A Framework for Object Detection and Segmentation in Medical Images Using Arbitrary Shapes

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Abstract: *Detection and segmentation objects are crucial to extract useful information from medical images [1] and still challenging tasks in CAD software development. Due to the irregular structure and high variability of objects of interest, there is no universal solution for detecting objects and segmenting them in all kinds of medical images. This work is a part of a larger project aimed mostly at detection, coarse segmentation and visualization of given objects in microscope images. The purpose of this paper is to introduce a robust framework to facilitate detecting objects with arbitrary size and shape and segmenting them in different kinds of medical images with the help of a library of irregular smooth shapes.*

***Keywords*:** Medical image analysis, CAD, Object detection, Segmentation.

1. INTRODUCTION

CAD (Computer-aided diagnosis) is fundamentally based on highly complex pattern recognition. Detection and segmentation objects are important steps in CAD systems and also complicated and still unsolved problems in some sorts of medical images.

The aim of any segmentation method is to extract boundary elements belonging to the same structure and integrate these elements into a coherent and consistent model of the structure. Several common approaches to segmentation that have been recently used are thresholding, region growing, classifiers, clustering, Markov random field models, artificial neural networks, deformable models and atlas guided approaches. Although there are many approaches to the segmentation problem, most of them are applicable in cases that target objects are simple and obvious. Though in some cases like biomedical images that have sophisticated pattern the problem become more complicated and we may have to localize the target first and then segment it.

Taking advantage of efficient segmentation methods is crucial for developing computer aided diagnosis systems. Several approaches have been reported in literature for the segmentation of target objects in special kinds of medical images [2-4]. Target objects differ from nodules in CT images to mitotic cells in histology images. Since every kind of target objects in different images has specific structure and dealing with each kind of medical and biomedical images has their own complexities, there is no universal method applicable to all kinds of images and targets objects then most of previous works have focused on special target objects in specific images. So devising a flexible and robust method able to be applied to any kinds of medical images is still challenging task.

In this paper we proposed a flexible method to detection and coarse segmentation of target objects in wide variety of medical and biomedical images. The high degree of flexibility and adaptability of the method is ensured by the use of replaceable shape libraries and plug-ins (software modules) calculating different kinds of feature vectors of image regions confined by corresponding shapes.

2. METHOD

In order to detect target objects presented in input images, a library of irregular smooth shapes with different sizes were generated. Despite we use shape templates [5] we pay major attention to content of under shape area and also instead of deforming [6] we use reshaping utilizing pre-generated shape library. Shapes of this library are then used as a template to create a training set of target objects and to extract features of their internal structure. Multiresolution algorithm is used to avoid exhaustive searching. Several shapes regarding interested objects type from library are applied to promising positions of input images based on multiresolution algorithm to extract feature vector of underlying image area and to compare it with feature vector of training items. Fig1 demonstrates applying multiresolution algorithm while detecting of an object in main image. Fig 3 shows the structure of developed framework. After detection of ROI containing prospective target object with several shape candidates, the best fitted shape is selected which most accurately segment out the object.

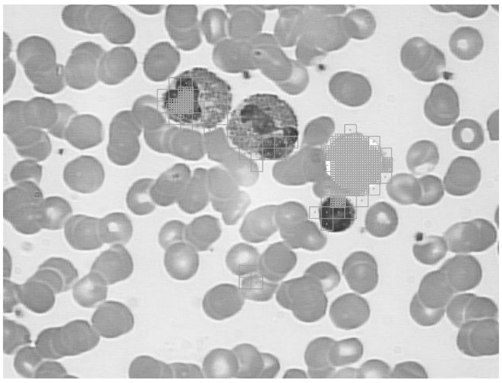

Fig. 1 - Using multiresolution algorithms while object detection

Procedure of coarse segmentation or selection of best fitted shape to target object is as follows: Let's consider T_1,.., T_m are the training set items feature vectors and C is the centroid of mentioned vectors and $V_1,\ldots,V_k$ are the feature vector of k areas of main image which are determined by arbitrary shapes of shape library and they are most similar areas within main image to target in term of feature vector similarity. Having each feature vector with n items, V_f is the nearest vector to C and the shape related to V_f is the most fitted shape. Distance of V_f and C is obtained via (1).

$$d(V_f, C) = \min\left\{\sum_{i=0}^{n-1}\left|(V_i)_j - C_i\right|\right\}, 1 \le j \le k \qquad (1)$$

Fig.2 shows localized and segmented target object in a histology image.

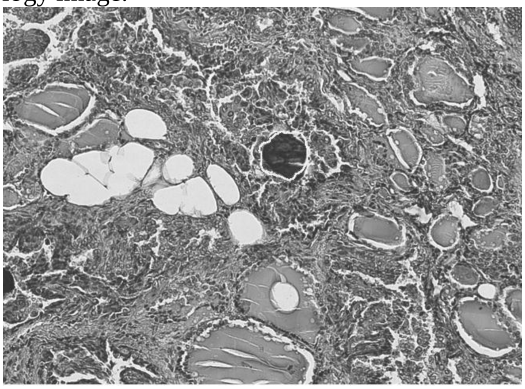

Fig.2 - localized and segmented target

2.1. Shape library

Regarding various target objects a library of smooth irregular connected shapes is generated and organized by shape generator module. Shapes of this library are generated automatically in multiple sizes and rotations. Each category of shapes in library was generated by some predefined template or they were generated just as random smooth irregular shapes. Generated shapes are used then as masks to set up training set items while training phase. They are also used to extract feature vector of underlying image area based on multiresolution algorithm and to compare it with feature vector of training items. Fig.3 shows some samples of shape library. The purpose of generating shape library is to simulate the behavior of active objects that are able to reshape and move on the main image searching target objects. Main advantage of using such library is that there is no need to reshape or deform active objects while run time and it decreases processing and time complexity. A simple method is used to generate irregular random smooth shapes. The instructions of shapes generation are as follows:

Step1: Randomly generate N points according to some template

Step 2: Join points by a thick line

Step 3: Apply Gaussian blur with a large σ

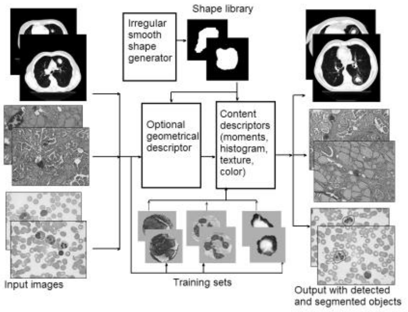

Fig. 3 - The structure of proposed framework

Step 4: Threshold with a permissive cut off

Step 5: Resize to create multiple sizes

Step 6: Rotate to create multiple rotations

Fig. 4 - Samples from shape library

2.2. Image descriptors

The following three types of image descriptors both color and gray-scale ones are implemented in the first version of the software: statistical moments re-scaled down to [0, 1], regional histograms, and texture descriptors. In case of statistical moment descriptor feature vectors of target and query area consists of three following components, Mean, standard deviation and skewness. Target area is a part of main image in other words it is underlying part of an arbitrary shape that is determined by user in training phase. In the other hand query area is also a part of main image or underlying part of an arbitrary shape that is determined by multiresolution algorithm during detection phase. We try to minimize the value of cost function which is shown in (2).

$$F = \alpha \times \Delta M + \beta \times \Delta STD + \gamma \times \Delta SK, \qquad (2)$$

where α, β and γ are coefficients, ΔM is absolute difference of target's mean color and current position's mean color which is determined by current shape of shape library, ΔSTD is absolute difference of target color's standard deviation and current position color's standard deviation. ΔSK is absolute difference of target color's skewness and current position color's skewness.

In case of histogram descriptor, to speed up feature extraction of target and query area we implemented 8 bit RGB color histogram. Since green and green shadows are rare in medical and biomedical images we used 3bit for Red, 2 bit for green and 4 bit for blue.

The texture was described with the help of generalized, third-order co-occurrence matrices recently introduced in [7]. Also we implemented optional geometrical descriptor for the cases when target objects are characterized mostly by their shape but not the internal content. For example in case of solitary pulmonary nodules (SPM) in lung CT images since there is no big difference between SPM texture and another regions in CT image. It is more convenient to detect SPM objects by geometrical features than texture features. While evaluation of above mentioned image descriptors in proposed framework we used and evaluated also the city block and the Euclidian distance similarity measures in our framework.

2.3. MATERIAL

The method is demonstrated on three different image types. Despite detecting solitary pulmonary nodules (SPM) in lung CT images is well-known as a hard segmentation task utilizing 3D, we have decided to include it into the experiments performed in the slice-wise manner even under condition the current version of software is 2D yet. This is to demonstrate flexibility, easy change-over, and some promising results which may complement existing methods.

The first test dataset consisted of 100 color images of white blood cells of 640x480 pixels in size containing all 5 types of white blood cells. The number of target objects (neutrophils) was 33 whereas the number of other white cells was 67. In the first dataset in addition to detection, segmentation and classification of target objects using proposed method, the efficiency of content based descriptors was evaluated.

The second dataset included 600 2D lung CT images of 60 patients. From each patient 10 slices with 4 cm mean gap were selected. The number of target objects in second dataset was 45 which belong to nodules greater than 1cm in size. A combination of geometrical descriptor with histogram descriptor was used to detection and segmentation of nodules.

The third dataset included 51 color histology images of 1024x768 pixels taken from thyroid gland tissue samples. The number of target objects in third dataset was 125 ROIs which belong to psammoma bodies. A texture descriptor was used to search and segment target objects using proposed method.

3. EXPERIMENTS AND RESULTS

In the first dataset, we have tried to detect and then segment and classify neutrophils in white blood cell images. We have run several experiments using proposed framework. Regarding time complexity using regional color histogram descriptor inside proposed framework was quicker than other descriptors. In case of detection precision, use of texture descriptor led to best results. Using mentioned descriptor, true positive rate was 0.97 and false positive rate was 0.04. Using texture descriptor as target and query images descriptor and city block similarity measure to compare target and query feature vectors had better results than using texture descriptor with Euclidian distance similarity measure. Fig.4 shows the evaluation of content descriptors and similarity measures in proposed framework in terms of ROC curves In second data set we have used mixture of geometrical descriptor and grayscale histogram descriptor to detect and segment nodules in lung CT images. Applying the method to the second dataset of CT images was led to detection and segmentation of 39 nodules out of 45. The object detection accuracy was 86.6% and there were also 20 false positives. Rather high amount of false positives in this dataset arises from 2D nature of images.

In third data set we have used texture descriptor in order to detect and segment nodules in lung CT images. In the third dataset of thyroid gland histology images, applying the method was led to detection and segmentation of 120 psammoma bodies out of 125 and also 10 irrelevant areas were detected as false positives. The detection rate in this data set was 96%.

4. CONCLUSION

Although the proposed method is in its early stage, it is promising enough as a potential tool for CAD.

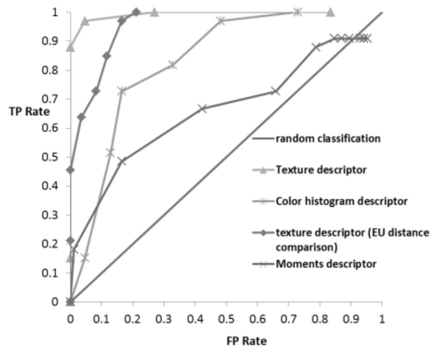

Fig. 5 - Results of white blood cells detection and classification

Depending on image type it has demonstrated the object detection accuracy ranged from 86.6% to 97%. The performance of framework is somehow dependent to training phase and shape library. Utilizing a large number of arbitrary shapes in multiple size and rotations will lead better results. Since proposed method is applicable to large variety of medical and biomedical images we need not only to a rich shape library but also combination of appropriate modules or proper configuration is necessary regarding specific kinds of images. In future works we will try to include 3D medical images in current framework and also we will implement active objects that are able to move and reshape automatically and also they will be able to localize and fit target objects based on some criteria. Then we will evaluate the performance and accuracy of current framework and future framework.

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