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Fetal Head and Femur Detection from USG image to Estimate Gestational Age

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Abstract— **Ultrasonography of fetal head can be used as one of the ways to measure the gestational age. However, its result does not always provide accurate information due to the poor quality of the image and the result is very dependent on the doctor observation so it is possible for errors to occur in the identification process. To reduce the errors of the identification, this paper conducted a research on the detection and segmentation of fetal head ultrasound image in order to get more accurate result of the estimation of gestational age. This paper also uses femur length of fetal as an additional parameter to increase the accuracy level of the result. Integral Projection is trained to get the object of the fetal head and femur. Biparietal Diameter (BPD) and Femur Length (FL) is parameter used to determine gestational age. From the result of the research, the proposed method can estimate gestational age more easily and more accurately. The accuracy rate for estimated gestational age was 97.77%.**

Keywords— Ultrasonography, fetus, Biparietal Diameter, Femur Length, Gestational Age, Integral Projection

I. Introduction

Pregnancy is something that couples will look forward to. they will do various ways to keep the mother and the candidate of their baby to stay healthy and can be delivered normally. There are several factors that can help the success in pregnancy, among others, is by calculating the age of pregnancy, knowing the development of the womb, and knowing the estimated delivery. By knowing the age of pregnancy, a mother can know the growth of the organ and monitor what is going on in the fetus, what are needed by the fetus and what are the things that should be and must not be done during the gestational age.

Gestational age can be determined by various ways, one of them is by through ultrasound imaging. Ultrasonography (USG) is a tool that uses the basic principles of high frequency sound waves. To know the age of pregnancy through ultrasound there are several parameters used, one of them is by measuring the head of the fetus. The head of the fetus is the most important part because it is very decisive and could affect the course of labor. But ultrasound itself can not necessarily produce accurate information because the resulted image has an inconsistent quality. The ultrasound results also depend heavily on the observation of the physician or the operator using it, so there is no possibility of errors in identification [1]. To reduce the errors of identification, this paper researched on the detection and segmentation on ultrasound image of fetal head using BPD (Biparietal Diameter). However, the identification results will be more accurate if it involves more than one parameter. So, in this research, FL (Femur Length) parameter will also be used.

In a previous study titled “Performance Analysis of Gaussian and Bilateral Filtering Case of Determination the Fetal Length”, the condition of fetal health through the Crown Rump Length (CRL) parameter using Watershed method segmentation is being discussed [2]. While in the study titled “Ultrasonographic Fetal Gestational Age Determination by Biparietal Diameter”, it aims to compare the accuracy of predicting gestational age by measurement of biparietal diameter in the second and third trimesters. The result of research has 66.28% accuracy level [3].

The method used in this research is pre-processing using Gaussian Filter [4], Morphology Operation, Canny Edge Detection [5], and Find Contour to improve and clarify the ultrasound image, segmentation using Integral Projection [6][7] to obtain head circumference and femur fetal length, parameter of BPD (Biparietal Diameter) [8] and FL (Femur Length) [9] is used to determine gestational age.

II. Methodology

The method used in this research is Gaussian Filter, Morphology Operation, Canny Edge Detection, Find Contour, Integral Projection. And the parameters used to estimate gestational age are Biparietal Diameter and Femur Length. The research flow diagram is shown in Figure 1.

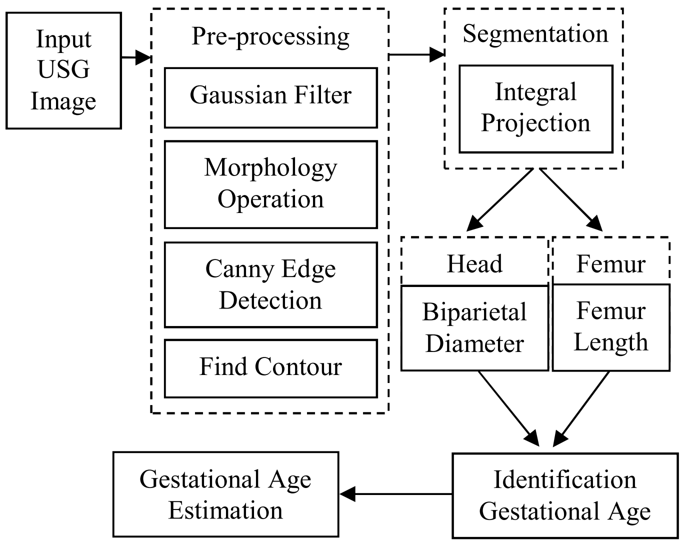


Fig1. Flow chart system

Input used in this research is the ultrasound result of two-dimensional head and femur fetus in the second trimester where has a low image quality level that has a lot of noise and contrast is less sharp. To improve the image quality is done by pre-processing method using Gaussian Filter, Morphology Operation, Canny Edge Detection, and Find Contour.

A. Gaussian Filter

Gaussian Filter is one of the finer filters that can prevent image edge errors. Gaussian filter also serves to reduce the noise in the image. This is as a result of excessive noise intensity. Gaussian works by removing the high-frequency components of the image, so the Gaussian Technique is said to be a low-pass filter. The Gaussian filter is obtained by multiplying the pixel value of the original image and the kernel in the form of a 2D Gaussian function.

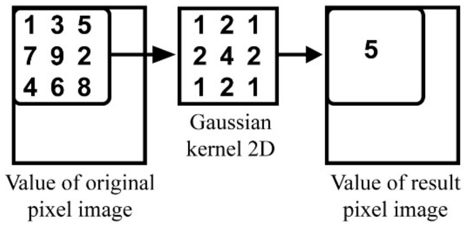


Fig2. Multiplication of pixel values in Gaussian Filter

Gaussian filter uses Gaussian distribution function. Then the filter is generally represented in the form of a two-dimensional array on [x, y]. Gaussian equations for two-dimensional space.

$$G(x,y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}} \quad (1)$$

G (x, y) is a Gaussian matrix element at position [x, y]. It is the standard deviation or sigma. The bigger the sigma, the weaker is the localization (distance between pixels), but the detection (edges, noise, etc.) gets better. The smaller the sigma, the better the localization (distance between pixels) is, but the detection (edges, noise, etc.) gets worse. (x,y) is the size of the Gaussian matrix that reaches the point -x to + x, and its midpoint is at x = 0, y = 0.

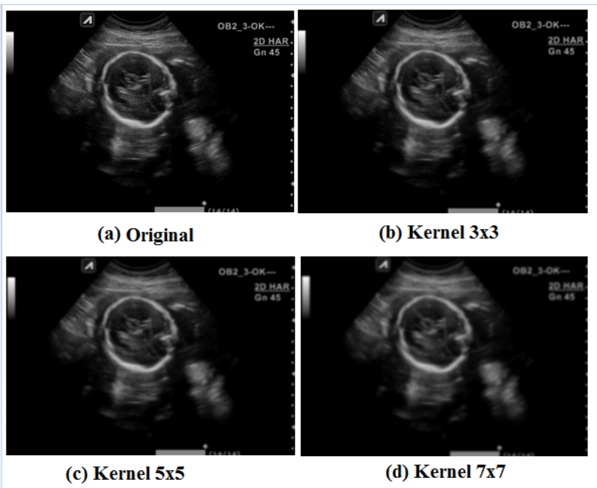


Fig3. Gaussian in different kernel

The larger the kernel used, the smoother the image will be.

B. Morphology Operation

Morphology operation is defined as a tool for extracting image components useful in the representation and description of regional forms. An image object can be represented in the form of a set of positions (x, y) of value 0 or 1. The morphological image processing is done by parsing a structuring element of an image in a manner similar to that of image convolution.

In morphology, an important key is the selection of elemental structures. The elemental structure has two important components, namely shape and size, both of which greatly affect the results of morphological operations. There are several examples of commonly used elemental structure forms, some of which are rectangular, square, line, disk, and diamond.

The morphology operation used in this study is the top-hat operation. Combining image measurement with opening and closing will result in top-hat and bottom-hat transformations. Top-hat transforms are used for bright objects in dark backgrounds. The top-hat transform of the grayscale image f is defined as f-minus the opening result:

$$T_{hat}(f) = f - (f\,0\,b) \quad (2)$$

An important use of top-hat transformation is to improve uniform illumination effects, because good illumination (uniform) plays an important role in the process of extracting objects from the background. This process, called segmentation, is one of the first steps to be done in automated image analysis. Commonly used segmentation approach for input image threshold.

C. Canny Edge Detection

Edge Detection on an image is a process that produces the edges of image objects, its purpose is to mark the part that becomes the detail of the image and fix the detail of the blurred image, which occurs due to error or the effect of the acquisition process image. A point (x, y) is said to be the edge of an image when the point has a high difference with its neighbors. One of the modern edge detection algorithms is edge detection using the Canny method. Canny edge detection was discovered by Marr and Hildreth who examined the modeling of human visual perception.

The steps to perform the Canny Edge Detection process are as follows:

First, smoothing the image with image convolution and Gaussian filter g (x, y) For digital image processing, zero mean Gaussian two variables are expressed by the following equation:

$$\frac{g(x,y)}{c} = e^{-\frac{x^2+y^2}{2a^2}} \quad (3)$$

Second, finding gradients on each pixel by applying a sobel operator. The equation for estimating the gradient in the x and y directions by using the kernel as follows:

$$\text{a } K\ Gx = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \quad (4)$$

$$K\ Gy = \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix} \quad (5)$$

Furthermore, in order to give a better result that is to determine the edge direction with the equation as follows:

$$\theta = arctan\left(\frac{|Gy|}{|Gx|}\right) \quad (6)$$

Where θ is the angle of gradient used to determine the direction of pixel comparison in the next process. The next step is non-maximum suppression or peak detection only maintains the gradient points which have the highest intensity value of the neighbor. This process is done by utilizing the direction information of an edge. Furthermore, the thresholding process is checked for the pixel value against the threshold value, if the pixel value is greater than the upper threshold, then the pixel is recognized as the strong edge. The equation is as follows:

$$T = (fmax + fmin) /2 \quad (7)$$

If the pixel value lies below the upper threshold and below the upper threshold then the pixel is recognized as the weak edge. Finally, the point recognized as the strong edge and the weak edge obtained from the double thresholding result will be checked. If the pixel value is greater than the upper threshold then the pixel is the edge pixel. If the pixel is smaller than the lower threshold then the pixel is ignored.

D. Find Contour

Find contour here is used to remove the small noise that still exists after the canny edge detection process.

Here are the stages of the Find Contour process.

1. Read the data to be processed using find contour.
2. Change the input image to grayscale.
3. Make the image blur
4. Edge detection using Canny Edge Detection.
5. Edge detection results are used to search for contour.
6. Calculate the area of each contour that has been found and give a limit if >100 then contour is drawn.
7. Draw a contour that has an area of >100.

E. Integral Projection

Integral projection is a method used to locate the region or location of an object. This method can be used to detect the boundaries of different image areas. This method can also be called the integral row and column of pixels, since this integral adds pixels per row and pixels per column.

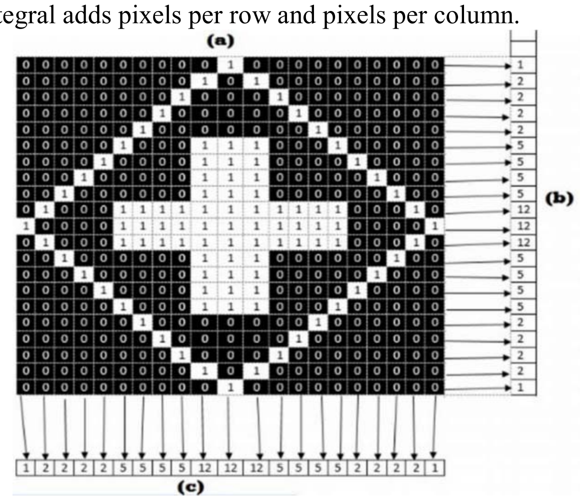


Fig4. (a) Integral projection matrix (b) Integral projection vertical (c) Integral projection horizontal

There are two types of projection, that are horizontal projection which is done by looking at the x-axis and vertical projection done by looking at the y-axis. The vertical projection is to calculate the number of pixels of the object to determine the coordinates of the upper and lower bounds of the text. The vertical projection process works by summing the pixel values in each column.

The horizontal projection is to calculate the number of pixels of the object to determine the right and left boundary boundaries of the text. The way the horizontal projection method works is to sum the pixel values of an image horizontally.

Integral projection is defined by:

$$h(j) = \sum_{i=1}^{N\,row} x(i,j) \text{ and } h(i) = \sum_{j=1}^{N\,row} x(i,j) \quad (8)$$

Where:

i = row

j = column

0	1	2	3
1	0	1	2
2	2	0	4
3	3	2	

The value of each row and column are summed, then get the feature number from the image as follows:

3	3	2	3	2	4

The vertical projection process works by summing the pixel values in each column, as shown in the equation:

$$VIP(j) = \sum_{i=1}^{m} f(i,j) \quad (9)$$

In this vertical projection process there is a modification of the usual Integral Projection process.

The way the horizontal projection method works is to sum the pixel values of an image horizontally as shown in the equation:

$$HIP(j) = \sum_{j=1}^{n} f(i,j) \quad (10)$$

F. Biparietal Diameter

Biparietal Diameter (BPD) is the maximum distance between the front and back parietal bones at the head position of occiput transverse. The most accurate measurement of BPD in the determination of gestational age between 12-28 weeks where BPD growth shows a linear line.

In the measurement of BPD sought a symmetrical head piece, then split perpendicular to the midline and searched for the smallest piece.

If the cutting method is done by elliptical approach, then the calculation of BPD can be assumed equal to the calculation to find the diameter on the ellipse, that is:

$$Diameter = 2 * b \text{ (semi minor)} \quad (11)$$

G. Femur Length

Femur Length is a measurement of the femur length where this measurement has the same accuracy as BPD in determining the gestational age. Although to get a femur picture is more difficult than BPD, especially in the fetus is very active to move, but the measurement is easier to do because it is a long bone, then the measurement error is smaller than other parameters.

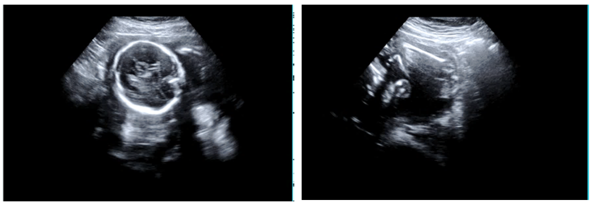
This FL measurement is done by finding Euclidean Distance or the distance between the end coordinates (x, y) with the calculation:

$$\text{Distance} = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2} \qquad (12)$$

Femur display measurements are searched by scanning the left border of the image and the right border of the image. When the intensity is more than 200. Once obtained the coordinates are then calculated using the Euclidian formula.

III. Experiment Result

Input used in this research is the ultrasound result of two-dimensional head and femur fetus in in the second trimester which has a low image quality level that still has a lot of noise and contrast is less sharp. The system input is shown in Figure 5.



(a) (b)

Fig5. (a) Input of fetal femur (b) input of fetal femur

To improve the image quality of head and femur then pre-processing using Gaussian Filter method, Morphology Operation, Canny Edge Detection, and Find Contour are performed. The result of pre-processing the fetal head is shown in Fig. 6 and the result of pre-processing of the fetal femur is shown in Fig.7.

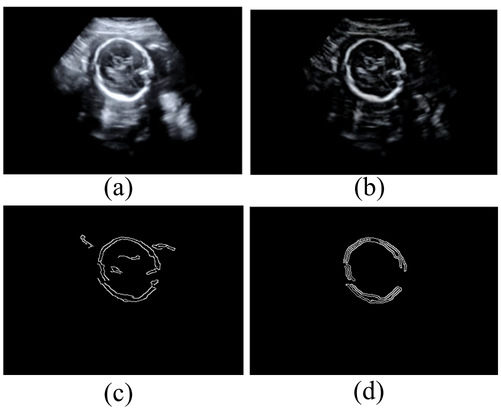


Fig6. Fetal Head (a) Gaussian Filter (b) Morphology Operation (c) Canny Edge Detection (d) Find Contour

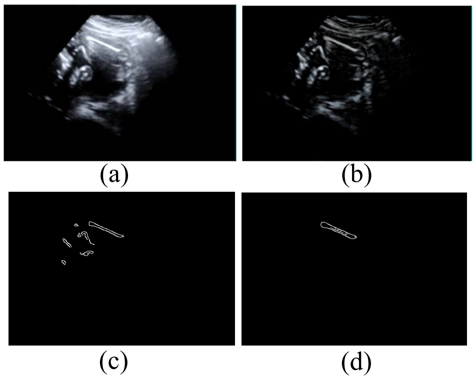


Fig7. Fetal Femur (a) Gaussian Filter (b) Morphology Operation (c) Canny Edge Detection (d) Find Contour

In this research, Gaussian Filter is employed to remove components that have high-frequency in the picture. Then after the Gaussian filter method performed, an improvement to the effects of illumination which is not uniform is done by using top-hat morphology. With morphology, top-hat lighting is not evenly distributed on the image of ultrasound for the better. Next is to clarify the edge of the image with Canny Edge Detection. In this method obtained the edge of the femur head and femur object. The final method of pre-processing is Find Contour which is used to remove any small noise that remains.

After pre-processing is done, then the segmentation is performed. The process of segmentation is the separation of objects from another area within an image so that it can be used for other processes. In this research, the objects in interest are the head and femur of the fetus. This segmentation method uses integral projection to detect fetal head and fetal femur.

Segmentation using Integral Projection on the fetal head is done by scanning pixels horizontally and vertically. Therefore, the left, top, and bottom points used to create ellipse could be obtained.

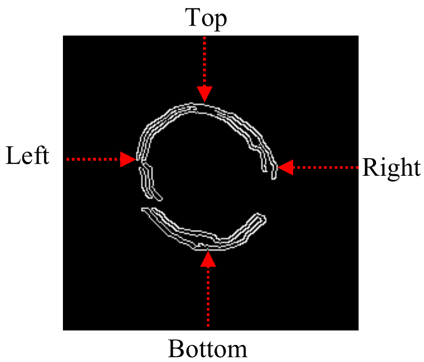


Fig8. Detection point left, right, top, bottom in fetal head object

After obtaining the leftmost point, right, top, and bottom is then included in the equation ellipse.

$$\frac{(x-h)^2}{a^2} + \frac{(y-k)^2}{b^2} = 1 \qquad (13)$$

After the results obtained from the ellipse equation then the results of ellipse are shown in Figure 9.

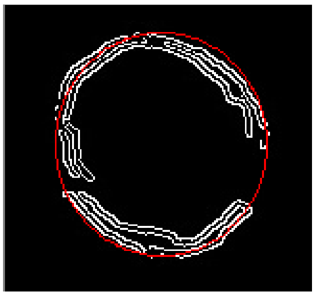


Fig9. Output of integral projection in fetal head object

While on femur fetus pixel scanning done horizontally so get the point of left and right.

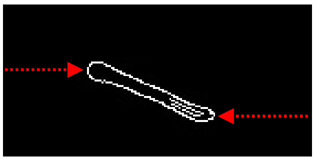


Fig10. Detection point left and right in fetal femur

So, the result of integral projection on femur fetus as in figure 11.

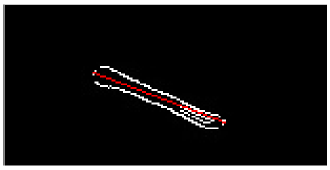
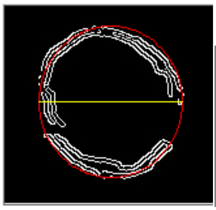
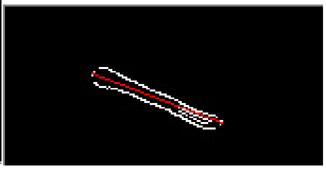


Fig11. Output of integral projection in fetal femur object

After the segmentation is done, the next process is calculating Biparietal Diameter and Femur Length. Biparietal diameter was obtained from the shortest diameter of ellipse while Femur Length was obtained from Euclidean Distance. Biparietal Diameter and Femur length results are shown in Figure 11.



(a)



(b)

(c)

Fig11. (a) Biparietal Diameter (b) Femur Length (c) Biparietal Diameter and Femur Length Result

After obtained the value of Biparietal Diameter and Femur Length is completed, the next process is identifying the age of pregnancy by comparing the results of Biparietal Diameter and Femur Length with standardization table [10].

TABLE I Standardization table

GA (Week)	BPD (cm)	FL (cm)
16	3.23	2.05
17	3.6	2.37
18	3.95	2.67
19	4.3	2.98
20	4.64	3.27
21	4.97	3.56
22	5.3	3.84
23	5.62	4.11
24	5.93	4.38
25	6.23	4.64
26	6.53	4.89

According to table I, GA is the Gestational Age, BPD is the measurement result of Biparietal Diameter, and FL is the result of the measurement of the Femur length. To use the standardization table, when the BPD measurement results are 3.23, the gestational age is 16 weeks. when the BPD measurement results are 3.6, the gestational age is 17 and above. When the size has not reached a certain value, it will be included in the previous gestational age. Same thing applied for FL. Estimates of gestational age were obtained from the mean gestational age of Biparietal Diameter and Femur Length.

$$\frac{\text{Age of Biparietal Diameter} + \text{Age of Femur Length}}{2} \quad (14)$$

Results from estimated pregnancy age with 30 data are in Table II.

TABLE II Result of Gestational Age

No	Name	Doctor Estimation (Week)	System Estimation (Week)	Percentage of Success (%)
1	01.jpg	23	25	91.30
2	02.jpg	24	25	95.83
3	03.jpg	24	24	100.00
4	04.jpg	25	24	96.00
5	05.jpg	25	25	100.00
6	06.jpg	16	16	100.00
7	07.jpg	23	23	100.00
8	08.jpg	17	18	94.12
9	09.jpg	25	25	100.00
10	10.jpg	17	16	94.12
11	11.jpg	16	16	100.00
12	12.jpg	22	22	100.00
13	13.jpg	17	17	100.00
14	14.jpg	23	24	95.65
15	15.jpg	17	17	100.00
16	16.jpg	18	19	94.44
17	17.jpg	17	17	100.00
18	18.jpg	25	25	100.00
19	19.jpg	20	21	95.00

20	20.jpg	18	18	100.00
21	21.jpg	22	22	100.00
22	22.jpg	18	18	100.00
23	23.jpg	20	20	100.00
24	24.jpg	16	17	93.75
25	25.jpg	25	25	100.00
26	26.jpg	22	22	100.00
27	27.jpg	17	18	94.12
28	28.jpg	19	19	100.00
29	29.jpg	22	21	95.45
30	30.jpg	15	16	93.33
Average				**97.77**

Table II shows the success rate of the system that has been built. The results obtained by the system are compared with the results of estimates by obstetrics and gynecology doctors. The results of the experiment involved 30 ultrasound images of fetal head and femur. The minimum percentage of success is 91.30% with a distance of 2 weeks and the maximum success is 100% with a range of 0 weeks. The results can still be considered to be valid when the range between the system results and the doctor's results is not more than 2 weeks. Based on 30 experiment data, it can be obtained an average success of 97.77%.

IV. Conclusion

From the result of the research, the pre-processing process can be used to minimize the noise in USG image. Segmentation using Integral Projection can detect the fetal head and femur object. Biparietal Diameter and Femur length parameter can be used to identify the gestational age. Thus, the proposed method can estimate gestational age more easily and more accurately. The accuracy rate for estimated gestational age was 97.77%. The next plan is to add other comparative parameters such as the abdominal circumference to increase the accuracy of the estimated results of gestational age.

Acknowledgment

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