Snakes: Active Contour Models

CS 6640

Guido Gerig

SCI Institute, School of Computing

University of Utah

(some material from Zoltan Kato http://www.cab.u-szeged.hu/~kato/variational/)

Materials

- Kass, Witkin, Terzopopoulos, Int. Journal of Computer Vision, 321-331, 1988
- Trucco and Verri, Introductory Techniques for 3-D Computer Vision, Chapter 5
- Bryan Morse, Lecture 21 Image Understanding

Websites

- Andy Witkin's homepage: http://www.cs.cmu.edu/~aw/
- Terzopoulos: http://www.cs.ucla.edu/~dt/vision.html → Snakes: Active Contour Models
- Original snake demo: Kass, Witkin, Terzopoulos 1988: http://www.cs.ucla.edu/~dt/videos/deformable-models/snakes.avi
- Other Demos:
  - Xu/Prince: http://www.iacl.ece.jhu.edu/static/gvf/
  - http://users.ecs.soton.ac.uk/msn/book/new_demo/
  - http://www.markschulze.net/snakes/index.html

Snake's Energy Function

- Position of the snake $v(s) = (x(s),y(s))$
- $E_{snake} = \int [\ E_{int}\ v(s) + E_{image} v(s) + E_{con} v(s)]\ ds$
  - Internal: Internal energy due to bending. Serves to impose piecewise smoothness constraint
  - Image: Image forces pushing the snake toward image features (edges, etc…)
  - Constraints: External constraints are responsible for putting the snake near the desired local minimum

Internal Energy

- $E_{int} = [\ \alpha(s)\ |v_s(s)|^2 + \beta(s)\ |v_{ss}(s)|^2\ ]$
  - First order term: membrane, α(s): ”elasticity”
  - Second order term: thin plate, β(s): “rigidity, stiffness”
  - If α(s)=β(s)=0, we allow breaks in the contour

Image Forces

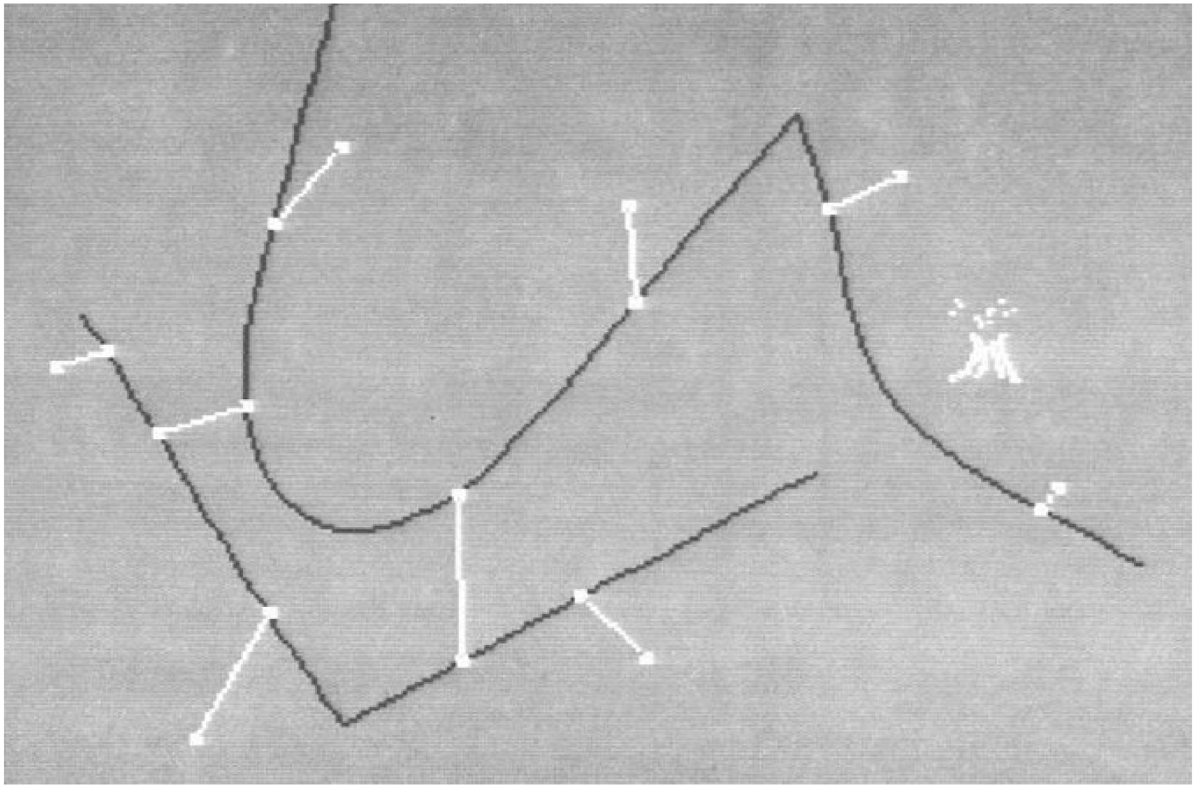
- Edge Functional : negative gradient magnitude: $E_{edge} = - |\nabla I(x,y)|^2$
- Better: negative gradient magnitude of Gaussian-smoothed image:

$$E_{edge} = - |\nabla G(\sigma) \otimes I(x,y)|^2$$

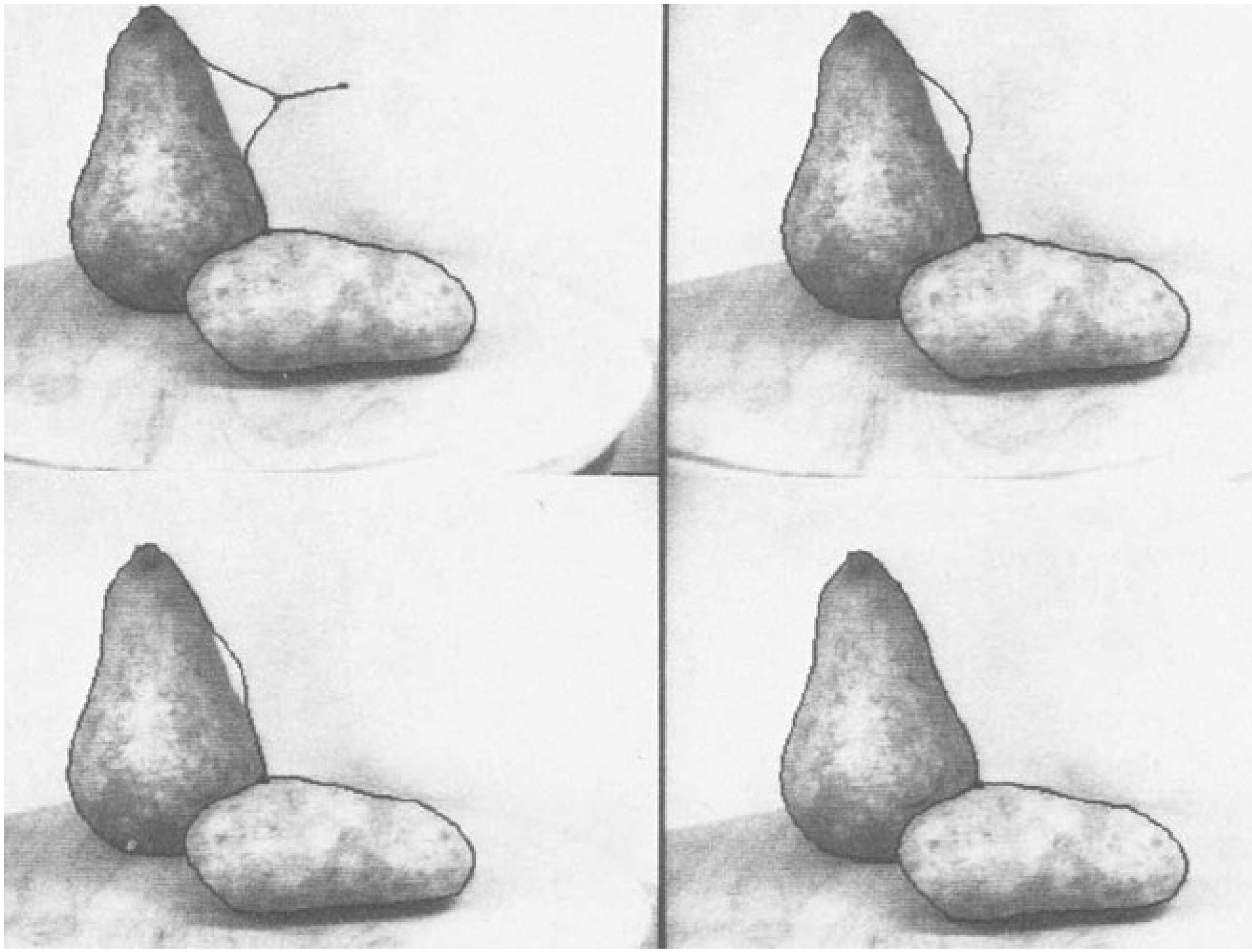
→ Attracts the snake to locations of large gradients = strong edges

External Constraint Forces

- Springs: add -k(x1-x2)2 to E_{con}
- Volcano: 1/r2 repulsion force, combine with image potential



External Constraint Forces: Spring



Original Demo Kass et al., 1988

Click to run

http://www.cs.ucla.edu/~dt/videos/deformable-models/snakes.avi

Numerical Solutions

$$-\frac{d^2}{ds^2}\left(\frac{\partial E}{\partial\left(\frac{d^2x}{ds^2}\right)}+\frac{\partial E}{\partial\left(\frac{d^2y}{ds^2}\right)}\right)+\frac{d}{ds}E_{v_s}-E_v=0$$

Numerical Solutions

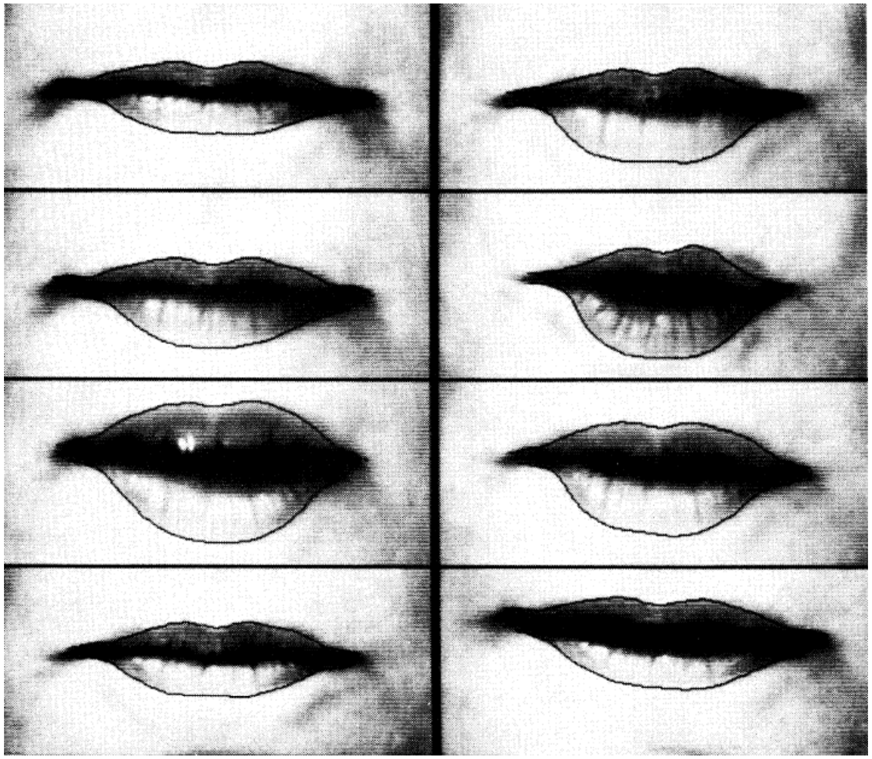
- The spline v(s) which minimizes E^*_{snake} must satisfy

$$-\frac{d^2}{ds^2}\left(\frac{\partial E}{\partial\left(\frac{d^2x}{ds^2}\right)}+\frac{\partial E}{\partial\left(\frac{d^2y}{ds^2}\right)}\right)+\frac{d}{ds}E_{v_s}-E_v=0$$

- Solutions: Greedy local updates, Euler Lagrange etc. (see handouts)

Using Snakes for Dynamic Scenes

- Once a snake finds a feature, it „locks on”
- If feature begins to move, the snake will track the same local minimum
- Fast motion could cause the snake to flip into a different minimum



Example Movie Sequences