Quantification of Capillary Density and Inter-Capillary Distance in Nailfold Capillary Images Using Scale Space Capillary Detection and Ordinate Clustering

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ABSTRACT

The visual analysis of Nailfold Capillary images manually requires trained medical staff and also, the intra-observer variations can be very high. A computer assisted capillary analysis reduces this burden to a great extent. The authors propose an automated system using advanced techniques such as Scale Space construction using Anisotropic Diffusion and Ordinate clustering algorithm. The classification of capillaries is evaluated on the basis of Sensitivity, Specificity and Classification Accuracy. The effectiveness of anisotropic filtering and Ordinate clustering in eliminating erroneous detection is demonstrated. The capillary density and inter-capillary distance are important capillary parameters which can contribute to the diagnosis of different diseases.

KEYWORDS

Anisotropic Diffusion, Bi-Cubic Interpolation, Harris Corner Detection, Nailfold Capillary, Ordinate Clustering Algorithm

INTRODUCTION

Nailfold capillaroscopy is a non-invasive diagnostic tool useful in the diagnosis of various diseases. Capillaries are very thin blood vessels which form a crucial part of the circulatory system. Although capillaries are found everywhere in the body, they are present parallel to the skin surface the nailbed of fingers and lend themselves to be imaged properly at the nailfold. The nailfold capillary image shows a series of parallel placed, reverse-U shaped capillaries. In these images, various morphological features are extracted such as capillary density, inter-capillary distance, capillary dimensions (height and width), shape of the capillary and orientation of the capillaries. Capillary density and inter-capillary distance are important features in a nailfold capillary image which can contribute to medical diagnosis of diseases such as Hypertension and Dermatomyositis. There is a need of trained medical staff to measure these parameters and interpret them. Also, inter-observer variations among different medical staff can affect the conclusions drawn. A computerized analytical system is a reliable clinical aid which helps to overcome these issues. Capillary density refers to the number of capillaries present in one millimeter length. This parameter is the most crucial parameter in diagnosis of diseases such as hypertension. In addition, distance between capillaries can be used to reinforce this aspect. Feng et al. mention that much of the reduction in capillary density in essential hypertension was because
of the structural (anatomic) absence of capillaries, although functional capillary rarefaction (because of nonperfusion) also existed.

A nailfold capillary image has two rows of capillaries apart from the subplexus below; top row corresponds to the row of capillaries just below the skin, while the second row of capillaries corresponds to the inner row of capillaries under the skin. Only the capillaries just below the skin are useful and hence need to be separated from the other row. Ordinate clustering helps in separating the two layers of capillaries so that only the upper layer is selected. It is necessary to process the image so that only corner features corresponding to capillary tips are obtained. This is achieved using Scale Space filtering and by Anisotropic Diffusion. Harris corner detector is found to give more accurate results compared to other corner detectors. Then, the total number of capillary tips and the Euclidian distance between the tips is determined (see Figure 1).

The structure of this article is as follows: ‘Introduction’ gives a peak into the topic of nailfold capillaroscopy and the use of capillary morphology to diagnose diseases. ‘Literature review’ section deals with the related work both in medical research and technology. ‘Materials’ section mentions the image database considered. ‘Methods’ section elaborates on the various techniques used for image resizing, filtering, feature extraction and calculations. The section ‘Experimental analysis’ details the experiments which has helped us to decide on a particular technique and the justification for the selection. The section ‘Results and discussion’ tabulates the various results obtained, along with an interpretation of the results. Finally ‘Conclusion’ section gives a summary of the work carried out.

Figure 1. Sample Capillary image of (a) Healthy control and (b) Hypertensive subject

(a)  
(b)
Uberveillance, Standards, and Anticipation: A Case Study on Nanobiosensors in U.S. Cattle
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