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Object detection based on deep learning for urine sediment examination

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ABSTRACT

Urine sediment examination (USE) is an important topic in kidney disease analysis and it is often the prerequisite for subsequent diagnostic procedures. We propose DFPN(Feature Pyramid Network with DenseNet) method to overcome the problem of class confusion in the USE images that it is hard to be solved by baseline model which is the state-of-the-art object detection model FPN with RoIAlign pooling. We explored the importance of two parts of baseline model for the USE cell detection. First, adding attention module in the network head, and the class-specific attention module has improved mAP by 0.7 points with pre-trained ImageNet model and 1.4 points with pre-trained COCO model. Next, we introduced DenseNet to the baseline model(DFPN) for cell detection in USE, so that the input of the network's head own multiple levels of semantic information, compared to the baseline model only has high-level semantic information. DFPN achieves top result with a mAP of 86.9% on USE test set after balancing between the classification loss and bounding-box regression loss, which improve 5.6 points compared to baseline model, and especially erythrocyte's AP is greatly improved from 65.4% to 93.8%, indicating class confusion has been basically resolved. And we also explore the impacts of training schedule and pre-trained model. Our method is promising for the development of automated USE.

1. Introduction

Urine sediment examination (USE) is a well-established and valuable adjunctive test used in the evaluation of patients with kidney disease which could change the density of various cells in the urine [1] for an experienced nephrologist. For example, glomerulonephritis, tubules(distal collecting duct lesions) and renal dysfunction can lead to leukocytosis [2]. However, the manual microscopy of USE is labor-intensive, time-consuming imprecise and subjective [3,4], and the automated USE has become an inevitable trend in medical field.

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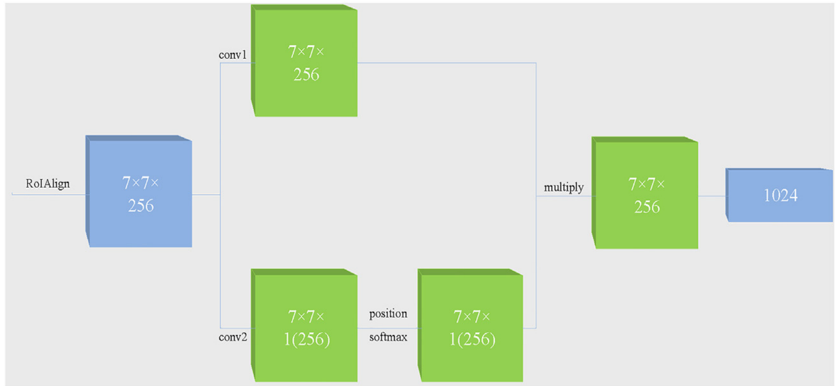
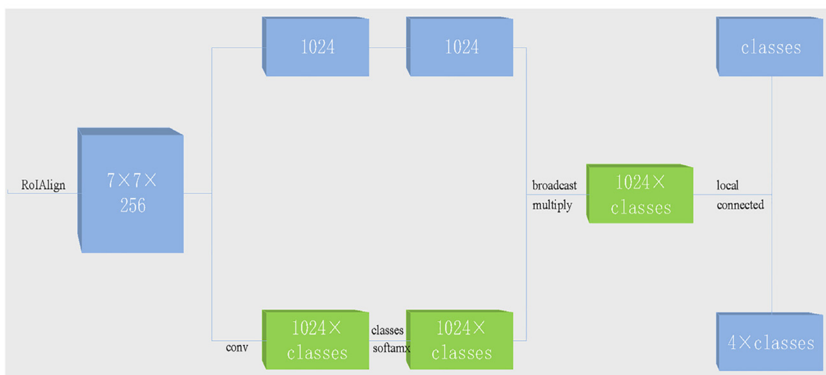


(a)



(b)

Fig. 1 – Three attention module. Green parts represent the new layers, and Blue are original. All changes are made in the classifier. (a) Channel-against(wise) position-attention module. The module is embedded between RoIAlign pooling and full connected layers. (b) Class-specific attention module. We implement class-specific by constructing a new branch in parallel with the full connected layer and then using locally connected operation.

Traditional automated USE comprises three steps: cell segmentation, feature extraction and classification. Notably, accurate cell segmentation is crucial to the success of automated USE system, since extensive research so far has been devoted to improve segmentation result [5–7]. However, there is still a big gap for application. In the actual scene, there are three main characteristics of urine sediment cells images. First, the phenomenon of severe cell adhesion makes it difficult to divide the cells; second, class confusion is serious, cell features of the same class are very different and the features of partial cell from different classes are highly similar, especially for erythrocyte; third, the size of most cells is small. All these characteristics make it hard to achieve a good result for traditional automated USE.

In this paper, we propose to apply convolutional neural networks for automatic sediment detection. We choose the state-of-the-art network that integrates Faster-RCNN [8] and FPN [9] as the basic model, replacing RoI(Region of Interest) pooling [10] with RoIAlign pooling [11]. In practice, erythrocyte just gains AP 65.4% illustrates that it couldn't be a good solution to class confusion.

This requires the network must focus on the fine-grained feature of the category so we exploratively change the head and backbone structure of the network. In networks head, we add three attention modules(Fig. 1) in baseline model independently: channel-wise position attention module, channel-agnostic position attention module and class-specific attention module. Nevertheless, only class-specific attention module achieves 82.0% mAP, slightly superior to the FPN.

For backbone network, we replace the backbone network from ResNet [12] to DenseNet [13] and denote it as DFPN because FPN(Fig. 2) architecture with ResNet cannot extract the fine-grained features in USE images. Moreover, after balancing between classification loss and bounding-box regression loss, we achieve a top result on the USE test set with a mAP of 86.9% compared to 81.3% which is the performance of baseline model, especially the erythrocyte is boosted by a large margin of 28.4 points, achieving top

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