CREASEG: A FREE SOFTWARE FOR THE EVALUATION OF IMAGE SEGMENTATION ALGORITHMS BASED ON LEVEL-SET

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ABSTRACT

This paper describes a free open source software in Matlab (named Creaseg, `http://www.creatis.insa-lyon.fr/~bernard/creaseg`) for the evaluation of the performance of different level-set based algorithms in the context of 2D image segmentation. The platform gives access to the implementation of six level-set methods that have been chosen in order to cover a wide range of data attachment terms (contour, region and localized approaches). The software also gives the possibility to compare the performance of the proposed algorithms on any kind of images. The performance can be evaluated either visually, or from similarity measurements between a reference and the results of the segmentation.

Index Terms— free software, level-set methods, segmentation evaluation

1. INTRODUCTION

1.1. Evaluation of image segmentation algorithms

Segmentation is a fundamental step in image processing. It allows to detect and visualize objects in scene. For example in biomedical imaging, it is used to extract organs, cells or structures inside the body. It is also a necessary step for the functional analysis and the diagnostic of pathologies. Unfortunately, many difficulties can arise during the segmentation process yielding incorrect results. Classical difficulties encountered can be noise, variation of contrast, inhomogeneities in the boundaries of the object of interest, motion blurring artifacts. As a consequence, a lot of segmentation algorithms have been proposed in the literature over the last thirty years. In this context, the publication of a new algorithm can be validated only after a comparison step with existing methods. Due to the numerous existing segmentation algorithms, this task appears commonly tedious. Thus there exists a strong need of an open source platform which allows to easily compare a new method with classical ones.

1.2. Our solution

The originality of this work is to propose a free open source software, named Creaseg, specifically designed for the validation of 2D image segmentation algorithms (The current interface allows to deal with 2D images, but an extension in 3D is expected). The main interface of this software is presented in Fig.1. It has to be noted that a complete documentation of Creaseg (giving a high detail description of the software) is accessible at the following web link address `http://www.creatis.insa-lyon.fr/~bernard/creaseg/userguide.html`

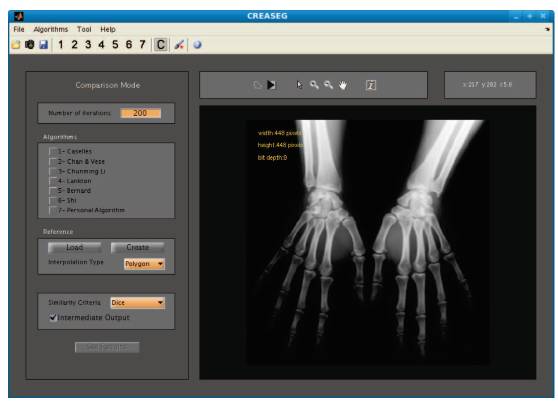


Fig. 1: Main interface of Creaseg, in comparison mode

The choice of developing this software under Matlab has been motivated by the following reasons: it makes the interface user-friendly, portable to the main operating systems (Windows, Linux or Mac OS based) and allows a standard handling of data files and graphical output. Moreover, it provides an easy understanding of the code (as the project is open source) and it allows the user to easily integrate a new method to be evaluated. Creaseg is focused on level-sets based segmentation, which are now a well-established and popular tool in the field of image processing, as shown by many surveys. This is linked to their ability to handle topological changes automatically and to the fact that their formulation is straightforward for any dimension. Level-sets correspond to a class of deformable models where the shape to be recovered is captured by propagating an interface represented by the zero level-set of a smooth function which is usually called the level-set function. The evolution of the interface is generally derived through a variational formulation: the segmentation problem is expressed as the minimization of an energy functional that reflects the properties of the objects to be recovered [1]. Moreover the segmentation process is expressed in an Eulerian framework. This removes the problem of contour self intersections and the need for control point regridding mechanisms. Creaseg gives access to six different level-set based methods. Classical methods such as contour-based approaches (Caselles [2]) or region-based approaches (Chan&Vese [3]) can be for instance selected, as well as more recent methods such as localized (Li [4] and Lankton [5]), parameterized (Bernard [6]) or discrete approximation-based techniques (Shi [7]).

The paper is organized as follows. In Section 2, we give a brief overview of the software. We show in Section 3 how this interface can be used for the evaluation of biomedical image segmentation algorithms. We give the main conclusions of this work in Section 4.

2. SOFTWARE OUTLINE

Creaseg was designed to provide the features commonly needed for the evaluation of the performance of a segmentation algorithm in an easy to use framework. It offers tools for image selection from a wide range of types including dicom format, image segmentation and comparison of segmentation results. The evaluation is performed between a created or loaded reference segmentation and the segmentation results obtained from the selected algorithms.

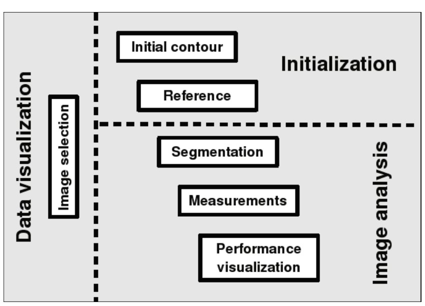


Fig. 2: The design of Creaseg covers the usual tasks for the evaluation of the performance of a segmentation algorithm.

2.1. Main modules

Creaseg can be divided into 3 modules as presented in Fig. 2. A complete description of the software can be found on the Creaseg website (`http://www.creatis.insa-lyon.fr/~bernard/creaseg/`).

Data visualization: The data visualization module allows the user to load a grayscale or color image. The supported format corresponds to classical types such as bmp, gif, jpeg, pgm, png, tiff and the dicom format encountered in medical applications.

Initialization: Because of the choice of level-set framework, the user has to create an initial curve before using the proposed algorithms. This initial curve can be either selected from predefined shapes (ellipses, rectangles, bubbles) or manually drawn by the user using polygonal or spline representation. Moreover, in order to evaluate the final segmentation result, the user has to give a reference contour to be compared with. This reference can either be loaded or drawn by the user, in the same way as the initial contour.

Image analysis: The image analysis module is designed to provide an easy evaluation of image segmentation. The user has the possibility to choose between six implemented level-set algorithms (that are presented in section 2.2) and its own implemented method. At the end of the segmentation process, the final contours of each selected methods are displayed on the same image. Moreover, the computational time and the similarity criterion of each algorithm are displayed in a table and save in a text file (see Sec. 2.3). Fig.1 shows the interface in comparison mode. The user can select several algorithms, the reference contour and the similarity criteria using the panel on the left.

2.2. Implemented level-set algorithms

The interface gives access to six different level-set algorithms that have been chosen in order to represent a wide range of level-set-based methods. Three of them (Bernard, Lankton and Li) have been implemented by their respective author while we have implemented the three others (Caselles, Chan&Vese and Shi). These algorithms have been tested on several images in order to check if the behavior of the method corresponds to the one described in the relative paper. Each algorithm is associated to a panel that can be displayed on the left side of the interface. This panel lists the specific parameters of the method and gives the possibility to modify them. Fig.3 gives an example of the use of the software to test the Lankton algorithm. The left part of the interface corresponds to the parameter panel while the right part displays the segmentation result. A complete description of the parameters of each method is given in the documentation of Creaseg. Table 1 summarizes the main properties of each proposed methods.

These level-set methods can be distinguished from two main features: the data attachment type and the way the interface evolution is driven. The data attachment type directly influences the way the level-set evolves towards the object of interest. It can be derived from contour information (for example based on gradient [2]) or region information (for example based on statistics [3]). Moreover, recent approaches

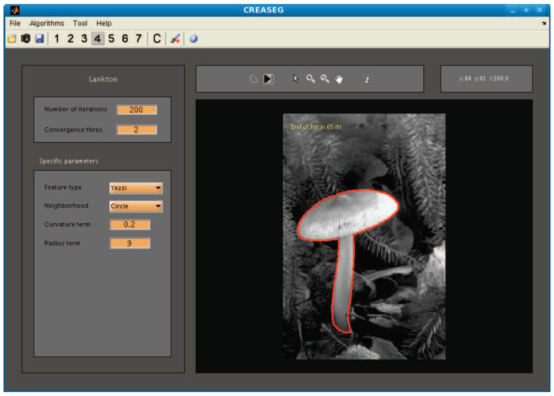


Fig. 3: Main interface of Creaseg, displaying a result obtained from the Lankton method

Method	Energy type	Evolution
Caselles	Contour-based	Narrow band
Chan&Vese	Region-based	Narrow band
Shi	Region-based	Narrow band
Bernard	Region-based	Whole domain
Li	Localized region-based	Whole domain
Lankton	Localized region-based	Narrow band

Table 1: Main properties of the six implemented algorithms in terms of energy type and evolution.

[4, 5] have proposed to localize the energy functional in order to segment objects with inhomogeneous statistical properties.

Depending on the implementation or modeling issues, the level-set interface may be allowed to evolve either on the whole domain at each iteration [6, 4] (allowing to develop new contours far from the zero level-set) or only on a small region around its zero level-set (region called narrow-band). The choice of this feature is application dependent as illustrated in Section 3.

Note that the sixth algorithm (Shi's method) uses a discrete representation of the level-set function values (level-set function is approximated by a piece-wise constant function taking only four values). This gives the possibility to study the influence of the discretization on the segmentation results. It has to be noted that there also exists an empty panel that allows the user to add its own method (to be compared with other implemented algorithms).

2.3. Similarity measurements

Creaseg gives the possiblity to qualitatively and quantitatively measure the performance of each algorithms through three kinds of criteria. These measurements allow to choose the algorithm which is best suited for a particular application, as demonstrated in Section 3. The criteria are the following:

- visual criterion: the segmented image is displayed with the final contours of each selected algorithms and the reference image;
- computation time: at the end of the comparison phase, the time that each algorithm needed to reach convergence is displayed. This gives an overview of the speed of a specific algorithm in comparison with others methods;
- similarity criterion: this criterion measures the closeness between the reference segmentation and the segmentation provided by each selected algorithm. Several similarity criteria have been implemented such as the Dice coefficient, the PSNR, the Hausdorff distance and the mean sum of squared distance (MSSD).

3. APPLICATION: SEGMENTATION EVALUATION FROM A MRI HEART IMAGE

In this Section, we show how this software can be useful for segmentation evaluation purposes. For the experiments, we use the default parameters of each method, given by the corresponding authors. The comparisons are illustrated using the Dice coefficient as a similarity criterion. Given a final segmented region Ω_s and the corresponding reference region Ω_r, the Dice coefficient DC is defined as $DC(\Omega_s, \Omega_r) = 2Area(\Omega_s \cap \Omega_r)/(Area(\Omega_s) + Area(\Omega_r))$. This coefficient varies from 0 to 1 and measures the degree of agreement between the two regions. It is 1 when the two regions are identical and 0 when they are completely different.

As an illustration, we use the software to evaluate the performance of the six level-set algorithms on a MRI image of heart as shown in Fig.4-a. The initialization used is the same for all the algorithms and the reference contour used for the computation of the Dice criterion is shown in Fig.4-b.

As the object that we want to segment (*i.e.* the left ventricular cavity) shares properties (such as its gray level value) with other regions of the image (*e.g.* area 1 and 2 of Fig. 5), methods that evolve on the whole image (like Li or Bernard method) fail to recover only the left ventricular cavity and tend to oversegment the image.

From Table 2, it can be seen that both contour-based and region-based approaches that evolve only on a narrow-band succeed in segmenting the image (Dice coefficient equal to 0.95 or 0.96). However, it has to be noticed that the contour approach (Caselles method) requires the highest computation

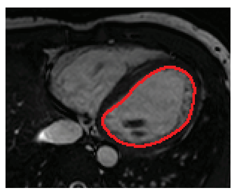
Methods	Time (in seconds)	Dice coefficient
Caselles	9.42	0.96
Chan&Vese	0.77	0.96
Shi	0.42	0.96
Bernard	1.12	0.52
Li	33.15	0.46
Lankton	28.45	0.97

Table 2: Computation times and Dice coefficients of the six implemented methods obtained for the segmentation of MRI image of heart.

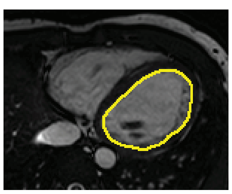
time to reach convergence. This can be explained by the fact that the smooth intensity variation of the blood (shown in area 3 of Fig.5) slows down the evolution of the interface. Lankton algorithm also gives good results in term of Dice coefficient but needs more time to converge towards the boundaries of the object. This higher computation time is mainly due to the fact that the method requires to compute local statistics for every point of the evolving interface at each iteration.

The best results in term of both the Dice coefficient (higher than 0.96) and computation time (less than 0.5s) are achieved by Chan&Vese and Shi algorithms. As these algorithms only evolve on their narrowband and are region-based, they are not disturbed by the presence of bright region far away from the contour or by the smooth variations of intensity inside the object. Although both algorithms give similar results in term of Dice criterion (equal to 0.96), the final contour of Chan&Vese algorithm looks smoother than the one of Shi, which is a result of the discretization of the level-set function used in Shi algorithm.

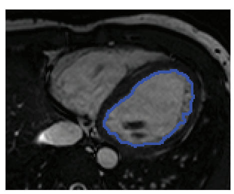
(a) Initialization



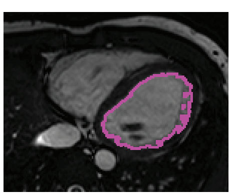
(b) Reference



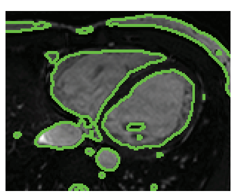
(c) Caselles



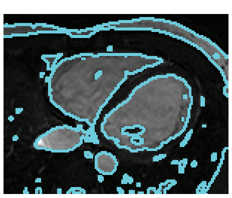
(d) Chan&Vese



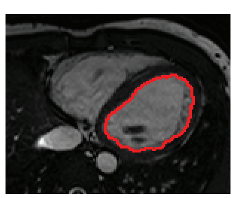
(h) Shi



(g) Bernard



(e) Li



(f) Lankton

Fig. 4: Segmentation of a MRI image of heart. The same initialization (a) and expert segmentation (b) have been used for all the experiments. The displayed results were obtained from Caselles (c), Chan&Vese (d), Shi (e), Bernard (f), Li (g) and Lankton (h) algorithms.

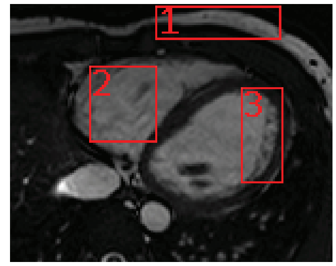


Fig. 5: MRI image of heart. Regions 1 and 2 share intensity properties with the object to be segmented; in region 3, smooth intensity variations will slow down the evolution of contour based method

4. CONCLUSION

We described in this paper an original free open source software for the evaluation of the performance of different level-set based algorithms in the context of image segmentation. This work has been developed in Matlab to provide an easy understanding of the code and to allow a user to easily integrate of a new method. An illustration of the usefulness of this software for the evaluation of segmentation of a MRI image is given.

5. REFERENCES

[1] Stanley J. Osher and Ronald P. Fedkiw, *Level Set Methods and Dynamic Implicit Surfaces*, Springer, 2002.

[2] V. Caselles, R. Kimmel, and G. Sapiro, "Geodesic active contours," *International Journal of Computer Vision*, vol. 22, pp. 61–79, 1997.

[3] T. Chan and L. Vese, "Active contours without edges," *IEEE Trans. Image Process.*, vol. 10, pp. 266–277, February 2001.

[4] C. Li, C.-Y. Kao, J. C. Gore, and Z. Ding, "Minimization of region-scalable fitting energy for image segmentation," *IEEE Trans. Image Process.*, vol. 17, pp. 1940–1949, October 2008.

[5] S. Lankton and A. Tannenbaum, "Localizing region-based active contours," *IEEE Trans. Image Process.*, vol. 17, pp. 2029–2039, November 2008.

[6] O. Bernard, D. Friboulet, P. Thévenaz, and M. Unser, "Variational B-Spline level-set: A linear filtering approach for fast deformable model evolution," *IEEE Trans. Image Process.*, vol. 18, pp. 1179–1191, June 2009.

[7] Y. Shi and W. C. Karl, "A real-time algorithm for the approximation of level-set based curve evolution," *IEEE Trans. Image Process.*, vol. 17, pp. 645–656, May 2008.