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A NOVEL METHOD TO DETECT BONE CANCER USING IMAGE FUSION AND EDGE DETECTION

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Abstract

Employing an efficient processing technique is considered as an essential step to improve the overall visual representation of clinical images, and as a consequence provides better diagnosis results. This paper employs an easy, fast and reliable technique to detect cancerous tissue in bone by using different image processing techniques such as contrast enhancement, edge detection and image fusion. The experimental results show, the proposed method could obtain the smooth image with edge showing the disease affected part without the spatial and spectral noises.

Key words: contrast enhancement, edge detection, image fusion

1. INTRODUCTION

A bone tumor, (also spelled bone tumour), is a neoplastic growth of tissue in bone. Abnormal growths found in the bone can be either benign (noncancerous) or malignant (cancerous). Bone tumors may be classified as "primary tumors", which originate in bone or from bone-derived cells and tissues, and "secondary tumors" which originate in other sites and spread (metastasize) to the skeleton. Carcinomas of the prostate, breasts, lungs, thyroid & kidneys are the primary carcinomas that most commonly metastasize to the bone. Secondary malignant bone tumors are estimated to be 50 to 100 times as common as primary bone cancers. Primary tumors of bone can be divided into benign tumors and cancers. Common benign bone tumors may be neoplastic, developmental, traumatic, infectious, or inflammatory in etiology. Some benign tumors are not true neoplasms, but rather, represent hamartomas, namely the osteochondroma. The most common locations for many primary tumors, both benign and malignant include the distal femur and proximal tibia. Since, by definition, benign bone tumors do not metastasize, all secondary bone tumors are metastatic lesions which have spread from other organs, most commonly carcinomas of the breast, lung, and prostate. Reliable and valid statistics on the incidence, prevalence, and mortality of malignant bone tumors are difficult to come by, particularly in the oldest (those over 75 years of age), because carcinomas that are widely metastatic to bone are rarely ever curable, biopsies to determine the origin of the tumor in cases like this are rarely done.

The survival of bone cancer patients is related to the extent of their disease at the time of diagnosis. In the absence of distant metastases, the spread of tumors to the mediastinal lymph nodes is a major determinant of both the prognosis and the therapeutic approach. Proper staging is important for selecting patients who may benefit from surgical resection and for defining the treatment modalities of patients who will undergo radiotherapy.

Tomographic imaging in nuclear medicine is based on the metabolic activity of tissues and may be useful for identifying pathological changes before they are detected by radiological examinations such as CTs. CT provides the anatomical structure and SPECT and PET and PET[11] provides the functional information of organs and tissues. PET (positron emission tomography) scans with ^{18F}-FDG (^{18F}-fluorodeoxyglucose) have superior sensitivity and specificity compared to chest CTs and are considered the most accurate imaging method for staging patients with bone cancers. However , there are limitations related to positive predictive value of this method because there may be FDG uptake in inflammatory cells. The sensitivity can also be decreased when lymph node metastasis is microscopic or below the spatial resolution threshold of current, state-of-the-art scanners. The availability of PET is restricted to a few institutions because of equipment costs. Alternatively, single-photon emission computed tomography (SPECT) is widely available, has lower costs than PET, and does not require the presence of a cyclotron adjacent to the hospital.

The association of functional images and anatomical information from CTs may be useful in interpreting SPECT by providing more accurate data regarding the location and extent of tumor lesions. Hybrid devices usually have dual detectors, with scintillation cameras and low-dose CT scanners. Sequentially, data from both CT and SPECT are acquired. The two images are merged, creating SPECT images that are superimposed on corresponding anatomical planes. This image fusion may help to differentiate between tumors and other areas of physiological activity.

Image fusion is the process of integrating information from two or more images of the same position into a single image that contains more information and is more appropriate for visual perception. For the purpose of most clinical applications, medical image fusion intends to reduce ambiguity and minimize redundancy in fused image while maximizing the relative information specifics.

This paper proposes a new method to detect cancerous parts in body by using different image processing techniques. Preprocessing techniques are done on SPECT, CT images and then the edge of CT image is detected by using a new method to enhance the disease affected part. Then the SPECT and edge detected CT images are fused with HIS,PCA and integrated retina inspired model (RIM)[2].

2. THE IHS, PCA AND RETINA INSPIRED FUSION MODELS

2.1. The RGB-IHS Conversion Model

The IHS[3] transformation converts a multispectral image or panchromatic image with red, green and blue channels (RGB) to intensity, hue and saturation independent components. The intensity displays the brightness in a spectrum, the hue is the property of the spectral wavelength, and the saturation is the purity of the spectrum. This technique may be used for the fusion of multi-sensor images.

To understand the whole fusion process preferably, we must review the RGB-IHS conversion model. There are two essential RGB-IHS conversion models. In this study, we select a more close to the real visual effect model- triangular spectral model. The IHS triangular model can produce a fused and enhanced spectral image.

2.2. PCA Transform Fusion Approach

The whole idea of the method is described in detail in References , and here the fundamentals of PCA[5] fusion are briefly outlined as follows. Firstly, a multispectral image is transformed with PCA transform and the eigen values and corresponding eigenvectors of correlation matrix between images in the multi-spectral image’s individual bands are worked out to obtain each matrix’s principle components. Next, the panchromatic image is matched by the first principle component using histogram method. Finally, the first principle component of the multispectral image is replaced with the matched panchromatic image and with other principle components, followed by the transformation with inverse PCA transform to form the fused image.

2.3. Retina-Inspired Model

The RIM[6] fusion consists of five basic layers, fusion structure diagram of which is depicted in Fig. 1. The earliest layer represents an array of high resolution cone photoreceptors, while the second layer is a high scale spatial feature extractor. The third layer is the array of low resolution receptors (horizontal cells), the fourth and the last layers are made of bipolar and ganglion cells. Every layer has its own mathematical model and corresponding expressions.

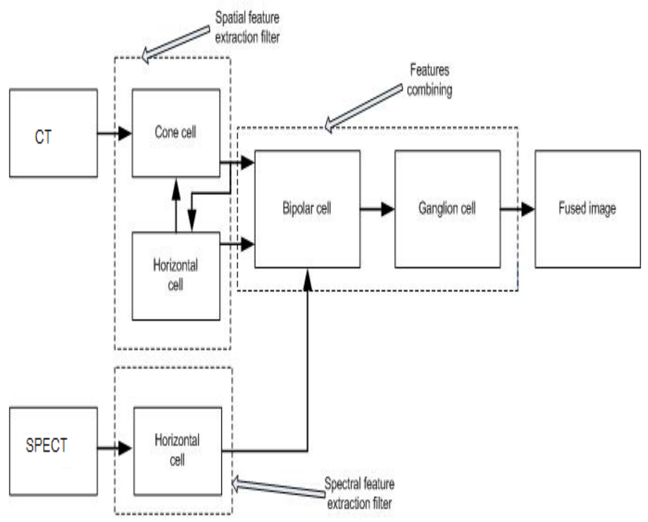

fig1.Retina inspired model

In the proposed fusion approach, we use a black box to represent the RIM model, which is just a part in the whole system, its internal structure and some cells detailed information in the fusion process shown the same as Fig. 1.

3. The Sobel edge detector

An edge[8], in an image, is a collection of connected high frequency points. Visually, an edge is a region in an image where there is a sharp change in intensity of the image. Edge detection refers to the operation(s) performed on an image to detect the edges in an image. The output of edge detection is usually thresholded to retain only the edge. Edge detection plays a vital role in object detection and feature extraction and plays pivotal role in machine vision. There are different types of edges – step edges, roof edges, line edges, colour edges, gray level edges, texture edges etc. Not all edges are detected by all edge detection operators. Each operation has its specific specialty in edges and better the edge detection, usually, more complex and costly is the operation. An edge has both magnitude and direction. The direction is used to identify the next possible edge point. Finally, all the edge points are linked together to form an object boundary. In an ideal scenario, all edges are connected and we get a perfect boundary, but this is seldom the case due to various reasons such as difference in illumination, partially visible objects, texture variation, inefficiency of the edge detection operator etc. Some times, the edge detection operation might even result in false edges. To resolve these issues, there have been a number of edge detection operators defined throughout the history of Image Processing. All the edge detection methods are based upon the description of 'changes of continuous functions using derivatives' given by calculus. Simply put, all operators are gradient operators.

Gradient edge detectors are those which describe edges by means of partial derivatives. A change in the image function can be described by a gradient that points in the direction of the largest growth of the image function. They are of three types: Operators performing derivatives by using differences. Eg: Sobel , Operators based on the zero crossings of the second derivatives. Eg: Canny edge detector. , Operators that match the image function to a known parametric model of the edges.

The well-known and earlier Sobel edge detector computes the 2-D spatial gradient measurement on an image. It consists of a pair of 3×3 convolution kernel:

−1	−2	−1	−1	0	1
0	0	0	−2	0	2
1	2	1	−1	0	1

Sobel

Figure2: The convolution kernel for the Sobel Edge detector. Note the emphasis on the horizontal and vertical edges

The detector responds maximally to vertical and horizontal edges, as can be observed from the values of the masking kernel. It gives gradient nagnitude in both horizontal and vertical direction.

The gradient component of Sobel edge operator:

$$G_x = (z_7 + 2z_8 + z_9) - (z_1 + 2z_2 + z_3)$$

$$G_y = (z_3 + 2z_6 + z_9) - (z_1 + 2z_4 + z_7)$$

4. PROPOSED METHOD

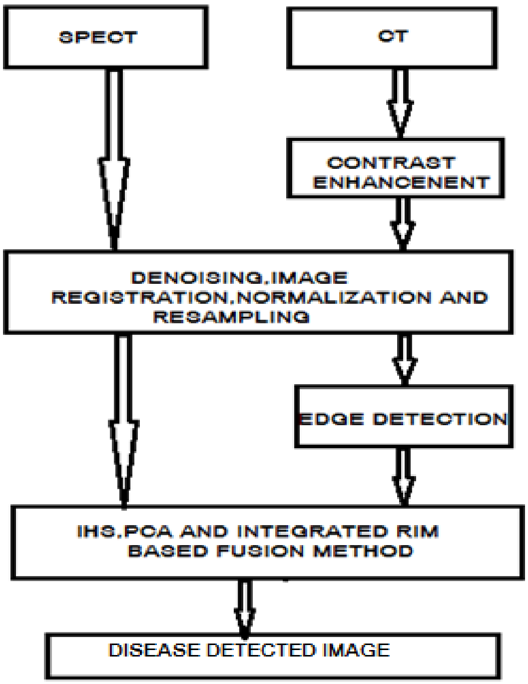

Figure3: proposed method

4.1 PREPROCESSING STEPS

Contrast Enhancement: Computed tomography (CT) imaging is one of the areas that have seriously concerned lately [1]. CT medical images are affected by different types of degradations such as noise [2], blur [3] and contrast imperfections. This method[9] handles the issue of enhancing the contrast of CT medical images only. Generally, the computed tomography (CT) medical images own a low contrast, and enhancing the intensity of CT images is a vital issue for humans. The contrast of any image is decided by its dynamic range, which is defined as the ratio between the brightest and the darkest pixel intensities. Many reasons led to imperfection in the contrast such as varying display devices, acquisition methods, transmission storage, restoration and enhancement algorithms. Improving the contrast of medical images would lead to better visual representation of the images, improved syndromes diagnosis, more accurate detection of diseases and as a consequence enhancing the contrast of the CT images will show smaller components and features of the medical image allowing the therapist to perform a healthier treatment for the patient. Enhancing the contrast of CT images is considered as a pre-processing step in many medical image processing applications.

When enhancing the contrast of computed tomography (CT) medical images, two factors to complete the task must be considered, those are speed and efficiency. The proposed technique considers these two factors by supplying a fast processing with effective results. This technique has been utilized in the spatial domain. Moreover, it has been applied to the entire image directly instead of processing the image pixel by pixel. Normalizing the image based on its size takes the following course: first, the size of the processed image is determined. Then the enhancement variable (K) is computed using the subsequent equation:

$$K = \frac{\sum_{i=1}^{i} \sum_{j=1}^{j} x(i,j)}{m \times n}$$

Where (*x*) is the degraded image, the above equation sums all pixels values and divides them by the size of the image represented by (*m*) and (*n*). Finally, the image is enhanced using the following equation:

$$EI = \frac{[x - \min(x)]e^{K}}{\max(x) - \min(x)}$$

Where (*x*) is the degraded image, (*min*, *max*) are the minimum and maximum pixel values of the processed image, (K) is the enhancement variable, and (EI) is the contrast improved image. The following flow chart represents the enhancement methodology:

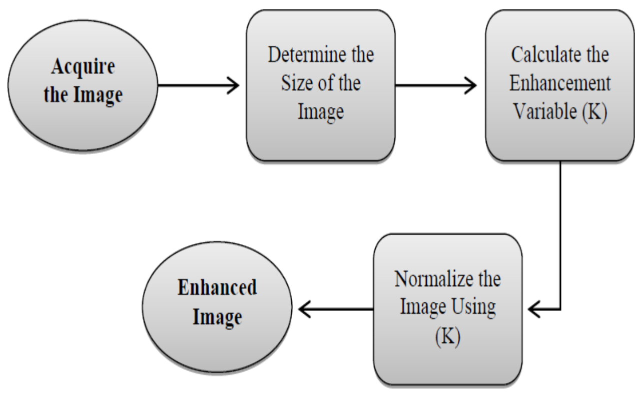

Figure4 :Contrast Enhancement Method

Image Registration: Image registration[12] is the process of transforming different sets of data into one coordinate system. Data may be multiple photographs, data from different sensors, from different times, or from different viewpoints.[1] It is used in computer vision, medical imaging, military automatic target recognition, and compiling and analyzing images and data from satellites.

Registration is necessary in order to be able to compare or integrate the data obtained from these different measurements. Image registration essentially consists of following steps Feature detection: Salient and distinctive objects (closed-boundary regions, edges, contours, line intersections, corners, etc) in both reference and sensed images are detected.Feature matching: The correspondence between the features in the reference and sensed image established.Transform model estimation: The type and parameters of the so-called mapping functions, aligning the sensed image with the reference image, are estimated.Image resampling and transformation: The sensed image is transformed by means of the mapping functions.

Image resampling (RS): RS[12] is the procedure that creates a new version of the original image with a different width and height in pixels. Simply speaking, RS can change the size of the image. Increasing the size is called upsampling, for example. On the contrast, decreasing the size is called downsamplig. Note that the spatial resolution would not change after the RS procedure, either upsampling or downsamplig.

Image normalization: A common problem associated with the use of multisource image data is the grey value differences caused by non-surface factors such as different illumination, or sensor conditions. Such differences make it difficult to compare images using same color metric system. Image normalization[12] is required to reduce the radiometric influences caused by non-surface factors and to ensure that the grey value differences between temporal images reflect actual changes.

4.2 EDGE DETECTION

Edge detection[1] is one of the fundamental steps in image processing, image analysis, image pattern recognition etc. Edge can outline the target objects profile, which is an important attribute of extract from the images recognition. Edge information in CT image is an important characteristic because lung region contains an abundance of edges like vessels, air tree, air sacs, artery branches etc.. In real world applications, medical images contain object boundaries and object shadows and noise. Therefore, they may be difficult to distinguish

the exact edge from noise or trivial geometric features.

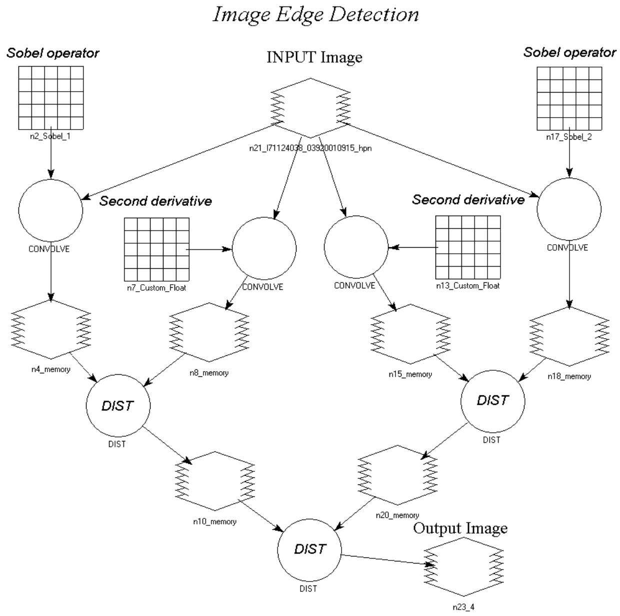

Fig5: Proposed edge detection

The proposed edge detection method can visualize the disease affected part well and which is shown below.Edge detection steps include :The input image is first convoluted with the horizhontal and vertical components of Sobel operator and second derivative of Sobel operator. Then take the distance function between the outputs of Sobel and Second derivative since second derivative operator enhances only smaller edges and sobel operator enhances all types of edges. Then taking the convolution of horizontal and vertical components. By taking the edge detection

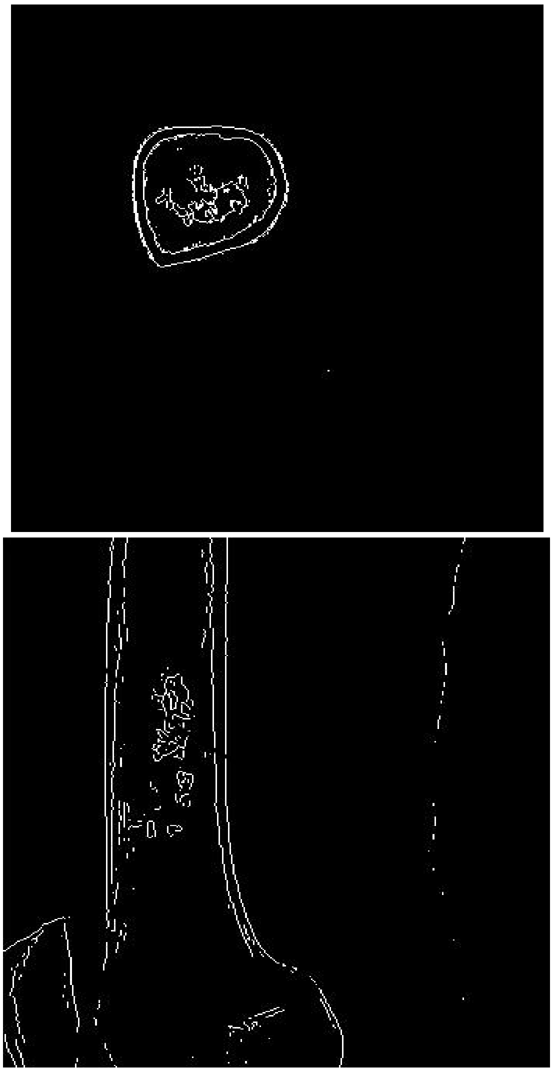

Figure6 : edge detected images of bone

4.3 IMAGE FUSION

Fig. 7 shows the whole fusion process[2] of the proposed approach, which may be divided into the following several steps. Firstly, the MS image is transformed into the IHS triangular model components. Then, histogram matching is applied to match the histogram of the CT image with the SPECT intensity component. Next, the PCA transform extracts their own principal components of MS intensity image and new CT (called New Pan), and selects corresponding components' weight coefficients by calculating their spatial frequency respectively to obtain a new intensity component. Finally, the approach is performed by combining the new intensity component and original SPECT intensity component, using retina-inspired fusion model.

In this stage a final intensity image is obtained, which contains the same spatial detail of the original CT and has the same intensity distribution to the original SPECT. In the meantime, it also avoids some superfluous details and artifacts in the previous transformation. Ultimately, we can obtain a satisfied fused image by inverse IHS transform exploiting the new intensity component and original H and S components of SPECT image.

This fusion process generates a new high resolution color image. The new image contains both the spatial details of the CT source image and the spectral information of the SPECT source image, simultaneously. How to select two principal components' weight coefficients after PCA transform is a critical problem. This paper propose an adaptive selection method by calculating spatial frequency (SF) of original MS intensity image and old CT image.

The expression for a $K*L$ pixels image $f(x, y)$ is defined as:

$$SF = \sqrt{RF^2 + CF^2}$$

where RF and CF are the row frequency and column frequency respectively.

$$RF = \sqrt{\frac{1}{K \times L}\sum_{x=1}^{K}\sum_{y=2}^{L}[f(x,y) - f(x,y-1)]^2}$$

$$F = \sqrt{\frac{1C}{K \times L}\sum_{x=1}^{K}\sum_{y=2}^{L}[f(x,y) - f(x-1,y)]^2}$$

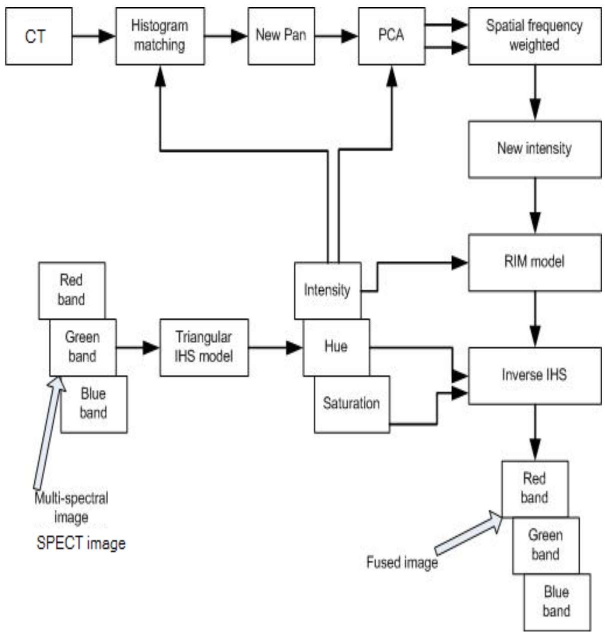

Fig7. Proposed fusion method

The selection of two principal components' weight coefficients based on SF can be depicted as:

$$I = \alpha I_1 + \beta I_2$$

$$\alpha + \beta = 1$$

Where I_1, I_2represent the principal component of New Pan and original multispectral intensity component, respectively. α and β are normalized SF values.

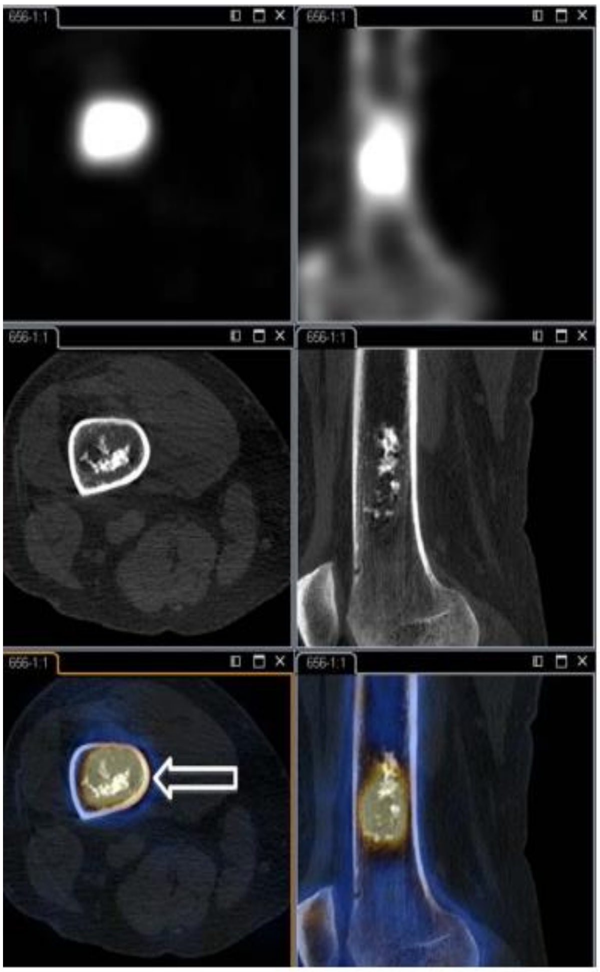

Figure8: SPECT, CT images and SPECTCT fused images of a patient with bone cancer.

5. CONCLUSION

This paper proposed a simple and easy image fusion method to detect the bone cancer. Edge detected CT is fused with the SPECT image to enhance visualization of disease affected region. SPECT are shown in pseudo-color. The SPECT produces images with suitable color and low spatial resolution, while CT provides appropriate spatial resolution with no color information content. This study integrated the merits both preserving spatial information of the IHS transform, reduces the spectral distortion by using RIM and minimizing redundancy of PCA transformation and obtained the satisfying fused results.

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