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In silico dermoscopy with detailed subsurface scattering

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Abstract

We describe an approach to modeling dermoscopy, the imaging modality for the examination of skin lesions, using accurate subsurface scattering in human skin. We make use of an open-source, path-tracing program with advanced physics models as a rendering tool. Rendered scenes are based on biological details from human skin, such as layering, optical properties, and lesion variability, as well as on the properties of the image acquisition device. Preliminary results suggest that this can be an efficient and effective way to generate arbitrarily large datasets of fully featured images with known classification labels.

1. Introduction and Scene Description

Large and well curated image databases are needed for the training, testing, and performance evaluation of digital dermoscopy devices for skin cancer that rely on algorithmic decision making [EKN*17]. Current databases are relatively small, poorly annotated and the procedures to determine the truth label associated with each image suffer from uncertainty. This project aims at developing an in silico computational tool to generate image databases of annotated photo-realistic images of both normal and cancerous skin conditions. We use an open-source path-based Monte Carlo ray tracer (PBRT [PH10]) to render custom skin and lesion models, defined by the absorption and scattering coefficients for each distinctive skin layer.

Our design allows the user to specify several key parameters to create a scene file compatible with PBRT. Each image is obtained by following the paths of simulated photons through the skin layers in the scene.

We modeled a scene mimicking features similar to the practical use of a dermatoscope during an examination. The dermatoscopic camera is modeled with as an ideal sensor with 512×512 pixels, covering an area of 14 mm with a field of view of 90°. LED source lights commonly found in such devices are modeled as point lights in the scene.

Human skin has a complex structure and is challenging to model but can be simplified into several layers consisting of homogeneous materials with shared optical properties [MM02, BGT11a, DWd*08]. We modeled four layers: muscle, subcutaneous fat, dermis, and epidermis [BGT11b]. The boundaries between layers are modeled as triangle meshes perturbed by Perlin noise [Per02]. For added realism on the epidermis a depth map was used to model surface texture.

We introduced a lesion model to simulate the presence of a cancerous growth. The discrete geometry of each skin layer in the model allows for skin lesions to be trivially inserted within the boundaries of any given layer. For demonstration, we have chosen to use lesion optical properties selected to create color contrast between the inserted lesion and the surrounding skin.

2. Future Work and Conclusion

Grounding skin boundary parameters to biological attributes would help to more accurately model the subsurface geometry of the scene. Similarly, expanding the computations to include wavelength-dependent optical properties would allow for a more accurate transport albedo. As the model's components become more sophisticated further subdividing layers by more subtle distinctions might be needed. The model already allows for an arbitrarily high number of subdivisions of skin into subsurface layers.

Future work will implement a more realistic lesion model [dSBZ*15]. This model will be time-dependent to allow for accurate tags to be applied to images for use in deep learning algorithms.

Testing the fidelity of the model is a challenging problem. A popular method to investigate the realism of synthetic image datasets in radiology is to perform a "fool the human" test [PSZ*15], which is a modification of Turing's test on machine intelligence [Tur50]. A better approach should look at the effect of training and testing on sets of synthetic and patient images in terms of algorithm efficiency and diagnostic performance similar to the study described by Cha *et al.* [CPP*19].

By performing photon transport with an accurate subsurface scattering model we can generate a set of images grounded in physical and biological measurements of human skin. This work continues to move towards fully featured datasets of dermatoscopic images rendered in silico.

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