学 位 論 文 内 容 の 要 旨

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学 位 論 文 題 名

Realization of 3D image reconstruction from transillumination images of animal body
（生体透視像からの 3D 像再構成の実現）

Three-dimensional (3D) imaging with X-ray or MRI has contributed greatly not only to medical diagnosis, but also to life science. The number of experimental animals killed for experimentation would be reduced if the animals ’ internal structures can be visualized non-invasively. In transillumination imaging using near-infrared (NIR) light, the location of internal bleeding, infection, and angiogenesis can be visualized. Functional imaging is also possible using spectroscopic principles. With specific contrast media, the usefulness of NIR imaging is expanded significantly. However, the NIR transillumination technique has not been used widely. The major reason for that relative lack of use is the difficulty of the strong scattering in tissues. In transillumination images, the deeper structure is blurred and cannot be differentiated from the shallower and less-absorbing structure. To overcome this problem, great effort has been undertaken to develop optical computed tomography (optical CT) techniques. The typical technique for a macroscopic structure is diffuse optical tomography (DOT). Using this technique, cross-sectional imaging of human breasts and infant heads was achieved. Once the cross-sectional images become available, 3D imaging is possible. However, current techniques require great computational effort such as finite element method calculation, and large devices such as numerous fiber bundles around the object body.

It would be possible to reconstruct the 3D structure with a common filtered back-projection algorithm and with a CCD or CMOS camera if the scattering effect in transillumination images can be suppressed effectively. They require much simpler and more compact device as well as much less computational effort. This study proposes the 3D imaging of internal absorbing structure of a small experimental animal from two-dimensional (2D) NIR transillumination images using new scattering suppression techniques. This thesis presents the principle, implementation, and the results to show the feasibility of the proposed method.

For scattering suppression, the deconvolution technique using the point spread function (PSF) is effective. In previous study, the PSF for the light source located inside the medium had been derived by applying the diffusion approximation to the equation of transfer. With a known depth of the light source in a diffuse medium, the light distribution can be recovered clearly through an interstitial tissue by the deconvolution with this PSF. Therefore, realization of the 3D imaging from the transillumination images can be expected if this light-source PSF can be applied to the transillumination image of light-absorbing structure. Through theoretical and experimental study, the applicability of the PSF for the light source to the transillumination images of the light-absorbing structure was confirmed. The

effectiveness of this technique was also confirmed in the experiments with a tissue-equivalent phantom and animal tissue.

The PSF is depth-dependent, and the technique explained above was applicable only for an object with known internal structure. To expand the applicability of this technique, new algorithms were devised. An observed transillumination image is deconvoluted with the PSFs of different depths. Then the deconvoluted images are summed up to produce a new image that serves as a projection image in cross-sectional reconstruction. The projection image contains the projection of the true absorption distribution and the incompletely deconvoluted projection as well. To suppress the effect of this erroneous projection, an erasing process was devised. An initial cross-sectional image is reconstructed from the projection images obtained from many orientations. It is used as a template to erase the erroneous distribution in the cross-section. After the application of this erasing process, a new improved projection image is formed in which the effect of the erroneous distribution is suppressed effectively. Using the projections from many orientations obtained in this process, an improved cross-sectional image can be reconstructed. With the cross-sectional images at different heights, the 3D image can be reconstructed.

The feasibility of the proposed technique was examined in a computer simulation and an experiment with a model phantom. The results demonstrated the effectiveness of the proposed technique. Finally, the applicability of the proposed technique to a living animal was examined. An anesthetized mouse was fixed in a transparent cylinder. To produce a transillumination image of good quality, a light trap in the cylinder was devised. Using the proposed technique, the 3D structure of the mouse abdomen was reconstructed. High-absorbing organs such as the kidneys and parts of the liver became visible.

Results of this study suggest that a new optical CT having different features from those of currently available techniques is possible. This simple system can provide a cross-sectional image and reconstruct the 3D structure of internal organ in the mouse body. It can provide a useful and safe tool for the functional imaging of internal organs of experimental animals and for optical CT imaging of the near-surface structure of a human body.