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3D Imaging of Turbid Medium from Single-shot Transillumination Image
— For macroscopic imaging of animal body —

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Internal structures of animal bodies can be visualized in near-infrared transillumination imaging (NIR-TI). Functional imaging is also possible using the principle of spectroscopy. However, the image of a deep-seated structure is blurred severely because of strong light scattering in body tissues. The image only shows the structure close to the observed surface. The vein patterns obtained using current vein viewers are only contrast-enhanced images of peripheral veins. These limitations of shallow imaging and two-dimensional (2D) imaging have hindered the widespread adoption of NIR-TI in medical fields that require useful macroscopic body imaging.

To overcome these limitations, NIR-TI must be advanced to 3D imaging. In recent decades, various attempts have been made for depth-resolved optical imaging through body tissue [1, 2]. Among them, diffuse optical tomography and acousto-optic imaging techniques are applicable to macroscopic body imaging. Although they are useful, they require not only large computational effort and complicated instrumentation, but also direct contact with the human body. NIR-TI does not have these constraints. Therefore, if we can solve the problem of scattering blur and attain 3D imaging, then NIR-TI can add another tool that is widely applicable to various medical fields.

To provide another modality for three-dimensional (3D) medical imaging, new techniques were developed [3] to reconstruct a 3D structure in a turbid medium from a single blurred 2D image obtained in NIR-TI. One technique uses 1D information of a curvilinear absorber, or the intensity profile across the absorber image. Profiles in different conditions are calculated by convolution with the depth-dependent point spread function (PSF) of the transillumination image [4]. In databanks, profiles are stored as lookup tables to connect the contrast and spread of the profile to the absorber depth. One-to-one correspondence from the contrast and spread to the absorber depth and thickness were newly found.

Another developed technique uses 2D information of the transillumination image of a volumetric absorber. A blurred 2D image is deconvolved with the depth-dependent PSF [4], thereby producing many images with points of focus on different parts. The depth of the image part can be estimated by searching the deconvolved images for the image part in the best focus. To suppress difficulties of high-spatial-frequency noise, we applied a noise-robust focus stacking method. Experimentation (Fig.1) verified the feasibility of the proposed techniques, and suggested their applicability to curvilinear and volumetric absorbers such as blood vessel networks and cancerous lesions in tissues.

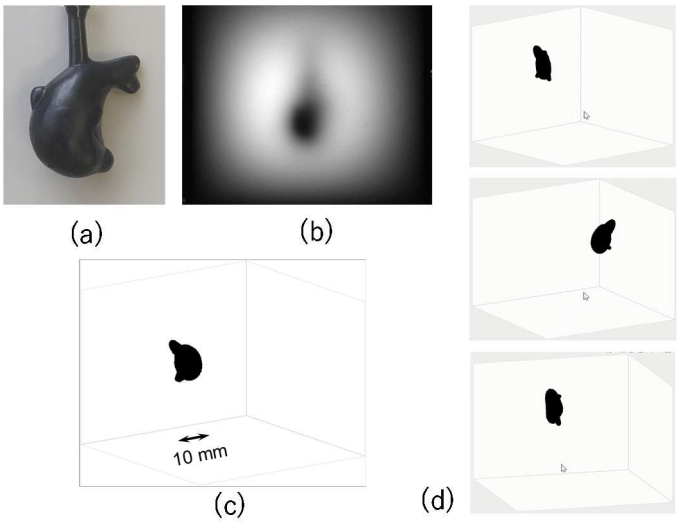

Figure 1. Clear 3D reconstruction from a single blurred image in a turbid medium: (a) object in air, (b) image in NIR-TI, (c) reconstructed image, (d) from different view angles.

References

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