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ORIGINAL ARTICLE

Using morphological transforms to enhance the contrast of medical images

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Abstract Medical imaging plays an important role in monitoring the patient's health condition and providing an effective treatment. However, the existence of several objects overlapping in an image and the close proximity of adjacent pixels values in medical images make the diagnostic process a difficult task. To cope with such problems, this paper presents a new method based on morphological transforms to enhance the quality of various medical images. In this method, a disk-shaped mask whose size fits that of the original input image is chosen for morphological operations. Afterward, the proposed filter from the Top-Hat transforms is applied to the image, using the chosen mask in a multi-step process. At each step, the size of the mask is increased. Consequently, an enhanced image is provided for each mask size. The number of required steps and the final enhanced image are determined based on the Contrast Improvement Ratio (CIR) measure. Indeed, this approach applies an exfoliation process on the images, in which one or several objects in the image are prominently manifested using morphological filter, hence provide an appropriate image for analysis. The results in this research indicate that the proposed approach makes a better contrast and works much better than the other existing methods in improving the quality of medical images.

1. Introduction

Medical images have an important role in diagnosing a disease and monitoring the effect of the selected treatments. In spite of the increasing progress in the methods of capturing these images, the produced images may not pose enough quality for an accurate diagnosis. Emergency situations, environmental noises, patients' special conditions in photography, lighting conditions and technical constraints of imaging devices are among the reasons why images may have low quality (1–3). In such cases, image enhancement techniques can be useful, especially when reimaging is impossible. These new techniques are used to repair the damaged images and to enhance their quality and contrast.

The method presented in (1) enhances a medical image using wavelet transformation. In this method, the high-frequency sub-images are decomposed using the Haar wavelet transform. Then, noise in the high-frequency sub-bands is reduced using soft-thresholding. Finally, the enhanced image is obtained using inverse wavelet transformation. Another

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method was presented for enhancing CT medical images based on Gaussian Scale Mixture (GSM) model for wavelet coefficients in multi-scale wavelet analysis in (4). In this method, first, noise is removed from the noisy image using Wiener filter. Then, through the qualitative analysis and classification of wavelet coefficients for the signal and noise, the wavelet's approximate distribution and statistical characteristics are described, combining GSM model for wavelet coefficient. This algorithm can enhance CT images whose noise is removed.

Another common method for medical image enhancement is histogram equalization (5) that enhances the contrast of image by increasing distribution of gray levels. This method does not necessarily obtain good results for all areas of an image because contrast enhancement may damage the image and the border areas. Because of this, there are different generalizations of this method to improve its performance (6,7). An algorithm for improving abdominal ultrasound images is proposed based on combination of histogram equalization and wavelet transformation in (8). This algorithm improves edges and surroundings of abdominal walls and has real time performance in dynamic applications.

Another method for medical image enhancement is Gamma correction (9). In this method, Gamma values of individual pixels are locally optimized by minimizing the homogeneity of co-occurrence matrix of the original image. The Gamma correction method enhances dynamic range and improves the image.

In (10) a morphological filter is proposed for sharpening medical images. In this method, after locating edges by gradient-based operators, a class of morphological filter is applied to sharpen the existing edges. In fact, morphology operators, through increasing and decreasing colors in different parts of an image, have an important role in processing and detecting various existing objects in the image. Locating edges in an image using morphology gradient is an example that has comparable performance with that of classic edge-detectors such as Canny and Sobel (11). In another method presented in (12), vessels in angiography images are enhanced based on their special patterns and morphological filters.

In capturing a medical image from body, since different organs are in various depths, the image does not have sound quality to be analyzed by the physician. For instance, in an image taken from chest by X-ray or ultrasound, organs such as skin, heart, lung, bone, ligaments, vessels, cartilage and lymphatic fluid appear simultaneously in an image while overlapping. Since each body organ has different structure or texture, we can prominent one or several of them in the image using morphological filter, hence provide an appropriate image for analysis. We name this as an exfoliation process. A similar function is performed in processing aerial images (taken by airplane or balloon) to remove clouds to achieve more clarity (13).

In the present study, a new method based on particular transforms of mathematical morphology is proposed to enhance the contrast of medical images. To do so, we first determine the shape and size of the desired mask for morphological transforms. Achieving suitable result and reducing computation time in morphology-based methods depend on the shape and size of a mask; so, the selected mask for a problem should be in appropriate shape and size. Generally, the desired mask is selected arbitrarily. Since disk-shaped mask is independent of changes in rotation, it is more commonly used in medical imaging compared to type of masks. The size of mask is also dependent on input image and can take different values for different images; therefore, in the proposed method, we use a disk-shaped mask to apply morphology transforms whose initial size is determined through trial and error and based on the input image. Then, exfoliation process is done by applying a filter of Top-Hat transforms using different masks in various radii. We will have an enhanced image per each mask. The best enhanced image is selected among the produced images using Contrast Improvement Ratio (CIR).

The organization of the paper is as follows: Section 2 introduces the images under study. Section 3 explains general mechanisms of mathematical morphology method such as operators, selecting proper mask and Top-Hat transforms and CIR. In Section 4, the proposed algorithm is described. The result of applying the proposed method and its comparison with other improvement methods is analyzed in Section 5 and conclusion will be the last section.

2. The medical images under study

The medical images used in this paper are CT-Scan and X-ray images. The CT-Scan images have been taken from different parts of body such as chest, abdomen and brain which are used by a physician to determine skeletal problems, size and location of a tumor and diseases of blood vessels; and give guidelines for surgical processes and chemotherapy treatments for cancer. The X-ray images were taken from foot, hand and chest. These images can also be enhanced using the proposed method. The CT-Scan and radiology images used in this paper are in resolution of 72 pixel/in.

3. Mathematical morphology

Methods of mathematical morphology act based on the structural properties of objects. These methods use mathematical principles and relationships between categories to extract the components of an image, which are useful in describing the shape of zones. Morphological operators are nonlinear, and two sets of data are their input. The first set contains the original image and the second one describes the structural element (mask). The original image is binary or in gray level and the mask is a matrix containing zero and one values (12).

It is after applying the final image to the morphological operators that a new value for each pixel is obtained through sliding the mask on the original image. Value 1 in each mask indicates effectiveness and value 0 indicates ineffectiveness in the final image. Different formats can be selected to form a mask. Fig. 1 shows a disk-shaped mask with radius of 4 (9 * 9 matrix).

$$
\begin{matrix}
0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 1 & 1 & 1 & 1 & 0 & 0 \\
0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 \\
0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 \\
1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\
0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 \\
0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 \\
0 & 0 & 1 & 1 & 1 & 1 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0
\end{matrix}
$$

Fig. 1 Disk-shaped structural element (mask) with radius of 4.