Evaluating the Effects of Image Filters in CT Liver CAD System

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Abstract. The main objective of image preprocessing is to improve the quality of the image being processed. It makes the subsequent phases of image processing like segmentation and recognition easier. It has techniques for enhancing contrast, removing noise, emphasizing certain features or isolating regions of interests. Filtering is a key primitive preprocessing step including the contrast stretching, sharpening and smoothing. This paper aims to evaluate and analyze the effect of several image filtering techniques on the computer aided diagnosis performance. These filtering techniques include contrast stretching, convolution, median, average, inverse transformation and Logarithm transformation filters. An application of CT liver imaging has been chosen and the selected filters have been applied to see their ability and accuracy to segment and isolate the liver region of interest using region growing segmentation approach. The effect of the filtering techniques on the segmentation performance of the CAD system is investigated by means of mean square error (MSE) and similarity index (SI). The highest performance in liver images were achieved for contrast stretching filter (MSE = 0.1869, SI = 0.8423) and the combination of contrast stretching and average filter was (MSE = 0.17198 and SI = 0.83257).

Keywords: Preprocessing, filtering, segmentation and CAD.

1 Introduction

Currently, developing an efficient computer aided diagnosis system (CAD) that assists the radiologist has thus become very interesting, the aim is not to replace the radiologist but to offer a second opinion [15]. Consequently, many efforts have been made to incorporate techniques for image processing. Unfortunately, the techniques developed have not been sufficient to introduce an efficient computer-aided analysis in clinical use.
A computer-aided diagnosis (CAD) system consists of several stages, such as preprocessing, segmentation and classification. Usually, the computer-aided diagnosis system starts with the pre-processing, which includes digitization of the medical image with different sampling and quantization rates. Then, the regions of interests selected from the digitized images are enhanced. The segmentation process is designed to find suspicious areas, and to separate the suspicious areas from the background that will be used for extracting features of suspicious regions. In the feature selection process, the features of suspicious areas will be extracted and selected, and suspicious regions will be classified into normal and non-normal [15]. This paper aims to analyze several well known filtering techniques and its combinations including contrast stretching, convolution, median, average, inverse transformation and Logarithm Transformation filters, then evaluate the effect of the preprocessing on the computer aided segmentation performance. An application of CT liver imaging has been chosen and the selected filters have been applied to see their ability and accuracy to segment and isolate the liver region of interest using region growing segmentation approach. The effect of the filtering techniques on the segmentation performance of the CAD system is investigated by means of mean square error (MSE) and similarity index (SI).

The rest of the paper is organized as follows. Section 2 gives a brief introduction to the introduced filtering techniques including contrast stretching, convolution, median, average, inverse transformation and Logarithm Transformation filters. Section 3 presents the segmentation CT liver image analysis approach in detail. Experimental results are discussed in Section 4. Conclusions are discussed in Section 5.

2 Filtering techniques: Preliminaries

Image filtering for the enhancement of liver plays an important role for improving the sensitivity and specificity in computer aided detection systems. This section will give a brief introduction to six image filtering techniques including contrast stretching, convolution, median, average, inverse transformation and Logarithm Transformation filters and combinations of them. Contrast filters aid in determining the contours of liver, while smoothing hides the small details like veins and ligaments. Sharpening filters are excluded because they show small details which is not needed to segment the liver. Also some smoothing filters that do not give a promising results are excluded such as correlation transformation, histogram equalization, Laplacian, Gaussian, Laplacian of Gaussian, Prewitt, and Sobel [4, 7–10]. An application of CT liver lesion imaging has been chosen and each filter have been applied to see their ability and accuracy to segment the whole liver images. This section reviews the used filtering techniques in brief and the reader may refer to [1, 5, 6, 11, 12, 14] for an extensive overview of the image filtering techniques.
- **Contrast stretching filter** is a process of expanding the range of intensity levels in an image to span the full intensity level. Data is saturated at low and high intensities increasing the contrast of the image. The boundaries of low and high intensities of the input image is stretched to new boundaries in the output image.

- **Inverse transformation filter** uses the inverse transformation of contrast stretching approach with a condition of high boundary of the output image is less than the low boundary of the output image then the output image is reversed.

- **Convolution filter** is a Linear filtering works by setting the filter mask’s center over each image pixel to compute the sum of products of the mask with the intensity of the underlying pixel. We have to note that the difference between correlation and convolution is rotating the correlation mask 180°.

- **Logarithm transformation filter** maps a narrow range of low intensity in the input image into a wider range of output levels. It expands the values of dark pixels and compresses the higher level values.

- **Average filter** smooths an image by reducing the variation in intensities. This is done by replacing the intensity level at a point by the average of the intensities in a neighborhood of the point.

- **Median filter** is a nonlinear filter that replaces each pixel with the median of the accumulated values of the mask. Median filter is used to reduce noise in an image. Moreover, it is used to reduce image resolution without losing the edges and resulting in a smoothed image.

3 Region growing segmentation approach

Segmentation methods are moving around two main categories, edge-based segmentation and region-based segmentation. While edge-based segmentation uses the gradient to determine edges using the discontinuity concept, region-based segmentation uses similarity difference to determine regions. Edge-based category is represented in many methods like Sobel, Prewitt, Roberts, zero crossings, Laplacian of Gaussian (LoG) and canny. Region-based includes methods like region growing, region split and merge [3], watershed [14] and level set [13]. Region growing has been chosen to be used in liver segmentation which is the process of segmenting liver from the abdomen image. When segmenting liver organ, some liver properties cause some limitations and problems in segmentation process. Observation provides some of these limitations such as (1) Liver is adjacent to the ribs that are covered by flesh cells and muscles that have similar intensities to liver. So liver segment might include this flesh and (2) The intensity values of stomach, kidneys and spleen are too close to liver intensity. If there is a slight band connecting between them, they might be included in liver segment. Sometimes almost the whole abdomen could be included in a wrong way. A number of filters and its combinations will be used to aid solving this problem.

Ribs boundary algorithm has been suggested to solve the problem of muscles and flesh adjacent and connected to liver. It uses the intensity of ribs that exceeds
certain value close to white color to extract ribs boundaries pixels. The ribs pixels are extracted outside the original image, and then the lines are drawn in the original image. This will guarantee a better connection between the ribs. Algorithm (1) shows the steps of ribs boundary connecting process and Figure (1) shows the visual results of such process with adjust contrast from 0.5-0.6 to 0.1-0.9.

**Algorithm 1** Ribs boundary algorithm

1. Clean image annotation and machine bed that appear in white color.
2. Apply contrast stretching filter that maximizes the values of the ribs. The used values of low-in, high-in and low-out and high-out are [0.5, 0.06, 0.1, 0.9]. This is a temporary image.
3. Trace ribs values in temporary image from left to right using value threshold (> 190) through certain band of columns less than the half of the image.
4. Keep the first pixel coordinates.
5. Move to next rows to extract the next rib pixel.
6. In original image, draw a line between the two pixels to separate ribs and repeat till the last row to determine ribs boundary.
7. Rotate the two images three times and apply step 3 after each rotation.
8. Rotate the image once more to get the original orientation of the image.

**Fig. 1.** Adjust Contrast to emphasize the ribs feature (a) Original image, (b) Adjust 0.5-0.6 to 0.1-0.9

As for the above mentioned intensity values of stomach, kidneys and spleen problem which is similar to liver. This is manipulated by some other filters and its combinations. Then comes region growing segmentation approach. Algorithm (2) shows the detailed steps of the region growing segmentation approach.
Algorithm 2 Region Growing algorithm

1. Pick up a set of seed points that represents an initial region.
2. Check the intensity of the neighboring pixels of its boundary band in all direction. Add the pixels similar to the seed points to the region.
3. The sudden change in brightness expresses an edge, that stops moving in pixel direction.
4. Repeat the second step until obtaining the segmented region.

4 Experimental results, analysis and discussion

In the following experiments, real liver CTs acquired from patients were used for performance evaluation. To study the accuracy of the used filtering combinations, we used number of twenty six (26) images and we calculate the accuracy using similarity index (SI) and mean square error (MSE) as defined on Equations (1-2).

\[
SI(I_{\text{auto}}, I_{\text{man}}) = \frac{I_{\text{auto}} \cap I_{\text{man}}}{I_{\text{auto}} \cup I_{\text{man}}} \tag{1}
\]

where \(I_{\text{auto}}\) is the binary automated segmented image and \(I_{\text{man}}\) is the binary manual segmented image.

\[
MSE(A, B) = \frac{1}{MN} \sum_{m=1}^{M} \sum_{n=1}^{N} ||A(m, n) - B(m, n)||^2 \tag{2}
\]

Figure (2) shows some visual results obtained when using the filters and their combinations. The implementation of the methodology described above has more than ten different filter combinations based on four procedures (1) Cleaning the image from the unnecessary details that affects segmentation, includes removing bed white line and drawing black area in the right half of the image, starting from the highest white point in the backbone and moving diagonally to the right. Considering that liver normally occupies the left half of the image, and sometimes it occupies more to the right, (2) Drawing lines around the ribs all over the image using adjust contrast and tracing ribs as mentioned above, (3) Using one or more combined filters including contrast stretching, inverse, convolution, logarithm, median and average filters, and (4) Using region growing as a fixed segmentation method. Figure (3) shows the connecting ribs with white lines when applying adjust contrast to emphasize the ribs feature.

By using connected ribs, cleaned image and region growing approach, we neutralize all other parameters except filter effect. A detailed description of the different combinations and its numbering are (1) Normal image without ribs, neither connected nor cleaned and region growing, (2) Using adjust contrast with values [0.52, 0.1, 0.9, 0.1], ribs connecting procedure and region growing, (3) Using adjust contrast, connected ribs, cleaned image (this is neutralized image) and region growing, (4) Using neutralized image with \textbf{convolution} filter and region growing, (5) Using neutralized image with \textbf{convolution} filter and region...
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Fig. 2. Sample results of some filter techniques (a) original image, (b) Contrast stretching, (c) Inverse, (d) Contrast stretching + correlation, (e) Convolution, (f) Inverse + convolution, (g) Inverse + Histogram Equalization, (h) Laplacian + Contrast stretching, (i) sobel + Contrast stretching, (j) Contrast stretching + Gaussian, (k) Histogram Equalization, (l) Median + sharpening

growing without enlarged liver option, (6) Using neutralized image with no other filter and region growing without enlarged liver option, (7) Using neutralized image with median filter and region growing, (8) Using neutralized image with average filter using mask [9 9] and region growing, (9) Using neutralized image with median filter, threshold (40-185) and region growing, (10) Using neutralized image with average filter using mask [7 7] and region growing, and (11) Using neutralized image with inverse filter using values [0.1, 0.8, 0.9, 0.1] followed by logarithm and region growing. Tables (1-2) shows the effect of these eleven methods against several filters and their combinations including maximum and minimum of SI. It should be noticed that some filters (like average, logarithm, histogram equalization, laplacian, gaussian, LOG, Prewitt, Sobel and unsharp) result in an image with double values between 0 and 1.
5 Conclusion

Filters in general, have three main affects, contrast, sharpening and smoothing. Sharpening emphasizes edges between regions, which is required. But unfortunately it creates much more edges and small details in liver that results almost in no segment. So sharpening filters like Sobel, Prewitt are excluded in this paper. Contrast filters change the difference between upper and lower intensity. Filters like inverse, convolution and histogram equalization are affecting contrast. But it is noticed that histogram equalization distort the image completely and not suitable for segmentation. But the other two filters could be tried. Smoothing filters are good for segmenting and removing the small details in the region of liver. Filters like Gaussian, Average and Median should be tried in segmentation of the liver.

Segmentation of liver has many difficulties to get good results. Using filters has an impact on the image that has no noise or distortion. Since filters have 3 categories handling contrast, sharpening and smoothness, it is obvious that sharpening is not efficient in segmentation a because it emphasizes the details of the liver, which is not needed for segmenting a gross region. Contrast stretching is used successfully in connecting the ribs which is very important to cut the bridging area between the liver in the left side of the image and the flesh and muscles that goes around the whole abdomen, and sometimes connects parts in the right half of the image. On the other hand, using smoothing filters like median and average on the image that has no noise, have a slight negative effect on the overall average of segmentation.
Fig. 4. Comparison from methods 1 to 6
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Fig. 5. Comparison from methods 7 to 11 including maximum and minimum of SI
References