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Noise Reduction of Single-Shot Dual-Energy Images

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1. Introduction

Although radiography is an old technology that has been developed, it still remains the mainstream in diagnosis of pathologies due to its low cost and dose characteristics. The technical advance of digital radiography through the introduction of high-resolution large flat-panel detectors (FPDs) made this possible.

However, limitation of radiography in diagnosis still remain. Since radiography projects three-dimensional human anatomical information into a two-dimensional image, lesions can be hidden or superimposed by normal tissue or bone [1]. This hinders lesion conspicuity.

To enhance lesion conspicuity in radiography, dual-energy digital radiography has been introduced. As shown in Fig. 1, this technique enhances object of interest within a two-dimensional radiograph by combining two images acquired in different x-ray energy circumstance [2]. A common way to decomposing dual-energy image is weighted log-subtraction of two images obtained at different x-ray energy conditions.

While this process maximizes lesion conspicuity by removing anatomical noise, it amplifies the quantum noise of the resulting dual-energy images as shown in Fig. 2. The amplification of quantum noise in dual-energy images has motivated development of algorithms that reduce amplified noise as a result of weighted log-subtraction [3]. Studies applying these algorithms to dual-shot dual-energy techniques have been performed [4]. It is necessary to perform quantitative evaluation in the single-shot dual-energy imaging. The single-shot technique is able to solve motion artifact problems in the dual-shot technique, but it also has a disadvantage in larger quantum noise amplification [5]. Therefore, it is important to apply the noise reduction algorithm.

The purpose of this study is to evaluate performance of noise reduction algorithms for single-shot dual-energy imaging. In addition, we quantitatively compare noise characteristics between noise reduction algorithms by experimental method.

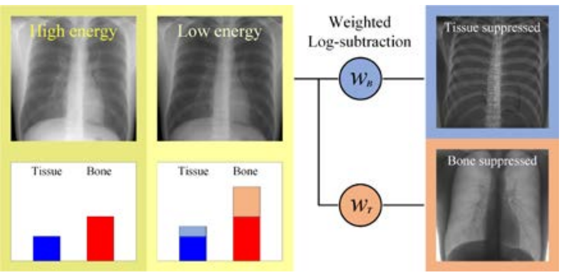

Fig. 1. Concept of weighted log-subtraction for dual-energy imaging.

2. Materials and Methods

For this study, a single-shot detector that stacked two FPDs was used. Each FPD consist of complementary metal-oxide semiconductor matrix addressed photodiode array. The scintillator of rear detector is thicker to achieve high quantum efficiency with the higher energy spectrum. A thin copper sheet was placed between the two FPDs to improve spectral separation.

2.1 Weighted log-subtraction

The most prevalent form of dual-energy image decomposition is weighted log-subtraction of low- and high-energy images.

$$I_{DE}(x,y) = -wI_L(x,y) + I_H(x,y) \quad (1)$$

where, w is tissue cancellation parameter, I_L and I_H are the low- and high-energy log images, respectively.

2.2 Simple smoothing

In dual-energy image decomposed by log-subtraction, the most contributor of quantum noise is the high-energy image. A low pass filter applied to the high energy image prior to subtraction can mitigate this problem [3,4,6]. The resulting algorithm called "simple smoothing" of the high-energy image, expressed as

$$I_{SS}(x,y) = -wI_L(x,y) + I_H(x,y) * h_{LPF}(x,y) \quad (2)$$

where h_{LPF} denotes the low pass filter.

2.3 Anti-correlated noise reduction

The anti-correlated noise reduction algorithm is based

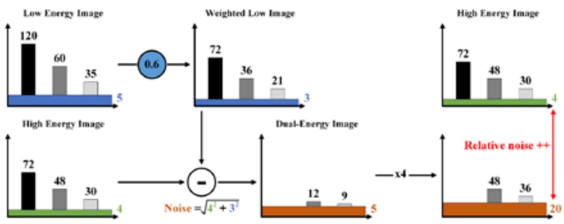

Fig. 2. A scheme of quantum noise amplification in dual-energy imaging.

on the fact that quantum noise in the soft tissue image and bone image is anti-correlated. In decomposing a soft tissue or bone image, the algorithm applies a high pass filter to the complementary image (i.e., the bone image or the soft tissue image, respectively). This can leave only quantum noise and little artifact in complementary image, where the quantum noise is anti-correlated to the quantum noise in the original dual-energy image The dual-energy image and filtered complementary image are then added, weighted by a parameter, w_n. The soft tissue image decomposed by anti-correlated noise reduction algorithm is thus

$$I_{ACNR}(x,y) = I_{DE}(x,y) + w_n I_{DE}^c(x,y) * h_{HPF}(x,y) \quad (3)$$

where

$$I_{DE}^c(x,y) = w_c I_L(x,y) - I_H(x,y) \quad (4)$$

is the complementary image, w_c is the tissue cancellation parameter for the complementary image, and h_{LPF} is the high pass filter. w_n is able to determined quantitatively through the minimization of quantum noise [3,4,7].

3. Preliminary results

The noise reduced dual-energy bone images of chest phantom are shown in Fig. 3. As can be seen form the figure, the quantum noise in the dual-energy is definitely reduced in Fig 3(b) and (c). Particularly in (c), the performance of dual-energy bone image is improved compared to (a).

4. Further study

We will apply several noise reduction algorithms for single-shot dual-energy image and evaluate the performance of noise reduction in single-shot dual-energy imaging by an experimental method. Also, quantitative optimization of parameters pertinent to algorithms will be performed. The performance of each optimized algorithm is compared using quantitative index such as noise power spectrum.

ACKNOWLEDGMENTS

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REFERENCES

[1] H. Kashani, C. A. Varon, N. S. Paul, G. J. Gang, R. V. Metter, J. Yorkston, J. H. Siewerdsen, Diagnostic performance of a prototype dual-energy chest imaging system: ROC analysis, Academic radiology, Vol. 17, No. 3, pp. 298-308, 2010.

[2] R. E. Alvarez, and A. Macovski, Energy-selective reconstructions in x-ray computerised tomography, Physics in medicine and biology, Vol. 21, No. 5, pp.733-744, 1976.

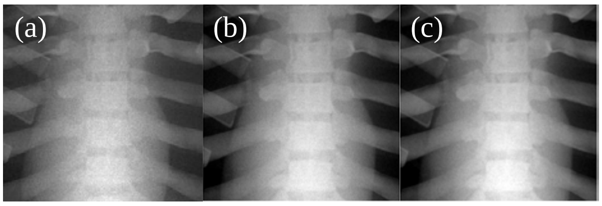

Fig. 3. Enlarged dual-energy bone images of chest phantom. (a) weighted log subtraction, (b) simple smoothing, and (c) anti-correlated noise reduction.

[3] S. Richard, and J. H. Siewerdsen, Cascaded systems analysis of noise reduction algorithms in dual-energy imaging, Medical physics, Vol. 35, No. 2, pp. 586-601, 2008.

[4] R. J. Warp, and J. T. Dobbins, Quantitative evaluation of noise reduction strategies in dual-energy imaging, Medical physics, Vol. 30, No. 2, pp. 190-198, 2003.

[5] J. C. Han, H. K. Kim, D. W. Kim, S. Yun, H. Youn, S. Kam, J. Tanguay, and I. A. Cunningham, Single-shot dual-energy x-ray imaging with a flat-panel sandwich detector for preclinical imaging, Current Applied Physics, Vol. 14, No. 12, pp. 1734-1742, 2014.

[6] P. C. Johns, and M. J. Yaffe, Theoretical optimization of dual-energy x-ray imaging with application to mammography, Medical physics, Vol. 12, No. 3, pp. 289-296, 1985.

[7] W. A. Kalender, E. Klotz, and L. Kostaridou, An algorithm for noise suppression in dual energy CT material density images, IEEE transactions on medical imaging, Vol. 7, No. 3, pp. 218-224, 1988.