Report on Image Analysis using Snakes
Labwork for Medical Image Analysis
MSCV, M1
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1 Summary:

In using snakes, our aim here is to refine a given initial closed contour over the image domain such the final contour is aligned along interesting features of the underlying image such as lines, edges and terminations. The image can then be segmented into two regions, corresponding to the interior and exterior of the closed contour.

2 Introduction:

A snake is an energy minimizing (active) spline guided by 'forces' or 'energies' that arise from image properties as well as the configuration of the snake itself, such that the snake is iteratively aligned along interesting image contours such as lines, edges and corners [1].

Model of a snake consists of a set of points $V = \{(x_1, y_1), (x_2, y_2), ..., (x_N, y_N)\} = \{v_1, ..., v_N\}$, and a set of polynomials fitted to the set of points locally, and joined at junction points (splines), that continually tries to minimize some energy. The minimization considers two 'forces' or 'energies', $E_{internal}$ and E_{image}. We can also include forces that can come from higher level image interpretations such as those from a user through an interface [1]. However, in the following experiments, these were not included.

Each snake point is iteratively updated to occupy another point in its neighbourhood that represents minima of a composite energy E_{snake} which may be written as :

$$E_{snake} = w_{in} E_{internal} + w_{ext} E_{image} \quad (1)$$

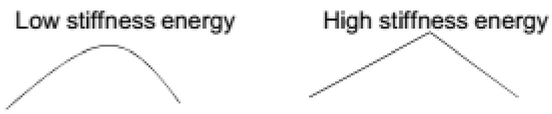
$$E_{internal} = \alpha \; |\nabla_s|^2 + \beta \; |\nabla_{ss}|^2 \quad (2)$$

$$E_{image} = w_{line} E_{line} + w_{edge} E_{edge} + w_{term} E_{term} \quad (3)$$

Internal Forces: ∇_s and ∇_{ss}, in context of a point to be updated, are first and second order derivatives of the local polynomial influenced by the point. ∇_s is also called the 'membrane term' and ∇_s^2 the 'thin plate term'. These terms serve to impose continuity constraints [1]. Intuitively, α controls the tension and β the rigidity (stiffness) of the snake [2].

Image Forces: The image energy E_{line} at location (x, y) is image intensity $I(x, y)$. Consequently, positive values of w_{line} attract the snake toward dark image regions. E_{edge} is set to $-|\nabla_{xy} I(x, y)|^2$, so that positive values of w_{edge} attract the snake toward image regions with strong gradients. Finally, E_{term} is a function of first and second derivatives of image intensities that, for positive values of w_{term}, attracts the snake **toward** terminations of line segments and contours [1], which are points with high curvature.

The iterative updates are performed on each point using the local gradient of energy with a step size $gamma(\gamma)$. The parameter $kappa(\kappa)$ affects how much weight the image energy term is given.



3 Results:

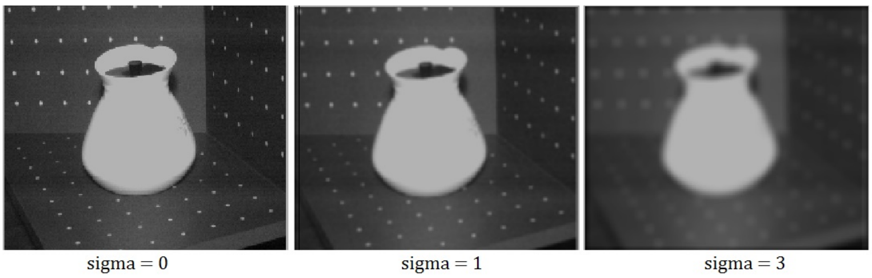


Figure 1: Effect of Sigma: Smoothing as pre processing before initializing snake.

Higher values of sigma make the edges wider (blurrier). Local variations in intensities are also removed which prevents the snake from being effected by large gradients that do not lie along edges.

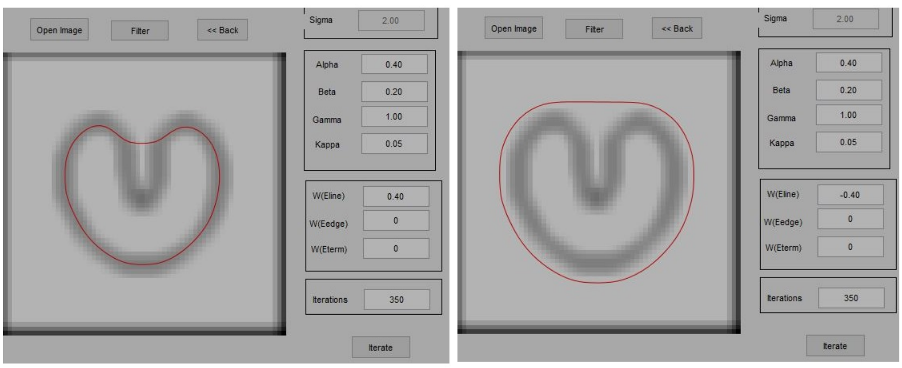
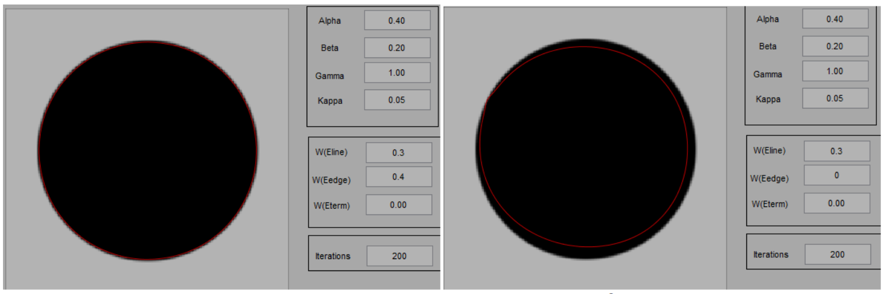


Figure 2: Sign of w_{line} determines whether snake aligns with dark or bright edge contour.

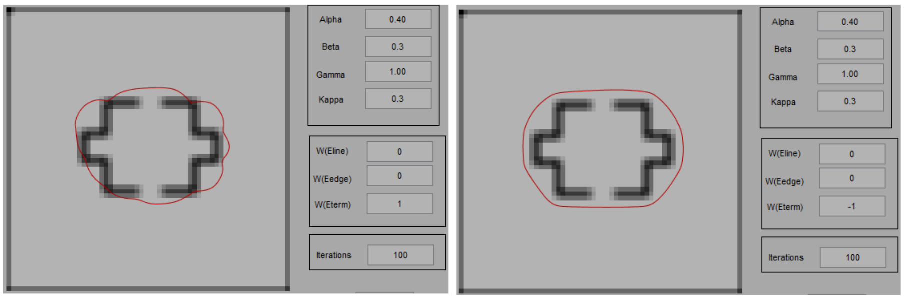
In Figure 2, we notice that if the value of w_{line} is less than zero, the snake is attracted to bright image points. Because the weights for internal energies are non zeros, the snake also experiences a contraction force and aligns along a bright contour.



a b

Figure 3: (a) Contour is influenced by both intensities and gradients (b) only influenced by intensities.

In Figure 3, when w_{edge} is set to zero, the contour does not stop at the edges. Positive value of w_{line} attracts the snake toward dark image areas.



a b

Figure 4: Snake under the influence of only terminations in image in addition to internal parameters.

Positive w_{term} attracts the snake towards image regions with high curvature, as in Figure 4 (a) where E_{image} comes from terminations only. A negative value of w_{term} (Figure 4(b)) repels the snake from areas of high curvatures.

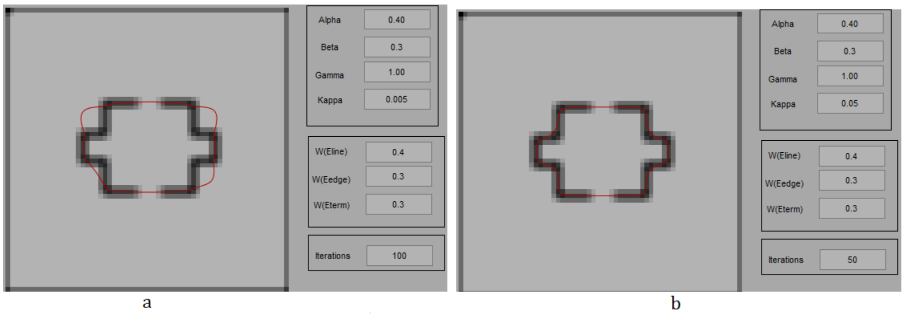


Figure 5: Larger $kappa(\kappa)$ allows faster convergence by increasing influence of E_{image}.

The snake in Figure 5(a) with $\kappa = 0.005$ has not converged in 100 iterations while that in 5 (b) with $\kappa = 0.05$ has converged in 50.

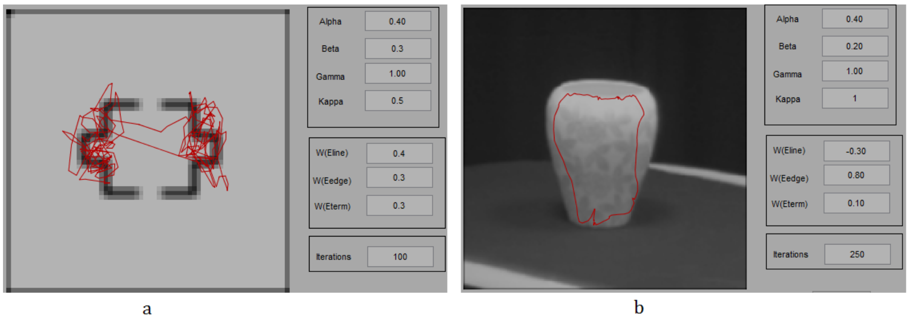


Figure 6: Very Large values of $kappa(\kappa)$ make the snake too sensitive to image features.

When the energy scaling function is too large, the snake is very sensitive to image features. It is thus more difficult to find a set of parameters such that the snake finds equilibrium along interesting contours in the image instead of being attracted to uninteresting locations with strong intensities or gradients.

When we make the snake very rigid (by assigning a high value to β), it can not track sharp corners in image contours, like in Figure 7(b).

The parameter $alpha(\alpha)$ controls the tension in the snake. Concretely, higher values of α cause the snake to shrink more rapidly (irrespective of image features, since 'tension' is internal to the snake).

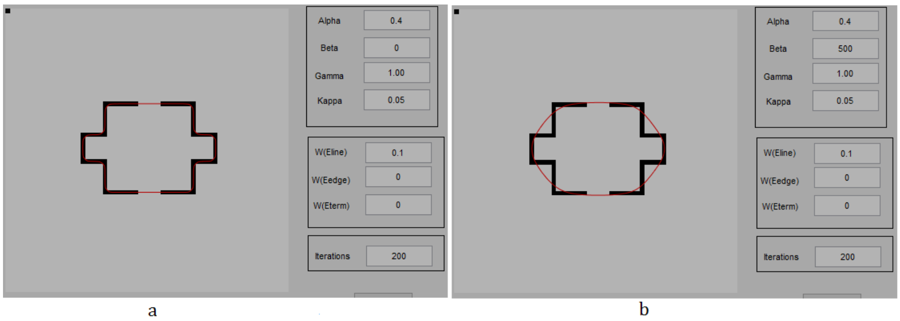


Figure 7: Small values of $beta(\beta)$ allows snake to align along sharp corners.

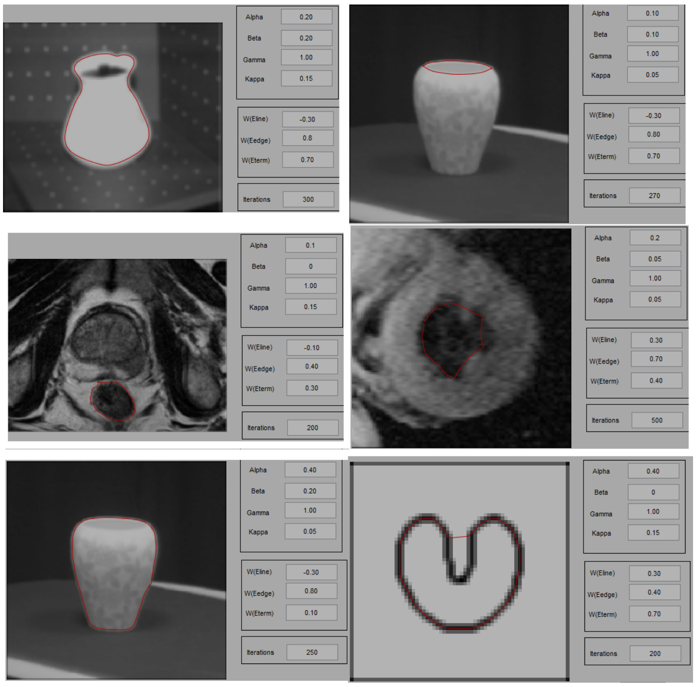


Figure 8: Some interesting results with corresponding snake parameters. Bottom right: snake can not morph into concavities.

4 Conclusion:

A snake can be an effective tool for image segmentation. It has, however, several drawbacks:

1. High sensitivity to initialization of contour
2. High sensitivity to change in parameters

It is also limited in not being able to change its topology to segment discrete image regions. This, in addition to the complexity of its formulation, makes snakes a tricky tool to use straight-out-of-the-box.

5 References:

[1] Kass, Michael, Andrew Witkin, and Demetri Terzopoulos. "Snakes: Active contour models." International journal of computer vision 1.4 (1988): 321-331.

[2] Class slides on Shape modelling by Dr. Joan Marti.

[3] Lecture 10, Snakes, Professor Todd Wittman, The Citadel