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A new strategy for urinary sediment segmentation based on wavelet, morphology and combination method

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ABSTRACT

This paper presents a strategy for segmenting urinary sediment based on wavelet, morphology and combination method. Firstly, the wavelet transforms and morphology are used to get rid of the effect of the defocusing and get the subimages that include the particles. Then based on the characteristics of the subimages, edge detection and adaptive thresholding are employed adaptively. Finally, a simplified watershed algorithm for the overlapping particles is used. The experiment results show that the method can segment the defocusing urinary sediment images effectively and precisely.

1. Introduction

Urinary sediment detection is a very important task to help diagnose diseases such as kidney inflammation, urethra inflammation, bladder inflammation and so on. The content of urinary sediment includes red cell, white cell, cast, epithelium and crystal. The first four kinds are organic elements that need to be recognized and calculated. In order to classify the elements effectively and automatically, an effective urinary sediment image segmentation method is desired.

So far, a lot of segmentation methods have been reported, including clustering, edge detection, region extraction and so on. Clustering is to detect the semblable points in characteristic space, then label each cluster as a different region [1]. However, usually the number of clusters is unknown, and it does not consider spatial interactions between neighboring pixels. Edge detection is also used to detect the boundary of different regions by locating points of abrupt change in intensity values. A lot of the operators have been used for edge detection. But not all edges produced by these operators are satisfying, so post-processing is still necessary to identify significant edges. Region extraction groups pixels into a set of regions based on similarity. Concretely, regions growing performs well for some kinds of image segmentation, but it has problems to find the initial seeds point, stop rule, and has expensive computational cost. Image thresholding is very effective and well investigated, including global thresholding and local thresholding [2–6]. Usually, for uneven intensity images, local thresholding method is better than the global one. However, a good thresholding method should not only depend on local image characteristics, but also the global image information from the entire image. Yan et al. [2] and Kin and Park [4] proposed the adaptive thresholding method based on multi-stage and regions of interest, respectively. They made good use of the global and local characteristics of images, the relevant results are satisfying to some extent, but it cannot be applied to defocusing image segmentation problem.

Wavelet transform is a good multi-resolution method for edge enhancement, noise removal, compression [7,8]. Morphology is also an effective method for image processing. Nomura et al. [9] proposed a method based on adaptive morphology for degraded character image segmentation, the

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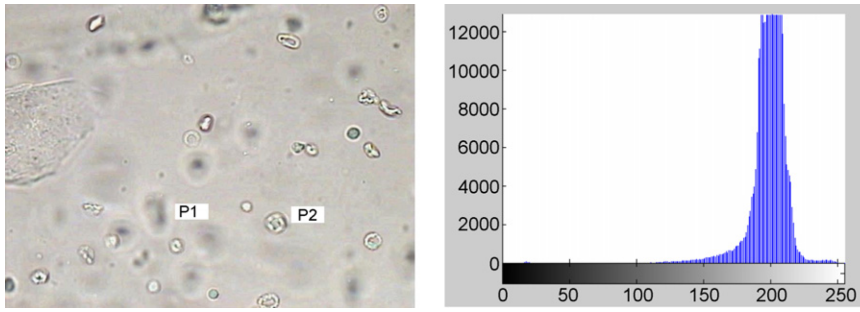

Fig. 1 – Urinary sediment image.

result is satisfying to some extent. However, compared with the images discussed in this paper, those sample images has the following characteristics: edge is clear, the overlapping is not serious, the category is simple, arrangement is regular, so the method in Ref. [9] is not suitable for urinary sediment image segmentation directly. The method that combines the wavelet transform with morphology was also demonstrated. Rosito [10] used wavelet transform to remove image noise and enhance the edges, got the enhanced gradient image, then did watershed transform on it. The method needs post-processing to remove over segmentation and some priori knowledge such as the rule of the post-processing. Kim and Kim [11] proposed another method, it first used wavelet transform to get the lowest resolution image, then watershed segmentation algorithm to segment it, did the region merging, finally did inverse wavelet transform to project the segmented low resolution image with label into a full resolution image (original image). However, the calculation cost is very high and the region merging rule for urinary sediment image is hard to determine.

Fig. 1 shows a defocusing urinary sediment image needed to be segmented. It can be seen that the image has some characteristics: (1) the particles are very complex; (2) defocusing is very serious, some defocusing elements that do not need to be segmented as the point P1 and some non-defocusing particles that need to be segmented as the point P2 are mixed together; (3) the edges of some particles are very blurry, such as the cell in the left of the image; (4) the overlapping is very serious; (5) the contrast of some elements is very low, the inside of some particles is very similar to the outside of them, For that case, the thresholding segmentation method cannot be applied directly; (6) edge detection will result in false edges and over segmentation.

Based on the investigation of the characteristics of the urinary sediment image, a novel combination segmentation method is proposed. Firstly, wavelet transform and morphology are used to locate the elements and fulfill the coarse segmentation, and get the subimages including the elements. According to the characteristics of the subimages, two segmentation methods are applied adaptively to segment each subimages, those are edge detection with morphology and adaptive thresholding with morphology. Finally, simplified watershed algorithm is used to solve image-overlapping problem. The proposed method can be applied to defocusing urinary sediment image. This paper is organized as follows: Section 2 presents the analysis of the method and the theories and algorithms involved. Section 3 introduces the major process of the method. The experimental results are given in Section 4. Section 5 includes the discussion and conclusion.

2. The principle and theory

Due to the effect of defocusing, generic thresholding and edge detection cannot distinguish the defocusing elements and non-defocusing elements. Since the wavelet transform can decompose the low frequency part and high frequency part with multi-scale to eliminate the effect of defocusing. The location of the particles can be achieved by combining wavelet transform with morphology. In order to segment each kinds of elements of urinary images precisely, especially organic elements, this paper introduces combination segmentation idea, first locates the particles with global characteristics of images (coarse segmentation), then precisely segments the particles after coarse segmentation with local characteristics of subimages. During investigation, we found that adaptive thresholding performs well for red cell and white cell segmentation, but is not suitable for those casts and epitheliums whose inside and outside are similar and edges are blurry. While edge detection performs well for these kinds of casts and epitheliums. According to the characteristics of the elements after coarse segmentation, adaptive thresholding or edge detection is chosen to do further segmentation. For overlapping problem, the simplified watershed algorithm is used to solve it. The details of wavelet transform, morphology, adaptive thresholding and edge detection are described in the following sections.

2.1. *Wavelet transform*

When processing transient signals having short temporal/spatial extent, the Fourier transform (FT) analysis exhibits high-frequency noise owing to the periodic-mode contributions outside the localization of the transient signal, so some researchers have suggested the windowed FT operation. But owing to the fixed window, high-frequency signals are sampled at a high rate, and low-frequency signals are sampled at a low rate. The wavelet transform (WT) represents a different approach to overcome the above problem and is successful in representing a signal both in time/spatial and frequency domains.