

Automated Retinal Cyst Detection in OCT Images Using Classical Image Processing Techniques

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Abstract –This report details a classical image processing system of automated retinal cyst segmentation in optical coherence tomography (OCT) scans. This is due to the clinical significance of the cysts in the retinal disease such as Diabetic Macular Edema (DME) and Age-related Macular Degeneration (AMD). The proposed pipeline employs morphological refinement, noise reduction, contrast enhancement, and adaptive thresholding to identify cystic areas. Unlike the deep learning models, the approach cares about transparency and efficiency. The method based on Python generated through OpenCV and scikit-image, featuring average Dice coefficient (0.179) and IoU (0.100). Although small, the results suggest that adaptive thresholding may be applied as repeatable minimum to cyst segmentation processes.

KEYWORDS: The current paper will be devoted to the research on optical coherence tomography (OCT) and its use in the area of the retinal cysts segmentation. Optical Coherence Tomography (OCT), Retinal Cyst Segmentation, Adaptive Thresholding, Image Processing, Morphological Operations, Computer Vision, Dice Coefficient, IoU.

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I. INTRODUCTION

1.1 BackGround: Optical Coherence Tomography (OCT) is a non-invasive way of imaging, but it enables a close-up look at the retina in the form of a cross-sectional image, thus enabling clinicians to study layers of the retinal structure and detect abnormalities. The Retinal cysts occurring in the form of dark spots topped with fluid in the OCT images are typical symptoms of such illnesses like Diabetic Macular Edema (DME) and Age-related Macular Degeneration (AMD). The manual procedures of segmenting the cyst are time consuming and subjective and there is the risk of lack of consistency and it is due to this that automated methods should be used. Automated segmentations are investigated in a number of different variants. Xu et al. suggested adaptive local thresholding with region refinement and Raja et al. introduced morphological filtering to complement the original method in cyst localization. The same morphology-based techniques were used by Soomro et al. to enhance the limits of the cysts.

1.2 Challenges: Deep learning models are now more precise, but very expensive in regard to large datasets of labeled data and processing resources. Conversely, classical image processing algorithms such as adaptive thresholding are easy and understandable and are efficient.

1.3 Objective: The aim of the current research is to come up with a generalizable, adaptive threshold based segmentation algorithm that could be applied to enhance image contrast, reduce noise and isolate cystic regions without any sophisticated training or large datasets. The methodology focuses on the degree to which it is clear and efficient in computation in addition to offering a consistent base of subsequent hybrid or learning-based enhancements.

II. METHODOLOGY

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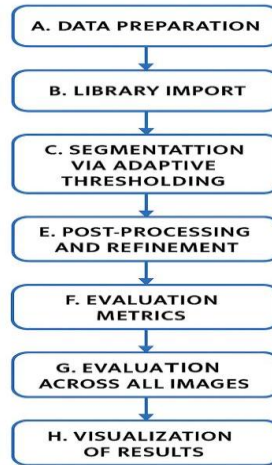


Fig2.1: flow chart of cyst segmentation

The segmentation pipeline proposed consists of three key steps, namely, pre-processing, segmentation, and post processing. It was written in Python and tested on OCT B-scan images and provided ground-truth masks.

2.1. Data Preparation

The data was in OCT images and binary cyst masks, which were classified into individual folders to allow systematized access. This provided proper image-to-mask matching on segmentation and assessment in Jupyter Notebook.

2.2. Evaluation Metrics

The quantitative performance of the segmentation method was assessed by two performance measures that are common:

- **Dice Coefficient (D):**

$$D = \frac{2 | A \cap B |}{| A | + | B |}$$

and A is the ground truth mask, and B is the predicted mask..

- **Intersection over Union (IoU):**

$$IoU = \frac{|A \cap B|}{|A \cup B|}$$

The values of both measures fall between 0 and 1 with higher values approaching 1 meaning more similarity between the predicted and actual cyst regions. Dice measures and IoU differ in that dice measures are less strict in the evaluation of segmentation performance whereas IoU is the more strict.

2.3. Segmentation via Adaptive Thresholding

Local adaptive thresholding was performed to deal with the illumination variations. The local mean intensity in a 35x35 window was determined on each pixel and an offset of 10 was taken in order to determine the threshold. Pixels that fell under this value were considered cysts resulting in a binary mask that identified possible cystic regions.

2.4. Pre-Processing

OCT images are typically characterized by speckle noise and low contrast and cyst boundaries may be obstructed. In a bid to overcome this, a number of pre-processing phases had to be undertaken in a serial manner:

Contrast Enhancement (CLAHE):

Local contrast was enhanced by Contrast Limited Adaptive Histogram Equalization which re-distributes pixel intensities locally (tiles) in small image blocks. Such an approach improves the visibility of dark cystic areas and inhibits the amplification of background noise.

Noise Reduction (Median Filtering):

A 3x3 median filter was used to reduce the effects of speckle noise and retain the edges. The median intensity of the neighborhood of each pixel was used to replace it, making sure that it did not change cyst boundaries so that they could be segmented. A combination of these operations resulted in cleaner, higher contrast images and cystic regions became more discriminative to threshold-based segmentation.

2.5. Post-Processing

Morphological operations were used to improve results: Opening: Cysts were left intact and small noise patches were removed. Small Object Removal: Removed pixel area false positives. Hole Filling: Seals empty areas in cystic regions in order to enhance the continuity of shapes. These enhancements resulted in smoother and more precise cyst margins.

2.6. Comparison of All the pictures.

This entire pipeline of segmentation was repeated on all the available OCT-mask pairs. Each picture was calculated by dice and IoU scores and averaged to evaluate the performance of the model in general. Based on the results of the experiment on ten OCT images, the proposed adaptive thresholding approach had a mean **Dice coefficient of 0.179 and a mean IoU of 0.100.**

2.7. Visualization of Results

Qualitative performance was evaluated by showing side-by-side performance of the original OCT, ground truth, and segmented images. Dice and IoU scores bar charts also indicated that the model was consistent and which areas should be improved.

III. IMPLEMENTATION DETAILS

The segmentation system was realized based on a set of open-source Python libraries that were selected because of their high strengths and effectiveness in traditional computer vision activities:

3.1 Libraries Used :

OpenCV: for median filtering, morphological operations, and binary mask processing.

scikit-image: for adaptive histogram equalization (CLAHE), local thresholding, and morphological refinement.

NumPy: for numerical operations and matrix manipulations.

Matplotlib: It will be used to visualise the intermediate steps and final results of segmentation.

These libraries formed the basis of a modular, interpretable, and computationally efficient system of constructing the cyst segmentation system.

IV. RESULTS

Dice Coefficient and Intersection over Union (IoU) metrics were used to evaluate the segmentation performance- using these measures the overlap of the predicted and ground-truth cyst regions.

4.1 Table 1 — Quantitative Evaluation of Segmentation Results

Image	Dice	IoU
TRAINING1.tif	0.149	0.081
TRAINING10.tif	0.138	0.074
TRAINING2.tif	0.235	0.133
TRAINING3.tif	0.090	0.047
TRAINING4.tif	0.295	0.173
TRAINING5.tif	0.159	0.086
TRAINING6.tif	0.179	0.098
TRAINING7.tif	0.260	0.149
TRAINING8.tif	0.241	0.137
TRAINING9.tif	0.041	0.021
Average Dice:	0.179	Average IoU: 0.100

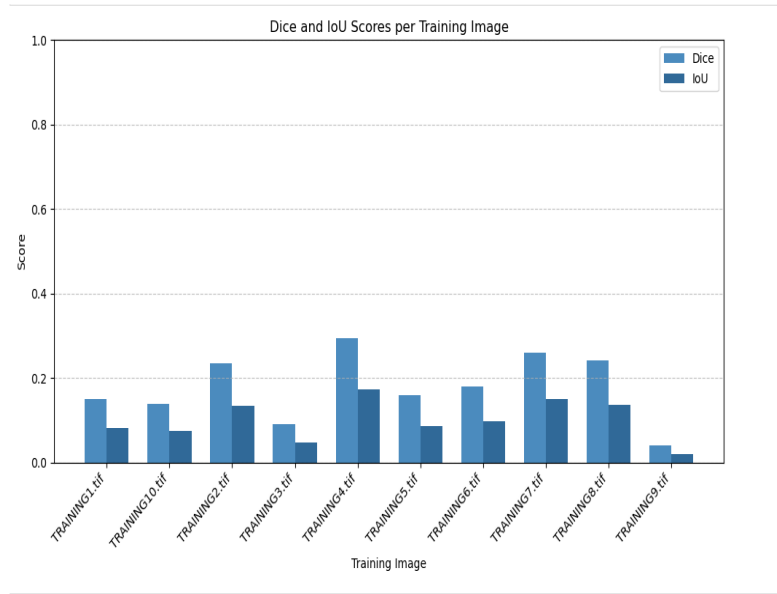


Fig4.2: Graphical representation of Dice and Iou result

V. DISCUSSION

5.1 Summary: These findings indicate that the adaptive thresholding approach was capable of identifying large cystic areas in OCT images with an intermediate level of accuracy with an average dice score of 0.179 and an intersection over union value of 0.100.

5.2 Strength: The large and visible cysts were well addressed using the technique, and the small or low-contrast areas, which are more difficult to distinguish, were not.

5.3 Limitations: One of the major advantages of this method is that it is easy to comprehend and modify all the steps in the processing, so it is easy to use as a standard scale in a research or clinical study. It is also light and fast, and it has a low amount of computational power in comparison with the models that use deep learning..

VI. CONCLUSION

6.1 Summary: In this report, an interpretable, lightweight method of processing images was shown with the purpose of segmenting retinal cysts on OCT scans.

6.2 Achievements: Adaptive histogram equalization, median filtering, and adaptive thresholding were used to result in automatic cystic region segmentation and automatic cystic region refinement through morphological operators.

6.3 Limitation: In even under-performing metrics (Dice 0.179, IoU 0.100), the system provides a defined, repeatable piece of groundwork to do further work involving the use of classical and learning-based methods..

REFERENCE

1. Xu et al., Retinal cyst detection in OCT images with adaptive local thresholding and region refinement, IEEE Access, vol. 8, pp. 12012025.
2. R. Raja et al., "Automated analysis of retinal cysts in OCT using traditional segmentation," Comput. Methods Programs Biomed., vol. 193, pp. 105426, 2020.
3. A. Soomro et al., "Macular cyst segmentation in OCT images using morphological techniques," Biomed. Signal Process. Control, vol. 59, pp. 101927, 2020.
4. K. Venhuizen et al., "Robust segmentation of retinal cysts in OCT using a fully convolutional neural network," Biomed. Opt. Express, vol. 9, no. 2, pp. 1122–1136, 2018.