CMP 717 – Programming Assignment 3: Segmenting images using Markov Random Fields

Due date: Tuesday, 2017-05-2, 11:59 PM

Overview

The goal of this assignment is to familiarize you with Markov Random Fields (MRFs). In this assignment, you will use MRFs to segment a given image using a graph-cut-based formulation.

Problem

You are provided some MATLAB files at the course webpage. You will use these files to segment a given image with minimal user input or with an additional saliency map.

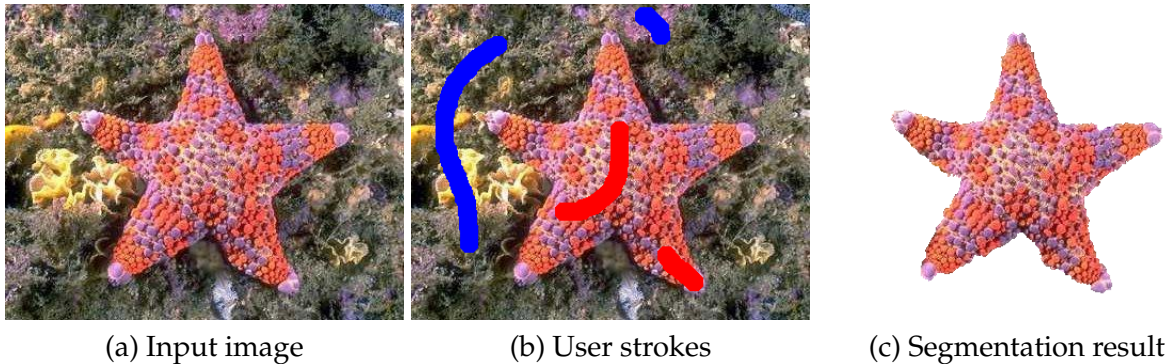(a) Input image   (b) User strokes   (c) Segmentation result

Figure 1: A sample segmentation result.

As Figure 1 shows, the user mark some pixels as belong to foreground (red stroke) and some other as belong to background (blue stroke). These user strokes are then used to build the foreground/background appearance models and the segmentation is accordingly obtained by solving the following energy minimization problem with graph cut:

$$E(\mathbf{x}) = \sum_i \theta_i \left(x_i, z_i \right) + \sum_{i,j \in \mathcal{N}} \theta_{ij} \left(x_i, x_j, z_i, z_j \right) \tag{1}$$

where $\mathbf{x} \in \{0,1\}^n$ is the unknown segmentation labels, $\mathbf{z}$ is the given image and $\mathcal{N}$ denotes the neighbourhood system (4- or 8-connected). The unary potential function $\theta_i \left(x_i, z_i \right)$ is the color likelihood estimated by the learned appearance models via Gaussian Mixture models (GMMs). The pairwise potential function $\theta_{ij} \left(x_i, x_j, z_i, z_j \right)$ is defined as:

$$\theta_{ij} \left(x_i, x_j, z_i, z_j \right) = |x_i - x_j| \left(\lambda_1 + \lambda_2 \left(-exp(-\beta \| z_i - z_j \|_2) \right) \right) \tag{2}$$

with $\beta = 2 \left(\text{mean}(|z_i - z_j|) \right)^{-1}$, λ_1 and λ_2 representing the regularization parameters. Setting the value of λ_1 to a positive value corresponds to switching on the Ising prior. Setting λ_2 to a positive value let the contrast-sensitive (edge) information guide the segmentation process.

Problem 1.1

In the first part of the assignment, your task is to analyze the provided segmentation model. You should try the code with several images of your own with different foreground/background strokes. Your experiments should be designed in a way that you can comment of the effects

of the three model parameters (`Parameters.neighborSystem`, `Parameters.lambda1` and `Parameters.lambda2`) on the segmentation results. Please make sure to document and interpret your results in your reports.

Problem 1.2

In the second part of the assignment, your task is to transform the code provided to you into an iterated model as in the GrabCut model we discussed in our class. That is, you should revise the code which uses fixed GMMs-based appearance models for the foreground and the background derived from the users strokes, and obtain a model where the appearance models are updated by the obtained segmentations results, which in return is used to get new results until convergence. You should analyse what the new model doing by examining the results and the segmentation energy at each iteration. Please make sure to document and interpret your results in your reports.

Problem 1.3

In the third part of the assignment, your task is to transform the code provided to you so that the segmentation is guided by a saliency map instead of a user input. That is, you should revise the code which uses users strokes to construct the GMMs-based appearance models, and obtain a segmentation model where the appearance models are constructed by taking into account a saliency map encoding the most discriminative part of an image as shown in Figure 2. Thus, the developed code can be used to segment out salient object(s) exist in the given image.
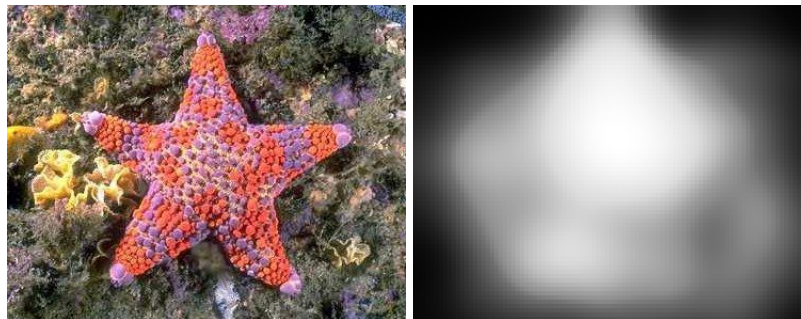
(a) Input image   (b) Saliency map

Figure 2: A sample image and its saliency map.

In particular, for this part you need to form GMMs for foreground and background colour models by thresholding the given additional saliency map. For example, the foreground model can be computed from the pixels with a saliency score higher than a threshold which is set to the 95% quantile of the saliency distribution in the whole image. Similarly, the background model can be estimated from the pixels with the saliency smaller than a second a threshold which is set to the 30% quantile. You should analyse what the new model doing by examining the results and by playing with thresholds for the foreground and background regions. Please make sure to document and interpret your results in your reports.

For the tests, you have two options for the additional saliency maps. You can use the online tool which is available at `https://deepgaze.bethgelab.org/` to extract the saliency map of any given image by the DeepGaze2 model. Alternatively, you can use the precomputed saliency maps of the images from SALICON validation set (`http://salicon.net/download/`) or MIT1003 dataset (`http://people.csail.mit.edu/tjudd/WherePeopleLook/index.html`), which is available at `https://github.com/marcellacornia/mlnet`.

Notes

You can run `main.m` to segment an image. The segmentation codes include some MATLAB mex routines. Thus, you may need to compile them by going into the directory `code/Optimization` and typing `mex GraphCut.cpp graph.cpp maxflow.cpp`.

Grading

The assignment will be graded out of 4: 0 *(no submission)*, 1 *(an attempt at a solution)*, 2 *(a partially correct solution)*, 3 *(a mostly correct solution)*, 4 *(a correct solution)*, 5 *(a particularly creative or insightful solution)*.

What to Hand In

You are required to submit all your code along with a report in HTML format. The codes you will submit should be well commented. Your report should be self-contained and should contain a brief overview of the problem, the details of your implemented solution and your comments about the experimental analysis on the aforementioned issues. Finally, prepare a ZIP file named `name-surname(s)-p3.zip` containing

- `README.txt` - text file containing anything about the assignment that you want to tell but is not appropriate for the writeup webpage

- code/ - directory containing all your code for this assignment

- html/ - directory containing all your html report for this assignment, including images

The ZIP file will be submitted via email to `erkut@cs.hacettepe.edu.tr`.

Credits

This assignment is adapted from the exercise given by Carsten Rother, Microsoft Research, Cambridge, UK at INRIA CVML Summer School 2010.

Late policy

You may use up to five *extension* days (in total) over the course of the semester for the three programming assignments. Any additional unapproved late submission will be weighted by 0.5.

Academic Integrity

All work on assignments must be done individually unless stated otherwise. You are encouraged to discuss with your other classmates about the given assignments, but these discussions should be carried out in an abstract way. That is, discussions related to a particular solution to a specific problem (either in actual code or in the pseudocode) will not be tolerated. In short, turning in someone elses work, in whole or in part, as your own will be considered as a violation of academic integrity. Please note that the former condition also holds for the material found on the web as everything on the web has been written by someone else.