Snakes: Active Contour Models

CS/BIOEN 6640

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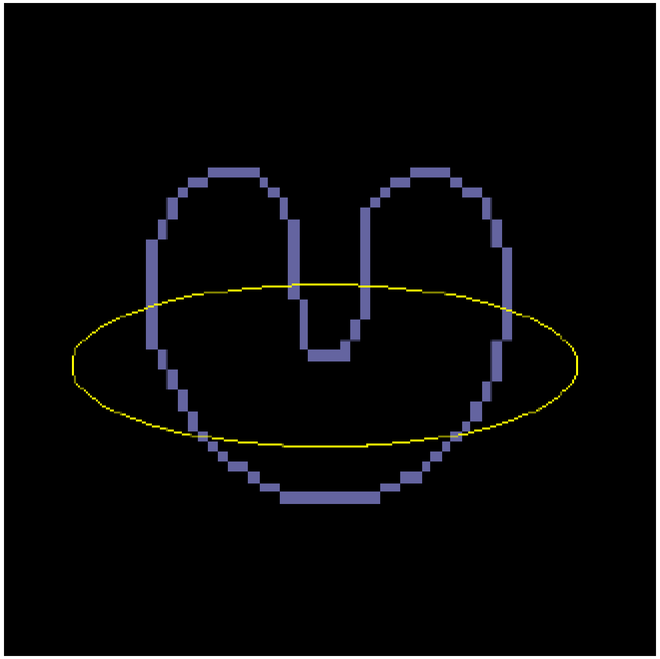
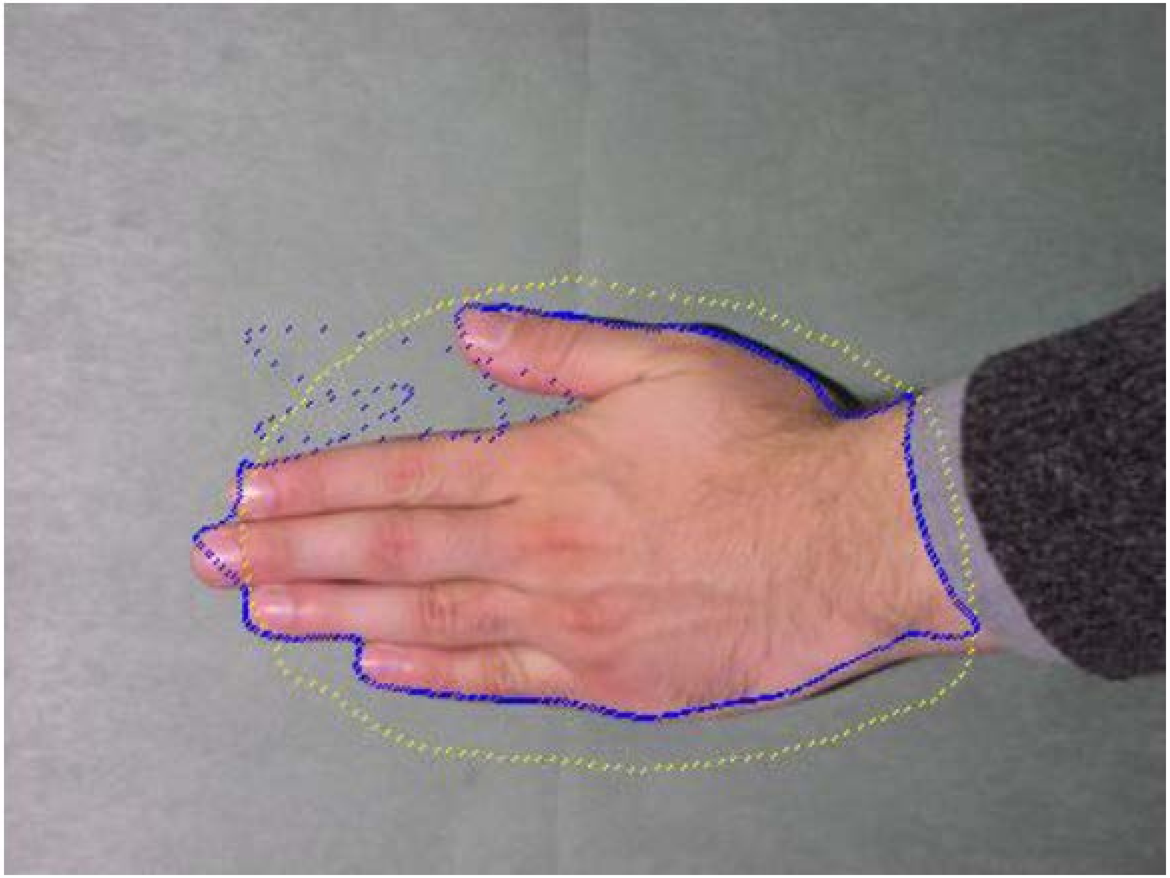
(some material from Zoltan Kato http://www.cab.u-szeged.hu/~kato/variational/)



J. Prince, JHU: http://www.iacl.ece.jhu.edu/static/gvf/gvfsnake5.html

Principle: Active Contour Models



http://www.ee.iitb.ac.in/uma/~krishnan/research.html

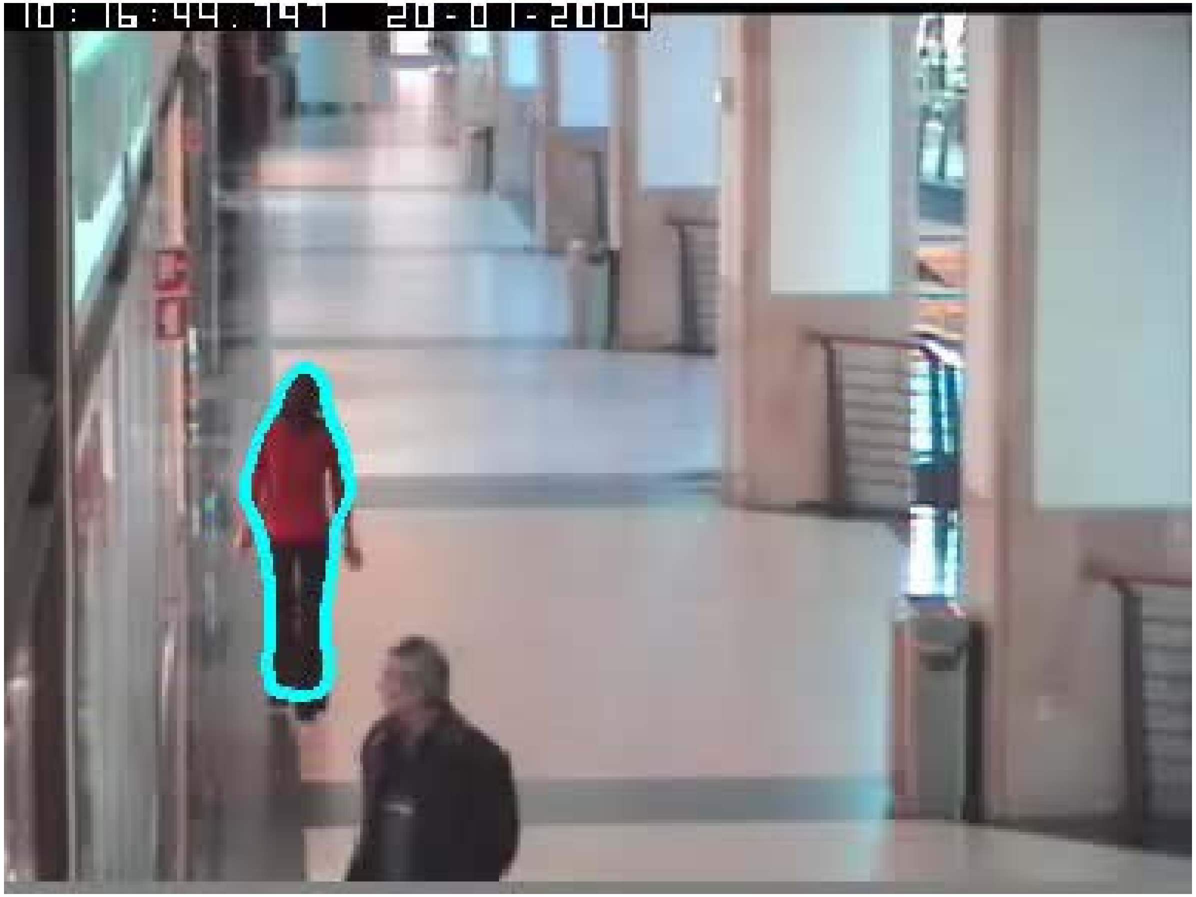
Materials

- 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

Video Analysis



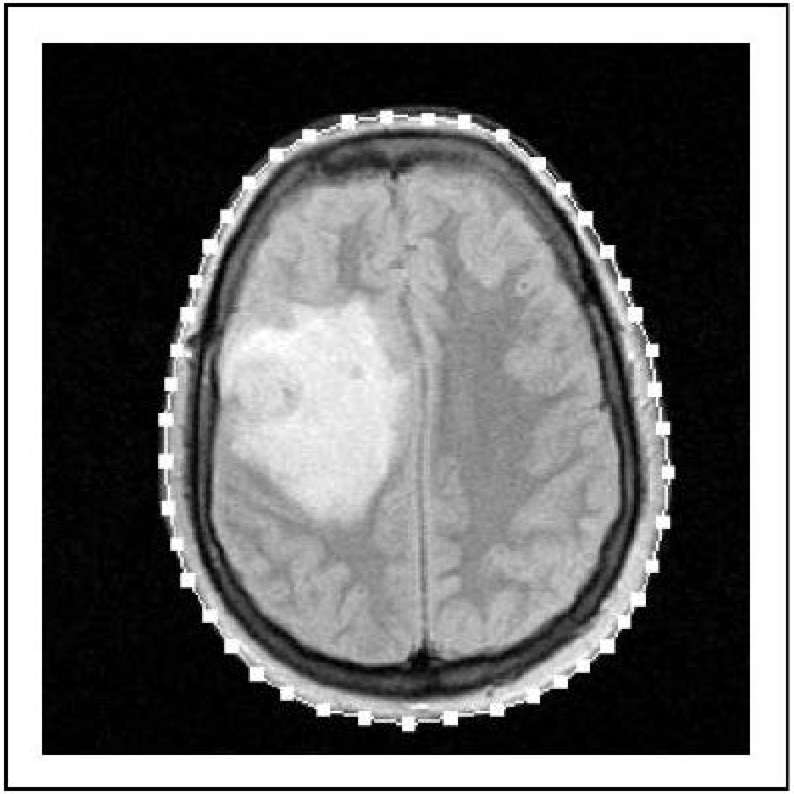
movie

http://www.ee.iitb.ac.in/uma/~krishnan/OneStopNoEnter2cor-SS.avi
http://www.ee.iitb.ac.in/uma/~krishnan/ShopAssistant1cor.avi

Snake: Active Contour Model

(a) Initial Snake

(b) Final Snake



From: PhD thesis Dr Jim Ivins

http://www.computing.edu.au/~jim/thesis.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, $\alpha(s)$: ”elasticity”
  - Second order term: thin plate, $\beta(s)$: “rigidity, stiffness”
  - If $\alpha(s)=\beta(s)=0$, we allow breaks in the contour

Image Forces

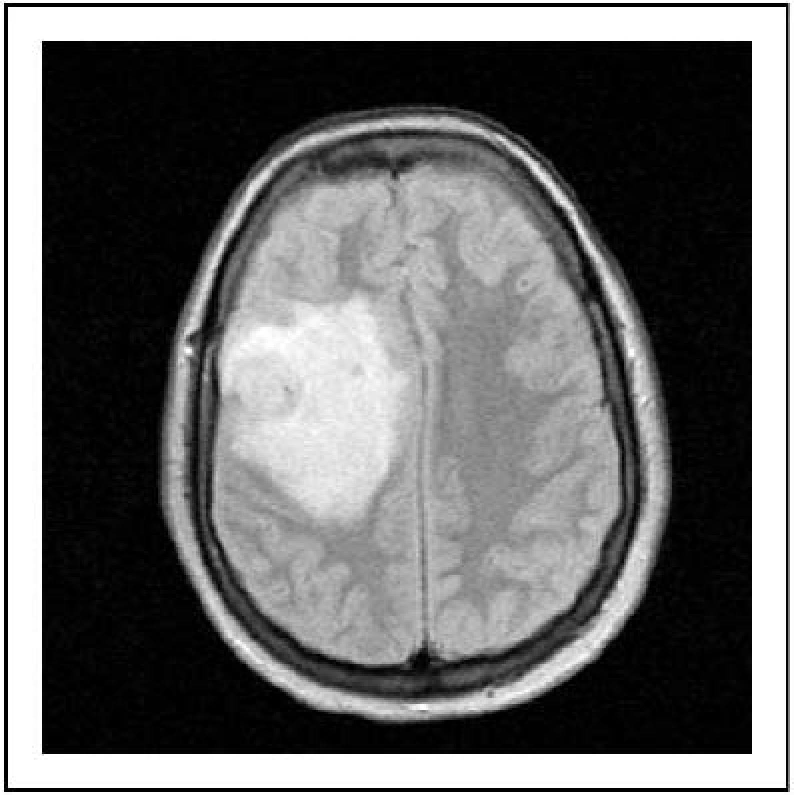
- Edge Functional : negative gradient magnitude: $E_{edge} = - |\nabla I(x,y)|^2$
- Better: negative gradient magnitude of Gaussian-smoothed image:

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

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

Image Term: Potential Energy

(a) Unprocessed Image



(b) Potential (Edge) Energy

From: PhD thesis Dr Jim Ivins

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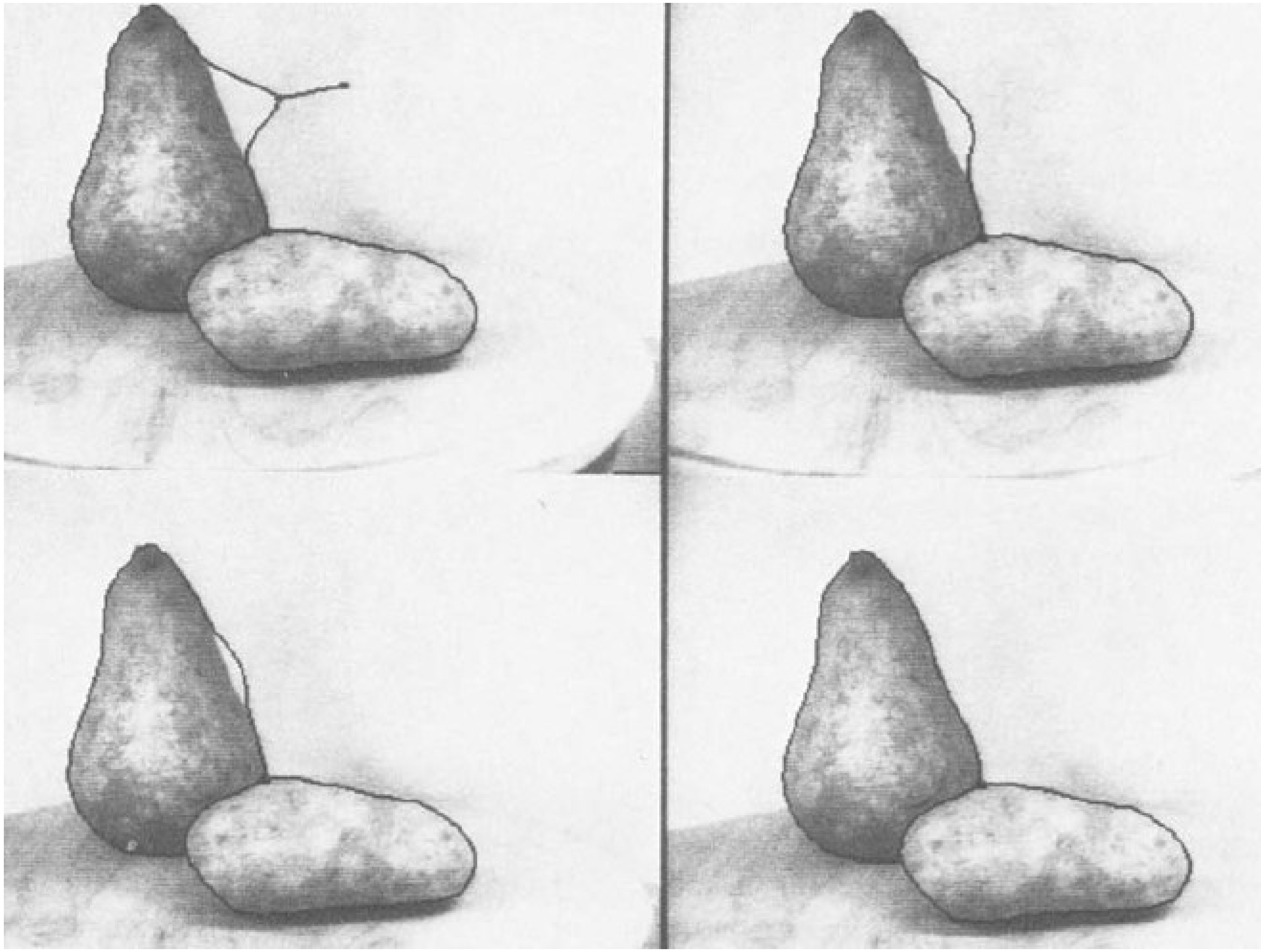
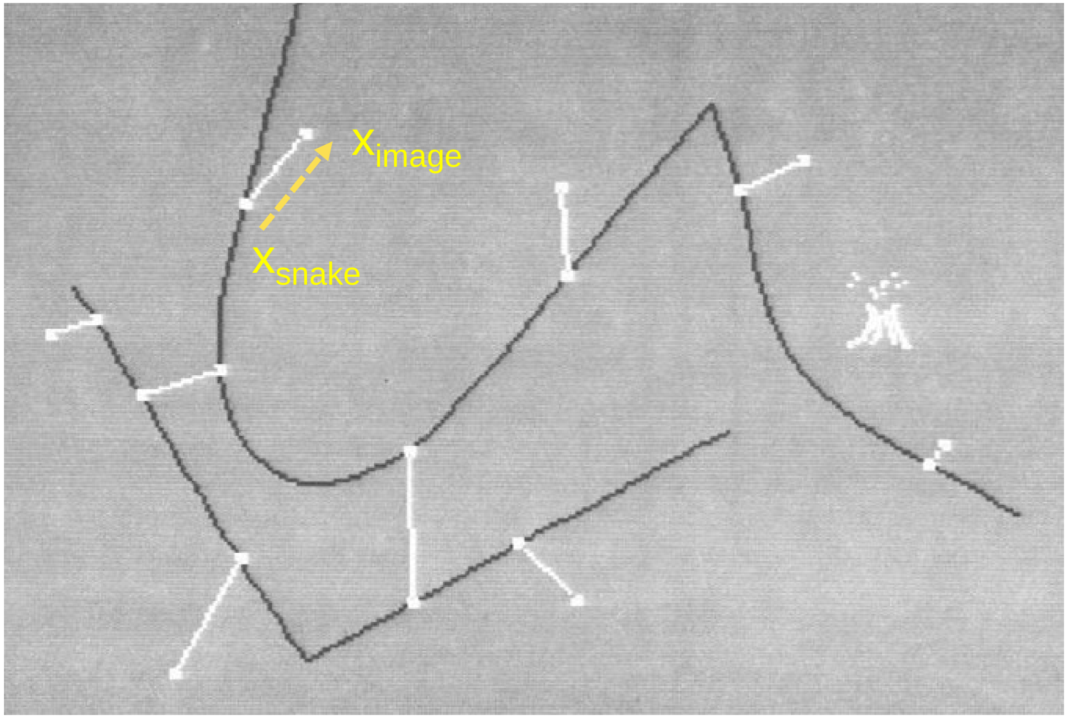
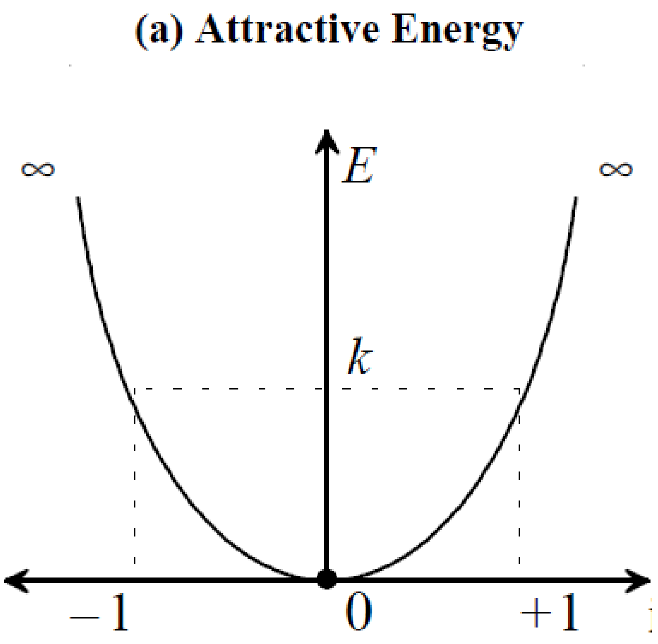
External Constraint Forces: Spring



External Constraint Forces

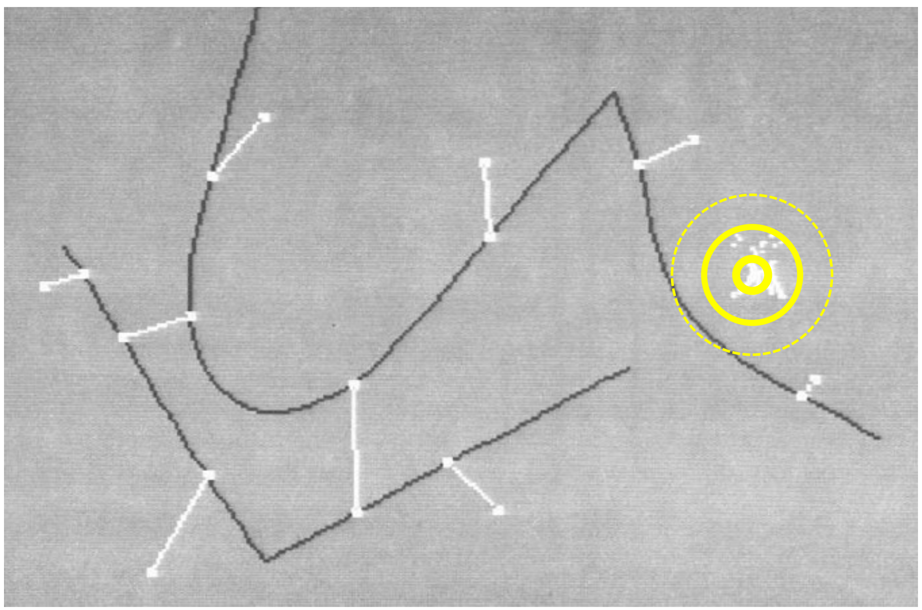
- **Springs**: add $k(x_{snake}-x_{image})^2$ to E_{con} : energy becomes zero when x_{snake} moves to $x_{image,}$ otherwise gets large

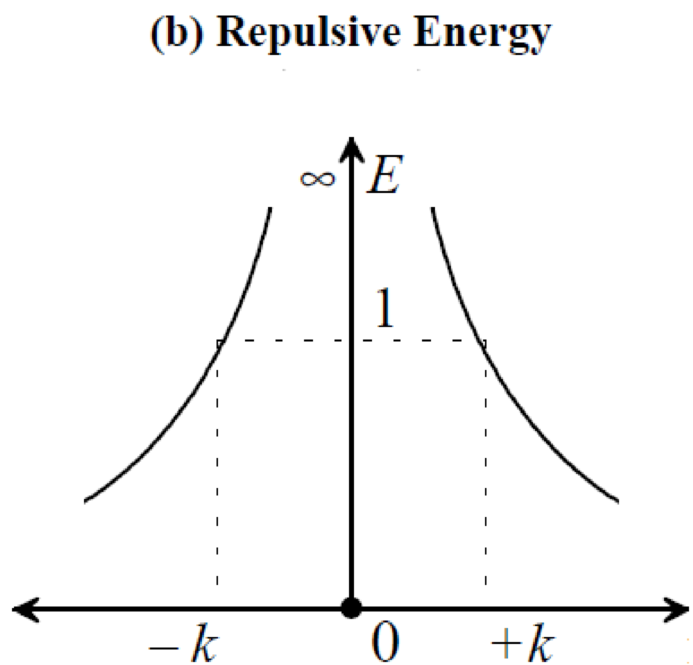




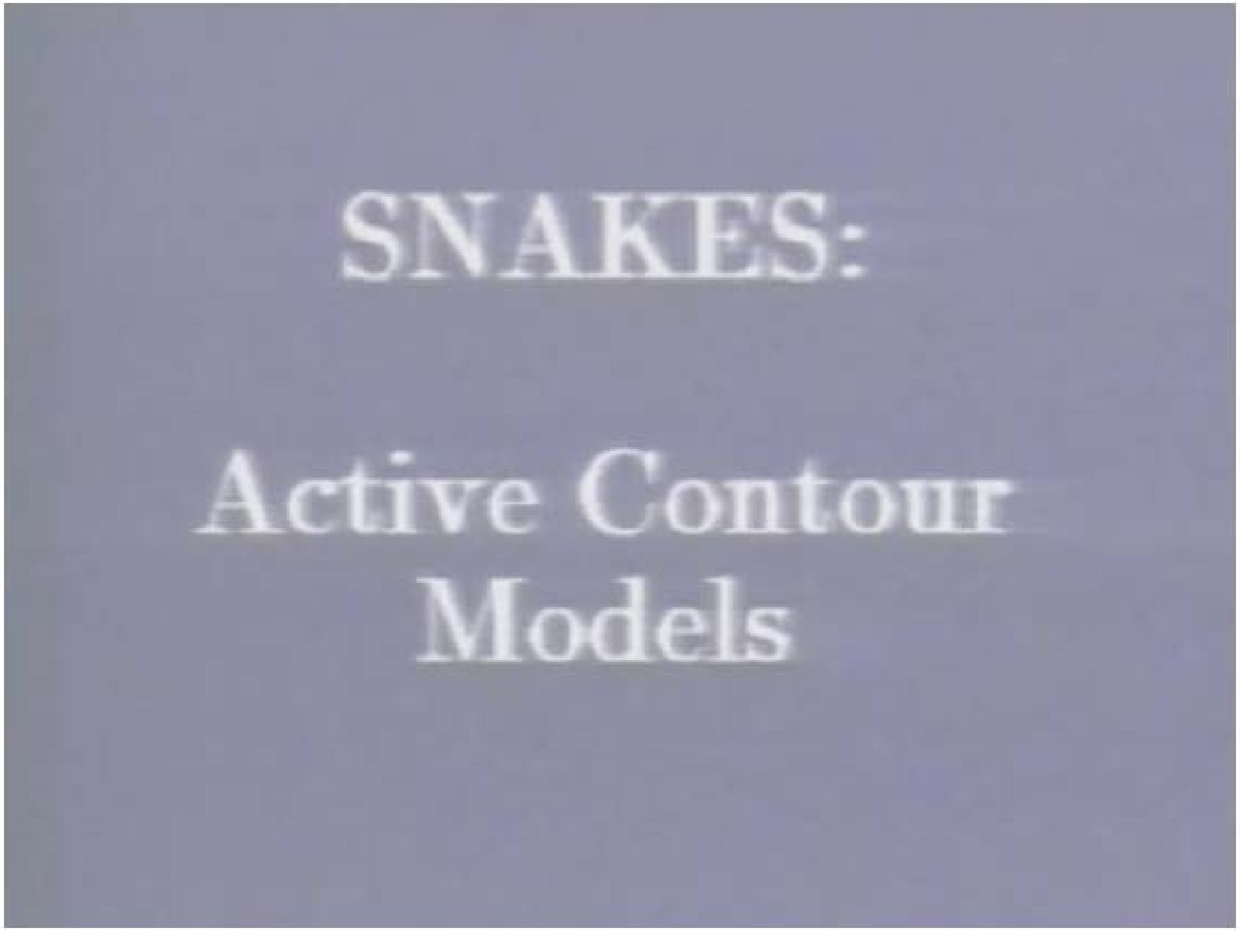
External Constraint Forces

- **Volcano**: $1/r^2$ repulsion force, combine with image potential: $E_{con} = k/(x_{snake}-x_{volcano})^2$: large at volcano center, fades off with distance





Original Demo Kass et al., 1988

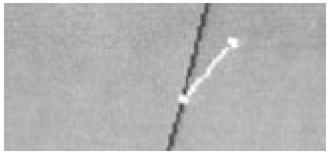


Click image to run

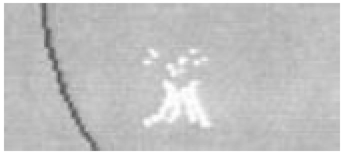
Local link

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

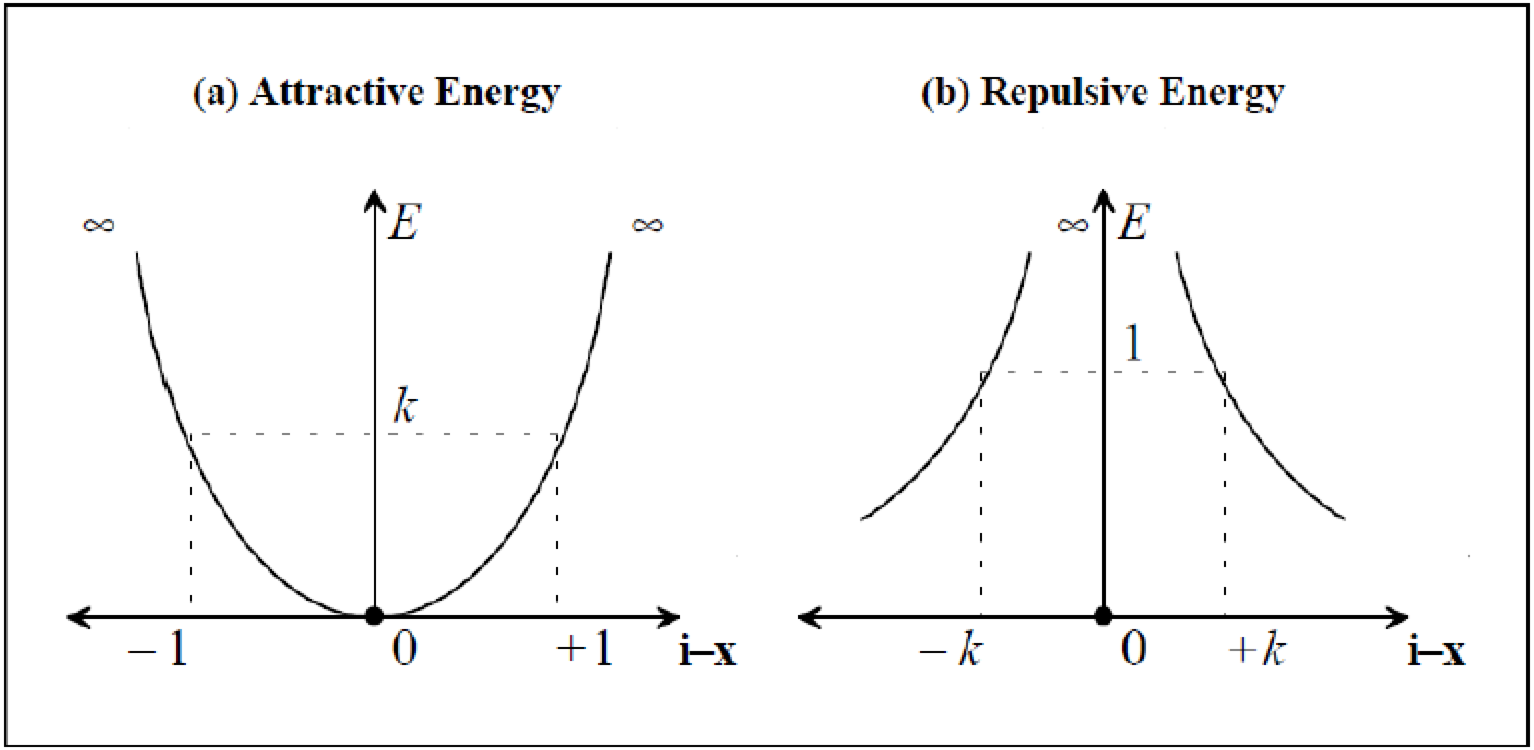
External Constraint Forces



Spring force



Volcano force

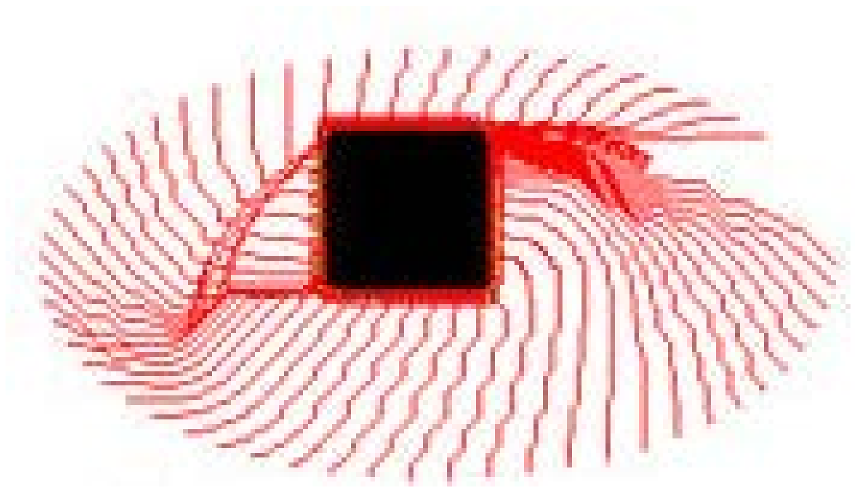


From: PhD thesis Dr Jim Ivins

http://www.computing.edu.au/~jim/thesis.html

Web-Demo

- **Computer Vision Demonstration Website, Electronics and Computer Science, University of Southampton**
- http://users.ecs.soton.ac.uk/msn/book/new_demo/Snakes/



External Forces (Suri/Farag)

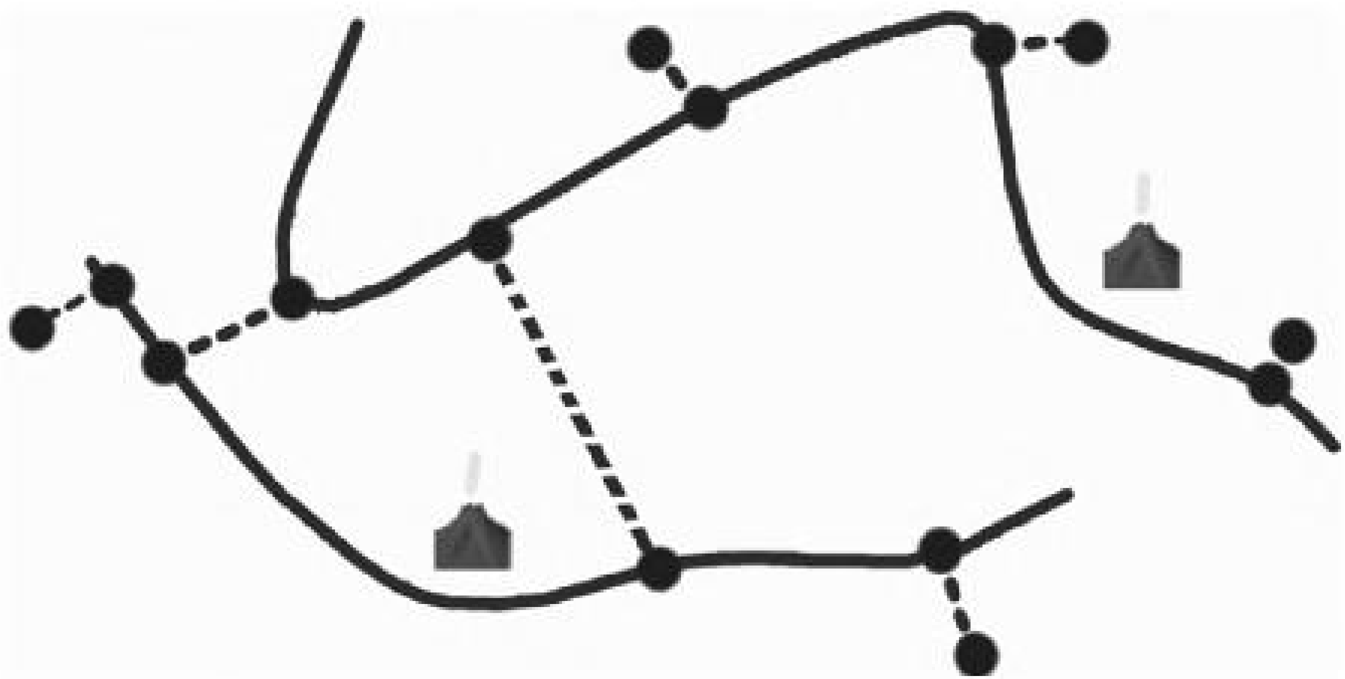


Figure 6. Geometric interpretation of Snake Pit. The two dark curves are different snakes, and the tow springs (dashed line) are connected between them to create a coupling effect. The other springs attach points on the snakes to fixed positions in the image. In addition, two volcanos are set to bend a nearby snake. See attached CD for color version.

External Forces (Suri/Farag)

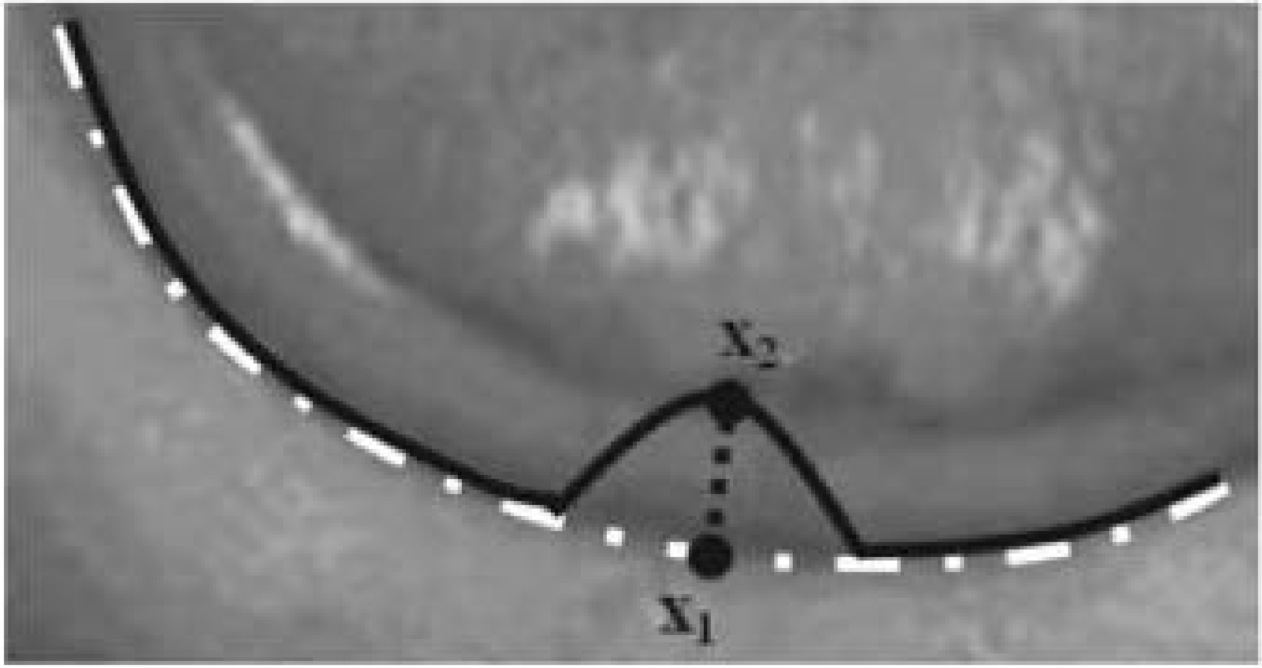
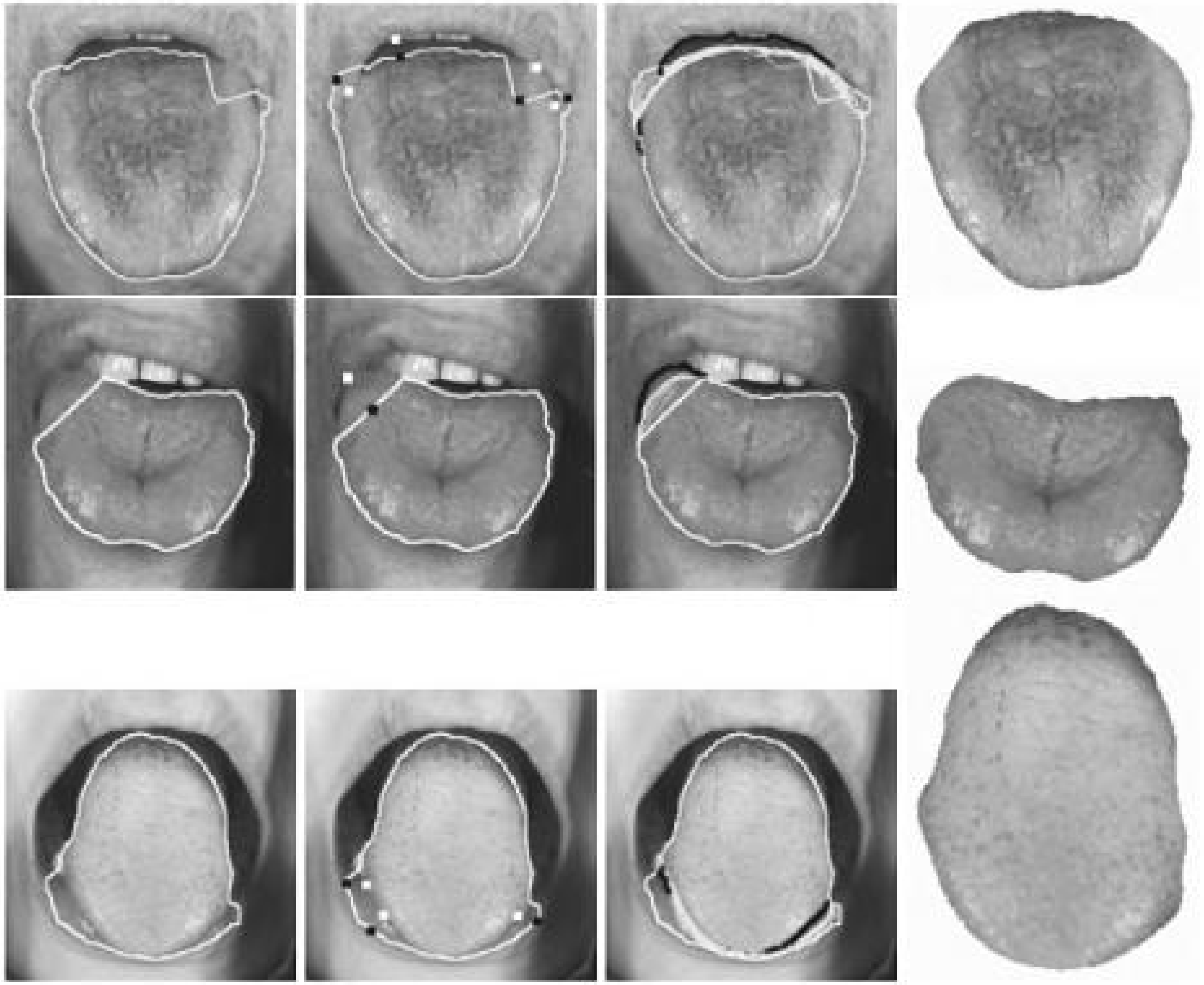


Figure 7. A pair of points for the snake pit. See attached CD for color version.

Spring: Adds $-k(x_1-x_2)^2$ to E_{con}

Use: Pull a snake to the specified true boundary

External Forces (Suri/Farag)



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

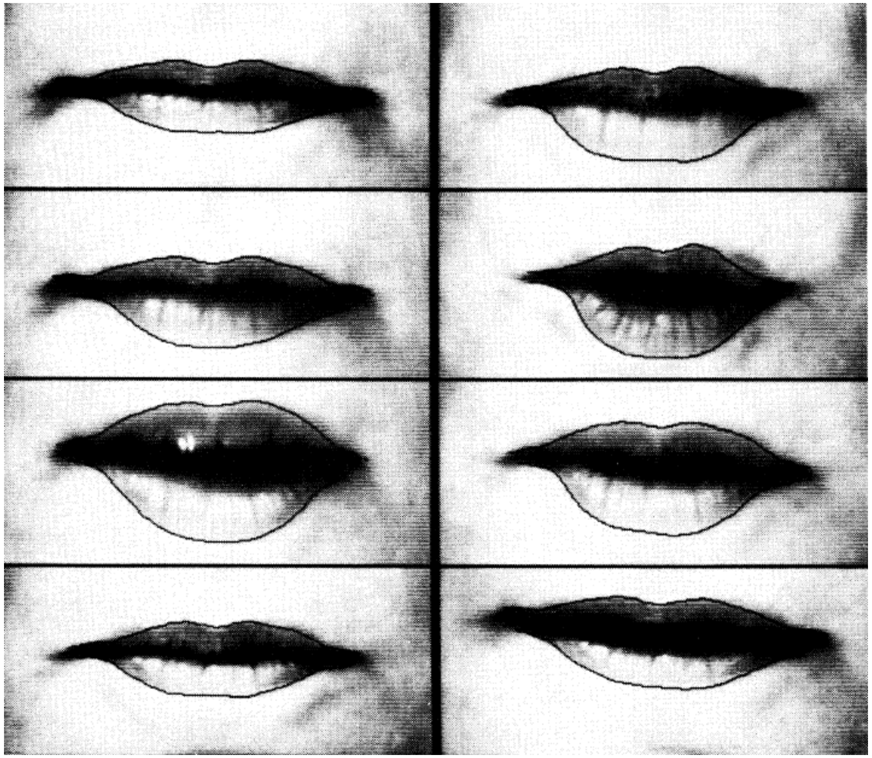
- The spline v(s) which minimizes E^*_{snake} must satisfy

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

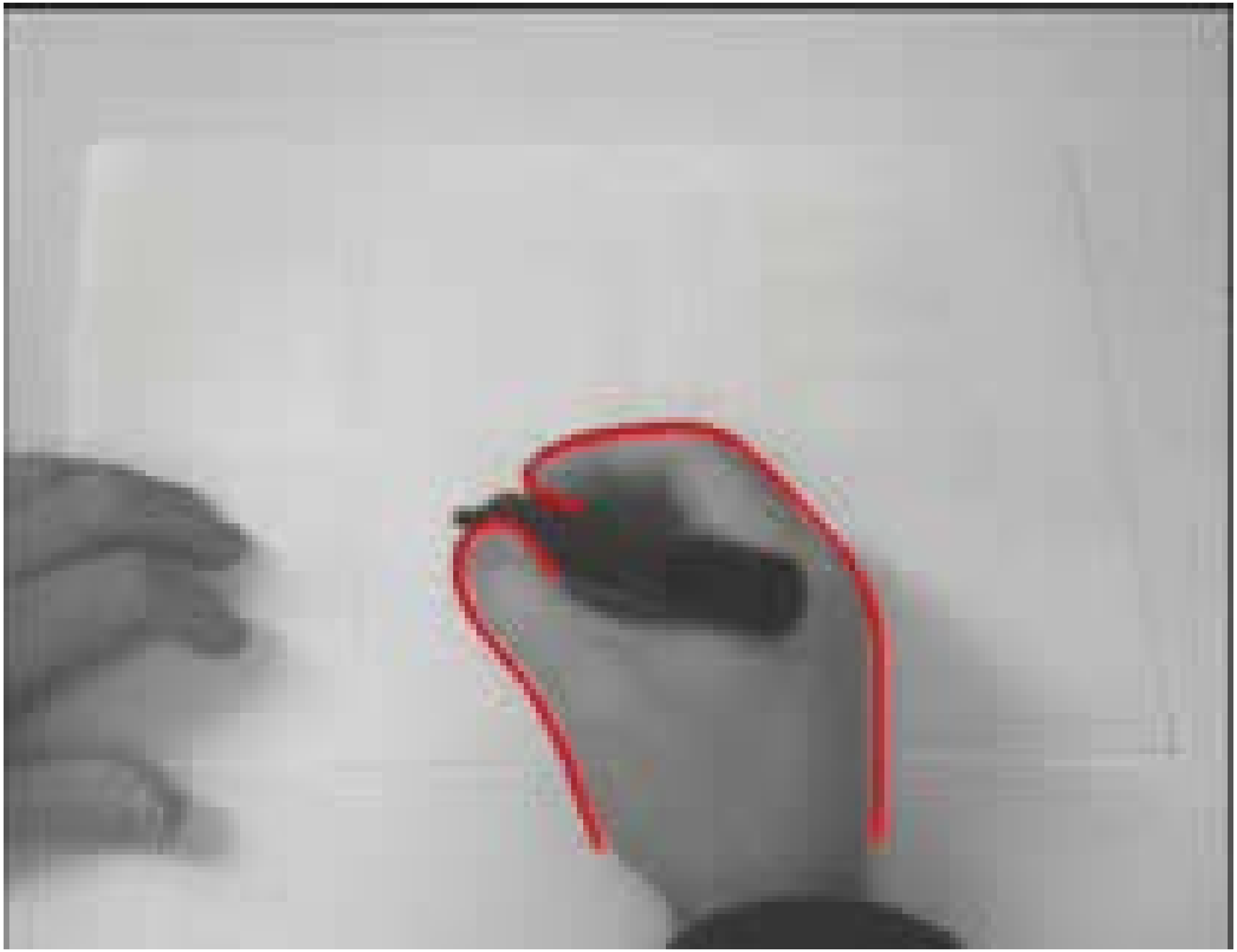
- Solutions: Greedy local updates, Euler Lagrange etc. (see handouts)

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



movie