Optimizing Active Contour Evolution for Robust Object Segmentation in Medical Imagery

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Abstract: In image processing, Segmentation means to partition a digital image into multiple regions. Active contours, or snakes, are computer-generated curves that move within images to find object boundaries. These models can provide smooth and closed contours as segmentation results. With the development of modern computer technology and digital medical equipment, medical image has become an important means for clinical doctors to diagnose diseases. It is difficult for a doctor to manually interpret and understand an image, an image may contain more information as compared to required one. It requires more time to manually interpret an image as well as the interpretation remains subjective to previous knowledge. For a focused investigation, the clinician is always interested in a particular object or an ill organ (brain, bones, vessels). The goal of this research is How to improve segmentation for robust extraction of object of interest for a detailed analysis? Accordingly, we will propose an improved segmentation method and test this for a variety of objects including synthetic and clinical imagery.

Keywords: *Image segmentation, active contour models, object contour detection, global region-based segmentation, localizing region-based segmentation, MATLAB.*

1. Introduction

Image processing is a technique which is used to derive information from the images. It has many applications in the areas of medicine, photography, security monitoring etc. Image segmentation, which is a branch of image processing, is a procedure of dividing an image into multiple sections in order to analyze an image and to study about an image. Innovative and new technologies are rising in many or all areas of image processing especially in domain of image segmentation. The proficiency of segmentation methods is their speed, perfect shape matching and good connectivity with results of segmentation [1,2]. Image segmentation has various applications in medical imaging processing. It helps in segmenting particular object or ill organ from an image. There are many techniques used for segmentation of desired objects from image, among them one of the most popular and widely used method is active contour model. Active contour model or snake [3] introduced by Kass and his coworkers is an energy minimization spline instructed by internal and external forces that move it towards the boundary of an object. These are computer generated curves that moves within an image to find object contour. In medical image processing, active contour model is used to segment regions of interest from different medical images such as MRI images, CT scan images, cardiac images and different images of organs or regions in human body [4]. Snakes do not solve an overall issue of finding contours of objects, since this method requires knowledge of desired object contours in advance. Therefore, this method requires modification. Medical image is an important mean for doctors to diagnose diseases. Health of a person is a conscious issue; therefore, it requires large interpretations and perfect decisions regarding any phenomena of human body. Human body is a composite structure. Segmentation of these complex structures is an important step for morphology detection, for the purpose of studying in temporal changes, estimating volume for object of interest, visualization for planning surgeries. Cost effective segmentation system for medical images with better results can help doctors/medical practitioners for fast detection and study of brain tumor, fracture etc.[5]. An image may contain more information as compared to required one. In cardiac CTA, brain MRI, object of interest comprises of 2% of image data, while 98% of information is considered as background [6]. For the purpose of investigation or interpretation it is better to segment that 2% of information while suppressing 98% background.

2. Related Work

Main function of an active contour model is to capture desired object contour. Its energy functional is sum of internal and external forces. Internal force is responsible for smoothness of curve, pull it towards edges, while external forces are due to gradients of an image, edge is detected if energy is minimized where magnitude of gradients are high. During minimizing their energy, contours slither, has been called as snake. Position of snake is represented parametrically by u(s)= x(s), y(s), hence the energy function is:

$$\mathrm{E(s)} = \int_0^1 E(s)\, u(s) ds$$

$$= \int_0^1 \mathrm{E_{int}} u(s) + E_{img} u(s) + E_{con} u(s) ds$$

where $\mathrm{E_{int}}$ represents internal energy, E_{img} represents image forces, E_{con} rises external constraint forces.

For specifying image contours interactively, snakes have been proven useful [3]. In order to minimize diagnostic

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errors, precise detection of abnormality is extremely essential. The variations in sizes and shapes of different types of tumors are quite complex. The presence of tumors at different locations in human body with different intensities make detection and segmentation of tumor from CT scan image, ultrasound image, MRI image extremely difficult [7]. Active contour model is difficult to use when the edges of features are noisy, weak and diffuse. It has tendency to get distracted and got trapped by nearby features [8].

The major drawback of this model is the existence of local minima in active energy functional which makes initial curve or guess confused or critical for getting satisfactory results [9]. Tony F. Chan and Luminita A. Vese proposed another model based on Mumford-shah functional for segmentation[10] to detect objects from an image. They proposed a different active contour model which is not based on the gradient of the image. They worked on an idea of region-based segmentation model that can detect objects by dividing image into two regions and define energy minimization by considering “fitting term”. The fitting term is minimized only in the case when the curve is on the boundary of the object [11]. Shawn Lankton and Allen Tannenbaum proposed a framework that converts region-based segmentation into a local mechanism. In this framework background and foreground are described in local small regions [12].

For image segmentation, there is much to upgrade. Active contour models have acquisition to segmentation of images and more advantages, but limitations or disadvantages are also present such as dependency on initial points of contours[13]. Simple yet efficient methods are those that can demonstrate their efficiency for object segmentation, any method that can be combined with active contour model which achieves better overlap with manual annotations[14]. The main conclusion from this work is that there is no ideal segmentation method, it is important to observe that an efficient segmentation method should necessarily add some level of intrinsic knowledge to the model for the target of solving focused problem domain[15].

3. Methodology

There are two techniques used for active contour model; edge-based segmentation technique, region-based segmentation technique. For edge-based segmentation, image gradients are utilized to find desired object contour. Energy functional is minimized only in the case when the curve is on the boundary of an object, where magnitude of image gradients is high. Region-based segmentation works in different manner. This method divides an image into two regions and define energy minimization by considering “fitting” term. The energy functional calculate means of these two regions, subtract each pixel from that mean and add the results of both regions. Curve is on the contour of an object when the sum equals to zero, means no fitting error. The fitting term is minimized only in the case when the curve is on the boundary of the object. This technique is usually not ideal for segmenting heterogeneous objects. In cases where the object to be segmented cannot be easily distinguished in terms of global statistics, region-based active contours may lead to erroneous segmentations. Solution for segmentation of heterogeneous objects is a framework that allows region-based segmentation energy to be re formulated in a local way by repeating this process at each point along the curve. To compute these local energies, local regions are required. To generate local regions, local neighborhoods are split into local interior and local exterior. Area of these regions are decided through radius parameter. There are no any criteria is present yet that can help for the selection of radius. Each image has different factors such as different object sizes, multiple objects, variations in background, shades, noise etc. Medical images such as CT scan images, MRI images have many details present at small distances or objects are present very close to each other.

It is difficult to segment desired object from those images. If we want to segment tumor from brain MRI image , it is required to put proper radius for segmenting tumor contour from an image as more radius means going towards global region based segmentation which is not effective for such kind of images as proposed model could get distracted due to different object boundaries, curve can collapse in multiple objects or variations in background. For the purpose of accurate segmentation, it is required to select proper radius. For selecting proper radius, we used bounding box which is a rectangle around an object. It is a property of MATLAB function “Regionprops” which defines co-ordinates of a rectangular border that fully encloses an object over an image. It gives details of upper left corner along with width and height of an area or object inside this box.

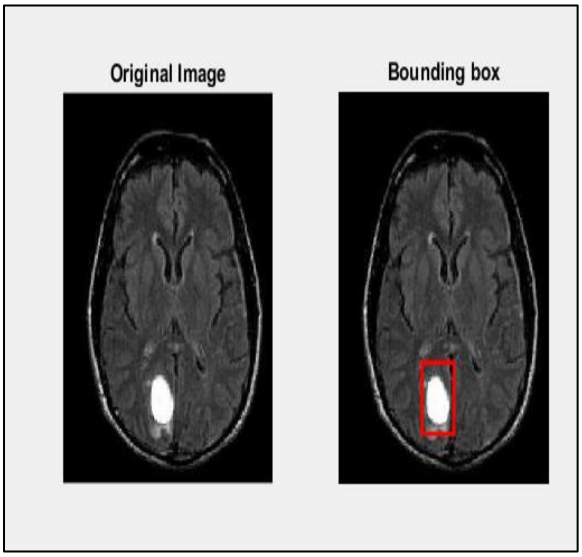
The procedure for choosing accurate radius has following steps:

- Compute size of an image
- Draw bounding box around desired object .
- Compute ratio of size of an object vs size of an image.

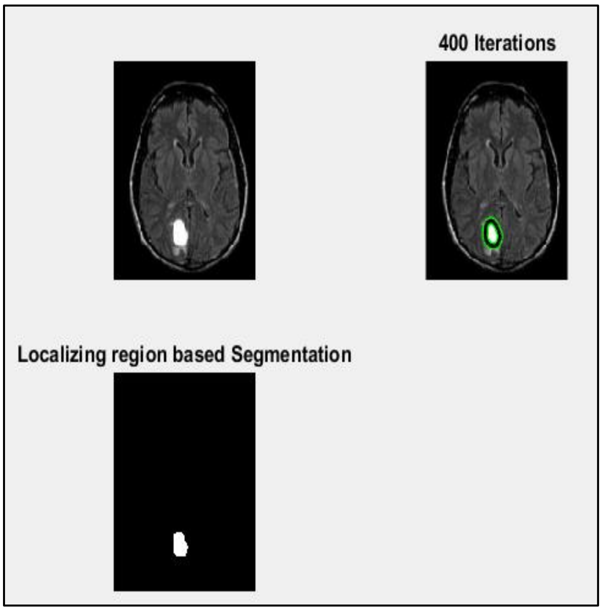
Predict radius based on that ratio. If ratio is in small range, then choose small value of radius; if ratio is in medium range, then choose values that are not so high and not so low; if ratio is in high range, then choose large values for radius.

4. Results and Discussion

We have tested this method on different images including synthetic, real time and medical images. We have designed a MATLAB based framework to perform all steps described above for the purpose of predicting correct radius values to segment desired object. We took different medical images, one of them is brain MRI image. For segmenting tumor from that image. First, we compute size of this image that is 320x257. In order to segment tumor from that image, we draw a bounding box around that tumor and find the size of this object that is 52x64. Then we compute ratio of object size vs image size that is 0.1, 0.2. Based on these calculations, it is obvious that object size is smaller with respect to image size. We choose small radius value for segmenting tumor from that image.

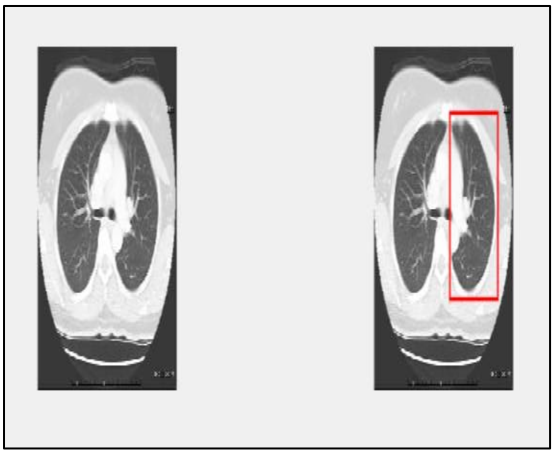


(a) bounding box around desired object

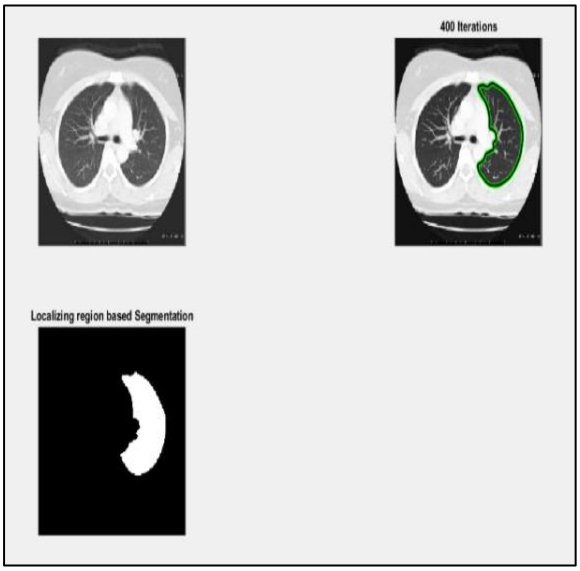


(b) Segmented tumor image with radius 2

Fig 1. Segmentation of tumor from brain MRI image using localizing region-based segmentation.

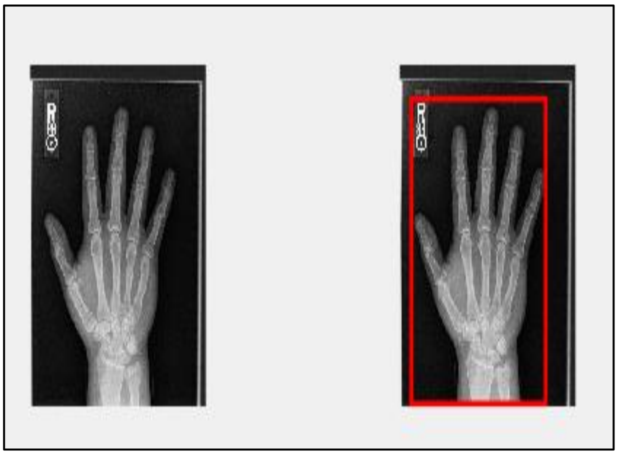


(a) bounding box around right lung

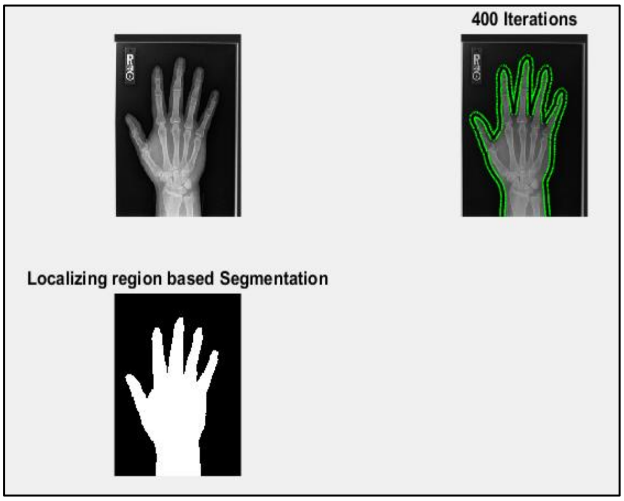


(b) segmented right lung image with radius 4

Fig 2. Segmentation of right lung from CT scan image of lung having image size 358x400, object size 138x194, ratio 0.38.0.48.



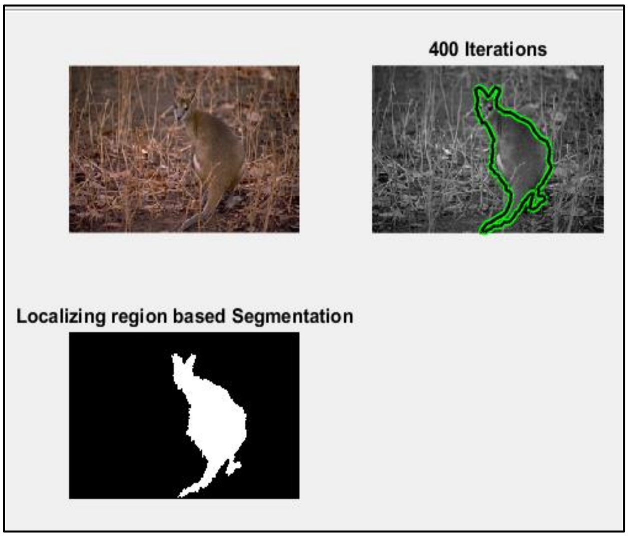
(a) bounding box around hand



(b) segmented hand image with radius 14

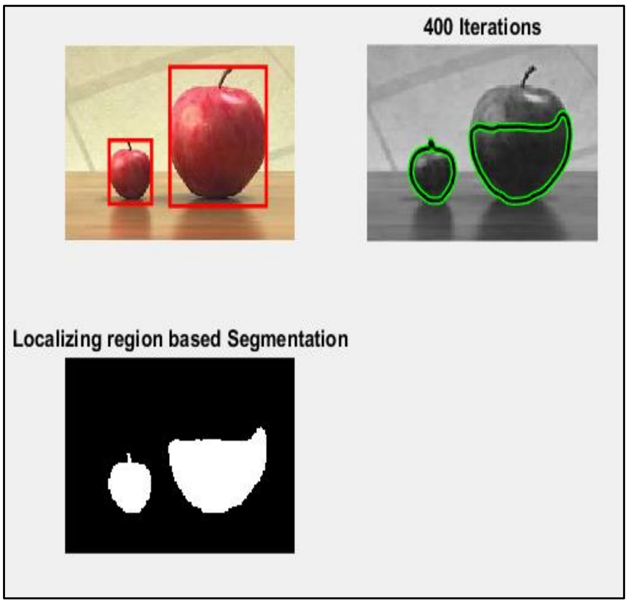
Fig 3. Segmentation of hand having image size 512x506, object size 310x457, ratio 0.6, 0.9.

(a) bounding box around animal

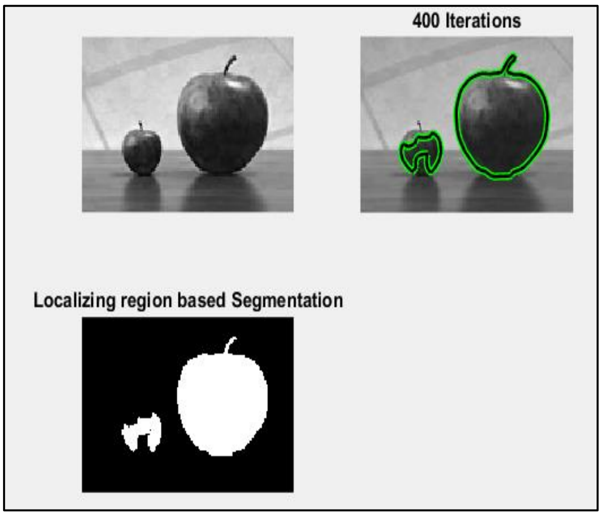


(a) segmented image of animal with radius 8

fig 4. segmentation of animal from real time image having image size 324x481, object size 182x286, ratio 0.5,0.6.

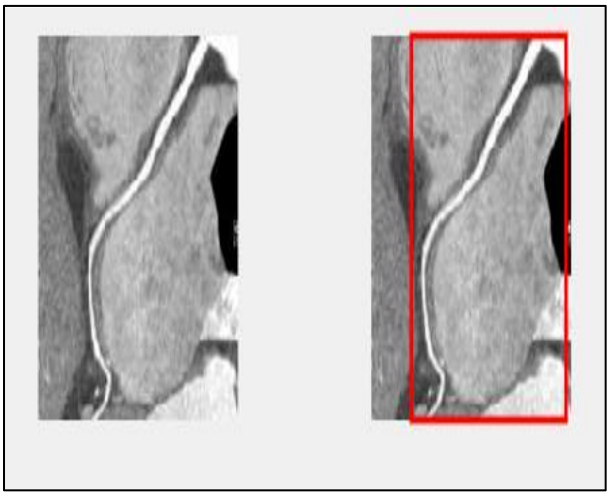


(a) segmented image of two apples with bounding box around each apple, radius 2.

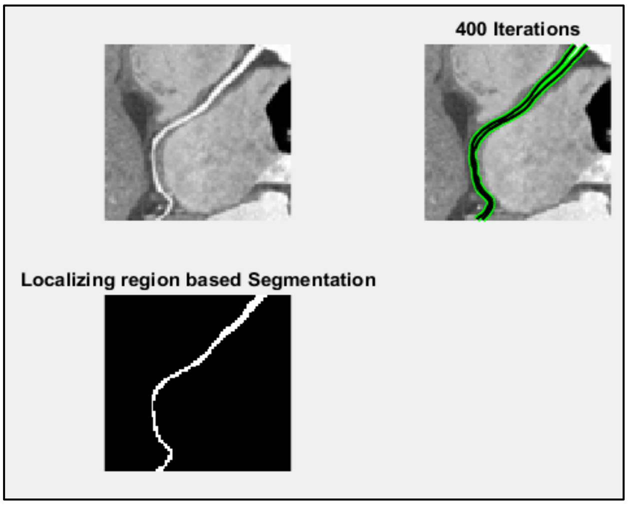


(b) with radius 8

Fig 5. Segmentation of two apples, one is small, one is large with different radius values.



(a) bounding box around right coronary of CTA(computed tomography angiography) volume 01.



(b) segmented right coronary.

Fig 6. Segmentation of right coronary of CTA volume 01.

Table.1. Results of segmentation using localizing region-based segmentation for different images including synthetic, real time, medical images.

#	Image name	Image size	Object size	Ratio	Radius 2	Radius 4	Radius 8	Radius 14	Radius 18	Radius 28
1	**MRI.jpg**	320x257	52x64	0.1,0.2	✓	X	X	X	X	X
2	**Lung.jpg**	358x400	138x194	0.38,0.48	X	✓	X	X	X	X
3	**Hand.png**	512x506	310x457	0.6,0.9	X	X	X	✓	X	X
4	**Vessel.bmp**	110x111	99x110	0.9x0.9	X	X	X	✓	X	X
5	**Ctscan.jpg**	800x688	227x230	0.2,0.3	✓	X	X	X	X	X
6	**FElbow.jpg**	648x195	488x100	0.8,0.5	X	X	X	✓	X	X
7	**Vessel3.bmp**	103x131	98x110	0.9,0.8	X	X	X	✓	X	X
8	**FElbow2.jpg**	526x650	374x101	0.7,0.12	X	X	✓	X	X	X
9	**Animal.jpg**	324x481	182x286	0.5,0.6	X	X	✓	X	X	X
10	**SApple.jpg** **LApple.jpg**	183x276	51x61 116x131	0.3,0.2 0.6,0.5	✓ X	X X	X ✓	X X	X X	X X
11	**Lemon.jpg**	233x216	85x85	0.4,0.4	X	✓	X	X	X	X
12	**Monkey. png**	240x320	183x215	0.8,0.7	X	X	X	✓	X	X
13	**Coins.png** **MCoins.png**	246x300	60x56	0.2,0.18	✓ X	X X	X X	X X	X X	X ✓
14	**RCACPR.jpg**	313x409	197x309	0.6,0.75	✓	X	X	X	X	X
15	**CPR.jpg**	156x160	120x156	0.76,0.97	✓	X	X	X	X	X

5. Conclusion

This method has been tested on various images. The results are demonstrated in table 1. By following procedural steps described above, it is obvious that those images where ratio between image size and object size is in small range as 0.1 to 0.2, radius 2 works perfectly. Images have ratio in range 0.3 to 0.4 radius value 4 helps in robust segmentation of desired object. Images have ratio in range 0.5 to 0.6 radius value 8 gives better results. Images have ratio from 0.7 and so on radius value 14 and further high values work good for robust segmentation of required object contour. Some drawbacks are also found as images named as “RCA_CPR” and “CPR” in table 1 have ratio in high range as 0.8 to 0.9. Bounding box drawn around right coronary as shown in fig6 (a), occupies large space; therefore ratio between image size and object size is in high range but vessel inside an image which lies among several objects contains small size and low level of details but it is spread over large area in curve form, that’s why width and height of bounding box has high values but to segment this right coronary, radius value 2 works good as vessel itself contains small area inside an image.

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