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Development of a noninvasive optical technique to visualize physiological functions inside animal bodies

Abstract:

Leveraging the deep penetration capability of near-infrared (NIR) light through the skin, we are able to noninvasively visualize the subcutaneous blood vessel structure. However, deep-seated structures suffer from severe blurring due to intense light scattering within body tissues. To address this, we have devised scattering suppression techniques enabling the acquisition of clear three-dimensional (3D) images of absorbing structures within turbid media, such as the blood vessel network inside animal bodies. In transillumination imaging, we can effectively mitigate diffusely propagated light components by selectively detecting near-axis scattered light. In addition, we can achieve superior blur reduction by employing a depth-dependent point spread function (PSF) derived from the diffusion approximation to the energy transfer equation. Moreover, this PSF facilitates deep-learning techniques, generating abundant training pairs of both unblurred and corresponding blurred images at various depths below the skin surface. Through neural networks trained on this dataset, we successfully reconstruct clear 3D images from a single blurred image, even when the depth of the absorbing structure remains unknown. Experimental validation, involving studies with both animal and human subjects, underscores the validity and versatility of our developed techniques. Expanding beyond structural imaging, we extend this methodology to functional imaging, enabling visualization of physiological changes occurring beneath the skin surface. By utilizing NIR light to measure physiological parameters like oxygen saturation within subcutaneous blood vessels, our technique becomes a valuable biomedical tool with applications in dermatology.

Biography

Koichi Shimizu received M.S. (1976) and Ph.D. (1979) degrees, from University of Washington, Seattle, USA. He was Research Associate in University of Washington 1974-79. He was an Assistant-, an Associate- Professors, and a Professor in Hokkaido University, Sapporo, Japan in 1979-2016. He is currently a Professor Emeritus of Hokkaido University, Japan, an Invited Research Professor of Waseda University, Japan and a Professor of Xidian University, Xi'an, China. He has been engaged in the studies of biomedical engineering. He served as associate editors of IEEE Trans. ITB in 1999–2007 and Advanced Imaging from 2023. He has been a Fellow of the Electromagnetics Academy, and an editorial board member of Scientific Reports, Nature.