

Prostate Tumor Segmentation for Gamma Image Using Region Growing Approaches

LAI KHIN WEE^{1,2}, EKO SUPRIYANTO¹, YEOH JING WUI¹, NURAINI MD ISA¹, BUSTANUR ROSIDI¹

¹Department of Clinical Science and Engineering
Faculty of Health Science and Biomedical Engineering
Universiti Teknologi Malaysia
UTM Skudai, 81310 Johor
MALAYSIA

²Faculty of Computer Science and Automation
Institute of Biomedical Engineering and Informatics
Technische Universität Ilmenau,
98684, Ilmenau
GERMANY

eko@utm.my kwlai2@live.utm.my <http://www.biomedical.utm.my>

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 slowly grows and does 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.

Key-Words: - Prostate cancer, gamma imaging, Gabor filter, region growing segmentation

1 Introduction

Prostate cancer is a significant growing health problem and is frequently happening in men. It is usually slow growing and the early sign is usually subtle. However, there is also prostate cancer which is aggressive with a rapid growth. Prostate cancer is the most common non-dermatologic cancer and the second most common cause for cancer related deaths in American men [1]. Hence, the early prognosis is vital in this course.

The traditional treatment options include surgery, radiation therapy, and hormonally based intervention [2]. ProstaScint scan is a diagnostic imaging test which is commonly used to locate and determine the extent of prostate cancer by using a special molecule called monoclonal antibody that is

designed to bind to the prostate-specific membrane antigen on the cancer cells. Gamma imaging or gamma camera will be used to detect the antibody that is paired with the radioactive material. This method allows for local or regional diagnosis where the prostate cancer part will be clearly seen which can be differentiated from the surrounding healthy tissues.

Even various imaging techniques are widely used in the diagnosis of prostate cancer; there is still no optimal imaging technique that can be used to clearly portray the edge of the tumor in the prostate gland. Besides, the speckle noise and the resolution of the imaging technique will highly affect the quality of image obtained.

The size of the prostate tumor cannot be measured accurately. This will pose the possibility

of wrong interpretation and diagnosis by doctor. This can also affect the decision made to provide the appropriate treatment. Image processing technique need to be applied on the image to enhance the accuracy of interpretation. Image segmentation can be used to partition an image into region of interest which is the prostate tumor in this case for interpretation of shape and size. Noise reducing filter must be first applied to improve the image quality which can ease the image segmentation process.

There are several scopes to be included for the effectiveness of this project. The main scope is the detection of prostate tumour from gamma imaging image by using image processing method from MATLAB. The method that will be used is the segmentation and image filtering. Original and post-processing image will be shown to demonstrate the effect of the techniques used.

The limitations when executing this project are the image used does not have any patient's information as it is obtained from internet resources and there are difficulties for choosing the best method to process the image

2 Background

2.1 Clinical Review

The prostate is a gland that produces, secretes and controls the flow of fluid. It is also part of the urinary system [3]. The prostate is located beneath the bladder and in front of the rectum. Bladder is a place where urine is stored. It encircles, like a donut, a section of the urethra which is the tube that carries urine from the bladder out through the penis.

The prostate is consists of three lobes that is encased in an outer covering, or capsule. It is flanked on either side by the seminal vesicles, a pair of pouch-like glands that contribute secretions to the semen. Seminal vesicle is located next to the two vas deferens which are the tubes carrying sperm from the testicles. The testicles are the place that generates sperm and testosterone. Testosterone is the male sex hormone that controls the prostate's growth and function.

Scientists divide the prostate up into different zones according to their function. The zones are Central (CZ), Peripheral (PZ) and Transitional (TZ). Prostate cancer can begin and spread from any of these zone. Most of prostate cancers cases are adenocarcinomas which arise from glandular tissue. More rarely, cancer begins in the tissues surrounding the gland. Prostatic intraepithelial

neoplasia (PIN) is the abnormal change in the prostate cells which is malignant.

In 2007, 27050 men died from prostate cancer [4]. The degree of prostate cancer is characterized by the abnormality of the tissue. Most used grading system is the Gleason score which ranged from 2 until 10 [5]. For more aggressive tumor, the value is higher. Cancer happens when there is abnormal cell growth (tumor). Tumor can be benign or malignant. Cancer is when the tumor attack human body and affects internal human body system.

In 2007, 27050 men died from prostate cancer [3]. The degree of prostate cancer is characterized by the abnormality of the tissue. Most used grading system is the Gleason score which ranged from 2 until 10 [4]. For more aggressive tumor, the values are higher.

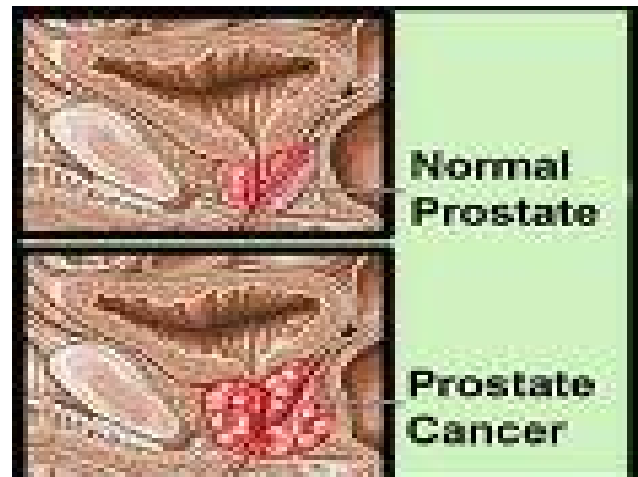


Fig. 1 The comparison of normal prostate and prostate cancer

Prostate carcinoma usually arises near the gland's surface in which can be detected during a digital rectal examination (DRE).

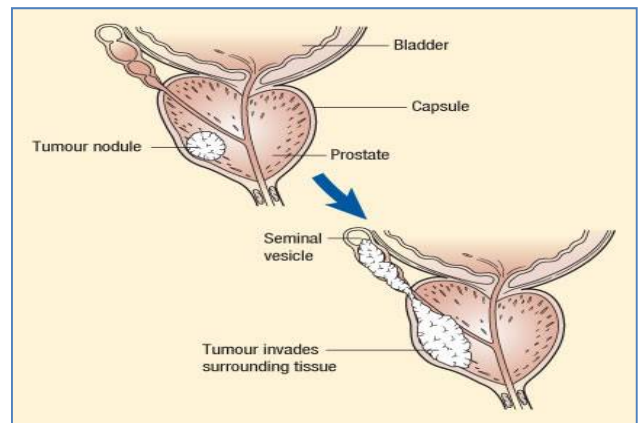


Fig. 2 The spread of cancer cell

Once the tumor grows, it expands around urethra and cause urinary problems. By the time the tumor is large enough to cause symptoms; it has often spread beyond its capsule. Cancer cell in the prostate spread when it breaks off from tumor and enter the lymphatic system. The cancer cell spread to other part of human body via network of vessels that rain fluid throughout the body.

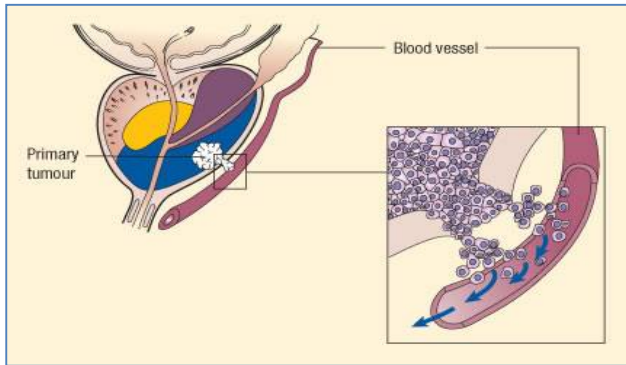


Fig. 3 The cancer cell spread through blood vessel

Cancer cell may invade surrounding fat and tissue, the seminal or the neck of the bladder. There are cases where it invades lymph nodes in the pelvic region. Later, prostate cancer spread to the bones primarily those in the spine, hip, pelvis, and chest. Metastasis often occurs in the lungs, liver, and adrenal glands. Patient for advanced prostate cancer metastasis have less chance to live but those who have early detection mostly can survive [6].

2.2 Image Processing

Image processing has become one of the most important steps in analyzing image obtained from imaging modalities. The difference between structure, tissue and foreign object can be easily done by choosing the right method of recognition. There are many types of recognition method that can be used in enhancing the image quality. Another important step in image processing is the filtering. Filtering is used to eliminate artefact that can interrupt the accuracy of the image taken.

There are many methods used in the image processing. This method is chose based on the type of the image and analysis to be made. The most methods used for image processing are segmentation, Euclidian geometry transformation, colour correction, interpolation, image registration, morphing, filtering, wavelets, image compression, image restoration, and many more. Each method will result in different image analysis and approach.

One of the important characterizations in image texture is the pixels and pattern.. There are three important variable is texture. There are the size of the area, relative size of tonal features and spatial distribution of tonal features [7]. Cancer cells cause abnormal growth of blood tissue [8]. Cancerous tissues have different variance of edges compared with normal tissue. It has more edges and distance between edges is smaller than normal tissue.

Gray Level Co-occurrence (GLCM) is also one of the methods used in enhancing image of prostate cancer. GLCM used to differentiate gray levels exist in the image by considering square window in the desired area [6]. GLCM works by moving and overlap the square image with image taken [6]. The gradient-based improvement is used to separate the prostate and the surrounding area [9]. But, this method is unable to separate both prostate and rectum area completely. Another method used in enhancing image is the fuzzy logic-based algorithms. This method is used to improve and enhance the contrast of the image taken. In some cases, a modified fuzzy means-based segmentation algorithm is used to detect prostate's boundary pattern and even to find accurate region of interest (ROI) [8]. Wavelet features extraction is also one of the methods available. This method utilizes the extraction of wavelet features from desired region [10].

The most used method used in prostate cancer detection is the snakes or active contours. This method is based on the detection of deformable contour which match object and motion. Snakes method is used for segmentation, shape modelling and curve detection [11]. Segmentation of image refers to the concept of designate label to image's area in quantized manner based on the image's pixel [12]. Image segmentation has four main approaches. There are the thresholding, boundary detection, region based and hybrid methods [13]-[19]. Thresholding technique based on hypothesis that image's pixel value within certain range. Boundary based method assume that pixel between two regions are different.

Region-based segmentation assumes intensity in surrounding pixels in a region is similar while hybrid method combined the other segmentation method. Region growing segmentation is when the adjacent pixel is tested and added to region class if there are no edges detected. By using region-merging algorithm, weak edges are eliminated. The region's border formed by region growing is thin and connected.

3 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.

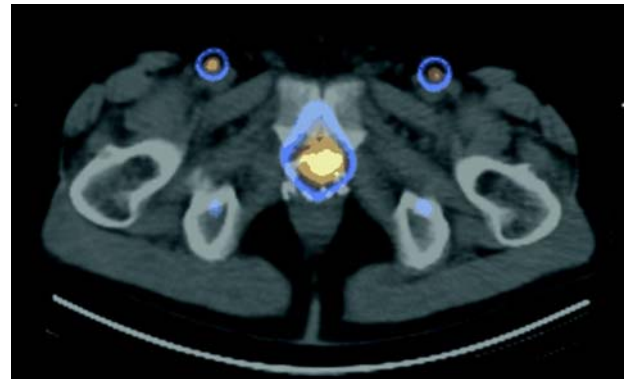


Fig.4 The picture above is the original image of Hybrid Gamma camera-fusion of SPECT-CT scanner that indicates the prostate cancer.

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

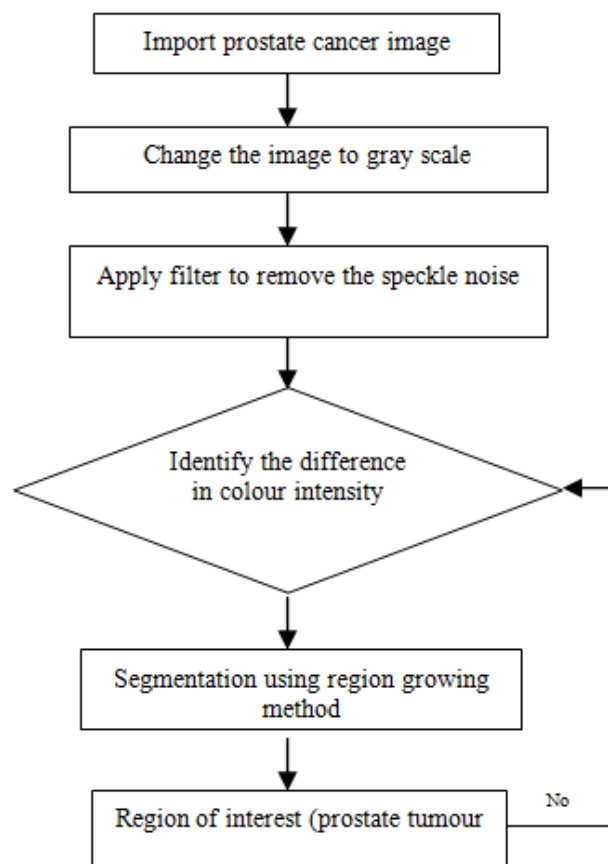


Fig. 5 The flow chart for the whole filtering and segmentation process

3.1 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.

Gabor filter is used to obtain the optimal resolution in both spatial and frequency domains by acting as a band-pass filter for the local spatial frequency distribution. It is widely used as convolution operator to smooth images and to remove noise which is almost similar to the mean filter. Additionally, it is efficiently used for edge detection and also for segmentation of texture features especially in the fingerprint recognition. By varying the standard deviation of the Gaussian function, the degree of smoothing can be adjusted. The equation for the 2D isotropic Gaussian function is as follow [20].

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

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).

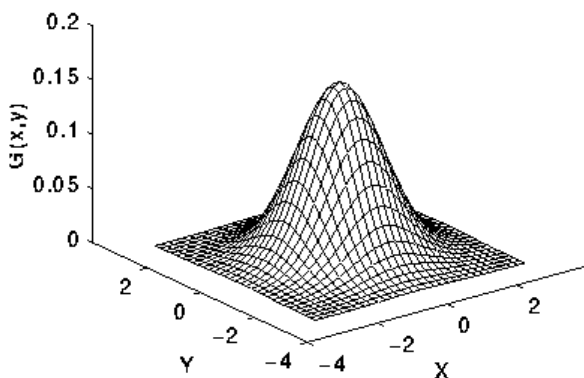


Fig. 6 The 2D of Gaussian distribution with mean (0, 0) and S_x and $S_y = 1$

The complex Gabor function in space domain is defined as;

$$G(x, y) = S(x, y) * g(x, y) \quad (2)$$

$$S(x, y) = \exp(2\pi * i * (U_x + U_y)) \quad (3)$$

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 [21].

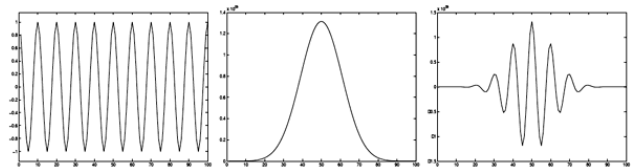


Fig. 7 The 1D function of Gaussian

The full equation for Gabor filter is as follow;

$$G(x, y) = \frac{1}{2\pi S_x S_y} \exp \left[\frac{-1}{2 \left(\frac{x}{S_x} \right)^2 + \left(\frac{y}{S_y} \right)^2} + 2\pi * i * (U_x + U_y) \right] \quad (4)$$

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.



Fig. 8 (a) Example pre-filtering image and (b) image after using Gabor filter

3.2 Region based Segmentation

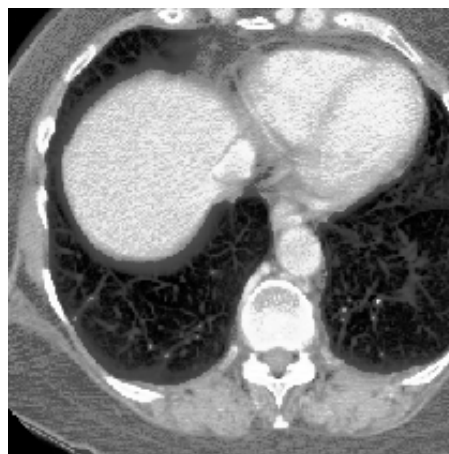
Image segmentation that can facilitate the delineation of regions of interest is widely used in the medical imaging. Segmentation can be mainly classified into merging algorithms where the neighbouring regions are compared and merged if they have close properties and splitting algorithms in which large 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.



(a)



(b)

Fig. 9 (a) The liver tumour before and (b) after segmentation

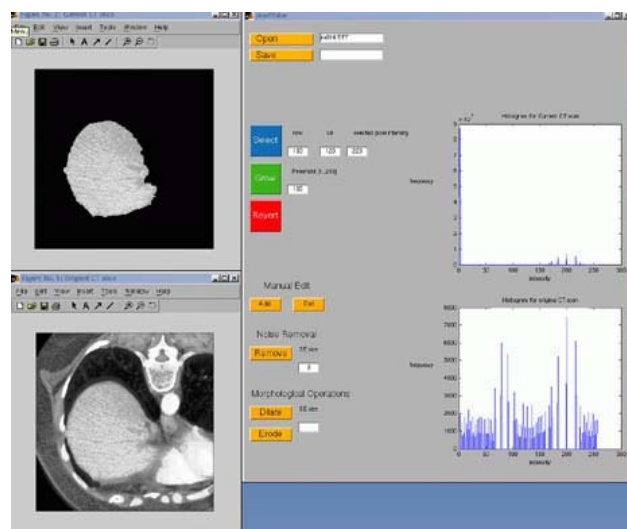


Fig. 10 The GUI that shows the segmented image and histogram

Figure 9 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;

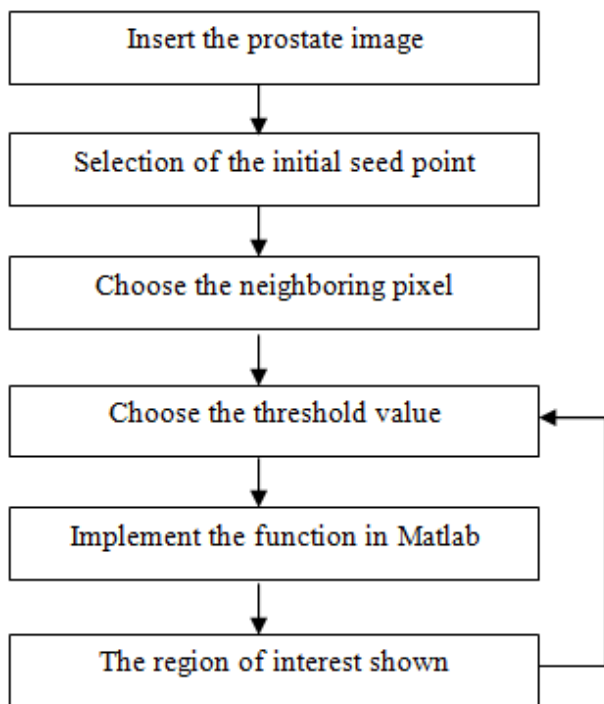


Fig. 11 The flow chart for segmentation process

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

4 Results

Use 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.

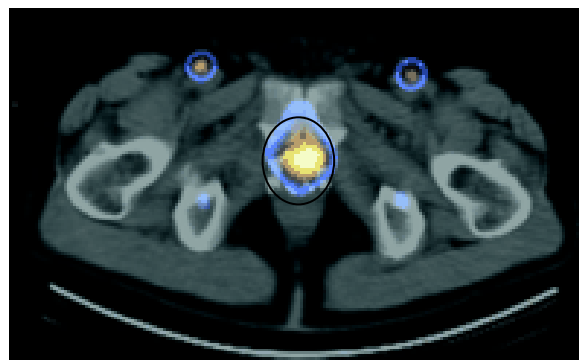


Fig. 12 The original image with prostate tumour

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.



Fig. 13 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.

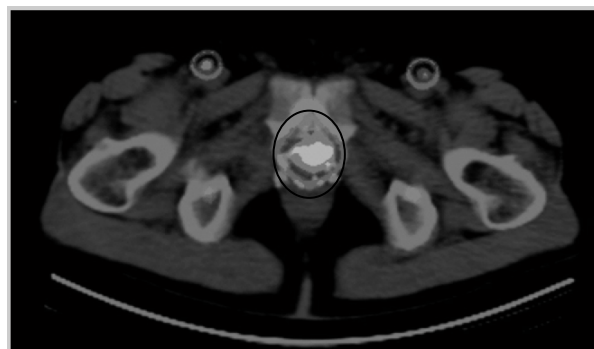


Fig. 14 The filtered image after implementing Gabor filter

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

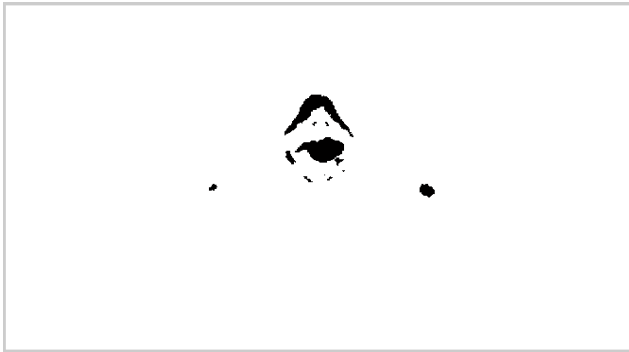


Fig. 15 The segmented image that shows the whole prostate

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

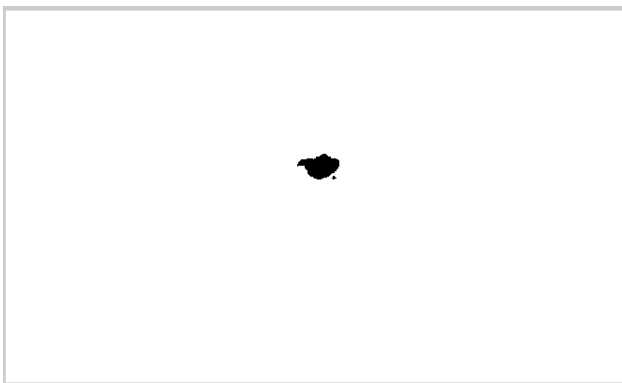


Fig. 16 The segmented image with only the prostate tumour

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

4.1 Prostate Tumor in MRI Image

The circle part is the prostate tumor.

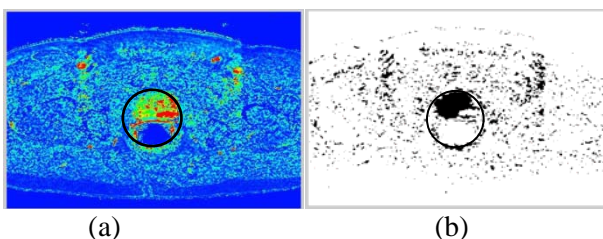


Fig. 17 (a) The original image with prostate cancer (b) The result segmented prostate tumour image

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.

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

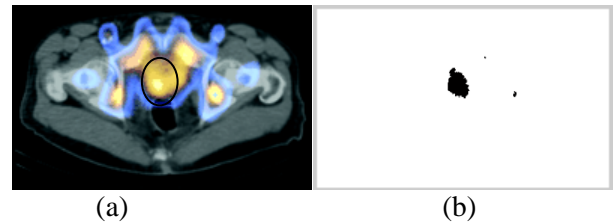


Fig. 18 (a) The original image that show the prostate tumor with the brighter color (b) The tumour after processed by using the proposed techniques

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

4.3 Radionuclide bone scanning image with prostate tumor

The tumour has spread outside the prostate gland which shows a white small area.

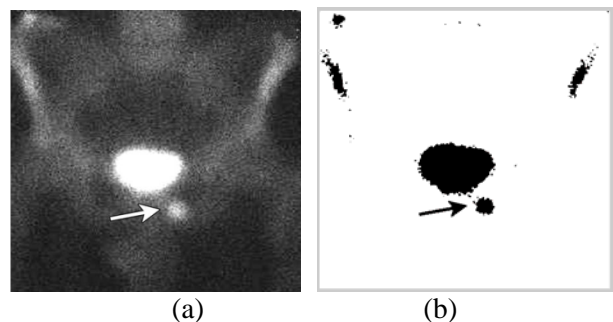


Fig. 19 (a) The original image with prostate cancer obtained from bone scan (b) The prostate tumour after implementing the proposed techniques

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.

4.4 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.

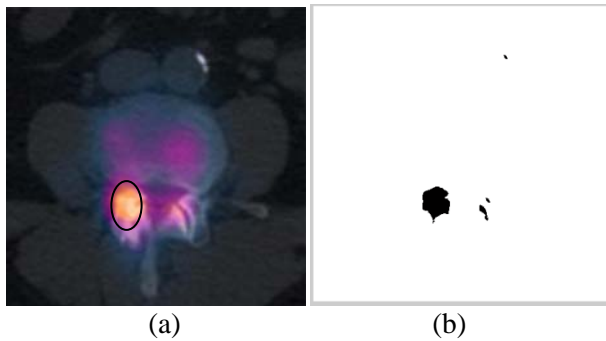


Fig. 20 (a) The original image from SPECT/CT (b) The resultant image that shows the prostate tumour

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.

4.5 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.

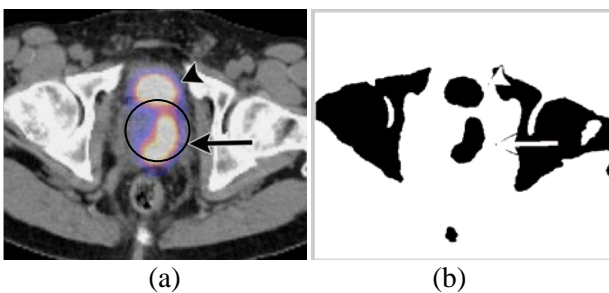


Fig. 21 (a) The original image with prostate cancer (b) The result after implementing with proposed techniques

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.

5 Discussions

Generally, radionuclide is used for the detection of tumour. Gamma camera is needed to capture the radiation of the radiotracer. The increase in the amount of accumulation indicates the part of the cancer cells. However, most of the imaging method will also present some noise on the image taken. This noise can affect the quality of the image which will then reduces the accuracy of diagnosis.

Gabor filter is used to reduce to speckle noise by smoothing the image. Before implementing the filtering process, the colour image will be converted to gray scale image to simplify the processing techniques but still can perform all the tasks needed. By varying the value of the variances along the x and y-axis and also the centre frequencies of the filter, the degree of the smoothing can be adjusted to get a better image with minimum noise.

Since there are differences in the gray intensity in the image, segmentation is used to partition the prostate tumour from the normal surrounding tissues based on the intensity. Segmentation is used to isolate the tumour as it is hard for the naked eye to clearly identify the border of the tumour. The segmented prostate tumour can assist in diagnosis or measuring process in determining the tumour size to inspect the development of the tumour.

This segmentation technique is worked by observing the histogram that shows the frequency of the gray intensity. The intensity range is different for each image due to the different modalities used and the concentration of the radiotracer. It must be changed to get the most precise shape of the prostate tumour.

After verifying the proposed techniques with five images that are scanned by different modalities, it can prove the validity of the techniques. Most of the segmented images can clearly isolate the prostate tumour from the surrounding tissues. However, there are some images cannot really partition the tumour part due to the low differences in the gray intensity between the tumour and the surrounding tissues but the clear border of the tumour still can be seen. Hence, this process still can help in the determining of the prostate tumour size even there is some cases cannot really partition the tumour part alone.

6 Conclusions

Since prostate cancer is the second cause for the cancer mortality among the males, the technique of the early diagnosis and the constant inspection for the severity is significantly needed to reduce the risk

of mortality. Currently, there is an increase in the use of the local or regional diagnosis for prostate cancer which can get more precise observation and identification. ProstaScint technique that employs the imaging through the prostate-specific antigen by using radiotracer that will bind to the antibody which will be injected into the bloodstream is commonly used in the local detection for prostate cancer.

This proposed image processing techniques to be applied on the image of gamma imaging is to enhance the image quality by minimizing the noise and to clearly portray the region of interest where in this case is the prostate tumour. This purpose is to ease the radiologists in inspecting the severity of the cancer by measuring the tumour size as this technique can show the clear border of the tumour. Besides, it also assists radiologists in making decision for the provision of appropriate treatment after determining the size of the prostate tumour.

However, in some cases, this proposed techniques is not really proficient in isolating the prostate tumour alone as there are low differences in the gray intensity that may due to the concentration of the radiotracer and the resolution of the different modalities used. Hence, other contrast enhancement technique may be needed to improve the contrast in the gray intensity so as to complement the weakness of this proposed technique.

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

References:

- [1] Yeh Hong Tan, Khurram Siddiqui, Glenn M. Preminger, David M. Albala, Hand-Assisted Laparoscopic Nephrectomy for Inflammatory Renal Conditions, *Journal of Endourology*, October 2004, 18(8): 770-774.
- [2] Aref Agheli; Yelena Patsiornik; Yu Chen; M. Rashid Chaudhry; Howard Gerber; and Jen C. Wang. Prostate carcinoma, presenting with a solitary osteolytic bone lesion to the right hip. *Radiology Case Reports*, Vol 4, No 4, 2009
- [3] Kathleen J. W. Wilson, Anne Waugh, *Anatomy and Physiology in Health and Illness*, Eighth Edition, 1996
- [4] Hamilton W, Sharp D, Peters TJ, Round A. Clinical features of prostate cancer before diagnosis: a population-based case-control study. *British Journal of General Practice* 2006; 56:756-782.
- [5] Barry MJ (2001). Clinical practice. Prostate-specific-antigen testing for early diagnosis of prostate cancer. *New England Journal of Medicine*. 344(18):1373-7
- [6] Sheppard, M.A.; Liwen Shih; Image Texture Clustering for Prostate Ultrasound Diagnosis, *IEEE Ultrasonics Symposium*, 2007, 2473 - 2476
- [7] Baraldi, A.a.F.P., An Investigation of the textural Characteristics Associated with Gray Level Cooccurrence Matrix Statistical Parameters. *IEEE transactions on Geoscience and Remote Sensing*. 33, 1996, pp. 293-304.
- [8] Slezak, A.E.H.a.D., Rough Neural Intelligent Approach for Image Classification: A Case of Patients with Suspected Breast Cancer, *International Journal of Hybrid Intelligent Systems*, 2006; p. 205-218.
- [9] Xin Liu, D.L.L., M. A. Haider, T. H. Van der Kwast, A. J. Evans, M. N. Wernick, and I. S. Yetik, Unsupervised Segmentation of the Prostate Using MR Images Based on Level Set with a Shape Prior, *Engineering in Medicine and Biology Society*, 2009, 3613 - 3616
- [10] Hassani, A.E.; Al-Qaheri, H.; Schaefer, G.; Banerjee, S., Intelligent analysis of prostate ultrasound images, *World Congress on Nature & Biologically Inspired Computing*, 2009, 263 - 268
- [11] Anthony Yezzi, J., Satyanad Kichenassamy, Arun Kumar, Peter Olver, and Allen Tannenbaum,, A Geometric Snake Model for Segmentation of Medical Imagery. *IEEE Transactions on Medical Imaging*, April 1997. 16(2)
- [12] Seiffert, U.; Bollenbeck, F, Fuzzy Image Segmentation by Potential Fields, *IEEE International Conference on Fuzzy Systems*, 2008, 1118 - 1123
- [13] Zheng Lin, Jesse Jin, Hugues Talbot, Unseeded region growing for 3D image segmentation, *Proceeding of the Pan-Sydney workshop on Visualisation*, vol.2, 31-37
- [14] Lai Khin Wee, Adeela A., Eko S., Computerized Automatic Nasal Bone Detection based on Ultrasound Fetal Images Using Cross Correlation Techniques, *WSEAS Transactions on Information Science and Applications*, 2010, Volume 7
- [15] Lai Khin Wee, Too Yuen Min, Adeela Arooj, Eko Supriyanto, Nuchal Translucency Marker Detection Based on Artificial Neural Network

and Measurement via Bidirectional Iteration Forward Propagation, WSEAS Transactions on Information Science and Applications, Issue 8, Volume 7, August 2010

- [16] [Lai Khin Wee, Lim Miin, Eko Supriyanto, Automated Trisomy 21 Assessment Based on Maternal Serum Markers Using Trivariate Lognormal Distribution, WSEAS Transactions on Systems, Issue 8, Volume 9, August 2010
- [17] Lai Khin Wee, Eko Supriyanto, Automatic Detection of Fetal Nasal Bone in 2 Dimensional Ultrasound Image Using Map Matching, 12th WSEAS International Conference on Automatic Control, Modelling & Simulation (ACMOS), Italy 2010, Pages 305-309
- [18] Lai Khin Wee, Lim Miin, Eko Supriyanto, Automated Risk Calculation for Trisomy 21 Based on Maternal Serum Markers Using Trivariate Lognormal Distribution, 12th WSEAS International Conference on Automatic Control, Modelling & Simulation (ACMOS), Italy 2010, Pages 327-332
- [19] Eko Supriyanto, Lai Khin Wee, Too Yuen Min, Ultrasonic Marker Pattern Recognition and Measurement Using Artificial Neural Network, 9th WSEAS International Conference on Signal Processing (SIP), Italy 2010, Pages 35-40
- [20] R. Fisher, S. Perkins, A. Walker, and E. Wolfart, Hypermedia Image Processing Reference (Wiley, New York, 1996).
- [21] Atul K. Chhabra, Vishal Misra and Juan Arias, Detection of horizontal lines in noisy run length encoded images: The FAST method, Graphics Recognition Methods and Applications, 1996, Volume 1072/1996, 35-48.