Automatic Anatomically Adaptive Image Enhancement in Digital Chest Radiography

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ABSTRACT

We present an algorithm for automatic anatomically adaptive image enhancement of digital chest radiographs. Chest images were exposed using digital radiography system with a 0.143 mm pixel pitch, 14-bit gray levels, and 3121 X 3121 matrix size. A chest radiograph was automatically divided into two classes (lung field and mediastinum) by using a maximum likelihood method. Each pixel in an image was processed using fuzzy domain transformation and enhancement of both the dynamic range and local gray level variations. The lung fields were enhanced appropriately to visualize effectively vascular tissue, the bronchus, and lung tissue, etc as well as pneumothorax and other lung diseases at the same time with the desired mediastinum enhancement. A prototype implementation of the algorithm is undergoing trials in the clinical routine of radiology department of major Korean hospital.

Keywords: Automatic anatomically adaptive image enhancement, digital chest radiographs, maximum likelihood method, fuzzy domain transformation

1. INTRODUCTION

In digital Radiogrphy, various image proceesing algorithms have been used to increase the diagnostic utility of images. In the case of chest radiography, the goal of these algorithms is to reproduce faityfully or enhance both the lungs and the mediastinum in spite of their normally large difference in X-ray transmission. The mediastinum is often underexposed in routine chest radiographs. Therefore, the aim of automatic anatomically adaptive processing in chest radiography is to meet the different enhacement requirements of the lung field and the mediastinum at the same time.

Effective image enhacement for diagnostic purpose can be achieved by including certain basic human visual system properties ,which is able to discern details in image depending on the characteristics of the surrounding area. One of the most important properties is commonly known as the Weber's law[1]. As a direct consequence of Weber's law, image processing system must treat the darker regions of an image very carefully because a human observer would perceive any imperfections more easily here than in the brighter areas.

In this paper, We propose a thresholding technique that uses maximum likelihood method (proposed by R. A. Fisher) to automatically determine a gray-level threshold between the lung field and the mediastinum[2]. Further, Considering the uncertainty and fuzziness of the boundaries of tissue structures in chest radiograph, we propose to incorporate the concept of fuzzy logic into the enhancement method, thereby achieving better local adaptive enhancement.

2. MATERIALS AND METHODS

2.1. Overall Scheme

Chest images were exposed and processed using digital radiography system with a 0.143 mm pixel pitch, 14-bit gray levels, and 3121 X 3121 matrix size. A anatomic analysis to classify the chest image into two regions and aimage processing through fuzzy domain transformation and enhacement were carried using a developed worksation . The proposed algorithm was applied to chest PA and Lateral images

2.2. Anatomic analysis by maximum likelihood classification

The two regios of the lung field and mediastinum in the chest image were distinguished by a maximum likelihood classification. In this study, the lung field includes vascular tissue, the bronchus, and lung tissue, etc as well as pneumothorax and other lung diseases. The mediastinum defines mainly large structures, such as trachea, spine, and heart, and abdomen. Some of the lung filed is overlaped in the retrocardiac and subdiaphragmatic area.

The threshold technique to classify the lung field and mediastinum uses PDF(probability density funtion) that defines a distribution of image pixel density. The used maximum likely hood classification is statistic method based on the assumption that a random variable x is Gaussian with unknown mean. The case deviating this premise was solved through image processing in the fuzzy domain.

2.3. Fuzzy image processing

Fuzzy image processing is not a unique theory. It is a collection of different fuzzy approaches to image processing. Fuzzy image processing has three main stages: i) image fuzzification, ii) modification of membership values, iii) and image defuzzification. The coding of image data (fuzzification) and decoding of the results (defuzzification) are steps that make possible to process images with fuzzy techniques. The main power of fuzzy image processing is in the middle step (modification of membership values). After the image data are transforemd from gray-level plane to the membership plane (fuzzification), appropriate fuzzy techniques modify the membership values.

2.3.1. fuzzification (Fuzzy Domain Transformation)

Before performing image enhancement, we apply a fuzzy domain transformation that transform the gray level of each pixel in an image to a fuzzy membership value between 0 ~ 1. Usually, there is some degree of fuzziness in an image. If the fuzziness of an image is reduced, the objects in the image become more visible. Fuzzy membership is assigned to each pixel in order to determine the degree to which each pixel belong to a particular content, where x is the input gray level. In Fig.(1), m can be the lung/mediastinum gray-level threshold or a proper constant. The fuzzy transformation, $F(x)$, is illustrated in Fig.1.

When enhancing an image, it is necessary not only to adjust the dynamic range of the image, but also enhance the details in the image. The fuzzy domain transformation, $F_D(v)$, for the dynamic range of an imge is as follows :

$$F_D(v) = G(I(v) - M) \quad (1)$$

For input gray image $I(v)$, M is a proper constan (m). G(.) is a specific transformation, for instance, a trigonometric funton. The fuzzy domain transformation, $F_S(v)$, for the details of an Image is defined as follows:

$$F_S(v) = G(I(v) * HP(v)) \quad (2)$$

$I(v) * HP(v)$ is an image obtained by high-pass filtering.

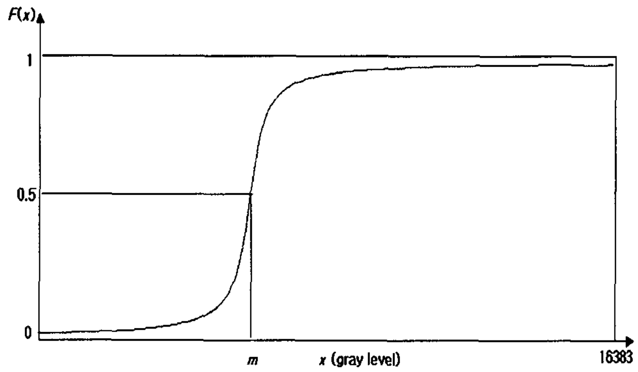


Fig. 1. Fuzzy domain transformation funtion.

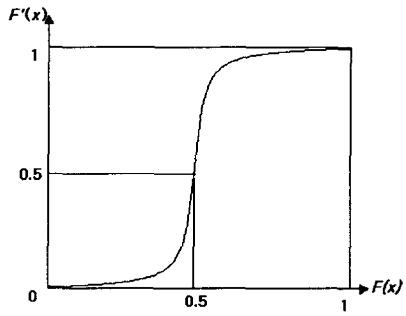


Fig.2. Fuzzy domain enhancement function.

2.3.2. Modification of membership values (Fuzzy Domain Enhancement)

After transformation the dynamic range and detail components of an image to the fuzzy domin, for fuzzy domain enhacement , $F(x)$ is transformed to $F'(x)$. Given the input gray level x, fuzzy domain enhancement is defined by the following function:

$$F'(x) = E(F(x)) \quad (3)$$

Where $E(x)$ is the enhacement funtion, which is S-shaped funcion, such as the logarithm or sine function. An example for the fuzzy domain enhancement $F'(x)$ is shown in Fig.2.

2.3.3. Defuzzification (Inverse Transformation)

After the dynamic range of an image is adjusted, and image details are enhanced in the fuzzy domain using Eq.(1), (2) and (3), the inverse transformation of the fuzzy domain data is applied to obtain a resulting enhanced image.

3. RESULTS AND CONCLUSION

We have developed an automatic threshold selection technique based on maximum likelihood classification to determine a lung/mediastinum gray-level threshold using the chest radiograph. Fig.3. illustrates a proper separation of the lung and mediastinum of the chest PA and Lateral Radiograph. We also proposed a fuzzy image processing technique for chest radiogrph. Fig.4. shows both unprocessed image and processed image of chest radiograph. With compared with Fig.4-a(unprocessed image), Fig.4-b(processed image) shows clear visualization of the nodules and vessels behind the heart and diagphram. The lung fields were enhanced appropriately to visualize effectively vascular tissue, the bronchus, and lung tissue, etc as well as pneumothorax and other lung diseases at the same time with the desired mediastinum enhancement.

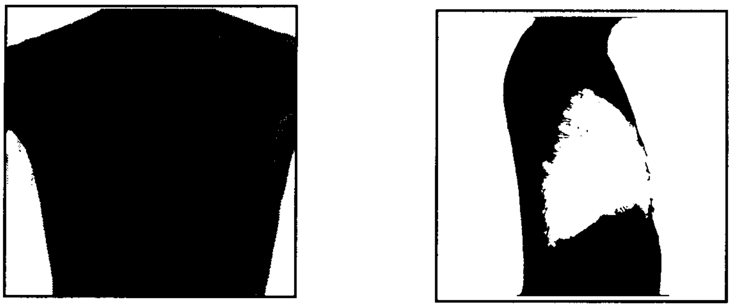
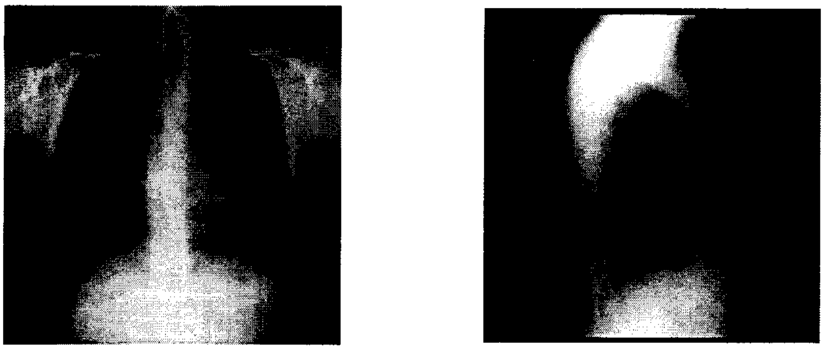
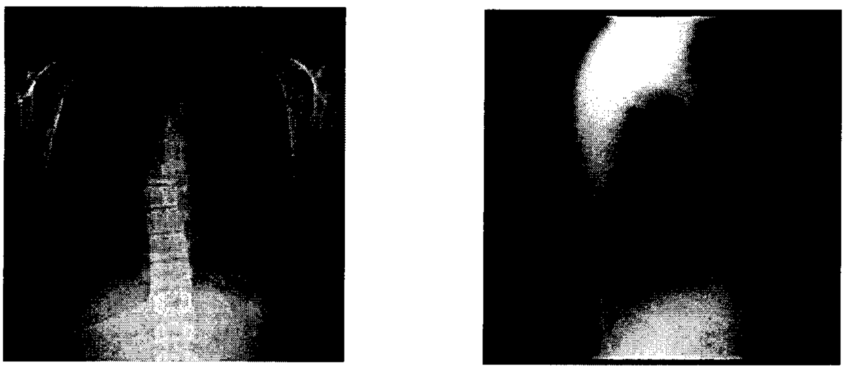


Fig.3. The binary imges representing the lung and mediastinum region obtained by the proposed method.



(a) Unprocessed images of the chest PA and Lateral Radiogrphs.



(b) Processed images of the chest PA and Lateral Radiogrph.

Fig.4. (a) Unprocessed(original) images of the chest Radiogrph, (b) Processed images of the chest radiograph by the proposed method.

Fig.5. shows comparision of lineplots across center of the heart on the unprocessed and processed image. Preserving the global contrast, edge enhancement was achieved in processed image.

Once the images are enhanced, the question of their quality arise. Generally, some measures of quality such as SNR, MSE and PSNR are used in image processing to ensure good quality. These measures, however, are not suitable for judgement of image quality if the obserber's demands should play the central role. The main reason is that there is no logical relatonship between such objective measures on the one side, and the subjective impression of human observer on the other side. The determination of diagnostic accuracy must be done with large multiobserber (ROC-type) studies using the appropriate mix of normal versus and abnormal patients and, subtle versus obvious disease. Such studies are currently underway in the clinical routine of radiology department of major Korean hospital.

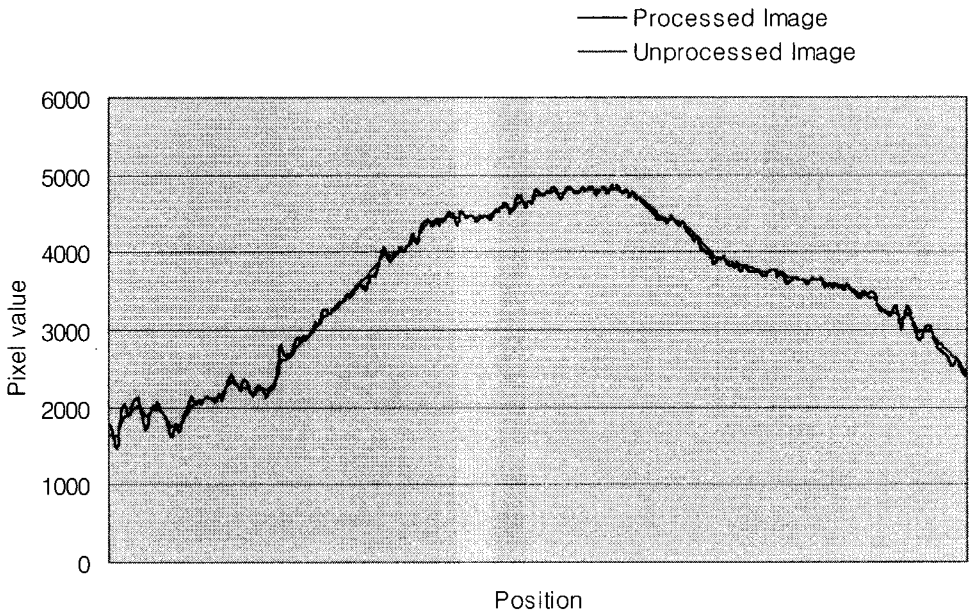


Fig.5 Comparision of lineplots across center of the heart on the unprocessed and processed image. Preserving the global contrast, edge enhancement was achieved in processed image.

4. REFERENCES

1. Richard D. Nawfel, Karen H.Chan, Douglas J. Wagenaar, and Philip F. Judy, "Evaluation of video gray-scale display", Med. Phys. 19 (3), pp. 561-567, 1992.
2. Michael F. McNitt-Gray, Member, IEEE, H.K. Huang, Senior Member, IEEE, and James W. Sayre, "Feature Selection in the pattern Classification Problem of Digital Chest Radiograph Segmentation.",IEEE Trans. Med. Imag., Vol. 14, No. 3, pp. 537-547, 1995.