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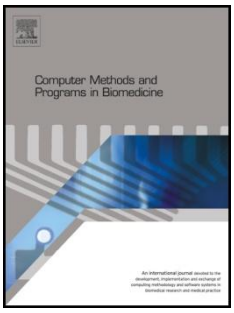

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A Fully Automatic Nerve Segmentation and Morphometric Parameter Quantification System for Early Diagnosis of Diabetic Neuropathy in Corneal Images

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Highlights

- A fully automatic, efficient real-time corneal sub-basal nerve segmentation and morphological parameter quantification system is developed.
- This system underpins the expertise of ophthalmologists.
- A number of useful clinical features that can be used to save a useful amount of clinician time in the process.
- A new algorithm has been proposed to calculate the average nerve thickness.
- An efficient technique is proposed to connect the discontinuous nerves
- It is able to trace corneal sub-basal nerves for the early detection and follow up of (DPN) from CCM images.
- A clinically helpful diagnostic system for busy clinic and patient care.

ABSTRACT

Diabetic Peripheral Neuropathy (DPN) is one of the most common types of diabetes that can affect the cornea. An accurate analysis of the nerve structures can assist the early diagnosis of this disease. This paper proposes a robust, fast and fully automatic nerve segmentation and morphometric parameter quantification system for corneal confocal microscope images. The segmentation part consists of three main steps. Firstly, a preprocessing step is applied to enhance the visibility of the nerves and remove noise using anisotropic diffusion filtering, specifically a Coherence filter followed by Gaussian filtering. Secondly, morphological operations are applied to remove unwanted objects in the input image such as epithelial cells and small nerve segments. Finally, an edge detection step is applied to detect all the nerves in the input image. In this step, an efficient algorithm for connecting discontinuous nerves is proposed. In the morphometric parameters quantification part, a number of features are extracted, including thickness, tortuosity and length of nerve, which may be used for the early diagnosis of diabetic polyneuropathy and when planning Laser-Assisted in Situ Keratomileusis (LASIK) or Photorefractive keratectomy (PRK). The performance of the proposed segmentation system is evaluated against manually traced ground-truth images based on a database consisting of 498 corneal sub-basal nerve images (238 are normal and 260 are abnormal). In addition, the robustness and efficiency of the proposed system in extracting morphometric features with clinical utility was evaluated in 919 images taken from healthy subjects and diabetic patients with and without neuropathy. We demonstrate rapid (13seconds/image), robust and effective automated corneal nerve quantification. The proposed system will be deployed as a useful clinical tool to support the expertise of ophthalmologists and save the clinician time in a busy clinical setting.

Keywords: Diabetes, Diabetic Peripheral Neuropathy, Corneal Confocal Microscopy, Corneal Subbasal Epithelium, Automatic Nerve Segmentation, Anisotropic Diffusion Filtering.

1. Introduction

The cornea consists of five layers: the Epithelium layer, Bowman's layer, the Stroma, Decement's membrane layer and the Endothelium layer [1] (Fig.1). It contains sensory and autonomic nerves located at the interface between the Bowman's layer and the basal epithelium. Corneal Confocal Microscopy (CCM) is a rapid non-invasive in vivo clinical technique for capturing images of the different corneal layers [2]. Morphological alterations in the epithelium, stroma and endothelium provide insights into a variety of corneal diseases [3,4] and assessment of the effects of wearing contact lenses [1], LASIK or PRK [5], fungal keratitis [6], corneal transplantation [7] or conditions such as keratoconus [8,9]. CCM has also been used in the assessment of peripheral neuropathies [10,11,12,13,14,15,16,17,18,19]. The development of automated imaging algorithms for the processing of CCM images [20,21,22,23] is a necessary accompaniment to such work.