Medical Image Processing using A Machine Vision-based Approach

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Abstract

The information extraction process of medical image, for example heart image from specific camera, is full of complexities and noises. As a result, cost spent on such processing like time and resources is high, especially for large and complex amount of information. This paper uses machine vision-based approach to address the challenges. This approach primarily includes four stages with different algorithms to deal with the medical heart images. Firstly, smoothing algorithm is used to reduce the noise. Secondly, filtering algorithm is used for image analysis so as to identify the target area. Thirdly, further enhancement algorithm is used to figure out the image features within the target area, finding out the basic outline of the image. Eventually, reduction algorithm is utilized to convert the original images into more smooth and precise pictures. Experimental results show that machine vision-based medical image processing algorithm can accurately extract the relevant data and achieve better results, comparing with the traditional image processing method.

Keywords: *Medical Image Processing; Machine Vision; Algorithm; Heart Image; Digital Image*

1. Introduction

Machine vision is a product of a high degree of integration of science and technology. As a discipline, computer vision is concerned after artificial systems theory science [1]. It is extracted from the image information. The image data may be obtained by using various ways, such as a video sequence, from the plurality of cameras, or multi-dimensional view of the data from a medical scanner. As a technical discipline, the purpose of computer vision is to achieve the construction of computer vision systems by using the theories and models. Traditional machine vision system applications include the following aspects [2]: (1) control process (for example, industrial robots or autonomous vehicles); (2) detection of an event (such as video surveillance or people counting); (3) organization information (such as index database of images and image sequences); (4) modeling objects or the environment (*e.g.*, industrial inspection, medical image analysis or topographical modeling); (5) interaction (such as human-computer interaction input devices).

Very broad applications of machine vision in the image, such as the production of three-dimensional computer graphics model data, often generate from the image data model through three-dimensional aspects [3]. Computer vision is based on scene reconstruction, event detection, video tracking, target recognition, learning, indexing, motion estimation and image restoration. Machine vision is a diverse and relatively new area. The most closely related to the field are image processing, image analysis and machine vision. These related fields are included in the range of technologies and applications using the same basic technology. Machine vision tends to focus on one or more images, for example, how to rebuild a three-dimensional projection of the scenes structure or other information from one or more of the images [4-5]. This approach often relies on the assumption that the described scenario in the image is more or less complex.

One of the most prominent application areas of machine vision is medical image processing. The characteristics of the application areas are the information extracted from a patient's medical diagnostic imaging data [6-7]. Generally, data may be from a microscopic image in the form of X-ray image, the contrast image, the ultrasonic image and the tomographic image. The data can be extracted from these images, for example, detection of tumor, arteriosclerosis, or other harmful changes. Data can also be from organ size, blood flow, and other measuring, *etc*. The useful information is useful to build up the structure of medical quality [8]. Thus, the medical image processing has important and practical significance to save peoples' lives.

The main methods of machine vision in medical image processing are classified as the following categories: (1) linear filtering; (2) principal component analysis; (3) independent component analysis; (4) hidden Markov model; (5) partial differential equations; (6) Self-organization chart; (7) neural network; (8) wavelet. With the development of computer application technology, new methods are emerging. The level set method is widely used in the field of machine vision. It is mainly the increase of image, de-noising, segmentation, repair, tracking outstanding advantages. Curve evolution method is an application which requires the gradient of the image information for active contour model [9]. The model can extract complex shape of the target, and the main outline of the initial contour. The sensitivity is also reduced. For overcome the shortcomings of the level set function depends signed distance function, a new variational formula is used to remove the re-initialization step so as to improve the speed of the curve evolution. Finally, it reduces the time complexity of the level set function.

Medical heart images, using the methods of machine vision, are processed in this paper through a new approach. The approach is mainly divided into the following steps: Firstly, edge adaptive smoothing algorithm is applied to the heart image processing to remove noise. Secondly mean filtering algorithm for image analysis, is used to identify the target area. Thirdly, enhancement algorithm is applied to get the image of the target area characteristics and to identify the basic outline of the image. Fourthly, final image restoration algorithm is used to build the image of the three-dimensional model.

2. A Machine Vision-based Medical Image Processing

Cardiac medical images obtained by special machines, contain rich texture and complexity of the information presented in the form of the heart itself. But got by a special instrument, the image includes a lot of noise and artifacts [10-11]. Noises and artifacts not only affect the texture results, but also influence the impact of the judgment on the area of heart attack. Thus, it is necessary to smooth the original image. The machine vision-based medical image processing includes four steps which are detailed illustrated as follows.

2.1. Step1: Smoothing

The traditional image smoothing algorithm compromises Gaussian smoothing, the mean smoothing and Gabor smoothing. Gaussian smoothing uses a Gaussian function:

$$f(x) = ae^{-\frac{(x-b)^2}{2c^2}} \tag{1}$$

The method uses a Gaussian function to constitute a low-pass filter in the frequency domain. The filter has a smooth performance of the multiplication for this purpose. The mean smoothing manner uses nonlinear method to get the mean value from N pixels. Gabor smoothing uses the Gabor function to localize the time frequency precisely, adopting Gabor window for the purpose [13]. A nonlinear smoothing algorithm is proposed in this article to process the medical images. The algorithm concerns the local discontinuity and the continuous degrees texture to obtain the average quantization for a smooth image:

$$
\begin{aligned}
&Exy = \frac{E_{H_{xy}} + E_{V_{xy}} + E_{D_{xy}} + E_{C_{xy}}}{4} \\
&where \\
&E_{H_{xy}} = | I_{x+1,y} - I_{x-1,y} |, E_{v_{xy}} = | I_{x,y+1} - I_{x,y-1} | \\
&E_{D_{xy}} = | I_{x+1,y+1} - I_{x-1,y-1} |, E_{C_{xy}} = | I_{x+1,y-1} - I_{x-1,y-1} |
\end{aligned}
\qquad (2)
$$

Cardiac medical images are on pixel gray usually, there are some differential deviations. Some gray values of the image are easily affected by noise. But the information of each pixel in the image field can reduce the impact. The proposed smoothing algorithm calculates the gray mean, variance and normalization through discontinuity quantitative texture. Thus it is easily to obtain:

$$\tilde{\sigma}_{xy}^2(R) = \frac{\sigma_{xy}^2(R) - \sigma_{\min}^2(R)}{\sigma_{\max}^2(R) - \sigma_{\min}^2(R)} \qquad (3)$$

$\tilde{\sigma}_{xy}^2(R)$ is the discontinuity of (x, y). Let $\tilde{\sigma}_{xy}^2(R)$ denote as a threshold value, a smoothing algorithm formula could be expressed as:

$$\phi(\tilde{\sigma}_{xy}^2(R), \theta_\sigma) = \begin{cases} 0 & \tilde{\sigma}_{xy}^2(R) < \theta_\sigma \\ \tilde{\sigma}_{xy}^2(R) & \tilde{\sigma}_{xy}^2(R) \geq \theta_\sigma \end{cases} \qquad (4)$$

2.2. Step2: Mean Filtering

The mean filtering algorithm is based on the proposed approaches from Duda and Hart [14]. These approaches use error square dynamic clustering method to process the image. For the cardiac image specifically concerned in this paper, the following function is adopted for mean filtering:

$$j_c = \sum_{j=1}^{c} \sum_{k=1}^{n_j} \left\| x_k - m_j \right\|^2 \qquad \text{wher e}, m_j = \frac{1}{n_j} \sum_{k=1}^{n_j} x_k \qquad j = 1, 2, \ldots c \qquad (5)$$

For the moothed image, all the pixels are in the initial cluster centers c. Selection of c is according to the information content of the image. After different experiments, a fixed value of 16 is chosen. That is, each cluster contains 16 pixels, because $2^4 = 16$. Taking the four field points' values as a mean, m_j is the lean value of No. j cluster. By this method, it is possible to further uniform the grayscale values of pixels within the image. Therefore, aims of improving the contrast of the target area and the remaining image regions are achieved. This is the foundation for the next processing - image enhancement.

2.3. Step 3: Enhancing

Cardiac medical image texture has a wealth of information [6, 10]. Image enhancement not only directly relates to heart detail enhancement, but also considers the entire texture information results in a certain sense. This paper has an important role and significance of processing these textures based on the value of texture information. Thus, the contrast of the image $C(x, y)$ is determined by the texture information $u_f(x, y)$:

$$C(x,y) = \frac{\left| u_f(x,y) - \bar{u}(x,y) \right|}{\left| u_f(x,y) + \bar{u}(x,y) \right|} \tag{6}$$

Where $u_f(x,y)$ is

$$u_f(x,y) = \sum_{i=x-\frac{k-1}{2}}^{x+\frac{k-1}{2}} \sum_{j=y-\frac{k-1}{2}}^{y+\frac{k-1}{2}} (u(i,j) \times \sigma(x,y)) \tag{7}$$

By using this image enhancement algorithm, the contrast enhancement of heart images considers not only the global pixel information, but also synthesizes local details information. Detail partial information is concerned through weighting function to consider enhanced by the image pixel intensity. The function is in the form of user-defined local enhancement of different image types. The exponential function is used for this purpose:

$$\sigma(x,y) = x^{-\sum_{i=0}^{t} \frac{p_i}{\sum_{i=0}^{t} p_i} \ln \frac{p_i}{\sum_{i=0}^{t} p_i}} + y^{-\sum_{i=0}^{t} \frac{p_i}{1-\sum_{i=0}^{t} p_i} \ln \frac{p_i}{1-\sum_{i=0}^{t} p_i}} \tag{8}$$

p_i is the number of statistics probability in the entire image grayscale. The weighting method is used to improve the target area and the contrast of other regions, providing the most important information for the final image reduction.

2.4. Step 4: Restoration

The image restore is the last step. Image restoration algorithm is based on machine vision, not only of the structural characteristics, but also for the texture information which has to been grasped. Especially it is efficient and effective for color change visible region and contour with a good robustness. For colored heart medical images based on texture information structure pixel, setting weights to improve the accuracy of the image can also be greatly enhanced color balance. The similarity of image restoration block is defined as:

$$d(\varphi_x, \varphi_y) = \sum_{i,j \in \varphi \cap u_f(x,y)}^{n} W(i,j) \times L(x,y) \tag{9}$$

Where φ is the pixel of restored block. $W(i, j)$ is the weight. $L(x, y)$ is the sum of square differences from color degree. Therefore, image restoration formula can be carried out according to the following manner:

$$L(x,y)=(R(x,y)-R(x-1,y-1))^2+(G(x,y)-G(x-1,y-1))^2+(B(x,y)-B(x-1,y-1))^2 \quad (10)$$

Where R,G,B represents the component values of red, green and blue respectively.

3. Experiments and Discussions

The experiments are based on cardiac medical images. The proposed method has been adopted on processing these images. Matlab 2008a has been used for this purpose. The computer environment is HP Compaq Core 2.0 CPU 6600@2.40GHZ 2.39GHZ, 3.49 GB OF RAM. The images used in the experiment come from 1024*768 pixel color of cardiac medical images. Original image shown in Figure (1) which presents the image obtained using a special instrument, but on the presence of a lot of noise. The rich texture of the image is obvious but not prominent. Therefore, it is not available in the medical professional field of the image information represented by accurate diagnosis, such as coronary heart disease, myocardial necrosis. It is necessary for carrying out the image processing before doing the diagnosis.

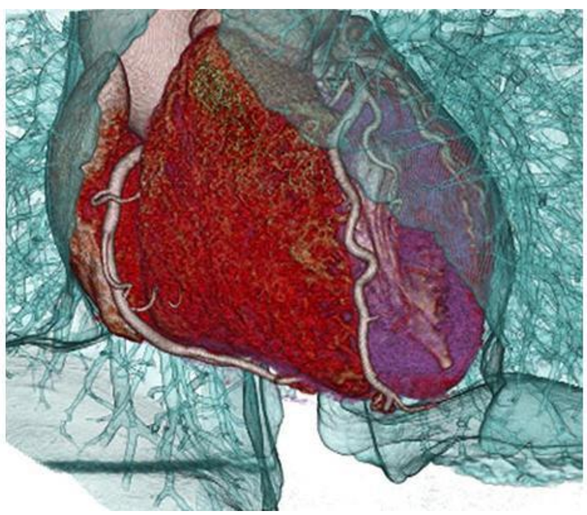

Figure 1. The Original Image

Using the proposed smoothing and filtering algorithms, Figure (2) presents four images from different dimensions obtained after the smoothing and filtering of the proposed algorithm for image processing. The above two is the images obtained after the smoothing algorithm. It can be seen that the image is positive and negative results after the smoothing which has reduced a lot of noises. In addition, the positive and negative (*i.e.*, the image is inverted 180 degrees) for smoothing is because that all the information of the image of the heart may be presented, especially vascular and cardiac subtle texture. If the single always smooth used, some important information might be ignored.

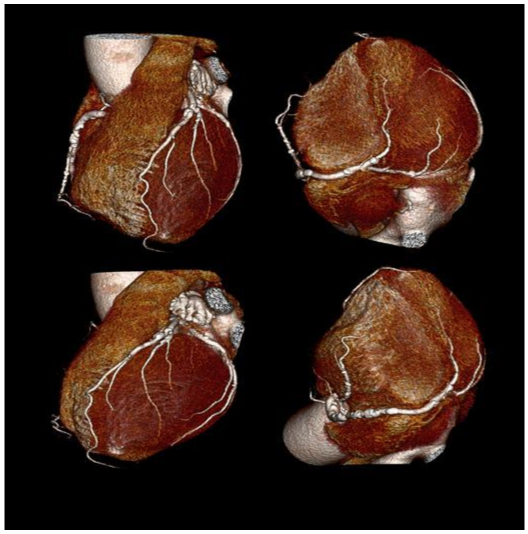

Figure 2. Images after Smoothing and Filtering

The two images from the bottom in Figure 2 are color images after filtering. Compared with the above two figures, wherein the texture feature, especially arteries and major texture region are prominent features out. This is because the filtering not simply uses filtering algorithm pixel filter to process the image. And the squared error of the pixel cluster is calculated. Thus, the focus area of image texture characteristics is highlighted. After that, it is necessary to add the average absolute distance to describe smoothed image filtering pixels difference, using the following formula:

$$Mad(P,M) = \frac{1}{2}\{\frac{1}{n}\sum_{i=1}^{n} d(p_i, M) + \frac{1}{k}\sum_{j=1}^{n} d(m_j, P)\} \tag{11}$$

Where $P = \{p_1, p_2, ...p_n\}$, $M = \{m_1, m_2, ..., m_n\}$, $d(p_i, M) = \min\|m_i - p_i\|$.

Figure 3 (a) Images after Enhancement; (b) Images after Restoration

As can be seen from the Figure (2), the concerned regions are more concentrated after filtering through a description of the distance image. This methodology not only amplifies the information area, but also obtains more characteristic values from the observation.

Figure 3 (a) shows a color effect after the image enhancement using the proposed enhancement algorithm. It can be seen that the image focus areas and prominent feature values (for example, blood vessels, and myocardial texture) are weighted. The weighted values are used for image enhancement. Other areas, such as the smooth cardiac weights decreased, thereby are obtained for the display results. It has been observed that the approach has a better highlight effect of the heart medical images ventricular artery and ventricular nerve texture. Figure 3 (b) shows the restored image after using the machine vision-based algorithm. It can be seen from the figure, the method can not only restore the heart images by different regional block to reflect the actual image, but also highlights the outer wall of the blood vessels of the heart tissue. The use of colored RGB for the reduction of the basic unit truthfully reflects the actual image of myocardial texture and structure of organizations, achieving a good image restoration effect. Through the four-step processing approach for medical image proposed in this paper, the experiments outperformed over the traditional methods. The algorithm at the medical heart image processing uses these steps based on machine vision. Image smoothing algorithm, filtering algorithms, enhance, and restore algorithm are included within four-step approach which can effectively deal with the access to the heart of the medical image of a particular instrument. The experiment results showed that it can achieve a good image desired effect.

4. Summary

This article presents an approach for medical color image processing (take the heart images obtained by special instruments for example). This approach has four steps. For the first processing, the smoothing algorithm is to remove noise and artifacts in the image. Then smooth the image is addressed by the filter algorithm which performs in the filtering process. The use of the image distance difference method is to increase the filtering effect. Subsequently, the image enhancement algorithm uses weighted enhanced images of different regions. Finally, restoration algorithm is used to restore the color images of the heart. The experimental results show that the proposed four-step method can be effectively used to achieve a good image expected effect.

Future research directions may be carried out from several aspects. First, the experimental use of the sample images will do the comparison algorithm for multi-capacity effect pending further study. Second, the image restoration algorithm for medical image information of the entire heart is efficiency. But changes in the heart muscle gradient needs detailed study. Finally, connection analysis about heart, and other organs, such as move, is inadequate in this paper. Therefore, the aspects of the proposed algorithm, and the way to in-depth research or extension applications could be studied in the future.

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