# Ultrasound Image Segmentation Using a Combination of Edge Enhancement and Kirsch's Template Method for Detecting Follicles in Ovaries

**Siti Nur Balqish Binti Azli @ Mohd Azli**
Graduate Student,
Department of Electrical, Electronic and Systems Engineering
Faculty of Engineering and Bulit Environment
Universiti Kebangsaan Malaysia
Bangi, Selangor, Malaysia
balqishazli@gmail.com

**Noraishikin Zulkarnain***
Senior Lecturer
Department of Electrical, Electronic and Systems Engineering
Faculty of Engineering and Bulit Environment
Universiti Kebangsaan Malaysia
Bangi, Selangor, Malaysia
shikinzulkarnain@ukm.edu.my

**Asma Amirah Nazarudin**
Postgraduate Student
Department of Electrical, Electronic and Systems Engineering
Faculty of Engineering and Bulit Environment
Universiti Kebangsaan Malaysia
Bangi, Selangor, Malaysia
p102835@siswa.ukm.edu.my

**Siti Salasiah Mokri**
Senior Lecturer
Department of Electrical, Electronic and Systems Engineering
Faculty of Engineering and Bulit Environment
Universiti Kebangsaan Malaysia
Bangi, Selangor, Malaysia
siti1950@ukm.edu.my

**Mohd Faizal Ahmad**
Clinical Specialist and Lecturer
Department Of Obstetrics and Gynaecology
Faculty of Medicine
Universiti Kebangsaan Malaysia
Cheras, Kuala Lumpur, Malaysia
drmohdfaizal@ukm.edu.my

## Abstract

Polycystic ovary syndrome is a common medical problem affecting women worldwide. It is attributed to excessive hormone production that causes an increase in the number of follicles in the ovaries. To detect this condition, specialist doctors examine ultrasound images by calculating the number and size of follicles in the ovaries. However, this procedure can yield inaccurate findings and endanger patients. Another tool used in this field is an ultrasonogram, but it is considered inaccurate because the noise from application processing can produce blurred images that appear to be clear contact segments. In this study, a segmentation method for detecting follicles in the ovaries is proposed to analyse the image quality of an ovarian segment. The watershed method and a combination of the edge enhancement method and Kirsch's template are implemented to create and efficiently examine a segmented image of an ovary. Results show that the proposed method with the addition of a histogram on the threshold image can be effectively used to extract the morphological closing image of follicles. Follicles can be detected more clearly, and segmentation can be performed more efficiently. The mean square error and the peak signal-to-noise ratio of the combined methods and the watershed method have no significant differences. Thus, the combined method can produce clear images and reveal the number of follicles more quickly and easily than the watershed method.

## Keywords
PCOS, ovary, Watershed Method, Edge Enhancement Method, Kirsch's template

## 1. Introduction
Polycystic ovary syndrome (PCOS) is a common medical problem affecting women worldwide. The total number of follicles detected through ultrasound in women is evidence of women's fertility (Haar Romeny et al. 1999, Nazarudin 2020). A follicle is a type of round or oval ovarian stromal tissues filled with fluid. Women suffering from PCOS experience many side effects, which lead to high blood pressure, irregular menstrual cycle, hirsutism, obesity and acne; it can even cause cancer and infertility. This disease occurs in 5%–10% of women in their reproductive age (Saravanan and Sathiamoorthy 2018). A normal ovary consists of 8–10 follicles measuring 2–28 mm. Groups of follicles less than 18 mm in size are called antral follicles, and those whose sizes are in the range of 18–28 mm are known as dominant follicles. Women having ovaries with 12 or more follicles measuring 2–9 mm are considered to have PCOS (Ali et al. 2016). To detect PCOS, a specialist doctor manually checks the size and number of follicles. However, this method involves a time-consuming process and needs serious focus to obtain an accurate diagnosis (Nazarudin 2020).

Ultrasound, which is also known as a sonogram, is widely used in the medical world because it employs harmless waves to detect any body tissue and form a segmentation of an image on a screen. It is made by sending a pulse wave with a certain frequency into tissues via a probe. Waves resonating from different tissues reflect various levels. These echoes are recorded and displayed on the screen (Anju and Radhakrishnan 2015). The ultrasound is then examined by a specialist doctor counting the number and measuring the follicles. However, it can yield inaccurate findings and endanger patients. Ultrasonograms can also be inaccurate because the noise from signal processing can produce blurred images due to less clear segmentation.

Despite the modern technology, medical practitioners still manually count follicles in the ovaries. However, this procedure can cause some consequences because it involves a time-consuming process to ensure that the follicle size is below 2 mm and accurate observation to obtain the exact number can affect the health of female patients. In this study, a segmentation method is proposed to detect follicles in the ovaries and analyse the image quality of a segmented ovarian image. Next, the scope of this study is to achieve the objectives of the study that have been determined such as ultrasound images used on the ovaries and ultrasound data images used are data from 16 patients taken from ultrasound machine at the Medically Assisted Conception (MAC) Clinic, Hospital Canselor Tuanku Muhriz UKM (HCTM).

The above-mentioned problems associated with the use of ultrasound can be overcome by using an automated system that can detect PCOS with ultrasound images. In general, follicles can be detected using systems with machine learning approaches and stereological approaches. In this study, a machine learning approach involving the watershed method, K-means clustering method, 3D image segmentation method and edge enhancement method is used.

### 1.1 Objectives
In this study, the watershed method and a combination of the edge enhancement method and Kirsch's template are used to compare the segmented images for detecting follicles. By using MATLAB 2020a for implied the methods for detecting follicles in ovaries are being made. Thus, the peak signal-to-noise ratio (PNSR), mean square error (MSE) and structure equation index measure (SSIM) are applied to determine which method is more reliable for image segmentation.

## 2. Literature Review
Ji and Shi (2011) analysed the weakness of a watershed segment and proposed a new water flow image segmentation method based on morphological gradient reconstruction. In the proposed method, morphological opening and closing operations are used to rearrange a gradient image, maintain important additions to details and noise of regional contours and avoid the common water flow separation phenomenon. It also overcomes the contour positioning of the region derived from traditional morphological opening and closing operations for the original image. Their simulations show that in terms of visual effects or eliminating too much segmentation, the position and contour of the area of noise and other properties. Rawat and Gupta (2018) proposed a method that combines fuzzy C means and Darwinian particle swarm optimization (PSO). Among fuzzy-based clustering algorithms, the FCM algorithm is the most popular, butit can have a locally optimal solution because of a random centroid onset. To overcome such problems, they recommended optimization algorithms, such as PSO or other evolutionary algorithms. With the proposed method, lesion parts from different medical images can be segmented, and multiple images can be obtained with high accuracy by using FCM–Darwinian PSO to detect the outer lines of images. The search results of the algorithm are evaluated by various parameters, such as sensitivity, specification, Jaccard index and dice coefficient (Rawat and Gupta 2018).

Saravanan and Sathiamoorthy (2018) developed a computerized segmentation technique based on active contours without outline techniques for an effective PCOS classification of 3D ultrasound images. In this technique, the location and size of follicles are calculated automatically by combining information from local and global conditions under new probabilistic conditions. Then, the identified follicles are segmented via database-guide graphical cutting segmentation. Thereafter, a clustered marginal space learning method is used to identify the detected objects effectively. The proposed system is evaluated using 501 ovarian volumes consisting of a women's left or right ovary with 8,108 available follicles. Their approach is the first to identify and segment ovarian follicles in a 3D ultrasound volume automatically (Saravanan and Sathiamoorthy 2018).

Bian et al. (2006) used automatic and manual contour methods to select the follicular wall area and set the contour pixel values as the segmentation threshold. From the segmented follicles, 14 characteristics, including homogeneity, contrast, correlation, and energy, are calculated from the grey-level incidence matrix. Then, the side contrast and side density are calculated on the basis of side frequency measurements. Texture law features are also determined to increase the discriminatory ability of the proposed feature descriptors. For classification, the classification method in MATLAB 7 is applied. Thus, the combination of side contrast, side density, homogeneity and energy characteristics of the event matrix, along with the grey level, achieves 100% accuracy. Kiruthika and Ramya (2014) converted images into luminance (CIE-LAB) colour spaces to measure visual differences and used discrete waveforms to remove sound spots. Then, they applied cluster methods to segment images and trace the sides by using Laplacian of Gaussian edge operator to identify the side of follicles more effectively (Kiruthika and Ramya 2014). In past studies feature extraction using Convolutional Neural Network has proposed manually. Therefore, Soni and Vashisht proposed a methodology in which we will add segmentation prior CNN so as to delete or eliminate redundant data and to achieve better accuracy. Segmentation allows to divide the data or images so as deeply extract the exact information what is needed (Soni and Vashisht 2019). Table 1 shows a summary of the literature review of this study.

Table 1. Summary of the literature review

| Research Paper | Research Method | Results |
| --- | --- | --- |
| *A Novel Method of Image Segmentation Using Watershed Transformation* (Ji and Shi 2011) | The watershed method is modified by using morphological opening and closing operations. | The algorithm shows that the operations successfully reduce segmentation redundancy. |
| *Image Segmentation Using FCM–Darwinian Particle Swarm Optimization* (Rawat and Gupta 2018) | Darwinian PSO and fuzzy C means are combined to solve image segmentation problems. | The proposed method can be highly accurate for detecting the external line of segmentation. |
| *Detection of Polycystic Ovarian Syndrome: Literature Survey* (Saravanan and Sathiamoorthy, 2018) | Morphological comparisons are implemented to modify machine learning efficiency. | The efficiency of the automated system needs to be upgraded. |
| *Evaluation of Texture Features for Analysis of Ovarian Follicular Development* (Bian et al. 2006) | A combination of lateral density and lateral contrast methods is used to measure the follicular wall. | The proposed method achieves high accuracy during the menstrual cycle. |
| *Automatic Segmentation of Ovarian Follicle Using K-Means Clustering* (Kiruthika and Ramya 2014) | Laplacian method of Gaussian edge operators and cluster segmentation are utilised. | The proposed method achieves accuracy with manual comparison. |
| *Image segmentation for detecting polycystic ovarian disease using deep neural networks* (Soni and Vashisht 2019). | CNN image segmentation is added between feature extraction and cnn so as to eradicate unwanted data and to detect the disease with high accuarcay and precision. CNN proves good results for detecting multiple objects as it works in layers. | Proposed methodology generated accurate results and give minimum execution time so as to save the time of doctors as it basically segment the images and then classification results will be applied accordingly. |

## 3. Methodology

This section describes the application of the combination of Edge Enhancement and Kirsch's Template and Watershed methods for image segmentation. An experiment using MATLAB software has been performed using an ultrasound ovary image scanned from a female sample. Segmentation of an ultrasound image is one of the most difficult image processing operations because the ultrasound image contains strong speckle noise and attenuated artifacts.

### 3.1 Combination of Edge Enhancement and Kirsch's Template Method

In this study, image segmentation and feature extraction in MATLAB are used to detect follicles in the ovaries. In feature extraction, the behaviour of images is determined, and locations are shown in terms of storage taken and efficiency in classification. Figures 1 shows the flowchart of proposed method for detecting follicles in the ovary.

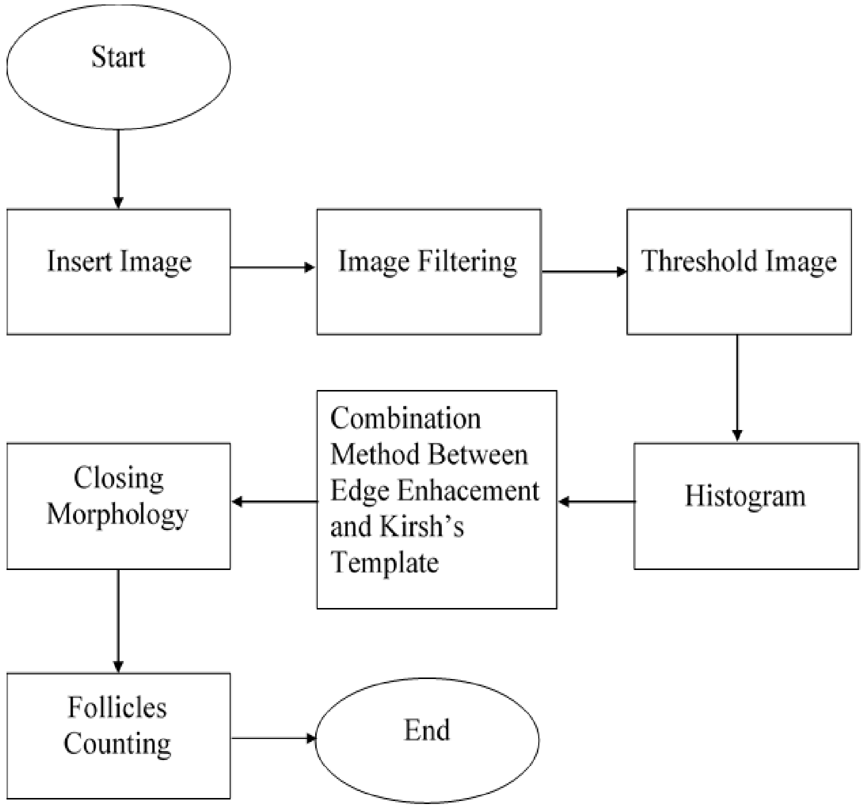



Figure 1. Flow chart of proposed method

Histogram equalization is performed to improve image contrast, especially image data with close contrast values. In addition, image contrasts can be compiled using histograms to obtain a better image. Thus, low-contrast areas have high pixels and vice versa. The histogram equation can be derived by using a scale of values evenly. This method is used on two-colour images or greyscale images. Discrete consideration of the grey image {x} and allow this to be the grey level occurrence number *i*. The probability of occurrence of a grey-level pixel *i* is expressed as Equation (1):

$$p_x(i) = p(x = 1) = \frac{n_i}{n}, 0 \leq i < L. \quad (1)$$

Filtering is conducted to reduce noise or improve the image quality of data. However, noise occurs because lateral detection methods do not yield accurate results. Through an average filtering method, each data point can be simply replaced with the average of the neighbouring points defined in their lifespan. Low filtration, together with an emission reaction through the difference equation, is expressed as Equation (2):

$$Y_s(i) = \frac{1}{(2N+1)}[y(i + N)y(i + N - 1) + \cdots + y(i - N)]. \quad (2)$$

Image segmentation is a process by which an image is divided into object and region elements. Therefore, the characteristics of follicles that can be segmented from a given image of ovaries have a high density because of the stroma and blood vessels. The principle of this method is applied to break the image into the same region based on a pre-real set of threshold values and then extract the object. If the original image is expressed as *f*(*x,y*), then the threshold image *g*(*x,y*) is expressed as Equation (3):

$$g(x.y) = \begin{cases} 1, & f(x,y) > T \\ 0, & f(x,y) \leq T \end{cases}. \quad (3)$$

If the pixels in an image are larger than *T*, then they belong to the background. If the pixels are lower than *T*, then they indicate that follicles can be segmented.

A threshold image is a binary image that can be used as an image mask of another image. The pixels in the threshold image are shown in the middle of the image as a binary image (black/white), and the original image of the pixels is shown to be masked in the left image (grey/colour). Data entry is low and threshold values are high at the beginning and file name of the image or matrix image. This threshold image returns the threshold value and the end colour of the loop used to select the threshold. Pixels lower than the threshold set value are converted to black (zero-bit value), and pixels higher than the threshold value are converted to white (one-bit value). This threshold image process is sometimes described as an image that separates the background and the foreground. A simple threshold operation generates a universal threshold value for all pixels in an image regardless of any local variation in contrast.

Morphological opening and closing are conducted to create a structuring element, which is a matrix consisting of only zeros, can have a disk shape, and has specific measurements. Dilation is a process through which pixels are added to the boundaries of an object in an image. Erosion is carried out to remove pixels as the boundaries of an object. Widening and erosion are used in combination to perform image processing operations. Erosion followed by widening is referred to as image opening morphology, whereas widening followed by erosion is known as image closing morphology. In morphological opening, light features are extracted from an image. In morphological closing, dark features are extracted from an image. By combining these two images, the contrast of the given image can be improved.

Figure 2 shows Kirsch's template rotation automatically. Kirsch's operator is one of the first discrete-order derivative versions used for side-by-side enhancement and detection. To detect the sides, the operator uses eight templates that rotate sequentially by 45°. The gradient is then calculated by rolling the figure with eight arrays of template impulse responses in each pixel. Thus, different directional gradients are achieved. The final gradient is the enhanced side aggregation by considering all directions for the RGB channel rather than a single channel only. From the results, a larger template is considered for product production and then extracted. Kirsch's operator can set and reset the threshold to find the perfect diagram (Badsha et al., 2013).

| | | |
|---|---|---|
| 5 | -3 | -3 |
| 5 | 0 | -3 |
| 5 | -3 | -3 |

$0^0$

| | | |
|---|---|---|
| -3 | -3 | 5 |
| -3 | 0 | 5 |
| -3 | -3 | 5 |

$180^0$

| | | |
|---|---|---|
| -3 | -3 | -3 |
| 5 | 0 | -3 |
| 5 | 5 | -3 |

$45^0$

| | | |
|---|---|---|
| -3 | 5 | 5 |
| -3 | 0 | 5 |
| -3 | -3 | -3 |

$225^0$

| | | |
|---|---|---|
| -3 | -3 | -3 |
| -3 | 0 | -3 |
| 5 | 5 | 5 |

$90^0$

| | | |
|---|---|---|
| 5 | 5 | 5 |
| -3 | 0 | -3 |
| -3 | -3 | -3 |

$270^0$

| | | |
|---|---|---|
| -3 | -3 | -3 |
| -3 | 0 | 5 |
| -3 | 5 | 5 |

$135^0$

| | | |
|---|---|---|
| 5 | 5 | -3 |
| 5 | 0 | -3 |
| -3 | -3 | -3 |

$315^0$

Figure 2. Kirsch's operator arrays

### 3.1 Watershed Method

Touching objects in a picture must be separated, but this process is a difficult image processing operation (Abdallah and Hassan 2015). As such, watershed transformation is conducted. In this method, a 'catchment basin' and a 'water boundary line' are determined in an image by treating is as a surface where light pixels are high and dark pixels are low. Segmentation involving watershed transformation works well if it can identify or 'mark' foreground objects and background location. This basic procedure applies to the segmentation of the watershed controlled by a marker by initially calculating the segmentation function. This image contains dark areas as objects that need to be segmented. Then, foreground markers are calculated as blobs of pixels connected to one another. Afterward, background markers are calculated as pixels that are not part of the object. Subsequently, by modifying the segmentation function so that is only selects a minimum at the location of the foreground and background markers. Lastly, the modified segmentation watershed transformation is calculated. Figures 3 illustrates the flowchart of the watershed method for detecting follicles in the ovary.

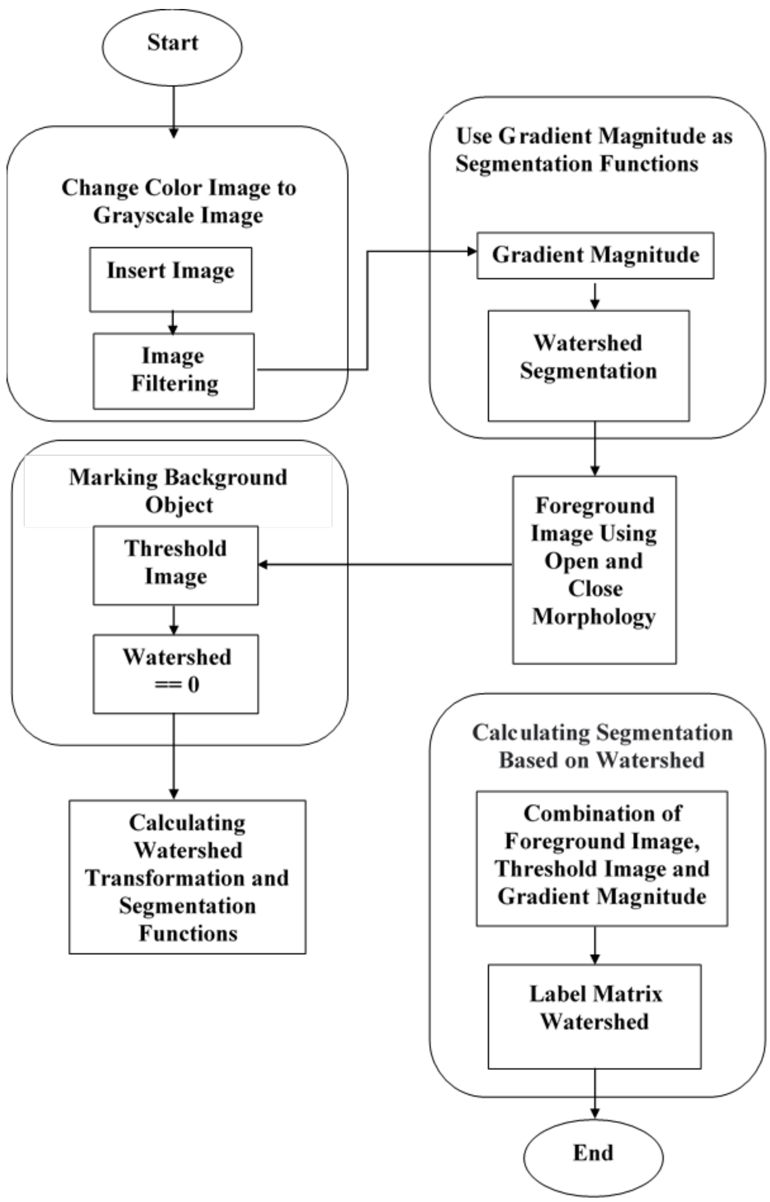



Figure 3. Flowchart of watershed method

## 4. Data Collection

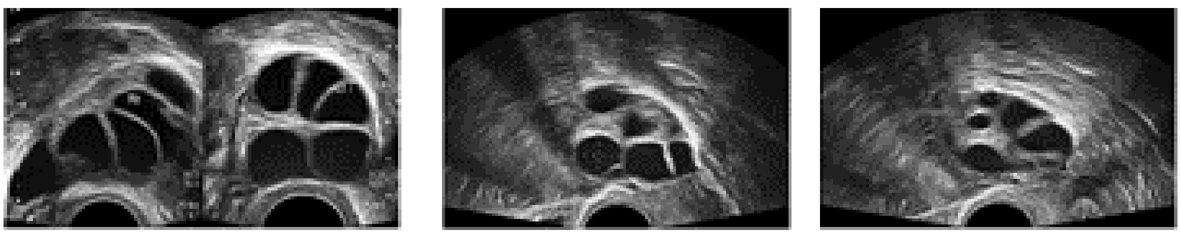
The ultrasound images were collected from MAC Clinic, HCTM. The follicle count in the ovary was calculated by medical practitioners. These data are the ground truth for this study. There were a total of 3 ultrasound images used in this study. Using the segmentation methods, the follicle counts were calculated and tabulated. The follicle counts were compared with the counts calculated by the medical practitioner. Other than follicle counts, the segmentation of the two methods were compared and tabulated. The tabulated evaluations were then discussed.

## 5. Results and Discussion

This part discusses the results obtained using the methods described in the Methodology. The results of the manual calculations, the watershed method and the combined methods are compared. Then, they are analysed using three parameters, namely, PNSR, MSE and SSIM.

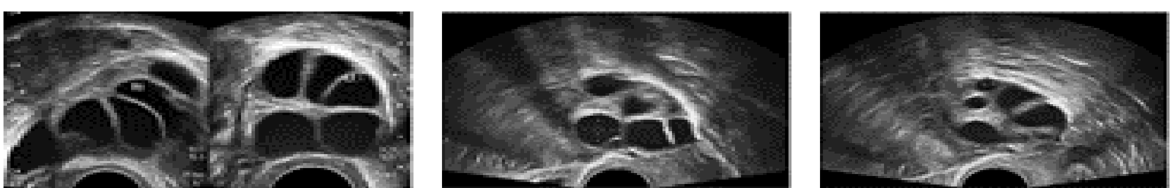
### 5.1 Proposed Method

This method involves side enhancement with a combination of Kirsch operators. Figure 4 presents an initial image of a patient with PCOS at MAC Clinic, HCTM, for processing. Figure 5 illustrates a noise filtering process to identify the pixel values for producing a noiseless image. Figure 6 shows a threshold image by taking a sensitivity value of 0.48. Figure 7 displays a histogram equalization image to detect follicles more clearly. Figure 8 exhibits the edge enhancement method involving the Kirsch operators for the enhancement of the image to be processed. Figure 9 presents an image of morphological closing.



(a) Image 1 (b) Image 2 (c) Image 3

Figure 4. Original image of PCO patient



(a) Image 1 (b) Image 2 (c) Image 3

Figure 5. Noise filtering

(a) Image 1 (b) Image 2 (c) Image 3

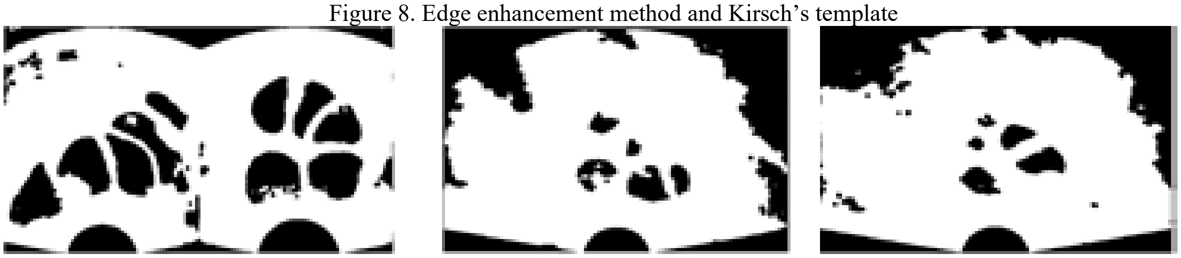
Figure 6. Threshold image

(a) Image 1 (b) Image 2 (c) Image 3

Figure 7. Histogram equalization

(a) Image 1 (b) Image 2 (c) Image 3

Figure 8. Edge enhancement method and Kirsch's template

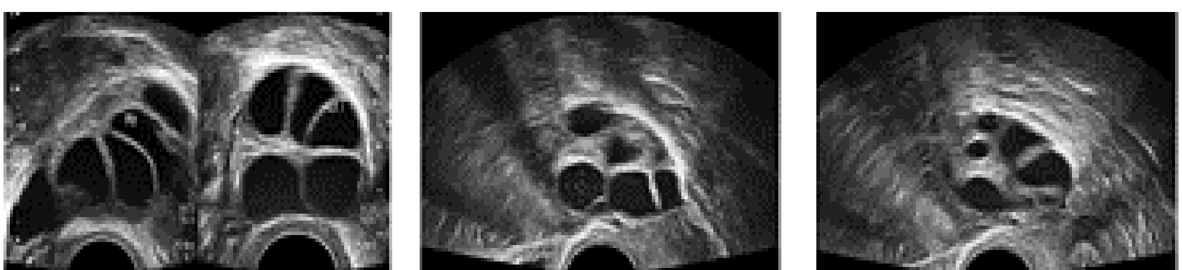


(a) Image 1 (b) Image 2 (c) Image 3

Figure 9. Morphological closing

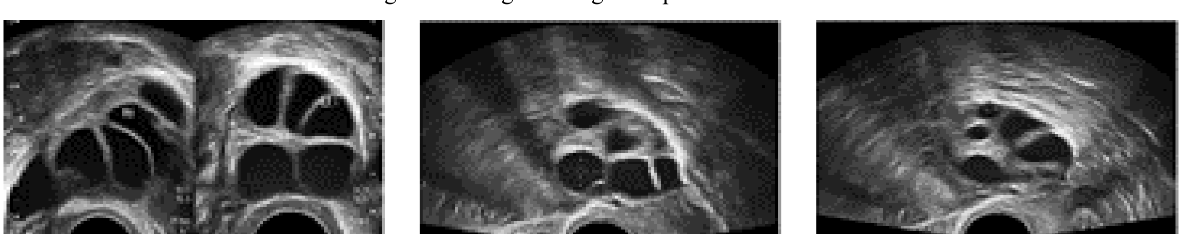
## 5.2 Watershed Segmentation

Implementing the watershed method in MATLAB involves six steps. In the first step, a colour image is converted to grayscale reading (Figure 10) is an actual ultrasound image of a patient. Figure 11 shows a noise filtering process for identifying the pixel values used in producing a noiseless image. In the second step, a magnitude gradient is used as a segmentation function. Thus, a *sobel edge mask* is utilised to process the magnitude gradient (Figure 12). In Figure 13, which is segmented using the watershed method based on Figure 12.



(a) Image 1 (b) Image 2 (c) Image 3

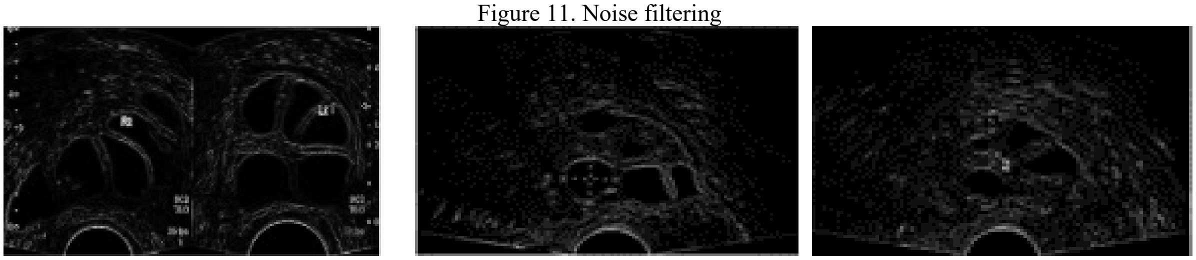
Figure 10. Original image of a patient with PCOS



(c) Image 3

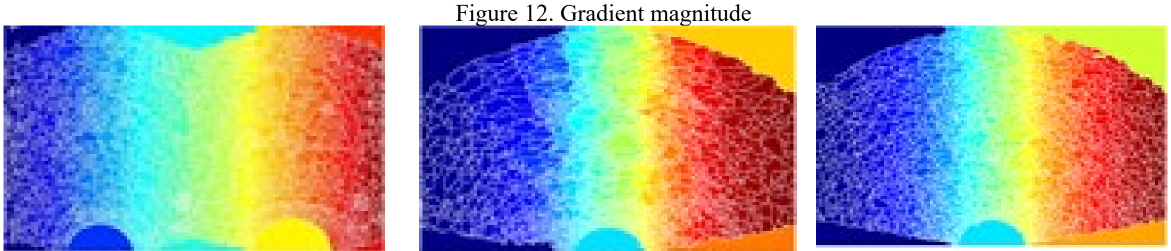
(a) Image 1 (b) Image 2

Figure 11. Noise filtering



(a) Image 1 (b) Image 2 (c) Image 3

Figure 12. Gradient magnitude



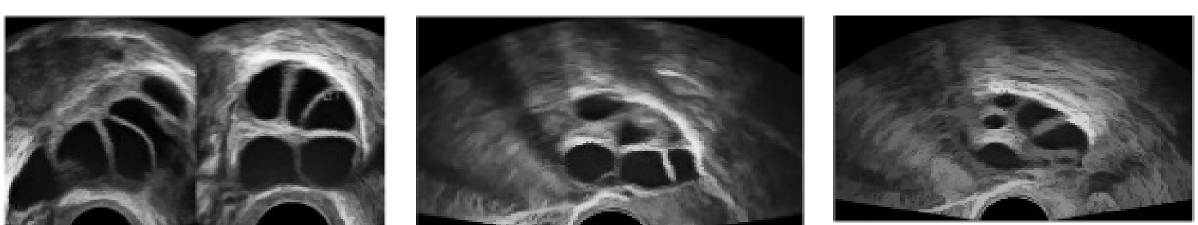
(a) Image 1 (b) Image 2 (c) Image 3

Figure 13. Watershed transformation

In the third step, the foreground object is marked. Various procedures can be applied to locate a foreground marker, which must be associated with a cluster pixel inside each foreground object. In this study, morphological techniques are used to perform 'opening-by-reconstruction' and 'clean up' the image. Through this operation, an average maximum is created inside each object that can be placed using *imregionalmax*. Opening erosion followed by widening, while opening after construction is erosion followed by morphological reconstruction as shown in Figure 14. The, the opening by reconstruction is calculated using *imerode* and *imreconstruct* (Figure 15). The first *imclose* code is tested as shown in Figure 16. The *imdilate* code is used followed by the *imreconstruct*. The image input and *imreconstruct* output is completed (Figure 17).

(a) Image 1 (b) Image 2 (c) Image 3

Figure 14. Morphological opening

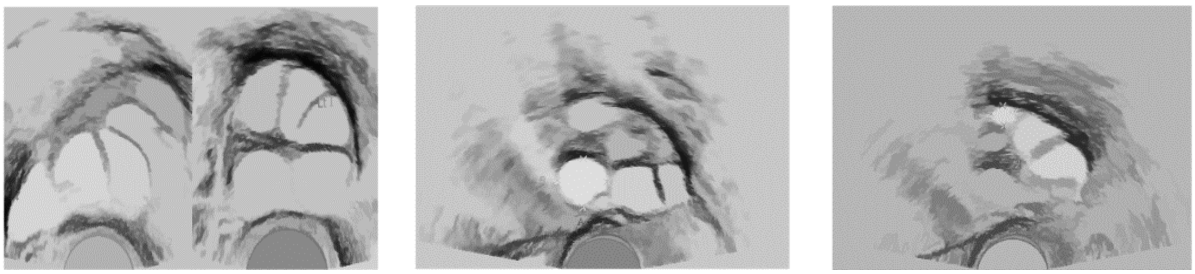


(a) Image 1 (b) Image 2 (c) Image 3

Figure 15. 'Opening-by-reconstruction' morphology

(a) Image 1 (b) Image 2 (c) Image 3

Figure 16. Opening–closing morphology



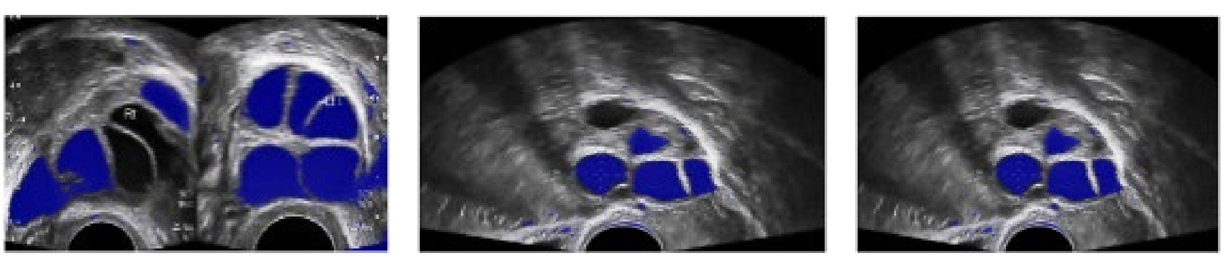
(a) Image 1 (b) Image 2 (c) Image 3

Figure 17. 'Opening–closing-by-reconstruction' morphology

When *Iobrcbr* with *Ioc* is compared, construction-based opening and closing are found to be more effective than standard opening and closing in removing small objects without affecting the overall shall of the object. The maximum *Iobrcbr* area is calculated to obtain a good foreground marker (Figure 18). For interpreting the results, the image of the foreground marker is placed on the original image (Figure 19). Some of the most hidden objects and shadows are unmarked, indicating that these objects are not segmented correctly in the result. Foreground markers on some objects also reach the edges of objects. The side of a marker blob should be clean and shrunken slightly through closure followed by erosion. However, this procedure tends to leave some isolated pixels that must be removed using *bwareaopen*, which eliminates all blobs with several pixels less than a particular number (Figure 20).

(a) Image 1 (b) Image 2 (c) Image 3

Figure 18. Regional maxima of 'opening-closing-by-reconstruction' morphology



(a) Image 1 (b) Image 2 (c) Image 3

Figure 19. Regional maxima superimposed on the original image

(a) Image 1 (b) Image 2 (c) Image 3

Figure 20. Modified regional maxima superimposed on the original image

In the fourth step, a background marker is done. The background needs to be marked. In a cleaned image, namely, *Iobrcbr*, the dark pixels belong to the background, and the threshold operation can be started (Figure 21). The background pixels are black, but the background marker should not be too close to the side of the object that will be split. The background is 'thinned' from the foreground of the binary image (*bw*) by calculating the watershed transformation from the distance transformation *bw* and then finding the watershed side line (DL = 0; Figure 22).

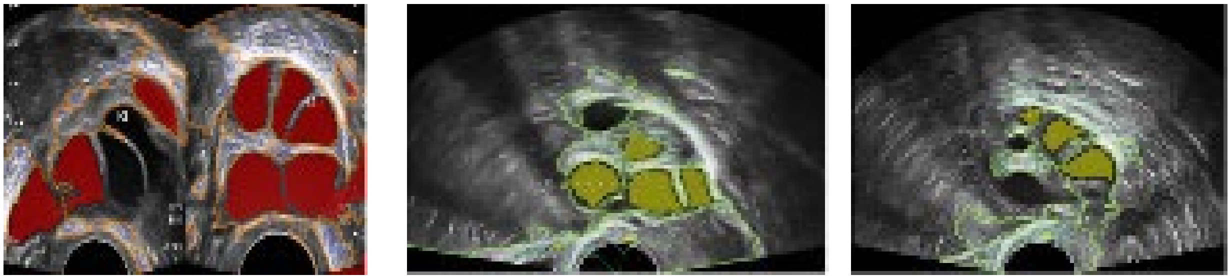
(a) Image 1 (b) Image 2 (c) Image 3

Figure 21. Threshold image

(a) Image 1 (b) Image 2 (c) Image 3

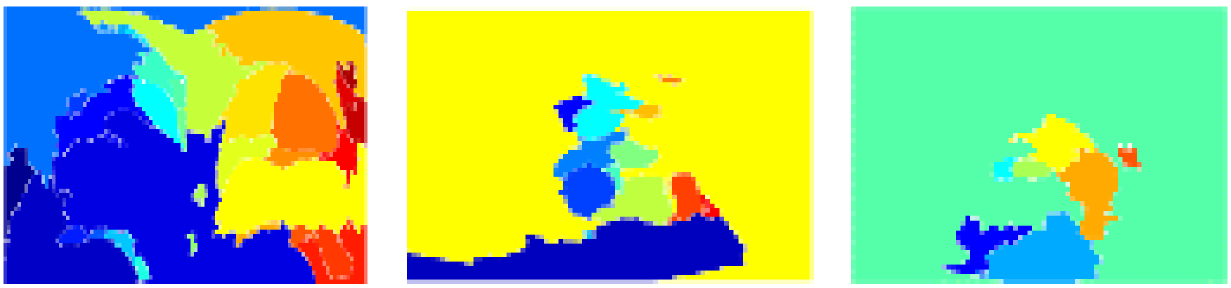
Figure 22. Watershed line

In the fifth step, the watershed transformation and segmentation function are calculated. The *imimposemin* function can be used to modify an image so that it has a minimum number of regions only in the desired locations. Here, *imimposemin* is utilised to modify the image of a gradient magnitude so that only the area that occurs on the foreground and background marker pixels. Then, segmentation is calculated on the basis of watershed transformation. One of the visualization techniques involves placing foreground markers, background markers and segmented object boundaries on the original image. Widening can be applied to obtain certain aspects such as object boundaries and make them more visible. The boundaries of the object are at L = 0 (Figures 23, 24 and 25).



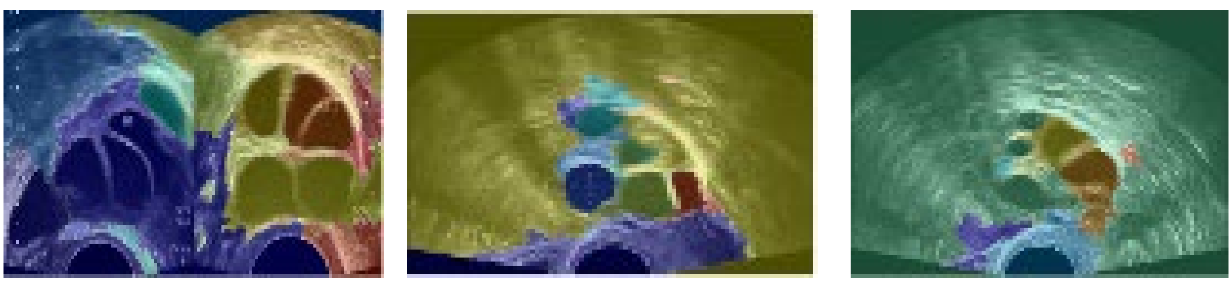
(a) Image 1 (b) Image 2 (c) Image 3

Figure 23. Foreground and watershed line on the original image



(a) Image 1 (b) Image 2 (c) Image 3

Figure 24. Matrix label watershed colour



(a) Image 1 (b) Image 2 (c) Image 3

Figure 25. Transparent coated colour labels on the original image

Thus, the combined methods and the watershed method can be used to extract follicles from a real image for a comparison of follicle segmentation.

## 5.3 Discussion

The PNSR is used to compare the errors between an actual image and a constructed image. High PNSRs indicate a better image quality. The MSE represents the cumulative square error between a compressed image and the actual image. The lower the MSE is, the lower the error will be. The SSIM is an analytical method used to determine the similarity of two images. As the SSIM approaches zero, the image quality decreases. Table 2 shows the differences in the number of follicles that can be detected from the calculations by a specialist doctor and the proposed methods. Tables 3, 4 and 5 respectively present the PNSR, MSE and SSIM of three ultrasound images of patients with PCO via the combined methods and the watershed method.

Table 2. Number of follicles detected

| Image | Specialist Doctor | Proposed Method | Watershed Method |
|---|---|---|---|
| Image 1 | 9 | 10 | 8 |
| Image 2 | 6 | 5 | 7 |
| Image 3 | 5 | 5 | 6 |

The original image is compared with the segmented image. Although high PNSRs indicate that the image has a low quality, some cases have high-quality images. Thus, the algorithm is carefully validated using the MSE.

Table 3. Peak signal-to-noise ratio (PNSR)

| Image | Proposed Method | Watershed Method |
|---|---|---|
| Image 1 | 35.4629 | 35.5138 |
| Image 2 | 33.3299 | 33.1967 |
| Image 3 | 32.7948 | 32.7869 |

Table 4. Mean square error (MSE)

| Image | Proposed Method | Watershed Method |
|---|---|---|
| Image 1 | 0.2306 | 0.2333 |
| Image 2 | 0.1247 | 0.1245 |
| Image 3 | 0.1368 | 0.1411 |

The PNSR is determined by calculating the signal-to-peak ratio in decibels through two images. The ratio is used to identify the quality of the measurement between actual and compressed images. In Table 2, the PNSRs of the three images differ because of the quality of the resulting images. The PNSR and the MSE are used to compare the quality of the compressed images. They are inversely proportional. The SSIM can be analysed when it approaches the value of an image with a better quality.

Table 5. Index equation structure measure (SSIM)

| Image | Proposed Method | Watershed Method |
|---|---|---|
| Image 1 | 0.9587 | 0.9587 |
| Image 2 | 0.8995 | 0.8987 |
| Image 3 | 0.8950 | 0.8944 |

## 6. Conclusion

In conclusion, the combination of edge enhancement and Kirsch's template proposed with the addition of a histogram on the threshold image can be applied to extract follicles from a closing morphological image. In comparison with other methods, the proposed combination allows for a clearer detection of follicles and a more efficient segmentation. Although the MSE and PNSRs between the combined methods and the watershed method have no significant differences, the combined methods can produce clear images and obtain follicle values more quickly and easily than other methods.

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## Biographies
**Siti Nur Balqish Binti Azli @ Mohd Azli** is an Electrical and Electronic Engineering student at the Department of Electrical, Electronics and Systems Engineering, Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia majoring in Power Engineering from 2017 to 2021. Her research area related to image segmentation for follicle identification in polycystic ovarian syndrome.

**Noraishikin Zulkarnain** is a senior lecturer at the Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia. She received her degree in Bachelor of Engineering (Electrical and Medical Electronics) with honours from Universiti Teknologi Malaysia in 2011. In 2016, she had an opportunity to further her PhD studies with a fast-track programme. She received her PhD degree in Control System from Universiti Teknologi Malaysia. Her research area of interest covers control system, image processing and medical electronics engineering.

**Asma Amirah Nazarudin** is a graduate research assistant and MSc student at the Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia. She received a degree in Bachelor of Engineering in Control System and Electronic Engineering from Moscow Aviation Institute in 2015. She has participated in several international conferences and presented research related to image segmentation for follicle identification in polycystic ovarian syndrome.

**Siti Salasiah Mokri** is a senior lecturer at the Department of Electrical, Electronics and Systems Engineering, Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia. She obtained a bachelor's degree in Electrical Engineering from University of Malaya in 2000, an MSc in Mechatronics from International Islamic University Malaysia in 2008 and a PhD in Biomedical Engineering from University Putra Malaysia in 2016. Her research interests are image processing, biomedical images, artificial intelligence, control system and mechatronics.

**Mohd Faizal Ahmad** is a clinical specialist and lecturer of Obstetrician and Gynaecology in Hospital Canselor Tuanku Mukhriz Universiti Kebangsaan Malaysia (HCTM UKM), specializing in Reproductive Endocrinology & Oncofertility. He currently serves as one of the reproductive specialists in Advanced Reproductive Center (ARC) HCTM UKM. In addition to reproductive medicine, he is also interested in the oncofertility field. In 2019, he initiated the oncofertility services under ARC by managing fertility preservation (FP) for oncology cases. Subsequently, he received Takeda Science Foundation Award to pursue his oncofertility fellowship under St Marianna School of Medicine Hospital, Kanagawa, Japan. His training is mainly in the cryobiology field; In-vitro Maturation (IVM), and Ovarian Tissue Cryopreservation (OTC). He obtained the credentialing in IVM & OTC and currently initiated these services under ARC as oncofertility services. He also initiates testicular tissue cryopreservation (TTC) for pre-pubertal research using the mice model under the supervision of Prof Nao Suzuki during his fellowship attachment in Japan. He currently serves as Vice President of Malaysian Society of Fertility Preservation (MSFP) and as Board Member of Asian Society of Fertility Preservation (ASFP) representing Malaysia. He has conducted research, published several papers in reproductive medicine and oncofertility, and presented in national and international congresses. His latest research is mainly on endometriosis – elucidating HOXA 10 expression following GnRH modulator and In-Vitro Maturation Oocytes Quality Assessment via Gene Expression (PTS2, GREM) supported by KPT Research Grant Ministry of Education.