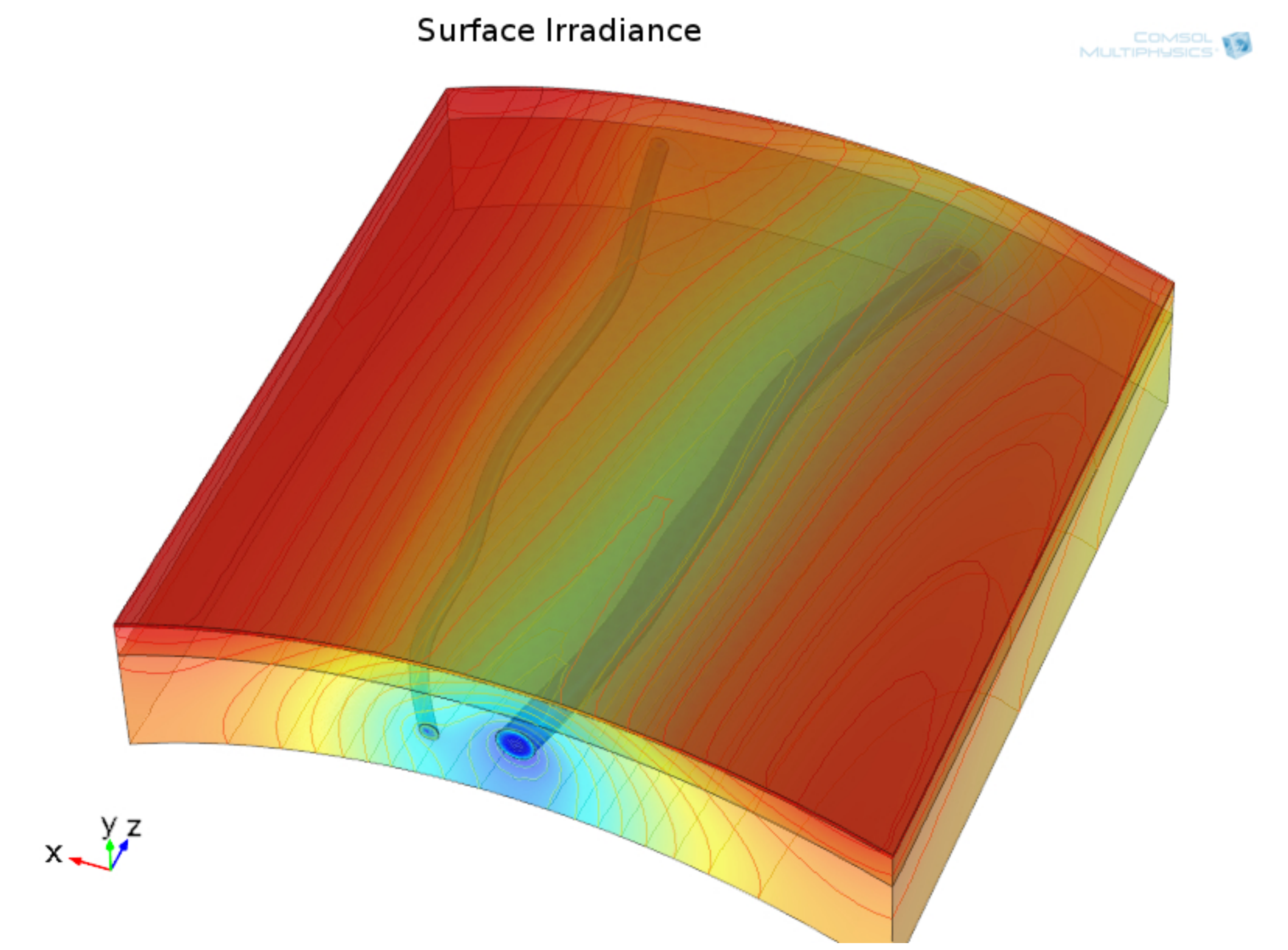

Figure 2: Contour lines and surface plot of irradiance of light from the skin

## Results

The simulation using light of a wavelength of 880 nm returned the irradiation profile in Figure 2. There is a contrast directly around the vessel that is 2 mm in diameter, but the smaller vessel shows only minimal contrast. Another test was run using a model containing only the large vein to compare the irradiation for the different wavelengths of light. This comparison, in Figure 3, reveals 880-nm light to give the most contrast between the highest and lowest irradiation values.

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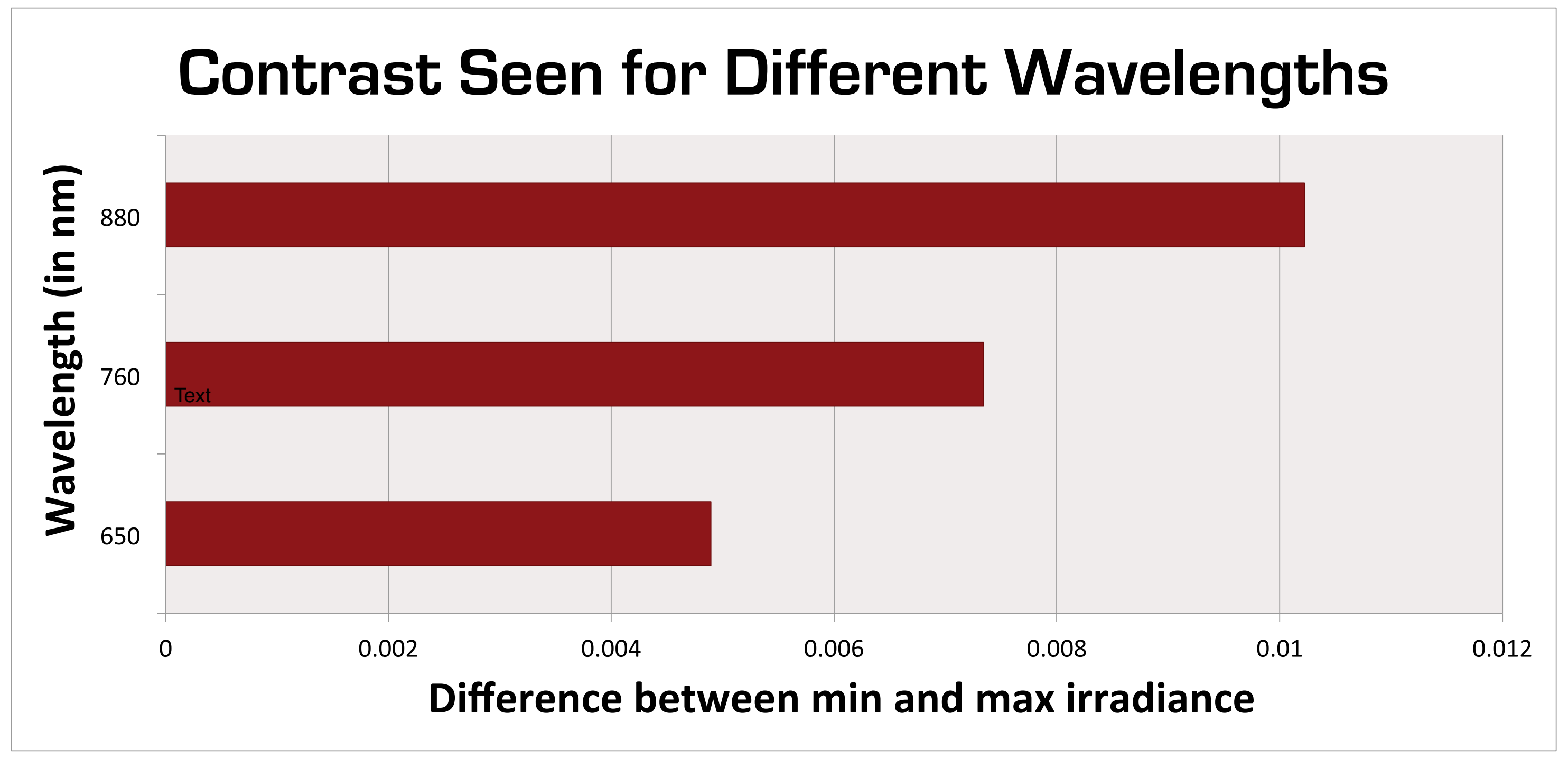

Figure 3: Comparison of contrast of maximum and minimum irradiance magnitudes for different wavelengths of light

## Conclusion

We made a model that allows for analyzing the light transfer in an arbitrary 3D geometry of the skin. It reveals a contrast, which is accentuated at the 880 nm wavelength range of light. The contrast patterns from this model can be used for improving the detection of actual vessels under the skin.

## Future Work

- Look at effects of light scattering and absorption in the vicinity of the round veins
- Include reflectance at the surface and at interfaces between layers using Robin-type boundary conditions
- Track effects of using multiple frequencies, which shows promise for improving contrast[3,4]
- Consider skin pigment types
- Find depth of veins using infrared light
- Take different source geometries into consideration

## References

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