Abstract: Prostate is a gland of male reproductive system to store semen. The prostate cancer is prevalent among the male which may cause mortality. It is usually unpredictable in the clinical course as the prostate cancer mostly slows grow and do not manifest in the early stage. Recent imaging technique is usually focused on the local or regional imaging so that the tumor can be more precisely identified. The measurement of tumor size can be used to inspect the progress of the severity. Gamma imaging that employs the radiotracer is widely used in the imaging of prostate cancer. However, the imaging technique is still unable to show clearly the edge of the tumor where it may cause wrong diagnosis and wrong measurement of the tumor size. Therefore, in order to increase the image quality, Gabor filter is used to reduce the noise of the image and to smooth the image. Segmentation with region growing method will be implemented to subdivide the image into the region of interest (tumor) to facilitate the radiologist in identifying and measuring the tumor size to make a more precise decision in provision of appropriate therapy. This technique is verified by five other images with prostate cancer from different modalities in radiology. The results show that the tumor can be accurately partitioned alone from the surrounding normal tissues by varying the intensity range. However, there are some cases cannot really isolate the tumor alone but it still can show clearly the tumor shape and edge. Hence, it can be concluded that this technique is valid to be applied in the clinical field to assist in the interpretation process.

Keywords: - Prostate cancer, gamma imaging, Gabor filter, region growing segmentation.
2 Materials and Methods

This project is to filter the noise of the prostate image to improve the image quality and to reduce the speckle noise. This pre-processing technique is required in order to ease the process of segmentation. After noise filter applied, segmentation technique will be used to partition the part of interest that is the prostate tumour or cancer to ease the process of size determination of the tumour facilitating the evaluation of the stage or development of the tumour.

The original image is obtained from the Hybrid Gamma camera-fusion of SPECT-CT scanner after injection of ProstaScint which is a murine monoclonal antibody with indium-111 that will specifically react with the membrane antigen for prostate cancer cell. The increased radiotracer on the image indicates the location of cancer cell. However, there are still some noise appears on the image.

In order to ease the process of diagnosis, Gabor filter will be used for noise suppression and preserve the true structure. Segmentation with region growing based method will be used to partition an image into region of interest which is the prostate tumour that demonstrates different colour intensity with the surrounding or background. All the mentioned techniques will be elaborated in detail in this section.

![Original Image of Hybrid Gamma Camera-Fusion of SPECT-CT Scanner](image)

Fig. 1 The picture above is the original image of Hybrid Gamma camera-fusion of SPECT-CT scanner that indicates the prostate cancer.

Algorithm for the implementation of image filtering and segmentation for the prostate cancer image are shown as Fig. 2.

A. Gabor Filter

Before starting the image processing, image obtained must be first converted into grey scale. Then just start the pre-processing procedure. Gabor filter can be viewed as a linear filter where its impulse response is basically defined by a harmonic function multiplied by a Gaussian function. A sinusoid plane is usually used as the harmonic function and will then be modulated by a Gaussian envelope. The Fourier transform of a Gabor filter is the convolution of the Fourier transform for harmonic function and the Gaussian function due to the multiplication-convolution property.

\[
g(x, y) = \frac{1}{2\pi S_x S_y} \exp \left[ -\frac{1}{2 \left( \frac{x^2}{S_x^2} + \frac{y^2}{S_y^2} \right)} \right]
\]

(1)

Where

- \( S_x \) is the variance along x-axis
- \( S_y \) is the variance along y-axis

And the distribution is assumed to have a centre on the line \( x = 0 \) (mean of zero).
The complex Gabor function in space domain is defined as:

\[
G(x, y) = S(x, y) \ast g(x, y)
\]

(2)

\[
S(x, y) = \exp(2\pi i \ast (Ux + Uy))
\]

(3)

Where,

\[S(x, y)\] is a complex sinusoid

\[g(x, y)\] is the Gaussian-shape function

It then requires convolution kernel in order to get the more accurate representation. The convolution will be performed by convolving in x direction and then in y direction with 1D Gaussian. The 1D function can be shown as follow [10].

The full equation for Gabor filter is as follow;

\[
G(x, y) = \frac{1}{2\pi SxSy} \exp \left[ \frac{-1}{2\left(\frac{y}{Sx}\right)^2 + \left(\frac{y}{Sy}\right)^2} + 2\pi i \ast (Ux + Uy) \right]
\]

(4)

Where,

\[U_x\] is the centre frequency along the x-axis

\[U_y\] is the centre frequency along the y-axis

From the Gabor filter function, firstly, the input need to be determined and the result will return logical 1 if it is of the double class. For the value range between variances along the x and y axis, the formula (4) is applied. Then, 2D convolution is done where the central part of the convolution of the same size as I will be returned.

The value of variance and centre frequency will be changed to observe their effect of variation in the image. The following is an example of before and after image after applying the Gabor filter. Gabor filter is used to filter the noise while smoothing the image.

![Example pre-filtering image and (b) image after using Gabor filter](image)

B. Region based Segmentation

Image segmentation that can facilitate the delineation of regions of interest is widely used in the medical imaging. Segmentation can be mainly classified into merging algorithms where the neighbouring regions are compared and merged if they have close properties and splitting algorithms in which large non-uniform regions are broken into uniform smaller area. The simplest segmentation process is by using the grey level thresholding from the histogram which is fast and oldest segmentation method but highly used due to its simple application.

The thresholding looks for the boundaries between the regions by referring to the discontinuities in gray levels or colour. The basic formulations for segmentation are as follow.

1. Every pixel must be in region
2. The points in a region must be connected in some sense.
3. The region must be disjoint
4. \( P(R_i) = \text{true} \) if all the pixels in the segment have same gray level.
5. \( P(R_i \cup R_j) = \text{false} \) for the adjacent region \( R_i \) and \( R_j \)

Region growing method is based on the fact that the pixels have similar gray value if they are close together. The first step is to choose the appropriate seed point where the region begin as the location of these seed points. The point can be chosen by referring to the histogram. Then the regions will be grown from these seeds to other adjacent points based on the pixel intensity or gray level texture. The chosen of threshold value or array is high dependent on the knowledge of histogram. 8-connected neighbourhood will be used to grow from the seed points. They will be classified as seed points if they have the same value with the seed points. The similarities or homogeneity is the crucial concern to classify the
image into regions.

![Image showing liver tumor before and after segmentation](image)

**Fig. 6** (a) The liver tumour before and (b) after segmentation

![Image showing GUI for segmented image and histogram](image)

**Fig. 7** The GUI that shows the segmented image and histogram

Figure 6 show the image before segmentation process and the segmented image to partition the part of tumour for liver cancer and also the graphical user interface that shows the histogram. The algorithm for the implementation of segmentation will be described as follow;

3 Results and Analysis

After the implementation of the techniques of gabor filter to remove the noise and the region-based segmentation, the prostate tumor can be partitioned and isolated from the surrounding soft tissues in an gamma imaging image. This can assist doctor in inspecting the development of prostate tumor and possibly can determine the size of the tumor from the segmented image. Figure below shows the original image from an old man with prostate cancer which has been detected by the Hybrid Gamma camera-fusion of SPECT-CT scanner. The bright colour shows the accumulation of radiotracer at the cancer cell.

![Image showing prostate image and segmentation](image)

**Fig. 8** The flow chart for segmentation process

The verification of the techniques will be done on five prostate images with prostate cancer.

![Image showing original prostate image](image)

**Fig. 9** The original image with prostate tumour

The image will be changed into gray scale first before proceeding to the Gabor filtering which is used to remove the noise. Gray scale image is where the only colour is shades of gray but different in their gray intensity. It is much simpler in implementing all the tasks instead of using the colour image which needs a much harder work.

![Image showing gray-scale image](image)

**Fig. 10** The gray-scale image
The image is then inserted into the Gabor filter to remove the speckle noise and to smooth the image. The reduced noise image can ease the process of segmentation that will be used later. For this image, both variances along x and y axis are set at 1 and the centre frequencies are 100Hz.

Fig. 11 The filtered image after implementing Gabor filter

The image will then be implemented with the region growing segmentation technique to detect the area of interest (the prostate tumor).

Fig. 12 The segmented image that shows the whole prostate

Then, by varying the intensity range again to get image with only the prostate tumor.

Fig. 13 The segmented image with only the prostate tumour

We have tested the proposed techniques with five images with prostate cancer. All the original images and post-processing images are shown as follow.

A. Prostate Tumor in MRI Image
   The circle part is the prostate tumor.

Fig. 14 (a) The original image with prostate cancer (b) The result segmented prostate tumour image

After the proposed image processing techniques implemented, part of the prostate tumor is clearly shown by varying the intensity range. Since the gray intensity of the image is not much different, we cannot really remove all the surrounding soft tissues. The accuracy for this image is moderately high.

B. Prostate tumor from fused image of SPECT-CT scanner with gamma camera

Fig. 15 (a) The original image that show the prostate tumor with the brighter color (b) The tumour after processed by using the proposed techniques

The result indicates that the proposed techniques well define the prostate tumor from the other irradiated area and the surrounding soft tissues.

C. Radionuclide bone scanning image with prostate tumor
   The tumour has spread outside the prostate gland which shows a white small area.

Fig. 16 (a) The original image with prostate cancer obtained from bone scan (b) The prostate tumour after implementing the proposed techniques

From this image, the accuracy to detect the prostate
tumour is considered efficient as we can see clearly the shape of the tumour and can easily differentiate from the adjacent soft tissues.

**D. The SPECT/CT image that shows the prostate tumour**

The radionuclide will emit the radiation. The colour part is the prostate gland and the prostate tumour. The part with orange colour shows prostate tumour.

![Image: SPECT/CT](image1.png)

Fig. 17 (a) The original image from SPECT/CT (b) The resultant image that shows the prostate tumour

After implementing the proposed techniques, the tumour is clearly isolated from the surrounding. The shape is almost the same as we have seen from the original image. The accuracy is high for this image due to the higher difference in the intensity of gray colour on the image.

**E. Combined PET/CT scan that shows the prostate tumour**

The colour part is due to the high FDG (fluorodeoxyglucose) activity which is used to localize the cancer cell with high metabolism.

![Image: PET/CT](image2.png)

Fig. 18 (a) The original image with prostate cancer (b) The result after implementing with proposed techniques.

From the resultant image, we can see clearly the shape of the prostate tumour which localized to the left side of the prostate gland. However, the tumour cannot be totally isolated from the surrounding tissue due to the low difference in their gray intensity.

**4 Conclusion**

Although there are some cases which cannot really isolate the prostate tumor alone from the surrounding tissues, the edge of the tumor and the shape still can be clearly shown. Hence, this technique is still possible to aid the radiologist in identifying and measuring the tumor size more accurately compared with the image obtained from the imaging modalities where the border of the tumor is usually unclear.

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