# An Enhanced Segmentation Method by Combining Super Resolution and Level Set

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***Abstract*—High accuracy in image segmentation is highly demanded in today's technological world. In this paper combining super resolution image reconstruction with level set image is proposed as a way to improve image segmentation. The term Super resolution, resolution enhancement, is a process to increase the resolution of an image. This improvement quality is due to sub-pixel shift of low resolution (LR) images from each other between images. In fact, each LR image has new information of the image and the main aim of super resolution is to combining these LR images to enhance the image resolution. Following this method, allows users that without any demand for additional hardware, overcoming the limitations of the imaging system. Moreover, the main goal of segmentation is to distinguish an object from background. Segmentation can do that by dividing pixels of an image into prominent image regions. In fact, a specific region is corresponding to individual objects or natural parts of objects. Segmentation can be used in different fields such as image compression and image editing. Vandewalle algorithm and level set segmentation are used in the super resolution and segmentation part respectively. Additionally the regularity of the level set function is conserved via level set regularization term to evade expensive evolving level set function re-initialization. Experiment results for real and magnetic resolution (MR) images indicate the performance of our method. Using level set segmentation technique with super resolution, improves segmentation results in both normal and MR images.**

***Index Terms*—segmentation, super resolution, level set, magnetic resonance imaging**.

## I. Introduction

It has been well around three decades since the first attempts on image processing by computer. The most important reason of this effort is that the majority of data that human being receive is by his observation and image processing. Image processing techniques are applied in a wide variety of fields, like medical imaging, surveillance, robotics, industrial inception and remote sensing. Therefore, in many applications the demand for highly detailed images is gradually increasing.

High resolution (HR) means that the number of pixels within a given size of image is large. Therefore a HR image usually offers important or even critical information for various practical applications [2]. Although, charge coupled device (CCD) and CMOS image sensors have been widely used in recent decades, the current resolution level in these sensors does not meet the increasing demands in the near future. Furthermore, the main aim of image segmentation is to partition an image into meaningful regions. As a matter of fact, segmentation is based on measurements taken from the image and might be gray level, color and motion. Segmentation scheme is one of the most crucial techniques that are introduced as a useful method for image analysis, understanding and interpretation. Actually, by using two basic image processing methods, the boundary based (edge-based) segmentation and region-based segmentation [3]; feature-based image segmentation is performed.

Mean Shift [4] is a segmentation technique that has been used in recent years. The advantages of this technique are the simplicity of parameter (window size) and robustness of this technique to outlier. However, the dependency on window size and limitation of scale configuration in respect to the dimension of feature space is its disadvantages. Normalized cut is another segmentation technique that has been used in recent years. This method can be applicable with different features and affinity framework. However, this segmentation scheme has some drawbacks such as: high storage requirement, time complexity and bias toward partitioning into equal segments [2].

The idea behind level set, as a segmentation technique, is to specify an initial contour which is moved by internal and external forces to boundaries of the desired object. During the deformation process, the internal force tries to keep the model smooth, while external force moves the model towards an object boundary. Level set segmentation scheme has several advantages such as: bias toward partitioning into equal segments, providing direct

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estimation of the geometric properties of the evolving structure, optimization framework, changing topology. Moreover, level set segmentation method is intrinsic and is a free parameter scheme [5].

In this paper the results of applying Level Set segmentation on both low and high resolution images has been compared. In super resolution part, Vandewalle algorithm in the motion estimation part and interpolation with factor 2 as a reconstruction algorithm has been used. Using 10 LR images a HR is obtained. Then the level set segmentation is applied on both LR and HR images. The results indicate that level set segmentation has better outcome on super resolution images. To the author's knowledge this combination has not been used so far especially for the brain MR images. Along this technique, segmentation is improved slightly.

## II. METHOD

### A. Super Reolution Method

The concept of super resolution is based on achieving HR image from the noisy, blurred and aliased image. Having formulation that relates HR model to the observed LR image is a must. Observation model can be represented as below [6]:

$$\boldsymbol{Y_k = DB_kM_kX + n_k} \qquad (1)$$

where $\mathbf{X}$ is HR image in lexicographical notation as vector $\mathbf{X} = [\boldsymbol{X_1}, \boldsymbol{X_2}, \dots, \boldsymbol{X_N}]^{\boldsymbol{T}}$whit *N= L1N1 ×L2N2*, $\mathbf{Y}$ is LR image denoted in lexicographic notation as $\mathbf{Y_k} = [\boldsymbol{Y_{k1}}, \boldsymbol{Y_{k2}}, \dots, \boldsymbol{Y_{kC}}]$for *k = 1, 2, ..., p*and *C = N1 ×N2*. $\mathbf{M_k}$ is the warp matrix due to the motion that occurs during image possessions. This factor consists of a transformation and rotation. $\boldsymbol{B_k}$ is the blur matrix because of relative motion between the imaging system and original scene or optical system such as aberration and out of focus. Blur can also cause by point spread function (PSF) of the LR sensor which can be modeled as a special averaging; and $\boldsymbol{n_k}$ is the Gaussian noise vector. $\boldsymbol{D}$ is considered as a sub-sampling matrix that can generate images from the warped and blurred HR images. By using sub-sampling, different size of LR images can be achieved.

Two of the most common difficulties in super resolution concept are noise and blur. Basic methods for denoising, Bayesian and Median filtering [7], were included to remove image details and over smooth the edges. While complicated techniques like wavelet based and bilateral filtering use the properties of initial image statistics to strengthen large intensity and decrease lower intensity edges[8].

### B. Level Set Image Segmentation

Level set segmentation method use image features such as edges and contrasts to obtain differential equations for segmentation. Basis of level set segmentation is to express associated energy to a contour as a sum of internal and external energy and then try to make it minimum. Active contour or snakes have been evaluated because algorithms are easily trapped in local minima. Therefore, segmentation result is highly dependent on initialization. Active contour models can be classified into two major groups [9]:

- Edge based active contour model which uses of image edge information by exploiting image gradient to stop the evolving contours of the object boundaries.
- Region based methods which without using image gradient try to identify each region of interest. Therefore, this characteristic has made region-based method less sensitive to image boundaries.

Model-based active contour*:* Consider a given value image $\mathbf{I}: \Omega \to \mathbf{R_d}$ where $\Omega \subset \mathbf{R_n}$ , and $\mathrm{d} \geq 1$ is the dimensionof the vector $\mathbf{I(x)}$. $\mathbf{d}$ =1is considered for the gray level images and $\mathbf{d}$=3 is considered for the color images. Moreover, $\mathbf{C}$ isintroduced as a closed contour which separates the image domain into outside$\mathbf{C}(x\Omega_1)$ and inside $\mathbf{C}(\Omega_2)$ regions. So, thelocal intensity fitting energy is defined as:

$$\boldsymbol{E_x^{fit}(C, f_1(x), f_2(x))} = \sum_{i=1}^{i=2} \boldsymbol{\lambda_i} \int_{\Omega_i} \boldsymbol{k(x,y)\|I(y) - f_i(x)\|^2\, dy} \qquad (2)$$

where $f_1(x)$ and $f_2(x)$ are two values that approximate intensities in $\Omega_1$ and $\boldsymbol{\Omega_2}$ regions. $k$as a Gaussian Kernel function which is defined as below:

$$k_{\boldsymbol{\delta}}(\mathbf{u}) = \frac{\mathbf{e}^{-\frac{\|\mathbf{u}\|^2}{2\delta^2}}}{(\mathbf{2\pi})^{-\frac{n}{2}}\boldsymbol{\delta}^{\mathbf{n}}} \qquad (3)$$

$k\|\boldsymbol{x} - \boldsymbol{y}\|$ is effectively zero when $\|\boldsymbol{x} - \boldsymbol{y}\| \geq \boldsymbol{3\delta}$. So, only the intensities in the neighborhood $\boldsymbol{y}: \|\boldsymbol{x} - \boldsymbol{y}\| \leq \boldsymbol{3\delta}$are dominant in the $\boldsymbol{E_x^{fit}}$and it can be said that $\boldsymbol{E_x^{fit}}$is localized aroundthe point $\boldsymbol{x}$. As the intensity $\boldsymbol{I(y)}$ in equation (2) can be vary from the entire image domain which corresponds to a large $\boldsymbol{\delta}$centered at $\boldsymbol{x}$to a small neighborhood which corresponds to a small $\delta$ of the point $\boldsymbol{x}$, it is much more convenient that call $\boldsymbol{E_x^{fit}}$ a Region-Scalable Fitting (RSF) energy; with given a center point $\boldsymbol{x}$, the fitting energy $\boldsymbol{E_x^{fit}}$which is defined as equation (2) minimized when the contour $\mathbf{C}$is exactly on the object boundary.

In this situation, $f_1$ and $f_2$ approximate the image intensities on the both sides of $\mathbf{C}$. Given a center point $\boldsymbol{x}$in the image domain; when a contour $\mathbf{C}$ is exactly on the object boundary, the fitting energy $\boldsymbol{E_x^{fit}}$ can be minimized. Therefore, the energy functional can be defined as (4) [9].

$$\boldsymbol{E}(\mathbf{C}, \boldsymbol{f_1(x)}, \boldsymbol{f_2(x)}) = \int \boldsymbol{E_x^{fit}}(\mathbf{C}, \boldsymbol{f_1(x)}, \boldsymbol{f_2(x)})\boldsymbol{dx} + \boldsymbol{\nu}\|\mathbf{C}\| \qquad (4)$$

The goal of this paper is to find a method to achieve segmented image with high performance in both normal and MR images. Experimental results show that segmentation process has better results on super resolution images.

## III. SOFTWARE PACKAGE

Two software packages that were used in this paper are: a) Super resolution image reconstruction software package downloaded from: [10], b) Level set segmentation software downloaded from [11].

### *A. Super Resolution Image Reconstruction Software*

Vandewalleet. al. [8] developed a collection of methods, including non-uniform interpolation using delaunay triangulation. This software enables users to compare different methods of super resolution that exist today. The algorithm that was used for the motion estimation is Vandewalle algorithm.

In this method instead of using whole frequency spectrum only parts of frequency spectrum is considered that the signalto noise ratio is highest and aliasing is minimal. So, this algorithm is not able to reconstruct a better image as the method uses exactly this under sampled information. Although, one advantage of using this algorithm is the high frequency components, where aliasing may have occurred is discarded.This method is suitable with slight camera motion or satellite images. The performance of this method surpasses many other frequency algorithm and directive spatial algorithm in terms of SNR and objective quality. The reconstruction algorithm that was used here is interpolation algorithm with factor 4. In this algorithm the software simply aligns all the pixel of the image on a high resolution grid and then using Matlab'sgriddatafunction, applies bicubic interpolation.

### *B. Level Set Segmentation Software*

The software that was used in this paper was proposed by Chunming Li [9]. The software is based on the "Region Scalable Fitting Energy". The variety of parameters were used in this software, in terms of application, have different values. More information about effects of variation of these parameters can be found in [9].

## IV. RESULTS

In segmentation evaluation part, we first partitioned images into image segments and then analyzed them based on texture, shape or spectral features. There are many types of algorithms in image segmentation which each of them developed for a variety of applications from remote sensing [1] image analysis to medical imaging.

Having a benchmark for deciding which of them can perform better is highly demanded. Such as segmentation, there is no standard way for evaluation of segmentation.

As a matter of fact, segmentation evaluation is completely subjective and is a serious problem in image analysis field. In some circumstances, the concept of evaluation of segmentation is based on how well the segmented image corresponds to the ground truth segmentation based on pixel by pixel differences. But, there is no unique ground truth of segmentation for images. However, if a specific model of ground truth is selected, in almost all applications of scene analysis, the difference between segmented image and ground truth should be minimized. Hence, the criterion of segmentation is rather harsh in terms of penalizing algorithms severely if they don't segment accurately. On the other side, in some applications, for instance medical imaging, overlapping of segmented image with the true region would be sufficient. Hence, if segmentation only partially detects the true region or border can be considered acceptable.

The segmentation package parameters setting are as follow: Iteration number that defines the number of iterations that depends on the location of initial contour. Scale parameter that controls the size of image intensities in a region that corresponds to scale parameter in Gaussian-Kernel that set to 1. Time step that defines the value of this parameter is set to 0.1. Furthermore, the super resolution setting can be found in each example separately.

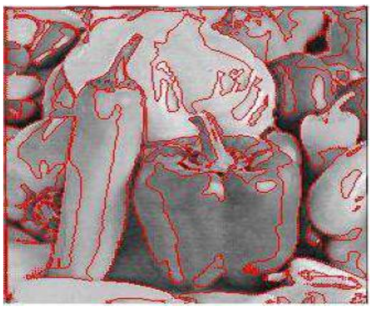

Figure 1. SR image segmentation

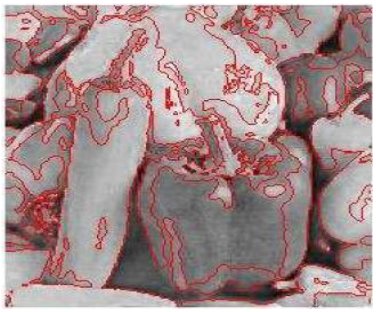

Figure 2. LR image segmentation

Fig. 1 and Fig. 2 show the results of segmentation of both super resolution and low resolution images. The Images were taken from Berkley segmentation Database. If we look at Fig.1 we conclude that in high resolution image, borders have been represented more distinctly. It is worth mentioning that super resolution segmentation achieved by 1500 iterations meanwhile LR achieved by 400 iterations.

Figure 3. SR image segmentation

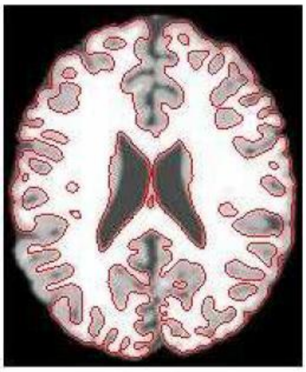

Figure 4. LR image segmentation

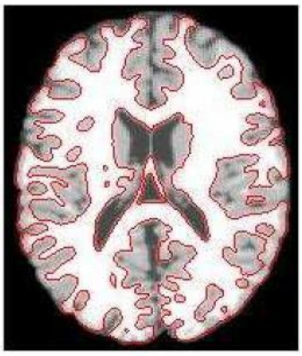

Figure 5. SR image segmentation

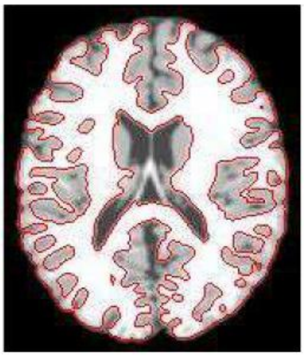

Figure 6. LR image segmentation

By comparing segmentation results in Fig. 3, Fig. 4, Fig. 5 and Fig. 6 we see that segmentation has better results in SR MR images; segmentation of some parts of the image has missed in LR image and if we look carefully, we see that segmentation acts better in face with boundaries and edges in super resolution image. The number of iterations that used for all images are 3000.

## V. NEW OF BREAK THROUGH WORK TO BE PRESENTED

As the main goal of this paper is to find a suitable scheme to improve image segmentation, we propose images first need to be processed by super resolution software then to be sent them to segmentation part. The images used here are both normal and MR images. According to the achieved results it can be concluded that segmentation of super resolution images is slightly better than LR images.

## VI. CONCLUSION

The objective of this paper was to find an appropriate approach for image segmentation and simply classification of images. Combining super resolution image reconstruction with level set image segmentation introduced in this paper, so we applied segmentation on super resolution images. As the experiment results show, using this technique enhanced the segmentation of both ordinary and MR images.

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