MONTE CARLO SIMULATION OF SPECTRAL REFLECTANCE IMAGES OF HUMAN SKIN WITH EMBEDDED LESIONS

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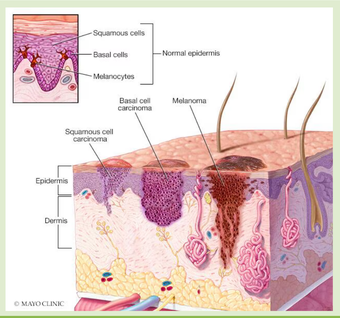
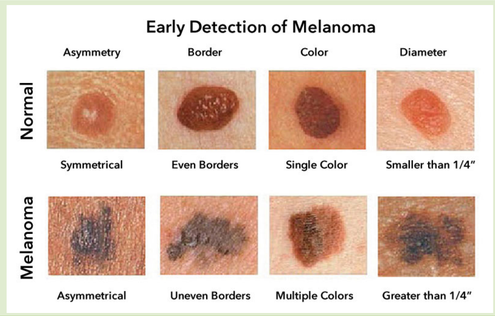
INTRODUCTION

One of the most critical applications of Monte Carlo based modeling is the identification of skin lesions through their color and spectral signatures, particularly for detecting tumors like malignant melanoma. This aggressive skin cancer exhibits distinct optical properties due to variations in melanin concentration, absorption, and scattering. Monte Carlo modeling allows for characterization of these variations, providing estimations for non-invasive means of differentiating malignant and benign lesions.

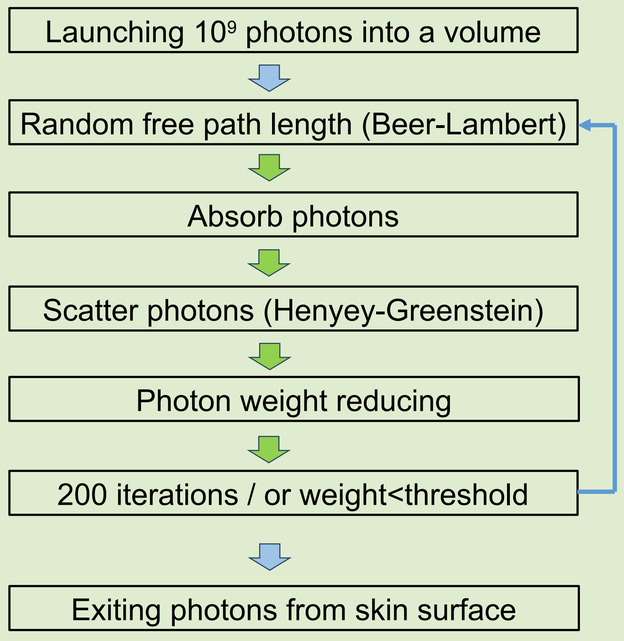


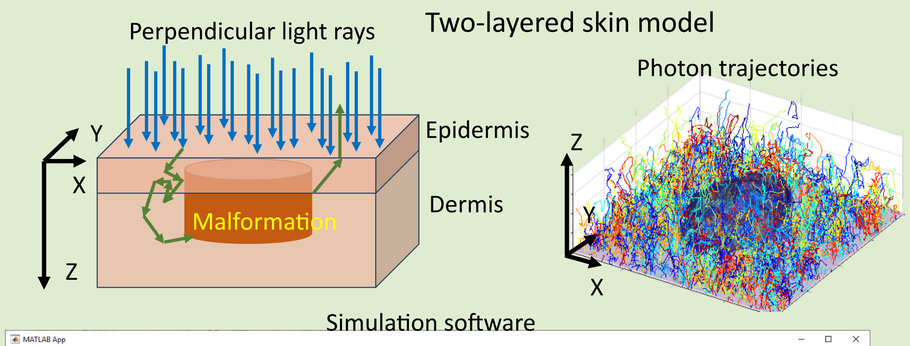


METHODS

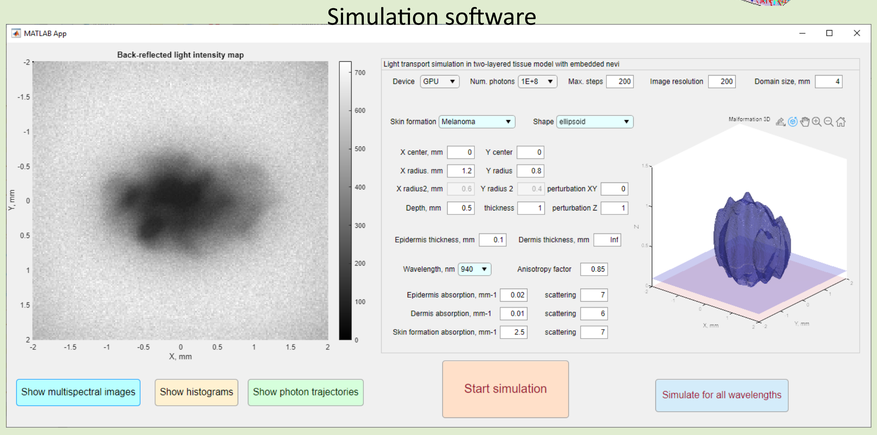
Monte Carlo (MC) modeling is a statistical method used to simulate the random nature of photon propagation in highly scattering and absorbing media such as biological tissues. In this model, a large number of photons are launched into the skin tissue perpendicularly to its surface, and each photon undergoes random scattering and absorption events based on the tissue's optical properties (μ_a, μ_s, g).

The simulation tracks the paths of individual photons, and records the photons that exit the tissue back through the surface. Such simulations are useful for analyzing how sub-surface features (skin moles, vascular lesions, or tumors) influence the reflected light patterns.

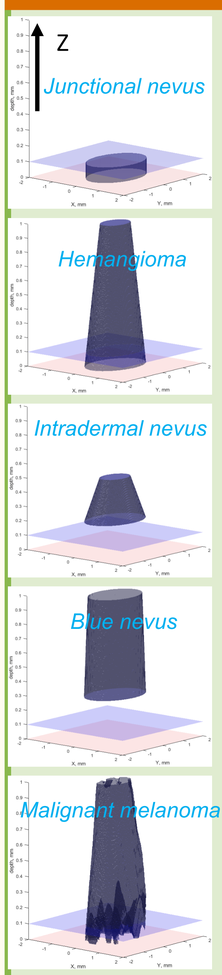




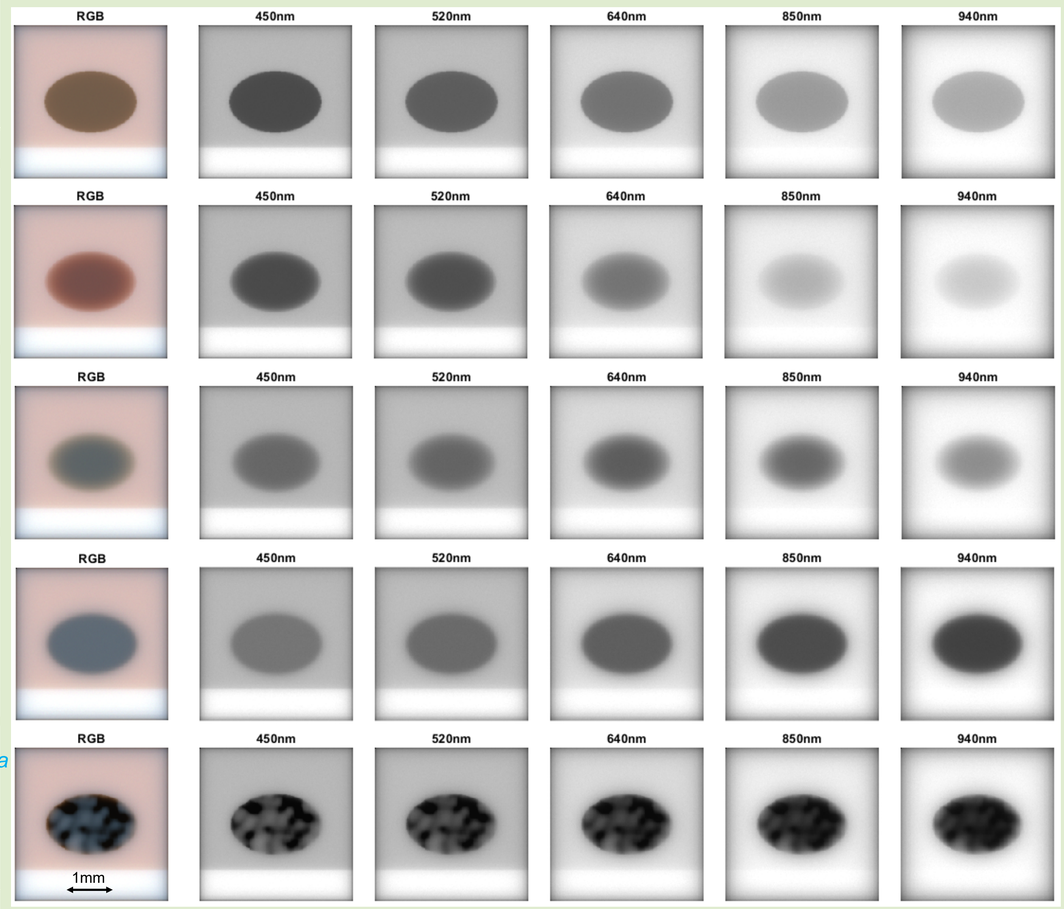
Simulation software



RESULTS



Simulated back-scattered intensity images



Optical properties of simulated skin and malformations [1-3]

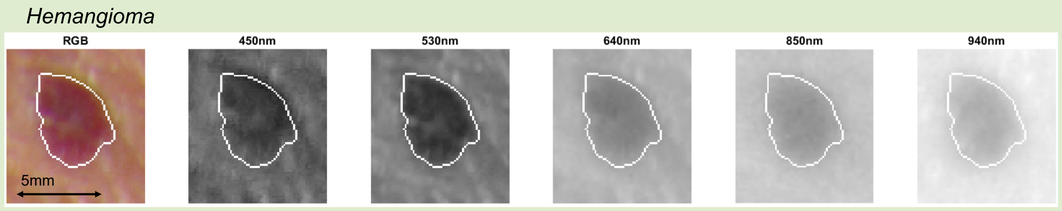
Tissue type	Depth, mm	Thickness, mm	μa, mm^{-1}	μs, mm^{-1}	g
Epidermis	0	0.1	0.02 – 0.5	7 – 30	0.85
Dermis	0.1	Infinity	0.01 – 0.1	6 – 15	0.85
Junctional nevus	0.05+-0.05	0.05	0.4 – 2.0	2 – 7	0.85
Intradermal nevus	0.2+-0.1	0.3	2.0 – 3.5	4 – 11	0.85
Blue nevus	0.5+-0.4	3.0	2.0 – 5.0	6 – 13	0.85
Hemangioma	0.05+-0.05	1.0	0.1 – 1.2	7 – 22	0.85
Malignant melanoma	0.2+-0.2	5.0	2.5 – 7.0	7 – 15	0.85
White reference	0	Infinity	0	7 – 30	0.85

All lesions have higher melanin concentration compared to the surrounding skin. Junctional nevus is shallow, limited to the epidermal-dermal junction, and has brown color. Hemangioma has reddish color due to higher hemoglobin content. Intradermal nevus extends deeper, mainly within the dermis. Blue nevus penetrates deep into the dermis, and it appears blue due to the Tyndall effect. Malignant melanoma can be highly invasive, reaching deep into the dermis, it has the highest melanin absorption, it may be seen more clearly at near-infrared illumination.

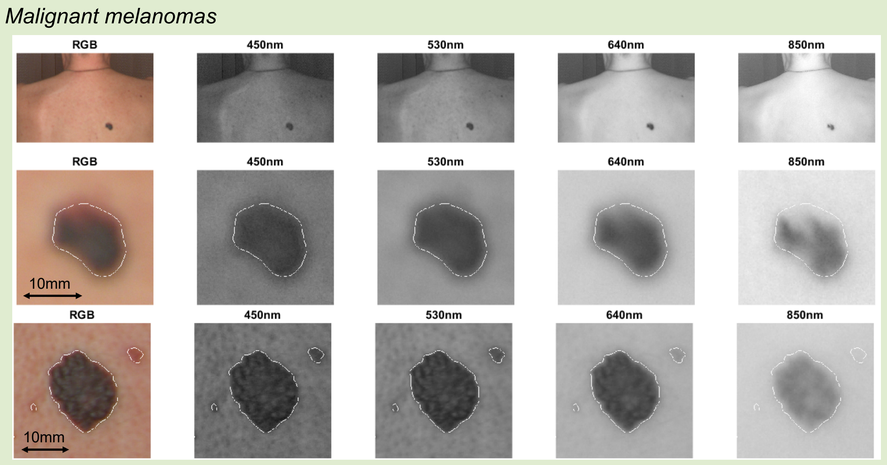
Clinical spectral images

Junctional nevus

Hemangioma



Malignant melanomas



Typical junctional nevi and hemangiomas can be detected in the visible light spectrum, especially at 450 nm and 520 nm. As the malignant melanoma can be highly invasive, reaching deep into the dermis, it has the highest absorption due to high melanin content. As the near-infrared 850-940 nm radiation penetrates deeper, malignant melanoma may be seen more clearly.

CONCLUSIONS

Our first results on MC-simulations of skin spectral images comprising several types of pathologic inclusions are presented, with notable differences in contrasts depending on the lesion's type. The optical parameters can be further varied according to specific anatomic features of skin and embedded lesions.

REFERENCES

[1] Wang, L., Jacques, S. L., & Zheng, L. (1995). MCML—Monte Carlo modeling of light transport in multi-layered tissues. Computer Methods and Programs in Biomedicine, 47(2), 131-146.
[2] Jacques, S. L. (2013). Optical properties of biological tissues: a review. Physics in Medicine & Biology, 58(11), R37-R61.
[3] F. Tuchin, V. V. (2015). Tissue optics: Light scattering methods and instruments for medical diagnosis. SPIE Press.
[4] Jönsson, J. (2021). Multi-Scattering: Computational light transport in turbid media. Chapter 3. Doctoral thesis, Dept. of Physics, Lund University.

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