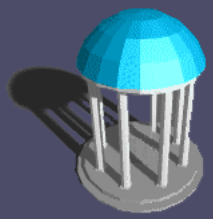
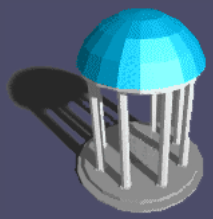


Active Contours and their applications

Julien Jomier

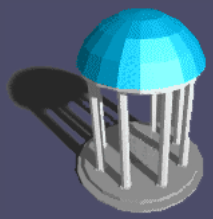
Comp 258

Geometric and Solid Modeling



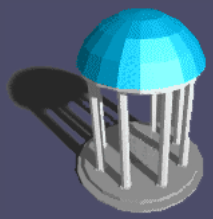
Outline

- Introduction
- Kass Algorithm
- Internal energy
- Image forces
- Edge Based and Termination functional
- Applications
- Problems with snakes

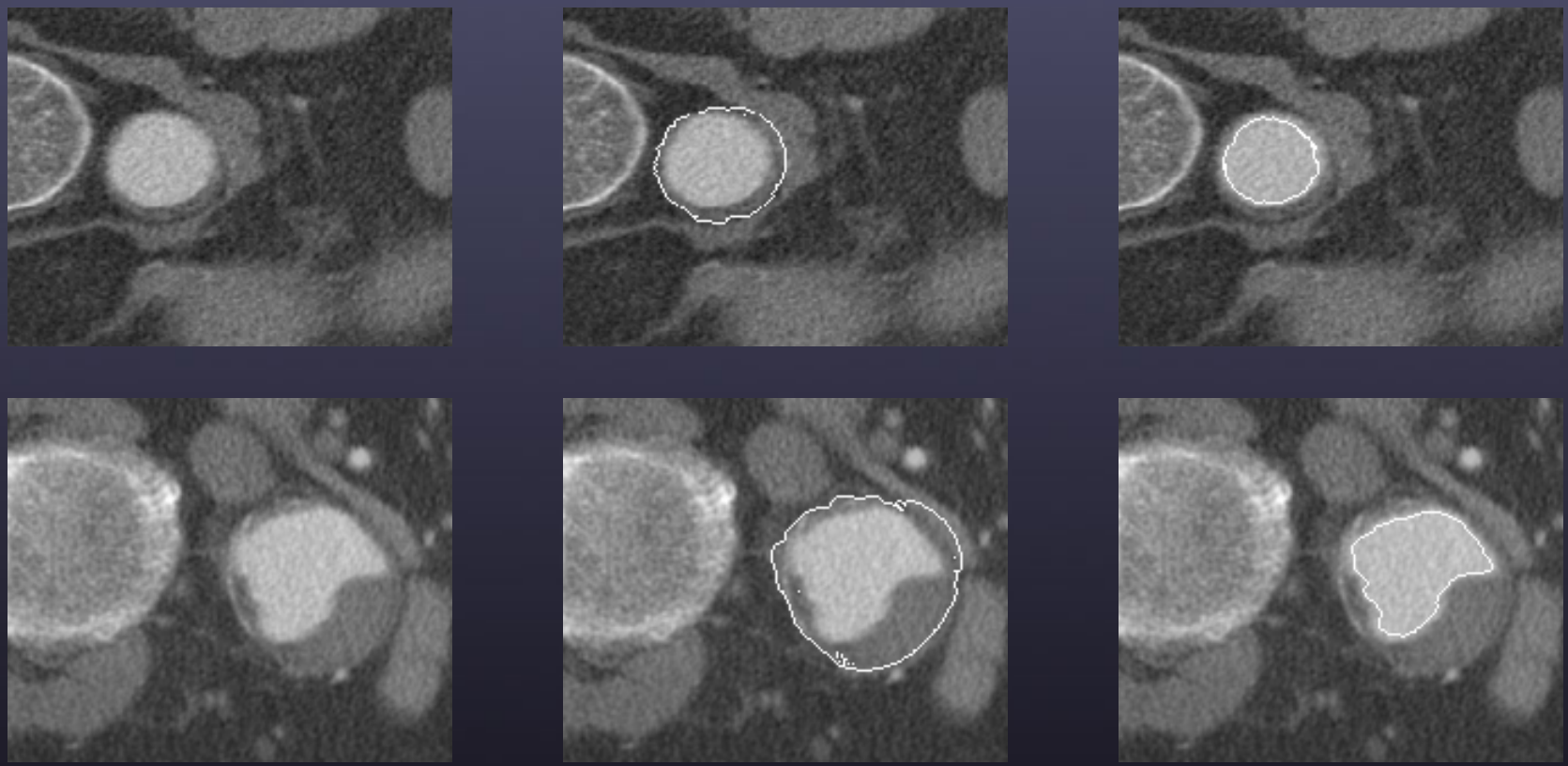


Introduction (1)

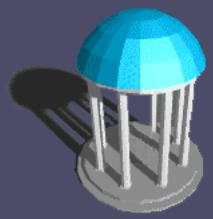
- The active contour model, or **snake**, is defined as an energy-minimizing spline.
- Active contours results from work of **Kass et.al.** in 1987.
- Active contour models may be used in image segmentation and understanding.
- The snake's energy depends on its shape and location within the image.
- Snakes can be closed or open



Introduction (2)

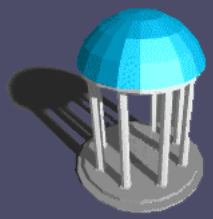


Aorta segmentation using active contours



Introduction (3)

- First an initial spline (snake) is placed on the image, and then its energy is minimized.
- Local minima of this energy correspond to desired image properties.
- Unlike most other image models, the snake is active, always minimizing its energy functional, therefore exhibiting dynamic behavior.
- Also suitable for analysis of dynamic data or 3D image data.



Kass Algorithm

- The snake is defined parametrically as v(s)=[x(s),y(s)], where s∈[0,1] is the normalized arc length along the contour.

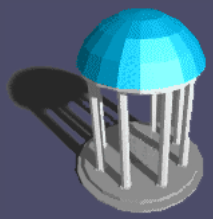
  The energy functional to be minimized may be written as

$$E^*_{snake} = \int_0^1 E_{snake}(v(s))\,ds$$

$$= \int_0^1 E_{\text{int}}(v(s))\,ds + \int_0^1 E_{image}(v(s))\,ds$$

$$+ \int_0^1 E_{forces}(v(s))\,ds$$

where, E_{int} = internal energy of the spline due to bending. E_{image} = image forces and E_{forces} = external constraint forces.



Internal Energy

- The internal spline energy can be written as

$$E_{\text{int}} = \alpha(s)\left|\frac{dv}{ds}\right|^2 + \beta(s)\left|\frac{d^2v}{d^2s}\right|^2$$

where $\alpha(s)$, $\beta(s)$ specify the elasticity and stiffness of the snake.

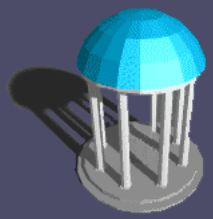


Image forces

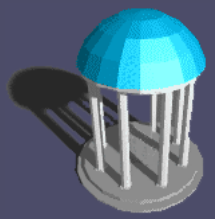
- The image forces E_{image} are derived from the image data over which the snake lies.
- Three important features the snake can be attracted to are line, edge and termination functions. The total image energy can be expressed as a weighted combination of the three.

$$E_{image} = \omega_{line} E_{line} + \omega_{edge} E_{edge} + \omega_{term} E_{term}$$

- The simplest useful image functional is the image intensity

$$E_{line} = I(x, y)$$

- Depending on ω_{line} the snake is attracted to dark or light lines.



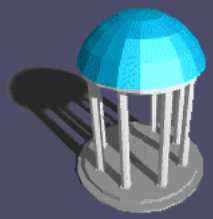
Edge based and Termination Functional

- The edge-based functional

$$E_{edge} = -\left|\Delta I(x,y)\right|^2$$

attracts the snake to contours with large image gradients, that is, to locations of strong edges.

The termination functional can be obtained by a function checking the curvature of level lines in a slightly smoothed image.



Minimization

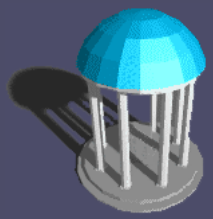
- A contour is defined to lie in the position in which the snake reaches a local energy minimum. The functional to be minimized is

$$E^*_{snake} = \int E_{snake}(v(s))ds$$

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

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

- Solution is rather complex. Several methods exist, e.g. dynamic programming, neural nets.
- Problems with numerical instability.

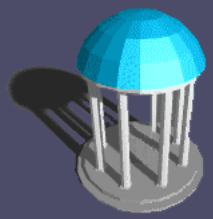


Applications

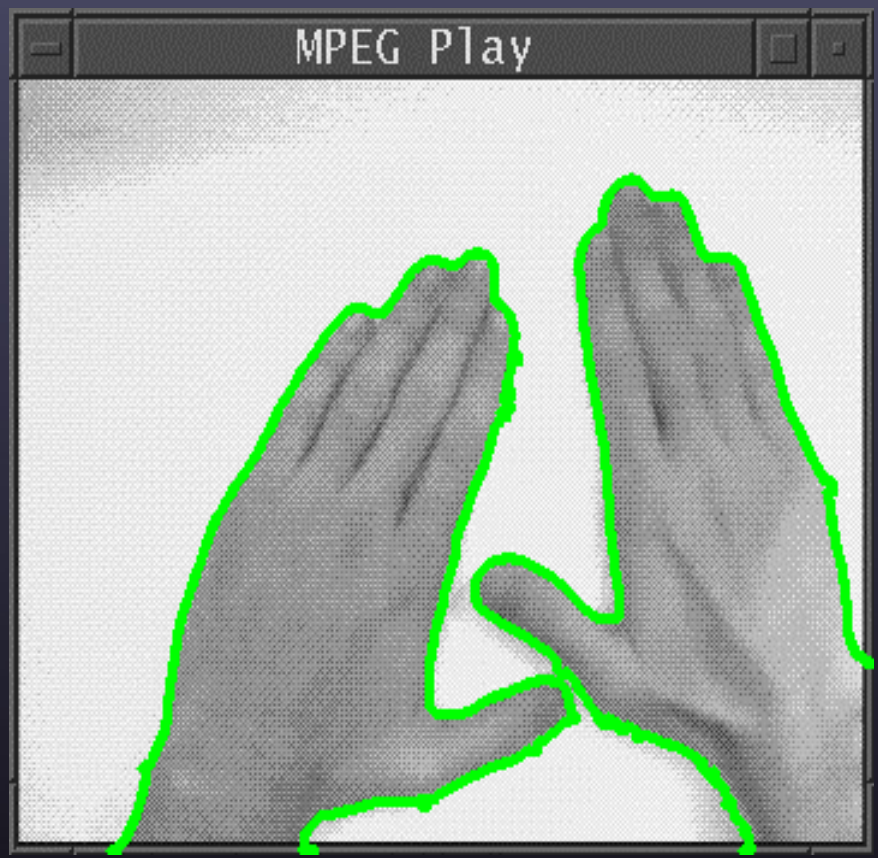
http://www.markschulze.net/snakes/

Main Applications are:

- Segmentation
- Tracking
- Registration



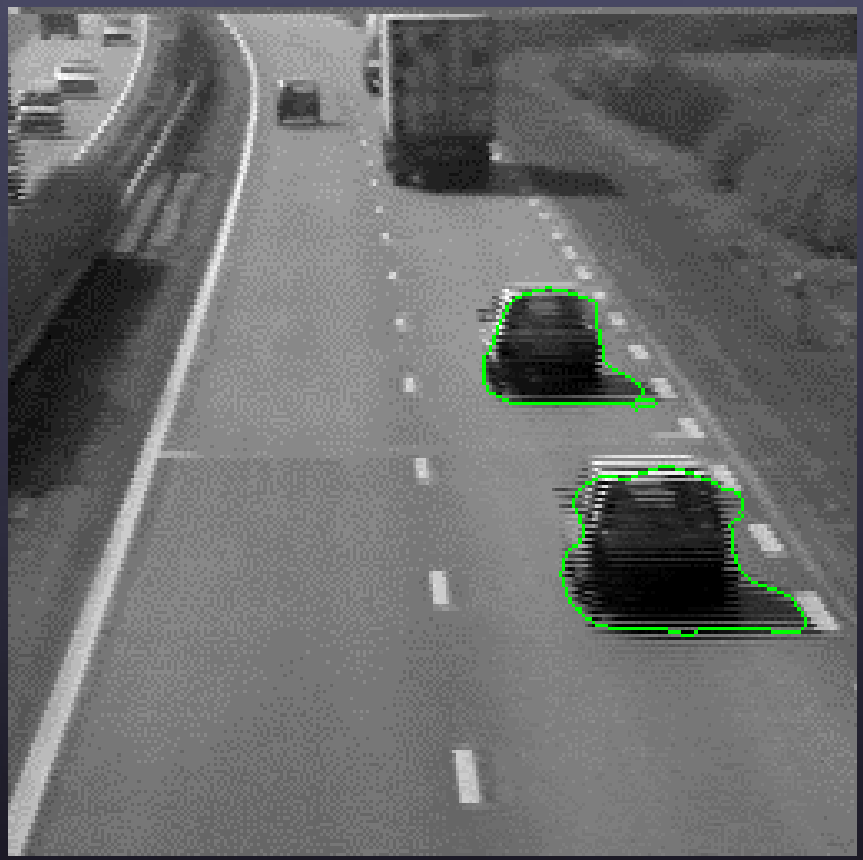
Examples (1)



Hands

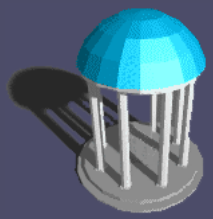
People

Examples (2)

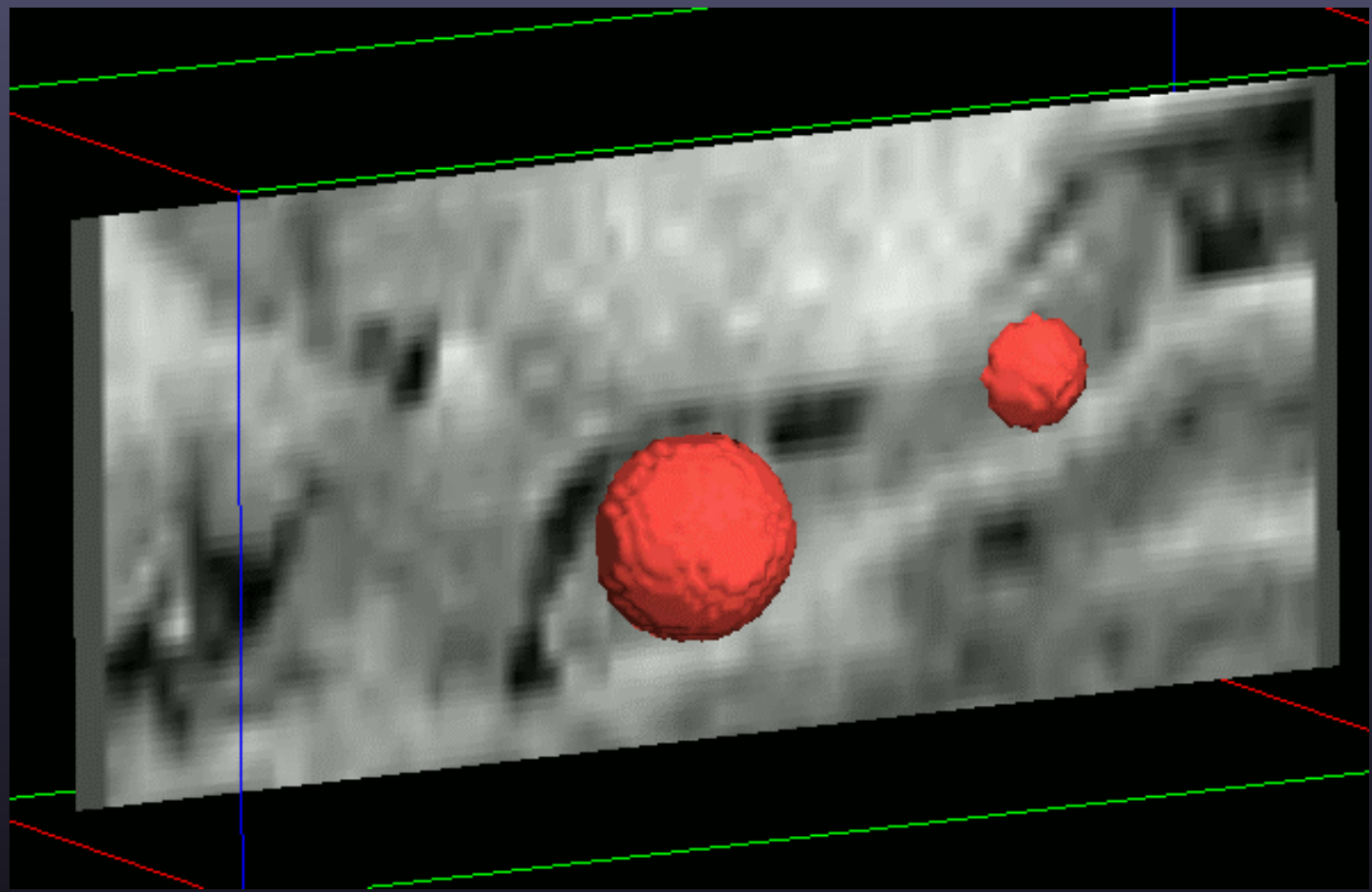


Highway

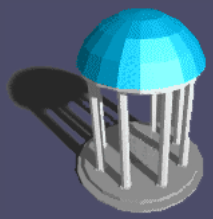
Heart



Examples (3)



3D Segmentation of the Hippocampus



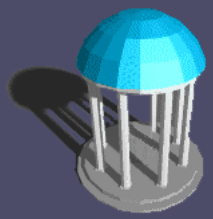
Problems with snakes

- Snakes sometimes degenerate in shape by shrinking and flattening.
- Stability and convergence of the contour deformation process may be unpredictable.

  Solution: Add some constraints: External forces or Physical properties

- Initialization is not straightforward.

  Solution: Manual and Statistics



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- *Yongjik Kim*. **A summary of Implicit Snake Formulation**.
- *Jorgen Ahlberg*. **Active Contours in Three Dimensions**.
- *M. Bertalmio, G. Sapiro and G. Randall*. **Morphing Active Contours**. IEEE PAMI, Vol 22, No 7, July 2000