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A Novel Tumor Margin Assessment Algorithm for Hyperspectral Cancer Images

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Abstract— ***Hperspectral Images (HSI) has been emerged as a strong proposal for the rapid and early detection of the cancer. The basic and fundamental step involved in the cancer treatment is the surgical resectioning of the tumor. But the tumor margin detection is a challenging task since it is difficult to distinguish between the normal and abnormal tissues. The positive resection margin can cause local re-occurrence of the disease, additional surgeries and it can be the reason for rising mortality. Here a novel tumor margin assessment algorithm is introduced for HSI cancer images based on an improved watershed transform. The watershed transform is improved by adding certain morphological operation along with the usual watershed algorithm. The algorithm has been made efficient in predicting the case of malignancy by incorporating optimal band selection technique and estimation of kinematic parameters in the HSI images, along with the watershed transform. The proposed algorithm is found to be an effective method for the cancer boundary detection in HSI.***

Index Terms—Hyperspectral Images (HSI), Cancer, Tumor margin assessment, Optimal Band selection, Watershed Transform, Kinematic parameters.

I. INTRODUCTION

In [1] it was mentioned that around 1.7 million people had been diagnosed with cancer in 2014 and around 585,720 patients died from the disease in the United States in the same year. The survival and quality of the life assured to a cancer patient is directly related with the primarily diagnosed tumor size. Thus the early detection of the suspicious lesions could improve both the survival and the incidence. The common diagnostic tool used for the cancer screening is biopsy. But the biopsy is an invasive and time consuming procedure. Also it is subjective and inconsistent. The Hyperspectral Images (HSI) has been introduced as a promising tool for early cancer detection [2].

The most common and the fundamental step in the cancer treatment is Surgery. But during surgery the complete removal of tumor is necessary for the ensuring the post operative well being of the patient. The positive resection margins after the surgical resectioning can cause the local reoccurrence of the diseases, extra surgeries and the chances for raising the mortality rate. Therefore, a a completeness in the tumor removal is essential for the ensuring the quality of life of the patient and for considerably reducing the loss of money. But in surgical resectioning the it is extremely difficult to distinguish malignant tissue from healthy tissue. Visual inspection is not always effective because of the similarity in tissues and it is highly subjectivity. By the conventional methods it is not possible to get a conclusion about the tumor margin; it is viable for histological and sampling errors. Also the histological process is time consuming process and is having anesthesia risks. Therefore surgeons require a real-time imaging method for the localization and assessment of tumor margin during surgery.

The HSI has a unique feature that it includes numerous bands associated with a single image, so that its resolution will be so high that in accumulate many unique features of the subject. It includes both the spatial and spectral information, since it is a two dimensional spatial images spread out in hundreds of bands of large spectral resolution. Its band not only include just the visible spectrum, but also it includes the UV and near-Infrared (IR) bands. Thus it can be a perfect imaging tool and can well examine all the internal properties of a tissue like emissivity, reflectivity, absorptivity etc which is not possible in conventional imaging techniques. The major advantage of the HSI is that it is fast, cost effective, no radiation effects and no requirement of the contrast agent or it is a completely non-invasive procedure. It is actually an optical spectroscopy technique. It can be applicable for the surgical assistance, especially for the image-guided surgery. In case of the image guided surgeries there is no need of the speed of image acquisition is the major concern.

Hyperspectral images based cancer detection and hyperspectral image guided surgeries has been reported in the literature Khalid Masood et al [3] proposed automatic classification of histology images, for supporting the pathologists in their diagnosis. A comparative study between 3D spectral-spatial analysis (SSA) and 2D spatial analysis (SA) for the classification of colon biopsy samples from their hyperspectral images. Kiyotoki et al.[4] reported for or the distinction of gastric cancer from normal mucosa from endoscopy resected lesions by combining HIS. Svetlana V. Panasyuk et al [5] introduced medical hyperspectral imaging to facilitate residual tumor identification during Surgery. Here an adequate evaluation of breast tumor resection at surgery continues to be an important issue in surgical care. Here they had used an experimental DMBA-induced rat breast tumor model to examine the intra operative utility of MHSI, in distinguishing tumor from normal breast and other tissues. David T. Dicker et al[6] has explained the differentiation of normal skin and melanoma using high resolution hyperspectral imaging. Here they experimented the use of high resolution hyperspectral imaging microscopy to detect abnormalities in skin tissue using hematoxylin eosin stained preparations of normal and abnormal skin, benign nevi and melanomas. Hamed Akbari et al[7] proposed cancer detection using infrared hyperspectral imaging. Baowei Fei et al [8] claimed that hyperspectral imaging is an emerging modality for medical applications. Its spectroscopic data can be utilized to noninvasively detect cancer. Gebhart et al.[9] used a reflectance imaging scheme for the guidance of human brain resection, combining diffuse reflectance and fluorescence techniques. And it is capable enough to differentiate main anatomy structures and differentiation of the bile duct.

II. PROPOSED METHOD

Here HSI cancer images are taken and are utilized to extract the exact tumor margin by applying a tumor margin assessment algorithm. The preprocessing has not much relevance in the HSI, it only includes the rgb to gray conversion and a simple filtering operation. But the optimal band selection is an inevitable step for the HSI, Where the unnecessary bands may be get eliminated. The key algorithm used here is an improved watershed algorithm. The some morphological operations are added with the conventional watershed transform to make it more adaptive enough for the tumor margin assessment. And one the features extracted for further analysis of the subject the kinetic parameters and the area estimation is employed. That will give a more detailed view of the tumor.

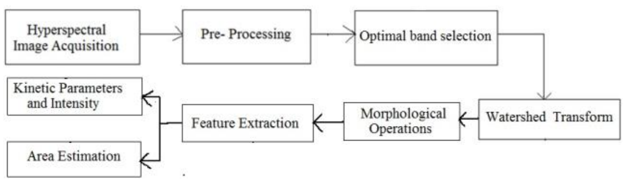

Figure 1: Block Diagram of proposed method

A. HSI ACQUISITION

The HSI tumor images are used for the purpose. The images are taken under specialized conditions using hyperspectral cameras. Here the images are taken from [3].

B. PRE-PROCESSING

The HSI has an advantage that it does not require complex preprocessing steps. The preprocessing includes the conversion of the HSI image obtained in ‘hdr format’ to ‘ldr format’ using tone mapping. And it is followed by usual rgb to gray scale conversion.

C. OPTIMAL BAND SELECTION

The optimal band selection is one of the important step in HSI image processing. Here from the numerous bands available in HSI only those bands containing the necessary features alone may be considered, which can be tracked by this method. Here the bands may be distributed as pattern intensity. And the intensity threshold limits taken here is 40-190 range.

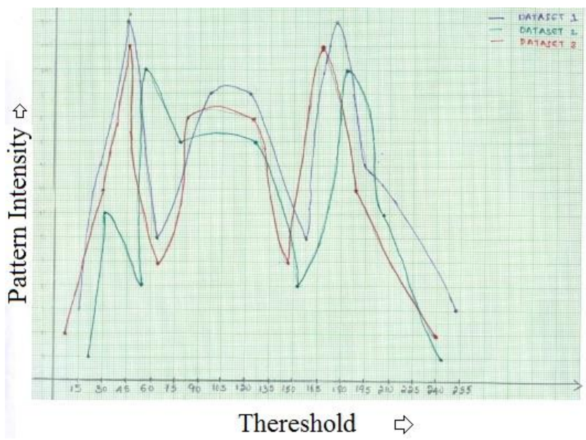

Figure 2: Optimal Band Selection

D. TUMOR MARGIN ASSESSMENT ALGORITHM

The algorithm is mainly contributed by a modified watershed transform, it is conventional watershed transform supported by certain morphological operations. The watershed will give the proper boundary of the malignant tissue. The feature so extracted is not progressive enough if it cannot give any idea about the properties of the tissues. In order to undertake this requirement, kinetic parameters and the area estimation are being employed. The kinetic parameters and kinetic intensities could give an outline about the variation in tissue feature. And the area estimated can give a guide line for the surgeons.

III. PROPOSED ALGORITHM

A. IMPROVED WATERSHED SEGMENTATION

The method is done to find the actual area of tumor speeded throughout the malignant lesions are done by selecting the region [10]. It includes the following steps:

Noise Reduction: Since edge detection is susceptible to noise in the image, first step is to remove the noise in the image with a 5x5 Gaussian filter.

Gradient of the Image: Smoothened image is then filtered with a Sobel kernel in both horizontal and vertical direction to get first derivative in horizontal direction (Gx) and vertical direction (Gy). From these two images, can find edge gradient and direction for each pixel as follows:

$$Edge\_Gradient\ (G) = \sqrt{G_x^2 + G_y^2} \qquad (1)$$

$$min_u \left\{ G(u,f) = TV(u) + \frac{\lambda}{2}\|u-f\|_2^2 \right\} \qquad (2)$$

Gradient direction is always perpendicular to edges. It is rounded to one of four angles representing vertical, horizontal and two diagonal directions.

Non-maximum Suppression: After getting gradient magnitude and direction, a full scan of image is done to remove any unwanted pixels which may not constitute the edge. For this, at every pixel, pixel is checked if it is a local maximum in its neighborhood in the direction of gradient.

Hysteresis Thresholding: Any edges with intensity gradient more than threshold are sure to be edges and those below threshold are sure to be non-edges, so discarded. Those who lie between these two thresholds are classified edges or non-edges based on their connectivity. If they are connected to"sure-edge"' pixels, they are considered to be part of edges. Otherwise, they are also discarded.

Edge Gradient (G) = jGxj + jGyj

That is based on the canny edge detection method to sharpen the edges. And sobel operator is also applied as a part of preprocessing techniques.

Watershed transform for segmentation: It is one of the most commonly used method of segmentation applied in mammogram and MRI, thus it can be applicable in HSI as well. In watershed transform the image may be treated as a topographic surface in gray scale, with varying gray level in it indicates the altitude and the constant gray field indicates the flat surface. The term watershed means a separating area that divides the whole land by a river system. So a brief idea of this method is been illustrated. Performing on an image, the system is usually applied on its gradient image. In this case, each object is distinguished from the background by its up-lifted edges. Here certain morphological operations are added with the conventional watershed transform to avoid the over segmentation problem associated with it. In order to avoid the over segmentation in watershed the marker based approach has to be followed, this can be achieved by adding certain morphological operations with it.

The associated morphological operations are opening by reconstruction and open-closing by reconstruction. It is simply the morphological erosion and dilation operations applied in an effective way.

B. KINETIC PARAMETERS AND KINETIC INTENSITY

Morphological features and kinetic parameters [4] were evaluated to predict the case of malignancy and benign. The foremost regular kinetic, morphological and morpho-kinetic patterns on HSI can be easily predicted. The differences in the frequency of lesion types were technically done by significant variations of their kinetic morphology. The morphological patterns and morphologic features based on the regular patterns of the mass or tumor like fibro glandular mass-like enhancement, segmental enhancement in different shapes, were detected and analyzed. There is no significant difference in the frequency of morph-kinetic patterns. The objective was to analyze the morphological parameters and kinetic features of images in the database to define the most frequent morphologic and kinetic pattern. Here a graph is obtained that shows the kinetic parameters based on position and intensity of the mass region. The diagnosis based on the intensity is also made so that the exact mass lesion is identified for further treatment.

C. AREA ESTIMATION

For having more detailed and predictive information about the tumor, knowing the exact area of the is important. The estimated area could give a guideline for the surgeons. It is based on the number of pixels associated within the detected boundary.

IV. SIMULATION RESULTS

The results of improved watershed algorithm are shown in figure 3. The input HSI image and its rgb-to-gray converted versions are respectively shown in the fig 3. (a) and (b). Then the gradient magnitude and the watershed transform of the gradient magnitude are depicted in the fig 3. (c) and (d). This step is followed by certain morphological operations for making the watershed transform more sensitive for the exact features. It includes the usual dilation and erosion and is depicted in fig 3. (e), (f), (g) and (h). That can be respectively described as the opening, opening-by-reconstruction, open-closing and open-closing -by -reconstruction. The fig 3. (i) Shows the actual tumor boundary.

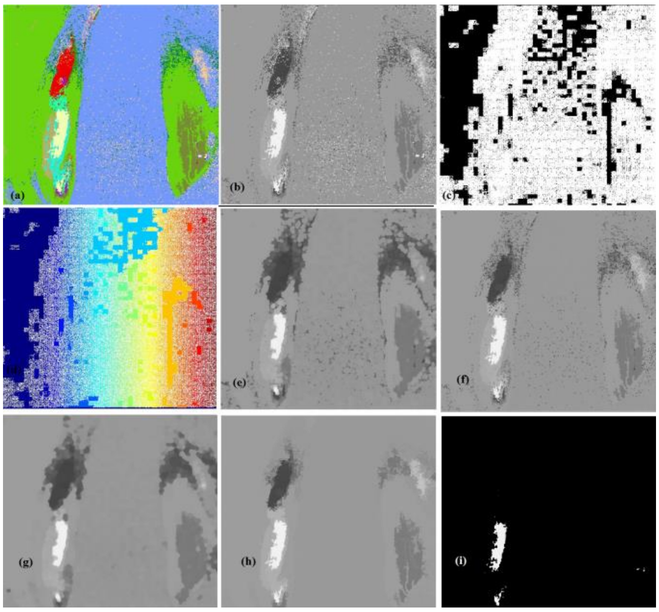

Figure 3: Various steps associated with boundary detection using watershed transform

The analysis of the tumor identified from the watershed transform is the next stage. It includes the kinetic parameter analysis and the area estimation steps. Both these steps utilize the intensity features of the result. The variation in the intensity with respect to the position and variation in the kinetic parameter with respect to the tumor boundary are respectively shown in the fig. 4 and 5. And the area estimation result is depicted in fig. 6. It calculates the area purely based on the intensity profiles.

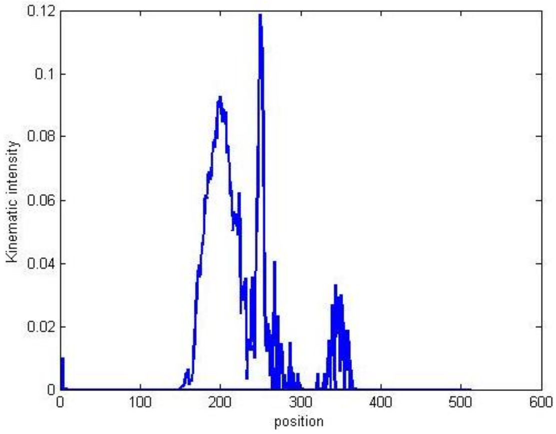

Figure 4. Variation in the kinetic intensity with respect tio the position

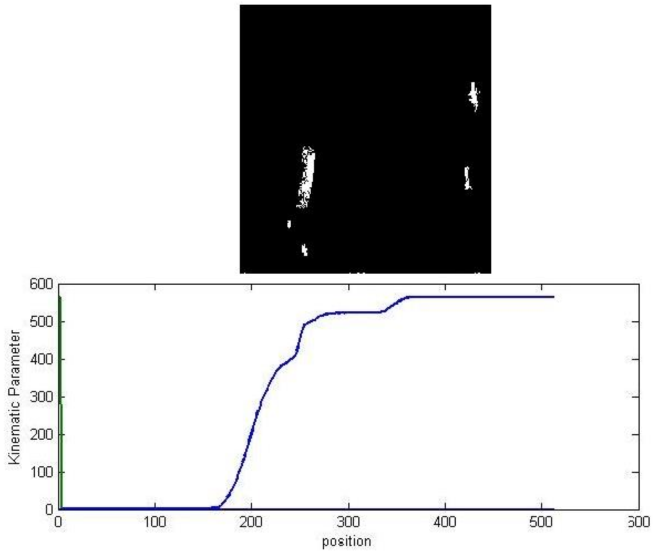

Figure 5.The variation in kinetic parameters with respect to the boundary

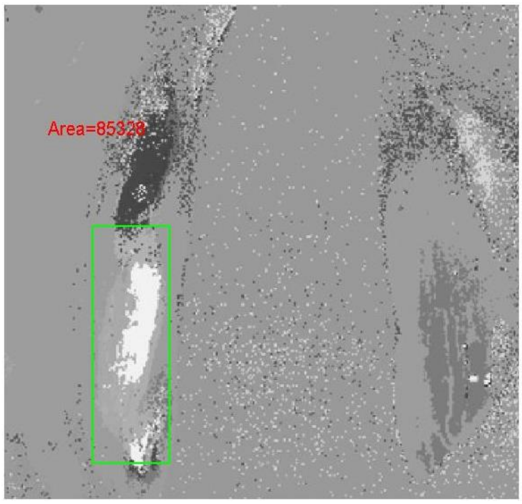

Figure 6: Estimated tumor area

V. CONCLUSION

Here a novel tumor margin assesment algorithm is proposed based on the improved watershed transform. It can properly track the boundary of the tumor margin and could be a good supporting aid for the surgons. The detailed analysis of the tumor can be possible with the extra added features such as the kinetic parameters and the area. Both will ensure as a key for the guideline for undertaking the surgery. The tumor margin assesment algorithm delivered a good performance with the all the selected HSI images. And can be used as apromising tool for supporting surgical resectioning..

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