Image Quality Assessment of 3D Ultrasound Images Based on SSIM

SSIM による三次元超音波画像の画質評価

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1 Introduction

A method for quantitatively evaluating image quality, which is one of the important performances of 3D ultrasound imaging systems used in the medical field, has not been established, and it is not possible to evaluate the system based on a unified standard.

In this paper, we will examine a method for quantitatively evaluating the image quality of ultrasound images using SSIM (Structural Similarity), which is generally used for image quality evaluation of photographs.

2 Simulation overview

In this paper, simulations were performed using MATLAB 2020a, which is numerical analysis software, and FieldII, which is an acoustic propagation simulator that operates on MATLAB. The imaging system assumes a noise-free situation with a one-dimensional linear array. The imaging region was the abdomen of the human body and was within the red frame in **Fig. 1**.
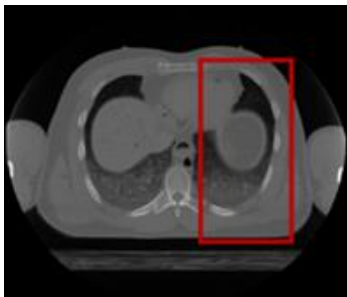

Fig.1 Imaging region.

3 Create a Numerical Phantom

A Numerical Phantom is a data file that defines the coordinates and reflectance of many scatterers arranged at random positions in the imaging region. The reflectance of ultrasound waves is determined by the acoustic impedance (density $\rho \times$ sound velocity c). The reflectance distribution in the living body is obtained by spatial differentiation with respect to the propagation direction of acoustic impedance. If the speed of sound c in the living body is constant, the reflectance is determined by the difference in density ρ. On the other hand, the pixel value of the X-ray CT image is proportional to the density of the tissue. Therefore, the pixel value is normalized to the maximum value, converted to a value from 0 to 1, and the difference in the depth direction is calculated to obtain the reflectance data of the Numerical Phantom.

4 Create an ideal image

In this paper, in order to realize the spread of the image with respect to the point object of the actual ultrasound image, by convolution of the Numerical Phantom and the ideal point spread function (Gaussian function PSF) given by the Gaussian function, Generate an ideal image.

5 SSIM(Structural Similarity)

SSIM is an index proposed by Wang et al.[1] That compares the similarity between two images based on changes in brightness value, contrast, and image structure. The SSIM is

expressed as follows.

$$SSIM(x,y) = [l(x,y)]^{\alpha} \cdot [c(x,y)]^{\beta} \cdot [s(x,y)]^{\gamma} \quad (1)$$

$$SSIM(x,y) = \frac{(2\mu_x\mu_y + C_1)(2\sigma_{xy} + C_2)}{(\mu_x^2 + \mu_y^2 + C_2)(\sigma_x^2 + \sigma_y^2 + C_2)} \quad (2)$$

SSIM is calculated in a small area divided into 8 * 8 * 8 pixels. The evaluation value of the entire image is obtained by averaging the SSIM evaluation values of all the small areas, and this is called MSSIM (Mean SSIM). In this paper, MSSIM was used as the evaluation value of the entire image.

6 Simulation Results and Discussions

Check if the created test image and ideal image can be evaluated using SSIM. This time, we created an image with reduced image quality by changing the two parameters of the number of driving elements and the active region length of the ultrasound array probe.

6.1 Simulation1

The simulation is performed with the active region length fixed at 15 mm and the number of driving elements set to 6,16,32,64,128,256. The simulation results are shown in **Fig. 2** and **Fig. 3**.
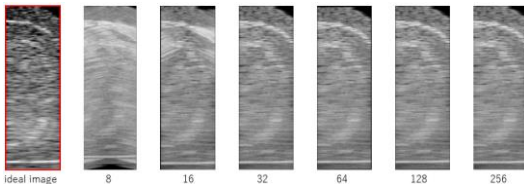

Fig.2 Ideal image and image obtained by each driving element number.
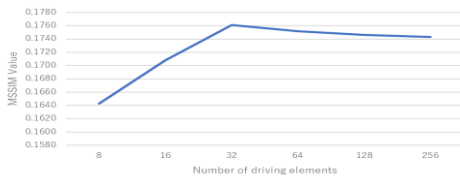

Fig.3 Transition of MSSIM value with respect to the number of driving elements.

It was confirmed that the MSSIM value decreased when the number of driving elements was reduced. In addition, when the number of driving elements was 32 or more, the transition of the MSSIM value was almost flat.

6.2 Simulation2

The simulation is performed with the number of driving elements fixed at 32 and the active region length set to 5,10,15,20,25,30 mm. The simulation results are shown in **Fig. 4** and **Fig. 5**.
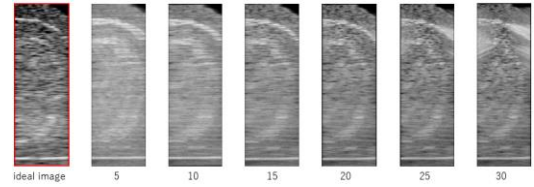

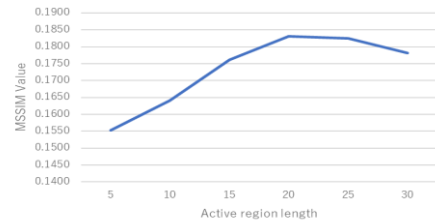Fig.4 Ideal image and image obtained with each active region length.

Fig.5 Transition of MSSIM value with respect to active region length.

It was confirmed that the MSSIM value decreased when the active area length was 15 mm or less and 30 mm. The reason why the MSSIM value decreases when the active region length is if 30 mm is that the number of driving elements is fixed at 32, so it is thought that the feeling of the driving elements becomes wider as the active region length is increased.

7 Summary

A Numerical Phantom was created based on the X-ray CT image, and 3D ultrasound imaging was performed. In addition, we were able to show the possibility of quantitative evaluation of image quality by comparing the 3D image obtained by the Gaussian functional PSF and the ultrasound image using SSIM.

References

1. Z. Wang, A. C. Bovik, H. R. Sheikh, E.P.Simoncelli,: IEEE Trans. Image Process (2004) p. 600

2. Jørgen Arendt Jensen, Peter Munk : Acoustical Imaging (1997) p. 75