# Automatic Gestational Age Estimation by Femur Length using Integral Projection from Fetal Ultrasonography

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***Abstract*—The accuracy of scanning is important to properly know a fetus condition in the womb. However, the results still depend on a doctor's observation, so there are possibility of errors in identification. We propose an automatic gestational age identification system of images using femur length parameters to reduce identification errors. The method used is a combination of Gaussian Filter, Morphology Operation, and Canny Edge Detection methods to improve scanning result and to minimalize the noise. Find Contour method is used to obtain the fetal femur object, then searched for femur length using Integral Projection. This study uses samples of fetal femur data in second trimester. From the result of the study Integral Projection can be used to measure the femur length with an average success rate of 94.8% and the identification of gestational age with an average success rate of 97.6%.**

***Keywords—Fetus; Automatic; Gestational Age; Femur Length; Integral Projection;***

## I. Introduction

There are several factors that can help the success in pregnancy, which are by calculating the age of pregnancy, identifying the development of the womb, and knowing the estimated delivery due time. By knowing the age of pregnancy, a mother can know the development or the growth of the organ in the fetus, what the fetus needs and what things are allowed and prohibited to do during the gestational age. In addition, by knowing the age of pregnancy, a pregnant woman can estimate the examination schedule that must be done with the doctor or the midwife, so that the pregnancy will not face any problem and will lead into a successful delivery [1].

Gestational age can be known by many ways, one of them is through ultrasonography (USG). To know the age of pregnancy through USG, there are several parameters used, one of them is the measurement of fetus femur. But, it is alone may not necessarily produce accurate information because the resulted image has a low quality.

The results also depend heavily on the observation of the physician or the operator using it, so there is no possibility of errors in identification [2]. To reduce the error of identification, we create a system that can detect the age of pregnancy automatically using fetal femur.

The method we use is a combination of Gaussian Filter method, Morphology Operation, and Canny Edge Detection to improve the image. Find Contour used to get the fetal femur object. And Integral projection is used to obtain fetal femur length. This study also aims to make it easier for doctors to get more accurate gestational age from the fetal femur through ultrasound. With this system the doctor no longer needs to pull certain points to get the fetal femur length. The system will automatically get objects along with the size of the fetal femur length.

## II. Related Work

Previous researches also discussed the measurement of fetal biometry through the length of the fetus, and the fetal head. The length of the fetus is measured using Crown Rump Length (CRL) [3], [4] and the fetal head is measured using Biparietal Diameter (BPD) [5], [6].

Gusti Ayu Almira and Ahmad Puji Santoso has built a system to analysis of the fetal health condition. The research using Crown Rump Length (CRL) and the gestational sac diameter to get the basis for determining the level of the fetal health. Gestational age from the CRL and gestational sac would be compared with the calculation of the first day of last menstruation (HPHT). This research has an error rate of 5%. CRL is preferred to the measurement of gestational age at the beginning of pregnancy or first trimester.

Whereas in the study using Biparietal Diameter from Lokesh Kumar has built a system to compare the accuracy of predicting the gestational age using Biparietal's Diameter measurement in second and third trimester. Prediction of gestational age before 30 weeks has an accurate result but the precision declines after that. Measurement using Biparietal Diameter often having trouble when engaged fetal head, direct occipito-anterior and occipito-posterior positions and in breech presentation. The results of the study have an accuracy rate of 66.28%.

## III. Method And Material

The femur picture of the fetus is obtained from the measurement of a specialist gynecologist who manually that is, by capturing an image that is good if possible, then pulling the point from one part to another on the fetal femur using a scroll mouse on an ultrasound machine. Images taken from patients with 16 to 23 weeks gestation (second trimester).

Machine used to take pictures of fetus femur is Alpinion E-CUBE 9 Diamond with jpg format. The flow chart system for gestational age estimation of the femur length can be described in Fig. 1.

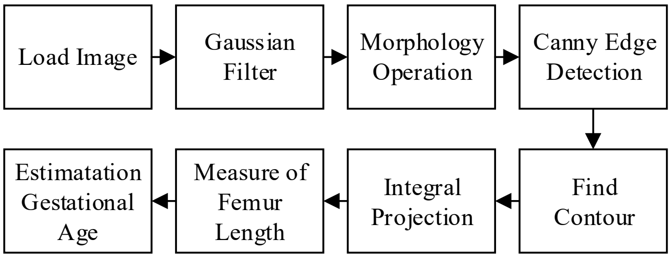



Fig. 1. Flowchart system

### *A. Gaussian Filter*

Gaussian filter efficient to smoothing images and used to remove noise and detail [7]. This is as a result of excessive noise intensity. How Gaussian works is to remove the high-frequency components of the image.

So the Gaussian Technique is said to be a low-pass filter method. 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.

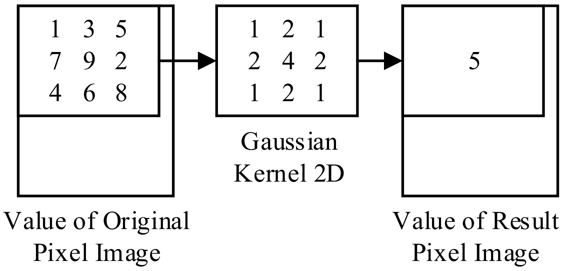



Fig. 2. Gaussian 2D function

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 $[x, y]$ is the standard deviation or sigma. The bigger: localization (distance between pixels) is weak or remote, but to detect (edges, noise, etc.) gets better. The smaller: localization (distance between pixels) is good, but for detection (edges, noise, etc.) is weak. is the size of the Gaussian matrix that reaches the point $-x$ to $+x$, and its midpoint is at $x = 0, y = 0$.

### *B. Morphology Operation*

The morphological operation are used to detect noisy pixels in the residue detector. Since the open removes salt noise and close removes pepper noise, through the operators the salt and pepper pixels noises can be notably determined. In general, these transformations find structures which have been removed by the opening and closing filters and the residual between the original image and the filtered image increases notably the contrast of the erased regions [8].

In this research the morphological operation used is Top-hat. Top-hat results from combining image reduction with opening and closing. The main principle of this transformation is to remove objects from images by using Structuring Elements in opening and closing operations that do not match the objects to be deleted. Top-hat transforms are used for bright objects in dark backgrounds, The equations of top-hat transformations are as follows:

$$T_{hat}(f) = f = (f \ o \ b) \quad (2)$$

The top-hat transform of the grayscale image f is defined as f minus the opening result.

### *C. Canny Edge Detection*

In the process of Canny edge detection, the edges of the image objects will be generated, which aims to mark the part of the image detail and improve the detail of the image is blurred, which occurred due to error or the effect of image acquisition process.

The steps to perform the Canny Edge Detection [9] process are as follows:

1. First, smoothen 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:

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

2. Second, find the 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:

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

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

3. Next, we must determine the edge direction to improve the quality of the image, with the equation as follows:

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

$\theta$ is the angle of gradient used to determine the direction of pixel comparison in the next process.

4. The next step is non-maximum suppression or peak detection which is used to maintain its gradient points which have the highest intensity value of its neighbors. This process is done by utilizing direction information from an edge.

5. Then, the thresholding process is done to check 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, with the equation as follows:

$$T = {(f_{max} + f_{min})}/{2} \quad (7)$$

If the pixel value lies below the upper threshold and below the upper threshold then the pixel is recognized as a weak edge.

6. Finally, the point recognized as the strong edge and the weak edge obtained from double thresholding 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. Obtain the input image which will be used in find contour processing.
2. Change the input image to grayscale.
3. Blur the image.
4. Perform Edge detection using Canny Edge Detection.
5. Perform Edge detection results are used to search for contour.
6. Calculate the area of each contour that has been found and gives a limit if > 300 then contour is drawn.
7. Draw contour that has an area of > 300.

### E. Integral Projection

An 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, so it can search the location of faces and features. This method can also be called an integral row and a pixel column, since this integral adds pixels per row and pixels per column [10]. The following is the integral projection equation used.

$$HIP = \sum_{j}^{n} 1f(i,j) \quad (8)$$

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

The picture below is an illustration of the integral projection method.

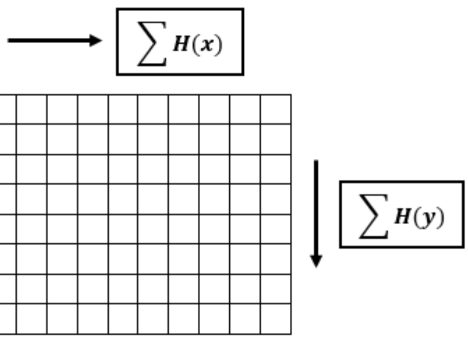



Fig. 3. Illustration of integral projection method

In this study vertical projection is used to find the starting point and end point of the femur segmentation of the fetus. The image used in this method is grayscale type.

### F. Femur Length

Femur Length measurements were obtained from measuring the tip of the femur to the other end of the femur which has been obtained from the integral projection method using the Euclidian Distance formula. Here is the Euclidean distance formula.

$$Euclidian\ Distance = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2} \quad (10)$$

After results obtained from the Euclidean distance which is the length of the femur it can be searched gestational age by comparing the femur length results with standardized table Hadlock [11]. The standardization table is in the Table 1.

TABLE I. STANDARIZATION TABLE

| GA (Week) | FL (cm) | GA (Week) | FL (cm) |
|---|---|---|---|
| 13 | 1.07 | 27 | 5.14 |
| 14 | 1.40 | 28 | 5.38 |
| 15 | 1.73 | 29 | 5.61 |
| 16 | 2.05 | 30 | 5.84 |
| 17 | 2.37 | 31 | 6.06 |
| 18 | 2.67 | 32 | 6.27 |
| 19 | 2.98 | 33 | 6.48 |
| 20 | 3.27 | 34 | 6.68 |
| 21 | 3.56 | 35 | 6.87 |
| 22 | 3.84 | 36 | 7.06 |
| 23 | 4.11 | 37 | 7.23 |
| 24 | 4.38 | 38 | 7.41 |
| 25 | 4.64 | 39 | 7.57 |
| 26 | 4.89 | 40 | 7.73 |

## IV. RESULT

The first stage in this research is loading the image of fetus femur. The fetus femur image can be seen in Fig, 4.

Fig. 4. Result of fetal femur

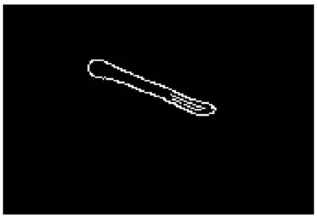
Images have a high enough noise level so that the preprocessing process needs to be done so as to reduce the noise contained in the images of fetus femur.

The preprocessing process used in this research is Gaussian Filter, Morphology Operation, Canny Edge Detection. The results of the preprocessing process can be seen in Fig. 5.

a. Gaussian filter

b. Morphology operation

c. Canny Edge Detection



d. Find contour

Fig. 5. Preprocessing process result

The results of the Gaussian Filter process have a blur effect instead of the previous image. The Gaussian Filter results are in Fig. 5 (a). Then the next process is Morphology Operation, the result is a picture of femur has a good illumination level when compared to previous images. To get the edge of the object then used Canny Edge Detection.

From the process of Canny Edge Detection still looks some noise. Noise in the intent is the small parts that exist between the objects of the femur. To fix the shortcomings of the Canny process then use Find Contour to select small parts. So, the object will look more clean. The find contour results are shown in Fig. 5 (d).

From the results of find contour process sought the starting and ending points of the femur using integral projection. Each pixel in the horizonal region is scanned from the left to find the starting point and then after finding the pixel with an intensity > 100 then the pixel is again scanned from the right to find the end point with an intensity pixel > 100.

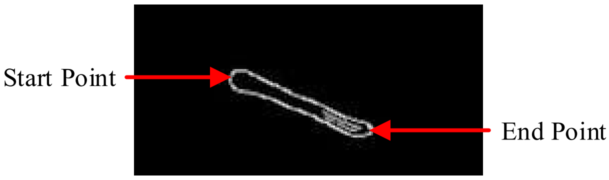



Fig. 6. Integral projection

Having obtained the starting and ending points of the femur image then to find the length of the femur used Differential Euclidian formula. The result of Euclidian distance is shown in Fig. 7.

Fig. 7. Femur length

After results obtained Euclidean distance it can be known the length of the femur and can be sought age of pregnancy. From several experiments yield different levels of accuracy. The results and percentage errors are listed in Table I.

TABLE II. FEMUR LENGTH MEASUREMENT

| File Name | System Result (cm) | Manual Result (cm) | Percentage (%) |
|---|---|---|---|
| 1.jpg | 4.38 | 4.18 | 95.2 |
| 2.jpg | 4.8 | 4.63 | 96.3 |
| 3.jpg | 4.26 | 4.38 | 97.3 |
| 4.jpg | 1.8 | 1.99 | 90.5 |
| 5.jpg | 3.84 | 4.14 | 92.8 |
| 6.jpg | 3.72 | 3.96 | 94 |
| 7.jpg | 2.1 | 2.05 | 97.6 |
| **Error Average** | | | 94.8 |

Table II is a table of femur length measurement results of the system that has been made and from the doctor's manual along with the percentage of success of the system that has been made. The maximum percentage of success rate is 97.6% of the seven data that have been tested and the average success rate is 94.8%.

TABLE III. GESTATIONAL AGE RESULT

| File Name | System Result (cm) | Manual Result (cm) | Percentage (%) |
|---|---|---|---|
| 1.jpg | 24 | 23 | 95.7 |
| 2.jpg | 25 | 25 | 96 |
| 3.jpg | 24 | 24 | 97.9 |
| 4.jpg | 15 | 15 | 100 |
| 5.jpg | 22 | 23 | 95.7 |
| 6.jpg | 21 | 22 | 97.7 |
| 7.jpg | 16 | 16 | 100 |
| **Error Average** | | | 97.6 |

Table III is a table of gestational age results of the system that has been made and from the doctor's manual along with the percentage of success of the system that has been made. The maximum percentage of success rate is 100% of the seven data that has been tested with an average success rate is 97.6%.

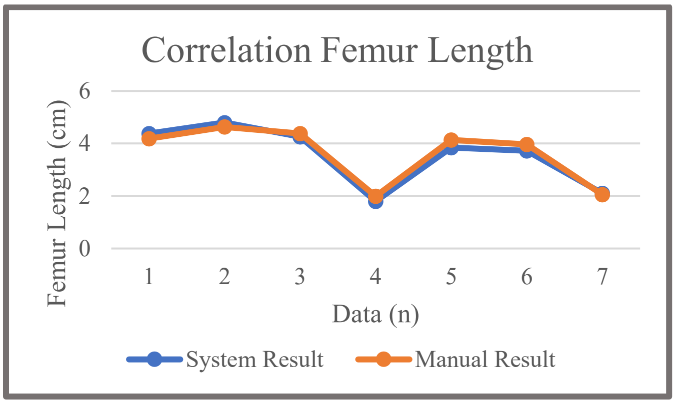



Fig. 8. Femur length correlation

Fig. 8 is a correlation graph of femur length between systems that have been made with doctors' manual results. The results of the system and also the results of doctors have a fairly high degree of similarity there are only slight differences and can still be categorized successfully because it has no significant difference.

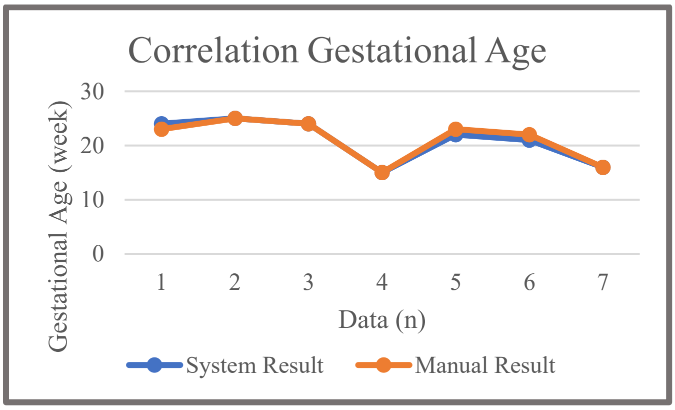



Fig. 9. Gestational age correlation

Fig. 9 shows a correlation graph of pregnancy age between systems that have been made with the results of the physician manual. Results of correlation of gestational age more have a higher degree of similarity when compared with the results of femoral length correlation. That's because the difference in the length of the femur is still within the same age range so it still has the same age value although the length of the different femur.

## V. CONCLUTION

The proposed automated method has a strong correlation with the manual system, therefore the measurement result between the proposed system and the manual system used by the doctor is quite similar. The average success rate of femur length measurement is 94.8% and the average success rate of gestational age measurement is 97.6%. Consequently, we can conclude that the proposed method is useful to improve clinical diagnosis result by minimalizing the error.

## ACKNOWLEDGMENT

We thank Obstetric and Gynecology Doctors of Graha Masyithoh Surabaya who had contributed to this research by providing the data of fetus femur. We also thank to the Ministry of Research, Technology, Higher Education of Indonesia who had funded this research.

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