Maximum-Likelihood Weight Parameters for Reconstructing Dual-Energy Radiography

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1. Introduction

Radiography is the most widely used tool for the diagnosis of internal diseases such as lesions and tumors. However, it generally suffers from low contrast of lesions due to the overlapped background anatomies. Computed tomography (CT) can solve this spatial overlap problem but it requires significant patient dose [1]. Another alternative to improve lesion contrast is the dual-energy imaging (DEI) technique. DEI is based on the fact that the attenuation coefficients of materials depend on the incident x-ray energy, and can provide bone- or soft tissue-suppressed radiographs by weighted subtraction of two images acquired with low- and high-energy x-ray spectra [2]. Therefore, the weight for the DEI procedure has the most important role to enhance the conspicuity of lesions in the resultant DE radiographs.

In this study, we introduce a method to determine the pixel-wise weights for the DEI process. Based on DE images of a postmortem mouse, the performance of the proposed method is comparatively analyzed with the conventional global weight method.

2. Methods

2.1 Global weight method

The global weight is the most generally used method for DEI and is used for the conventional weighted-log-subtraction algorithm [2,3].

$$I_{\mathrm{DE}} = w \cdot \log(I_L) - \log(I_H) \quad (1)$$

where I_{DE}, I_L, and I_H respectively denote the dual-, low-, and high-energy images and w is a global weight that minimizes contrast between the region to suppress and the background.

2.2 Pixel-wise weight method

The pixel-wise weight method consists of several steps to reduce the computational burden. First, low- and high-energy images are resized to a smaller size to avoid artifacts due to the misalignment. Then DE operation is performed with initial weight w', which is provided by the look-up table for a given energy range.

$$I = \frac{I_H}{(I_L)^{w'}}. \quad (2)$$

As a next step, the gradient and localization masks are calculated for the calculation of the characteristic mask.

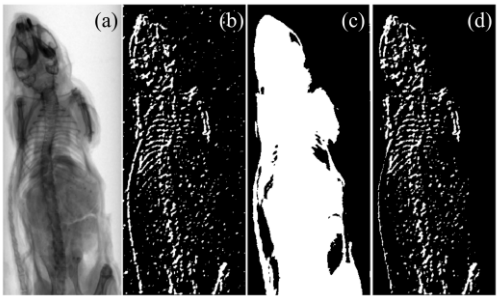

Fig. 1. (a) The projection image of a postmortem mouse and corresponding (b) gradient, (c) localization, and (d) characteristic masks for the pixel-wise weight method.

The resultant image I from Eq. (2) is differentiated to acquire a gradient image and the gradient image is converted to a binary image using the threshold to remove low-frequency features. A median filter can be used to remove high-frequency noise in the gradient image. The localization mask, which is a binary image representing the regions where the object exists, can be obtained by applying a threshold of the average pixel value to I_L. Then a characteristic mask that has only high-frequency features of the object can be obtained by multiplying the gradient and the localization masks. Finally, a characteristic mask is multiplied to low- and high-energy images and the pixel-wise weights are determined to minimize gradients, by applying Eq. (2).

2.3 Experimental

Low- and high-energy images for DEI are acquired for a postmortem mouse phantom, as shown in Fig. 1(a). An x-ray detector composed of 1024 × 512-formatted photodiode array (RadEye 1™, Teledyne Rad-icon Imaging Corp.) with a pixel pitch of 49 μm, and a 90 μm-thick gadolinium oxysulfide phosphor layer, and x-ray spectra in a range of 25 to 45 kVp produced from a tungsten target x-ray tube (XTF5011, Oxford Instruments, Oxfordshire, UK) are used for image acquisition.

3. Preliminary Results

Figs. 2 and 3 compares soft tissue- and bone-suppressed images obtained for various combinations of low- and high-energy images respectively. For soft tissue-suppression imaging, the combination of images with higher energy differences shows better DEI performance with less noise in a resultant image. Weights for DEI tended to increase with the decreasing

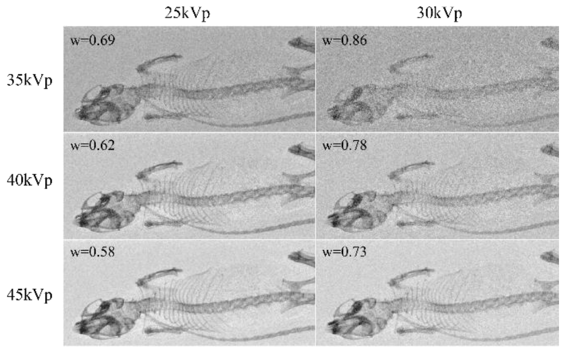

Fig. 2. Comparison of soft tissue-suppressed images obtained for various combinations of low- and high-energy images. Rows from top to bottom represent the tube voltage of 35, 40, 45 kVp used for the high-energy images, respectively. Columns from left to right represent the tube voltage of 25, 30 kVp used for the low-energy images, respectively. Numbers in the upper-left corner denote the global weight for DEI.

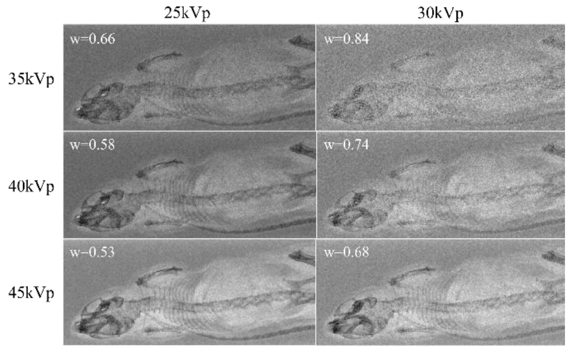

Fig. 3. Comparison of bone-suppressed images obtained for various combinations of low- and high-energy images. Rows from top to bottom represent the tube voltage of 35, 40, 45 kVp used for the high-energy images, respectively. Columns from left to right represent the tube voltage of 25, 30 kVp used for the low-energy images, respectively. Numbers in the upper-left corner denote the global weight for DEI.

energy difference. In contrast, the images with smaller energy differences show better noise performances for bone-suppression imaging, but the bone tissues are not suppressed enough. These poor DE performances may come from the low energy difference between low- and high-energy images.

4. Conclusions

A method to determine the pixel-wise weights for DEI has been introduced. As preliminary results, DEI for a postmortem mouse was performed by the conventional global weight method. The global weight method showed good results for soft-tissue suppression but was not suited for bone suppression. The pixel-wise weight method may be more efficient for bone suppression since it provides weights that minimize high-frequency features. More quantitative analysis for the various range of incident x-ray energies and the implementation of the pixel-wise weight method will be our future study.

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