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A non-parametric segmentation methodology for oral videocapillaroscopic images

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ABSTRACT

We aim to describe a new non-parametric methodology to support the clinician during the diagnostic process of oral videocapillaroscopy to evaluate peripheral microcirculation. Our methodology, mainly based on wavelet analysis and mathematical morphology to preprocess the images, segments them by minimizing the within-class luminosity variance of both capillaries and background. Experiments were carried out on a set of real microphotographs to validate this approach versus handmade segmentations provided by physicians. By using a leave-one-patient-out approach, we pointed out that our methodology is robust, according to precision–recall criteria (average precision and recall are equal to 0.924 and 0.923, respectively) and it acts as a physician in terms of the Jaccard index (mean and standard deviation equal to 0.858 and 0.064, respectively).

1. Introduction

Capillaroscopy is a diagnostic technique for viewing peripheral circulation and in studying microangiopathies which are manifestations of numerous pathologies during both the diagnostic and the monitoring phases of the disease. Indeed, alterations in the capillaroscopic picture can represent the only documentary evidence of an incipient disease. Morphological and densitometric changes are related to healthy or sick patients, suffering from systemic and/or non-systemic diseases such as lichen planus (oral and systemic), pemphigus and pemphigoid, diabetes, hypercholesterolemia, scleroderma, Sjögren's syndrome and rheumatoid arthritis [1,2]. The complexity of the segmentation of these images already been pointed out in [3]. Recently, a probabilistic estimate of nailfold capillary segmentation was obtained by the combination of multiple classifiers [4].

In early 2000, the videocapillaroscopic optical probe was applied to the oral mucosa which allows an easier investigation of peripheral microcirculation by virtue of its histological features. With respect to other mucosal tissues (e.g. anal, vaginal and respiratory), the oral mucosa is preferable because of its accessibility and repeatability. This visual inspection

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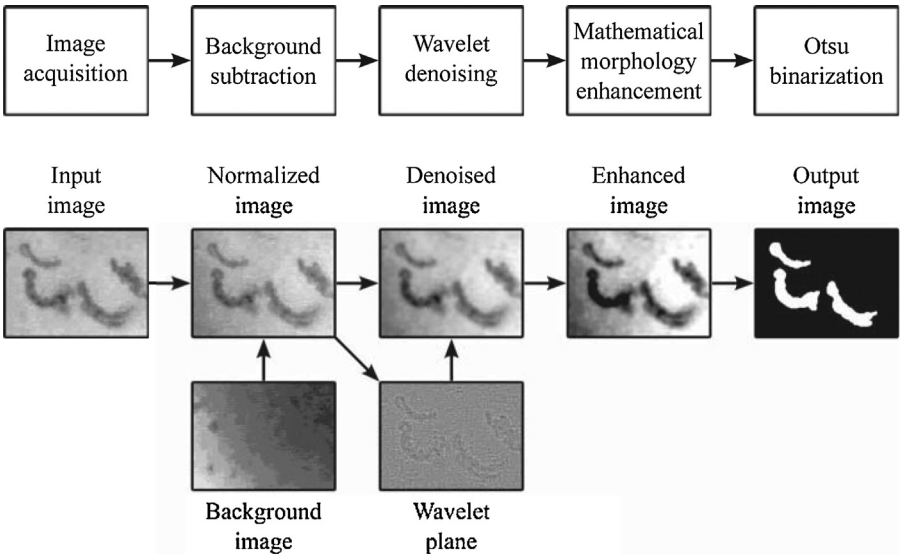

Fig. 1 – Main steps (above) of our methodology and counterpart sample results (below).

is time-consuming, subjective and error-prone and therefore a computer-assisted image analysis tool is required. This paper introduces a methodology tailored for oral capillaroscopic image segmentation, designed so that the user does not have to define any parameter. Current techniques are customized for nailfold capillary microscopy and to the best of our knowledge this is the first system in the literature devoted to the analysis of the oral mucosa. A description of the images we analyzed with a pre-processing step needed to normalize them and to mitigate the presence of artefacts is in Section 2. As reported in Sections 3 and 4, our approach exploits wavelet analysis for noise reduction and mathematical morphology to enhance the images for the segmentation, described in Section 5 (see Fig. 1). We used the Jaccard index and precision–recall to compare the output of our methodology and handmade segmentations, provided by three experts. The experiment and the ensuing results are detailed in Section 6. Conclusions are in Section 7.

2. Acquisition and pre-processing of the capillaroscopic dataset

All experiments were carried out under standardized conditions:

- room temperature of $24 \pm 1\,^{\circ}C$ was maintained constant by air-conditioning systems;
- illumination was through a neon light for medical use with a white point equal to 6500 K;
- pressure of the environment was forced slightly positive.

by using the following VideoCap 200 videocapillaroscope[1]:

- a central unit with a cold halogen 100 W light source fitted with automatic or manual control device to regulate luminosity and white balancing;
- an optic terminal connected to the central unit by a 2-m fiberoptic cable and made up of a color micro-television camera, a ferrule for fine focussing regulation and a radial ferrule at the tip with annular illumination to ensure a uniform illumination without shadows;
- VideoCap Software release 8.0 installed on a personal computer with dedicated graphics card connected to the central unit through a S-video cable;
- a Canopus ADVC-55 system connected the central unit to a secondary personal computer, to record the examinations at 25 frames per second.

Twenty healthy subjects were enrolled and gave their consent for the capillaroscopic examination to be performed and for the use of their personal medical data in scientific papers, in accordance with Italian laws on privacy and use of personal data.[2] The physicians of our group jointly investigated the mucosa of the upper and the lower lips; the left and right buccal mucosae; the vestibular masticatory/gingival mucous of the II and V sextant (see Fig. 2). They selected ten frames per subject according to medical evidence, as representative of the various phases of the investigation (i.e. two frames for each one of the five zones of the mouth), thus leading to a total of 200 images.

The detection of components embedded in microphotographs from capillaroscope is very hard because of closely clustered capillaries, color variations and aberrations caused by the optical system of the acquisition device. The image boundaries are generally out of focus because of magnification and blurred due to camera-subject movements. Moreover, it is easy to perceive separate parts as one object since the

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[2] Comitato Bieoetico dell'Azienda Ospedaliera Policlinico di Palermo. Verbale n.5/2012 del 16/05/2012.