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Nucleus and cytoplast contour detector of cervical smear image

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ABSTRACT

This paper develops a cytoplast and nucleus contour (CNC) detector to sever the nucleus and cytoplast from a cervical smear image. This paper proposes the bi-group enhancer to make a clear-cut separation for the pixels laid between two objects, and the maximal color difference (MCD) method to draw the aptest nucleus contour. The CNC detector adopts a median filter to sweep off noises, the bi-group enhancer to suppress the noises and brighten the object contours, the *K*-mean algorithm to discern the cytoplast from the background, and the MCD method to extract the nucleus contour. The experimental results show that the CNC detector can give an impressive performance. Besides cervical smear images, these proposed techniques can be utilized in segmenting objects from other images.

1. Introduction

An estimated 11,150 cases of invasive cervical cancer are expected to be diagnosed in the United States in 2007 and 3670 women are expected to die from the disease. Incidence and mortality rates have decreased steadily over the past five decades, largely due to the widespread use of the Pap smear which detects cervical cancer and precancerous lesions. The Pap smear has made cervical cancer one of the most preventable cancers, but older, poorer, and less educated women are less likely to be screened and screening is not available in many low-resource regions of the world. Worldwide, cervical cancer has a significant impact, with nearly 500,000 new cases and nearly 250,000 deaths reported annually (Women's Health Report, 2007).

Unlike other cancers that cause pain, noticeable lumps, or other early symptoms, cervical cancer has no telltale symptom until it is so advanced that it is usually unresponsive to treatment (Frable, 1982). Only in its latest stage, cervical cancer causes pain in the lower abdominal or back regions. However, most cervical cancer takes many years to develop from normal to dangerous stages. Cervical cancer is a preventable disease and, unlike most cancers, can be easily detected by a routine screening test. Currently, cervical smear screening is the most popular method to detect the presence of abnormal cells arising from the cervix. With a small brush, cotton stick or wooden stick, a specimen is taken from the uterine cervix, smeared onto a thin, rectangular glass plate (a slide), and dyed, making it easier to examine the cells under a microscope. The purpose of smear screening is to diagnose pre-malignant cell changes before they become cancerous.

Dysplastic cells have undergone precancerous changes. They generally have longer as well as darker nuclei, and a tendency to cling together in large clusters. Mildly dysplastic cells have enlarged and bright nuclei. Moderately dysplastic cells have larger and darker nuclei. The nuclei may start to deteriorate and to be granulation. Severe dysplastic cells have large, dark, and often oddly shaped nuclei; its cytoplast is relatively dark and small (Martin, 2003). Hence, pre-cancers and cancers are associated with a variety of morphologic and architectural alterations, including the textures, sizes, and shapes of cytoplast and nucleus, hyperchromasia and pleomorphism. It also increases nuclear–cytoplastic ratio. Fig. 1 shows the superficial squamous cells stained to enhance the contrast.

Current manual screening methods are costly and sometimes result in inaccurate diagnosis caused by human error. The introduction of machine assisted screening will bring significant benefits to the community, which can reduce financial costs and increase screening accuracy. An effective boundary detection algorithm locating the contours of the cytoplast and nucleus plays an important role in developing a useful computer-assisted diagnostic system.

Wu et al. (1998) introduced a parametric optimal segmentation approach which is suitable for the images of non-overlapping cells with smooth cell boundaries or contours. However, dealing with

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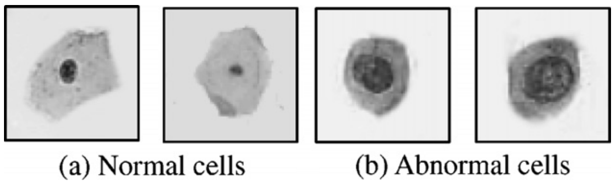

Fig. 1. Superficial squamous cells stained to enhance contrast.

the segmentation of a cell image, a priori knowledge of the nuclear characteristics should be fully used; these characteristics include the cell shape, size, and intensities relative to its background.

Mat-Isa et al. (2005) utilize the potential use of thresholding the region growing algorithm as a feature extraction technique. The proposed algorithm is called seeded region growing features extraction (SRGFE). The SRGFE is used to extract the size and grey level of a certain region of interest on a digital image. In the SRGFE algorithm, the user needs to determine the region of interest by clicking the mouse on any pixels in the region and to specify the threshold value, which makes the system impractical.

Walker (1997) uses a series of automated fast morphological transforms with octagonal structuring elements. Each gray-scale cell image is first globally thresholded, resulting in an incomplete segmentation of the nucleus in binary form. The cytoplastic background is removed by performing a closing of the image using a structured element which is smaller than the smallest nucleus, and the nuclear heterogeneity is corrected by an opening of a similar size. However, it is more appropriate for local thresholding and it cannot be fully automated.

Many other cytoplast and nucleus morphological segmentation methods have also been proposed in the related literatures (Busam et al., 2001; Collier et al., 2002; Corcuff et al., 1996; Inoue et al., 2000; Langley et al., 2001; Masters et al., 1997; Mat-Isa et al., 2005; Rajadhyaksha et al., 1999; Rajadhyaksha et al., 1995; Walker, 1997; Wu et al., 1998). However, the results are based on tedious hand-segmentation of images. Martin (2003) and Norup (2005) also take the CHAMP software to segment and classify cervical smear images. Unfortunately, the CHAMP software cannot provide a satisfying segmentation performance, especially for abnormal cervical cells. The aim of this paper is to develop an automated image segmentation system to sever the cytoplast and nucleus from a cervical smear image, without a priori knowledge of the image objects.

Generally, the accuracy of an object contour detector depends on the quality of an image. The heavily stained cervical smear may be masked by menstrual blood, vaginal discharge, air artifacts, etc., thus obscuring the abnormal cervical cells. Sometimes, overexposing or underexposing under the microscope light may also blur the cervical smear images. These problems may cause difficulties in extracting the cytoplast and nucleus of a cervical cell.

This paper proposes a bi-group enhancer to eliminate the noise on an image and to sharpen the contours of objects before extracting the object. Since the cytoplast and background on a cervical smear image can apparently be distinguished by their colors, this paper will employ *K*-mean algorithm to discern between the cytoplast and background on the image. Mostly, two different adjacent objects have dissimilar color distributions. Consider an image with only two different objects, as shown in the image in Fig. 2 for example. In this image, the red[1] circle indicates the boundary which separates object *A* from object *B* where the color difference of the pixels on the inside and outside of the circle is maximal. Based on the previously mentioned properties, this paper proposes a cytoplast

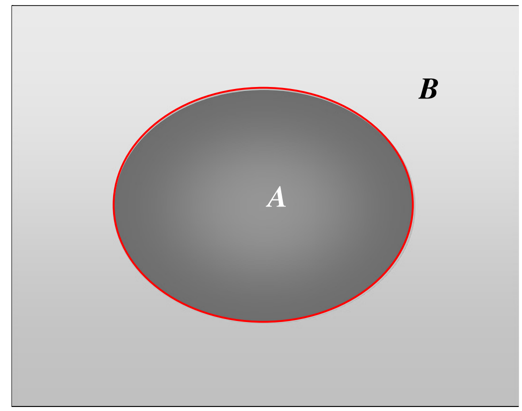

Fig. 2. An image with only two objects.

and nucleus contour (CNC) detector to perceive the cytoplast and nucleus contours of a cervical cell. Besides cervical smear images, these techniques can be employed to segment the objects of other images too. Tsai et al. (2007) briefly introduces the concept of the detector. This paper will describe it in more details and give more experiments and discussions.

2. The CNC detector

Edge detection is considered fundamental in image processing and computer vision, with a large number of studies having been published in the last two decades, i.e., the Canny edge detector (Canny, 1986), the Sobel edge detector (Davies, 1990), the Prewitt edge detector (Davies, 1990), and the Roberts Cross edge detector (Davies, 1990). Segmentation is the process of dividing an image into its constituent parts for further analysis. We commonly refer to such parts as regions of interest (ROI). Edge detection based segmentation is a frequently used technique which segments an image on the basis of dissimilarity or heterogeneity within image pixels or regions. Fig. 3 shows the edges (marked by red[2] lines) obtained by the above mentioned detectors. Fig. 3 illustrates that the above mentioned methods are only suitable to detecting the objects whose contours are obvious. The Canny edge detector can provide a better performance, but it is susceptible to noise.

The active contour model (ACM) (Xu and Prince, 1998) is adapted to a wide range of extracting the objects with vague, complex and/or irregular shape boundary, inhomogeneous and noisy interior, as well as contour with small gaps. However, Fig. 4 states that ACM cannot give a good segmentation when the quality of the image is poor. It is also difficult to decide the weighted parameters of the snake's tension and rigidity, since the contour of cytoplast is varied. In addition, ACM is very sensitive to the initial contour.

Most image segmentation methods perform well while the image has good quality and the object contours are distinct. However, cervical smear images are frequently contaminated and the cytoplast and nucleus contours of cervical cells are often vague, especially for abnormal cervical cells. This paper, hence, adopts a bi-group enhancer to intensify the contours of objects in an image. This paper also presents a maximal color difference (MCD) method to segment one object from others based on their color differences.

The CNC detector contains three approaches: bi-group, cytoplast contour detection, and nucleus contour detection approaches. The bi-group approach is to suppress the noises and emphasize the edge pixels; the cytoplast contour detection approach utilizes

[1] For interpretation of color in Fig. 2, the reader is referred to the web version of this article.

[2] For interpretation of color in Fig. 3, the reader is referred to the web version of this article.