BME42-731/ ECE18-795/CB02-740 Bioimage Informatics
Spring 2015
Project Assignment #4

Curvilinear feature detection and image segmentation

Assigned on Apr-08-2015
Report due on May-07-2015 (final exam week) in class. Group presentations due on May-07.

A. Overview

The main goal of this project is to introduce various line/curve detection and image segmentation techniques. The assignment is divided into two parts.

In the first part you are asked to implement Steger's curvilinear feature detection algorithm [1]. Test images are provided as part of the dataset for this project.

In the second part you are asked to study and test several image segmentation algorithms that are implemented in the ITK software package. An overview of ITK is provided at the end of this file. Specifically, you need to call the segmentation functions provided by ITK in MATLAB through the MAT-ITK interface, which was developed at Simon Fraser University.

The total score for this project assignment is **140 points**. There is also a total of **50** extra credit points.

B. Curvilinear feature detection (60 points + extra credit 20 points)

We will only implement the case with the same background level on both sides. The credit for implementing the line detection part of the algorithm is 60 points. The extra credit for implementing the line point linking part of the algorithm is 20 points. Three test images are provided (curv_det_01.tif, curv_det_02.tif, curv_det_03.tif).

C. Image segmentation (80 points + extra credit 30 points)

C.1 MAT-ITK and image data

The MAT-ITK package and the image data can be downloaded from the course portal in CMU blackboard (http://www.cmu.edu/blackboard/).

The data set is divided into two parts. The first part consists of two static images (60x_02.tif, Blue0001.tif). The second part is a time-lapse image sequence of mitochondria transport within Drosophila segmental nerves.

C.2.1 Segmentation of static images

Apply the two segmentation techniques assigned to your group to the two static images (20 points). <u>The techniques are assigned to each group in a random fashion.</u>

C.2.2 Segmentation of image series

- Apply the two segmentation techniques chosen by your group to the time-lapse image sequence and generate movies to visualize your segmentation results. (20 points)

- Choose three frames from the image sequence that have a reasonable number of objects and manually segment them (hint: manually trace the boundary in MATLAB). Use this manual segmentation as the ground-truth. Then calculate the following segmentation metrics for the three ITK algorithms you have tested on these three frames. Compare performance of the two algorithms. (10 points)

→ Metric I: volumetric overlap error (see reference [2]).

→ Metric II: false positive rate. Here we use the following definition (there are other definitions):

$$false\_positive\_rate = \frac{\text{number of false positive detections}}{\text{total number of ground truth detections}}$$

→ Metric III: false negative rate. Here we use the following definition (there are other definitions):

$$false\_negative\_rate = \frac{\text{number of false negative detections}}{\text{total number of ground truth detections}}$$

C.3 Theoretical background

In your report and presentation, give a summary of the theoretical background for each of the two algorithms assigned to your group. Please feel free to use any additional references. (30 points)

For C.2 and C.3, it is expected that you will need to read the document provided by ITK. Whenever applicable, you will need to tune related parameters for optimized performance and to use image morphology operations to further refine the segmentation results. Results from all groups will be compared.

C.4 Graph cut based image segmentation (extra credit: 30 points)

As you have seen from the reading assignment, there are different graph cut based image segmentation algorithms. You are asked to search for on the internet and test **two** different graph cut algorithms on the same images described in C.2.1 and C.2.2. It is expected that you will use the implementation provided by the authors but will tune the parameters to optimize the results to the extent possible. The one for normalized cut can be found here

http://www.cis.upenn.edu/~jshi/software/

In your report, briefly explain the algorithms and compare the results using the graph cut based algorithms with those of the ITK algorithms you have tested.

C. Report format

There is no page limit to the report.

Page size: letter
Line space: single
Page margins: no less than 1 inch
Font size: 12 points for the main text; 10 points for listed references

D. Submission of MATLAB code

We will follow the same protocol of submission as in previous project assignments.

References

[1] C. Steger, An unbiased detector of curvilinear structures, *IEEE Trans. Pattern Analysis and Machine Intelligence*, vol. 20, pp. 113-125, 1998.

[2] T. Heimann et al, Comparison and evaluation of methods for liver segmentation from CT datasets, IEEE Trans. Medical Imaging, vol. 28, pp. 1251-1265, 2009.

[3] http://www.itk.org

[4] T. S. Yoo, Insights into Images, A. K. Peters, 2004.

Introduction to ITK

Andy Chen
Center for Bioimage Informatics
Carnegie Mellon University
September 2010

ITK (Insight Segmentation and Registration Toolkit) is an open-source, cross-platform system that provides developers with an extensive suite of software tools for image analysis. Since ITK is originally written in C++, MATITK is written, allowing users to access certain ITK algorithms in MATLAB.

To use MATITK, you should copy “matitk.dll” to the desired location, launch MATLAB and set search path of MATLAB or change current directory to the location of “matitk.dll”. For help, you can type matitk('?') in MATLAB’s command window.

Generally, MATITK includes three categories of algorithms, such as: filtering, segmentation, and registration methods. You can type matitk('f'), matitk('s') and matitk('r') respectively to understand the algorithms in each category.

To use one method in MATITK, you need to input in the following format:
matitk(operationName,[parameters],[inputArray1],[inputArray2],[seed(s)Array],[Image(s)Spacing])

1. operationName, specifies the implemented ITK method to be invoked.

2. parameters, specifies the required parameters of the ITK method to be invoked.

3. inputArray1 and inputArray2, specify the input image volume. They must be three dimensional and contain double, float, unsigned char or signed integer data type elements. In the case where a second image volume is not required for the method being invoked, provide [] as the fourth argument.

4. seedsArray arguments specify the seed points (in MATLAB coordinate system) in the following order: [x_1, y_1, z_1, x_2, y_2, z_2, …, x_n, y_n, z_n]. Because it is three dimensional, the number of elements in seedsArray should be

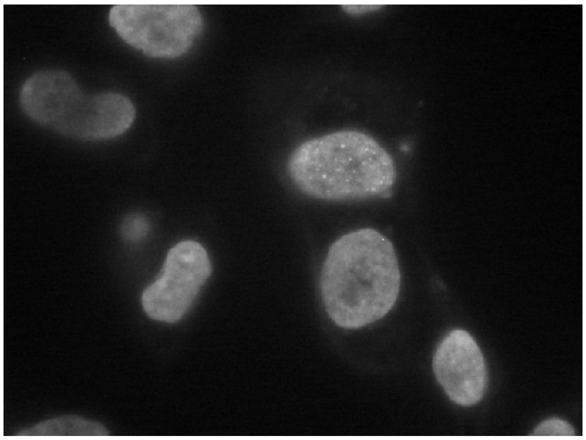
a multiple of three. In the case where seeding is not required for the method being invoked, provide [] as the fifth argument.

5. The last optional argument specifies the spacing of the supplied image volume. The performance of certain ITK methods may be affected by the spacing. If this argument is omitted, an isotropic spacing of [1,1,1] is assumed.

As you may see above, input data must be 3D, so when you need to process a 2D image, you have to first convert it to a 3D data before using MATITK. Here, I will give an example for nuclei segmentation in a 2D image:

```
% load image and get the size of this image
filename = 'Blue0001.tif';
Img = double(imread(filename));
imgSz = size(Img);

% show original image
figure; imagesc(Img); colormap gray; axis off; axis equal;
```



```
% in order to use matitk, we have to use 3D data
% so we first build a 3D volume of two layers, and each layer
% contains the original image
D = zeros(imgSz(1),imgSz(2),2);
D(1:imgSz(1),1:imgSz(2),1) = Img(1:imgSz(1),1:imgSz(2));
D(1:imgSz(1),1:imgSz(2),2) = Img(1:imgSz(1),1:imgSz(2));

% implement segmentation using Otsu's method
b = matitk('SOT',[max(D(:))], double(D));
figure; imagesc(squeeze(b(:,:,1))); colormap gray; axis off; axis equal;
```

For details of MATITK usage, please see: http://www.sfu.ca/~vwchu/matitkusage.html