Interpolation Snakes

Work by Silviu Minut

https://www.youtube.com/watch?v=r610mi5hiHM
Ultrasound image has noisy and broken boundaries

Figure 4: Application to ultrasound. (a) and (c) Initial interpolation snake. (b) and (d) Detected boundary. (e) Geodesic active contour. (f) Original image used in (a)-(e).
Snakes, or active contours

- Seek perimeter of region
- Perimeter is constrained by factors
- Smoothness or bending energy
- Fit to image gradient
- Fit to fixed points in image
- Define all factors mathematically and use optimization to find best perimeter
- Variational search needs starting point.
Define curve in 2D via 1D parameter $s$

$\gamma(s)$ maps $s \in [0,1]$ to perimeter set $\{(x_j, y_j)\}$

Define the energy of a curve

$$E(\gamma) = E_{img} + E_{int} + E_{ext}$$

Image energy is the gradient energy along the curve

$$E_{img}(\gamma) = -\int_\gamma |\nabla I| ds$$

Internal energy is the sum of speed and curvature

$$E_{int}(\gamma) = \int_\gamma |\gamma'|^2 + |\gamma''|^2 ds$$

External energy could be the sum of Euclidean distances of fixed points to the curve

TRADEOFFS!
Snake models settling down on simulated region

Green snake is interpolation snake

Red snake is geodesic snake. The literature is full of different snake species

Figure 3: Comparison to ground truth in a synthetic image. (a) Ground truth image. (b) Initialization of a 2-piece aggregate interpolation snake. Each piece starts and ends at a blue circle (fixed control point). (c) Detected boundary. (d) Geodesic active contour.
Ultrasound image has noisy and broken boundaries

Geodesic contour moves to smoothly fit gradient

Left ventricle of dog heart

Figure 4: Application to ultrasound. (a) and (c) Initial interpolation snake. (b) and (d) Detected boundary. (e) Geodesic active contour. (f) Original image used in (a)-(e).

¹Using the ITK (Kitware, 2005) implementation of the geodesic active contour model.
Analysis of the left ventricle of the heart is critical

- Change in chamber volume over the heart cycle is critical
- Ejection fraction is computed over the heart cycle
- What fraction of blood volume gets squeezed up the aorta compared to largest volume of the ventricle?
Snake seeks optimal fit to data + smoothness + eveness

Red points move in the optimization. Blue points do not move: they must be placed by the radiologist or some smart algorithm.
Can also train a distribution on the parameters of the snake.

Figure 5: Interpolation snakes without shape prior ((a),(b)) and with shape prior ((c),(d)). (e) Aligned training contours (green) and their mean (purple).