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Simulating medical applications of tissue optical property and shape imaging using open-source ray tracing software

Improved image contrast is needed for better cancer detection

Oesophageal cancer and colon cancer have low 5 year survival rated of just 15%[1] and 63%[2] respectively due to difficulty to detect. Current imaging could be drastically improved by:
→ Getting quantitative tissue information
→ Using shape information as cancer indication

Spatial Frequency Domain Imaging (SFDI) has been shown to image cancers and fringe profilometry, specifically Fourier Transform Profilometry (FTP), can image shape.

We have developed a full end-to-end imaging system in the *Blender* package

Many packages exist to generate SFDI & FTP data. However:
→ Do not fully consider lighting conditions
→ Do not offer full realistic imaging geometries

We simulated a basic SFDI and FTP system[3] capable of projecting any desired illumination pattern, imaging in different geometries, simulating a shaped object of specific optical properties.

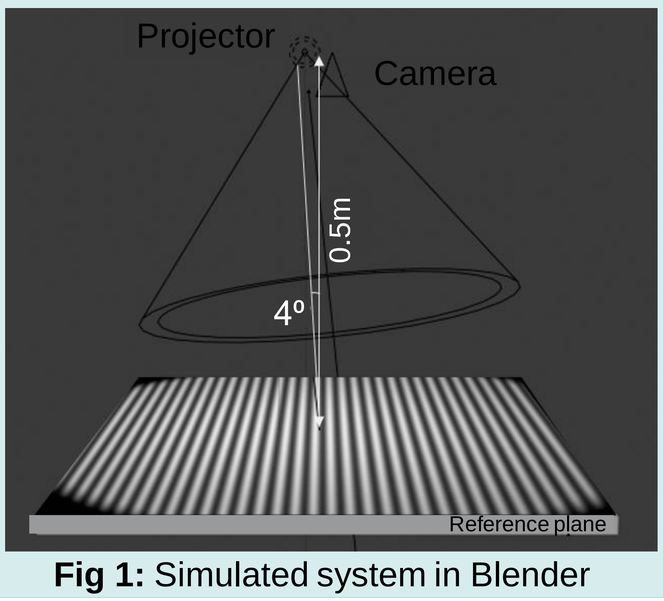

Fig 1: Simulated system in Blender

We developed a method of simulating absorption, scattering and shape of a material

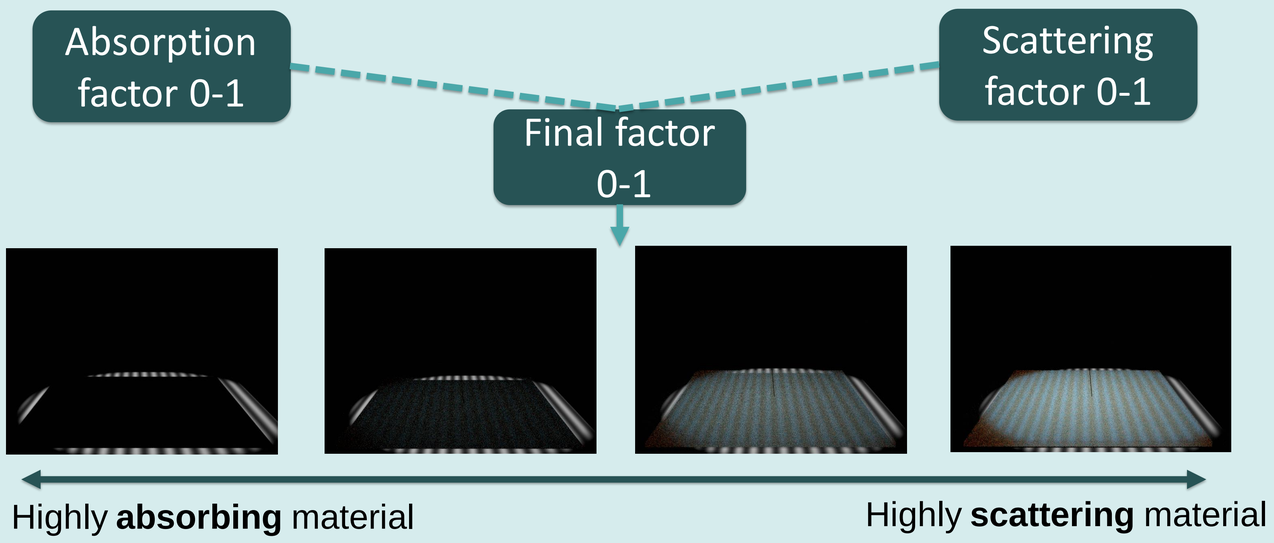

Fig 2: Varying optical properties of simulated material in Blender

By comparing diffuse reflectance values with curves from literature, we could calibrate the weighted factor parameters to produce known optical property values.

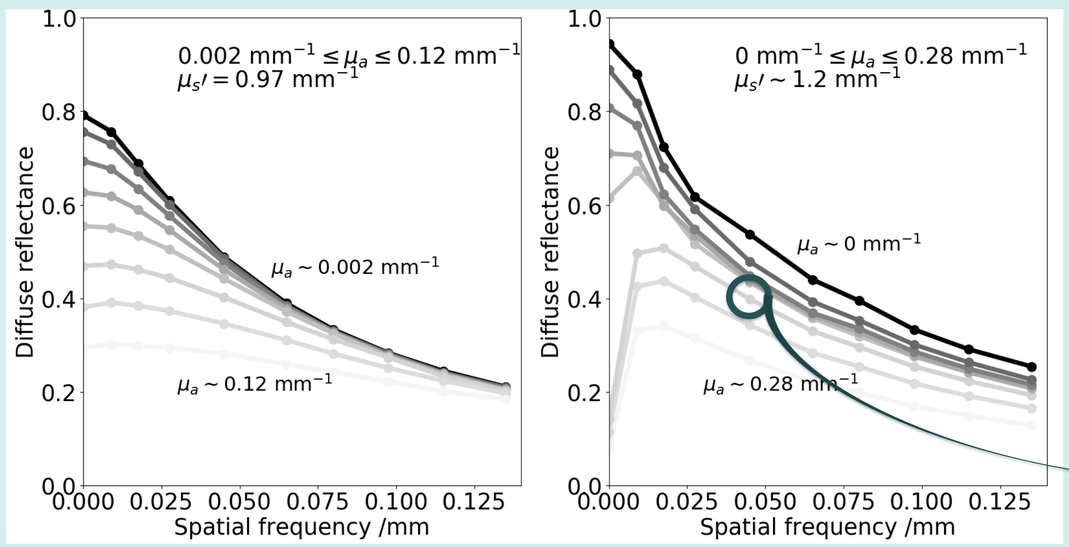

Fig 3: Optical properties achieved(right) matched those from literature[4](left)

Select desired optical properties and input to Blender

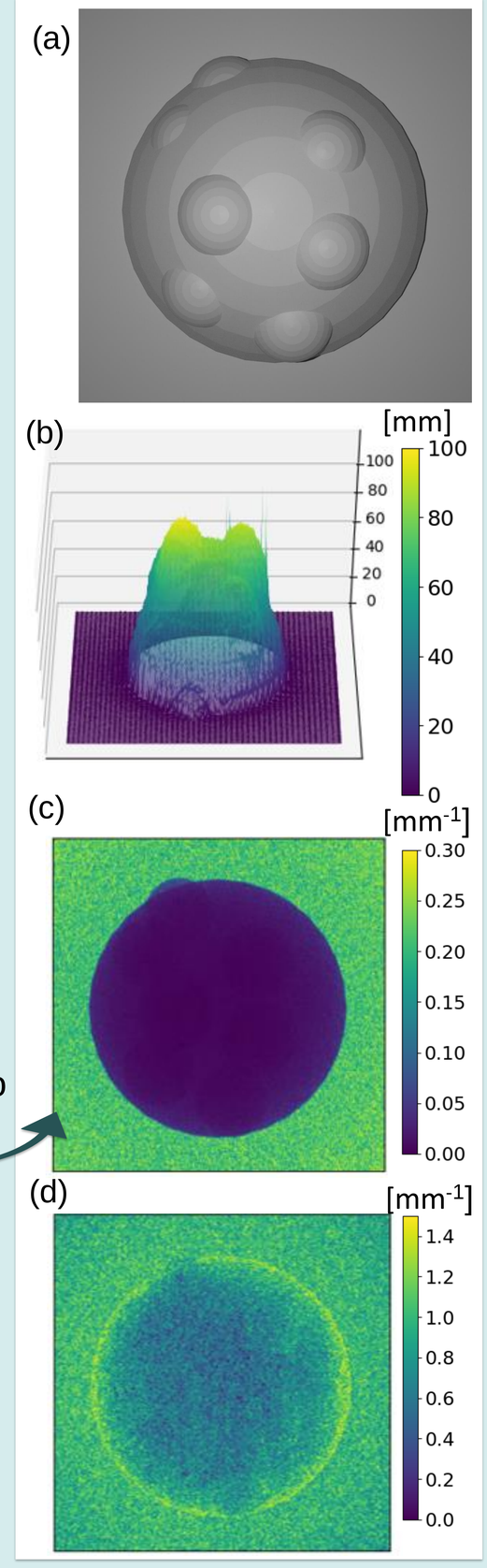

Fig 4: Simulated tumour sample **(a)** DC image, **(b)** height reconstruction by using FTP, **(c)** absorption coefficient map obtained using 3 phase SFDI, **(d)** reduced scattering coefficient map obtained using 3 phase SFDI

We demonstrated the capability to project in different system geometries

As a proof of concept, we projected uniform fringes in a tube geometry, representing the gastrointestinal tract. Concentric circles are more uniform than sinusoidal pattern.

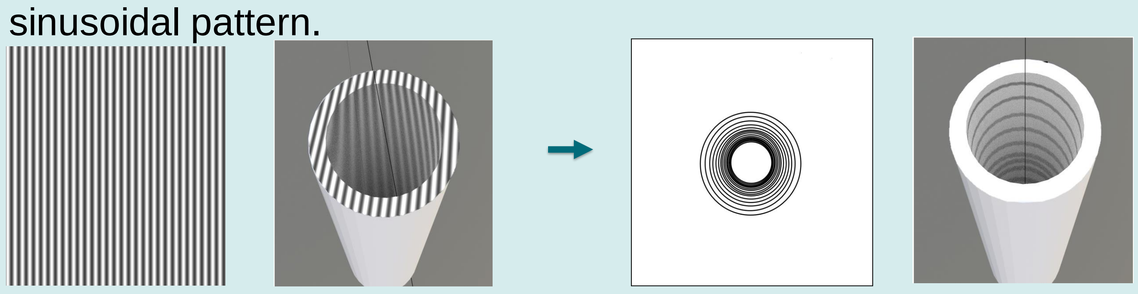

Fig 5: Uniform fringes projected down tube

Conclusion

SFDI and FTP can provide better contrast. These can be difficult to design in unusual geometries. We hope this will be used for future miniaturisation of medical systems.

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[1] CRUK, “Oesophageal Cancer Statistics,” (4, 2020)
[2] Cancer.net, “Colon Cancer Statistics,” (6, 2020)
[3] J. Crowley and G. S. D. Gordon "Simulating medical applications of tissue optical property and shape imaging using open-source ray tracing software", Proc. SPIE 11657, Biomedical Applications of Light Scattering XI, 1165707 (3, 2021)
[4] Cuccia, D. J., Bevilacqua, F., Durkin, A. J., Ayers, F. R., and Tromberg, B. J., “Quantitation and mapping of tissue optical properties using modulated imaging,” Journal of Biomedical Optics 14(2), 024012 (2009)