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An Efficient Localisation of Cellular Change Using Tuned Gabor Filter in Prostatic Cases

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Abstract

Investigative imaging has come a long way in diagnosing various kinds of diseases from tuberculosis to cancer. Significant success levels augmented with various other clinical proofing as MRI has become more or less popular. Several inflammatory conditions are diagnosed with the help of this imaging service. Prostatic is one of the obstruction causing organs, prone to inflammation. Successful imaging and successful detection are considered to be the most significant step in treating such inflammations. As the imaging technology has improved, the demand for various image processing techniques for specific detection of the condition of the body has become more vital. Here we present an efficient image analysis approach using tuned Gabor filter scheme to locate and mark the cellular change happening in prostate due to various reasons of inflammation. The process involves identifying a properly tuned Gabor filter parameter to detect subdued cellular variations manifested through intensity modulation in 2 dimensional images from MRI systems. We present here a method to detect the cellular variation available through MRI images using tuned Gabor filters .We also propose a segmentation approach suitable for characterization of these images.

Keywords: Gabor Transforms, Gabor Filters, Parameters To Tune Gabor Filter, MRI, Fuzzy C-Means

1. INTRODUCTION

The identification of demarcating features is the most important task in computer aided detection and diagnosis of medical images. In recent years the analysis of cellular changes has become a source of interest for researchers. The most significant after effect of cellular change is the growth of cancerous cells. Cancerous cells can be differentiated as malignant or benign. Malignant tumor is found to spread across human body with time affecting all organs. Hence accurate analysis of the MRI is required to evidently identify malignant tumors.

Prostate cancer is the second most common type of cancer and fifth most leading cause of cancer related death in men. It refers to the abnormal cellular change that occurs in the prostate gland of the male reproductive system. The growth of cancerous cells in these glands is very slow hence the detection of these cancerous cells at early stages is very important for its successful treatment. Patients become aware of this cancer only after it has spread to the various other body parts such as bones and lymph nodes. Prostate cancer screening is usually done by prostate specific antigen testing (PSA) .Even though diagnostic system are available and have increased with the betterment of imaging technology we still opt for a biopsy for the required confirmation as most cancer diagnosed by PSA remain asymptotic .The histological analysis involves steps such as segmentation and classification. However such analysis also may vary in terms of interpretation due to the subjective nature of the test.

Steerable filters have often been used in medical image analysis .These filters can localize the discontinuities in the images .This paper presents an extensive study of segmentation of digitized images of prostate gland using Gabor filter for separating plausible malicious parts before opting for an invasive approach .The main aim is to find the possibility of classifying the images as benign or malignant based on the intensity. In this context the Gabor filters have been used in medical image analysis in various studies .These filters are capable of dividing the image into regions based upon the difference in texture, intensities and hence capable of localizing the discontinuities in the image. Gabor filter is used to analyze the various intensity variations at different frequency and orientation to segment the prostate image where non invasive confirmatory methods are not available.

2. RESEARCH WORKS

Over the past few years' research interest in achieving non invasive technique for identifying cancerous tissues has been very high. Such research technique helps us to overcome the burden of undergoing unnecessary invasive methods. It has been noted that such attempts in identifying prostate cancer in a non invasive manner has been minimum. Studies in this area have shown that there is significant observer variability in grading the cancer tissues even after biopsy with differences nearly up to 47 % (3).Hence the research for grading and classification of prostate tumor is of utmost importance.

The research work done by Scott Doyle et. al (1) has been able to successfully segment the histological images post biopsy using architectural and textural image features. The classification into four different classes based on tissue texture was achieved using a support vector machine. Classification based on biopsy core specimens was proposed (2) based on intensity of given image into cancerous and non cancerous images.

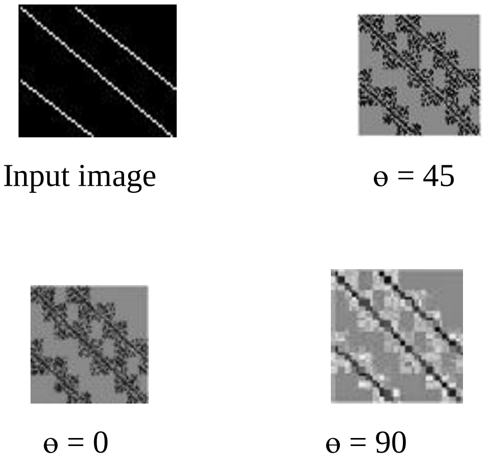


Figure 1: The Gabor Filter Response of various orientation For A Given Image at a given frequency

A novel technique was also suggested (4) where a boosting algorithm was used to identify and give the classifier the discriminating information.

Gaussian filters and its variants have been successful in segmenting and analyzing various images. Gabor filter have been used to detect spurious masses in radiological images. One of the earliest methods for classification in radiological images using Gabor bank was proposed by Zheng (6) where the Gabor filter was used to extract the edge histogram descriptor features. Gabor filter has also been used to detect true masses for reduction of false positive and false negatives (8).Gabor filters provide accuracy against varying brightness and contrast of images due to this they have been used in various applications for providing an accurate time frequency location (9-13).In this paper Gabor filter is applied to analyze the radiological images of prostate section.

3. THE THEORY OF GABOR FILTER

The prostate images are segmented in a localized manner using Gabor filter bank .The main aim of the segmentation is to divide the images into distinct patterns so as to classify and group the images. The Gabor filter is a type of band pass filter where the filter bank consists of an impulse response created by multiplying a Gaussian envelope with a complex oscillation. This type of multiplication helps in reducing the time uncertainty product. A two dimensional Gabor filter may be represented as follows

G(x,y) $$g(x,y) = \frac{1}{2\pi\,\sigma_x\,\sigma_y}\ \exp\left\{\frac{1}{2}\left(\frac{x^2}{\sigma_x^2} + \frac{y^2}{\sigma_y^2}\right)\right\} \qquad (1)$$

The spread of the Gaussian function in x and y direction are denoted by the symbols σ_x and σ_y respectively. The Gabor filter bank is applied on the images considering the center frequency to denote the orientation of the filter. In frequency domain the Gabor filter is based on the two dimensional frequency and orientation.

In this paper we take into consideration eight different orientation and frequency scenarios and a Gabor space is created by convolving these filters with the test images. This process is similar to the process occurring in the primary visual cortex of mammals. The frequency response of the filter is given by the formula

$$H(u,v) = 2\pi\sigma_x\sigma_y[exp(-2\pi^2[a+b])] \qquad (3)$$

Where $a = [(u-u_0)^2\sigma_x^2]$and $b = \left[(v-v_0)^2\sigma_y^2\right]$

This is equivalent of converting a Gaussian function by U_0 and V_0. Thus Gabor function can be thought of as being a Gaussian function shifted in frequency.

When an image is subjected to a Gabor filtering technique we obtain an image output that have components whose energy are concentrated near the spatial frequency points (U_0,V_0).Figure 1 denotes the various response of the Gabor filter to a given image at a particular frequency and orientation.

4. PROSTATIC CANCER AND MRI

Prostatic cancer refers to the abnormal growth of cancerous tissues in the prostatic gland .The prostatic region can be divided into basically 3 main regions : peripheral zone, central zone and transition zone[1].It is found that nearly seventy percent of the adenocarcinoma arise in the peripheral region. The possibility of occurrence of adenocarcinomas in the central and transition zones are 10% and 20% respectively.

Most of the adenocarcinomas appear in the glandular region of the prostate component.

The current method of prostate cancer detection involves the DRE and PSA level (14). The Gleason score with partin tables is the most widely used method to divide the tumor into benign or malicious group. Prostate carcinoma is usually detected when the amount of PSA serum is greater than 4 ng/mL. Recent research studies prove that nearly 70% of people with elevated PSA levels do not have prostate carcinoma. The use of nomograms such as partin helps to improve the accuracy in predicting the risk of treatment failure. These nomograms provide general probabilities and not specific risk for an individual patient. Prostate can be staged using staging systems such as TNM and Jewet – Whitmore staging system are in common usage and are based on nodal extent of disease [14] as shown in table 1.

Table 1: Prostate Cancer Staging table

TNM STAGING	JEWETT - WHITMORE	CONFINEMENT	DESCRIPTION
I (T1,N0)	A	Organ Confined	No distinction
II (T2,N0)	B	Organ Confined	Localized to a particular side
III (T3,N0)	C	Seminal vesicle invasion	Extra capsular extension is present
IV (T3,N1 & N2)	D1	Loco regional Adenopathy	Microscopic and macroscopic metastases
IV (T4, N3)	D2	Far Spread	Spread to other parts of body

Conventional MRI for prostate imaging involves the usage of endorectal and pelvic phased array coils on a magnet which is necessary to obtain high resolution images for accurate localization and staging of prostate cancer [1]. The peripheral region is a high intensity region while the prostate carcinoma is represented by a low intensity region .Conventional MRI is usually combined with MR-spectroscopy to evaluate the cancer region. The MRI evaluation for assessment of cancer usually involves a combination of anatomic T1 and T2 weighted images. On combining the MRI images to a morphologic and functional technique may enhance the ability to segment the images[1].

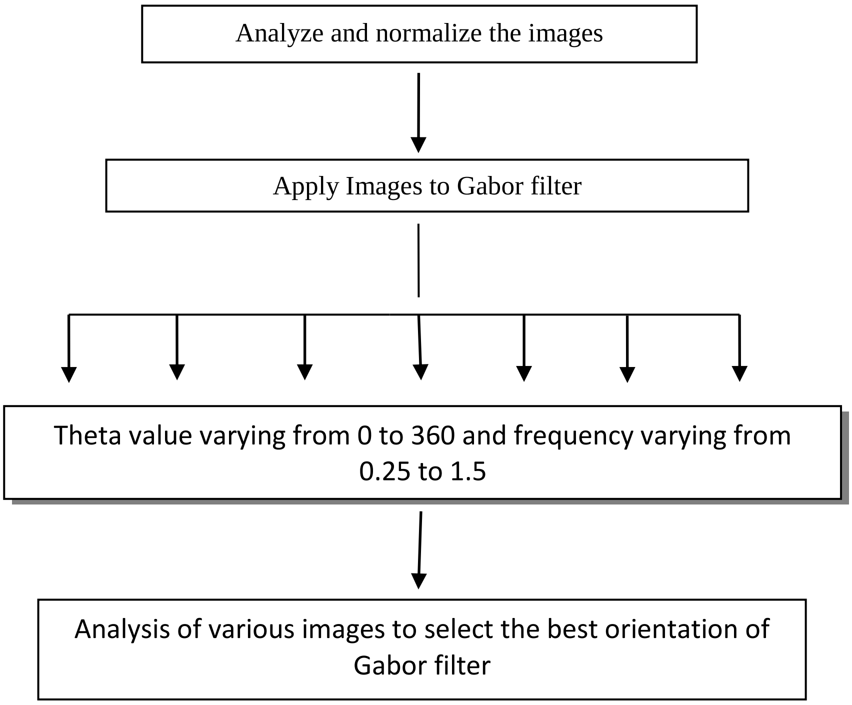


Figure 2: A functional block diagram of the mechanism involved for identifying the best orientation.

5. EXPERIMENTAL METHOD

5.1 PROSTATE CARCINOMIC MRI IMAGES

The prostate carcinoma MRI images are obtained from the TCIA cancer imaging database.

5.2 GABOR FILTERING TECHNIQUES

The given prostate MRI images are first analyzed and then normalized. The normalized images are then subjected to the Gabor filter bank. The Gabor filter bank consist of nine orientations and eight frequency orientation .Each result is analyzed and the best combination of Gabor filter components is selected that will help to achieve the best possible segmentation of the MRI image. Figure 2 gives a basic functional block diagram of the above process.

As shown in figure 3 and figure 5 the input image applied for analysis is subjected to Gabor filtering where each pixel in the image is considered and convolved with the sine valued Gabor filter at a frequency value 1.5. The filter response obtained suggest that the fragmentation is properly highlighted when the filter direction is at 90 and 270 degrees .Similarly when a cosine characteristic Gabor filter is convolved with the input image the fragmentation is properly highlighted at 0 and 180 degrees. When both the cosine and sine characteristics are convolved together the filter response produces a prominent result at 45 and 135 degrees. by combining the different aspect we can produce a proper result. Figure 4 and figure 6 denotes the response of the Gabor filter with sine characteristics at a frequency value of 0.5 where each pixel value is individually convolved with the cosine valued Gabor filter exponential. The filter response obtained as shown in the figure shows the best output result for horizontal axis values.

The output result shows that the filter best produces proper segmentation output when the orientation are parallel to axis in sine characteristics and when orientation are perpendicular to axis in cosine characteristics.

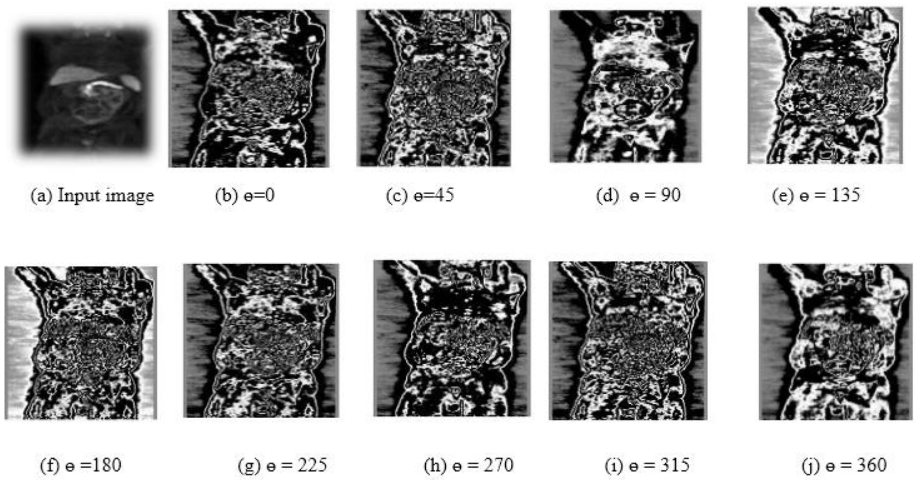


Fig 3 : Response of a Gabor filter with sine characteristics for various orientation at bw = 1.5

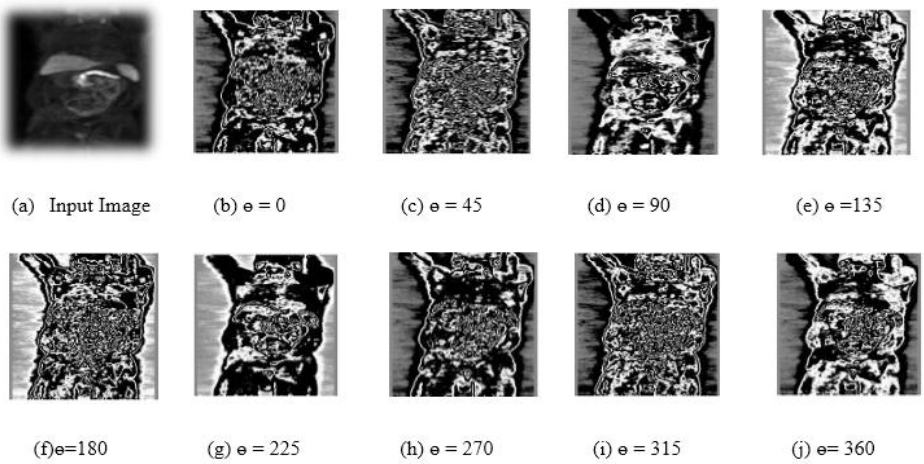


Fig 4: Response of a Gabor filter with sine characteristics for various orientation at bw = 0.5

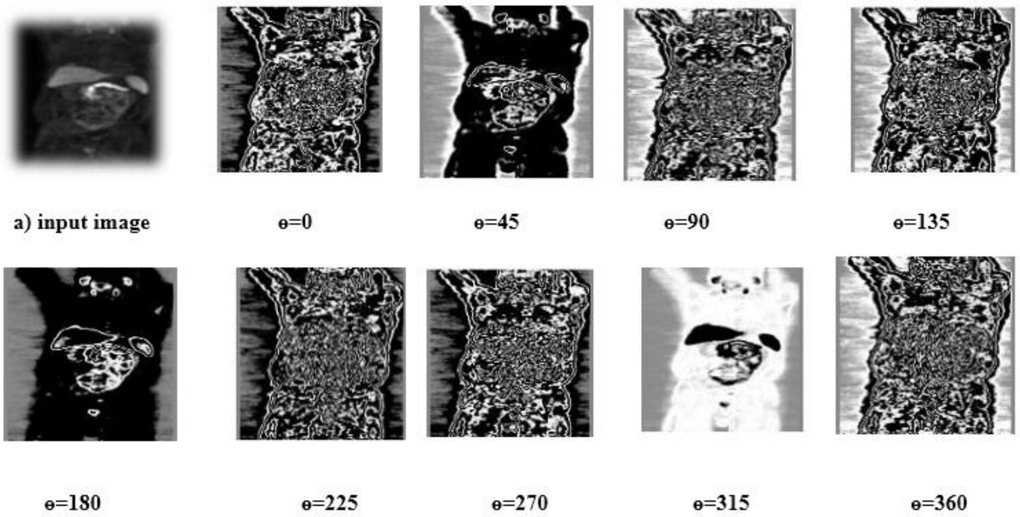


Fig 5: Response of a Gabor filter with cosine characteristics for various orientation at bw = 0.5

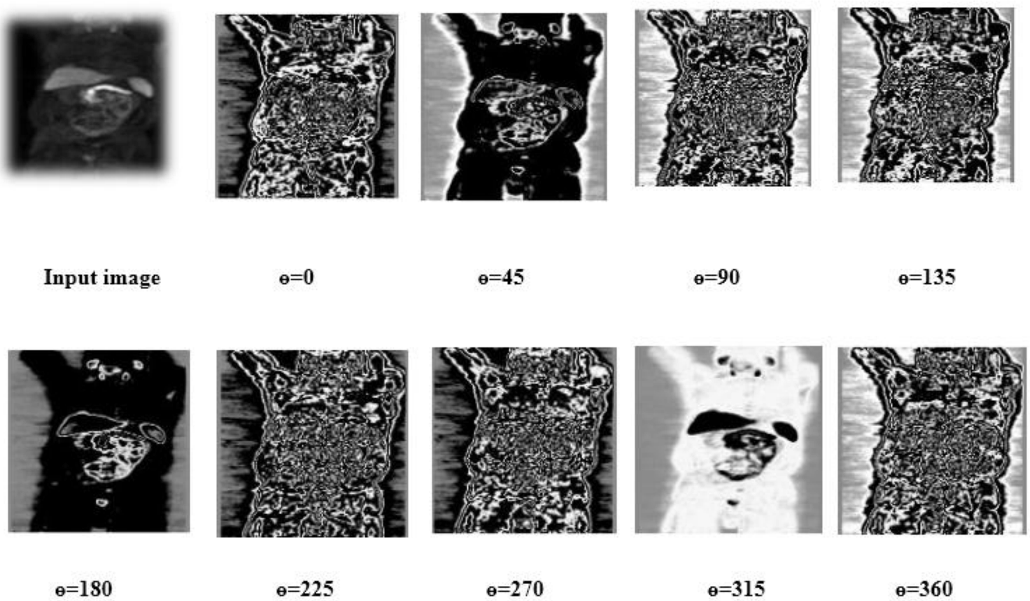
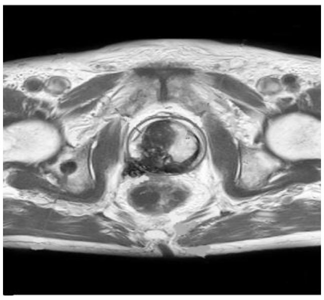
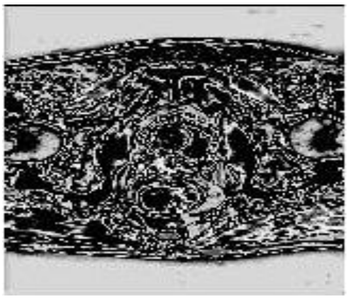
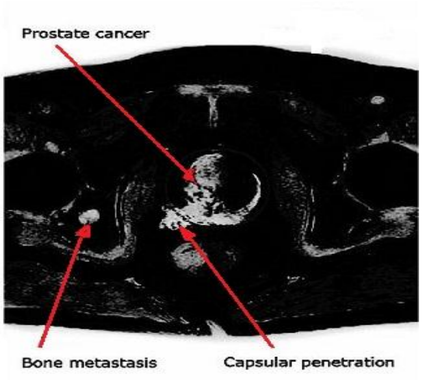


Fig 6: Response of a Gabor filter with cosine characteristics for various orientation at bw = 1.5



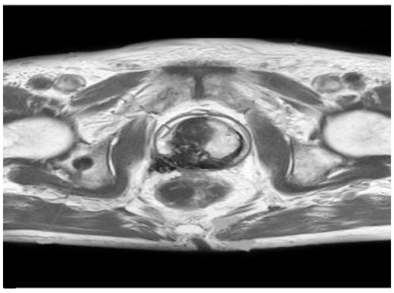


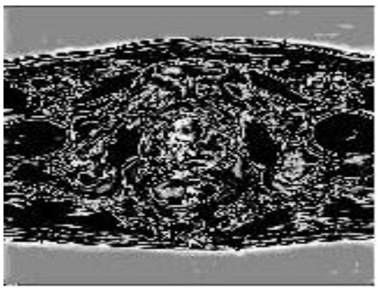
Input image **Filtered image**



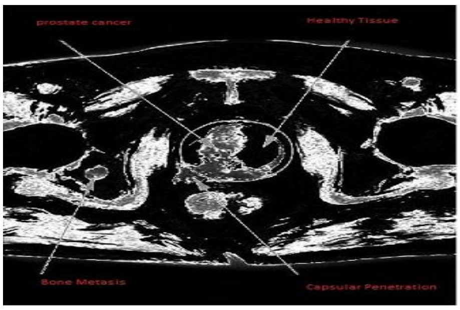
Segmented image

Fig 7: Segmented image at an orientation of 180 degrees with sine factor





Input Image **Filtered Image**



Segmented Image

Fig 8: Segmented image at an orientation of 180 degrees with sine factor

5.3 Clustering and Segmentation

The images obtained after the filtering is then subjected to segmentation using an automatic clustering technique called the Fuzzy c means technique. Clustering is basically a technique that allows to group together several pixels of the image into different groups based on their similarities. It is basically based on minimization of the objective function

$$J_m = \sum_{i=1}^{N} \sum_{j=1}^{C} u_{ij}^m \left\| x_i - c_j \right\|^2$$

Where m is any real number greater than 1, the fuzzy partitioning is done through an iterative optimization of the objective function. The cluster centers are given by the equation

$$c_j = \frac{\sum_{i=1}^{N} u_{ij}^m \cdot x_i}{\sum_{i=1}^{N} u_{ij}^m}$$

The basic Fuzzy C means Algorithm involves the following steps

[1] Initialize U = [u_{ij}] matrix, $U^{(0)}$

[2] At the K^{th} step calculate the center vectors $C^{(k)}$

[3] Increment the value of $U^{(k)}$ to $U^{(k+1)}$

[4] If $\{U^{(k+1)} - U^{(k)}\} < \varepsilon$ then stop , else return to step 2

In the above algorithm the degree of membership between each pixel and the center of the clusters is determined by the matrix U. The fuzzy clustering technique are one of the most commonly used technique in classifying and segmenting biomedical images (14-18).

6. CONCLUSION

This research paper is an attempt to segment spurious masses from normal surrounding in prostate radiological images .A method to segment the prostate radiological image using a tuned Gabor filter is suggested. The response of the filter when sine and cosine characteristics are separately applied is quantified and analyzed. The histogram responses after the images have been filtered indicate that the Gabor function has improved the image for further segmentation .On the investigation of the results it can be concluded that the prostate images can be segmented after a competitive analyses of the sine and cosine characteristic response on applying the Gabor filter.

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