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Utilizing Scattered X-rays to assist CT Reconstruction using a Neural Network

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***Abstract*— A new Computed Tomography (CT) technique that incorporates scattered X-rays to achieve more accurate image reconstruction via a neural network is presented. For network learning, 20,000 input-output data pairs linking projections to cross-sectional images were generated using a Monte Carlo simulation provided in EGS5. Through numerical evaluations, we confirmed that the accuracy of image reconstruction is improved using both the primary and scattered X-rays.**

***Clinical Relevance*— Utilizing scattered X-rays for CT reconstruction, which are removed in conventional methods, can significantly reduce patient dose.**

I. INTRODUCTION

X-ray CT is a powerful diagnostic tool for understanding the internal structure of the human body. Typically, scattered X-rays are removed by an anti-scatter grid, as they interfere with conventional reconstruction methods. However, since scattered X-rays are generated by interactions with potential objects of interest, they may provide useful information about the objects. Based on this idea, Toda et al. [1] introduced a simplified mathematical model, called the T-junction model, and theoretically demonstrated its ability to improve reconstruction accuracy by incorporating scattered X-rays. Subsequently, Ito et al. [2] provided a neural network method to verify the use of scattered X-rays in large-scale systems. While this method can accurately reconstruct images, the image size was only 6×6, and the image densities were set to random values.

In this study, we verified the use of scattered X-rays for the reconstruction of a large image (16×16) using a neural network method. The neural network was trained using 20,000 image-projection data pairs generated by a Monte Carlo simulation.

II. METHODS

To train the neural network, 20,000 virtual water-filled phantoms with dimensions 20×20×20 [cm] were generated. Of these phantoms, 10,000 contained small randomly distributed cubes with random densities and sizes, while the remaining 10,000 phantoms contained small randomly distributed spheres. The image-projection data pairs were obtained using a Monte Carlo simulation. For comparison, two reconstruction methods were tested; one utilizing the proposed method and the other utilizing the conventional method. For the proposed method, five flat detectors were deployed around the object, in addition to the primary detector, to capture the scattered X-rays. The conventional method employed only the primary detector. The neural network received the data from these detectors and was trained to output the true densities of the objects. The network had one hidden layer with a sigmoid activation function, and the generated dataset was split 90:10 for training and testing, respectively. The performance of the methods was evaluated using the root mean square error (RMSE) and correlation coefficient (CC).

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III. RESULTS

The conventional reconstruction produced a CC and RMSE of 0.838 and 0.378, respectively, while the proposed reconstruction method produced a CC and RMSE of 0.844 and 0.362, respectively. Fig. 1 shows the reconstructed images of a virtual phantom containing spheres.

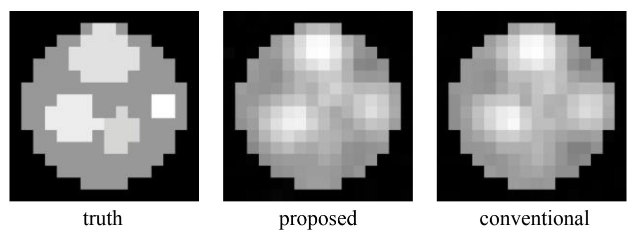

Figure 1. Example of a reconstruted image

IV. DISCUSSION & CONCLUSION

In this study, we verified the accuracy of CT images reconstructed by incorporating scattered X-ray data. To this end, we utilized a neural network to estimate a cross-section of the virtual phantoms. The results obtained demonstrated that the accuracy of reconstruction in terms of the RMSE and CC was improved by additionally incorporating the scattered X-rays, rather than the primary X-rays alone, as in conventional CT. Therefore, the proposed method for CT image reconstruction can reduce the exposure dose of the patient by incorporating the scattered X-ray information to improve reconstruction accuracy.

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