LEVEL SET CODE DESCRIPTION (MATLAB/C)

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Introduction:

This Matlab/C code contains routines to perform level set image segmentation according to:

(1): various multiphase (multiregion) formulations, including a fast scheme where the computation load grows linearly with the number of regions and,

(2): various region-based image descriptions which generalize the standard piecewise constant Chan-Vese model; the descriptions include Gamma distribution models for image data corrupted by multiplicative noise as in remote sensing synthetic aperture radar (SAR), and medical imaging ultrasound. Also included is kernel mapping as an alternative to explicit image modeling.

Usage:

Script *LevelSet.m* shows an example of how to use the software. Before running *LevelSet.m* in Matlab, the users need to (1) use *mex -setup* in Matlab and choose the Lcc compiler; and (2) compile the C files by running function *compiler.m* in Matlab.

The functions were tested on Windows with the following versions of Matlab and C:

Matlab version: *7.7.0.471 (R2008b)*

C compiler: *Lcc-win32 C 2.4.1* (note that the Lcc utility is included in the Matlab compiler)

This software can be used only for research purposes, and is provided “as is”, without warranty of any kind. Please cite the papers and book mentioned below in any resulting publication (the papers are included in the package). Formal and complete details on the implementations as well as on the derivation of the level set evolution equations for the various energy functional types used in the software can be found in the book "*Variational and Level Set Methods in Image Segmentation*" by Amar Mitiche and Ismail Ben Ayed, 2010, Springer, 1st edition.

Script *LevelSet.m* contains the following inputs which can be changed by the users.

Description of the inputs:

- *input_image*: the image to be segmented
- *output_image*: the segmentation result
- *nb_regions*: the number of segmentation regions
- *nb_iterations*: the number of iterations
- *curvature*: the weight of the curvature velocity (or smoothness term). The higher the weight, the smoother the segmentation boundaries. Noisy images (e.g., SAR data) often require a high smoothness weight, e.g., *curvature='2000'*.
- *time_step*: the gradient-descent time step of curve evolution. A large step yields faster evolution but lesser stability. Typical values of this parameter are in between 0.0001 and 0.001.
- *display_frequency*: the frequency of display of the active curve during the evolution. For instance, when *display_frequency='20'*, the active curve is superimposed on the image each 20 iterations.
- *initialization*: this option defines the initial curves which can be either circles centered about the middle of the image (*initialization='1'*) or small circles all over the input image (*initialization='2'*).

- *segmentation_method*: this variable defines the image model and/or the multiphase method. The following lists and explains the possible options for this variable:

  \- *segmentation_method = 'gamma'*

  This function implements level set image segmentation by minimizing a data term which measures the conformity of image data within each region to the Gamma model. It is useful for image data corrupted with a multiplicative noise such as in radar and ultrasound data. Please cite the following paper in any resulting publication:

  [1] I. Ben Ayed, A. Mitiche, and Z. Belhadj, *Multiregion level set partitioning on synthetic aperture radar images*, IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 27, no. 5, pp. 793–800, 2005.

  Note that this gamma segmentation function requires a small time step, e.g., *time_step='0.0001'*.

  \- *segmentation_method = 'ker'*

  This method implements a kernel function which maps implicitly the original image data into data of a higher dimension so that the piecewise constant model becomes applicable to images corrupted with various noise models. This leads to a flexible alternative to complex modeling of the image data. The function is applicable to a variety of real images such as medical, satellite and natural images. Please cite the following paper in any resulting publication:

  [2] M. Ben Salah, A. Mitiche and I. Ben Ayed, *Effective Level Set Image Segmentation with a Kernel Induced Data Term*, IEEE Transactions on Image processing, vol. 19, no 1, pp. 220–232, 2010.

  Note that this kernel segmentation function requires a small time step, e.g., *time_step='0.0001'*.

- *segmentation_method = 'mean'*

This function implements level set image segmentation by minimizing the classical Chan-Vese data term which measures the conformity of image data within each region to the piecewise constant model.

- *segmentation_method = 'Gaussian'*

This function implements a Gaussian generalization of the classical piecewise constant model.

Note that the case of a number of regions more than 2 (the multiphase case) uses several curves which can intersect. Therefore, a two-region formulation cannot be generalized directly by assigning a region to the interior of each curve because region membership becomes ambiguous when the curves intersect. The following lists the possible options to evolve multiple curves so that, at convergence, the curves define a partition of the image domain:

- *segmentation_method = 'clust'*

This method embeds directly a simple partition constraint in the curve evolution equations. Starting from an arbitrary initial partition, the constraints implements the rule that if a point leaves a region, it is claimed by a single other region. The scheme is fast, and results in a significant reduction in the computational load (the complexity grows linearly as a function of the number of regions). Note that this option uses the piecewise constant image model. However, other models can be easily added by modifying function *mean_clust_seg.c*. Please cite the following papers in any resulting publication:

[3] I. Ben Ayed, A. Mitiche, and Z. Belhadj, *Polarimetric image segmentation via maximum likelihood approximation and efficient multi-*

phase level sets, IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 28, no. 9, pp. 1493–1500, 2006.

[4] I. Ben Ayed and A. Mitiche, *A Partition Constrained Minimization Scheme for Efficient Multiphase Level Set Image Segmentation*, IEEE ICIP 2006, pp. 1641–1644.

[5] I. Ben Ayed and A. Mitiche, *A region merging prior for variational level set image segmentation*, IEEE Transactions on Image Processing, vol. 17, no. 12, pp. 2301–2313, 2008.

- *segmentation_method = 'part'*

This method implements a systematic general mapping between the segmentation regions and the regions defined by the curves and their intersections. The mapping guarantees, by definition, a partition at all times during curve evolution. Note that this option uses the piecewise constant image model. However, other models can be easily added by modifying function *mean_part_seg.c*. Please cite the following paper in any resulting publication:

[6] A. Mansouri, A. Mitiche, and C. Vazquez, *Multiregion competition: A level set extension of region competition to multiple region partitioning*, Computer Vision and Image Understanding, vol. 101, no. 3, pp. 137150, 2006.

- *segmentation_method = 'ker_part'*

This option implements the kernel method in [2] with the multiphase method in [6]. Please cite these two papers in any resulting publication.

Note that when *segmentation_method = 'gamma', 'ker', 'mean' or 'gaussian'* and when the number of regions is more than (*nb_regions* > 2), the default multiphase method is the one described in the following paper:

[7] C. Vazquez, A. Mitiche, Ismail Ben Ayed, *Image segmentation as regularized clustering: a fully global curve evolution method*, IEEE ICIP 2004, pp. 3467–3470.

This multiphase method views image segmentation as spatially regularized image data clustering, leading to the simultaneous minimization of N -1 functionals to segment an image into N regions, each minimization involving a single region and its complement. Please cite [7] in any resulting publication.