Watershed Segmentation of Cervical Images Using Multiscale Morphological Gradient and HSI Color Space

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Abstract - In this paper, a novel watershed segmentation algorithm is proposed for the segmentation of nucleus from the surrounding cytoplasm of cervical cancer images. The proposed method converts the input RGB image into HSI image which contains three components hue, saturation and intensity. The saturation component is thresholded to obtain the binary image and each pixel in the binary image is multiplied with hue component to obtain the product image. The intensity image is complemented, thresholded and merged with the product image and smoothened. The local minima are reduced using extended minima function and the multiscale gradient of this resultant gray scale image is segmented using watershed algorithm based on Hill Climbing technique. Experimental results add to the computational efficiency of the algorithm, its shape maintaining, edge preserving and scale-calibrating features. The performance is also superior to most other segmentation techniques.

I. Introduction

IMAGE segmentation is an important process in most medical image analysis tasks. An image segmentation algorithm decomposes an image into regions having visual similarity and strong statistical correlation. Extraction and classification of cervical cells is an important process that has many applications in medical imaging. A good segmentation algorithm will benefit clinicians and patients as they provide important information for 3-D visualization, surgical planning and early disease detection.

Mathematical morphology[2], a set theoretic, shape oriented approach treats the image as a set and the kernel of operation commonly known as structuring element (SE) as another set. Different standard morphological operations like dilation, erosion, opening, closing are basically set theoretic operations between these two sets. The shape and the size of the SE play an important role in detecting and extracting features of shape and size of the objects in the image, its different sizes can be accounted by the 'scale' attribute of the structuring element. Thus morphological operations with such scalable SEs can be used in multiscale image segmentation.

The watershed transform coming from the field of mathematical morphology plays an important role in medical image segmentation [3]-[10]. A fast and flexible algorithm for computing watersheds in digital grayscale images was introduced by Luc Vincent and Pierre Soille. [7]. The watershed transform possesses number of advantages: it is a simple intuitive method, it is fast and can be parallelized and it produces a complete division of the image in separated regions even if the contrast is poor, thus avoiding the need for any kind of contours joining. Some important draw backs also exist, and they have been widely treated in the related literature. Among the most important are over segmentation, Sensitivity to noise, Poor detection of significant areas with low contrast boundaries and Poor Detection of thin structures. The proposed segmentation algorithm overcomes these drawbacks of watershed algorithm with the enhanced features of extended minima transform, multiscale gradient, markers and morphological thinning.

The presence of abnormality such as the bleeding, growth of tumors, presence of polyps, polypoid lesions and cancerous growth provides a rough surface to the cervical cancer image for which watershed segmentation has better features for analysis when compared to the simple edge analysis, since the morphological watershed segmentation embodies the basic principal concepts such as detection of discontinuity, thresholding and region processing apart from producing more stable segmentation results, including the continuous segmentation boundaries[1]. Watershed technique is one of the classical techniques in the field of topography providing a simple framework for incorporating the knowledge based constraints in the segmentation process. When combined with other morphological tools, the watershed transformation becomes a basis for extremely powerful segmentation procedures.

The paper is organized in V sections. Section II discusses the Color model. Section III describes the features and the scheme of proposed segmentation algorithm. The Experimental analysis and simulation results are presented in Section IV. Conclusions are finally made in Section V.

II. Color Model

For segmenting color images, the first step is to choose a perfect color model. Color is a very useful feature in the analysis of image content for segmentation or retrieval. The conventional representation of color image is by red-green-

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blue (RGB) color model. Since the RGB components are highly correlated, it is not convenient to make the chromatic information useful directly. The proposed algorithm works on HSI color model. The distinguishable components of this color model are hue, saturation and brightness and the mixture of hue and saturation called the chromaticity.

The hue is a color attribute that describes a pure color where as saturation gives a measure of the degree to which a pure color is diluted by white light and the intensity is a subjective descriptor [1][8]. The HSI color model decouples the intensity component from the color carrying components, hue and saturation, in a color image. As a result the HSI model is an ideal tool for developing image processing algorithms based on color descriptions that are natural and intuitive to humans. The proposed method converts the input RGB image into HSI color space. The conversion from RGB to HSI coordinate system is done in two steps. First the RGB coordinates are rotated to form the coordinate system (I, V1, V2). The rotation is given by the linear transformation and the rectangular coordinates (V1, V2) can be transformed to polar coordinates n the second step.

$$\begin{bmatrix} I \\ V1 \\ V2 \end{bmatrix} = \begin{bmatrix} \sqrt{3}/3 & \sqrt{3}/3 & \sqrt{3}/3 \\ 0 & 1/\sqrt{2} & -1/\sqrt{2} \\ 2/\sqrt{6} & -1/\sqrt{6} & -1/\sqrt{6} \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

$$H = \tan^{-1}(V2/V1) \tag{1}$$

$$S = \sqrt{V1^2 + V2^2}$$

The hue coordinate range is [0…2π] or [0…360] degrees.

III. Watershed Segmentation of Cervical Images using Multiscale Morphological Gradient and HSI Color Space

The proposed segmentation algorithm is a novel technique that can be applied on cervical cancer images. The segmentation algorithm is more computationally efficient, its edge- preserving, noise removing, scale-calibrating, shape maintaining features are remarkable than many top-ranking color image segmentation algorithms. The input RGB image is preprocessed and smoothened by using morphological operators to get recovered from noise particles. The preprocessed RGB image is transformed to HSI color space representation in order to provide color descriptions that are natural and intuitive to humans. The product image obtained by multiplying hue component with binary image of the saturation component is merged with the binary image of complemented intensity image. This merged image is complemented and subjected to the extended minima transform. The multiscale morphological gradient of the output of the extended minima transform is obtained and given as input to the watershed algorithm which uses Hill-Climbing approach to identify and label the neighborhood pixels. The proposed segmentation algorithm is schematically illustrated in the block diagram shown in fig.1.

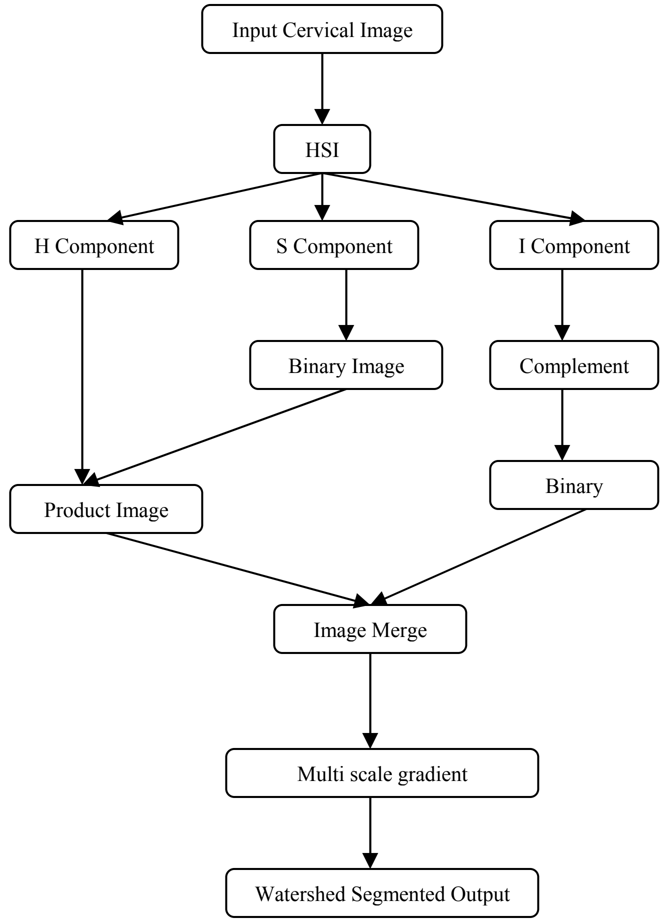


Fig. 1 Block Diagram of the proposed algorithm

A. Image Smoothening

A segmentation algorithm can give better output without over-segmentation on a preprocessed noise free image. Images can get corrupted by additive impulse noise in the acquisition or transmission stages. Such noisy images can be preprocessed and smoothened by a set of morphological operators [2].

B. Converting RGB to HSI

The proposed algorithm aims to segment the given image with visually distinct colors, so a human perception based color model is preferred. The representation of color images by Red-Green-Blue color model is the conventional method. But the three components of RGB color model are highly correlated, so that the chromatic information is not suitable for using directly. Therefore, the HSI color space is adopted because it is convenient to convert from RGB and also intimately related to human perception [1] byusing the equations (1).

C. Preprocessing steps for Watershed Algorithm

The watershed algorithm cannot be directly applied to color image. So the HSI color image is converted into gray scale with following preprocessing steps. Initially the cervical image in HSI color space is divided into three individual components namely hue, saturation and intensity. A thresholding technique is applied to the saturation component to yield a binary image. The hue component of each pixel is multiplied with the pixels of binary image of the saturation component to generate a product image. The pixels of the intensity component are subtracted from the value of 255 so that the bright features are darkened and vice versa. This complemented image is thresholded to obtain a binary image. The product image and the intensity binary image are merged together. The complement of this merged image is computed by subtracting each pixel from 255 so that the light pixels will become dark and dark pixels will become light. If watershed segmentation is applied to this image directly over segmentation occurs due to local minima creating number of basins. To overcome this difficulty extended minima transformation is provided to the complemented merged image. This transform is a thresholding technique that will bring most of the valleys to zero. The extended minima transform on the complement image with threshold value 't' is given below.

$$E = EM(N, t)$$

where E is the output image and N is the complement image.

The selection of threshold is very much important where the higher value of 't ' will lower the number of regions and lower value of 't' will yield higher number of objects. The output image, E is imposed on the complement image, N to control the excessive over segmentation. This imposed image is further given as input to the watershed segmentation.

E. Multiscale Morphological Gradient

In watershed transform the watershed lines are created at high gradient points. The basic morphological operators involved in this phase are listed below.

In the morphological analysis of gray- scale images, a 2-D image is defined as a subset of the 2-D Euclidean space RxR or its digitized equivalent ZxZ. In this paper, we deal only with intensity image that is defined as subsets of ZxZ.

The two most fundamental morphological operations are dilation and erosion. Dilation of the image, f by the 4 or 8 connected structuring element (SE), B expands the image while the erosion of f by B shrinks the image. They are defined respectively with f and B in the set ZxZ as

$$f \oplus B = \{X/ (B)x \cap f\} \tag{2}$$

$$f\ \theta\ B = \{X/ (B)\ x \subseteq f\} \tag{3}$$

Opening of the binary image f by the 4 or 8 connected structuring element B denoted as $f^{o} B$, is defined as

$$f^{o} B = (f \theta B) \oplus B \tag{4}$$

Closing of the binary image f by the 4 or 8 connected structuring element B denoted as $f \bullet B$, is defined as

$$f \bullet B = (f \oplus B)\ \theta\ B \tag{5}$$

The local gray-level variation in the image can very well be given by the morphological gradient. A gradient helps detecting ramp edges and avoids thickening and merging of edges providing edge-enhancements. The gradient image, G(f) is morphologically obtained by subtracting the eroded image, ε(f) from its dilated version, ∂(f). A multiscale gradient, MG(f) is the average of morphological gradients taken for different scales of the structure element, Bi. where Bi is a SE of size (2i+1) x (2i+1) [2][11].

H .Watershed Transform

The fast implementation of immersion-based watershed algorithm has been introduced by Vincent and Soille [8]. The authors simulated a flooding process, in which the water comes up out of the ground and floods the catchment basins without predetermining the regional minima. Alternatively, an ordered queue based watershed algorithm has been proposed by Meyer [14]. This algorithm determines the regional minima and starting from these minima, the recursive label propagation is performed using an ordered queue. It yields a complete tessellation of the image into its homogeneous regions without producing any watershed lines. Finally, several shortest-path algorithms for the watershed transformation with respect to topographical distance can be found in literature [5].

Here we proposed a fast watershed transform based on Hill Climbing technique [6]. The pseudo-code of the flooding phase of the proposed algorithm is presented below.

Input: Multiscale morphological gradient of imposed image
Output: label image L and distance image

Initialize: INIT=-2; NARM=-1; DIST IN=0; CURRENT LABEL=1;

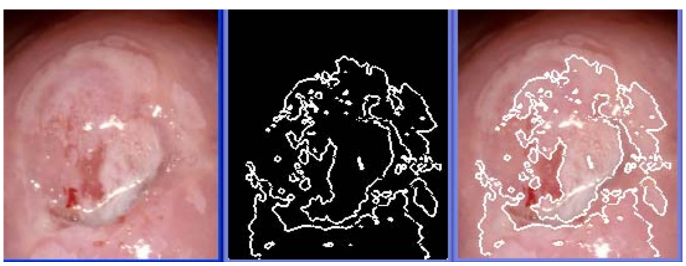
Initialize the Label image L and the distance image d with INIT and MIN DIST respectively;

For all p with L(p) = INIT Do
CURR DISTANCE=1;
Initialize the queues Qpd and Qpa;
While queue Qpd not empty Do
Dequeue the pixel q from the queue Qpd;
For all r ε N(q) {For all neighbors of q} Do
If the gray value of r = gray value of q Then
Assign the CURRENT LABEL to L(r) and
insert the pixel r into Qpd;
Else if the gray value of r < gray value of q Then
Assign the CURR DISTANCE to L(r) and enqueue the pixel q into the queue Qpa;
End if
End for
End while
Increment the CURR DISTANCE;
If queue Qpa is empty then
Increment the CURRENT LABEL;
End If
End For

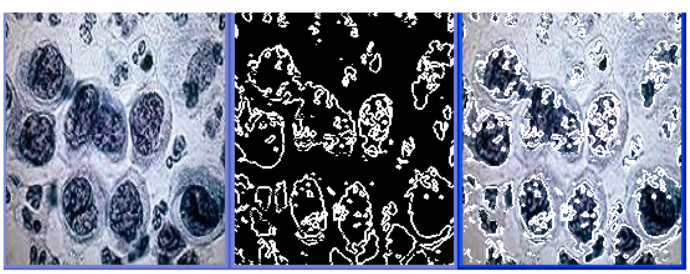
Since multiscale morphological gradient of imposed image is given as input to the Hill Climbing technique, number of local minima is reduced and better segmentation result is obtained. The complexity of the algorithm has been reduced by doing away with multiplication normally required to form a lower complete image in an intermediate step of the overall segmentation process. Its moderate complexity makes it amenable to dedicated hardware implementation.

IV. Experimental Results

The proposed segmentation algorithm is applied to wide variety of cervical cancer images and the results are subjectively analyzed. All the abnormal regions in the cervix are effectively segmented for taking a biopsy to diagnose cervical cancer. The threshold values are selected adaptively depending upon the textural features of the cervical cancer image. Morphological operations are employed to preserve the edges, shape and size of the objects. The proposed algorithm though prevents over segmentation, it preserves the sub features of the objects required for diagnosis. The segmentation results as are produced by the proposed algorithm are shown in fig.2.



(a) (b) (c)



(a) (b) (c)

Fig .2. Images segmented by Proposed Algorithm (a),(d) Original Image (b),(e) Label image (c),(f) Proposed segmentation Algorithm.

The algorithm effectively segments the cancerous regions even from the macroscopic and microscopic views of the cervical cancer images, a distinct quality of the proposed algorithm where it identifies objects from homogenous regions and heterogeneous regions as shown in fig. 2(c) and 2(f). These segmentation results can be used in the feature extraction and classification stages to distinguish normal cells from cancerous cells.

V. Conclusion

A novel watershed segmentation algorithm is proposed for the segmentation of nucleus from the surrounding cytoplasm of cervical cancer images. The watershed segmentation algorithm is provided additional capabilities to reduce over segmentation, to preserve edges shape, size and sub features of the objects. Experimental results add to the computational efficiency of the algorithm, its shape maintaining, edge preserving and scale-calibrating features. The performance is also superior to most other segmentation techniques as cancerous objects can be detected from both homogenous and heterogeneous regions of cancerous images.

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