Image Segmentation Based on 2D Otsu Thresholding with Histogram Analysis

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1 Introduction

Otsu method is one of thresholding methods and frequently used in various fields. Although two-dimensional (2D) Otsu method behaves well in many applications, it gives satisfactory results only when the numbers of pixels in each class are close to each other [1]. Otherwise, it gives the improper results. As for our renal biopsy samples, the object size is much less than background, the wrong classification of pixels by traditional Otsu method will lead to the failure segmentation. To solve this problem, this paper proposes a histogram analysis method to correct the threshold determined by Otsu method based on wavelet transform.

2 2D Otsu Method with Histogram Analysis

The Otsu method selects an optimum threshold by minimizing the sum of within-class variances of the foreground and background pixels. A fast recursive algorithm [2] for 2D Otsu method is used in this paper. Because Otsu method will give the improper results when the object size is very different from background, we project the 2D histogram in x and y axes to get the auxiliary threshold for correcting the Otsu threshold.

To eliminate the influence of the pseudo valley, use wavelet transform to obtain the smoothed histogram without tiny changes. Then put a search window with fixed width w in the smoothed histogram and calculate the differences of the adjacent elements in this window. There are five cases we may meet.

- First, the local histogram increases monotonically and all calculated differences are nonnegative.
- Second, the local histogram decreases monotonically and all differences are non-positive.
- Third, there exists a peak in the window and the differences change from positive to negative.
- Fourth, there exists a valley in the window and the differences change from negative to positive.
- Fifth, there is no change in the window and all differences are equal to 0. In this case, the further three situations need to be considered.
  - One, the last difference in previous window is positive and the first one in next window is negative, there exists a peak in current window.
  - Two, the last difference in previous window is negative and the first one in next window is positive, there is a valley in current window.
  - Three, if the last difference in previous window and the first one in next window have same sign or equal to 0, there is no peak or valley in the current window.

Based on above analysis, through moving the window with step w/2 in whole histogram, all peaks and valleys can be detected. Finally, backtrack the position to the corresponding extrema in the original histograms, and then we can get all valleys and peaks.

For our application, the object we want always has a high gray level. So after projection, the valleys corresponding to the last peak in x and y axes are regarded as the auxiliary threshold. Then the final threshold \((S_{final},T_{final})\) can be calculated as

\[
(S_{final},T_{final}) = \left(\frac{S_{otsu} + S_{hist}}{2}, \frac{T_{otsu} + T_{hist}}{2}\right)
\]  

(1)

Where \((S_{otsu},T_{otsu})\) is the threshold determined by Otsu method, \((S_{hist},T_{hist})\) is the auxiliary threshold by histogram projection analysis.

3 Experimental Results

The original gray level images shown in Figure 1(a) consists 512 × 512 pixels. Figure 1(b) gives the Otsu results after denoising. We can see that some unexpected noises attach to the object and become an obstacle for subsequent processing. This problem is solved by our method. Figure 1(c) shows that the noises are removed completely.

4 Conclusion

This paper introduces a 2D histogram projection analysis to solve the problem of traditional Otsu method. Using this method, the problem of the sensitivity to the object size can be overcome. It is very helpful for the subsequent processing and improves the success ratio of image segmentation.

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References