Efficient Segmentation of ultrasound images of abnormal kidney

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ABSTRACT

Image processing has large applications in the medical diagnosing, especially in Ultrasound Imaging (UI) that for its' safety. UI suffer from low resolution and noises, so, became a target for a lot of investigations. Three US images which represent Cyst, Benign, and Stone used in this study. Five contrast enhancement techniques and three denoising filter applied on them and best of them chose according to their PSNR and MSE values. It's found that best contrast enhancement methods were Contrast adjustment, for Benign and Cyst images, and sharpening for the Stone image. Then, the images denoised by Median filtering due to found it as better denoising filter than others studied here. Three segmenting methods (one ordinary and two hybrid techniques) were used here: thresholding, kmean with intensity selector, and bilateral filter with intensity selector. All techniques were segmented nearly same area of the cases. But thresholding needs a large of trial and error to obtain their segmenting. The kmean with intensity selector method was found better for the Benign case than other for its higher PSNR (16.68), lower MSE (1394.1), and small time of running (22.1 sec). But for Cyst and Stone images, Bilateral filter with intensity selector was found better than other according to same parameters. So, techniques of hybrid segmentation provided more efficient segmenting.

1. INTRODUCTION

Ultrasound is the standard method for first intentional evaluation of kidney. But, it sometimes couldn't differentiate between renal cysts and mixed solid tumors, so, another medical imaging techniques were used such as computed tomography, magnetic resonance imaging, and contrast-enhanced ultrasonography (Prakash and Wansaicheong, 2011).

Image segmentation divides an image into multiple parts that have homogeneity in pixel intensity, color or texture (Ahmed et al., 2015). Akhtaruzzaman et al. (2016) make an automated threshold to segment lower limbs from several image frames of human walking. That to overcome threshold strategy which
based on trial and error method. Another work uses a 3D bilateral filter to smooth spurious artifacts while preserving the strong edges of the cortical bone tissue (Nguyen et al., 2016). Sahadevan et al. (2016) use Bilateral filter as first step smoothing and maintaining edges and the support vector machine (SVM) classifier as second step to test benchmark hyperspectral image taken from the airborne spectrometer. Lee et al. (2016) use bilateral filter as first step to produced binarized image and extract edges using Canny edge algorithm. They compared their results with result of the normalized cut algorithm using kmeans. Their method needs smaller time of running. They used PSNR to compute objective evaluation of images produced by their proposed method.

The aim of the present study is to investigate different techniques of enhancements (denoising and contrast) for abnormal kidney (cyst, benign, stone) that given from 2D ultrasound. Also, performance of two stage segmenting on the three cases will be evaluated subjectively and objectively.

2. MATERIALS AND METHODS

Three ultrasound images for each of kidney abnormalities (benign, cyst, stone) studied in this work taken from ultrasound cases (Ultrasoundcases.info., 2017). They cropped to show only region interested region. Then, images contrast enhanced by using Histogram equalization (HE), Adaptive histogram equalization (AHE), Contrast adjustment, Image Sharpening, and Decorrelation stretch. Different input parameters of mentioned techniques optimized for maximum PSNR. Also, the images denoised as second enhancement step by optimizing three methods (Median filter, Wiener filter, Bilateral filter). The largest PSNR among these techniques listed in Table 1.

The enhanced images were segmented by two methods which going through two segmentation steps and thresholding segmentation used for comparison (see Figure 1). The first hybrid techniques use the Bilateral filter for smoothing ultrasound images with preserving their edges, then, use Intensity selector step to choosing interested region. While in the second hybrid technique Kmeans divide images to multi-regions and the interested region will choose by Intensity selector technique.

Figure 1: Shows steps of segmentation methods.

Thresholding is a technique of selecting optimum gray level value which separates the region of interest from other regions. Thresholding produced binary images from grey-level by making pixels below or upper a gray level value to zero and other remaining pixels to one. If \( g(x, y) \) is a threshold of \( f(x, y) \) at threshold value \( T \), it can be described as:

\[
g(x, y) = \begin{cases} 
1 & f(x, y) \geq T \\
0 & \text{otherwise}
\end{cases}
\]  

(1)

K-Means method divide pixels into a number of separate clusters. Its algorithm consists of two steps. First, it finds k centroid (k number of clusters) for pixels of the image and secondly relate each pixel to a centroid through using different methods of computing distance between them. One method for computing distance is the Euclidean distance which defined as follow:

\[
d = |p(x, y) - c_k|
\]  

(2)

Where \( p(x, y) \) is an input pixel to be cluster and \( c_k \) is the cluster centers. After grouping pixels into k sets (i.e. clusters) new Euclidean distance evaluated between each center and
pixels, so pixels assigned to the minimum Euclidean distance (Dhanachandra et al., 2015).

The Bilateral filtering is a technique for smoothing and sharpening edges of an image. It is obtained by applying two Gaussian filters. One applied for finding spatial domain and other for intensity domain. The output of the filter for a pixel \( s \) is given by using following equation:

\[
J(s) = \frac{1}{K(s)} \sum_{p \in B} (p - s)(I_p - I_s)I_p
\]  

(3)

Where \( K(s) \) is a normalization term:

\[
K(s) = \sum_{p \in B} f(p - s)g(I_p - I_s)
\]  

(4)

Where \( f \) uses a Gaussian in the spatial domain which represents the domain filter and \( g \) uses a Gaussian in the intensity domain which represents the range filter (Agarwal and Kumar, 2016).

Intensity selector method uses roicolor command in Matlab which Select wanted region according to color or intensity levels in grayscale image.

2.1. Performance Measurement

The quality of image segmentation can be done by using MSE and PSNR parameters which defined as follow (Lee et al., 2016):

\[
MSE = \frac{\sum_{m,n}(I_{m,n} - I_{ref})^2}{m \times n}
\]  

(5)

\[
PSNR = 10 \log_{10} \left( \frac{R^2}{MSE} \right)
\]  

(6)

where \( m, n \) are matrix dimension and \( R \) dynamic range of the image (i.e. their bits).

3. RESULTS AND DISCUSSION

Best methods of contrast enhancement among five techniques were Contrast adjustment, for Benign and Cyst image, and image sharpening techniques, for Stone image, according to values of MSE and PSNR. Generally, Median filter had better values of MSE (lower) and PSNR (higher) according to Table 1.

| Technique          | Benign | Cyst | Stone |
|--------------------|--------|------|-------|
| Contrast adjustment| 74     | 77   | -     |
| Image Sharpening   | -      | -    | 108   |
| Median filter      | 47     | 48   | 50    |

Table 1- Shows PSNR for enhancement methods for the three cases.

Figure 2 shows input, cropped, enhanced and segmented images for all three cases. The images were cropped to just enhance and segmented the region of interest. The enhanced images through contrast and denoising didn’t show any difference by comparing with cropped images visually. That may be due the degree of enhancement didn’t receive to a level which can be seen visually. All three segment methods for benign just segment about 70% of total area as estimated visually from Figure 2a. More areas (~90%) were segmented for cyst (Figure 2b) and nearly 40% of stone were segmented as shown in Figure 2c.

These differences of segmenting of region of interest belong to the difference of percent of inhomogeneity of intensity levels for all cases. Lee et al. (2016) through using their method, Bilateral filter with Canny edge, segment all area of region of interest that due to their clear image.

The kmean with Intensity selector method was found better for the Benign case than other for its higher PSNR (16.68), lower MSE (1394.1), and small time of running (22.1 sec) according to Table 2. But for Cyst and Stone images, Bilateral filter with Intensity selector was found better than other according to same parameters. The MSE and PSNR show quality of segmented images rather than the percent of segmenting.
Figure 2: Show input, cropped, enhanced, and different image segmentation for (a) Benign, (b) Cyst with septa, and (c) Stone.
Table 2- Show MSE, PSNR and time consuming for different segment methods for the three cases.

| Segment type       | Benign |          |          |          |          |          |          |          |          |
|--------------------|--------|----------|----------|----------|----------|----------|----------|----------|----------|
|                    | MSE    | PSNR     | t(s)     | MSE      | PSNR     | t(s)     | MSE      | PSNR     | t(s)     |
| Threshold          | 1671.8 | 15.89    | 3.1      | 92.48    | 27.54    | 2.7      | 499.36   | 21.15    | 2.3      |
| Kmean+             | 1394.1 | 16.68    | 22.1     | 100.37   | 27.18    | 21.8     | 538.18   | 20.82    | 16.1     |
| Intensity selector |        |          |          |          |          |          |          |          |          |
| Bilateral filter+  | 1702.6 | 15.81    | 37.8     | 92.26    | 27.55    | 31.7     | 499.36   | 21.15    | 25.5     |
| Intensity selector |        |          |          |          |          |          |          |          |          |

The minimum time of processing for all three cases (average 2.7 s) was for thresholding segmenting if trial and error are neglected for obtaining optimum threshold value. Bilateral filter with Intensity selector technique takes maximum time for running (average 31.6 s). So, best method, for time considering, was kmeans with Intensity selector technique.

4. CONCLUSIONS

Generally, 2D ultrasound images are noisy that makes difficulty for good segmenting interest region even using denoising techniques which reduce level of noise. The thresholding method was segmenting nearly same area of the cases as other two methods. It consumes small time of running but needs a large number of trial and error to get optimum threshold value. So, it neglected from the comparison. The kmean with Intensity selector technique better than Bilateral filter with Intensity selector for the Benign case due to higher PSNR, lower MSE, smaller time of running, even it segments nearly same area of three cases as other methods. The other technique more suitable for Cyst and stone cases due to same parameters. The other technique is more suitable for Cyst and stone cases due to same parameters.

Conflict of Interest

The author would like to express his acknowledgment to the Salahaddin University for supporting him with available tools.

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