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Research Article

AUTOMATIC DETECTION AND MEASUREMENT OF ABDOMINAL CIRCUMFERENCE IN FETAL ULTRASOUND IMAGES

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ABSTRACT

This study provides a new technique to determine the Abdominal Circumference (AC) of fetal in Ultrasound Images (US), the research presents an automated way to measure the circumference of the abdomen, the measurement process has applied to several ultrasound images without pre-processing step.We used the Hough Transform to detect the circuit that represents the abdomen inUS images. Before we apply Hough Transform, we convert the input gray-scale image to binary one, then we apply morphological operations to connect the converging regions and removing small objects in image, finally we use edge detector to find high-level pixels in image to insert it to Hough transform stage. We calculate AC via the radius which resulted from the output circle. The proposed method showed good performance to achieve substantial convergence between the manual measurement by a specialist doctor and the automated measurement results. The success rate up to have achieved 96%.

INTRODUCTION

Ultrasound images exposed to high amount of noise, which makes the visual appearance of these images is weak, also it suffers from lack of contrast as compared with other medical images, so it'sa difficult taskto detect any object in these images. Get those images need of an expert physician, because it takes the image after the emergence of specific elements within abdomen of the fetus (fetal stomach, portal sinus, umbilical vein), as Figure (1) shows. (Papageorphiou *et al*., 2013) As well as the absence of a skeleton framework around the fetus abdominal area makes detection process is a hard mission, because of the soft tissue surrounding the abdominal edges, which appears unclear in those images (Pam Loughna *et al*., 2009).

MATERIALS AND METHODS

The fetusabdomen appears in the ultrasound images as a circle with un clear limits in most cases, because of the soft tissue or the lack of bony structure surrounding the desired region (unlike the head area, for example), so it is necessary to use an effective algorithm for the right abdomen detection, and measuring the circumference accurately, Despite the lack of distinct limits, And the absence of phase to improve the inputimages. We threshold the input US images, then we apply several morphological operations on resulted binary images. After that we apply Hough Transform to detect abdominal area. In the following sections we will explain the most important techniques which used in our proposed method.

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Small Objects Removing

After we convert gray-scale image to binary one, we should improve the resulted binary image. This is accomplished through morphological operations and remove small items. MATLAB program offers function to do this task known as 'bwareaopen', represented as follows:

BW2 = bwareaopen (BW1, P, conn)

BW1 symbol represents binary input image, while BW2 represents the resulting binary image, and conn symbol defines the communication between the elements, or the neighborhood. It is a method to remove related items to the binary image, which is an area of less than P, where P represents an area of pixels that pre-defined by the user. Removing small objects is done by following algorithm:

1. Defines the connectedobjectsin the image.
2. Calculate the area of each object.
3. Removes objects that area quite smaller than the Parea.

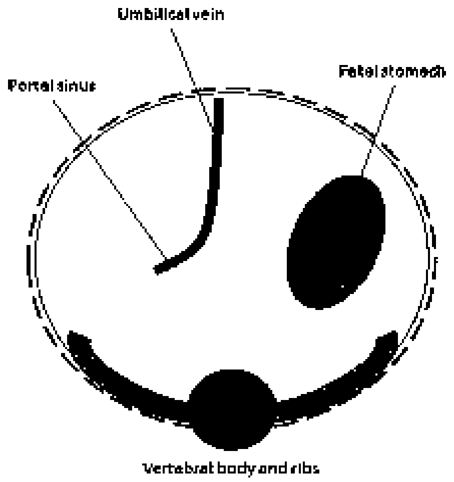

Figure 1. Abdominal Elements in Fetal US image

Morphological operations (Dilation): These operationsprocess input images based on the shapes of the mask. It applies Structuring Element on the input image. The resulting output image is the same size asinput, each pixel in the output image depends on the compared to the corresponding pixel in inputimage with its neighbors, and this in turn depends on the choice of the size and shape of the neighborhood (Senthilkumaran and Thimmiaraja, 2014). Expansion adds pixels at the edges of the elements in the image, the number of added pixels of element in the input image depends on the size and shape of the structural element whichused to processthat image. The method is: theoutput pixel represents the maximum value in the vicinity of the corresponding pixel in the input image. In binary casethe resulting output pixel is one when any of the pixel value under the structuring element mask is one in an input image, as shown in Figure (2) (Naser Jawas and Nanik Suciati, 2013):

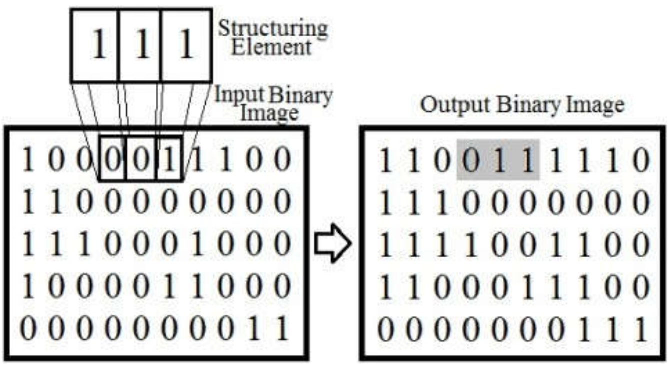

Figure 2. The idea of Dilation in binary image

Hough Transform

The first to use Hough Transform algorithm are researchers Richard and Peter in 1992, it was originally used to detect random elements in the image in different shapes, after that it has been developed to detect circular elementsinnoisy and lake of contrastimages, and then called Circular Hough Transform (CHT). The method is based on the conversion of grayscale images to binary images,and using the appropriate edges detection techniques. The goal of this technique is to find anomalies of the elements within a predefined set of objects through the Voting process (Yuen *et al*., 2008).

CHT depends on the circle equation:

$$r^2 = (x - a)^2 + (y - b)^2 \quad (1)$$

Symbols a, b represent center coordinates. And r is the radius of the circle. We expressthe parametric representation of the circle by:

$$x = a + r \cos(\theta)$$

$$y = b + r \sin(\theta) \quad (2)$$

CHT differ from the Line Hough TransformLHT, it depends on three parameters. This needslonger time and more memory storage, which is required to extract the necessary and sufficient information of thegiven image (Neelu Jain *et al*., 2012).

Circle Hough Transform techniquechoosesbetween the resulting candidate circles by voting in parametric Hough space, and select the maximum value in a matrix known as Accumulators. The parameters of the circle is defined by conical surfacesintersections which produce the resulting edges points of the resulted circle. The process can be divided into two phases: the first phase is to fix radius and finding the perfect center of the resulting circles in a two-dimensional parametric Hough space. The second phase is to find the perfect radius in a one-dimensional parametric space. To find parameters with known radius:if we fix the radius, then the parametric space will be reduced to a twodimension (includes only the coordinates of the circlecenter a, b), for each point (x, y) is located on the original circle,it can be defined as a circle centered at the point (x, y) and radius r, as in Equation (1). The intersection point of these circles in the parametric space will accordingto the center of the circle in the original image. Accumulators matrix used to track points of intersection in the parametric Hough space. Each point of intersection will increase the number of voting points by one. And thus will be selected local maximum point and that will represent the center in the original image, as the Figure (3) shows (Zhang Mingzhu and Cao Huanrong, 2008).

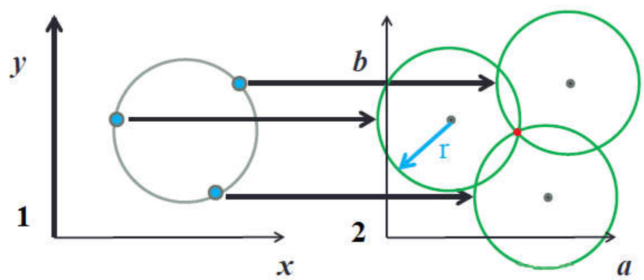

Figure 3. Find Center of circle with known radius.1- imagespace, 2- Hough space

Accumulator matrix are used to find the point of intersection in the parametric space. First, we need to divide the parametric space to "Buckets groups" using the Grid, and producetheAccumulator matrix according to thisgrid. The element in the accumulator matrix indicates the number of "circles" in the parametric space that pass through thegridcell,this number is also called the "Voting Number". Initially, each element in the array is the zeros,then each edge point in the original space corresponding to a circle in the parametric space, and increase the number of voters in the grid cell that pass through the circle. This process is called voting. After voting or election process, we can find the local maximum value in the Accumulatormatrix. This value is the opposite to circle centers in the original space (Zhang Xiao and Peng Weij, 2006). If we want to find circle parameters with unknown radius: Accumulators matrix here will be three-dimensional. The same prior method, but we are here to discuss different cases of radius lengths. as the Figure (4) illustrates.

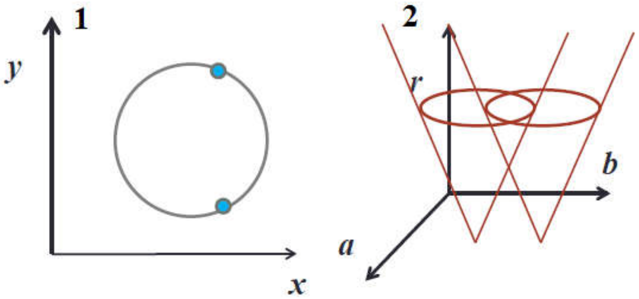

Figure 4. Find Circle parameters if radius were unknown. 1- original space, 2- parametric space

As we remark that the points position in parametric space would be a surface of the cone, which expresses the resulting cone from the single point (x, y). Therefore it will built different circles of various diameters for each level of r. This means that the edges of each point (x, y) located on the circle circumference will result a cone. Triple (a, b, R) will be met with the accumulator cell, where the maximum number of intersections for resulting conical surfaces (Yu Tong *et al*., 2006).

Table 1. Comparison result on four US images

	Img1	Img2	Img3	Img4
Auto Measurement	507.3	719.2	679.5	400.1
Manual Measurement	482.8	683.9	656.5	381.2

Figure 5. Four abdominal US images

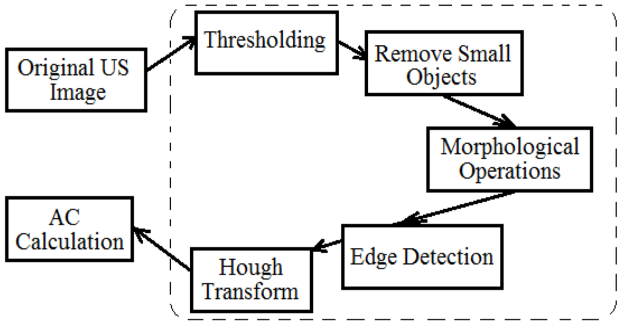

Figure 6. Box chart of proposed method

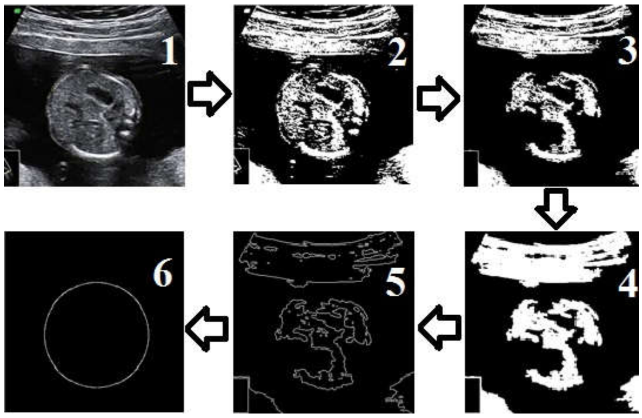

Figure 7. Apply proposed method on one of input images

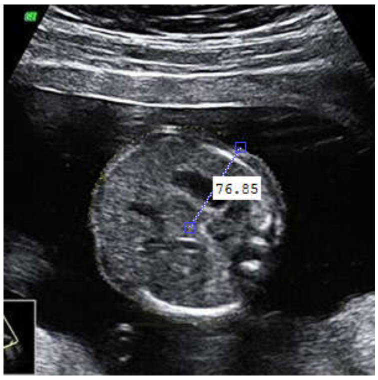

Figure 8. Manual radius measurement

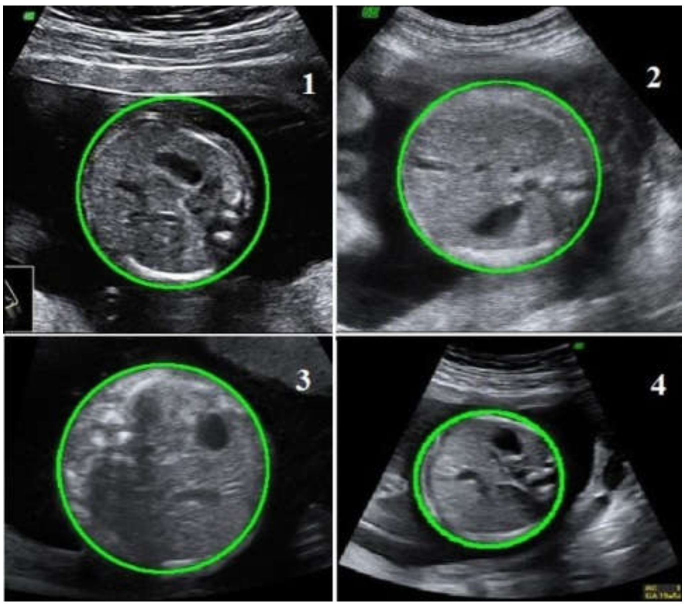

Figure 9. The result of proposed method

RESULTS AND DISCUSSION

We have to follow a series of steps to ensure that access to the circuit corresponding to the abdomen area automatically.We apply the proposed method on four US images, and shown in Figure (5). First we apply thresholding step to convert input image to binary one, after that we remove small objects via the "bwareaopen", Then we apply dilation process followed by edge detection In order to demonstrate the limits of the circle corresponding to the abdominal area.Finally we apply CHT, that returns the circle center coordinates and the radius, The Figure (6) shows the box chart of the proposed method. Knowing the radius we can calculate the abdominal circumference via the simple equation (2 * Pi * r). AC measure help doctor to know the information concerning the weight of the fetus, as well as in the calculation of the time of birth and date of conception (Bhandary *et al*., 2004) (Harlev *et al*., 2006).

Figure (7) shows the output of each step, if we apply the proposed method on one of the input images. We can judge the validity of the result automated measurement process of the proposed method by comparison with manual measurement. Manual measurement is done by a specialist doctor whois doing this by taking the AC measure on the screen of ultrasound device, or by "imtool" instruction in MATLAB, as the Figure (8) shows. The Table (1) illustrate the high convergence between the resulted measurements and the manual ones (in pixels). When we apply the proposed method on those four US images, we get the following results which appear in the Figure (9).

Conclusion

Despite the restrictions suffered by Hough transform, it is the best solution for auto circle detection in abdominal US images. These restrictions include the dependence on the quality of the data i.e. it depends on the outcome of theedges detector,also it influenced by noise, and it depends on location and size of the objectin image. These restrictions make it difficult to use in the detection other more complex shapes, Because other shapes require additional parameters exceed the three parameters (a, b, R). The resulted AC measurement is very important for the doctor, it helps him to determine the Gestational age and date of birth, as well as benefit him in the fetal weight estimation.

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