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Fast retinal vessel analysis

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Abstract We introduce a fast image processing system that allows to analyse digital data-bases of retinal images in a short time, and to process the image in situ while the patient is examined. While it achieves a comparable quality as state-of-the-art methods, it differs from most of them by the fact that it is extremely fast. Retinal blood vessels are enhanced via convolution with the second derivative of the local Radon kernel. It is rotated by different angles, and it adapts itself via a maximisation procedure to the vessel directions. We combine smoothing along vessel directions with contrast enhancement across them. We detect vessels as connected structures with very few interruptions. A subsequent skeletonisation allows a higher-level description of the vessel tree. To end up with a very fast system, we combine efficient algorithms for numerical integration, differentiation and interpolation, and we propose an automatic parameter selection strategy. Our convolution kernels are precomputed and stored into cached constant memory. All essential subroutines are intrinsically parallel, and the resulting system is implemented on GPUs using CUDA. Our qualitative evaluations with the DRIVE database and our own database show that the system achieves competitive performance. It is possible to process images of size $4,288 \times 2,848$ pixels in 1.2 s on an NVIDIA Geforce GTX680. Compared to our sequential implementation, this amounts to a speed-up by two orders of magnitude.

Keywords NVIDIA CUDA · Real-time retinal imaging · Vessel analysis · Vessel segmentation

Mathematics Subject Classfication 65Y05 · 65D99

1 Introduction

The inspection of retinal vessels is a well established and scientifically evaluated method for the screening of important vascular diseases. Widely available "Non-Mydriatic" cameras allow ophthalmologists to create considerable databases that prepare the path for unprecedented numerical and statistical analysis. Thus, it would be attractive to have an efficient image processing system for the analysis of huge databases of retinal images. In this way, it also becomes possible to test the quality of a retinal image in interactive time, while the patient sits before the camera, and to take another image, if necessary. Unfortunately, most systems that have been proposed in the research literature and give results of high quality are too slow for these tasks.

The goal of the present paper is to address these problems by introducing a system for retinal image analysis that combines high quality with high computational efficiency. It combines a number of very useful concepts:

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