Performance Analysis of Gaussian and Bilateral Filter in Case of Determination the Fetal Length

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Abstract—**One step in the image processing is filtering that located in the preprocessing. In the context of fetal analysis on the ultrasound image, filtering is really needed to enhance the quality of ultrasound image. This study conducted analysis of performance between Gaussian and bilateral filter in the fetal length. Peak signal to noise ratio (PSNR) was used to measure the quality of reconstruction the image compression. In case of early pregnancy, fetal analysis is important to determine some disabilities that might cause miscarriage. One indicator parameter for determine the fetal health on the early pregnancy is Crown Rump Length (CRL) or fetal length. Calculation of fetal length was performed with different filter (Gaussian and bilateral) after segmentation carried out. According to the experimental data, using Gaussian filter with kernel 3x3; 5x5; and 7x7, PSNR was achieved consecutively 31 dB, 28 dB, and 27dB. Furthermore, in the same ultrasound image, PSNR is 30 dB when the filter is bilateral. At the same time, fetal length was also counted separately for Gaussian and bilateral filter. The results of mean fetal length were 6.5 cm, 9.9 cm, 9.4 cm for Gaussian filter with kernel: 3x3, 5x5, 7x7 respectively; while the system was obtained fetal length 5.6 cm for bilateral filter. It is seen that by using a bilateral filter, the fetal length achieved quite accurately characterized with a mean error of fetal length is quite small.**

Keywords — Ultrasound image, Gaussian filter, bilateral filter, PSNR, fetal length

I. Introduction

Related to the image enhancement, the generalized Gaussian model has been created to automatic change detection in multitemporal SAR images [12].Combination between Gaussian and non-Gaussian and parallel system of Gaussian was also developed to make a good image reconstruction [13], [14]. Combination between Gaussian and Box Kernel to get approximationof bilateral filter using OpenCL has been observed [15]. Adaptive Gaussian image filter has been discussed and analysed related to the image quality [16].

Image denoising using bilateral filter or combine with the other filter have been developed by many researchers [17]. [18], [19], [20].The image compression using bilateral filter has been investigated by many researches; one of those is [21].The other side, the fast bilateral filter with arbitrary range and domain kernels has been developed by [22].

Analysis of performance between Gaussian and bilateralfilter associated with an image noise reduction e.g. ultrasound image has not been done. This study carried on performance analysis of two filters namely Gaussian and bilateral filter in case of condition of the fetus in early pregnancy. PSNR and fetal length on the early pregnancy were used as performance parameters. Input of this study is ultrasound image.

The image segmentation has been used in this study to simplify the fetal ultrasound image, making separated image of the fetal, gestational sac, and the background image. It is an important part of medical image processing. Segmentation has been adopted a lot in the ultrasound image using various methods, along with their advantages and disadvantages. So far, various image segmentations have been done using Fuzzy C-Means [7], Genetic Active Contour [4], Probabilistic Boosting Tree [6], and some more, in this study using the watershed segmentation.

II. System Design

The first step in this system was load an offline fetal ultrasound image with the age between 6 to 12 weeks. Furthermore, preprocessing was conducted using two different filters separately, first adopted Gaussian filter and the other one is bilateral filter. PSNR was computed for each Gaussian and Bilateral filter. The next step in the preprocessing was morphological process. Morphological opening was performed to smoothing the line objects and relieve the small objects, and morphological closing to overcome the narrow fractions in the image, eliminating the small holes and be able to fill a gap in the contour lines.

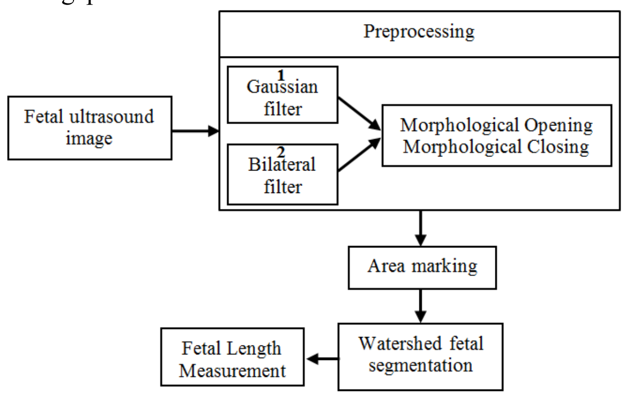


Figure 1.Block diagram of the system

The meaning of area marking in this system is area of segmentation process that marked manually by using mouse click. The shape of this mark is circle. The next process is fetal segmentation. It is used to separate the desired object (fetal) to its background. The method adopted in this study is Watershed segmentation.After the fetal is well segmented, the next step is calculating the fetal length by using minimum bounding box and Bressenham algorithm. Chronology of the research methodology is illustrated in Figure 1.

III. Gaussian and Bilateral Filtering

Preprocessing is done to enhance the low quality of ultrasound image before the image segmentation. In this study, there is a study analysis between two noise filtering. The two noise filtering are Gaussian filtering and bilateral filtering, followed by the next preprocessing by using morphological opening and morphological closing.

A. Gaussian Filtering

Gaussian filtering or Gaussian blur is a method that uses a Gaussian function to reduce the noise in an image. Gaussian filtering is a type of image-blurring filter that uses a Gaussian function for calculating the transformation to apply to each pixel in the image. Gaussian filtering needs a convolution process. Convolution is the sum of the whole matrix by multiplying matrix filter with neighboring extension of the point (x, y) in the image.

$$G_0(x,y) = Ae^{\frac{-(x-\mu_x)^2}{2\sigma_x^2} + \frac{-(y-\mu_y)^2}{2\sigma_y^2}}$$

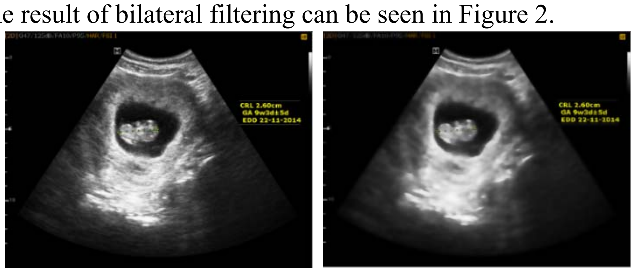
Where:

μ : mean (peak)

σ :varian (of each x and y variable)

B. Bilateral Filtering

Ultrasound image has so much noise that will cause failure on the image segmentation process. To resolve this problem, bilateral filtering is used to lower the number of speckle noise but still preserve the strong edges of the fetal image. In other words, bilateral filtering is an edge-preserving smoothing technique on an image. The comparison of original image and the result of bilateral filtering can be seen in Figure 2.



(a) (b)

Figure 2.Comparison between original image and the result of bilateral filtering. (a) Original Image, (b) The result of bilateral filtering with sigmaColor and sigmaSpace 150,150

C. Morphological Opening

After bilateral filtering operation is done, the next step to enhance the quality of ultrasound image is by using morphological opening. This method is used to smoothen the objects line and relieve the small objects. In this study, morphological opening is done to relieve unwanted objects on the ultrasound image, such us the green line on the original fetal ultrasound image.

Suppose that there are images A and element composition B, the opening A by B is expressed by the notation A o B and defined in equation (1).

$$A \circ B = (A \ominus B) \oplus B \quad (1)$$

So that the opening is an operation that consists of erosion followed by a dilation operation. The definition of equivalence is expressed in the equation (2).

$$A \circ B = \cup\{(B)_z | (B)_z \subseteq A\} \quad (2)$$

Which means that the A○B is the union of the entire shift B which is completely fit in A. The illustration of morphological opening can be seen on Figure 3.

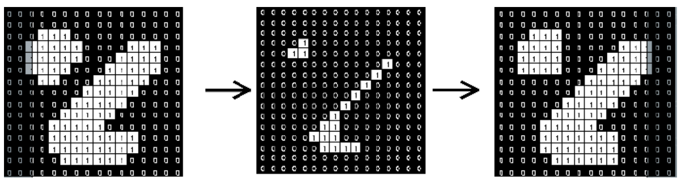


Figure 3.Morphological opening illustration

D. Morphological Closing

After morphological opening operation is done, the next step is to improve the image of the fetal using morphological closing. This method is to overcome the narrow fractions in the image, eliminating the small holes and be able to fill a gap in the contour lines. In this study, morphological closing is used to fill the hole caused by morphological opening operation.

Closing operations is defined as a dilation followed by erosion operation, denoted as A • B, so it can be expressed in the equation (3).

$$A \bullet B = (A \oplus B) \ominus B \quad (3)$$

Morphological closing illustration can be seen on figure 3 below.

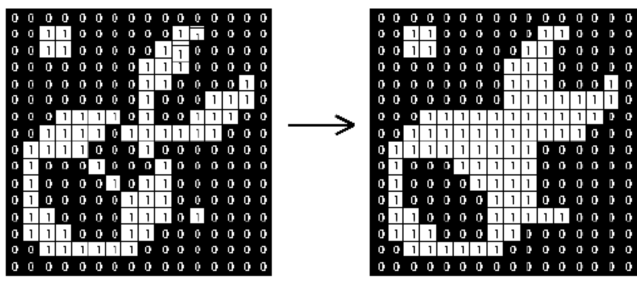


Figure 4. Morphological closing illustration

IV. PSNR of Gaussian and Bilateral Filter

PSNR of fetal ultrasound image was compared between Gaussian and bilateral filter. Gaussian filter that is compared consists of three kernels, 3x3, 5x5, and 7x7. These three kernels should be an odd number. Bilateral filter that is compared has a sigmaSpace and sigmaValue 150,150.

PSNR comparison between Gaussian filter with kernel 3x3 and bilateral filter is shown in Table 1

TABLE 1.PSNR between Gaussian filter with kernel 3x3 and bilateral filter

Image	PSNR	
	Gaussian	Bilateral
j01	31.4036	30.3257
j02	30.2177	30.816
j03	29.864	29.8631
j04	30.1907	30.7856
j05	29.4694	29.5634
j06	31.6374	30.6177
j07	31.7732	29.6143
j08	31.1553	29.5422
j10	31.8982	30.3887
j11	30.1375	30.8365
j13	31.4747	30.0674
j14	31.4889	30.1338
j16	31.2744	29.7198
j20	31.6911	30.9012
j21	31.5422	30.4432
j22	31.5474	29.983
Mean	31.0478563	30.2251

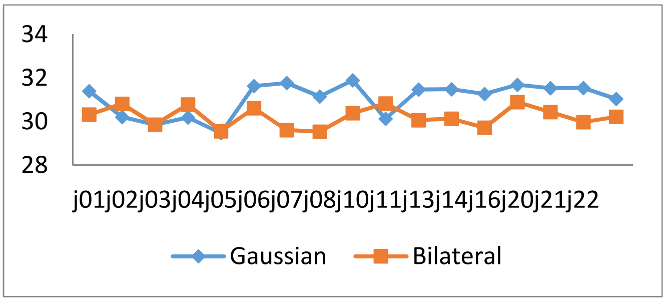


Figure 5. PSNR of Gaussian with kernel 3x3 and Bilateral filering graph

Table 1 and figure 5 above shows the comparison between PSNR of Gaussian with kernel 3x3 and bilateral with sigmaSpace and sigmaValue 150,150. Gaussian filtering has 31.048 of mean PSNR value which is bigger than Bilateral filtering, that has 30.225 of mean PSNR value.

Comparison between PSNR value on Gaussian filter with kernel 5x5 and bilateral filtering.

TABLE 2.PSNR between Gaussian filter with kernel 5x5 and bilateral filter

Image	PSNR	
	Gaussian	Bilateral
j01	28.9348	30.3257
j02	28.1063	30.816
j03	27.738	29.8631
j04	28.1418	30.7856
j05	27.4288	29.5634
j06	29.1542	30.6177
j07	29.2564	29.6143
j08	28.6211	29.5422
j10	29.3605	30.3887
j11	28.1017	30.8365
j13	28.9655	30.0674
j14	28.9963	30.1338
j16	28.6419	29.7198
j20	29.2598	30.9012
j21	29.0479	30.4432
j22	29.0805	29.983
Mean	28.6772188	30.2251

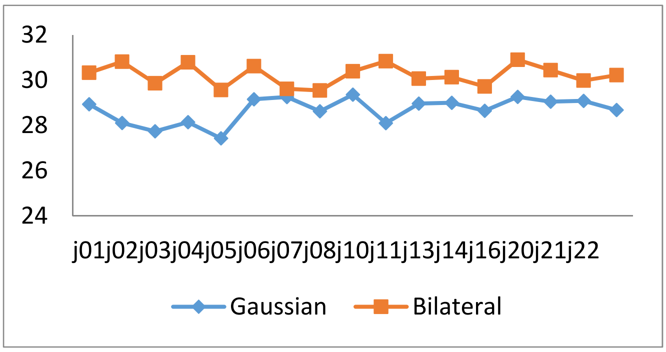


Figure 6. PSNR of Gaussian with kernel 5x5 and Bilateral filering graph

Table 2 and figure 6 above shows the comparison between PSNR of Gaussian with kernel 5x5 and bilateral with sigmaSpace and sigmaValue 150,150. Gaussian filtering has 28.678 of mean PSNR value which is smaller than Bilateral filtering, that has 30.225 of mean PSNR value.

The comparison between PSNR value on Gaussian filtering with kernel 7x7 and Bilateral filtering.

TABLE 3.PSNR between Gaussian filter with kernel 7x7 and bilateral filter

Image	PSNR	
	Gaussian	Bilateral
j01	27.268	30.3257

j02	26.5867	30.816
j03	26.162	29.8631
j04	26.6755	30.7856
j05	25.9511	29.5634
j06	27.4571	30.6177
j07	27.4827	29.6143
j08	26.8485	29.5422
j10	27.5333	30.3887
j11	26.6147	30.8365
j13	27.2205	30.0674
j14	27.2819	30.1338
j16	26.7973	29.7198
j20	27.6364	30.9012
j21	27.328	30.4432
j22	27.4024	29.983
Mean	27.0153813	30.2251

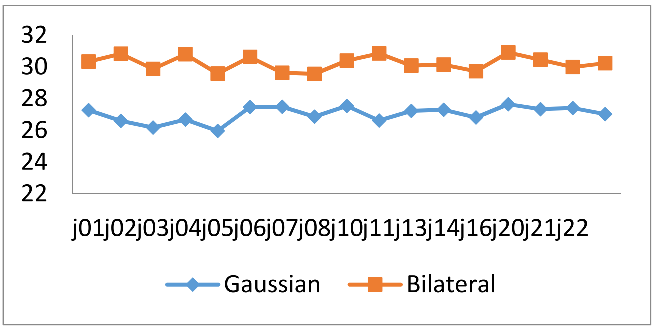


Figure 7. PSNR of Gaussian with kernel 7x7 and Bilateral filering graph

Table 3 and figure 7 above shows the comparison between PSNR of Gaussian with kernel 7x7 and bilateral with sigmaSpace and sigmaValue 150,150. Gaussian filtering has 27.015 of mean PSNR value which is smaller than Bilateral filtering, that has 30.225 of mean PSNR value.

V. Watershed Segmentation

Watershed transformation concept is to take an image of a three-dimensional shape that is the x and y position with each level of its color. The x and y position is a basic field and pixel color level, which in this case, the gray image (gray level) is the height of the image. When the value is closer to the white color, that mean it has the higher elevations. In this study, the segmentation area is marked manually by the user by using the mouse click. The segmentation process performed on the results of morphological closing image that has been marked by a circle (markers). Watershed segmentation result can be seen in Figure 9.

Watershed segmentation result is strongly influenced by the previous process, preprocessing. Bad preprocessing output will produce an over-segmentation, and the wanted object will not segmented well. While good preprocessing output will produce a well segmented image.

Figure 8.Marking the segmentation area

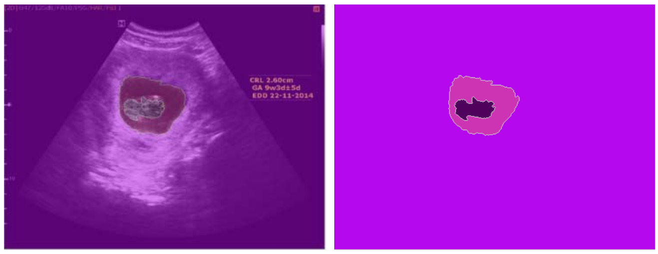


Figure 9.Result of watershed segmentation

VI. Fetal Length Measurement

The image input that is used for this length measurement process is the result of watershed segmentation. The fetal length. Here are the steps of the fetal length measurement.

- The segmented fetal image is converted to binary image using Threshold, then find the contour. From the fetal contour, find 4 points of the minimum bounding box that is surrounding the fetal. This box will fit and rotated according to the fetal object position. The illustration of minimum bounding box can be seen in Figure 10.

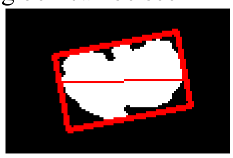


Figure 10. Minimum bounding box on the fetal image

- Draw a line crossing each side of the minimum bounding box. And then find the longest line inside the fetal. Read the pixel value on the minimum bounding box area. 0 indicates the black color which is the area outside the fetal, and 1 indicates the white color which is the fetal area.
- When the line first meet the white color (fetal area), it will initialized as the first point. And then, when the line meet the black color (outside fetal are), it will be initialized as the final point.
- The longest distance between two points will be initialized as the fetal length. The obtainable points are

the first point (jxedge1, jyedge1) and the final point (jxedge2, jyedge2). The points are illustrated in Figure 11.

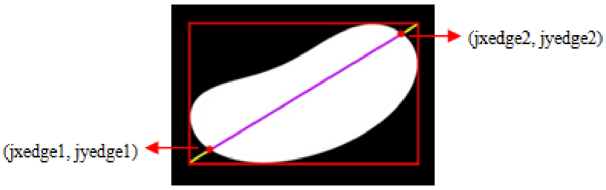


Figure 11. Points of fetal length illustration

- After the first point (jxedge1, jyedge1) and the final point (jxedge2, jyedge2) are obtained, the line is drawn using Bresenhams algorithm.
- The line that has been drawn on the fetal can be used to determine the fetal length in pixel. To convert the length into centimeters equation (4) is used.

$$centimeter = \frac{pixel}{skala} \quad (4)$$

VII. Experimental Results of The Fetal Length Related to The Gaussian and Bilateral Filter

Comparison between fetal length error on Gaussian filter with kernel 3x3 and bilateral filtering.

TABLE 4.Fetal length error between Gaussian filter with kernel 3x3 and bilateral filter

Image	**Fetal Length Error**	
	Gaussian	**Bilateral**
j01	9.85	4.92
j02	14.81	19.13
j03	14.45	8.09
j04	1.92	1.92
j05	9.92	0.78
j06	3.7	3.7
j07	3.24	4.86
j08	7.82	7.24
j10	2.47	1.23
j11	6.62	6.62
j13	0.94	8
j14	4.2	0.95
j16	4.34	9.42
j20	2.44	3.92
j21	4.56	2.69
j22	11.95	6.52
Mean	6.451875	5.624375

Table 4 and figure 11 shows the comparison between fetal length error of Gaussian with kernel 3x3 and bilateral with sigmaSpace and sigmaValue 150,150. Gaussian filtering has 6.45 of mean fetal length value which is bigger than bilateral filter that has 5.62 of mean fetal length value.

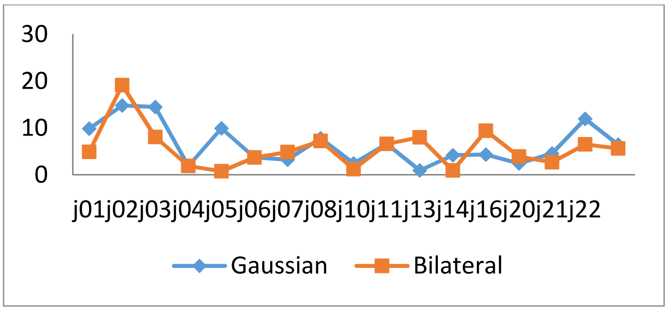


Figure 11.Fetal length error of Gaussian with kernel 3x3 and Bilateral filering graph

The comparison between fetal length error on Gaussian filtering with kernel 5x5 and Bilateral filtering.

TABLE 5.Fetal length error between Gaussian filter with kernel 5x5 and bilateral filter

Image	**Fetal Length Error**	
	Gaussian	**Bilateral**
j01	9.85	4.92
j02	22.22	19.13
j03	13.87	8.09
j04	3.46	1.92
j05	9.92	0.78
j06	4.62	3.7
j07	6.48	4.86
j08	4.34	7.24
j10	4.13	1.23
j11	11.44	6.62
j13	0.23	8
j14	9.75	0.95
j16	43.47	9.42
j20	5.88	3.92
j21	6.84	2.69
j22	1.81	6.52
Mean	9.894375	5.624375

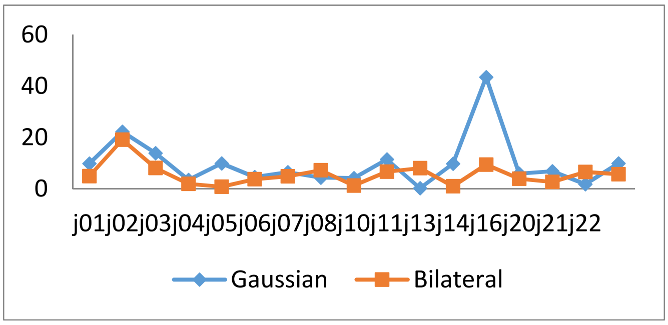


Figure 12. Comparison between fetal length error of Gaussian with kernel 5x5 and Bilateral filtering.

Table 5 and figure 12 above shows the comparison between fetal length error of Gaussian with kernel 5x5 and bilateral with sigmaSpace and sigmaValue 150,150. Gaussian filtering has 9.89 of mean fetal length value which is bigger than Bilateral filtering, that has 5.62 of mean fetal length value.

The comparison between fetal length error on Gaussian filtering with kernel 7x7 and Bilateral filtering.

TABLE 6.Fetal length error between Gaussian filter with kernel 7x7 and bilateral filter

Image	Fetal Length Error	
	Gaussian	Bilateral
j01	13.3	4.92
j02	19.75	19.13
j03	2.31	8.09
j04	0	1.92
j05	8.35	0.78
j06	5.55	3.7
j07	10.27	4.86
j08	7.82	7.24
j10	0	1.23
j11	11.44	6.62
j13	9.88	8
j14	10.89	0.95
j16	30.43	9.42
j20	3.92	3.92
j21	10.78	2.69
j22	5.79	6.52
Mean	9.405	5.624375

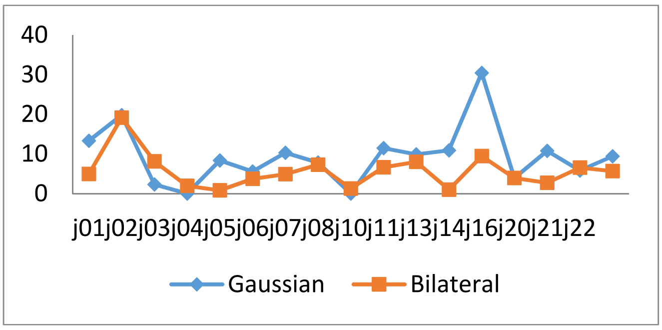


Figure 13. Comparison between fetal length error of Gaussian with kernel 7x7 and Bilateral filering.

Table 6 and figure 13 above shows the comparison between fetal length error of Gaussian with kernel 5x5 and bilateral with sigmaSpace and sigmaValue 150,150. Gaussian filtering has 9.405 of mean fetal length value which is bigger than Bilateral filtering, that has 5.62 of mean fetal length value.

VIII. Conclusion

Experimental data already conducted, PSNR was used to measure the quality of reconstruction the image compression. One indicator parameter for determine the fetal health on the early pregnancy is Crown Rump Length (CRL) or fetal length. According to the experimental data, using Gaussian filter with kernel 3x3; 5x5; and 7x7, PSNR was achieved consecutively 31 dB, 28 dB, and 27 dB. Furthermore, in the same ultrasound image, PSNR is 30 dB when the filter is bilateral. At the same time, fetal length was also counted separately for Gaussian and bilateral filter. The results of mean fetal length were 6.5 cm, 9.9 cm, 9.4 cm for Gaussian filter with kernel: 3x3, 5x5, 7x7 respectively; while the system was obtained fetal length 5.6 cm for bilateral filter. It is seen that by using a bilateral filter, the fetal length achieved quite accurately characterized with a mean error of fetal length is quite small.

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