Review of: "Automated retinal boundary segmentation of optical coherence tomography images using an improved Canny operator"

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Potential competing interests: The author(s) declared that no potential competing interests exist.

Overview

This paper presents an automatic method for retinal boundary segmentation in optical coherence tomography (OCT). The proposed method adapts the Canny edge detector for retinal boundary segmentation. Furthermore, it is an algorithm-driven and unsupervised approach that was tested on healthy subjects and patients with age-related macular degeneration (AMD). In general, the method tends to provide perfect segmentations or good segmentations that require minor corrections, according to the qualitative assessment of senior ophthalmologists.

Writing/Structure

Overall the paper is well written, easy to understand and there are several pictures that clearly illustrate the text descriptions. There are however some aspects that could easily be improved. For instance:

- the sentence " (…) Canny operator is recognized as the best boundary detection operator so far (…)" may lead to the discredit this work, because stating that Canny is the best boundary detection so far seems like an exaggeration, and even if true, there is no reference backing up this claim;
- the proposed method is based on the Canny detector, but there is no reference to the original paper describing the Canny detector;
- the sentence "Such boundary detection methods that relies on the "group effect" can accurately detect the retinal boundary (...)", the term "group effect" seem informal and may lead to misinterpretation. Using clearer and less colloquial terms would benefit this work.

Methods

The proposed method presents some interesting advantages over some other methods in the literature, such as:

- being unsupervised (no labelled data required);
- segments 11 layers, more than most methods in literature;
- allows for overlapping layers;
- no need for alignment of the A-lines;
- no need for definition of a search space;

- simple to understand and implement;
- fast execution (242 ms per B-scan), which can be improved through parallelization or by executing operations in GPU.

Nevertheless, the proposed method presents some limitations that should understood for those using it. This method is a 2D method, so it does not consider information of adjacent B-scans and it assumes that all layers exist in all columns. This assumption does not always holds true, particularly for diseased retinas, conditions like AMD could lead to the deterioration of retinal tissue to the extent of having regions without the RPE layer (i.e., geographic atrophy). Retinis pigmentosa is another disease that could cause deterioration of the layers containing the photoreceptors and also the RPE. The proposed method assumes that the boundaries between layers cause the gradients with largest magnitudes and that is not always the case, in some situations the strongest gradients are located inside the layers, an example can be seen in Fig. 6 (h) on the left side of the o-OS segmentation, which corresponds to the interior of the RPE.
Regarding more specific algorithmic decisions, there are some aspects that could be improved. One of them is the attenuation of low magnitude gradients thought the multiplication of an image smoothed with a Gaussian filter. While it is effective in this purpose and it is very important for dealing with posterior vitreous detachment, it also attenuates strong gradients in low intensity regions, like the photoreceptor inner segments (IS) layer and the outer nuclear layer (ONL). Thus, using another way to attenuate the weak gradients could be beneficial. Another relevant decision, was the use 3 or 5 pixel neighbourhood in the multipoint boundary search, which assumes that retinal boundaries in areas with weak gradients are smooth (i.e. do not change rapidly in from one column to the next). Some diseases or conditions could cause retinal layers to not be smooth, for instance in large pigment epithelial detachments (PEDs). The multipoint boundary search also uses seed points from the leftmost and rightmost regions of the retina, so the boundary search it is very reliant on these regions and if a disease were to cause severe structural changes on these areas the segmentation could be compromised. Perhaps, randomly selecting the seeds point would improve the robustness of the algorithm. Finally, the boundaries are labelled according to their position (relative or otherwise), thus this method may mislabel boundaries in the case of missing boundaries (e.g. GA regions in AMD), which could lead to coarse errors.

Results

The results of the proposed method were evaluated in a limited dataset (10 scans from healthy patients and 20 scans from AMD patients), apart from the boundaries ILM and o-OS, which were also evaluated in a public dataset with over 400 scans. The results for the private dataset seem to be about 1 to 2 pixels and 1 to 3 pixels, which is in the same range of other methods in the literature (evaluated in different datasets). For the ILM and o-OS, the proposed method attains comparable performance to a method present in the literature, but it performs worse in AMD patients for the o-OS. This method seems to make some assumptions (see previous section) that are mostly based on healthy retinas and that is possibly the reason for it to perform worse in AMD patients (quantitatively and qualitatively). The methods could also

have been compared to more methods in the literature, one easy way of doing it would be to have used the dataset in https://people.duke.edu/~sf59/Chiu_IOVS_2011_dataset.htm, which contains previously computed results of a shortest path based method. This work could also have been improved by performing statistical analysis to compare results between subsets of data (e.g. healthy and AMD) and between methods.

Summary

The proposed work presents some attractive advantages over other methods in the literature, such as being unsupervised, fast, simple, having few parameters while providing comparable performance to other methods in the literature. However, it makes some assumptions that are based on the morphology of healthy retinas and its performance seems to be sensitive when morphological changes caused by disease are present. Despite presenting some evidence that the proposed method could be used for segmenting retinal boundaries, it would need to be refined and more extensively evaluated on larger independent datasets before being deployed into clinical practice. Still, it could be useful for research settings and as starting point for a more complex and robust method.