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Design and Analysis of Image Segmentation with Efficient Energy Minimization Function

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Abstract— In image processing domain, there are variety of image segmentation techniques presented by research communities. Such segmentation methods are based on different image features. Segmentation of the target object(s) from images that have multiple complicated regions, mixture intensity distributions or are corrupted by noise. In addition, the conventional piecewise smooth level set models normally require prior knowledge about the number of image segments. To address these problems, we propose a novel segmentation energy function with two distribution descriptors to distinguish the background and the target region. The single background descriptor models the heterogeneous background with multiple regions. Then, the target descriptor takes into account the intensity distribution and incorporates local spatial constraint. Our descriptors, which have more complete distribution information, construct the unique energy function to differentiate the target from the background and are more tolerant of image noise. We compare our approach to multiphase level set and the Chan-Vese level set. This comparison using 160 synthetic images with varying levels and types of image noise and medical images with more complicated backgrounds showed that our method outperforms these models for accuracy and immunity to noise. On an additional set of 300 synthetic images, our model is also less sensitive to the contour initialization as well as to different types and levels of noise. The practical analysis of proposed work is carried by using well known image processing tool called MATLAB.

Index Terms— Image Segmentation, Image processing, Energy Minimization, Level Set Methods, Region based, Edge based, Minimizer.

1 Introduction

THERE are number of segmentation methods presented since from last two decades. But recent methods are based on energy minimization based image segmentation. Partial differential equation (PDE) is method for image segmentation. The segmentation of image is done by solving equations of PDE through the numerical methods. In this category, curve propagation is most famous method under the PDE and used in applications like object tracking, object extraction, stereo reconstruction, satellite imagine etc. The main idea of this method is to evaluate the initial curve towards cost function minimum potential. Apart from this many other methods presented under the domain of PDE equations. Parametric method is one of the PDE equations based method in which parameterization of counters is done as per sampling strategy set as well as elements evolving is done as per the internal terms and image. Another method called fast marching presented for image segmentation. Further this method was improved by allowing both positive as well as negative propagation speed. This improved method for image segmentation is referred as generalized fast marching technique.

After this, level set methods presented for image segmentation under this domain. These methods initially proposed by authors Osher and Sethian. At the time of their introduction, such methods are accepted majorly for capturing of dynamic shapes as well as interfaces. Level set function based methods basically work by setting the level set function in order to represent contour initially at zero level set of function of higher dimensional set as well as motion formulation of contour as evolution of function of level set. Models of level set can describe the target object through change in complex topology based on various functions of energy generated from input image. In parametric active counter models, the tasks like splitting and merging are difficult; hence this can be achieved by level set methods. The main challenging task with level set methods is that segmentation energy function definition. Minimization of energy function is done while evolving counter process is going based on edge energy through region energy or boundary detector based on the region-descriptor. Level set methods are divided into two main categories such as edge based method and region based methods according to the energy function definition [3] [4].

There are many methods presented fewer than two categories of level set methods, however they suffered from limitations. The existing level set methods are having disadvantage while producing the efficient segmentation without prior information over image segments and in noisy images. To overcome these limitations recently energy model proposed. However, such techniques required prior knowledge of number of level sets required. Also when images are corrupted with noise, then performance of existing segmentation methods becoming poor [1].

In this research work, the novel technique of image segmentation energy function is proposed with goal of overcoming the limitations of existing methods. In this prosed energy minimization based segmentation method, two distribution descriptors are used in order to distinguish the background and the target region. The single background descriptor models the heterogeneous background with multiple regions. Then, the target descriptor takes into account the intensity distribution and incorporates local spatial constraint. These descriptors are having more complete distribution information, construct the unique energy function to differentiate the target from the background and are more tolerant of image noise [2].

Reminder of paper is composed of sections listed as: in section II, literature review of different level set methods for energy minimization in image segmentation domain are discussed, section III will present the architecture of proposed algorithm and its mathematical formulation. IV the current results for proposed system elaborated and discussed. Section V presenting the conclusion and future work.

2 Literature Review

In this section we are discussing the different techniques based on level set approach for image segmentation. The main advantage of Level Set Method is that one can perform numerical computations involving curves and surfaces on a fixed Cartesian grid without having to parameterize these objects. The level set method amounts to representing a closed curve using auxiliary function called level set function which is represented as the zero level set. The level set method defines problem in one higher dimension. The zero level set at one point in time as a slice of the level set surface. The formulation of level set implies that the level set value of a point on the contour with motion must always be zero. The level set method is boundary driven and region driven model free segmentation.

In [4], author propose a novel level set based variation approach that incorporates shape prior knowledge into the Chan Vese model which can overcome the leakage and over segmentation problems. Statistical methods are used to get the prior shape and the training process allows the prior shape not exactly at the location of desired object. But all these models above fail to segment object from images where the objects are occluded by other objects or some parts of them are in low gray contrast or missing because they are all gray intensity based. These methods do not allow for translation, rotation, and scaling of the prior shape. The proposed method allows translation, rotation and scaling of the prior shapes and also performs object supervision before segmentation to achieve better result and higher performance. This is mainly achieved with the help of affine transformation. The proposed method novel level set base variation model for segmentation using prior shapes which helps us to detect the liver perfusion position and measure the intensity. This helps to achieve faster speed and we propose a new measure which help to perform the training of given shapes. If some part of the image is occluded or missing, we can still get a reliable segmentation result

In [5], author proposed the method for important branch of computer vision is image segmentation. The image segmentation problem can be solved with the help of mathematical frame work based on variational model and partial differential equations. This framework is defined in a continuous setting which makes the proposed model independent with respect to the grid of digital images This paper mainly introduces a segmentation method based on Variational approach. These models are defined in a continuous setting and are mathematically well established. Two well-known image segmentation based on variational approach is specified. They are Mumford Shah model and level set approach. The Mumford Shah model is mainly used to minimize the energy function. The level set method was introduced for tracking moving fronts. The theory of curve/surface convolution methods are used here which efficiently solve the problem of moving fronts especially in the problem of change of topology. In traditional level set methods it is necessary to initialize the level set method function as a signed distance function. But the proposed method suggests the following function as the initial function. Hence this method is more suitable than other existing segmentation methods.

In [6], author represents a novel level set approach to simultaneous tissue segmentation and bias correction of MRI.The intensity of each tissue is modeled as a Gaussian distribution of spatially varying mean and variance. The sliding window is used to transform intensity from one dimension to another. The objective function is distributed over each point and integrated over the entire domain to form a variational level set evolution. With the help of level set evolution process tissue segmentation and bias correction are achieved. The proposed method uses a variational level set approach to simultaneous segmentation and bias correction. The method uses a k-Means clustering which is weighted k-means variational level set. The proposed method use a special case SVMLS-Statistical & variational multiphase level set. Advantage of this method is that the smoothness of the computed bias field is ensured by the normalized convolution without extra cost.

In [7], author presented method which mainly requires the definition of a speed function that governs model deformation. This mainly considers the region intensity information while the existing methods usually do image gradient information. The region intensity information into the level set framework forms an accurate and robust segmentation. The level set approach the convergence to the final result may be relatively independent of the initial shape, and branches and splits and merges can develop without problems as the front moves. The challenges in level set approach are to construct an adequate model for the speed function. The main idea is to define a range of intensity values that classify the tissue type of interest and then base the propagation term on the level set equation for that intensity range. Using this approach the smoothness of the evolving surface can be used to prevent the leakage which is common in connected component schemes.

In [8], author presented another important technique. Due to the presence of speckle noise SAR image automatic segmen-

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tation is difficult task. A variational level set approach for SAR image is presented in this paper which states a new energy functional is defined by taking account of a statistical model of speckle noise. The energy functional produced in this paper is different from the energy functional with respect to the parameterized curve in general level set approach. By minimizing the energy functional in level set approach segmentation is achieved. The energy functional well describes the property of SAR image accurately and automatically extracts the region of interest in SAR image without any speckle pre-processing step. The functional consist of a region based term and a boundary based term. The region based term is derived from SAR image statistical property and measure the conformity of image data to a gamma model. The boundary based term is related to the edge gradient and alliance the boundary to the image pixels with maximum gradient while keeping its smoothness which describes region property and boundary property of SAR image simultaneously. Target extraction is implemented by minimizing the energy criterion via variational level set approach. The segmentation method based on this paper is more accurate than segmentation method with active contours and level sets.

In [9], author proposed variational level set approach to join segmentation and bias corrections of images with intensity inhomogenity. Intensities in small local regions are separable despite of the inseparability of the intensities in the whole image caused by intensity inhomogenity. A weighted k mean clustering objective function is defined for image intensities in a neighborhood around each point, with the clusters centers having a multiplicative factor that estimate the bias with in the neighborhood. The objective function is then integrated over the entire domain and in cooperated in to a variational level set formulation. The energy minimization is performed by a level set evolution process. This method is able to estimate bias of general profiles. This method is robust to initialization and allows automatic applications. The level set formulation mainly consists of N=2(two phase) and N=4(multi-phase process) by this we can reduce energy formulation and hence the segmentation is done. The advantage of this method is not sensitive to initialization and thereby allowing automatic applications. Reinitialization is also possible in this method.

In [10], author presented another technique for image segmentation. Radiographic medical Images are consider were boundaries are not silent and object having the same gray level as other structure in the image, so we need a prior information about the shape that forces the level set to be closed to a signed distance function which avoids the re initialization procedure. The proposed method uses a prior information about the boundary so that the active contour or level set will evolve according to a known shape. The proposed segmentation method needs a training shape. The shape variants are computed by principle component analysis (PCA). The new shape prior is the matrix of Eigen vectors and the vector of shape parameters to be determined. A new energy functional is defined for image segmentation which is used to avoid the re initialization process and its related draw backs

In [11], author proposed a new multiphase level set frame work for image segmentation using the Mumford and Shah Model for piece wise constant and piece wise smooth optimal approximations. This method is a generalization of active contour model without edges based two phase segmentation in the case of piece wise smooth only two level set functions formerly suffix to represent any partition based on the four colour theorem in the piece wise constant case only log n level set functions for any phases in the piece wise constant case. This avoids the problem of vaccum and overlaps and represents boundaries with complex topology including triple junction. The multiphase formulation is different than the classical approaches and has the advantages that the phases cannot produce vacuum or overlap by construction and it minimizes the computational cost by reducing the number of level set functions.

3 PROPOSED WORK

3.1. Introduction

In this section we are presenting the architecture and algorithm design for proposed energy minimization based image segmentation method. Below figure 1 is showing the flowchart of proposed energy minimization method.

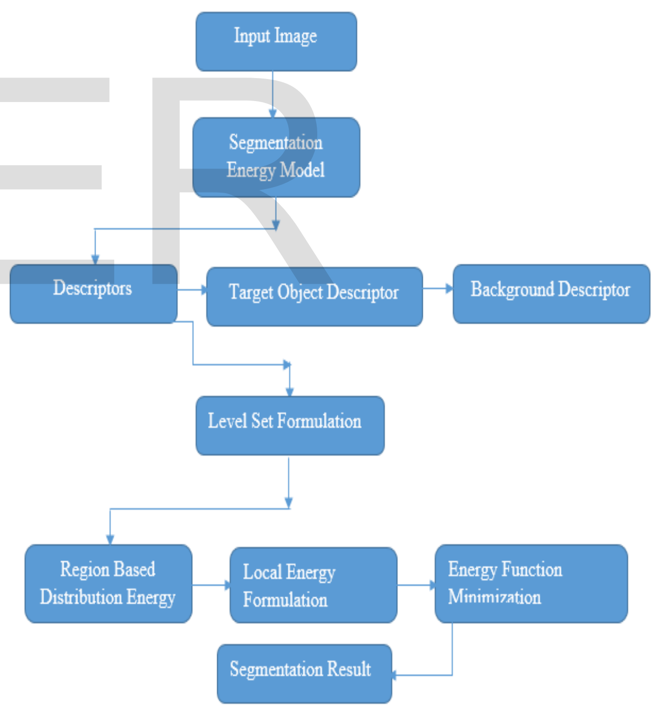

Figure 1: Proposed Algorithm Design

3.2. Algorithm Design

Step 1: Segmentation Energy Framework

1) Problem Description and Hypothesis on Segmentation

Model: A given imageu0 on an image domain **Ω** can be represented as N disjoint regions: $\cup_i^N \Omega_{i} = \Omega$ and $\cap_i \Omega_i = \emptyset$, and may be corrupted by different levels/types of image noises. These regions are to be partitioned into two major groups { Ω_W , Ω_B } = Ω including the target object(s) W represented as

$\Omega_W = \{\Omega_{K1}\}_t^W$=1; and the background regions B denoted as Ω_B *, and* $\Omega_B = \{\Omega_i\}_{i=KW+1}^N$ with an unknown number of the background regions. Any specific target object t with K_t regions is represented as $\Omega_{K1} = \{\Omega_i\}_{i=Kt-1}^K$+1. Deduced from the problem description, if we can define a unique descriptor for a target object and a single separate background descriptor, we should be able to distinguish the target object(s) from the background.

2) Formulation of Segmentation Energy Model: We define two unique descriptors to determine the label of every pixel belonging to the target (foreground) or the background, which are formulated as the target energy and background energy terms. By incorporating the energy terms from the target and the background, our energy functional is defined as below:

$$E = E_W + E_B = \int_{\Omega_W} O_W(u_0(x))dx + \int_{\Omega_W} O_B(u_0(x))dx \quad (6)$$

Where E_W is the target energy and E_W is the background energy that are derived from the target descriptor $O_W(u_0(x))$ and background descriptor $O_B(u_0(x))$.

The minimization of energy function M is performed to optimize the descriptors to fit the target object(s) and background to classify each pixel of u_0 belonging to the target object(s) or to the background. The first component E_W of the energy formulation (6) can be further expanded to describe multiple target object(s) as:

[1] $$E_W = \int_{\Omega_W} O_W(u_0(x))dx = \sum_{t=1}^{W}\sum_{i=K_{t-1}+1}^{K_t}\int_{\Omega i} O_t(u_0(x))dx \quad (7)$$

[2]

Where $O_t(u_0(x))$ is the descriptor of the target object t. Without loss of generality, in the following sections we present the energy formulation for segmenting a single target from a given image.

Step 2: The Descriptors Design

Two descriptors are designed such as target object descriptor and background descriptor.

Step 3: Minimization of the Energy Function

We introduced the distance regularized term [8] into our level set formulation to regulate the iterations of evolving surface without re-initialization. After embedding the distance regularized term with E_p and E_t^s. This function finally used to minimize the energy consumption performance of segmentation method.

4 COMPARITIVE ANALYSIS

4.1. Performance Metrics

This section deals with presentation and analysis of simulation work with different types of images for segmentation. We evaluated the proposed energy minimization based segmentation method against two well-known existing methods such as Level set method and Chan-Vese method in order to claim the efficiency of proposed technique. We are comparing three methods based on three important performance metrics:

Average CPU Time: This can be computed by using below performance metrics

CPU Time = I * CPI * T

Where,

I = number of instructions in program

CPI = average cycles per instruction

T = clock cycle time

Processing Time: This is performance metrics which is used to check total time required for image segmentation. This can be measured as

Processing time = end_time – start_time

Where,

start_time is variable which holds current system time when input image is taken for processing of segmentation

end_time is variable which holds the current system time when segmentation process completed.

Average Jeccard Distance (JD) Error: error metric for precise evaluation of the segmentation results. This can be computed using below equation

J D(Is , Im) = 100% × (1 − |Is ∩ Im| / |Is ∪ Im|),

Where,

Is is the segmentation result and Im is the groundtruth reference. The segmentation error rate is 0 for a perfect segmentation and 1 if segmentation and reference do not overlap at all.

4.2. Simulation Results

Below figure 2 is showing the image segmentation result for input image from used dataset with existing level set method and Chan-Vese Method against proposed energy minimization method.

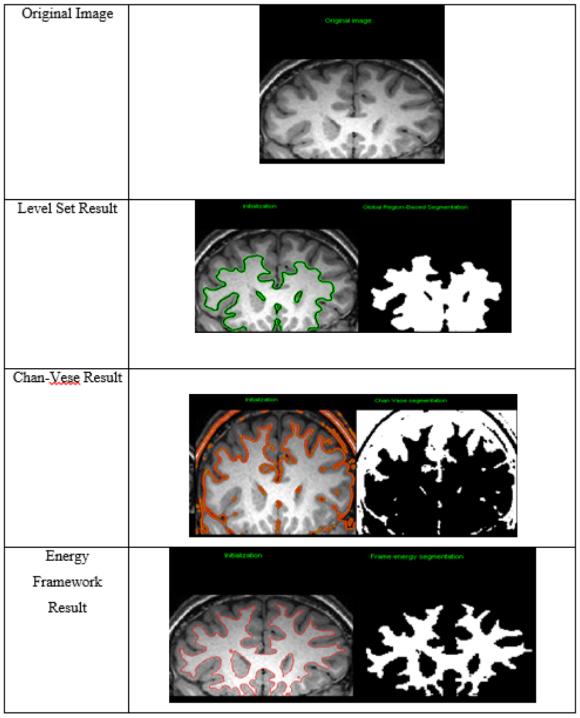

Figure 2: Image Segmentation Result with different methods

Table 1: Comparative Study of Energy Minimization Parameters

Image types	MULTIPLE LEVEL SET MODEL		CHAN-VESE MODEL		ENEGY FRAMEWORK (Proposed)MODEL	
	Average JD Error Rates	Average Running time (mean)	Average JD Error Rates	Average Running time (mean)	Average JD Error Rates	Average Running time (mean)
70 Images by GN&SPN	1.3 %	4.8746 second	0.9 %	27.9854 seconds	0.45 %	0.067923 seconds

5 CONCLUSION AND FUTURE WORK

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4 CONCLUSION

Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions. Authors are strongly encouraged not to call out multiple figures or tables in the conclusion—these should be referenced in the body of the paper.

REFERENCES

[1] [1] Luminita A. Vese and Stanley J. Osher. Modelling textures with total variation minimization and oscillating patterns in image processing. UCLA CAM Report, 02(20), 2002.

[2] [2] Tranos Zuva,Oludayo O,Olugbara,Sunday O,Ojo and Seleman Ngwira,Image Segmentation Available Techniques,Developmaents and Open Issues, Canadian Journal on Image processing and Computer Vision Vol 2 No:3 March 2011 .

[3] [3] StanleyOsher and J. Sethian, Fronts propagating with curvature-dependent speed: Algorithms based on Hamilton-Jacobi formulations, J. Comp.Phys., vol. 79, no. 1, pp. 12–49, Nov. 1988

[4] [4] Kan Cheng, Lixu Gu, and Jianrong Xu,A Novel Shape Prior Based Level Set Method for Liver Segmentation From MR Images, Proceedings of the 5th International Conference on Information Technology and Application in Biomedicine, in conjunction with The 2nd International Symposium & Summer School on Biomedical and Health Engineering Shenzhen, China, May 30-31, 2008.

[5] [5] Samir BARA,Mounir Ait Kerroum,Ahmed Hammouch and Driss Aboutajdine,Variational Image Segmentation Models:Application to medical images MRI, -978-1-61284-732-0/11/$26.00 ©2010 IEEE.

[6] [6] Kaihua Zhang a, Lei Zhang a, 1 and Su Zhang,A Variational Multi Phase Level Set Approach To Simultaneous Segmentation And Bias Correction

[7] [7] Pan Lin, Chong-Xun Zheng, Yong Yang,Model-Based Medical Image Segmentation: A Level Set Approach,Proceedings of the 5th World Congress on Intelligent Control and Automation. June 15-19, 2004, Hangzhou. P.R.China

[8] [8] Zongjie Cao, Yiming Pi, Xiaobo Yang, Jintao Xiong, a Variational Level Set SAR Image Segmentation Approach Based on Statistical Model

[9] [9] Chunming Li, RuiHuang, Zhaohua Ding, Chris Gatenby, Dimitris Metaxas,and John Gore, A Variational Level Set Approach to Segmentation and Bias Correction of Images with Intensity Inhomogeneity,D. Metaxas et al. (Eds.): MICCAI 2008, Part II, LNCS 5242, pp. 1083–1091, 2008. Springer-Verlag Berlin Heidelberg 2008

[10] [10] El Hadji S. Diop, Silèye O. Ba, Taha Jerbi and Valérie Burdin,Variational and Shape Prior -based Level Set Model for Image Segmentation

[11] [11] Luminita A. Vese & Tony F. Chan, A Multiphase Level Set Framework for Image Segmentation Using the Mumford and Shah Model, International Journal of Computer Vision 50(3), 271–293, 2002© 2002 Kluwer Academic Publishers. Manufactured in the Netherlands.