# Snakes: Active Contour Models

CS 6640

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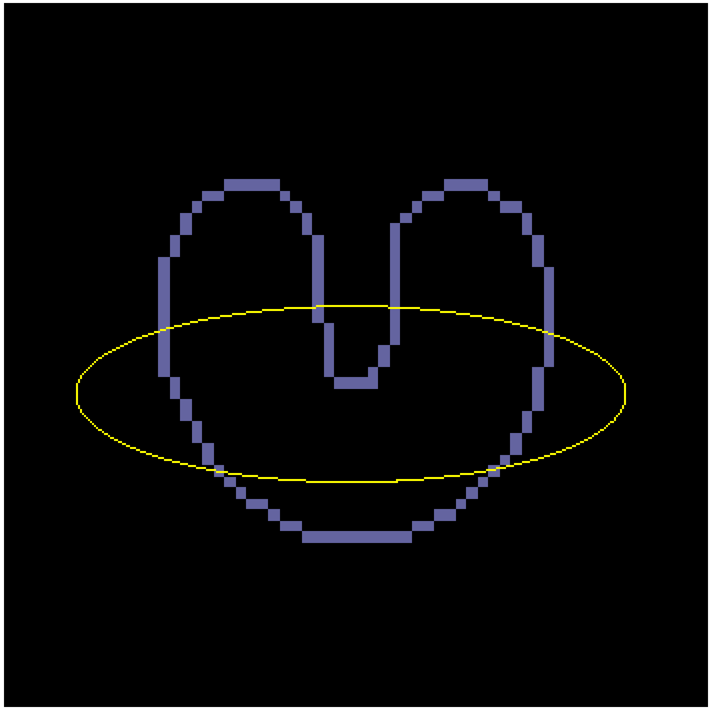
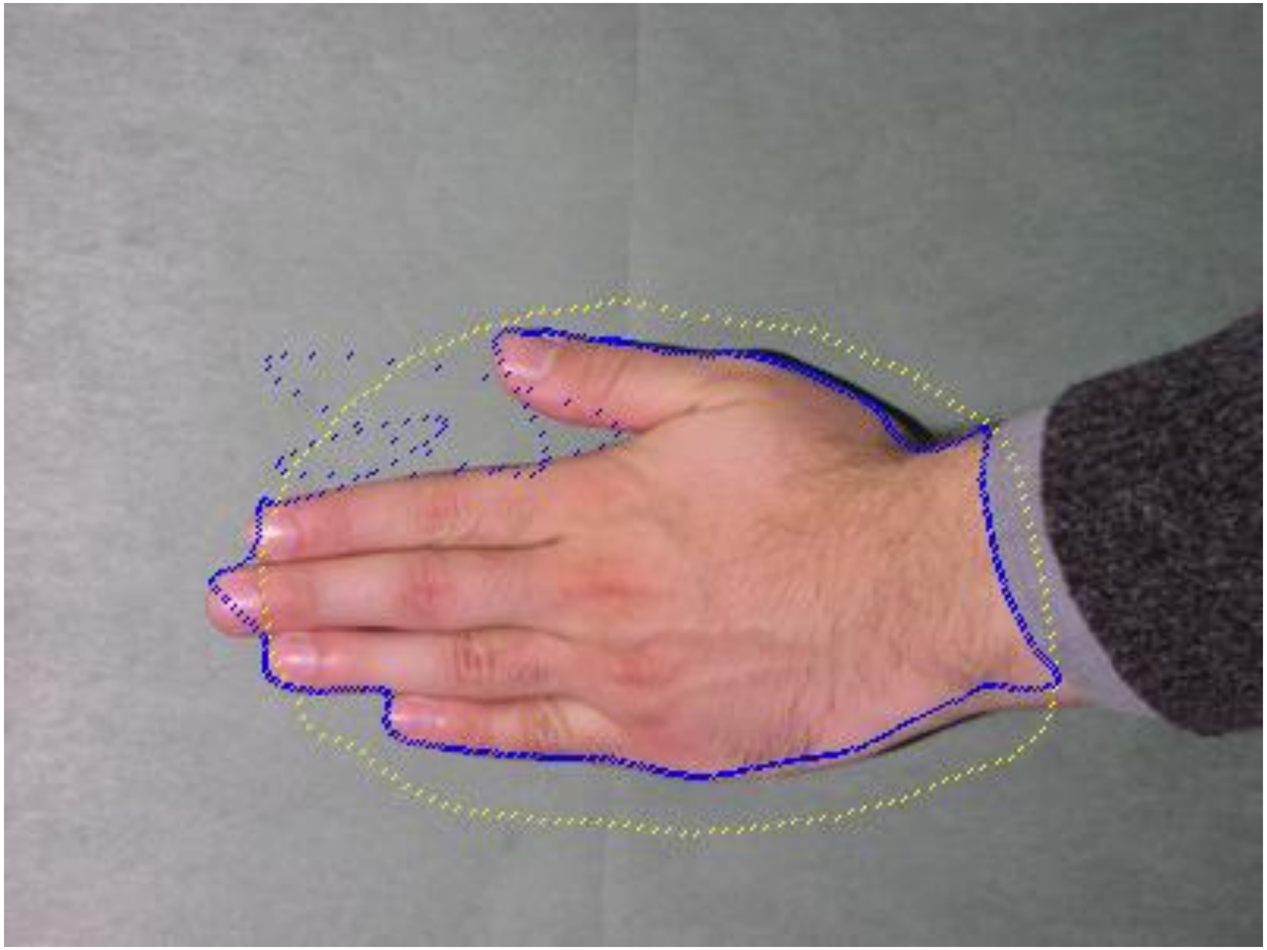
(some material from Zoltan Kato http://www.cab.u-szeged.hu/~kato/variational/)



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

# Principle: Active Contour Models

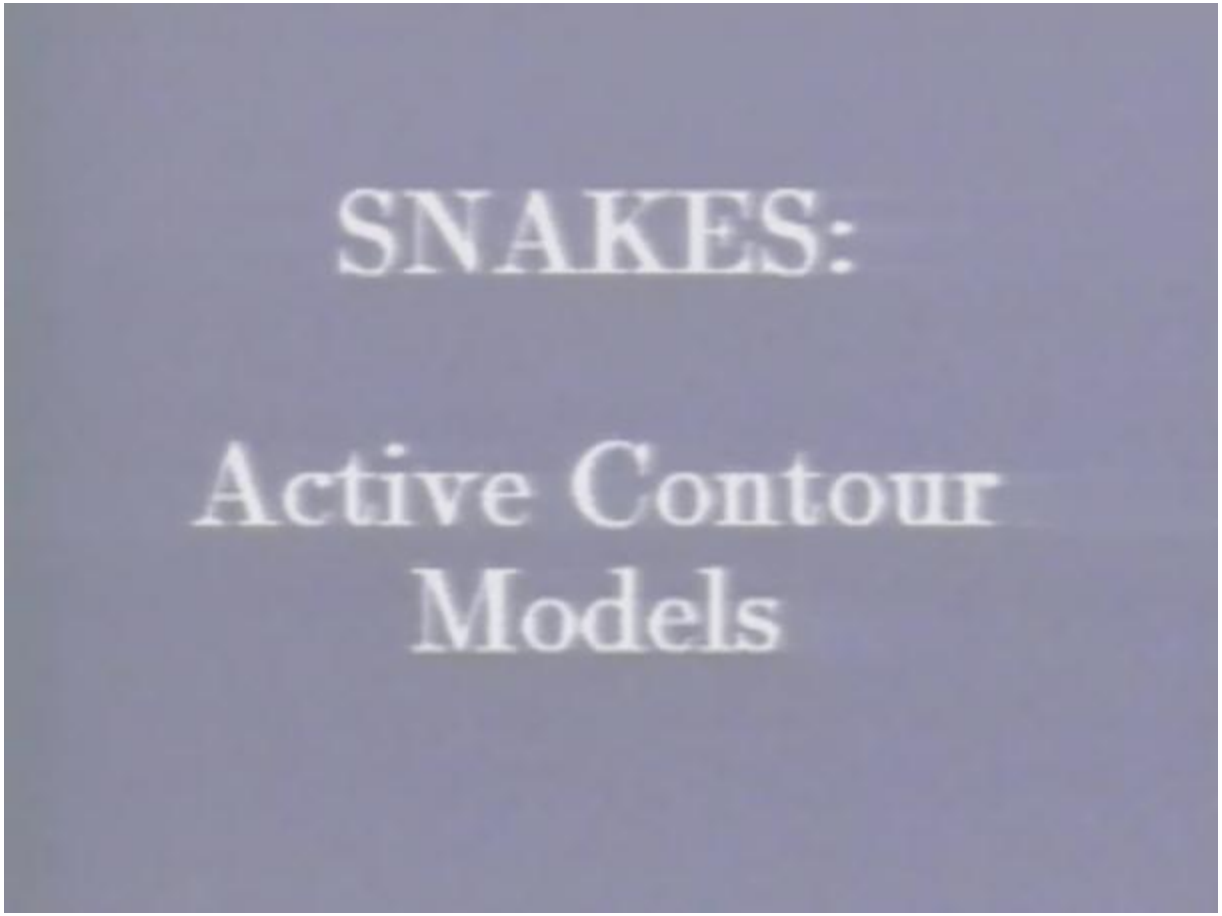


http://www.ee.iitb.ac.in/uma/~krishnan/research.html

# 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

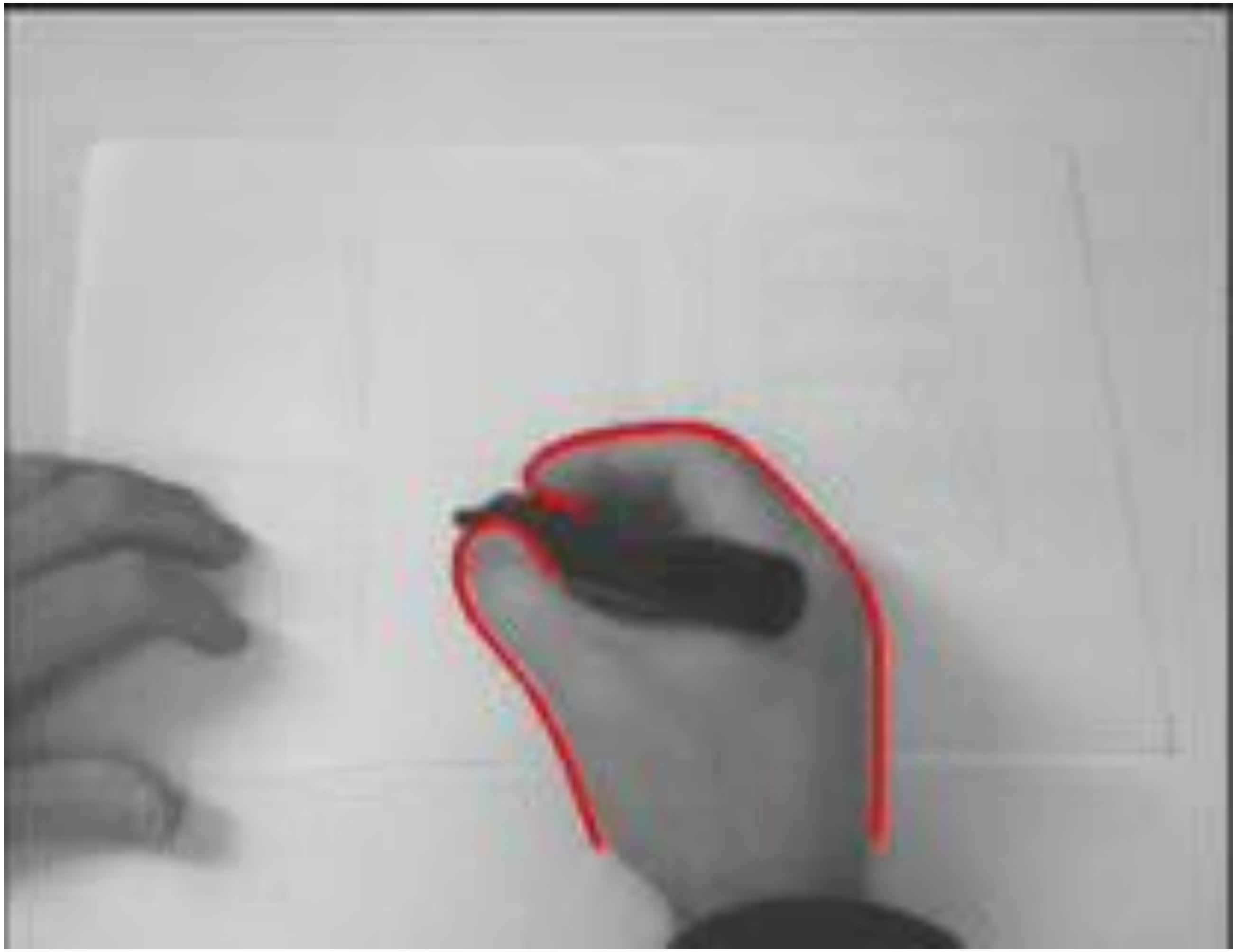
# Original Demo Kass et al., 1988




Click to run

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

# Example Movie Sequences

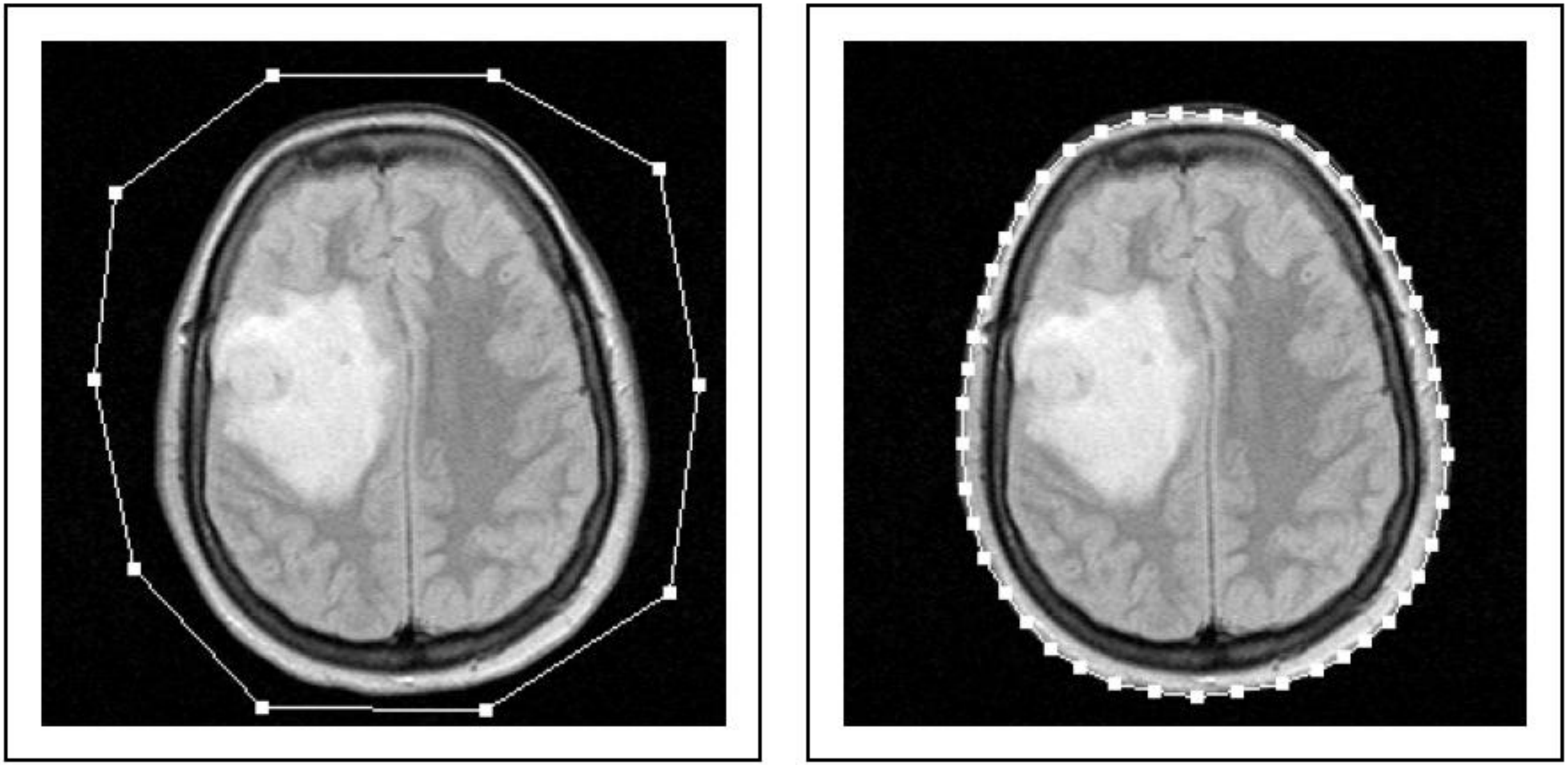


# Video Analysis


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

# 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: Potential Energy

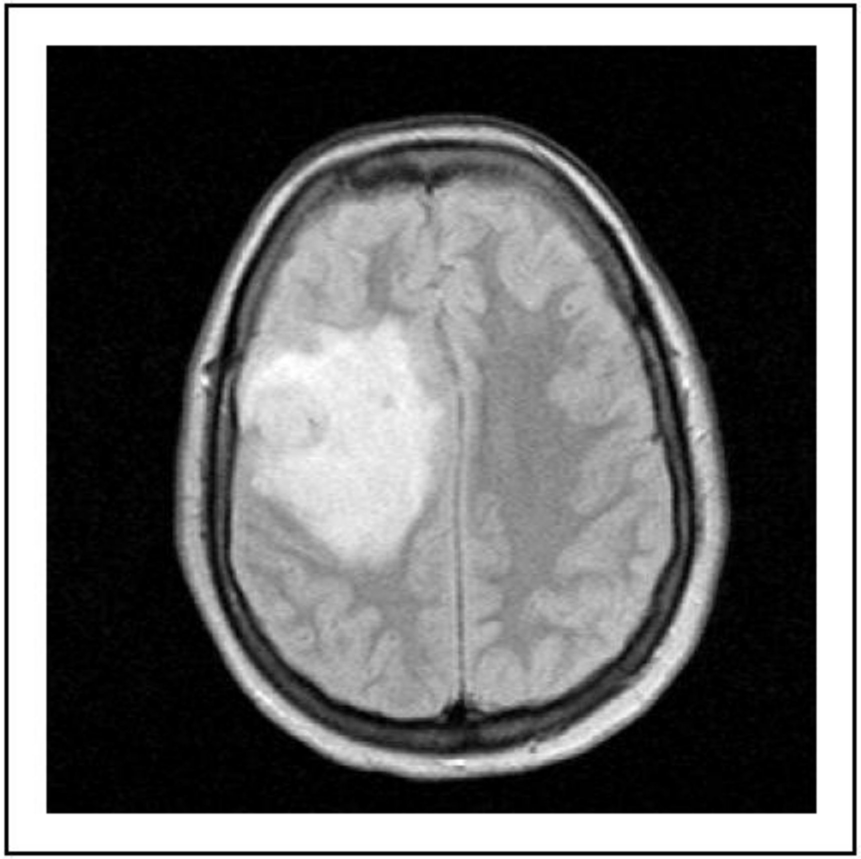
- Edge Functional : negative gradient magnitude: $E_{edge} = -|\nabla I(x,y)|^2$
- Better: negative gradient magnitude of Gaussian-smoothed image:

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

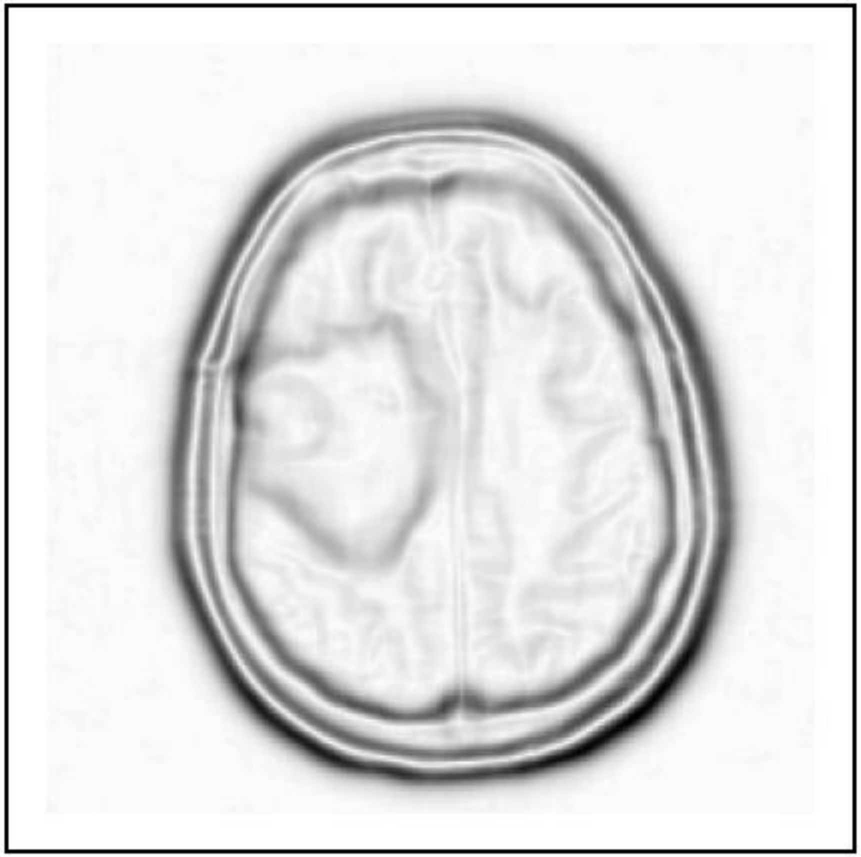
→ Attracts the snake to locations of large gradients = strong edges

# Image Term: Potential Energy

**(a) Unprocessed Image**

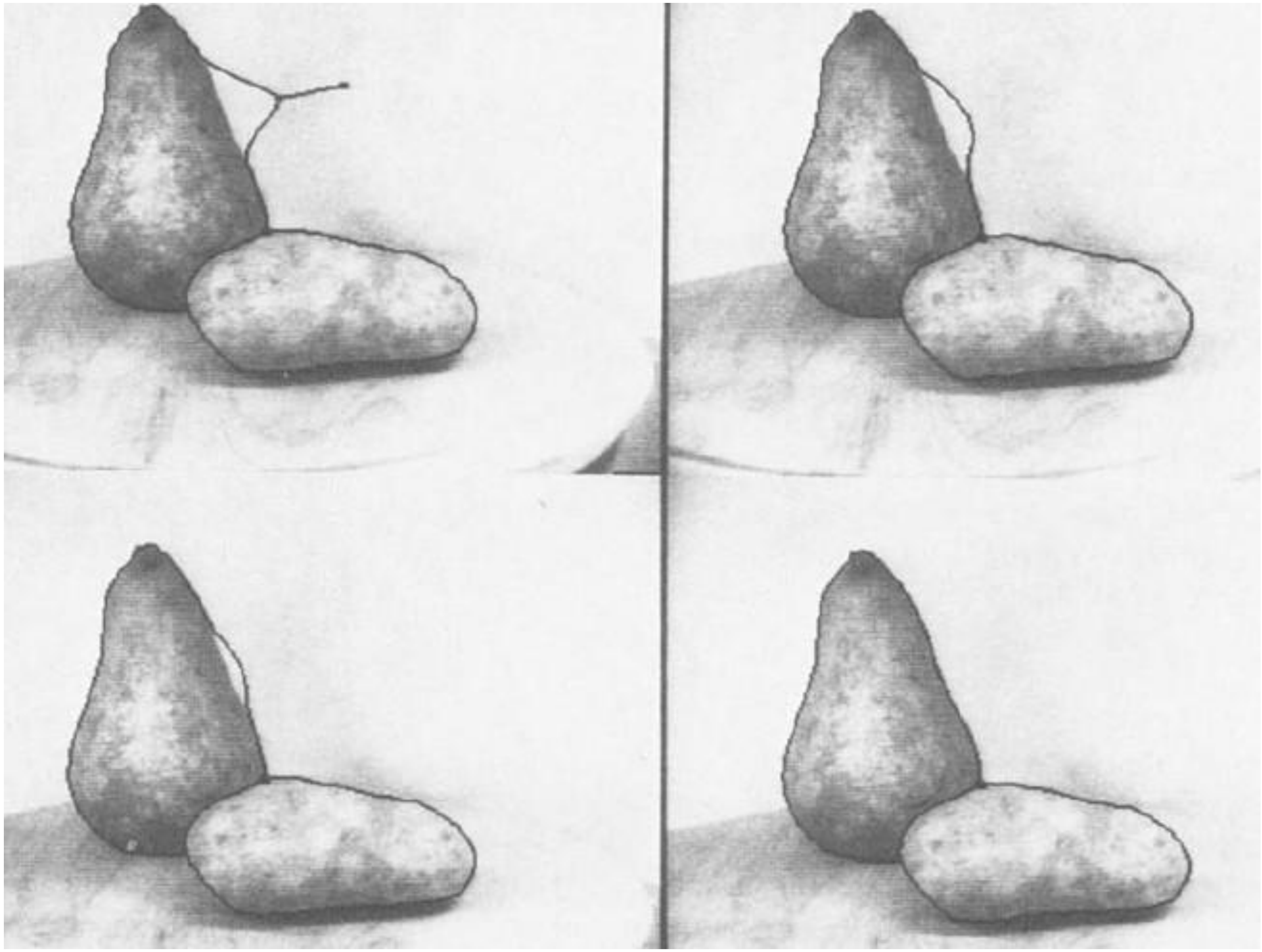


**(b) Potential (Edge) Energy**



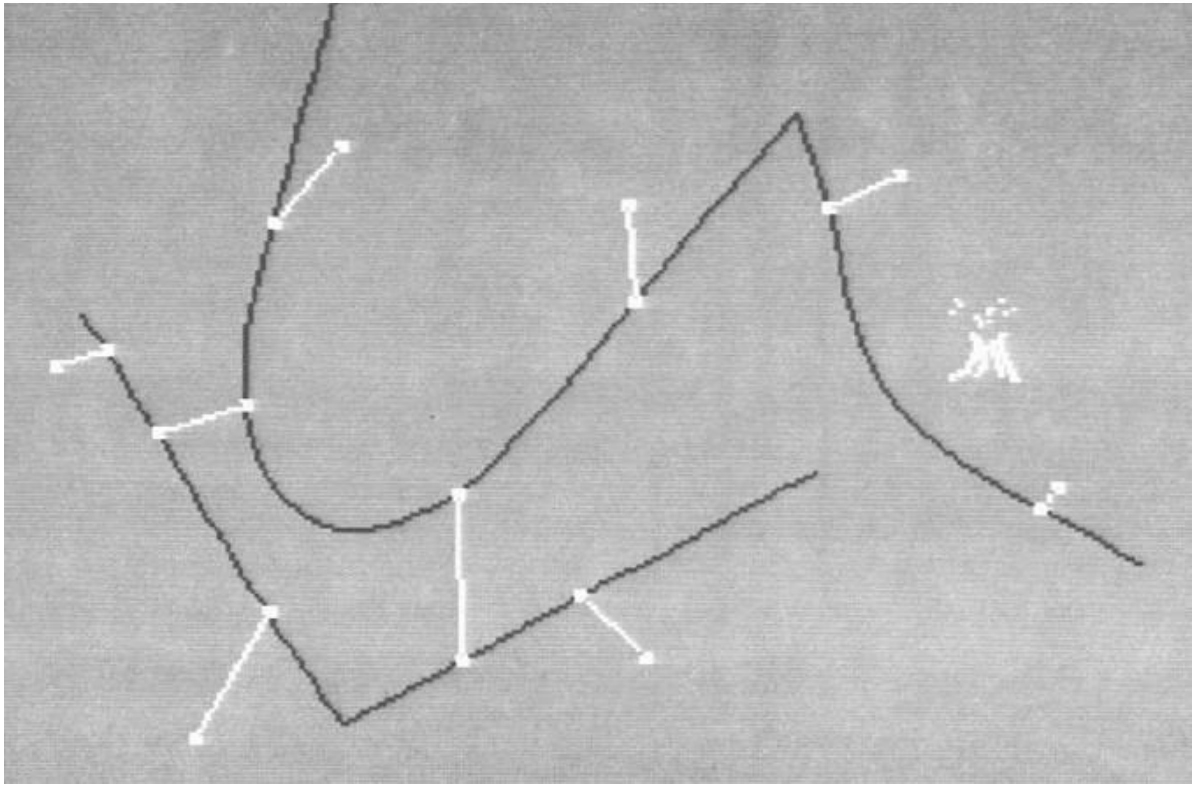
From: PhD thesis Dr Jim Ivins

# External Constraint Forces: Spring

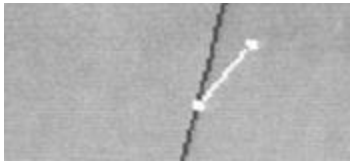


# External Constraint Forces

- Springs: add $k(\mathbf{x}_1-\mathbf{x}_2)^2$ to $E_{con}$
- Volcano: $1/r^2$ repulsion force, combine with image potential

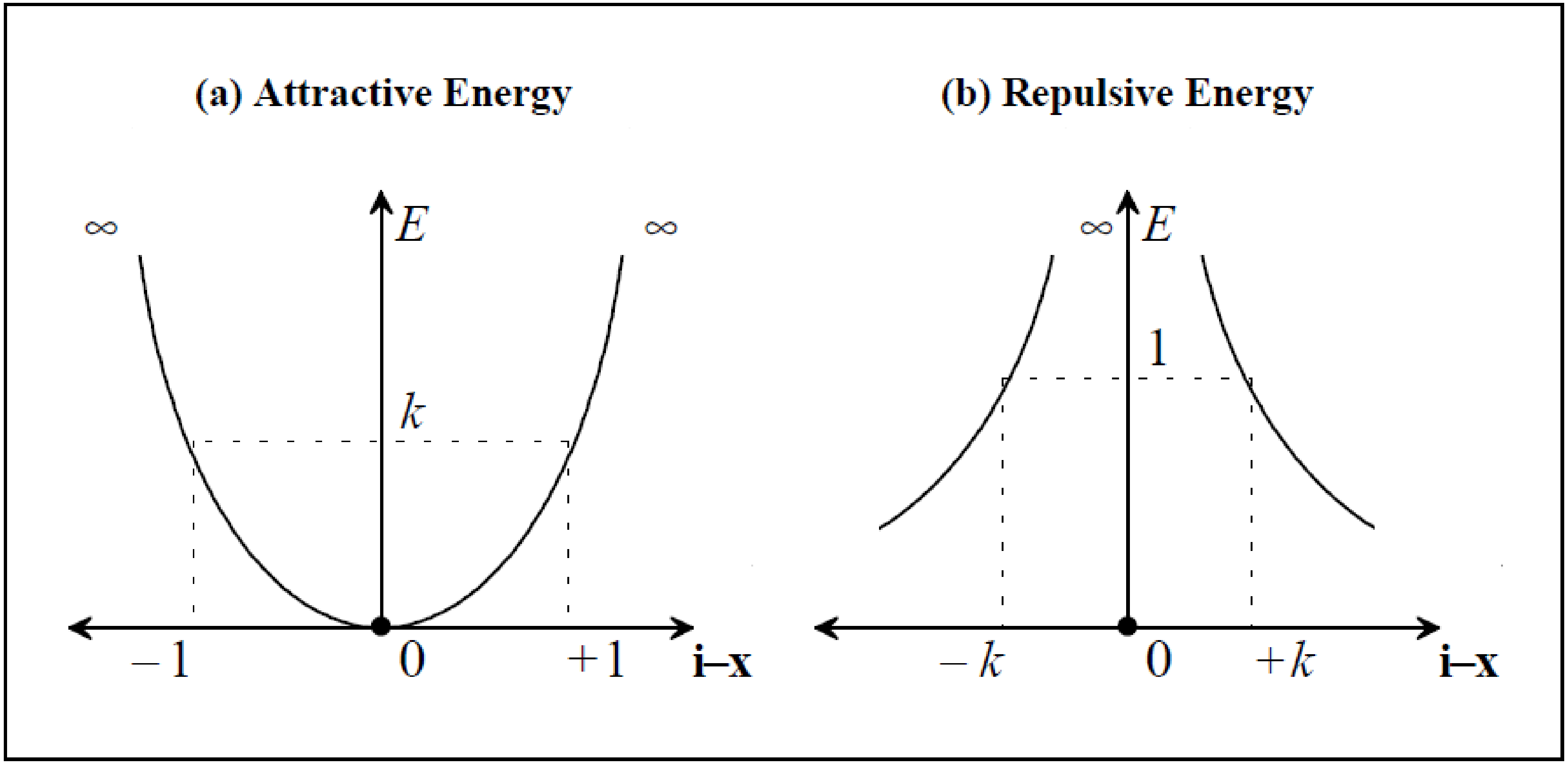


# External Constraint Forces



Spring force

Volcano force




From: PhD thesis Dr Jim Ivins

# External Forces (Suri/Farag)

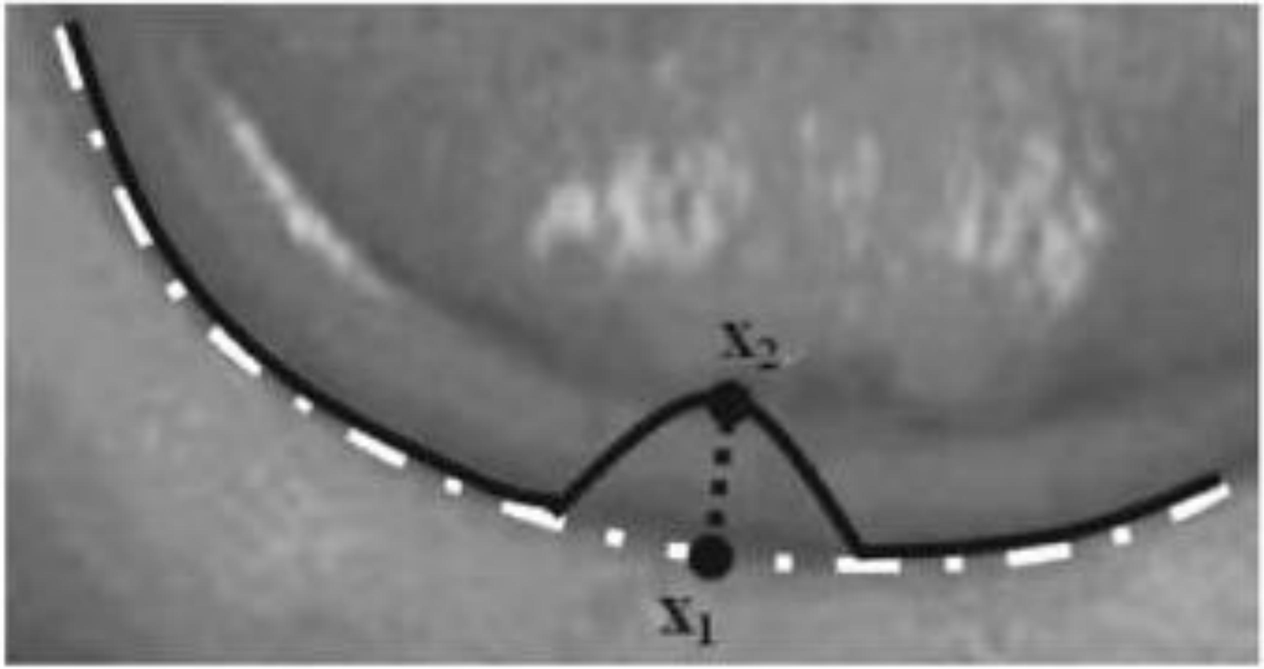



**Figure 7.** A pair of points for the snake pit. See attached CD for color version.

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

**Use:** Pull a snake to the specified true boundary

# External Forces (Suri/Farag)

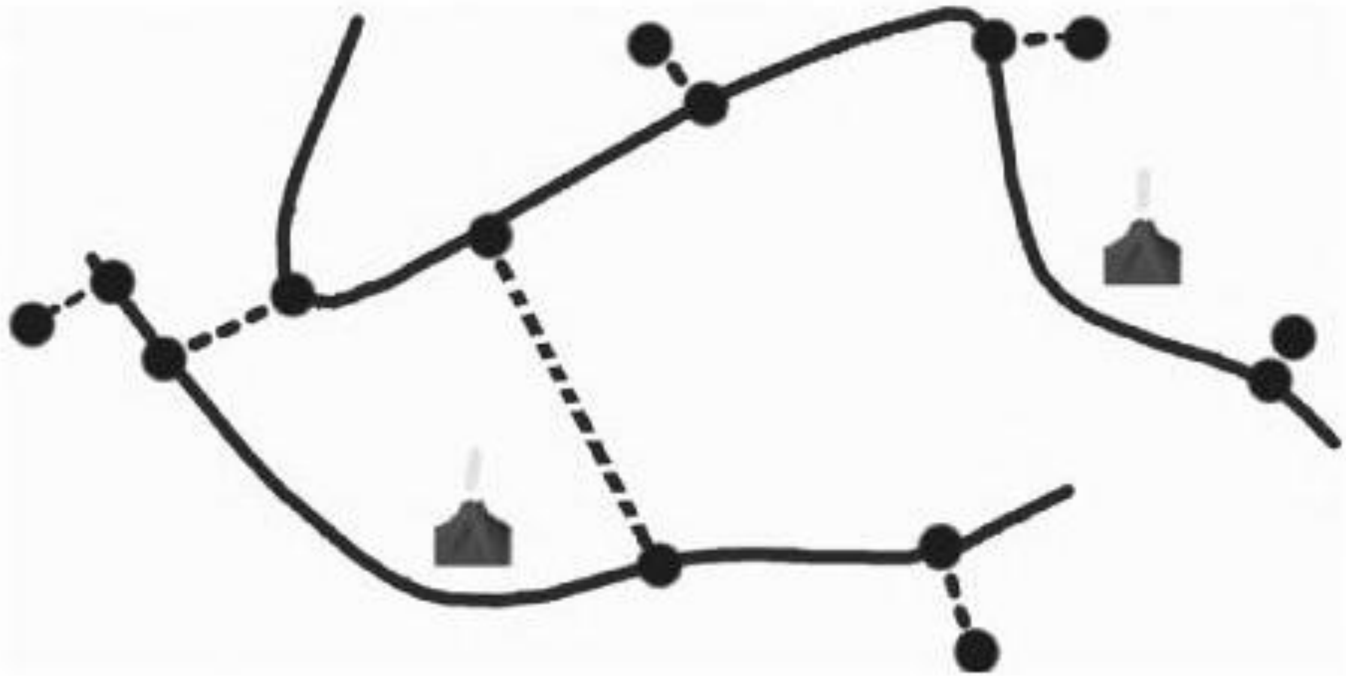
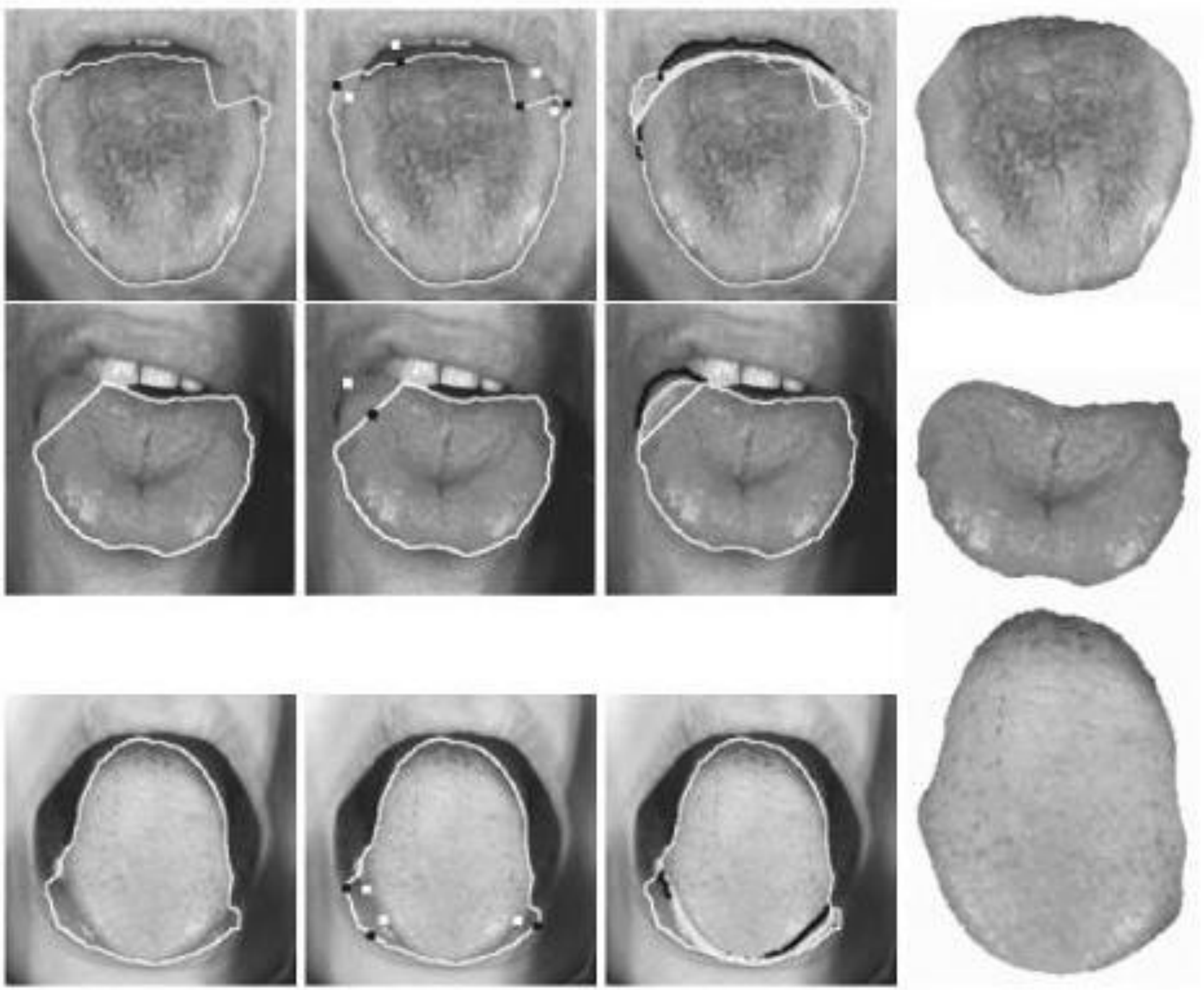


**Figure 6.** Geometric interpretation of Snake Pit. The two dark curves are different snakes, and the tow springs (dashed line) are connected between them to create a coupling effect. The other springs attach points on the snakes to fixed positions in the image. In addition, two volcanos are set to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

# External Forces (Suri/Farag)



# 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