Automated Segmentation of Indirect Immunofluorescence Images using Fast Fuzzy C-Means Algorithm for Keypoint based Differentiation of Homogenous and Speckled Shapes

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Introduction
Autoimmune disease is a medical condition which is caused by immune system dysfunction resulting in the healthy tissue degradation. Indirect Immunofluorescence (IIF) Imaging is the standard screening test for diagnosis of autoimmune diseases. Visual interpretation of the staining patterns is a challenging task and hence there is a growing demand for automated analysis of IIF images. Homogenous and speckled shapes are often misclassified due to their geometric similarity. Differentiation of these two patterns is essential in clinical environment since each pattern is indicative of specific autoimmune disease.

Hypothesis
Appropriate segmentation of the IIF images could improve the keypoint feature detection and increase the classification accuracy of the staining patterns.

Methods
In this study, an attempt has been made to differentiate the homogenous and speckled shapes using Fast Fuzzy C-Means (FFCM) segmentation and Bag-of-Keypoints (BoK) model. IIF images for this study are considered from the publicly available ICPR-2016 dataset. The images are pre-processed using edge-aware Local Contrast (LC) enhancement technique. After pre-processing, FFCM algorithm is implemented to segment the foreground cellular objects. Speeded up Robust Feature (SURF) keypoint features are extracted for the pre-processed images before and after segmentation. BoK model is implemented to generate visual vocabulary from the preprocessed images with and without segmentation. A 500-word visual vocabulary is generated and is fed to k-nearest neighbor (kNN) classifier for classification. 10-fold cross validation is carried out to obtain optimal performance of the classifier.

Results
The pre-processing and segmentation results of IIF images are shown in Figure 1. In Figure 1 (a, d), the cell nuclei are not clearly visible. From Figure 1 (b, e), it can be observed that LC enhancement has improved the cell structure visibility. Homogenous shape is observed to have uniform fluorescence and the speckled shape is found to have fluorescence as multiple nuclear dots inside the nucleus. Figure 1 (c, f) shows the segmented mask and it has been observed that FFCM is able to extract the cell nuclei boundaries. Figure 2 depicts the boxplot of number of SURF keypoints detected for LC enhanced images with and without segmentation. It can be observed that the number of keypoints has increased after segmentation for both shapes. Table I shows the comparison of classification accuracy with and without segmentation. Results show that the classification accuracy of kNN classifier has increased after segmentation of the IIF images.
Figure 1. Representative images of (a, b, c) homogenous and (d, e, f) speckled shapes
(a, d) original image (b, e) LC enhanced image (c, f) FFCM segmented mask

Figure 2. Comparison of number of detected SURF keypoints with and without segmentation for
(a) Homogenous shape (b) Speckled shape

Table I. Classification performance comparison of kNN classifier

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<tr>
<th>Method</th>
<th>Accuracy (%)</th>
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<tr>
<td>BoK without FFCM</td>
<td>57.6</td>
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<tr>
<td>BoK with FFCM</td>
<td>84.5</td>
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Conclusion
Results indicate that LC contrast enhancement has increased the cell structure visibility of the IIF images. FFCM segmentation has improved the detection of SURF keypoints in IIF images. BoK model is utilized to construct visual vocabulary of each shape. kNN is able to differentiate homogenous and speckled shapes in IIF images. Classification accuracy has improved after segmentation in IIF images. Hence, appropriate segmentation techniques have to be chosen for keypoint based differentiation of staining patterns in IIF images.

Statement of Impact
The proposed approach is able to clearly differentiate the complex and often misinterpreted shapes in IIF images. Hence this approach could be useful in computer assisted diagnosis of autoimmune diseases.

Keywords
autoimmune disease, indirect immunofluorescence, speeded up robust feature, keypoints, segmentation, fast fuzzy C-means, bag-of-features, k-nearest neighbor