Automated segmentation of gallstones in ultrasound images

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***Abstract*- Gallstones are solid particles formed from bile in the gall bladder. In this paper, we propose a technique to automatically detect Gallstones in ultrasound images, christened as, Automated Gallstone Segmentation (AGS) Technique. Speckle Noise in the ultrasound image is first suppressed using Anisotropic Diffusion Technique. The edges are then enhanced using Unsharp Filtering. NCUT Segmentation Technique is then put to use to segment the image. Afterwards, edges are detected using Sobel Edge Detection. Further, Edge Thickening Process is used to smoothen the edges and probability maps are generated using Floodfill Technique. Then, the image is scribbled using Automatic Scribbling Technique. Finally, we get the segmented gallstone within the gallbladder using the Closed Form Matting Technique.**

Keywords - Anisotropic Diffusion, Unsharp Filtering, NCUT, Floodfill Technique, Automated Scribbling, Closed Form Matting.

I. INTRODUCTION

Gallstones are formed in gallbladder from the bile. Gallstones within the gallbladder often cause no problems. If there are many or they are large, they may cause pain when the gallbladder responds to a fatty meal. If their movement leads to blockage of any of the ducts connecting the gallbladder, liver, or pancreas with the intestine, serious complications may result. Blockage of a duct can cause bile or digestive enzymes to be trapped in the duct. This can cause inflammation and ultimately severe pain, infection, and organ damage. If these conditions go untreated, they can even cause death. Gallstones fall under the genre of lifestyle related health conditions.

Gallstones are most common among overweight, middle-aged women, but the elderly and men are more likely to experience serious complications from gallstones.

Ultrasound images along with the history of the patient are vital in identifying the gallstones. Automated segmentation of gallstones can simplify the detection process. In our approach we take as an input, an image with a possibility of a stone or multiple stones. The output image shows explicitly the gallstone(s) encased in the gallbladder boundary. The approach is discussed in detail in section 2 and the experimental results are discussed in section 3. The images have been taken from a Wipro GE Voluson 730-Pro machine. Images used in the discussion have been procured within a frequency range of 3.5-5 MHz, depending on the subject's thickness.

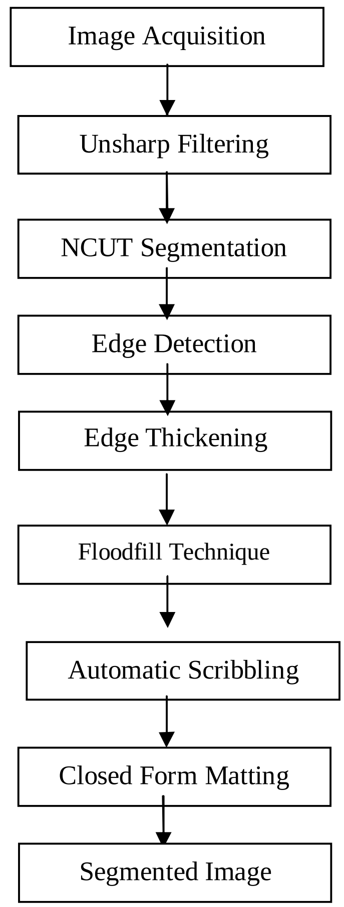

Fig.1 : AGS Technique Flowchart

II. SCHEMA

A) Anisotropic Diffusion Technique

This is a non-liner filtering technique introduced by Perona and Malik [1] to suppress the speckle noise. The advantage of this technique is that it suppresses the noise while leaving the fine structural features of the image intact. We applied this technique to the ultrasound image.

Here we intend to find $I(x, y)$ as a solution to a suitable diffusion process using $I_0(x, y)$ as the initial condition. We use the function :

$$I_t = div(c|\nabla I|\nabla I) \tag{1}$$

where div is the divergence operator ∇ is gradient operator and c an 'edge stopping function' given by Perona and Malik [1] as :

$$c(x) = \frac{1}{1+(x/k)^2} \tag{2}$$

where k is an application dependent parameter. Fig. 2b shows the image after applying the technique.

B) Unsharp Filtering

The unsharp filter [2] is a simple sharpening operator which derives its name from the fact that it enhances edges (and other high frequency components in an image) via a procedure which subtracts an unsharp, or smoothened, version of an image from the original image. The unsharp filtering technique is commonly used in the photographic and printing industries for crispening edges.

Unsharp filtering produces an edge image $g(x,y)$ from an input image $f(x,y)$ via

$$g(x,y) = f(x,y) - f_{smooth}(x,y) \tag{3}$$

where $f_{smooth}(x,y)$ is a smoothened version of $f(x,y)$ obtained after 2.1 . Unsharp Filtering produces the resultant image shown in Fig. 2c.

C) NCUT Segmentation

Here we use the segmentation technique proposed by J. Shi and J. Malik [3] which is known as NCUT Segmentation Technique. In NCUT the criterion of partitioning the image is minimizing inter group sum of weight of connections while maximizing intra group sum of weight of connections. For the paper we use the software provided by Timothee Cour *et al.* [4] which is for segmenting the image using the NCUT method. Using NCUT, the image is segmented into desired number of segments as shown in Fig. 2d.

D) Edge Detection

Edge detection is carried out using the Sobel Edge Detection. Sobel operator calculates approximate 2D spatial gradient magnitude at each point of the input image. Thus, we obtain the points at which the image changes. The gradient at each point of the image is a 2D matrix with horizontal and vertical component pair. A pair of 3X3 convolution masks is used. The resultant image is shown in Fig. 2e.

E) Edge Thickening

The resultant image we obtain after applying Sobel Edge Detection has discontinuities and gaps in between the edges. This can cause problems in Floodfill Technique (explained in section 2.6) by making some foreground portions of the probability map black and some background portions white which is undesirable and erroneous. So, thickening of the edges is carried out using some morphological functions which fills in the gaps in the edges and hence makes the image error-free. Fig. 2f shows the edge thickened image.

F) Floodfill Technique

Here, a plain white frame, say *P*, of same size as the input image is taken. The image we obtain after Edge Thickening is a black and white image with edges in white. We start by checking the colour of every pixel from left to right in the Edge Thickened image. We then change the colour of the pixel to black in frame *P* if we encounter a non-white pixel and halt on coming across a white pixel or the end of the frame. The procedure is now repeated from right to left, top to bottom and bottom to top directions. Fig. 2g shows the result of the operation.

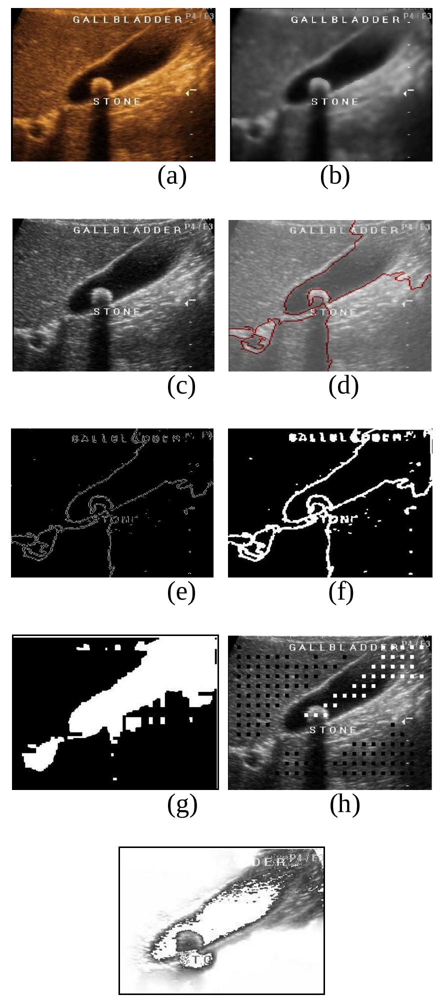

Fig. 2 : (a) Original Image. (b) Image after Anisotropic Diffusion. (c) Image after Unsharp Filtering. (d) Image after NCUT Segmentation. (e) Image after Sobel Edge Detection. (f) Image after Edge Thickening. (g) Constructed Probability Map. (h) Scribbled frame. (i) Final Segmented Image.

G) Automatic Scribbling

Automatic Scribbling, proposed by Abhishek *et al.* [5] and based on checking of the neighbouring pixel, is now put to use. Probability Maps have white colour in foreground and black in the background. Two parameters *n & k* are selected based on the dimensions of the image. Then, each pixel and *n* pixels in all directions from that pixel are checked. A *kxk* scribble is drawn in the original frame if all the *n* pixels have the same colour as the originating pixel. Pixel is left unchanged if colour is different. The resultant image is shown in Fig. 2h.

H) Closed Form Matting

Closed form solution to natural image matting, proposed by Levin *et al.* [6], is used in our approach. They derived cost function for grayscale images (ultrasound images in our case) with the assumption that the foreground and background remain steady over a small area around each pixel. Here, automatic scribbling method, proposed by Abhishek *et al.* [5], is used in place of manual inputs, to provide scribbles. Fig. 2i shows the final output with the circular stone surrounded with white.

III. EXPERIMENTAL RESULTS

In our experimental setup, we take as an input a Gallbladder ultrasound image with possibility of gallstone(s). First the image is smoothened by using anisotropic diffusion [1] which is shown in Fig. 2(b). Unsharp Masking [2] is then used to sharpen the edges, result of which is shown in Fig. 2(c). Image is then segmented using NCUT [3] as shown in Fig. 2(d). Edge Detection is then carried out as shown in Fig. 2(e). Thickening of the image then produces the result depicted in Fig. 2(f). Floodfill Technique to construct probability map is carried out producing the result in Fig. 2(g). Automatic Scribbling [5] is now employed which produces the result of Fig. 2(h). Finally, Closed Form Matting [6] demarcates the stone in white as shown in Fig. 2(i). This concludes The AGS Technique. Through this technique we are able to detect the presence of gallstone(s). This technique will help in eliminating the manual labour required to establish the presence of gallstone(s) by making the whole process automated.

Now, we show two more experimental results in Fig. 3 (a-i) and Fig. 4 (a-i), with all the steps carried out in the aforementioned manner.

IV. CONCLUSION

In this paper, we present a promising technique to segment gallstones. Experimental results clearly show that gallstone(s) along with the gallbladder can be readily segmented by our AGS technique. Our approach aids in demarcating a possible ailment in the form of stone(s) but, a concrete establishment of the diagnosis will require the patient's history.

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Fig. 3 : Steps 2.1 - .8

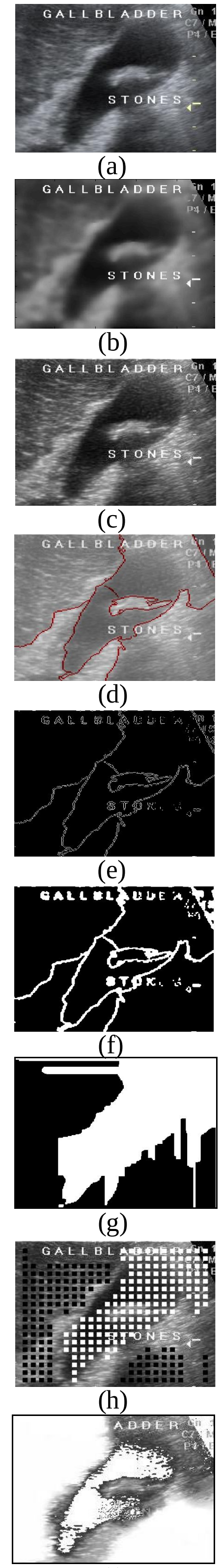

Fig. 4: Steps 2.1 - .8