Online Simulation Platform for Biophotonic Applications

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Currently optical methods are gaining ground for biomedical applications such as cancer and cardiovascular diagnostics, dermatology, ophthalmology, pharmaceutical research, cosmetics and healthcare industry. Benefits of optical techniques are their non-invasiveness, ability for remote monitoring and access to biological objects from cell to body level, to name a few.

Light irradiation dose, measurement volume, sensitivity of optical modalities are of crucial importance in biomedical diagnostics before implementing the developed techniques in in vivo research and clinical trials. An essential part of the preliminary studies is use of phantoms and simulations for optimal configuration of the setup and refining the measurement procedure. Up to now, such simulations were performed in every lab using own codes and local resources.

We report about the next step in the computational diagnostics, an online computational platform for the needs of biomedical optics and biophotonics. The platform serves as a tool for calculation of a sampling volume, fluence rate, skin spectrum, skin color, and a number of optical techniques including optical coherence tomography, polarization, coherent backscattering, pulse oxymetry, confocal microscopy, fluorescence, and diffuse wave spectroscopy.

We used the inheritance feature of Object-oriented programming (OOP) to create a ‘smart’ hierarchical structure of the Monte Carlo (MC) code to avoid having multiple classes for similar tasks. The hierarchy allows ‘allied’ objects to share variables and members, significantly reducing the amount of source code and paving the way to extend and generalize the MC. Depending on the application, objects can be tuned to an appropriate state of light-tissue interaction and to a particular optical diagnostic technique.

To achieve optical simulation performance, we employed a developed parallel computing framework known as Compute Unified Device Architecture (CUDA), introduced by the NVIDIA Corporation. Specially designed for professional 3D graphics applications, this technology allows each graphic chip to be logically divided into hundreds of cores, turning the graphics processing unit into a massive co-processor for parallel computations. This capability enables simulation of thousands of objects - i.e., simultaneous propagation of photons in the medium - that speeds the process of simulation up to 103 times.

The computational solution utilizes recent developments in HyperText Markup Language (HTML) 5, accelerated by the graphics processing units (GPUs), and therefore is convenient for the practical use at the most of modern computer-based devices and operating systems. Figure 1 shows the interactive user interface for selecting a particular MC application. The results of imitation of human skin reflectance spectra and the corresponding skin colors are presented in Figure 2.

The platform can ease research in a number of areas and can be used for professional and educational purposes.

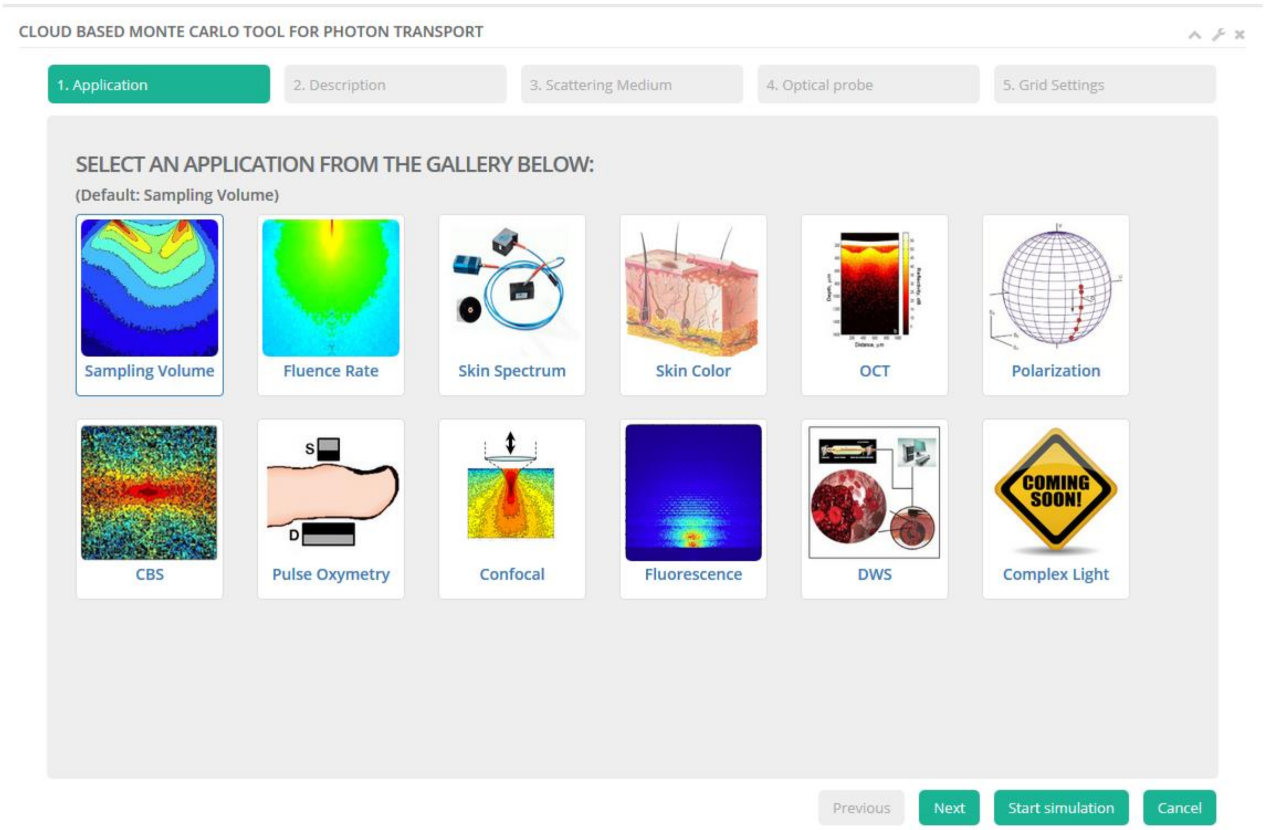
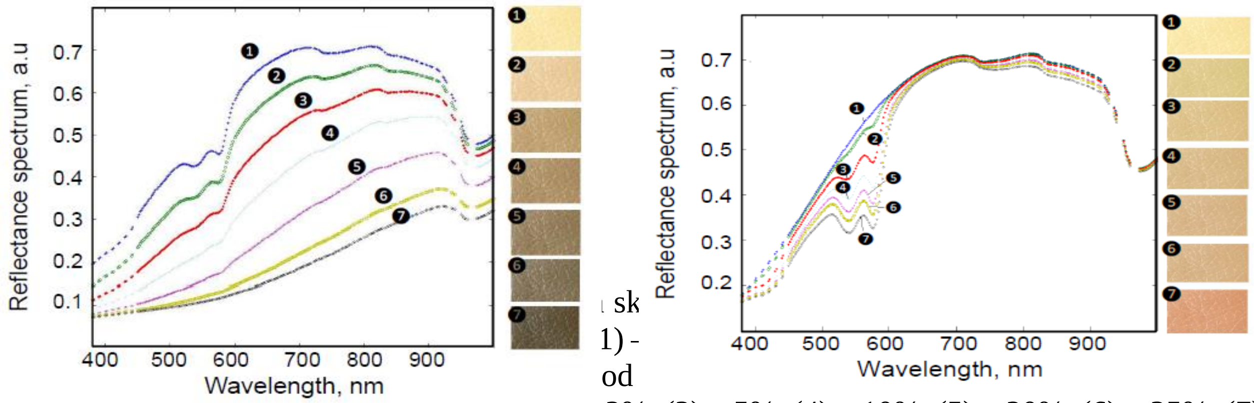


Figure 1. A variety of options offered by the online platform (www.biophotonics.fi).



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dermis to subcutaneous tissue: (1) – 0%, (2) – 2%, (3) – 5%, (4) – 10%, (5) – 20%, (6) – 35%, (7) – 45%, respectively.

References:

1. A. Doronin, I. Meglinski, "Online object oriented Monte Carlo computational tool for the needs of biomedical optics", Biomed. Opt. Express 2, 9, 2461-2469 (2011).
2. A. Doronin, H. Rushmeier, I. Meglinski, A. Bykov, "Cloud-based Monte Carlo modelling BSSRDF for the rendering of human skin appearance", Proc. SPIE 9719, Biophysics, Biology, and Biophotonics: the Crossroads, 97190F (April 27, 2016); doi:10.1117/12.2214512

Biographies of the authors

Alexey Popov, D.Sc. (Tech.) is a Senior Researcher and Docent in Optoelectronics and Measurement Techniques Laboratory at the University of Oulu, Finland. He graduated from the Physics Department of M.V. Lomonosov State University (Russia) with M.Sc. degree in 2003 and was awarded with PhD degree in 2006. He received his D.Sc. (Tech.) degree from the Faculty of Technology of the University of Oulu (Finland) in 2008. He is an author of 90 papers in international peer reviewed journals and SPIE proceedings and ca. 100 presentations at major international conferences, symposia and workshops including 15 invited lectures. Currently, he is a Senior Researcher and Docent in the Optoelectronics and Measurement Techniques Laboratory at the University of Oulu; a member of SPIE and a Faculty Advisor of the SPIE Student Chapter of the University of Oulu, Northernmost and 1st in Finland.

Alexander Bykov, Ph.D. (Phys.) and D.Sc. (Tech.), born in 1981, is curently a Postdoctoral Researcher at the Optoelectronics and Measurement Techniques Laboratory, University of Oulu. He has over ten-year experience in research in the fields of photonics and biomedical optics. He received M.Sc. diploma in Physics at the M.V. Lomonosov Moscow State University in 2005 and Ph.D. in 2008 from the same university. In 2010, he received D.Sc.(Tech.) degree from the Faculty of Technology at the University of Oulu and continued as a postdoctoral researcher at the Optoelectronics and Measurement techniques laboratory. He is an author and co-author of over 60 scientific papers published in refereed international journals and book chapters, cosupervisor of undergraduate and postgraduate students.

Alexander Doronin is a Postdoctoral Associate in Computer Science working in Computer Graphics Group, Yale University, USA. His research interests are interdisciplinary and lie at the interface between Computer Science, Physics, Optics and Biophotonics focusing on Physically-Based Rendering, Development of realistic material models, Monte Carlo modeling of light transport in turbid media, Color Perception, Translucency, Appearance and Biomedical Visualization.

Hannu Sorvoja, D.Sc. (Tech.), born in 1966, is currently a Laboratory Manager at the Optoelectronics and Measurement Techniques Unit, University of Oulu. He has over twenty-year experience in research in the fields of biomedical engineering. He received M.Sc.(Tech.) in Electrical Engineering 1993, Lic.Sc.(Tech.) in 1998, and D.Sc.(Tech.) 2006, all from the Faculty of Technology at the University of Oulu, and continued as a professor and a postdoctoral researcher. He is an author and co-author over 40 scientific papers published in refereed international journals or conferences and three patents. In addition, he has supervised over 30 M.Sc.(Tech.) and Lic.Sc.(Tech.) theses.

Professor Igor Meglinski, Ph.D. is Head of Optoelectronics and Measurement Techniques Laboratory, Faculty of Information Technology and Electrical Engineering, University of Oulu. He has over 20 years experience in biomedical optics, biomedical engineering, medical physics, and sensor technologies. He is an author and coauthor of over 200 research papers in the peer reviewed scientific journals, proceedings of international conferences and book chapters, and over 400 presentations at the major international conferences and symposia, including over 200 invited lectures and plenary talks. His research interests lie at the interface between physics, medicine, and biological sciences, focusing on the development of new non-invasive imaging/diagnostic techniques and their application in medicine and biology, material sciences, pharmacy, food, environmental monitoring, and health care industries. For the last ten years, he has been a Principal Investigator and/or Coordinator for over 60 research projects, supported by various funding bodies, including UK NHS trust, NATO, Royal Society, U.S. CRDF, New Zealand Ministry of Business, Innovation & Employment, Maurice Wilkins Centre (MWC), New Zealand Ministry of Foreign Affairs and Trade, A*STAR (Singapore), Federal Agency for Science and Innovations (Russia), Weizmann Institute of Science (Israel) and industrial partners including Procter & Gamble, Philips, General Electrics, Unilever and other (with a total cumulative budget of over $16M). Prof. Meglinski is a Fellow of the Institute of Physics (London, UK) and Fellow of SPIE.

Biomedical applications of biophotonics include light interactions in medicine and biology for the purposes of health care. Diagnostic biophotonics. Diagnostic biophotonics is used to detect diseases in their initial stages before actual medical symptoms occur in patients.Â Cellular level diagnosis: Sophisticated optical technologies involving lasers, and photonic and biophotonic applications in medicine provide assistance in observing and identifying cellular biochemistry and their functions, organ integrity, and the characteristics of tissues. Optical endoscopes: In medical applications, the combination of optical fibers and endoscopes is used for less invasive imaging and surgery of internal organs. Molecular probes Biophotonic Solutions. 11 Molecular probes The SBMS Experience commercialisation 1990 1987 1990 1992 2004 â€“ recent work.Â 19 PBG optical waveguide Nano-VCSEL Laser Integrated Biophotonic Sensors Alternative approaches to high-sensitivity, multiplexed biophotonic sensors: resonance condition for high sensitivity (e.g. dual-stripe mode-locked laser) spatial readout exploit bio-nano size match â€˜newâ€™ operational modes e.g. photonic bandgaps (PBG) Photonic Bandgap Biosensor. Share and download educational presentations online.Â Related Grant Applications MRC Capacity Building Area Studentships "Intracellular imaging/dynamics" 2 PhD studentships EPSRC Application: â€œNanoelectronic Circuits in silicon-on-insulator â€¦â€ Sweeney and Reed integration of optoelectronics with Si Platform applications including biosensing EU Framework 6 Application: â€œGallium Nitride Epitaxy and Devices for New Applicationsâ€ FP6 (Thales) Sweeney, Sale, Adams, Hosea integration of wide-gap light-emitting diodes with passive waveguides and microfluidics, and applications including biosensing Nanobio-electronics Mendoza - nanotubes for EE