Fast and Improved Level Set Method for Image Segmentation

Bibin Varghese, Shany Jophin

Abstract— In recent years, image segmentation algorithms are widely used for segmenting the image into different parts which can be used for further analytical purposes. Nowadays, many applications such as iris segmentation for authentication, brain tumor detection and number plate segmentation uses different segmentation methods. Among them level set methods emerged widely due to its efficiency in handling the change in the topology of images. For solving the level set equation, the conventional level set methods uses some finite approximations schemes for providing numerical stability. These schemes take lot of time for the curve to evolve. This problem is tackled using the lattice Boltzmann method (LBM). In this method, a fuzzy energy function based on fuzzy c-means objective function is minimized using the gradient descent method to create the level set equation and LBM is used to solve the level set equation in order to provide parallel programming. The proposed method is insensitive to the initial position of the contour. This method easily detects brain tumor, segmented iris and character from number plate of vehicle is selected.

Index Terms— Brain tumor detection, energy minimization, fuzzy c-means (FCM), image segmentation, iris segmentation, lattice boltzmann method, level set equation, number plate segmentation.

1 INTRODUCTION

In computer vision, image segmentation is an important task which aims to divide the given image into different regions or to identify the required object of interest from the background of image. The segmented image can be used for further analytical purposes such as change detection in SAR images [10], medical imaging etc. However, due to the intensity inhomogeneity problem, the task of image segmentation is very difficult.

Different segmentation algorithms are used to segment an image from the background of an image. Mostly used segmentation algorithms include clustering based algorithm [9], template matching [12] etc. Among these algorithms, clustering algorithms are used very efficiently on medical images. However, for each segmentation algorithms, there are some advantages and disadvantages.

Detection of brain tumor in medical images, iris segmentation in authentication process, character recognition in number plate segmentation etc. are some of the problems found in the image processing nowadays. They use different segmentaion methods for the segmentation purposes.

In recent years, level set methods are used for the segmentation of images because they can easily handle the changes in the topology of images. Level set methods belong to class of active contour models [6], [7] where these active contour models uses the energy functions to segment an image. Level set methods can be used to represent the evolving contour implicitly. It is done by making the evolving curve as zero level set of higher dimensional function. Hence the evolution of curve becomes numerically stable.

Existing level set methods uses two different approaches for the segmentation purpose. The first one includes the usage of image gradient flow to design an edge function and makes the evolving contour to move to the desired object boundary [4]. The chan-vese method can be used for segmenting image into intensity homogenous region. However, they are not suitable for parallel programming because this chan-vese method takes lot of C.P.U time for the evolution of curve and it also depends on the initial position of contour. This problem of intensity inhomogeneity can be tackled using the fuzzy c-means objective function. Similarly, a level set method based on mrf energy function [2], easily segments different types of images such as medical images, natural images, synthetic images etc. Hence, it is proven that level set method can be used to segment the image very effectively and level set methods can be used to detect brain tumor and iris detection from medical images and also can be used to detect the number plates of a vehicle.

Even though level set methods provides better segmentation results, they uses most classical schemes such as upwind schemes which are based on some finite approximation for solving the level set equation (LSE) which is partial differential equation (PDE). These schemes take lot of C.P.U time for the evolution of curve. This problem can be tackled using the lattice boltzmann method [LBM] which can be used for providing parallel programming. The LBM solves the curvature implicitly. Hence, less time is consumed for the evolution of curve.

This method uses a fuzzy objective function to design the energy function and for evolving the curve, the energy function designed is minimized using the gradient descent method. The level set equation is solved using the lattice boltzmann method. For detecting the brain tumor, iris segmentation and number plate segmentation, the output of this method is used.

- *Bibin Varghese is currently pursuing master's degree program in computer science and engineering in AJCE, MG University, India. E-mail: bibinv019@gmail.com*
- *Shany Jophin is working as Assistsnt Professor in the department of computer science and engineering in AJCE, MG University, India. E-mail:shanyjophin.s@gmail.com.*

This paper is classified as follows. Section 2 deals with related work, Section 3 describe the proposed method and its applications, Section 4 has the experimental results and finally Section 5 contains the conclusion.

2 Related Work

Clustering algorithms are nowadays widely used for segmentation because they can easily implement. Natural images can be effectively segmented even though noise presented in the image using the de-noising based clustering algorithms [9]. Also, clustering algorithms provides better results when segmenting medical images. A fuzzy clustering with a modified energy function [10], easily detects the change in SAR images. In level set methods, energy functions are used to evolve the curve. By minimizing the level set equation, the curve is usually evolved to the required object boundary. Stability of curve has main problem in different level set methods. In order to provide stability to the curve, a regularized energy function is added along with the conventional energy functions [3]. Since minimizing the energy function simultaneously provides less convergence rate, the energy functions are minimized separately in [6]. Different methods used different energy functions to solve the curve. An edge based level set method [4], which is in a relay fashion, provides segmentation without the human-computer interaction. In [6], tao proposed a method which provides interactive object segmentation by optimizing the geodesic active contours. The level set method can be also used for segmenting object from low depth of field images [7]. In this method, the object is segmented using a hybrid energy function and the segmentation provided is unsupervised. In [5], wang et.al proposed a unified three order tensor representation of the image properties including gray value. In this method level set equation is designed based on the unified tensor representation of image. These level set methods uses some finite approximation schemes for providing numerical stability of the curve which takes lot of time for the curve evolution. This is solved by yang et.al by introducing an MRF energy function along with the conventional energy functions [2]. However this method cannot provide better segmentation result when object background is blurry and also cannot provide parallel programming. This problem of evolution of curve in the level set method can be tackled using the lattice boltzmann method [1], which solves the curvature implicitly. Different types of segmentation algorithms are performed for detecting tumor, iris segmentation and number plate segmentation. For detecting brain tumor, an enhanced process is performed in [13] for avoiding distinct region fusion while segmentation is performing. In [14], optical character recognition is used for selecting the number plates. For iris segmentation, hough transform is performed in [15].

This method designs an energy function based on the fuzzy c-means objective function. In order to get the level set equation, this energy function is minimized using the gradient descent method. The level set equation is solved using the lattice boltzmann method. Finally the segmented image is used for different applications such as brain tumor detection, iris segmentation and number plate segmentation. The experiment was done on matlab 2013 and sufficient results were obtained.

3 Proposed Method

The proposed method uses the property of region to segment the given image. This method doesn't depend on the initial position of the contour. Hence, the initial contour can be selected anywhere in the input image. This method develops an energy function from which level set equation is developed and solving this LSE using the LBM drives the contour position to the object boundary. The segmented image can be used further for applications such as brain tumor detection, iris segmentation and number plate segmentation.

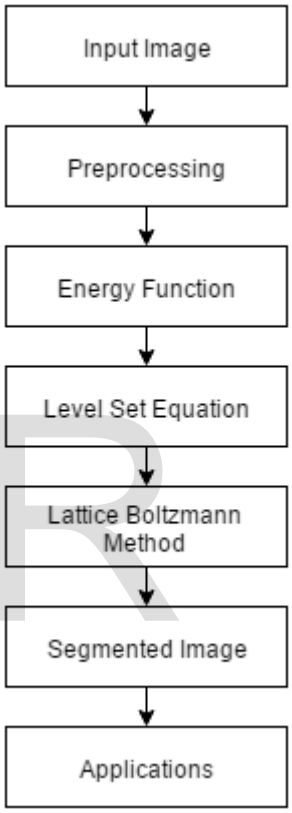

Fig 1: Proposed method

3.1 Preprocessing

Preprocessing of images is very essential. In this method, RGB images are given as input. For better processing of images, it is converted into gray images. After the conversion of image into gray, in order to provide the true intensity of the image, the gray image is transformed using the log transformation method. Thus log transformation method enhances the image for providing better segmentation result in the images.

3.2 Energy Function

Energy function in this method is designed using the objective function of the fuzzy c-means clustering algorithm because it can easily divide an image into different classes.

As in [1], the energy function is given by

$$E(U,V,B,Y,\Phi) = J(U,V,B,Y,\Phi) + v|C|$$

where $v|C|$ is the regularization term and C is is the given curve.

$J(U,V,B,Y,\Phi)$ is the objective function used in this method and it is given by

$$J(U,V,B,Y,\Phi) = \int_{\Omega} U_1^p(x,y)\,||\,Y(x,y) - B(x,y) - v_1\,||^2\,H(\Phi)dxdy + \int_{\Omega} U_2^p(x,y)\,||Y(x,y) - B(x,y) - v_2\,||^2\,(1 - H(\Phi))dxdy$$

where Φ is the signed distance function, B is the bias field, U is the partition matrix, V is the centroid vector and Y is the observe intensity of the image.

3.3 Level Set Equation

Usually, the curve moves to the desired object boundary by minimzing the energy function developed. In this method, the level set equation is created by minimizing the energy function by gradient descent method as in [1]. In order to solve this level set equation, lattice boltzmann method is used.

3.4 Lattice Boltzmann Method

Lattice boltzmann method is used solving the partial differential equation. In this method, a DBQ9 lattice is used. This lattice has eight links with its neighbors and one link for the cell of lattice itself. For each link, there is velocity vector and particle distribution. The lattice boltzmann equation is used to solve the level set equation developed.

In this method, an external force, F is added for moving the contour to boundary of the object which is required as in [1] and it is given by

$$F = \lambda(U_1^p(x,y)||\ Y(x,y) - B(x,y) - v_1\,||^2 - (U_2^p(x,y)||\ Y(x,y) - B(x,y) - v_2\,||^2)$$

A small force is also added along with this force to make the contour smoother.

3.5 Applications

This method segments the image into different segments very efficiently. So for the brain tumor detection, iris segmentation and number plate segmentation, segmented output of this method is used. A common step is proposed for the various applications.

3.5.1 *Implementation steps*

For the applications, a common step is used. In this method output of the segmented image is used for the different applications. The steps are as follows.

1) Load the image
2) Select the initial contour position
3) Segment the image
4) Convert the segmented image into binary image
5) Find the edges
6) Perform morphological operations
7) Crop the image in the case of number plate detection else go to step 8.
8) Select the portions of image that have connected objects with a pixel value of '1' for number plate segmentation and brain tumor detection. For iris segmentation, select the portions of image that have connected objects with a pixel value of '0'.

4 Experimental Results

For testing the efficiency of this method, the image from database BSD500 dataset is used. Ground truth of the image also provide in this dataset.

Fig 2: Sample image and its ground truth

The segmentation algorithms used in this method segments the image very efficiently. The following figure shows a segmented image using this method.

Fig 3: Segmented image

For brain tumor detection, an image with tumor is loaded into proposed method. This method detects the tumor very easily.

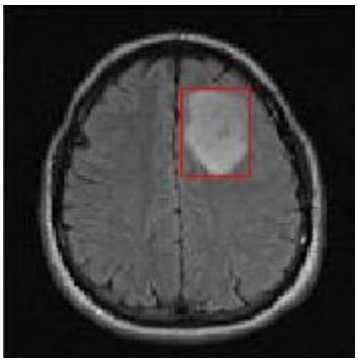

Fig 3: Detected tumor

For iris segmentation, an eye image which shows the iris of the eye is given as input. This method easily segments the iris from the image. This segmented iris can be used for authenti-

cation purposes.

Fig 4: Segmented iris

Similarly for the number plate segmentation, the number plate of different vehicles is provided as input. Different types of number plates are also tested with this method. From every number plate, the characters are easily segmented which can used for further analytical purpose.

Fig 5: Segmented characters from number plate

For the purpose of analyzing this method, Hausdorff distance and Martin's GCE criteria is used as in [1]. Generally, the Hausdorff distance and Martin's GCE measures the similarity between two images.
The Hausdorff distance is given by

$$HAU(I_c, I_{ref}) = \max\left(h(I_c, I_{ref}), h(I_{ref}, I_c)\right)$$

And Martin's GCE criterion is given by

$$GCE(I,V) = 1/A \ \ (min(\sum(E(s), \ \sum(E1(s)))$$

where I is the image, V is the ground truth and R is the segmented result. Lower the value of these metrics better will be the segmentation results.

Fig 6: Test images

Some images are randomly selected for the purpose of testing from BSD500 dataset. This method is compared with the well-known chan-vese method [11] and a k-means clustering algorithm. According to Martins GCE criterion, 0 signifies best segmentation and 1 signifies worst segmentation result.

Table1. Martin's GCE criterion

Test Images	Propsosed Method	Chan-Vese Method	K-means Method
1	0.0800	0.0806	0.1766
2	0.0733	0.1330	0.1338
3	0.0668	0.0694	0.1347

Table2. Hausdorff criterion

Test Images	Prosposed Method	Chan-Vese Method	K-means Method
1	5.9824	6.3484	6.9471
2	5.3157	5.3174	7.1420
3	5.5354	5.5236	7.5185

From these criterions, it is clear that this segmentation algorithm is better for segmentation. Hence it can be used for different applications very efficiently

5 Conclusion

Level set method used in this method is implemented using a modified energy function which is used to create the level set equation which is solved by the lattice boltzmann method. This method works very efficiently for natural images and medical images. Since objective function of fuzzy c-means clustering is used, the stopping criterion of evolving contour is determined by degree of membership of the active pixels. It is achieved using the fuzzy partition matrix. The problems found in the conventional level set methods such as for numerical stability, the usage of approximations schemes is tackled by using the lattice boltzmann method. The lattice boltzmann method evolve the curve without taking too much CPU time. Also brain tumor detection, iris segmentation and number plate segmentation is done very efficiently.

6 References

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