Feasibility Study for 3D Reconstruction of Internal Structure of Animal Body Using Near-Infrared Light

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Abstract — Using an array of near-infrared (NIR) LED’s, we can obtain transillumination images of an animal body and visualize the veins and arteries in the adult forearm as thick as 6 cm. To examine the feasibility of three dimensional (3D) reconstruction using these transillumination images, experiments were conducted to evaluate the image of an absorber in a tissue-equivalent phantom. An experimental system was designed to obtain a transillumination image of a model of blood vessels in the adult forearm. Imaging was accomplished with a high-resolution cooled digital CCD camera, placed at the opposite side of the phantom to the light source. The transillumination images were obtained with different depths of the absorber from the container wall.

Keywords — 3D reconstruction; turbid medium; transillumination; optical CT3.

I. INTRODUCTION

The importance of optical computed tomography (optical CT) in clinical applications has been recognized. However, it has not been widely used in practical applications. The intensity of transmitted light decreases rapidly as the object thickness increases. The image of the light-absorbing structure inside the body becomes severely blurred as its depth from the surface increases. To overcome these problems, we have devised some techniques to supply incident light to inside the body efficiently and to obtain transillumination image sensitively through a human body. Using these techniques, the veins and arteries were visualized in the adult forearm as thick as 6 cm [1-5].

With these 2D NIR transillumination images, we can expect to realize 3D optical CT of a human body. As the first step for the 3D imaging, we have conducted a basic study to examine the feasibility of this methodology. In this report, we present some preliminary results of the analysis on the detectable depth of an absorber in tissue-equivalent phantom.

I. MATERIALS AND METHODS

Measurement system: Figure 1 shows a schematic of the experimental system to obtain a transillumination image of the absorber in a cylindrical scattering medium. This phantom is a model of blood vessels in human body.

Fig. 1 Schematic of experimental system.
images were obtained with different depths of the absorber from the container wall.

**Phantom Model:** In this experiment, the scattering media with four kinds of absorption coefficient ($\mu_a$) were prepared. The scattering coefficient ($\mu_s'$) was made same in all the four phantoms, or $\mu_s'=1.0 / \text{mm}$. Intralipid suspension and black ink were mixed in distilled water to make tissue-equivalent medium ($\mu_s'=1.0 / \text{mm}$, $\mu_a=0.01–0.10 / \text{mm}$). It was contained in a cylindrical container (with 50 mm outer diameter) made of transparent polycarbonate. The wall thickness and the height of the container were 0.5 mm and 100 mm, respectively.

As an absorbing target structure, a cylindrical post with 5 mm diameter made of black-painted metal was used. This simulated a blood vessel in an adult arm. It was placed inside the medium at the far side of the container from the light source as shown in Fig. 1. Using a mechanical rotation system, the transillumination images were obtained from different directions around the curved surface of the cylinder.

**3D reconstruction from 2D images:** Prior to carrying out tomographic reconstruction, all images obtained were reviewed using an image processing program and corrections were made if necessary. For tomographic reconstruction and 3D reconstruction from 2D transillumination images, the techniques based on the principles of the filtered back-projection, the multi-view 3D reconstruction and the cone beam CT 3D reconstruction are used.

### II. RESULTS

Figure 2 shows the example of transillumination images of phantoms with different optical properties and the same absorber depth (1 mm).

![Fig. 2 Transillumination images of phantoms with different optical properties and the same absorber depth (1 mm).](image)

We calculated the contrast and sharpness at the center of transillumination images. Figure 3 shows the contrast (Michelson contrast) of the absorber image for different absorber depths and different $\mu_a$'s. The contrast decreases rapidly with the depth of the object absorber. However, the rate of the decrease is largely dependent on the $\mu_a$ of the scattering medium. The larger the $\mu_a$, the contrast decreases more rapidly.

![Fig. 3 Dependence of image contrast on $\mu_a$ of medium.](image)

Figure 4 shows the measured sharpness of the absorber image at 1 mm absorber depth. As the $\mu_a$ increases, the scattering effect is suppressed, and the image sharpness increases.

![Fig. 4 Dependence of sharpness on $\mu_a$ of medium.](image)

These results suggest that we should design the imaging system to optimize its performance for the specific $\mu_s'$ and $\mu_a$ of the scattering medium around the target object.