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Exploring illumination robust descriptors for human epithelial type 2 cell classification

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ABSTRACT

Strong illumination variation is a key challenge in the Human Epithelial Type 2 (HEp-2) cell classification task. Aiming to improve the robustness of the HEp-2 classification system to the illumination variation, this paper deeply explores discriminative and illumination robust descriptors. Specifically, we propose a novel Spatial Shape Index Descriptor (SSID) to capture spatial layout information of the second-order structures, and utilize a Local Orientation Adaptive Descriptor (LOAD), which was originally designed for texture classification, to the HEp-2 cell classification task. Both SSID and LOAD show strong discrimination and great complementarity to each other.

Four different sets of experiments were carried out to evaluate SSID, LOAD and their combination. Our two submissions achieved superior performance on the new Executable Thematic of Pattern Recognition Techniques for Indirect Immunofluorescence images analysis. Compared to the rank 1st method in the ICPR 2014 HEp-2 cell classification contest, both of our submissions achieved a better performance when only using the provided training data. Our approaches also demonstrated superior performance on a newly compiled large-scale HEp-2 data set with 63,445 cell images.

1. Introduction

Indirect Immunofluorescence (*IIF*) image analysis is an effective technique to diagnose some autoimmune diseases. In the *IIF*, the *Human Epithelial Type 2* (HEp-2) cells [1,2] are widely used to identify the presence of Anti-Nuclear Antibody (ANA). Before, the task to identify the types of HEp-2 cells is conducted by human experts. The annotation process is time-consuming, and subject to the experience of the experts. Recently, several HEp-2 cell classification contests adjunct with the International Conference on Pattern Recognition (ICPR) 2012 [3], the International Conference on Image Processing (ICIP) 2013 [4] and the ICPR 2014 [5] put forward the development of this area greatly.

Feature extraction dominated the HEp-2 cell classification task in the previous contests [3–5]. In the ICPR 2012 [3] contest, the rank 1st method was based on a Co-occurrence of Adjacent Local Binary Pattern (CoALBP) [6] feature. In the ICIP 2013 [4] contest, the rank 1st approach was based on a combination of Pairwise Rotation Invariant Co-occurrence of LBP (PRICoLBP) [7] and Bag of SIFT, and the rank 2nd approach [8] was based on a novel Shape Index Histogram (SIH) descriptor. In the ICPR 2014 [5] contest, the rank 1st approach [9] combined four different types of features. Besides of the above-mentioned approaches, many other features were also applied to this task, including LBP [10], Scale Invariant Feature Transformation (SIFT) [11], DAISY [12], Completed LBP (CLBP) [13], LBP variance (LBPV) [14], Multisupport Region Order-Based Gradient Histogram (MROGH) [15] and Dense Scale Invariant Descriptors (DSID) [16].

Strong illumination variation is a key challenge in the HEp-2 cell classification task. As shown in Fig. 1, the HEp-2 cells have two types: “Positive” and “Intermediate”, and the cell images between these two types have strong illumination variation. Even among cells from any single type, such as the “Positive”, there is strong illumination variation. Motivated by these observations, this paper aims to explore more discriminative and illumination robust descriptors for the HEp-2 cell classification task.

This paper deeply explored discriminative and illumination robust descriptors. Specifically, we proposed a novel Spatial Shape Index Descriptor (SSID) to capture spatial layout information of the second-order structures, and utilized a Local Orientation Adaptive Descriptor (LOAD) from texture classification to the HEp-2 cell classification task. Our two approaches with each based on one feature were evaluated at the Executable Thematic on Pattern Recognition Techniques for Indirect Immunofluorescence images analysis. Our two results, with the Mean-Class-Accuracy (MCA) 84.63% for LOAD and 84.57% for SSID respectively, substantially improved the state-of-the-art Shape Index Histogram (SIH) [8]

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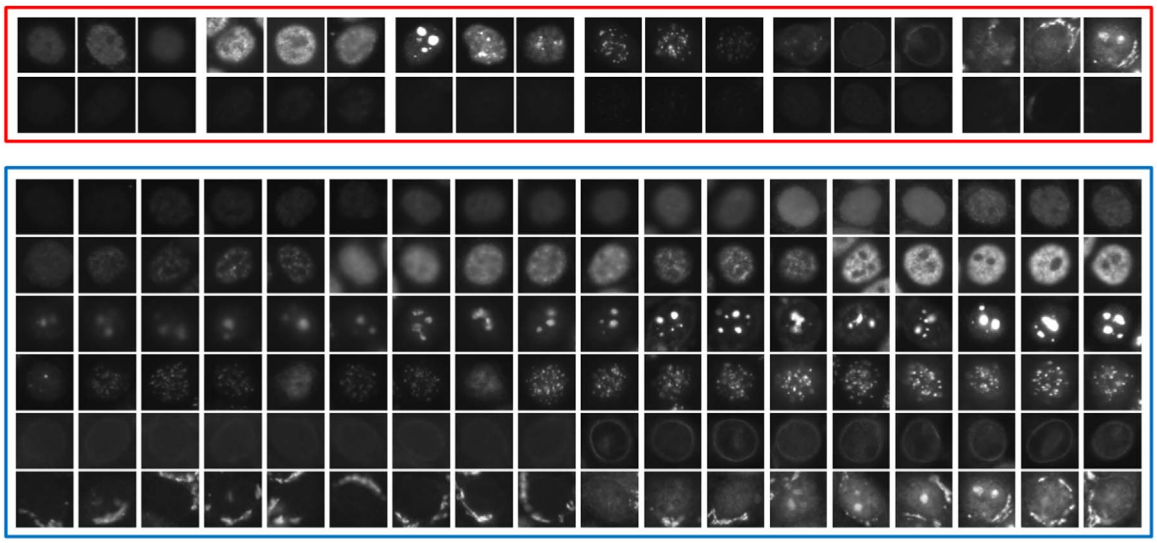

Fig. 1. An illustration of strong illumination variation existing in the HEp-2 cells. The images in the red box (the images in the first row belong to the "Positive" type and the images in the second row come from the "Intermediate") show that there is huge appearance variation between the "Positive" and "Intermediate" types from the same category. The images in the blue box (the images in each row come from one category) show that even only in the "Positive" type, the illumination varies a lot among the images. (For interpretation of the references to color in this figure caption, the reader is referred to the web version of this paper.)

descriptor. Meanwhile, both approaches achieved better performance than the first place of the ICPR 2014 contest that combined four different types of features when only using the provided training data. On a new created large-scale HEp-2 data set[1] that contains 63,445 cell images, both features also demonstrated superior performance compared to the SIH.

1.1. Related works

In the ICPR 2012 [3] contest, Nosaka and Fukui [6] proposed to use a Co-occurrence of Adjacent LBP (CoALBP) for the HEp-2 cell classification task. The CoALBP can be considered as an effective fusion of the LBP and Gray-Level Co-occurrence Matrix (GLCM). In the CoALBP, the co-occurrence was built on two LBPs with four neighbors. In their system, Gaussian smoothing was firstly used to remove the noise. To achieve better robustness to image rotations, the images were rotated to nine different orientations. In this manner, the number of training samples increased by a factor of ten. After obtaining the CoALBP features for all images, they trained a linear Support Vector Machine (SVM) classifier. In their system, Nosaka and Fukui only used the green channel because the pixel values of the other two channels in the IIF images are very small.

In the ICIP 2013 [4] contest, the rank 1st approach was based on a combination of Pairwise Rotation Invariant Co-occurrence of LBP (PRICoLBP) [7] and Bag of SIFT. The PRICoLBP provided an effective strategy to achieve rotation invariance for the co-occurrence feature. It was built on two LBPs with eight neighbors, thus it is more discriminative than the CoALBP. The Bag of SIFT have been widely used in many vision tasks, and proved to be effective. Also in this contest, Larsen et al. [8] achieved the 2nd place by introducing a novel Shape Index Histogram (SIH) descriptor.[2] The SIH summarized the statistics of the shape index into histograms using a new pooling scheme consisting of concentric donut-shaped rings centered on the cell. The pooling strategy endowed the SIH with good robustness to image rotations.

In the ICPR 2014 [5] contest, Manivannan et al. [9], the winner of the contest, proposed to combine four types of features including Multi-resolution Local Patterns (mLP), RootSIFT, Random Projections (RP), and Intensity Histograms (IH). In their system, Local-constrained Linear Coding (LLC) was used to encode these four types of features. They rotated the images into four different orientations and trained one classifier for each orientation of each feature. Finally, they conducted the classification based on the ensembles of sixteen classifiers (four features and four orientations).

Remarks: From all the above-mentioned methods, we observe that: (1) The winners in all three contests used the LBP variants including the CoALBP, the PRICoLBP and the Multi-resolution Local Patterns. (2) The winners in the ICIP 2013 and ICPR 2014 contests used the SIFT and the RootSIFT individually. (3) Feature extraction such as the CoALBP, the PRICoLBP, the SIH, the Bag of SIFT, and the Bag of RootSIFT, dominated previous contests. The SIH performed excellently with a very low computational complexity. All these three observations motivated us to further investigate the importance of these features.

2. Challenges in the HEp-2 cell classification

Strong illumination variation is a key challenge in the HEp-2 cell classification task. Due to their own characteristics of the HEp-2 cells, each category has two different types: "Positive" and "Intermediate". As shown in Fig. 1, illumination variation in the HEp-2 cells can be summarized into the following two types:

- Inter-type illumination variation. Each category consists of these two types. As shown in the red box of Fig. 1, the "Positive" type is usually visible to human eyes, but the intensities of the "Intermediate" images are usually small and not visible to human eyes.
- Intra-type illumination variation. As shown in the blue box of Fig. 1, even among the cell images from the same type (to facilitate visual observation, we only show the "Positive" type), they have large illumination variation.

This paper seeks to improve the HEp-2 cell classification task by designing discrimination features that are robust to the inter-

[1] The newly created data set can be downloaded from http://qixianbiao.github.io/HEp2Cell.

[2] In fact, the SIH achieved a higher Mean-Class-Accuracy than the first place of ICIP 2013 contest.