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Enhancement Algorithm Combining Pseudocolor Processing and Marker-based Watershed Transform for Medical Image

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Abstract. Medical images play a very important role in clinical medicine. They often have the features of low contrast, narrow gray scale and edge blurring between tissues. Aimed at the disadvantages, the paper presents a new medical image enhancement algorithm combining pseudocolor processing and marker-based watershed transform. The new algorithm and traditional pseudocolor processing in frequency domain are implemented using MATLAB, and their effectivity is evaluated by two parameters, mean and entropy. Results show that the proposed enhancement algorithm can improve the visual effect of different types of medical images, especially for the tissues in the low contrast regions in the image. The output image is more suitable for doctor's diagnosing. The algorithm has been used in the medical image fusion system we developed, and the performance is very satisfactory.

Introduction

Image enhancement is one of the most attractive fields of digital image processing. Generally, image enhancement methods include gray scale transformation, image smoothing, image sharpening and pseudocolor processing. *Pseudocolor image processing* consists of assigning colors to gray values based on a specified criterion[1]. It makes use of the sensitiveness of human's eyes to color, and improves the image quality greatly. These methods are used widely in many application areas.

Medical images play a very important role in clinical medicine. Almost all of the medical images are gray level images, and they have the features of low illumination contrast and narrow gray scale. Recently, with the improvement of computational speed of computer, color enhancement of diagnostic information has become a common procedure in the field of medical imaging. More and more scholars have make great efforts to research and develop the pseudocolor processing techniques in order to enhance the quality of medical images and raise the accuracy of diagnosing[2,3].

The study aims to develop an effective enhancement algorithm which can improve the visual effect of the medical images greatly and give more detail information for doctors' diagnosing.

Gray-level to Color Transformations in Frequency Domain

The methods for pseudocolor processing include spatial domain and frequency domain. Intensity slicing and gray level to color transformations both belong to spatial domain methods. The former uses some planes slicing gray scale into intervals and assigns different color to each interval. It is a powerful aid in visualization when the exact values of gray levels interested in are known. The latter performs three independent transformations on the gray levels of any input pixel. The color content of the result image depends on the nature of the transformation functions.

Compared with the methods in spatial domain, the techniques in frequency domain also make use of the three primary colors, but assign colors to each region according to the frequency components of the original image. This method can be described as the equation

$$g(x,y) = EH(h(x,y)\cdot f(x,y)) \quad (1)$$

where, $f(x,y)$ is the original image, $h(x,y)$ is the filtering function in frequency domain, $g(x,y)$ is the output image, and EH is the operators for enhancement. Firstly, change $f(x,y)$ from spatial to frequency domain using the forward transform. Perform three filters that have different transfer characteristics on the frequency components. Then inverse transforms are operated on the three independent results, obtain three monochrome images representing different frequency components, and perform additional process. Thirdly, the results are fed separately into the red, green, and blue channels, and get the final color image $g(x,y)$ .The whole procedure of gray level to color transformations is shown in Fig.1.

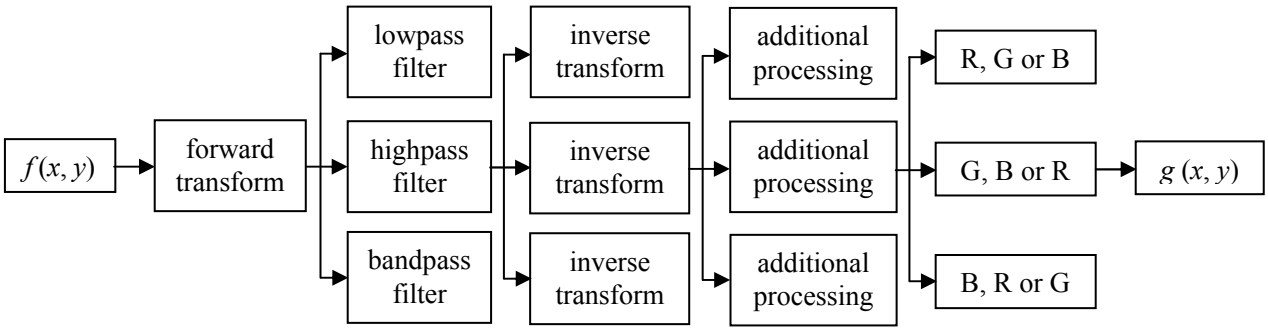


Fig. 1 Gray-level to color transformation in frequency domain

Improved Marked-based Watershed Algorithm for Segmentation

The watershed algorithm is one kind of segmentation methods based on region[4,5]. It can get closed precise border lines, but it is sensitive to noise and has over-segmentation problem. There are four types of improved methods for watershed algorithm: using filters to preprocess, marking before watershed transform, region merging after watershed transform, and other methods combined watershed with new techniques[6]. At present, marking and region merging are used widely.

In order to obtain better image quality, the paper adopts marked-based watershed algorithm preprocessing medical images, segments the medical image and enhances the tissue regions. The key steps of the improved marked-based watershed algorithm[1,7] consist of the following:

- Compute the gradient magnitude ∇f of input image $f(x,y)$

$$\nabla f = mag(\nabla f) = \sqrt{(G_x^2 + G_y^2)} \quad (2)$$

where, G_x and G_y represents the gradient image along x and y direction respectively.

- Compute the watershed transform of the distance transform of the input image $f(x,y)$, and obtain the external marker image, em. em shows the resulting watershed ridge lines.
- Obtain the internal marker image, im, by computing$H$-maxima transform of $f(x,y)$.
- Use em and im to modify ∇f using a procedure called minima imposition, and obtain the marker-modified gradient image $\nabla f'$.
- Compute the watershed transform of $\nabla f'$.

Algorithm Combining Pseudocolor Processing and Watershed Transform

Algorithm Description. The enhancement method combining pseudocolor processing and marker-based watershed proposed in this article operates as following:

Input the original medical image $f(x,y)$. Perform marker-based watershed transform on $f(x,y)$, and obtain the segmentation image $f_1(x,y)$. Merge $f(x,y)$ and $f_1(x,y)$, and get the image

$f_2(x,y)$ that has high contrast and obvious tissue objects. Use gray-level to color transformation in frequency domain to process $f_2(x,y)$, and get the final enhancement image $g(x,y)$. The flowchart of the algorithm is shown in Fig.2.

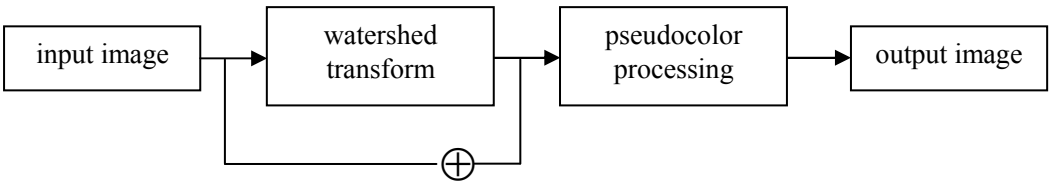
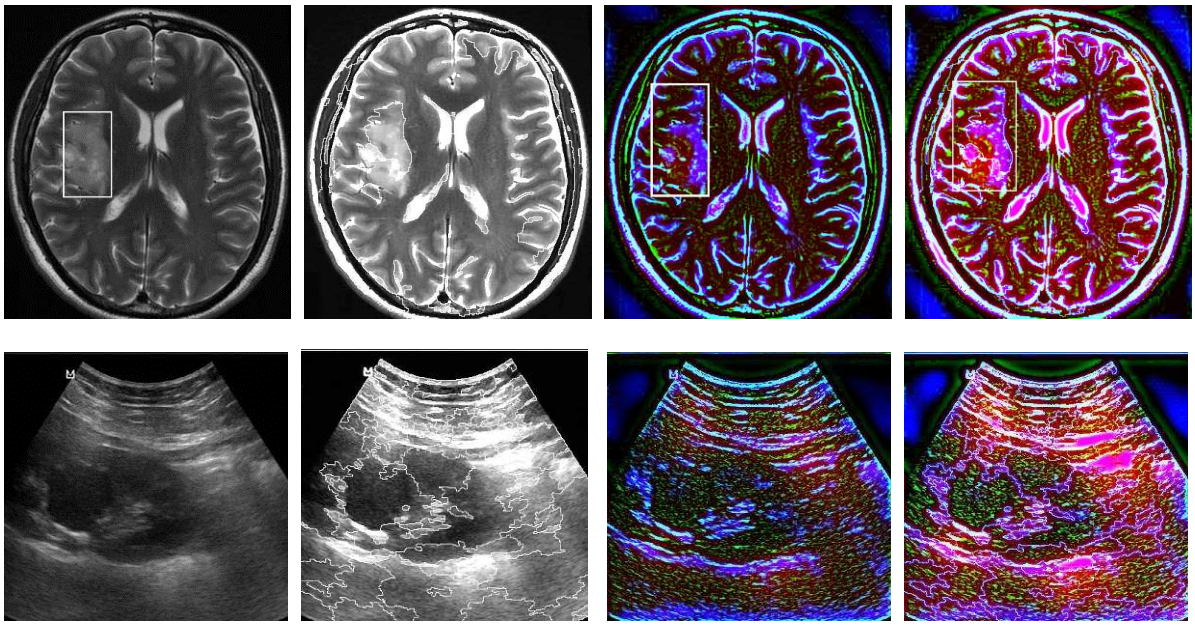


Fig. 2 Enhancement algorithm combining pseudocolor and marker-based watershed transform

Simulation Results. The algorithm is programmed based on MATLAB, and lots of computer simulations have been performed on medical images that have low contrast, narrow gray scale and dim edges. Fig.3 shows the stimulation results of two medical images. The spatial resolution for the MRI image is 414×390 , and the tumor is given in the rectangle. The spatial resolution for the B-scan ultrasonic image is 406×429 .



(a) (b) (c) (d)

Fig. 3 (a) the original medical images; (b) the fused images by (a) and the output image of marker-based watershed transform; (c) the images for traditional pseudocolor processing in frequency domain; (d) the final images of the algorithm proposed in the paper.

Two objective evaluating parameters are selected to assess the image quality of the two methods. Define the mean $\bar{f}$ and entropy of an image H using the following equations respectively:

$$\bar{f}=\frac{\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}f(i,j)}{MN} \tag{3}$$

$$H=-\sum_{i=0}^{255}p_i\log_2 p_i \tag{4}$$

where, $f(i,j)$ represents the final enhancement image, M and N are the size of $f(i,j)$, and p_i is the probability for the i th gray level.

The two parameters can reflect the average intensity and the quantity of information. They are used widely to compare the image quality and evaluate the visual effect of different images. The comparative data for Fig.3c and Fig.3d are shown in Table1.

Discussion About the Marker-based Watershed Transform. Using the marker-based watershed transform in the proposed algorithm can enhance the tissues' outline effectively and outstand the contrast in image. This step can reduce the complexity of the algorithm, and save time cost of the fusion system we developed. In addition, the value *H* for *H*-maxima transform of $f(x,y)$ is very important. It determins the segmentation quality .

Table1 The comparative results in mean and entropy for Fig.3c and Fig.3d

image	parameter	pseudocolor processing in frequency			algorithm proposed in the paper		
		R	G	B	R	G	B
MRI	mean	55.8112	45.2176	67.8632	112.6166	61.7499	86.6802
	entropy	6.6566	2.2598	2.0672	7.4867	2.2454	2.2454
B-ultrasound	mean	52.0607	45.5025	45.5025	110.1462	62.7813	92.2913
	entropy	6.8949	6.4379	6.4379	7.6088	6.6560	6.0313

Discussion About the Pseudocolor Processing in Frequency Domain. Firstly, the selection of filters of R, G, and B channels in frequency domain influence the enhancement effect directly. Practice proves that the second order Butterworth filters compared with other filters are more suitable for this algorithm. Howerver, the cut off frequency D_0 should vary with the different types of medical images. Secondly, the final color image has low contrast if the algorithm adopts histogram equalization as the additional processing. While, if the inverse transform multiplying an adequate factor, the final image has abundant colors and shows more details.

Conclusions

A new enhancement algorithm for medical image combining with pseudocolor processing and marker-based watershed transform is presented. The algorithm takes into account the features of medical image and the shortcoming of pseudocolor processing in frequency domain. Experimental results show that the algorithm is able to improve the visual effect of medical images, especially for the tissues in the low contrast regions. It can outstand the outline of the region of interested, and the output image is more suitable for humans' distinguishing details. The algorithm has been applied in the medical image fusion system we developed, and shows the practical value for diagnosing.

Acknowledgements

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