CS 7960, Advanced Image Processing
Spring 2010, Prof. Guido Gerig

Project 5: Snakes: Deformable Contour Segmentation

Out:	Thursday April-01-2010
Due:	Thursday April-15-2010
Office hours:	Tue 1pm to 3pm, please contact me in advance or ask for other arrangements.

Recommended Readings: Papers and Materials Lectures on Snakes (Paper by Witkin, Kass and Terzopoulos, **extracted pages from the Trucco and Verri Computer Vision book, see project web-page**, slides of course lecture).

Snakes

The name "snakes" is used for a methodology that uses deformable models for object segmentation. A user-defined model curve is deformed to match the desired contour, using internal forces (deformable properties of model) and external attraction forces from image structures to guide the initial contour close to the object boundary.

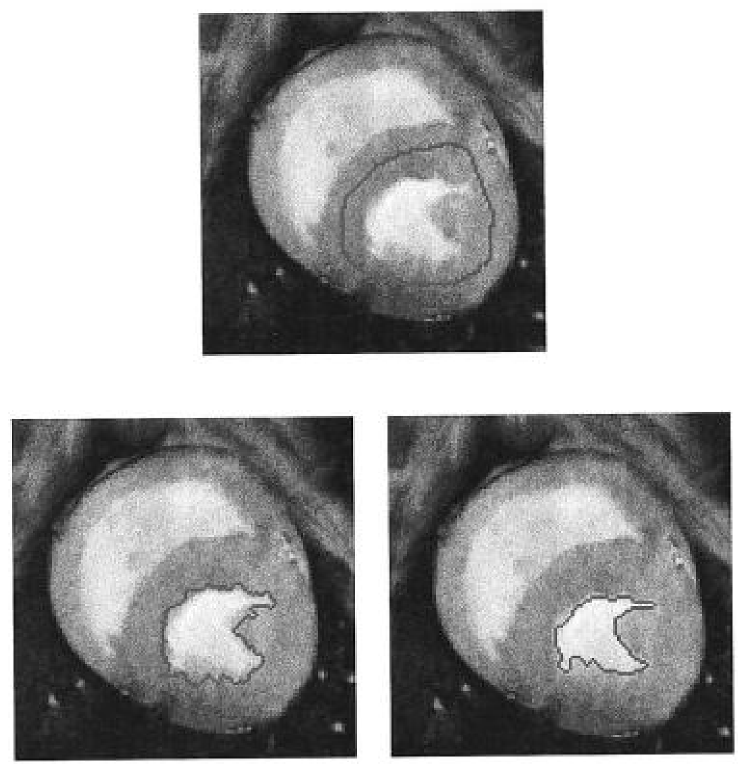

Fig. 3. Contour extraction from MRI heart image via snake.

Figure 1: Example of object segmentation by a snake (from Yezzi, TMI).

Instructions

You need to implement a snake algorithm for deformable object segmentation. Best is to follow the instructions in "Trucco and Verry" for a greedy implementation, i.e. using locally optimal choices with the assumption that they lead to a globally optimal choice. Better would be an implementation based on variational calculus, but it is not expected that we can implement that as part of this course and given the short time frame. Following the book chapter, the snake should have three terms, a contour term that ensures homogeneous sampling along the contour, a curvature term that guides the smoothness of the resulting contour, and an edge attraction term that guides the snake towards strong edges or contours:

$$\epsilon = \int (\alpha(s)E_{cont} + \beta(s)E_{curv} + \gamma(s)E_{image})ds.$$

Segmentation is defined an an optimization problem, i.e. minimization of the energy which is a balance between boundary smoothness and elasticity, and attracting the deformable curve towards strong object boundaries. A snake can be initialized by selecting a consecutive set of points as a rough initial contour. This discrete contour is then deformed using optimization for finding the state of minimum energy. A stopping criterion has to be defined, e.g. stopping when the total energy could not change considerably with new iterations. We will implement a greedy optimization technique.

1. Implement a procedure to initialize a contour by clicking at a sequence of points close to the object to be segmented, the contour is then defined as the descrete set of consecutive points (analogue to the shape vector used in ASMs).

2. Implement a procedure to define the image force term. The most common procedure is an edge detection which consists of a Gaussian smoothing followed by the calculation of the local gradient and gradient magnitude. The gradient magnitude image represents locations of strong boundaries and its negative value can be directly used as a energy potential that serves as an edge attraction term. Would you use line images (e.g. line drawings), the image intensity itself can be used as the image potential, preferably after Gaussian smoothing.

3. Implement a "snake" algorithm following the Trucco and Verri instructions with a greedy optimization. Design a stopping criterion for the iterative process (e.g., stop when the number of points to be moved would be below a certain threshold). (Please note that the snake might oscillate between two states of similar energy, so that a second criterion based on maximum number of iteration steps might be helpful too).

4. Systematic testing of the algorithm, its parameters, and the influence of the initialization of the contour to the final result on a set of images of your choice:

   (a) Choose a few test images with objects of your choice. Since we use the gradient magnitude as the edge attraction term, objects should preferably differentiate from the background by local intensity contrast. You might also choose a challenging picture showing a contour illusion (similar to the Kass, Witkin and Terzopoulos paper), e.g. from google images with search for "contour illusion".

   (b) Choose different initializations of your starting contour, also with different number of control points, and observe the evolution of the deformable contour. Interesting questions are, for example, if the snake can follow a protrusion or intrusion (concavities) of a contour, etc.

(c) Choose different image force fields by choosing different Gaussian smoothing as part of the image force term. How does the increased capture range for the image force term help to successfully guide the snake into the optimal solution?

(d) Systematically explore the parameters for continuity and curvature to explain its effects on the resulting contour.

(e) Note that the snake does not need to be a closed contour but can be an open curve, deforming under image forces. You might give it a try.

Report

You should write up a report summarizing your procedure and discussing your results and experiments. The report should be **written in html** and **accessible to the instructor via a web-browser**, if a web-system is not available you can create a pdf file.

- Short description of how you implemented the contour initialization, the image force field and the snake algorithm, which might require some more details.
- Describe the success of segmentations using variations of initializations and parameter settings. Do you find optimal parameter settings appropriate for a range of objects, or would these to be tuned for each new segmentation?
- Best is to use a few snapshots of the snake evolution process to demonstrate the dynamic evolution of the deformable contour. You do not need to include ALL your experiments into the report, it is sufficient if you illustrate the major results of the various experiments.
- Would you eventually suggest changes to the Trucco and Verri implementation based on your experience?

Additional Exploratory Analysis: Bonus

This section describes various ways to further explore "snakes". It is not expected that you would do all but just to give you hints on additional exploration give a successful implementation.

- You might apply your procedure to an image sequence with moving or evolving objects (e.g. a moving car or person in a video sequence, or an object evolving across a stack of slices in a 3D volumetric image).
  The interesting research question would be if the result of a first segmentation can be propagated to the next image, deformed and then propagated further to end up with a motion sequence of the object.
- This is a somewhat speculative research question: Could we eventually implement a coarse-to-fine concept by capturing the snake with a coarse-scale image force field but as the snake gets closer to the boundary, decrease the image smoothing to attract the snake to a more detailed boundary? Please note that there are two locations where smoothness is defined, first in the gradient-magnitude calculation at a specific scale and second in the curvature energy term. You might do an experimental design to answer this question and to test feasibility.