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Segmentation of Image Using Watershed and Fast Level set methods

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Abstract--**Technology is proliferating. Many methods are used for medical imaging .The important methods used here are fast marching and level set in comparison with the watershed transform .Since watershed algorithm was applied to an image has over clusters in segmentation . Both methods are applied to segment the medical images. First, fast marching method is used to extract the rough contours. Then level set method is utilized to finely tune the initial boundary. Moreover, Traditional fast marching method was modified by the use of watershed transform.**

The method is feasible in medical imaging and deserves further research. It could be used to segment the white matter, brain tumor and other small and simple structured organs in CT and MR images. In the future, we will integrate level set method with statistical shape analysis to make it applicable to more kinds of medical images and have better robustness to noise.

Categories and Subject Descriptors
I.4 Image Processing and Computer Vision
General Terms
Design, Experimentation.

Keywords-*Segmentation, Watershed transform, fast marching method and fast level set method.*

1.1 INTRODUCTION

The use of digital images is increasing rapidly in computer science, medical research etc. Digital image processing has become the most common form of image processing, and is generally used because it is not only the most versatile method, but also the cheapest. Along with this increasing use of digital images comes the serious issue of storing and transferring the huge volume of data representing the images because the uncompressed multimedia (graphics, audio and video) data requires considerable storage capacity and transmission bandwidth. Though there is a rapid progress in mass storage density, speed of the processor and the performance of the digital communication systems, the demand for data storage capacity and data transmission bandwidth continues to exceed the capabilities of on hand technologies. Besides, the latest growth of data intensive multimedia based web applications has put much pressure on the researchers to find the way of using the images in the web applications more effectively.

In computer vision, segmentation refers to the process of partitioning a digital image into multiple segments (sets of pixels) (Also known as super pixels). The goal of segmentation is to simplify and/or change the representation of an image into something that is more meaningful and easier to analyze. Image segmentation is typically used to locate objects and boundaries (lines, curves, etc.) in images. More precisely, image segmentation is the process of assigning a label to every pixel in an image such that pixels with the same label share certain visual characteristics.

The result of image segmentation is a set of segments that collectively cover the entire image, or a set of contours extracted from the image (edge detection). Each of the pixels in a region are similar with respect to some characteristic or computed property, such as color, intensity, or texture. Adjacent regions are significantly different with respect to the same characteristic(s). Structures of interest include organs or parts thereof, such as cardiac ventricles or kidneys, abnormalities such as tumors and cysts, as well as other structures such as bones, vessels, brain structures etc. The overall objective of such methods is referred to as computer-aided diagnosis; in other words, they are used for assisting doctors in evaluating medical imagery or in recognizing abnormal findings in a medical image.

In contrast to generic segmentation methods, methods used for medical image segmentation are often application-specific; as such, they can make use of prior knowledge for the particular objects of interest and other expected or possible structures in the image. This has led to the development of a wide range of segmentation methods addressing specific problems in medical applications

FAST MARCHING METHOD

Fast Marching Methods are designed for problems in which the speed function never changes sign, so that the front is always moving forward or backward. This allows us to convert the problem to a stationary formulation, because the front crosses each red grid point only once. This conversion to a stationary formulation, plus a whole bunch of numerical tricks, gives it its tremendous speed

Rather than follow the interface itself, the Fast Marching Method makes use of stationary approach to the problem. At first glance, this sounds counter-intuitive; we are going to trade a moving boundary problem for one in which nothing moves at all! To see how this is done, imagine a grid laid down on top of the problem:

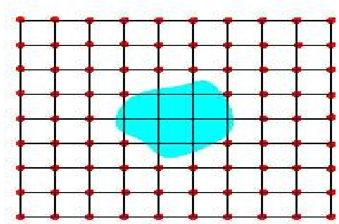


Fig. . Fast Marching Approach

Suppose that somebody is standing at each red grid point with a watch. When the front crosses each grid point, the person standing there writes down this crossing time T. This grid of crossing time values T(x,y) determines a function; at each grid point T, T(x,y) gives the time at which the front crosses the point (x,y).

As an example, suppose the initial disturbance is a circle propagating outwards. The original region (the blue one on the left below) propagates outwards, crossing over each of the timing spots. The function T(x,y) gives a cone-shaped surface, which is shown on the right. This surface has a great property; it intersects the xy plane *exactly* where the curve is initially. Better yet, at any height T the surface gives the set of points reached at time T. The surface on the right below is called the arrival time surface, because it gives Fig. 3 The arrival time.

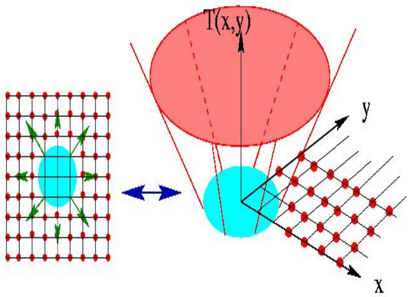


Fig.3 Arrival time surface

The reason it is called a "boundary value formulation" is because we have let the initial position of the front be the boundary for this arrival time surface T(x,y) that we would like to find. We have taken the idea of finding something that moves in time an exchanged it for a stationary problem in which the arrival surface contains the information about what is moving.

The *Fast Marching Method* imitates this process. Given the initial curve (shown in red), stand on the lowest spot (which would be any point on the curve), and build a little bit of the surface that corresponds to the front moving with the speed F. Repeat the process over and over, always standing on the lowest spot of the scaffold, and building that little bit of the surface. When this process ends, the entire surface has been built.

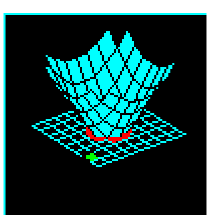


Fig. 4. Construction of stationary level set solution
Green squares show next level to be built

The speed from this method comes from figuring out in what order to build the scaffolding; fortunately, there are lots of fast sorting algorithms that can do this job quickly.

The main idea of level set method is to represent a closed curve $\Gamma(t)$ on the plane as the zero level set of a higher dimensional function Φ. The motion of the curve is then embedded within the motion of the higher dimensional surface. Let $\Gamma(t)$ be the closed interface or front propagating along its normal direction. This closed interface $\Gamma(t)$ can either be a curve in 2-D space or a surface in 3-D space.
Let $\Phi(x, t = 0)$, where εR^N be defined by $\Phi(x, t = 0) = d$, where d is the signed distance from position x to Γ(0) and the plus (minus) sign is chosen if the point x is outside (inside) the initial front
4Γ(0) [9]. An Eulerian formulation is produced for the motion of this surface propagating along its normal direction with speed F, where F can be a function of the surface characteristics (such as the curvature, normal direction etc.) and the image characteristics (e.g. the gray level, gradient etc.). The
equation of the evolution of Φ, inside which our surface is embedded as the zero level set is then given
by the following equation:

$\Phi t+F|\nabla\Phi|=0$ (1)

The major advantages of using this method over other active contour strategies include the following [10].
First, the evolving level set function $\Phi(x, t)$ remains a function, but the propagating front $\Gamma(t)$ may change topology, break, merge and form sharp corners as Φ evolves. Second, the intrinsic geometric properties of the front may be easily determined from Φ. For example, at any point of the front, the normal vector is given by $n = \nabla\Phi$. Finally, the formulation is unchanged for propagating interfaces in three dimensions.
One of the most popular level set algorithms is the so-called fast marching method. Now consider the
special case of a surface moving with speed > 0 (the case where F is everywhere negative is also
allowed). We then have a monotonically advancing front whose level set equation is of the following
form:

$|\nabla \boldsymbol{T}|\boldsymbol{F}=1$ (2)

This simply says that the gradient of arrival time is inversely proportional to the speed of the surface.
There are two ways of approximating the position of the moving surface: iteration towards the solution
by numerically approximating the derivatives in Eq. (1) or explicit construction of the solution function
T from Eq. (2). Fast marching method depends on the latter approach.
Equation (2) is one form of the Eikonal equations. Sethian proved that it is equivalence to solve the
following quadratic equation in order to get the arrival time T of the Eq. (2).

$$\left[\max(D^{-x}_{ij}T,0)^2+\min(D^{+x}_{ij}T,0)^2+\max(D^{-y}_{ij}T,0)^2+\min(D^{+y}_{ij}T,0)^2\right]^{1/2}=1/F_{i,j} \quad (3)$$

Where $D+$ and $D-$ are backward and forward difference operators:

$$\begin{cases} D^{+x}T=\frac{T(x,y+1)-T(x,y)}{2} \& D^{-x}T=\frac{T(x,y)-T(x,y-1)}{2} \\ D^{+y}T=\frac{T(x+1,y)-T(x,y)}{2} \& D^{-y}T=\frac{T(x,y)-T(x-1,y)}{2} \end{cases} \quad (4)$$

The steps of the traditional fast marching method are as follows:
1. Initializing step:
1) *Alive points:* Let A be the set of all grid points *{iA, jA}* which represents the initial curve. In
our algorithm, Alive points are the seeded points users assign to. See Fig. 1;
2) *Narrowband points:* Let Narrowband points be the set of all grid point neighbors of A. In our

Algorithm, those are the 4-nearest points of the seeded points. Set $T(x, y) = 1/F(x, y)$. See Fig. 1;
3) *Faraway points:* Let Faraway points be the set of all others grid points $\{x, y\}$. Set $T(x, y) =$ TIME MAX, See Fig. 1;

2. **Marching forwards**:
1) Begin loop: Let ($i$min, $j$min) be the point in Narrowband with the smallest value for T;

2) Add the point ($i$min, $j$min) to A; remove it from Narrowband;

3) Tag as neighbors any points ($i$min − 1, $j$min), ($i$min + 1, $j$min), ($i$min, $j$min − 1), ($i$min, $j$min + 1) that are either in Narrowband or Faraway. If the neighbor is in Faraway, remove it from that list and add it to the set Narrowband;

4) Recomputed the values of T at all neighbors according to equation 3, selecting the largest possible solution to the quadratic equation;

5) Return to top of Loop.

1.2 Level set Method

The main characteristic of the level set method is its ability to pick up the right topology of the shape we are segmenting. The accuracy of the segmentation process depends upon where and when the propagating hyper surface needs to stop. For the fast marching method, the segmentation results rely on the definition of speed function to a greater degree. Whether the speed function adopts the definition of there is a tunable parameter α or β which determines the value of speed function. It is important and also difficult to select the adaptive parameter value. So, on the condition of specified parameter value, it is necessary to use level set method to finely tune the rough contours obtained from fast marching method. In addition, through fast marching method, we can get the rough front and the location of each pixel. That is, we can determine where each pixel locates. It is useful and convenient to calculate the signed distance of the following level set method which is from each pixel to the front boundary.
The application of level sets in medical segmentation of medical imagery becomes extremely popular because of its ability to capture the topology of shapes in medical imagery. Since the proposal of level set method, many researchers have succeeded in applying level set method to image processing and computer vision. The motion equation of level set method is given by. Now we can discretize it by finite difference approximation on a regular grid.

Problems of traditional level set methods

1) High computational complexity of solving the PDE

(Unnecessary sub pixel accuracy)

To accelerate:

avoid solving of the PDE

1) Discrete representation, as simple as possible of the boundary

2) Simplify the velocity field

3) Reduce complexity of operations

The proposed fast level set method

Level set method contains many good mathematical properties which make it an accurate description for front propagation. For image segmentation, the level set method has the ability to handle objects with topology changes from the initial contour. This paper presents a fast level set method which keeps this advantage at a much reduced computational time.

Implementation

Let the interface is represented by 2 neighboring sets of grid points: Lin Lout

Roughly approximates the signed distance function

$\Psi(X) =$ 3 if X is an exterior point ($X \in \Omega b \wedge X \notin$ Lout);

1 if $X \in$ Lout;

-1 if $X \in$ Lin;

-3 if X is an interior point ($X \in \Omega \wedge X \notin$ Lin);

Velocity Field V

Reflects only the image based external force

Positive for a foreground image pixel and vice-versa

uses a modified Chan-Vese segmentation criterion

$V(X) = \{1$ if $-\lambda_1 ((f(x)-C_1)^2 + \lambda_2 (f(x)-C_2)^2 \geq 0;$

$\{-1$ if $-\lambda_1 ((f(x)-C_1)^2 + \lambda_2 (f(x)-C_2)^2 < 0;$

Interface Smoothing

_ Gaussian smoothing of the level set function Ψ

_ Gaussian filtering of Ψ is calculated only at Lin and Lout points

_ NEW: we use an anisotropic Gaussian filter G

_ The boundary is updated, if $(G * \Psi'(x)) * \Psi'(x) < 0$

Iteration and Control

Each major iteration consists of Ne evolution steps followed by Ng smoothing steps

_ Ne controls the penetrability of the evolving interface

_ Ng controls the amount of smoothing

_ two stopping criteria:

_ maximum number of major iterations

_ NEW: maximum number of boundary pixels changing state between major iterations

Proposed Algorithm

1. Compute the velocity field v;
2. Create the Gaussian mask G;
3. Create the Lin and Lout from ψ;
4. While the stopping criterion is not reached do:

for i = 1 to Ne do:

Outward evolution;

Eliminate redundant points in Lin;

Inward evolution;

Eliminate redundant points in Lout;

for i = 1 to Ng do:

Outward interface smoothing;

Eliminate redundant points in Lin;

Inward interface smoothing;

Eliminate redundant points in Lout.

5. Return final ψ

Advantage

1) Preserves all advantages of traditional level set methods

2)) discrete approach

3) The zero level set representation using a list of boundary points

4) Avoids computing any PDE

5) Regularization handled by a separate step of the algorithm

2. Watershed Transform

In geography a watershed is the ridge that divides areas drained by different river systems. A catchment basin means in this sense an area from which rainfall flows into a river or reservoir. The watershed transform applies these ideas to the gray-scale image processing to enable solution of a variety of image segmentation problems. Understanding the watershed transform requires us to consider a gray-scale image as a topological surface, where the values of $f(x, y)$ are interpreted as heights. The watershed transform finds the catchment basins and ridge lines in such a grayscale image. In terms of the problem related to image segmentation the key concept is to change the starting image into another one whose catchment basins are the objects or regions.

Watershed transformation is a powerful tool for image segmentation. In this paper, the different morphological tool used in segmentation is reviewed together with an abundant illustration of the methodology through examples of image segmentation coming from various areas of image analysis. There exists two basic ways of approaching image segmentation. The first one is boundary based and detects local changes. The second one is wavelet-based and searches for pixel. We shall see that the watershed transformation belongs to the latter class. The gradient image is often used in the watershed transformation, because the main criterion of the segmentation is the homogeneity of the grey values of the object present in the image .But, when other criteria are relevant, other functions can be used. In particular, when the segmentation is based on the shape of the objects, the distance functions is very helpful. The impression which the current literature on watershed algorithms makes upon the initiated readers can only be of one great confusion.

Often it is uncertain exactly which definition for the watershed transform used. Sometimes the definition takes the form of the specification of the algorithm. A careful distinction between algorithm specification and implementation is in many cases lacking without such a separation correctness assessment of proposed algorithms is impossible The watershed transform finds the catchment basins and ridge lines in such a grayscale image.

Algorithm

Different approches may be employed to use the watershed principle for image segmentation.

- Local minima of the gradient of the image may be chosen as markers, in this case an over-segmentation is produced and a second step involves region merging.
- Marker based watershed transformation make use of specific marker positions which have been either explicitly defined by the user or determined automatically

The key of fast marching method is the definition of speed function , due to the fact that speed function only depends on the gradient information (edge information) not the global information of the image region, it is easy to make mistakes in segmenting the blurred image boundary.

In general it is well known that the image is composed of many small regions. Each region is of homogeneity. Such as the contiguous intensity value, the similar texture structure. It is crucial for the final segmentation result to make full use of the region information. So we introduced watershed transform to over segment the original image in to many small regions.

The merit of introducing watershed transform lies in three aspects. Firstly . for fast marching method, let the initial contour region be the seeded point the segmentation accuracy can be improved since the final segmentation results are bounded to be potential boundaries of objects.

Finally the stastical similarity degree of the nearby regions is a good reference of speed function of fast marching method.

7. EXPERIMENTAL DETAILS (RESULTS)

Fig. GUI of the project

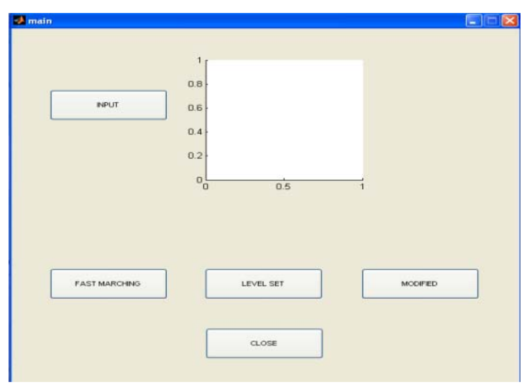


Fig. . Input to the project

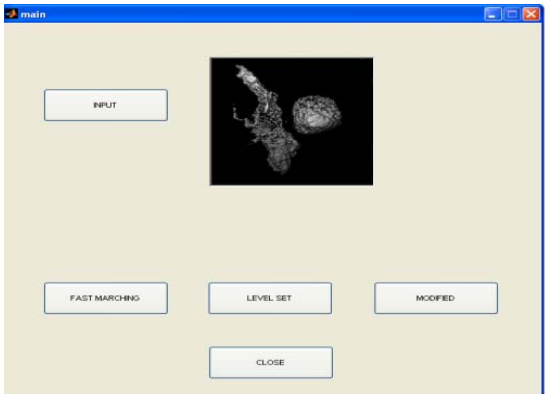


Fig. . Watershed transform

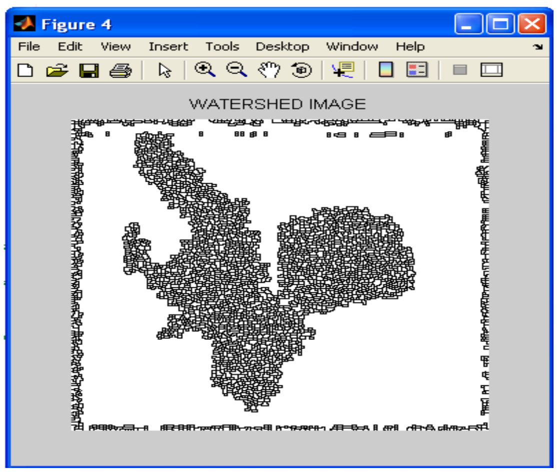


Fig. . Fast Marching Process

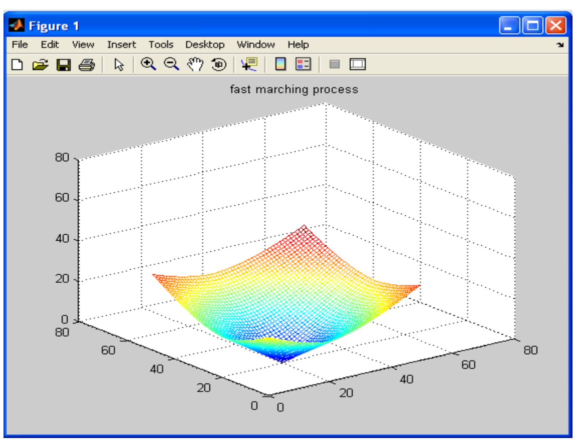


Fig. . Fast Marching Output

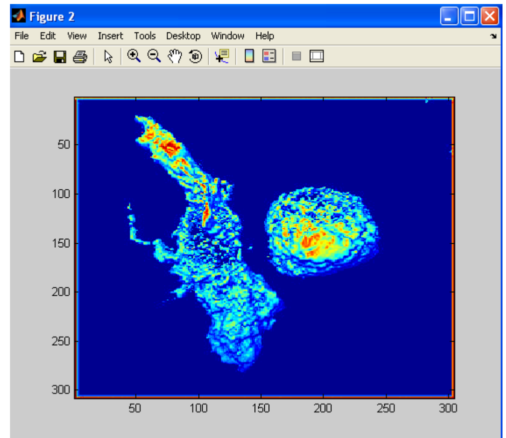


Fig. . Fast Level Set initial contour

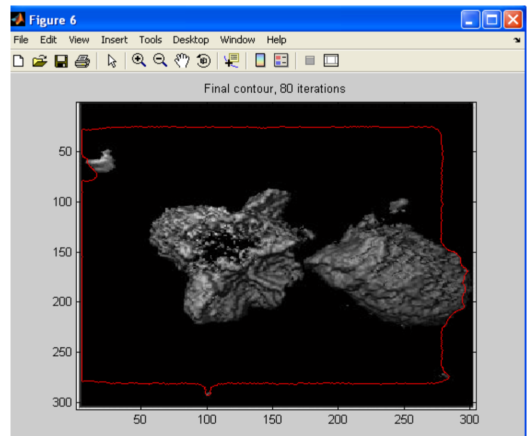


Fig. . Fast Level Set final contour

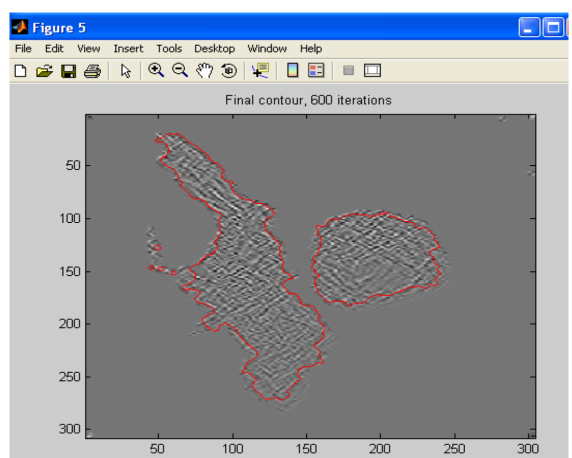
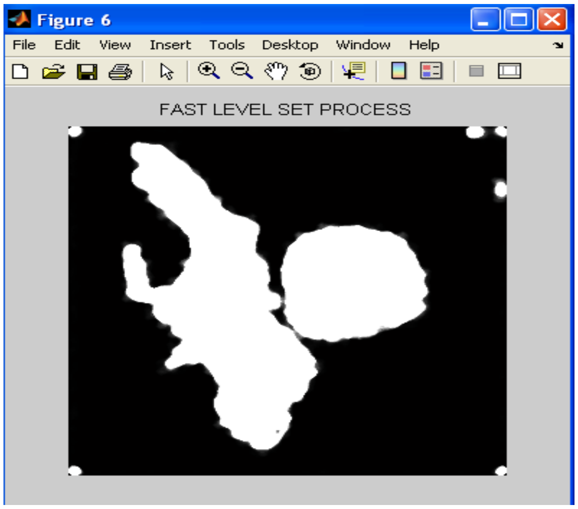


Fig. . Fast Level Set Output



3. CONCLUSION

Picture can say more than a thousand words. However, storing an image can cost more than a million words. This is not always a problem because now computers are capable enough to handle large amounts of data. However, it is often desirable to use the limited resources more efficiently. The importance of the image segmentation by combining the level set and watershed transforms. Watershed transform, is very sensitive to noise and we will have over segmentation. To solve this problem we combined level set and fast marching transforms for increasing result accuracy

3.1 Future Scope

In future work, we should look for 3d segmentation of medical images using different techniques to provide better result, we are going to apply three techniques first using modified fast marching method we select the region of interest than applying watershed transform to get the correct edges and finally applying the fast level set method for smoothing.

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