Chapter 6
Automated Categorisation of Nailfold Capillaroscopy Images

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ABSTRACT
Nailfold capillaroscopy (NC) is a non-invasive imaging technique employed to assess the condition of blood capillaries in the nailfold. It is particularly useful for early detection of scleroderma spectrum disorders and evaluation of Raynaud’s phenomenon. While automated approaches to analysing NC images are relatively rare, they are typically based on extraction and analysis of individual capillaries from the images in order to assign a patient to one of the commonly employed scleroderma patterns. In this chapter, we present a different approach that does not rely on individual capillaries but performs interpretation in a holistic way based on information gathered from an image or a selected image region. In particular, our algorithm employs texture analysis to characterise the underlying patterns, coupled with a classification stage to first identify patterns in fingers, and then, through a voting strategy, reach a decision for a patient. Experimental results on a set of NC images with known ground truth demonstrate the efficacy of the proposed approach.

INTRODUCTION
Nailfold capillaroscopy (NC) is a non-invasive imaging technique employed to assess the condition and morphology of capillaries in the nailfold. It is recognised as a reliable method for observing micro blood vessel characteristics and as a standard method for diagnosing diseases such as systemic sclerosis (SSc) (Grassi et al., 2001), Raynaud’s phenomenon (Cutolo et al., 2003), and other connective tissue diseases such as dermatomyositis, antiphospholipid syndrome (Cutolo et al., 2006), and Sjogren’s syndrome (Tektonidou et al., 1999) which lead to morphological alterations of capillaries. Specific NC patterns in SSc have been described in (Maricq & LeRoy, 1973), and were later refined into early, active and late patterns in (Cutolo et al., 2000).

Nailfold capillaroscopy is performed by observing capillaries in the nailfold area under
a microscope. A digital camera attached to the microscope enables the capillaries to be viewed and recorded. Morphological features that are indicative in NC images include enlarged and giant capillaries, haemorrhages (microbleeding), loss of capillaries, disorganisation of the vascular array, and ramified/bushy capillaries (Cutolo et al., 2005).

While diagnosis based on NC is typically performed by manual inspection, computerised nailfold capillaroscopy can help to reduce the inherent ambiguity present in human judgement while greatly reducing the time for diagnosis. Diagnosis using NC images involves the classification into the mentioned Early, Active and Late groups, also known as NC patterns or scleroderma (SD) patterns. Earlier approaches are typically based on extraction and analysis of individual capillaries from the images in order to assign a patient to one of these patterns. In this chapter, we present a holistic method for categorising NC images which does not rely on the extraction and definition of individual capillaries (Doshi et al., 2012d). For this, an image (or image region) is characterised using a set of texture descriptors, in particular multi-dimensional local binary pattern (MD-LBP) descriptors (Schaefer et al., 2012). These then form the input for a pattern classification stage that assigns each image to an NC pattern. Finally, the results from multiple fingers are combined to arrive at a decision for a patient. Experimental results confirm the efficacy of the presented approach.

**NAILFOLD CAPILLAROSCOPY**

Capillaroscopy is an established technique to investigate micro-vascular involvement in various diseases. Examination of capillaries for finding a relation between conjunctival inflammation and the presence of an inextricable knot of capillary loops was noted by Italian physician Giovanni Rasori about 200 years ago using a magnifying glass (Cutolo et al., 2003). In 1911, Lombard discovered that human skin capillaries can be observed using a microscope after the application of a drop of immersion oil. Further to this, Weiss, in 1916, was able to take a picture of capillaries using a primordial camera. In 1925, Brown and O’Leary have shown the use of capillaroscopy for observing capillary abnormalities in Raynaud’s phenomenon (RP) characterised by progressive sclerosis. Nevertheless, capillaroscopy was then mostly neglected for several decades until, in 1973, Maricq and LeRoy published the first paper describing specific capillaroscopic patterns in SSc (Maricq & LeRoy, 1973).

In a resurge of interest, various works on capillaroscopic patterns, emphasising mainly the relationship between capillary patterns and particular diseases, were published. At the same time, capillaroscopic image acquisition techniques and protocols improved significantly. For acclimatisation, the subject is typically kept in the procedure room for a minimum of 15 minutes, with the room temperature kept between 20 and 22°C. The nailfolds of several fingers are examined, and a drop of immersion oil is used to improve the image quality (Cutolo et al., 2005). Observation can be conducted using various instruments including ophthalmoscopes, stereomicroscopes, photomicrography and video-capillaroscopy systems.

The most important disease encountered underlying RP is systemic sclerosis (SSc) or scleroderma. SSc is characterised by progressive skin and visceral organ fibrosis. Early diagnosis of scleroderma is only possible by examination of nailfold capillaries (Angelis et al., 2009). Researchers have observed that 90% of patients with scleroderma show a typical NC pattern called scleroderma pattern or SD pattern. However, similar patterns are also observed in other closely related disorders such as dermatomyositis, and mixed connective tissue diseases. Typical SD patterns show enlargement of capillary loops, loss of capillaries, disruption of the capillary bed and distortion and budding of capillaries.
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