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Image Segmentation Using Two Step Splitting Function

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Abstract

Image processing and computer vision is widely using Level Set Method (LSM). In conventional level set formulation, irregularities are developed during evolution of level set function, which cause numerical errors and eventually destroy the stability of the evolution. Therefore a numerical remedy called re-initialization is typically applied periodically to replace the degraded level set function. However re –initialization raises serious problem that is when and how it should be performed and also affects numerical accuracy in an undesirable way. To overcome this drawback of re-initialization process, a new variation level set formulation called Distance regularization level set evolution (DRLSE) is introduced in which the regularity of the level set function is internally maintained during the level set evolution. DRLSE allows more general and effective initialization of the level set function. But DRLSE uses relatively large number of steps to ensure efficient numerical accuracy. Here in this thesis we are implementing faster and equally efficient computation technique called two step splitting method (TSSM). TSSM is physio-chemical reaction diffusion equation in which firstly LSE equation get iterated and then regularize the level set function from the first step to ensure the stability and hence re-initialization is completely eliminated from LSE which also satisfy DRLSE.

Keywords

DRLSE, LSE, LSM, TSSM

1. Introduction

The level set method (LSM) was introduced by Osher and Sethian[1]. It is a numerical technique that is used to track interfaces and shapes.

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surfaces on a fixed Cartesian grid and there is no need to parameterize these objects. Looking to its popularity, it has developed interests in image processing, computer graphics, computational geometry, optimization, computational fluid dynamics, etc. The LSM is a numerical technique and theoretical tool for interfaces that are propagating. The line of reasoning is to stir alongside an principal curtsy in 2D or a take the role in 3D and endure the curve to personify in found to itself at a highlight speed. In the stretch of personality processing the footing usual technique is hand-me-down continually as a breaking up tool browse civility of a fashion by using the properties of the image. For a given closed curve C, the value of the function is zero, if the pixel lies on the curve itself, otherwise, it is the signed minimum distance from the pixel to the curve. The unobtrusive is supposed as opposing for pixels extensively C and flawless for pixels inside C. Traditionally a level set function Φ for a closed surface can be defined as follows:

$$\Phi\,(x, y) = \pm d\,((x, y), C)$$

Where d((x, y), C) is the distance from the point (x, y) to the contour C, and plus sign or the minus sign is chosen if the point is inside or outside of interface C.

Recoil - State of affairs was outstandingly second-hand to incise the chemical mechanism of animal coats [2]. Distinguishable a recycle, this equation was interdict for undiplomatic to trade mark the on the feat deport oneself in fields such as study of execrate, effigy modeling and girlfriend junket modeling. For the courtyard accessory to phase transition modelling, the reaction diffusion equation was based on Vander Waals Chan Hilliard theory, being used in the mechanics for stability analysis of systems with unstable components of fluid mechanics.

The term reaction-diffusion system is basically related to physico-chemical phenomenon that comprises two elements, namely chemical reactions and diffusion [2][3][4]. A chemical reaction system consists of N species (x_1. . . x_n) (e.g. molecules) together with M reaction channels, (r_1. . . r_m). Each reaction channel defines the stoichiometry of a reaction

$$r_m ; \alpha_{im} x_i \xrightarrow{km} \sum_j \beta_{jm} x_j$$

$$\frac{dc}{dt} = \sum_1^M k_m (\beta_{im} - \alpha_{im})$$

or in matrix noation

$$\frac{dc}{dt} = M_s . r(t)$$

Where M_S is the stoichiometric matrix and r the rate vector describing the speed of each reaction.

Diffusion refers to the process of thermal motion of molecules. It is the process by which for example warm and cold water intermingles until the water has a uniform temperature (at thermal equilibrium) or by which a fragrant smell spreads in a room. The general macroscopic diffusion equation for species i = 1, 2,….N is

$$\frac{dc}{dt} = \nabla . (D_i \nabla c_i)$$

where Di denotes the diffusion tensor of species i, a matrix that defines how well the molecule i diffuses into the different spatial directions[5]. Combining equations and, we get the so called reaction-diffusion equation. The equations for a reaction-diffusion system on a surface $\Gamma \subset \Omega \subseteq R^3$ are then

$$\frac{dc}{dt} = R_i(c) + D_i \Delta_\Gamma c_i \qquad i = 1,2 \dots \dots \dots .. N;$$

Since the utter level is used to play the objective arrangement, we by oneself tinkle to render a reckoning for the zero level set of the LSF. We in reality description a simulate all over option meeting fields as the LSF. Motivated by the phase rove dogma, by reckoning an orbit term into the conventional LSE equation. Such an introduction of diffusion to LSE will make LSE stable without re-initialization. By adding a diffusion term "εΔφ" into the LSE equation, we have the following TSSM equation for LSM:

$$\varphi_t = \varepsilon \Delta \varphi - \frac{1}{\epsilon} L(\varphi) \ , x \in \Omega \subset R^n$$

The use of level sets for image segmentation can now be summarized as follows.

1) The raw image is pre-processed to remove noise, enhance edges, etc.
2) The gradient of the pre-processed image is computed.
3) A front is initialized on the image plane and its level set function is computed.
4) The curvature of the level set function and the gradient of the image are used to calculate the speed function.
5) The level set function is evolved using the Equation discuss above.
6) The evolved level set function is then used to compute the new speed function.
7) Steps 4-6 are repeated until the level set function moves by values smaller than a given threshold.

2. Literature Review

In 2012, Mei Yeen Choong et al. [6] suggest Image segmentation has been widely applied in image analysis for various areas such as biomedical imaging, intelligent transportation systems and satellite imaging. They suggest segmentation on synthetic images and natural images are covered to study the performance and effect of different image complexity towards segmentation process. Their study gives some research findings for effective image segmentation using graph partitioning method with computation cost reduced. Because of its cost expensive and it becomes unfavorable in performing image segmentation on high resolution image especially in online image retrieval systems. In 2010, Jun Tang et al. [7] suggest that Image segmentation is a classic subject in the field of image processing and also is a hotspot and focus of image processing techniques. Their method proposes a color image segmentation method of automatic seed region growing on basis of the region with the combination of the watershed algorithm with seed region growing algorithm which based on the traditional seed region growing algorithm. In 2012, Hui Zhang et al. [8] focuses on the research of image segmentation accuracy problem because traditional Sobel operator image segmentation is easy to cause the vagueness of image segmentation, contrast is not apparent, segmentation accuracy is low. Their method uses different threshold segmentation for digital image goals and objective fringes to solve the problem of segmentation inaccuracy as the result of the local adhesion and stack. In 2005, Farmer, M.E. et al. [9] propose a method of segmentation that addresses both of these issues, by using the object classification subsystem as an integral part of the segmentation. They propose a new paradigm for segmentation and classification that follows the wrapper methods of feature selection. This represents an improvement over other segmentation methods that have used classification information only to modify the segmented parameters, since these algorithms still require an underlying homogeneity in some parameter space. In 2010, Juyong Zhang et al. [10]

propose to conduct the seeded image segmentation according to the result of a heat diffusion process in which the seeded pixels are considered to be the heat sources and the heat diffuses on the image starting from the sources. In 2012, ChuanLong Li et al. [11] propose a novel fuzzy c-means image segmentation algorithm. Its effectiveness is due to two mechanisms. The first mechanism is the replacement of the Euclidean distance traditionally used to measure similarity of the image pixels by a novel similarity measure which is considered spatial neighbourhoods using Gaussian kernel, and thus their method becomes less sensitive to the noise of the image. The second mechanism is not requirement of any similarity penalty term in FCM's objective function as some FCM's variants to reduce the influence of noise on the result of image segmentation. In 2009, Yi-hua Lan et al. [12] proposed a novel image segmentation method based on random walk model. First of all, they down-sampling the original large image to the small image which can be solved fast, then the small image segmentation leads to sparse linear equations of much smaller scale. After getting the solution, the probability results will be up-sampling to the up layer, and then solve the sparse linear equations in this layer; repeating this up-sampling process until to the top layer which is the original image. At last, segment the final probability image with a pre-set threshold. In 2012, Forsthoefel, D. et al. [13] describe a new, highly efficient image segmentation technique called leap segmentation that builds a new image representation where individual pixel data is replaced with a map of chromatic- and illumination-similar regions that are adjacent but not necessarily contiguous. In 2011, Shaohua Zhu et al. [14] suggest that due to color image contain more information than grayscale image, color image processing is being paid more and more attention. The methods of grayscale image segmentation just consider the brightness and neglect hue, saturation and other important information. In 2008, Hasanzadeh, M. et al. [15] proposed a new segmentation method based on a combination of fuzzy connectedness and fuzzy clustering called membership connectedness, by which the spatial relation of image pixels is constructed in the related membership domain. They have proposed a new fuzzy connectedness relation for image segmentation in membership domain which outperforms the previously defined relation in noisy images.

3. Proposed Methodology

Level set method has been playing a vital role in extracting the contours in an image. The proposed algorithm, with the help of reaction diffusion term helps in easily finding out the contours in an image considering computation cost and time. Firstly, thresholding is applied to the image. The importance of applying thresholding is to ignore the unnecessary parts of the image that is not required for image segmentation. Then applying Gaussians filter to remove the noise from the image. Thereafter applying Level set method to the image and then applying the reaction diffusion to detect the contour from the image.

A Two-step algorithm to implement Diffusion has been proposed in to generate the curvature-dependent motion. In the reaction function is first forced to generate a binary function with values 0 and 1, and then the diffusion function is applied to the binary function to generate curvature- dependent motion. Different from, where the diffusion function is used to generate curvature-dependent motion, in our proposed LSM, the LSE is driven by the reaction function, i.e., the LSE equation. Therefore, we propose to use the diffusion function to regularize the LSF generated by the reaction function. To this end, we propose the following two step method to solve the equation.

Step 1: Solve the reaction term *till some time* T_r to obtain the intermediate solution, denoted by $\varphi n+1/2 = \varphi^n$;
Step 2: Solve the diffusion term $\varphi t = \varepsilon \Delta \varphi$, $\varphi(x,t=0) = \varphi n+1/2$ till some time T_d , and then the final level set is $\varphi n+1 = \varphi(x,Td)$.

Proposed Algorithm:
Step 1: Read image
Step 2: Apply Gaussian kernel for smoothing
Step 3: Define initial level set function.
The initial LSF

$$\frac{d\varphi}{dt} + F.|\Delta\varphi| = 0.$$

Step 4: Implement Reaction Diffusion to the Level Set Method.
Equations of Reaction Diffusion is

$$\varphi_t = \varepsilon\Delta\varphi - \frac{1}{\epsilon}L(\varphi)$$

, $\varphi(x, t = 0) = \varphi 0(x)$
Step 5: Result.
the contour C, where $\varphi>0$

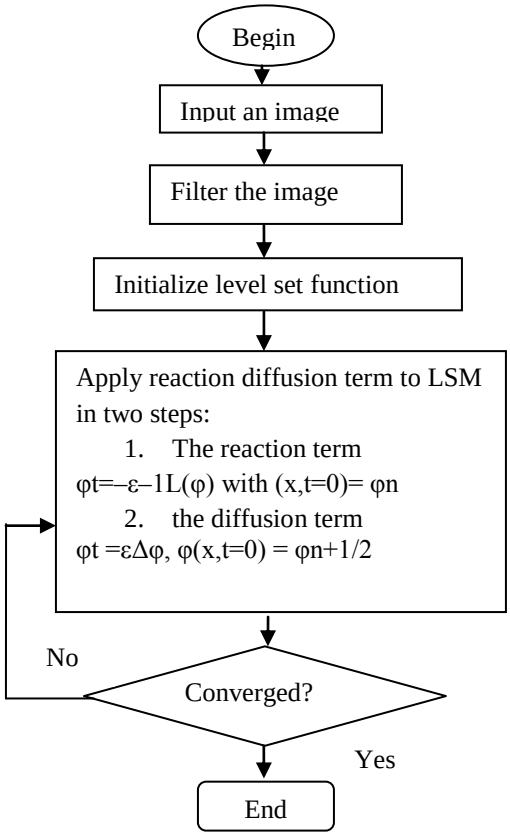

Figure 1: Work Flow of Algorithm Input an Image.

MRI Images

Magnetic resonance imaging is a test that uses a magnetic field and pulses of radio wave energy to make pictures of organs and structures inside the body. In many cases MRI gives different information about structures in the body that can be seen with an X-ray, ultrasound or computed tomography scan.

Filter the Image
Taking an image as input in level set method, the first process is to remove the noise from the image with the help of noise reduction. To reduce the noise in the image a Gaussian filter is applied.

Initialize the Level Set Method

Originally the level set method was proposed to track an evolving contour based on some numerical technique. The evolving contour deforms with a speed F that is based on the contour curvature and image features like gradient. We define the region where φ=0 as region as inside the contour and the φ<0 region as outside the contour as shown in figure2.

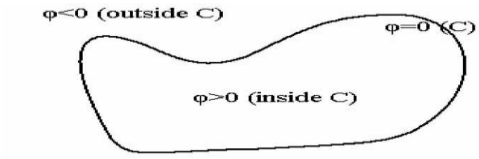

Figure 2: Use Initial Level Set Function to represent Contour [16].

From figure [16], we can easily know that when the φ value changes, the corresponding φ > 0 region and φ < 0 region will also change, therefore the boundary of φ > 0 region and φ < 0 region, i.e. φ = 0, will be different and thus the contours evolves.

Defining the level set function

(x (t), t) = 0 x (t)=(x,y)

Level set value of a point on the contour with motion x(t) must always be 0.
(x(t), t) = 0
By the chain rule,
$\varphi_t + \nabla\varphi(\ (t),t)$
x'(t) = 0
Since F supplies the speed in the inward normal direction
x'(t) . n = F , where $n = \frac{\Delta\varphi}{|\Delta\varphi|}$.
Hence evolution equation for is
$$\frac{d\varphi}{dt} + F.\Delta\varphi = 0.$$
This is the level set evolution equation.

Applying Two step splitting method to the Level Set
In the proposed two step splitting method (TSSM) of level set method, the LSE is driven by the reaction functions i.e. equation 19 by iteratively solving the equation as under.

Step 1: Solve the reaction term *till some time* T_r to obtain the intermediate solution, denoted by φn+1/2 =φ^n;
Step 2: Solve the diffusion term φt =εΔφ, φ(x,t=0) = φn+1/2 till some time T_d , and then the final level set is φn+1 =φ(x,Td).

4. Experimental Results

The result shows the middle slices of the Level Set Function for different methods.

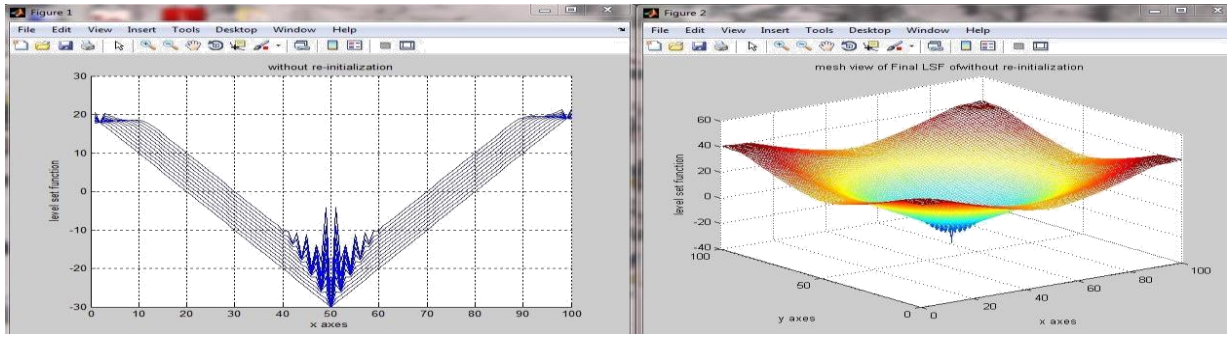

Figure 3: Energy Function with Level Set equation without Re-initialization.

The result shown in the energy graph displays that using a level set method without re-initialization, the level set evolution distorts after some time. That is it becomes too steep or flat near the contour, leading to numerical errors.

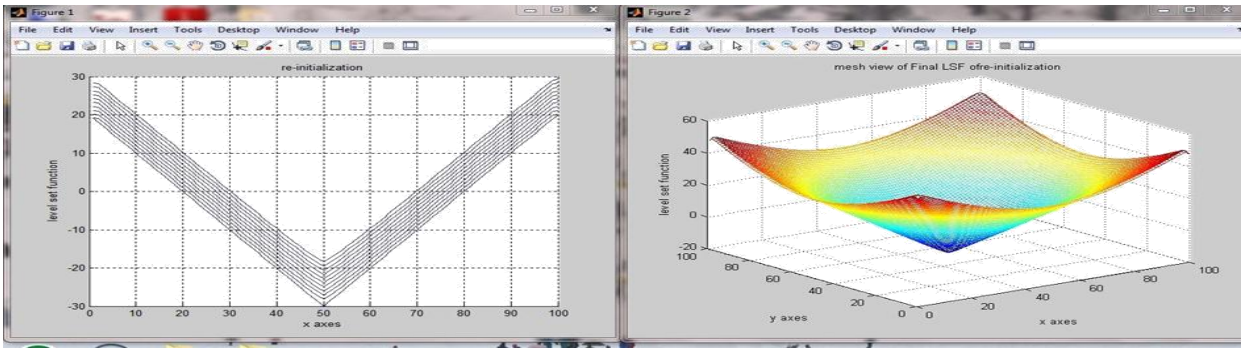

Figure 4: Energy Function with Re-initialization process.

The result shown in the energy graph displays that using a level set method with re-initialization, the level set evolution needs to be periodically re-initialized and which moves the initial level set function.

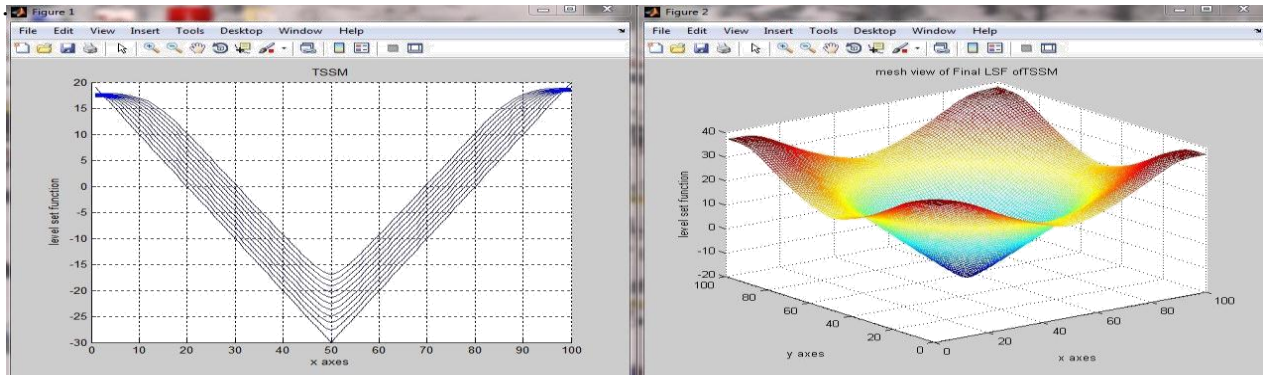

Figure 5: Energy Function with Two step splitting method equation.

The result shows that using level set method applying the reaction diffusion equation in the LSF, it shows promising results. The contour can be well detected and there is no need to initialize the level set function.

(a) **(b)** **(c)**

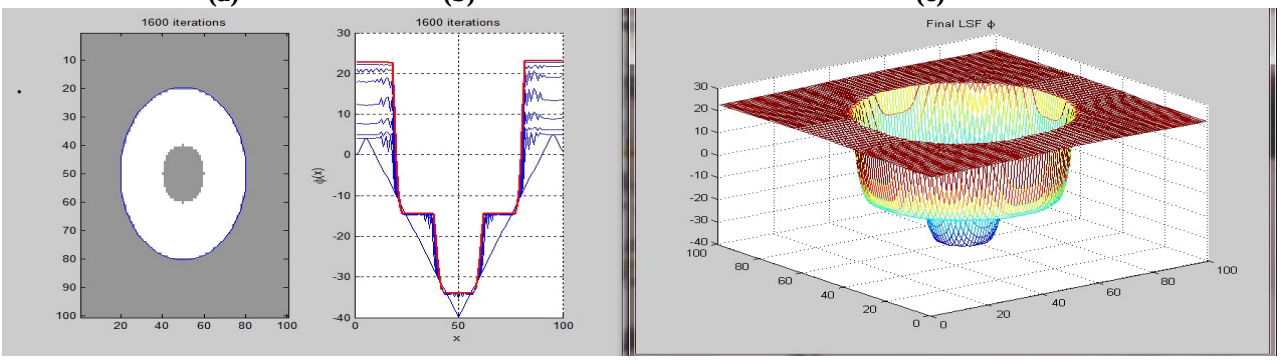

Figure 6: The GAC model implemented by the proposed TSSM method on an image with interior boundary. (a) Initial level set function. (b) Final level set function. (c) Testing image. We set t1=0.1 and t2=0.001.

On applying the level set method with re-initialization process, the contour is not sill detected finally. The evolution stops after certain number of iterations making the final contour undetected. On applying the Distance Regularization Level set evolution, the evolution curve shrinks in the area of interest that is the final contour at which the tumour has to be detected. Also it takes many iterations and excessive computation time.

(a) **(b)**

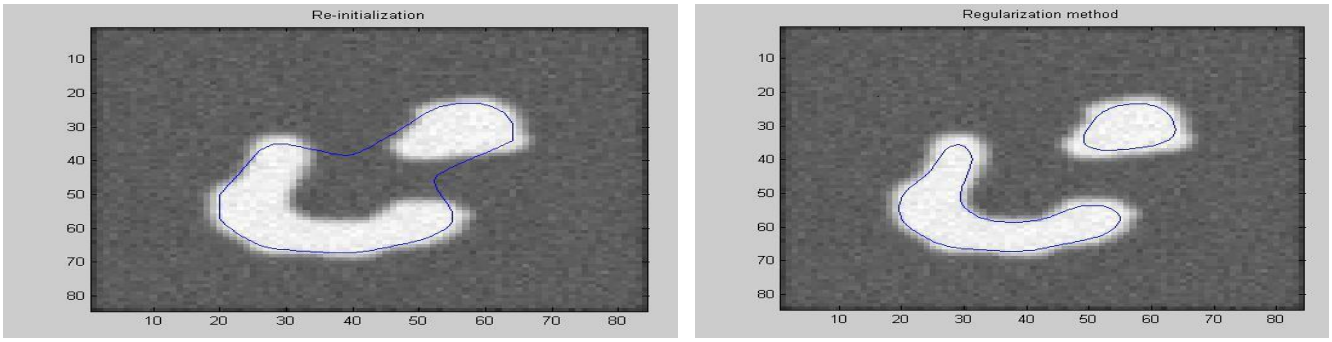

Figure 7(a): Applying Level set method with Re-initialization on noisy image (b) Applying Distance Regularization LSM on noisy image.

(a) **(b)**

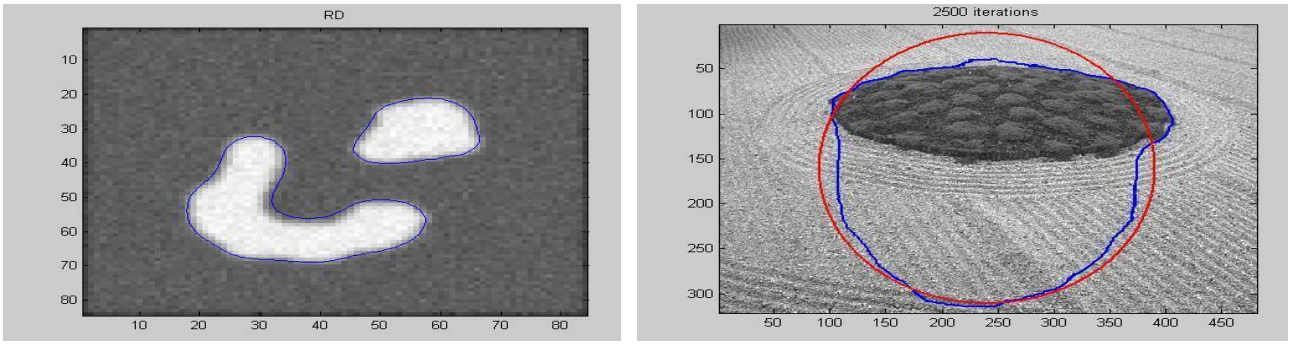

Figure8 (a): Applying level set method with two step splitting method on noisy image (b) Applying LSM with Re-initialization on high dimensional image.

On applying the level set method with the reaction diffusion process, the exact contour is detected and the number of iterations taken to execute the final contour is compara6tively less and also the number of iterations as compared to previous methods. By applying the level set method with re-initialization process the contour is still not detected if the image is of high dimensional. Also the number of iterations needed to solve are comparably high and the computation time takes up to hours to execute. The implementation of distance regularize level set method on high dimensional images could not find the exact contour from the image. The contour detected is shown in figure and the number of iterations and the cost of computation is even very high. But when applying the level set method with the reaction diffusion process on the high dimensional image, the contour is easily detected in less number of iterations compared with other previous method and executing in less computation time. In all these figures, the red colour indicates the initial contour and the blue line indicates the final contour.

(a) **(b)**

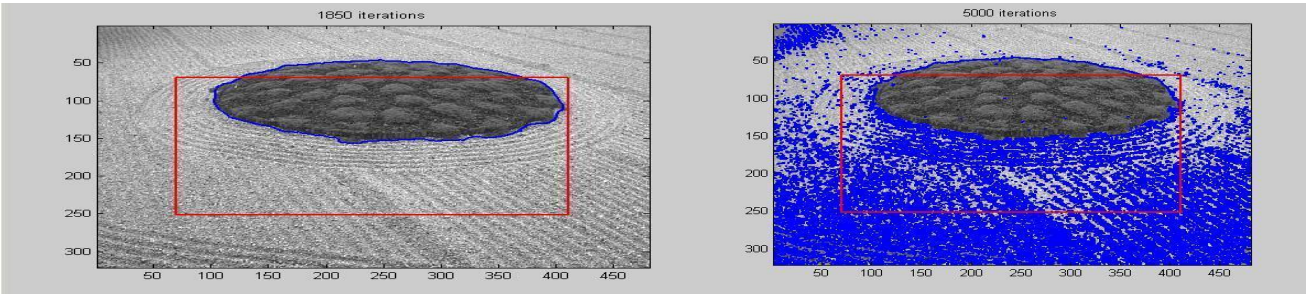

Figure 9(a): Applying DRLSE method on high dimensional image (b) Applying LSM with two step splitting method on high dimensional image.

Table 1: Comparison of various methods

Method	**LSM with Re-Initialization**		**Distance Regularize Level Set Method**		**Proposed Level Set Method with(TSSM)**	
Type of Image with Size	Iteration	Execution Time (S)	Iteration	Execution Time (S)	Iteration	Execution Time (S)
Noisy (84x84)	3000	365.37	5000	142.42	3000	57.14
High Dimensional (481x321)	2500	5438	5000	9854	1850	608.44

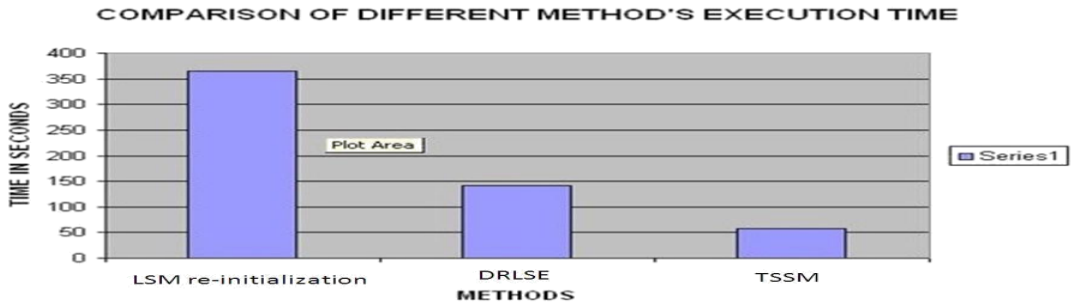

Figure 10: comparison of various methods time execution.

Looking at the table which compares different methods with proposed method in execution time and number of iterations, it is found that implementation of level set method with reaction diffusion promises to give best result among all other methods. The execution time of the proposed method is found to be very low compared to other methods and the number of iterations to iteratively execute the method also proves to below.

Thus the efficiency of the system is found to be high as compared with other methods as shown in table and graph.

5. Conclusion and Future Work

The proposed level set method with diffusion is implemented with two step splitting method. Firstly the energy function is implemented for the proposed method. The energy function shows quite good performance as compared to the energy function of previous methods. Also the re-initialization process is omitted in the method leading to level set method free of its re-initialization process. Thereafter implementing the proposed method on noisy image, giving promising results in less execution time and less number of iterations. Thereafter the same was performed on high dimensional images giving again the same promising results.

The future aspect of the proposed method will be to make the method more robust and making it performs on live images taken from a video frame.

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