Survey on Assessment of Carotid Arteries Using Various Segmentation Techniques

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Abstract: In digital verbalization, image segmentation is the process of segregating digital image into numerous sectors (sets of pixels, also known as super-pixels). The aim of segmentation is to reduce or change the portrayal of an image into something that is more consequential and clear to analyze. In many medical imaging applications, it plays an important part by robotizing or promoting the delineation of anatomical morphology and other zones of significance. Making accurate segmentations is an uphill struggle when there is an existence of high levels of speckles in ultrasound images. Ultrasound is also often employed in detecting pathology using textural classifiers but zones of significance are normally determined through human interaction. Due to immense signal noise and artefacts that generate interruptions in the edges and shadows that shield components of the received signal, segmentation in ultrasound (US) images is a threat in machine vision. In this paper, survey of various algorithms and methods required for segmenting, carotid arteries in particular are described in detail.

Index terms: segmentation, carotid arteries, active contours, CULEX, Evolutionary scheme, method development and evolutionary technique, ultrasound

1. Introduction

The primary objective of the segmentation technique is to split an image into sectors that are alike, concerning one or more quality or features. Segmentation is a significant job in medical image processing and it has been advantageous in many operations.

The applications comprise of tracking down of the coronary boundary in angiograms, collective sclerosis lesion determination, surgery simulations, surgical outlining, gauging tumor dimensions and its vibes to treatment, functional mapping, mechanical analysis of blood cells, examining brain augmentation, tracking down micro solidification on images. Different hypothesis about the features mammograms, image alignment, atlas-matching, heart image extraction film cardiac cine angiograms, tracking down tumors, etc.

Segmentation plays a vital role in medical imaging for feature separation, image valuation, and image demonstration. In a few applications, it may be effective to organize image pixels into anatomical parts, such as bones, muscles, and blood vessels, while in others into pathological vicinity, such as cancer, tissue abnormalities, and collective sclerosis lesions. In several studies, the objective is to isolate the complete image into sub arenas such as the gray matter, white matter, and cerebrospinal fluid areas of the brain, while in others single definite anatomy has to be separated, for instance breast cancers from magnetic resonance of the analyzed images lead to the adoption of distinct algorithms. Segmentation techniques can be branched into classes in varied ways, relying on classification schema:

- Manual, semiautomatic, and automatic.
- Pixel-based (local methods) and region-based (global methods).
- Manual delineation, low-level segmentation (thresholding, region growing, etc.), and model-based segmentation (multispectral or feature map techniques, dynamic programming, contour following, etc.).
- Classical (thresholding, edge-based, and region-based techniques), statistical, fuzzy, and neural network techniques.

A variety of segmentation methods has been discussed in this paper. The terminology of the aim of segmentation differs according to target of the study and the sample of the image input.

This paper is framed as follows: Section 2. Reports a brief description for the need for carotid artery segmentation, Section 3. discusses the different algorithms used in segmentation process with the condensed explanation of the same and finally, concluding the survey on various segmentation algorithms in Section 4.

2. Need for Carotid Artery Segmentation

During the medication of the subject under examination, circumscribing or demarcating organs
and more precisely the carotid artery or plaque is a critical task. However, allowing the human to handle the responsibility of segmentation is laborious, tiresome and deteriorate from intra- and inter-observer inconstancy. In order to pull off the above duty, advanced approaches are therefore essential.

In detecting susceptible atherosclerotic plaques exposed to rupture provoking stroke and in robotic interpretation of arterial disease severity, segmentation of carotid artery lumen in two-dimensional and three-dimensional ultrasonography is an influential step. Interactions between observers and the computer segmentation process is unavoidable due to the entanglement of anatomical structures and noise in conjunction with the need of detailed segmentation.

Specific assessment and understanding of the geometry of carotid arteries are crucial in executing and estimating the possibility for stroke. The prevailing schemes for the measurement of a disorder sternness in the carotid arteries involve DSA and/or duplex Doppler ultrasound. Tracking the development of carotid atherosclerosis is a vital task and depends upon the specific aspect of the vessel wall and plaques for patients who still have not been diagnosed with carotid endarterectomy. In either case, proper evaluation and scrutiny of vascular geometry and plaque examination depend upon reliable explanation or separation of lumen, plaque and carotid wall boundaries. Physical zoning of the lumen by human observers requires considerable understanding is tiring and is prone to instability.

3. Different Carotid Artery Segmentation Methods

A. Segmentation Using Active Contours:

A completely mechanized method for segmentation and recognition of carotid-arteries (CA) for the sake of enumerating varied influential characteristics such as intima media thickness (IMT) measurement and distal (far) wall segmentation is brought out here.

The suggested approach involves getting rid of the noise from the input ultrasound image using anisotropic filter and histogram equalization is used to enhance the denoised image, followed by extracting features from carotid artery ultrasound image taken as an input. Active contour algorithm is adopted for image segmentation then the IMT values are determined for the image and finally classification for the same is done by using SVM neural network.

Active contours, also called as snakes, are used largely in machine vision and image processing applications, explicitly to track down the object boundaries. Active contours, are loops described within the realm of an image that is able to navigate concealed by the impact of internal strength impeding from within the loop itself and exterior forces calculated from the image data. The main intention is to derive a curve or a surface concealed by constraints from image forces so that it is magnetized to characteristics of interest in an intensity image.

This technique has employed active contour to segregate the carotid artery ultrasound images in a robotized way. Using this technique, the intima-media thickness of the input ultrasound image is calculated as shown in the figure 1. This method is an asymptotic and sensitive technique for diagnosing and computing the existence of plaque in the carotid artery.

![Figure 1. (a) Original Image (b) Far wall and Near wall Segmentation](image-url)
B. Segmentation Based on Completely User-Independent Layer Extraction (CULEX) Algorithm:

In recent past, a Completely User-Independent Layers Extraction (CULEX) algorithm for the segmentation of the distal border of the common carotid artery (CCA) has been developed. The algorithm completes the detection of the Lumen Intima (IL) and of the Media–Adventitia (MA) interfaces originating from the input ultrasound image in DICOM pattern, without the obligation for any user cooperation. Both the Region of interest (ROI) detection and the interface segmentation are automatic and do not depend upon the choice of thresholds or image regions. Hence, this approach also suits the completely user independent segmentation of substantial number of ultrasound images, which consists of patients database.

CULEX was created in order to administer for distant wall CCA segmentation, since evaluation of the intima–media thickness (IMT) on the distal wall are more stable than estimation performed on the proximal wall which is because of the certainty that the geographical region of an interface may be finely described only if there is expanding acoustical impedance. Otherwise, backscattered reflections developed from the immense-impedence formations may shadow the minor impedance anatomi trailing them.

Since the algorithm was constructed in order to make it completely automatic, the initial phase of the algorithm is the determination of the fragment of the image where the CCA unicae are stationed (ROI selection). The vessel lumen is symbolized by pixels with low-intensity and proportionately low variance is surrounded by large-intensity pixels associated to the carotid walls, is one of the fact that has been exploited in this algorithm. Starting from the inmost imaged layers of the scan, the elemental concept is to explore for major-intensity pixels probably associated to the far adventitial wall.

The fundamental steps of the CULEX algorithm are described/below [3]:

1) low-pass filtering of the image (Gaussian filter of the 50th order, standard deviation equal to 10) in order to increase signal-to-noise ratio;

2) determination of the adventitial wall from the intensity profile of the image expressed column wise.

3) Individuation of the carotid lumen as the minimum point on the intensity profile whose mean intensity and variance of the neighborhood belong to the lowest classes. The minimum is searched, descending the intensity profile from the maxima found in step 2). When the minimum is reached, the corresponding point is taken as the marker of the carotid lumen and the starting maximum as the marker of the adventitia;

4) iteration of steps 2) and 3) for all columns

The CULEX algorithm can be effectively used for the segmentation of ultrasound images of the CCA wall as shown in figure 2. The advantage of this algorithm is that it is completely automatic. The raw ultrasound image in DICOM format can be handled without any user interaction. A feature of the algorithm revealed that the contour outlined by the CULEX is analytically commensurable to that of a human trained operator.

![Figure 2. Example of CULEX segmentation and of the 95% CI. The white line represents the IL border; the dashed white lines represent the IL 95% CI. The black line represents the MA border; the dashed white lines represent the MA 95% CI. In this example, 100% of the pixels fall into the CI.](image-url)

C. Segmentation Using Method Development:

A method for the assessment of segmentation algorithms that confesses computation of both the certainty and viability emerging from the user interaction variability is described. A Contour Probability Distribution (CPD) function to measure the completion of the algorithm with varied choices of seed area s imported. All the regional and universal metrics essential for the algorithm optimization process and the final evaluation is
contributed by the CPD. The evaluation technique stands unique from other approaches in [2]:

(1) Addressing interactive situations
(2) Providing complete local and global variability and metrics for evaluating the performance
(3) Introducing a new method for optimizing algorithms.

The segmentation procedure need only single seed point for computing the deformable contour. The justification for using one-seed point initialization is established on the certainty that the users can effortlessly determine the vessel, i.e., the proximate midpoint of the lumen, while choosing the numerous seed points on the boundary is not mandatory in maximum cases and thus less productive. The choice of a single seed point normally contribute significant information, for instance local mean gray level value, standard deviation of gray level values and other analytical, needed by the segmentation process. The selection of feature to analyze forces to deform or impede the/contour in deformable model is one of the significant drawback. To evaluate the optimal contour many deformable model based techniques search for the maximum gradient. Similarly, this technique also considers the gradient as the driving force, but a desired gray level contrast between the inside and outside of the contour is explored, as opposed to a maximum gradient path. To focus on the initialization, as opposed to the control of forces is the objective here. The intent is that the initialization method should be able to entertain noise, artefacts and few uneven lumen shapes. The initial contour should be adjacent to the chosen boundary and no external force is needed.

The deformable model that can be seen in figure 3, combines global geometric constraints, image gradien and contrast/features to optimize the segmentation results. The initialization is a four-step procedure [2]:

(i) Computing the entropy map,
(ii) Initial circle matching,
(iii) Thresholding the entropy map into a binary image with the initial circle,
(iv) Using the Euclidean Distance Map (EDM) to process the binary image.

D. Segmentation in Ultrasound Image based on Evolutionary Scheme:

To enhance the parameters that define such an ellipse, a strategy based on an evolutionary algorithm is adopted. It is a unique technique established on the geometric features of the artery, which takes up elliptical shapes. This technique segments the artery more precisely compared to other models. The optimization of the seed ellipse features is done with an evolutionary optimization technique. Because of the immense computing cost of the evolutionary models, it uses vast coordinated architectures and modern complicated algorithms to implement the segmentation in a feasible time.

A prominent stochastic technique is a basic for this scheme. Storn and Price has designed a technique based on an evolution scheme to determine optimal features in a subset of the solutions space, named differential evolution (DE) which demonstrates that functioning on low-structured problems yields a good performance. The goal of evolutionary scheme is to determine the parameters of a given ellipse that more appropriately fit in the boundaries of the artery. The solution to this optimization problem is using DE to obtain the parameters \((x_c, y_c, a, b, \theta)\) which defines an ellipse.

A segmentation method based on an evolutionary method best describes the edges of the artery. It also shows that the edges of the artery can be computed efficiently by making thorough use of a GPU platform as seen in figure 4. This technique
outperforms other methods, in terms of accuracy and also, it does not depend upon any kind of practice also it supports huge search areas which is an outstanding remark, unlike ASM or parametric snakes which needs to be initialized close to the solution.

Algorithm: Differential evolution (DE) pseudocode implementation [5].

1) Population = InitPopulation(MaxPar,MinPar);
2) FitPop = GetFitness(Population);
3) BestAgent = GetBestAgent(Population);
4) while (NumIter < NumIterMax)
5) MutPop =Mutate(Population,BestAgent,F);
6) CrPop = Cross(Population,MutPop,CR);
7) FitCr = GetFitness(CrPop);
8)Population=Replace(Population,CRPop,FitCr,Fi tP op);
9) BestAgent = GetBestAgent(Population);
10) NumIter = NumIter + 1;
11) end while
12) return BestAgent

Figure 4. Some results obtained with the proposed method in different patients.

4. Conclusion

The survey summarizes the four well known segmentation techniques for carotid arteries which have their own pros and cons. Active contour model are self-governing in minimal energy state and hence, can easily be employed which can be used to detect objects in both spatial and temporal domains. The method development contributes an integrated set of global and local metrics that can be used for evaluating efficiency and instability in the segmentation results. The Evolutionary scheme is a parameter independent and does not depend upon any initialization estimation unlike other techniques, also it’s a method with excellent performance gain which is solved in a feasible time.

Future groundwork in medical images segmentation will work towards achieving the accuracy, precision and processing speed of segmentation techniques, as well as decreasing the amount of human interactions. Accuracy and precision can be improved with the combination of discrete and continuous-based segmentation techniques and also by considering prior information from atlases. Computational efficiency, multiscale processing and parallelizable methods can be increased by taking advantage of neural networks. Use of Image segmentation have utmost importance in clinical settings hence, computerized segmentation is already in vogue by demonstrating their use in research applications and therefore computer aided diagnosis and radiotherapy are becoming popular. Automated segmentation methods replacing physicians is a contrary but they will likely become vital elements of medical image analysis therefore always there is a scope for advanced and economical medical image segmentation techniques.

References


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