A Machine Learning Approach For Blood Vessels Segmentation In Chorioallantoic Membrane Images

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Abstract

A machine learning approach was designed for the segmentation of the blood vessels in monochromatic images of the chorioallantoic membranes of chicken eggs. The Local Binary Pattern (LBP) method was applied to texture analysis using uniform and rotation invariant patterns. A feature vector and its corresponding label were generated and associated to each image pixel by varying LPB parameters. A little fraction of this information was used to train SVM classifiers and then automatically segment CAM images. Accuracy in the training phase was $\sim 75\%$ for each classifier, whereas when they were applied in new images, accuracy varied from 75% to 87%.

1 Introduction

The chorioallantoic membrane (CAM) of chicken embryo is a very convenient tool for an experimental toxicology approach to the effects of bioactive substances and materials upon angiogenesis, metastasis and teratogenesis [5]. CAM images are informative about the structure and function of the developing vascular network of this extra embryonic avian tissue. Quantitative measurements of vessel density, diameter, wall thickness, segment length, and branching points/area can be used to investigate biochemical and or biophysical challenges that affect normal development. Traditional segmentation methods provide good results. Threshold and background filtering procedures depend heavily upon optimal image capture conditions, however biological sampling is often associated with unavoidable shadows, blurring, illumination gradients, poor contrast, equipment associated artifacts. Usually, high resolution settings are only available for small fields observation. A machine learning approach for blood vessels segmentation was designed to overcome this constraints and allow quantitative measurements at capillary vessels network level in the whole CAM area, optimizing morphological assessment of vascular patterning.

2 Material and methods

2.1 CAM image acquisition

Digital images of CAM membranes were obtained with a high resolution scanner from samples placed on glass plate dishes. Five regions of interest (ROI) were extracted from each CAM membrane image, addressing rich information of vascular network. This procedure generated 250 monochromatic 1024×1024 CAM images. Afterward, seven CAM images were manually segmented, in order to provide a ground truth for the method accuracy evaluation. Extraction of ROIs, as well as manual segmentation, were performed by CAM morphology experts.

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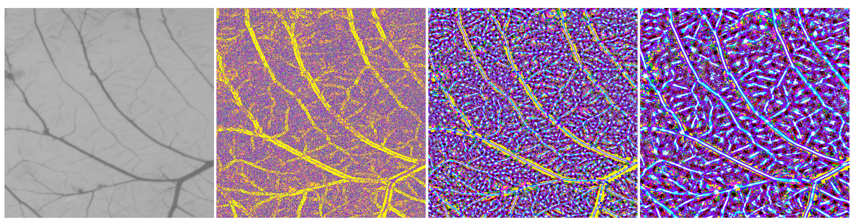
2.2 Feature extraction and automatic classification

The method of Local Binary Patterns (LBP), which is widely used in different areas of computer vision due to its high efficiency for texture analysis, was employed during the feature extraction phase [3, 1, 4]. Let I be a CAM image, and let δ_r^n be the operator which associates the intensity value of each pixel of I with one "uniform and rotation invariant" (RIU) pattern of the set T. According to [1], the number of RIU patterns composing T depend on the values r and n, which represent the distance radius and the number of neighbors, respectively. For convenience, RIU patterns are usually denoted by natural numbers. In this work, a feature vector was calculated for each pixel of I by applying the operator δ to I 35 times, fixing n to 8 and ranging the r values from 1 to 35. Fixing $n = 8$, it was possible to generate until 10 unique RIU patterns. Typical results are illustrated in Figure 1. Then, each pixel $\mathbf{p} = (x, y) \in I$ was identified by its corresponding sequence of 35 RIU patterns, S_{RIU}:

$$S_{RIU}(\mathbf{p}) = [\delta_1^n(I)(\mathbf{p}), \delta_2^n(I)(\mathbf{p}), \cdots, \delta_{35}^n(I)(\mathbf{p})]$$

Next, the feature vector associated to the pixel $\mathbf{p}$ was represented by the histogram obtained from $S_{RIU}(\mathbf{p})$. The data set X was constructed with randomly selected sequences of S_{RIU} from 1000 pixels corresponding to blood vessels and 1000 pixels corresponding to background, and a vector Y, containing the labels 1 or 0 corresponding to each of X sequences was created.



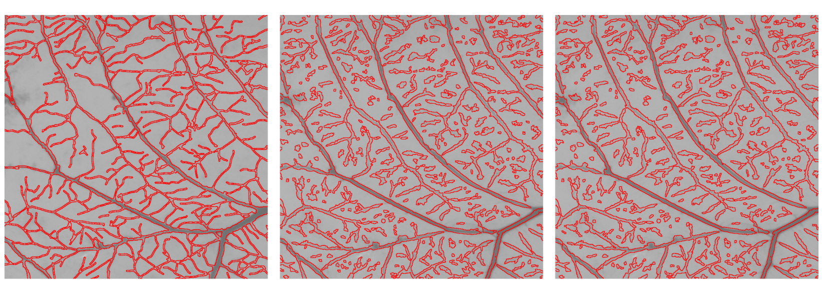
(A) Original Image (B) RIU Image, r = 1 (C) RIU Image, r = 10 (D) RIU Image, r = 20

Figure 1: Results of application of operator δ with different radius

In the automatic classification phase, a binary classifier (C^*) was built using the SVM algorithm [2]. Classifier C^* was trained using the matrix X and the vector Y. The accuracy obtained in the training phase for each classifier was $\sim 75\%$. The performance of C^* classifiers were evaluated after the automatic segmentation of the seven CAM images, by comparison with the manually segmented images.

3 Results and conclusions

The accuracy obtained from automatic segmentation varied from 75% to 87%. The LBP technique was demonstrated appropriate and useful for performing automatic segmentation of vascular network in CAM images, even for images with poor quality. Moreover, results can be significantly improved if more representative feature vectors are used instead of simple histograms. Noteworthy, classifiers trained with different images features, were able to produce similar segmentation results (Figure 2).



(A) Manual Segmentation (B) Segmentation using C3 (C) Segmentation using C5

Figure 2: Segmentation results of CAM image in Figure 1.A using classifier $C3$ and $C5$.

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