Vessels segmentation in computed scans of lungs

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Abstract

Image segmentation is a remarkable feat of technology. It provides a reliable source to identify different objects or shapes in several spaces. This strongly suggests that the topological analysis of vessel structures can be employed in different fields of medical studies. There's a substantial amount of research that has to be done in order to further evaluate the automated process of image segmentation.

1 Introduction

1.1 Background

Image segmentation is a branch of computer vision which specializes in the efficient grouping of similar subgroups within a digital picture. The end result of this process is a simplified subset from the global collection of pixels: this shows that not every region contains a set of objects which are considered as a meaningful group with similar attributes.There are numerous techniques to begin with, many of which can't be objectively evaluated as they operate with different procedures. This paper will show a classical computer vision approach based on Otsu's thresholding method of variance [1].

1.2 Objectives

This study aims to obtain an accurate estimate of the location of the major vessels in the lungs. With this in mind, a heuristic-based outlook was adopted while calibrating the filters to the desired degree of filtering. This way of proceeding does not guarantee the segmentation of the minor vessels, as they are removed during the enhancement phase [Figure 1].

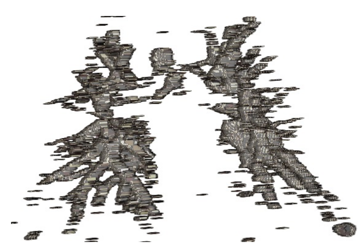

Figure 1: A 3D rendering of the final volume, only the major vessels are noticeable.

2 Materials and methods

2.1 Collected data

The scans were collected from anonymized image repositories of three hospitals and were used for the *VESSEL12* (VESsel SEgmentation in the Lung) challenge [2]. The broad and diversified dataset, which covers a wide range of patients with lung pathologies, has played a major role in choosing an automatic thresholding technique. This claim can be explained by the substantial differences in the scans, as many have different image qualities and contrasts. Moreover, each one of them contains objects of organic origin which could interfere with the image segmentation process. The data was processed by taking the individual two-dimensional slices from metal medical format images, which can be either visualized on two or three dimensions [Figure 2].

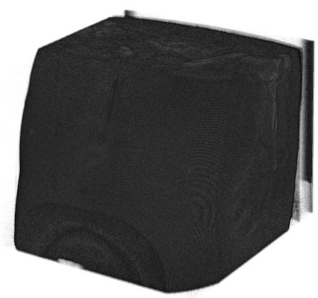

Figure 2: The *metal medical format* images can be 3D-renderized through MATLAB's volumeViewer application.

2.2 Proposed algorithm

2.2.1 Masking

First, the collected 2D slice gets filtered by removing the excess parts outside of the mask's boundaries. It is done doing a bitwise AND operation, affecting the image visibility without affecting the clarity.

2.2.2 Thresholding

The thresholding procedure may be divided into multiple phases :

1. In order to turn a grayscale image into a binary one, contrast enhancement is a must. The best results were obtained through *CLAHE* (contrast-limited adaptive histogram equalization) [3] : the image gets divided in 144 tiles and 256 histogram bins are used to build a contrast enhancing transformation.

2. Secondly, an average filter polishes the previous image, by smoothening out any minor branches.

3. Next, a bit wise subtraction is executed: the smoothened image subtracts the bits from the high contrast picture.

4. Finally, Otsu's algorithm applies to the result of the previous operation. It automatically determines the optimal threshold: the pixels above that value are ones, whereas the others are zeroes.

Otsu's method works by thinking of the image histograms as a set of two clusters obtained through an optimal threshold. It is obtained through the minimization of the weighted variance of these two classes denoted by [3]:

$$\sigma_w^2(t) = \omega_1(t)\sigma_1^2(t) + \omega_2(t)\sigma_2^2(t)$$

The weights $\omega_i(t)$ are needed parameters in order to evaluate the calculation of the weighted variance. They are obtained through the following formula:

$$\omega_i(t) = \frac{P_i(t)}{Pall}$$

$P_i(t)$ denotes the number of pixels identified as members of the i - class by using the threshold value t. The latter represents the optimal grayscale threshold computed through the analysis of the weighted variance. In this way, the intra-class intensity variance is minimized and the inter-class intensity variance is maximized [4].

2.2.3 Post processing

Last but not least, a morphological operator is applied to the result in order to fill the gaps between the detected vessels [Figure 3].

Figure 3: The picture before and after the algorithm. The post processing phase enlarged and filled the vessels.

2.3 Results

The results are obtained through a comparison of pixels from a set of ground truth images which were provided at the beginning of the research. The Dice - Sørensen Coefficient is used to compare the segmented vessels to the ground truth. It was calculated with the formula:

$$DSC = \frac{2TP}{2TP + FP + FN}$$

Where TP are the True Positives, FP the False Positives, FN the False Negatives [Table 1].

Scans	DSC
Scenario 1	0.758
Scenario 2	0.742
Scenario 3	0.724

Table 1: The results obtained from the comparison.

2.4 Observations

The algorithm is modest and has margin of improval. Uses may vary as it can be utilized for showing a more generalized shape of the vessels. Some morphological transformations would have been detrimental for its current use: thinning algorithms like Skeleton3D [5] or image erosion tools could have increased the number of false negatives. It is therefore possible to conclude that the choice itself lies on the use of the algorithm and on the design choices.

2.5 Recommendations

The study centered around the use and efficiency of a classic computer vision algorithm. Another point of interest could have been using multiple algorithms and comparing their performances relatively to this field of application. On the other hand, there's no real method of absolute evaluation, it all depends on the data set, the evaluated objects and the objectives of the study.

2.6 References

1. Anastasia Murzova, Sakshi Seth, *Otsu's thresholding with OpenCV*, 5th of August, 2020
2. Grand Challenge, *VESsel SEgmentation in the Lung 2012*, 2012
3. Muthukrishnan, *Method for image thresholding explained and implemented*, 13th of March, 2020
4. Umut Kuran, Emre Can Kuran, *Parameter selection for CLAHE using multi-objective cuckoo search algorithm for image contrast enhancement*, 4th of April, 2021
5. Philip Kollmannsberger, *Skeleton3D: Parallel medial axis thinning of a 3D binary volume*, September 2013