Gradient boosted segmentation of retinal fundus images

Author: Matúš Goliaš

Supervisor: Doc. RNDr. Elena Šikudová PhD.

FACULTY OF MATHEMATICS AND PHYSICS
Charles University

Introduction

In the field of ophthalmology, there has been an increase in the use of automatic methods in medical diagnosis. One of the most severe eye diseases is glaucoma. It is the leading cause of blindness and early treatment is the only way of preventing loss of vision.

Glaucoma is diagnosed mainly from the structure of the optic nerve head (ONH). This area is visible on fundus retinal images acquired using specialised devices. The ONH is composed of an optic disc (OD) and an optic cup (OC). We can develop methods for the extraction of these objects from a fundus image. Accurate segmentation of the OD and OC is a very important first step towards automatic glaucoma diagnosis.

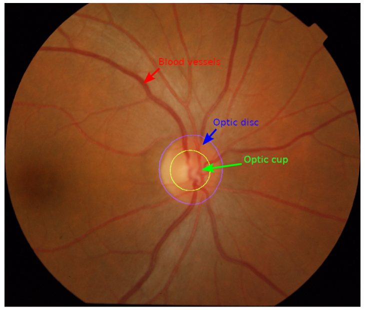

Figure 1: Fundus retinal image

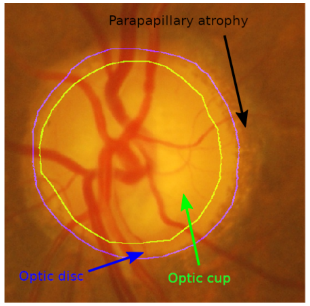

Figure 2: Optic nerve head

Algorithm overview

Our proposed approach consists of two main parts. Firstly, we extract the optic disc using an iterative threshold-based algorithm. It searches the range of viable thresholds and reduces the investigated intervals in each iteration. We select the most promising search range by comparing score values of optic disc candidates for each threshold. We define the score by our new empirical formula derived from the properties of our training dataset. Primarily, it considers ellipse similarity and vessel coverage of the object.

Secondly, we find the optic cup using gradient-boosted decision trees.The model classifies superpixels into two classes. Then we select the pixels belonging to the cup according to the model and create a binary mask representing the object. Features used for classification are based on image channel values from various colour spaces. They include centre-surround statistics estimating properties of the optic disc in a region around the given superpixel.

Both steps of our algorithm use pre-processing and post-processing techniques including improved region of interest selection, blood vessel detection and ellipse fitting. Consequently, we propose a customisable approach which can be tuned to the specific properties of a given dataset.

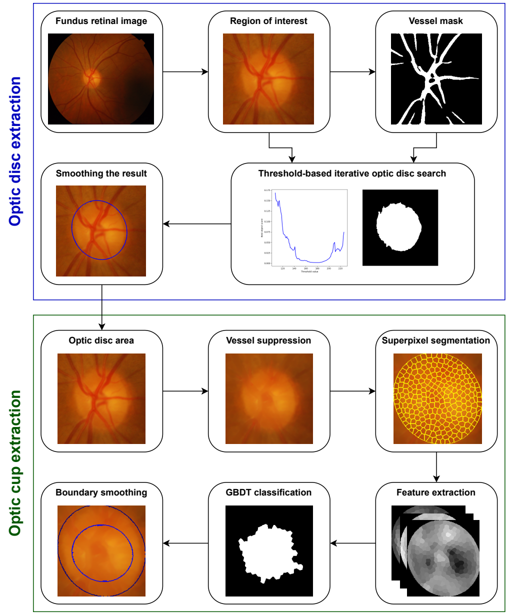

Figure 3: Complete segmentation pipeline

Results

We trained and evaluated our approach on the Drishti-GS1 fundus retinal image dataset consisting of 50 training and 51 testing images. For evaluation, we computed the intersection over union (IoU) of our predicted mask with respect to the mask selected by experts. Small datasets are used due to the difficulty of data acquisition.

Our approach shows promising results in segmentation of both the OD and OC. The average IoU is 0.92 for the disc extraction and 0.786 for the cup extraction on the Drishti testing set. Results published in the literature range from 0.9 to 0.94 for the disc and from 0.76 to 0.8 for the cup.

We also investigated modifications of the algorithm, e.g., different machine learning models for classification, to verify that the selected approach has the best performance.

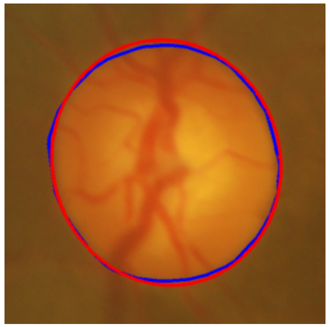

Figure 4: OD extraction result (blue - ground truth, red - predicted mask)

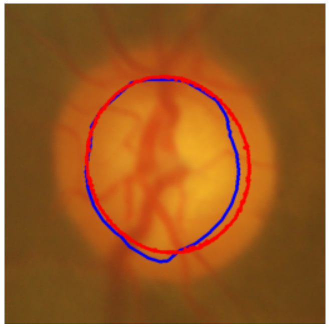

Figure 5: OC extraction result (blue - ground truth, red - predicted mask)

Conclusion

We developed a full optic nerve head segmentation pipeline. We improved existing algorithms to better suit our application. In addition, we proposed new approaches for several problems. We defined a formula which quantifies several properties of optic discs. Furthermore, we applied gradient boosting to the problem of superpixel classification for OC extraction, which has not been considered in the related literature. Our experiments show promising results and the model outperforms more commonly used machine learning techniques.

Therefore, our algorithm or some of its modules can be used in the development of automatic or semi-automatic methods for glaucoma diagnosis.