Active Contour Model: Snake

Graduate Student Seminar Day

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History

- Kass *et al.* [10] proposed in 1987 an active contour model named *snake* which uses global energy minimization guided by external constraint forces and influenced by image forces that pull it toward features, such as lines and edges.

Energy Function

- A active contour is defined by
- $v(s) = [x(s), y(s)]$ where $s \in [0,1]$
- Energy function is defined as

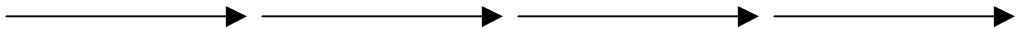
$$E[v(s)] = \int_0^1 \alpha \times E_{cont}(s) + \beta \times E_{curv}(s) + \gamma \times E_{image}(s)\, ds$$

$$E(s) = \sum_i \alpha \times E_{cont}(s_i) + \beta \times E_{curv}(s_i) + \gamma \times E_{image}(s_i)$$

The First Energy Term

- The first energy term represents the first-order continuity:

$$\frac{\left|\overline{d} - \left|v_i - v_{i-1}\right|\right|}{\max_j \left\{\left|\overline{d} - \left|v_{i,j} - v_{i-1}\right|\right|\right\}} \qquad \overline{d} = \frac{\sum_{i=1}^{n} \left|v_i - v_{i-1}\right|}{n}$$

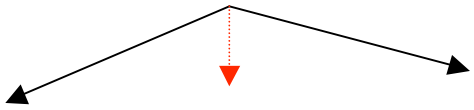


The Second Energy Term

- The second energy term represents the second-order continuity:

$$\frac{\left|v_{i-1} - 2v_i + v_{i+1}\right|}{\max_j \left\{\left|v_{i-1} - 2v_{i,j} + v_{i+1}\right|\right\}}$$

$$v_{i-1} - 2v_i + v_{i+1} = (v_{i-1} - v_i) + (v_{i+1} - v_i)$$



The Third Energy Term

- The third energy term represents the gradient magnitude of the image:

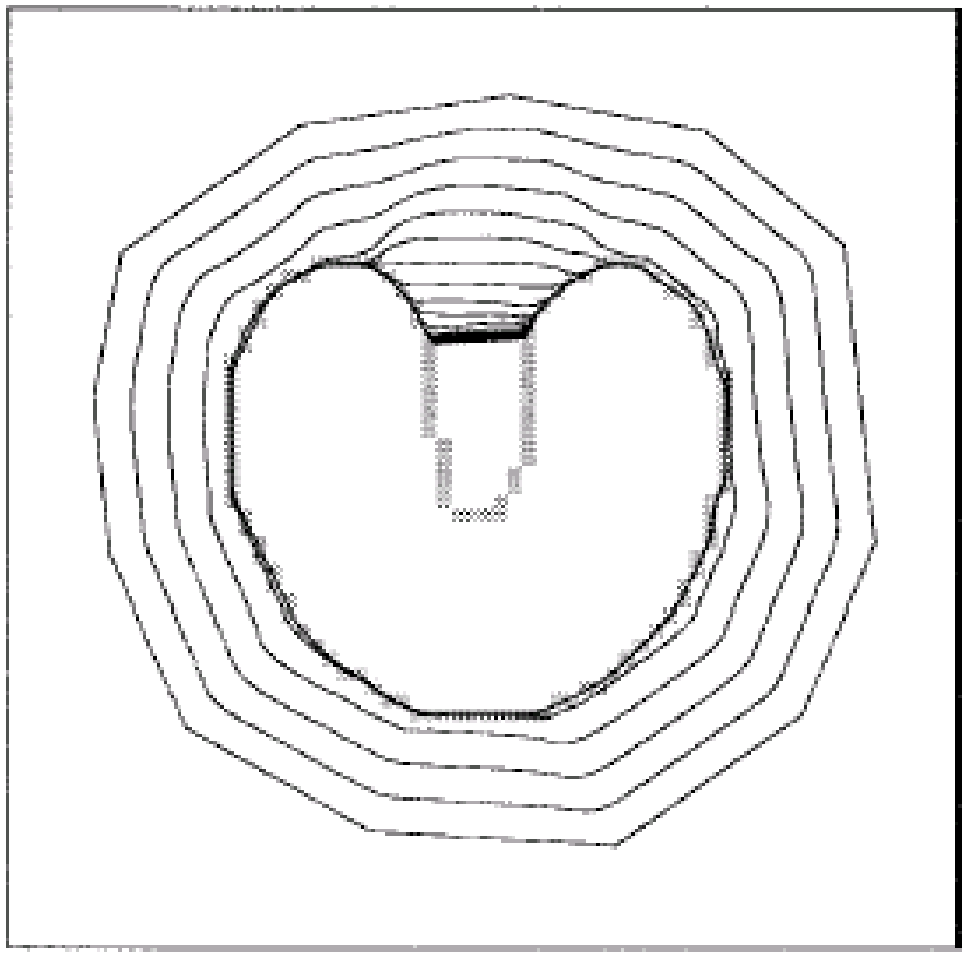
$$E_{image} = \frac{\min - mag}{\max - \min}$$

The Problems

- Problems of the original active contour model:
  - 1. Initialization
  - 2. Poor convergence to boundary concavities

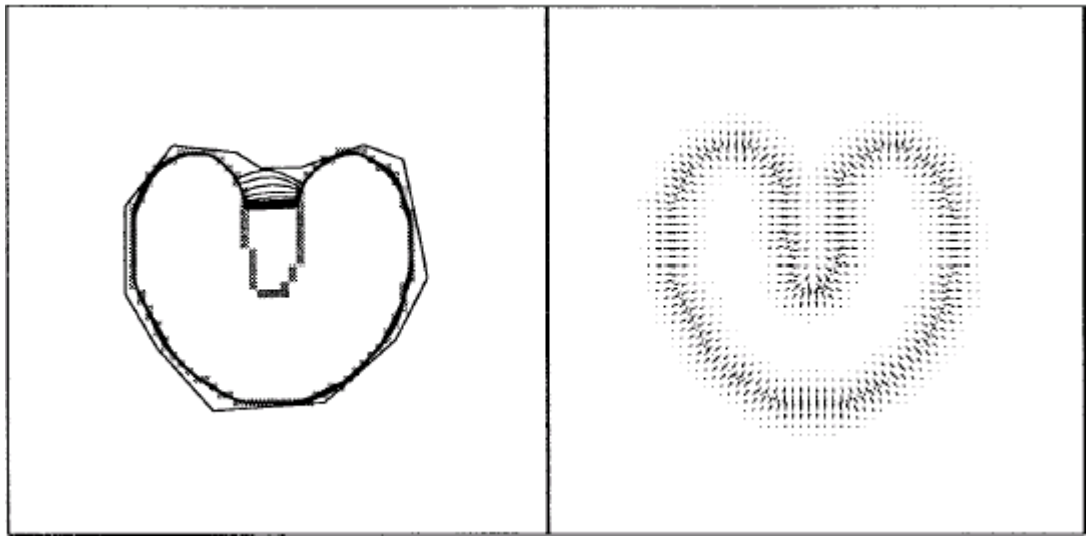
The Problems (cont.)

- Initialization

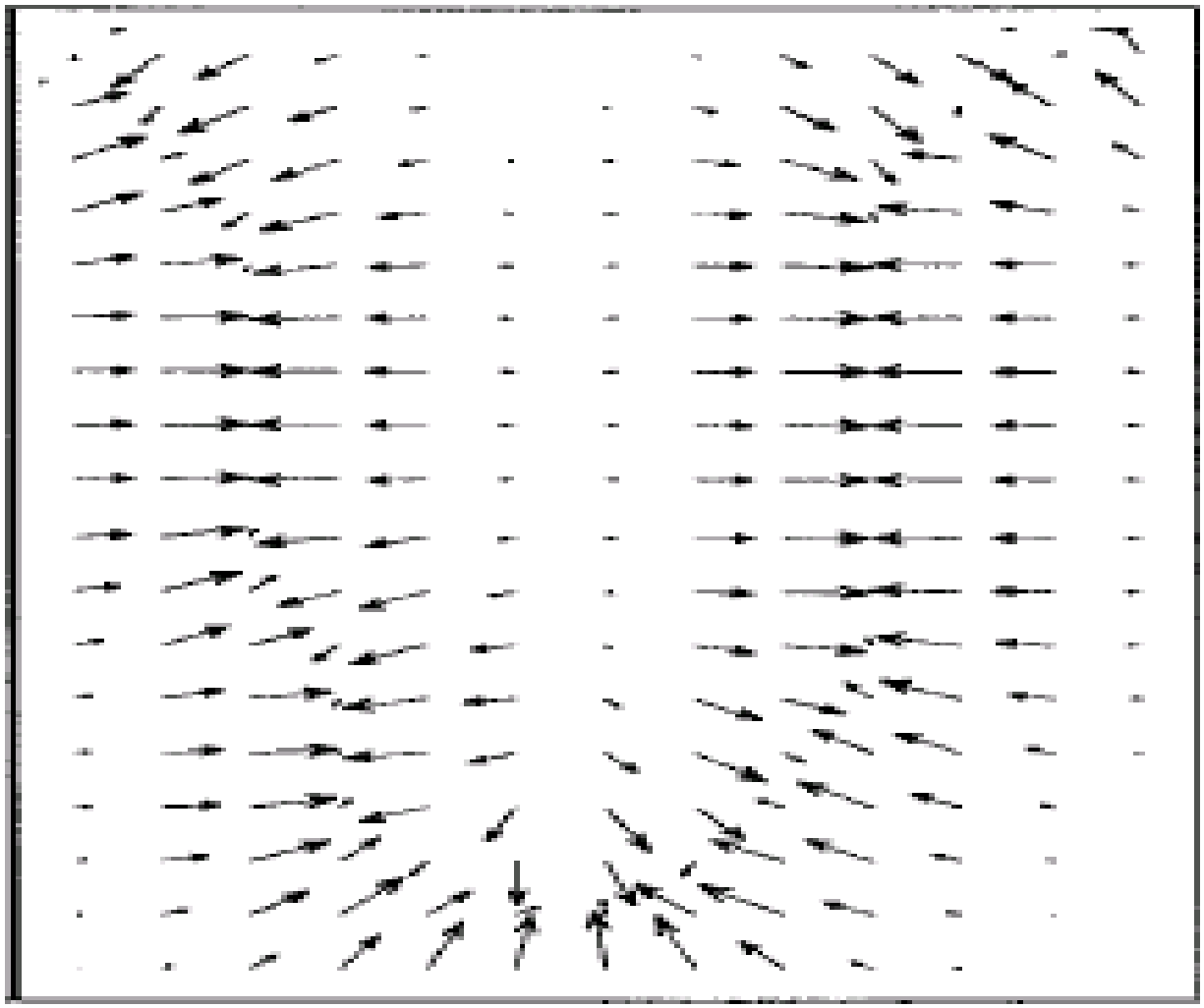


The Problems (cont.)

- Problems: boundary concavities



The Problems (cont.)

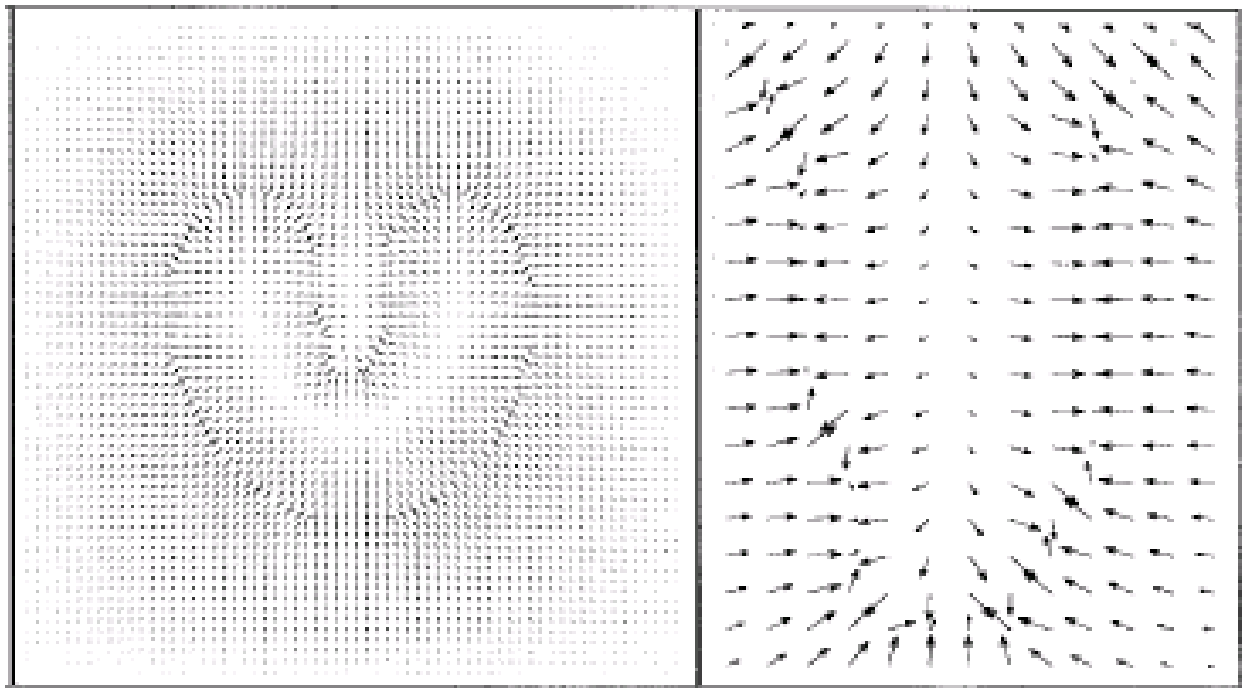


Xu and Prince' Work

- Xu and Prince [3]. They presented a snake based on the type of external force field, called *gradient vector flow*, or *GVF*. . This field is computed as a spatial diffusion of the gradient of an edge map derived from the image. This computation causes diffuse forces to exist far from the object, and pushes force vectors near the edges. The new GVF energy is defined as below:

$$E_{GVF} = \iint \mu(u_x^2 + u_y^2 + v_x^2 + v_y^2) + \left|\nabla f\right|^2 \left|V - \nabla f\right|^2 dxdy$$

Xu and Prince' Work (cont.)



(a) (b)

Greedy Algorithm

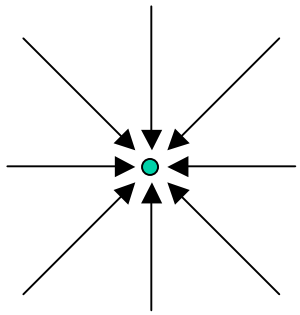
- The greedy algorithm presented by Williams and Shah [6] for active contour. The basic procedure is described below. After a user initializes an active contour by defining several snake points, the algorithm enters a loop. In this loop, each point on the contour is temporarily moved to one of its neighbors. Note that the user can define different sizes of neighborhood. At each neighbor, the energy is calculated and the one with the least energy is chosen as the new location for this point on the contour. One iteration will evaluate all the snake points and enter the next loop until the snake is stabilized or the pre-defined iterations have been reached.

Greedy Algorithm

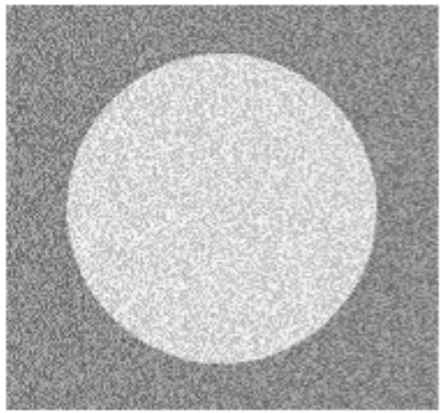
- *while n < iterations*
- *for j = 1 to numPoints* */* Check every snake point. */*
- *for k = 1 to numNeighbors*
- $E_{snake} = \alpha * E_{cont}[v_k(s)] + \beta * E_{curv}[v_k(s)] + \gamma * E_{image}[v_k(s)]$ *;*
- *end;*
- *Move this point to the new location that has the least energy;*
- *end;* */* main loop*/*
- */* Adjust the number of points along the contour. */*
- *end;* */* iteration loop*/*

Using Gravitation as a New External Force Field

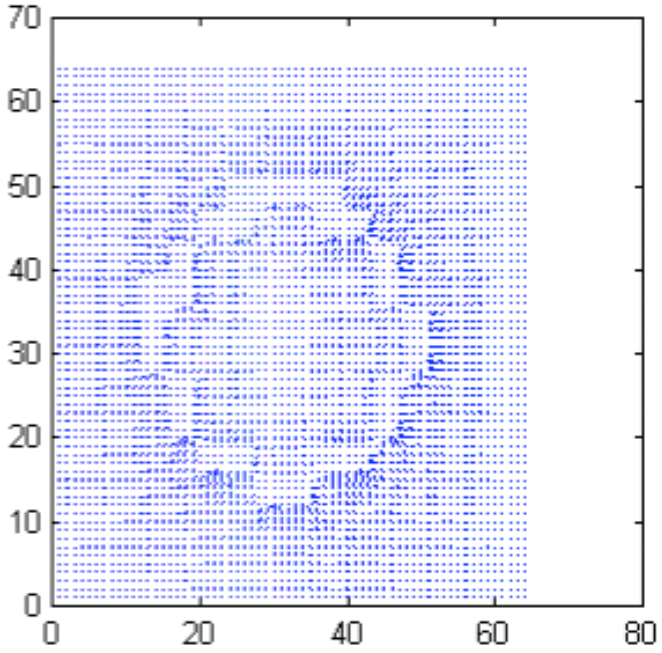
$$E_{gravtation} = \int_{\Omega} \frac{g(\vec{r})}{r} \hat{r} d\vec{r}$$



Gravitation Force Field

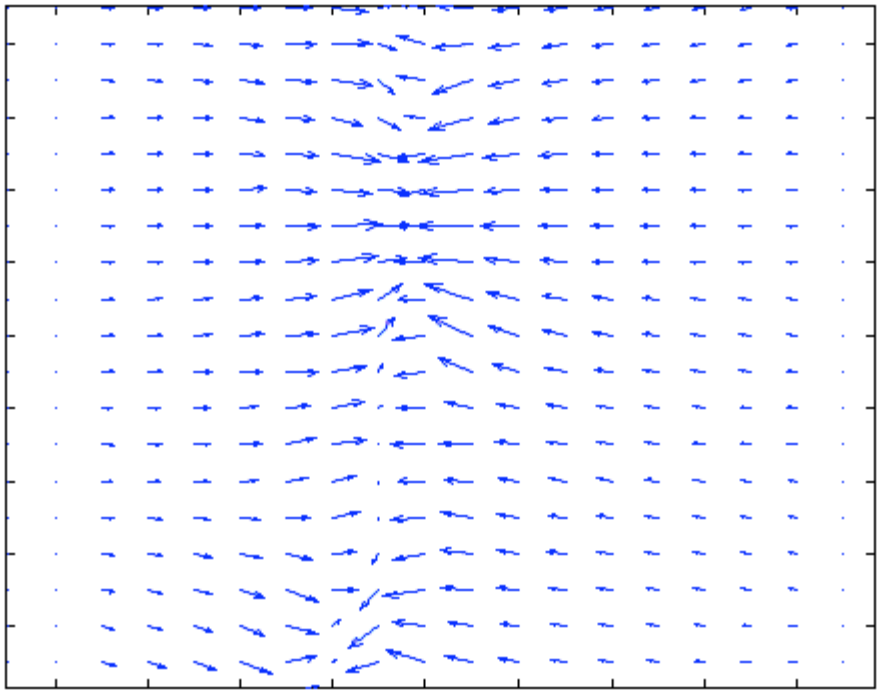


(a)

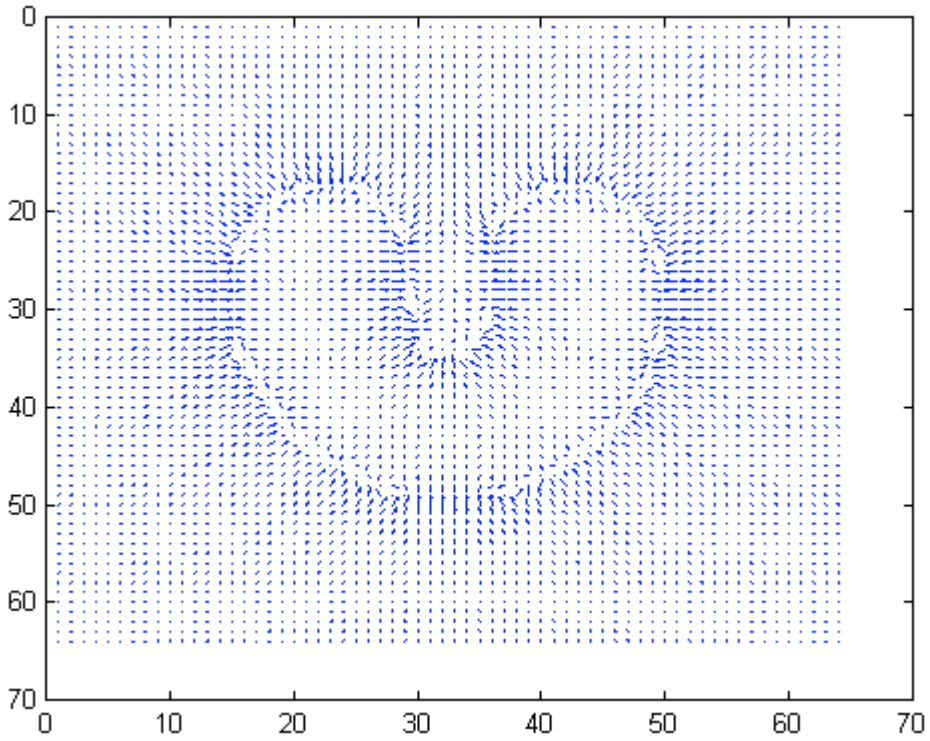


(b)

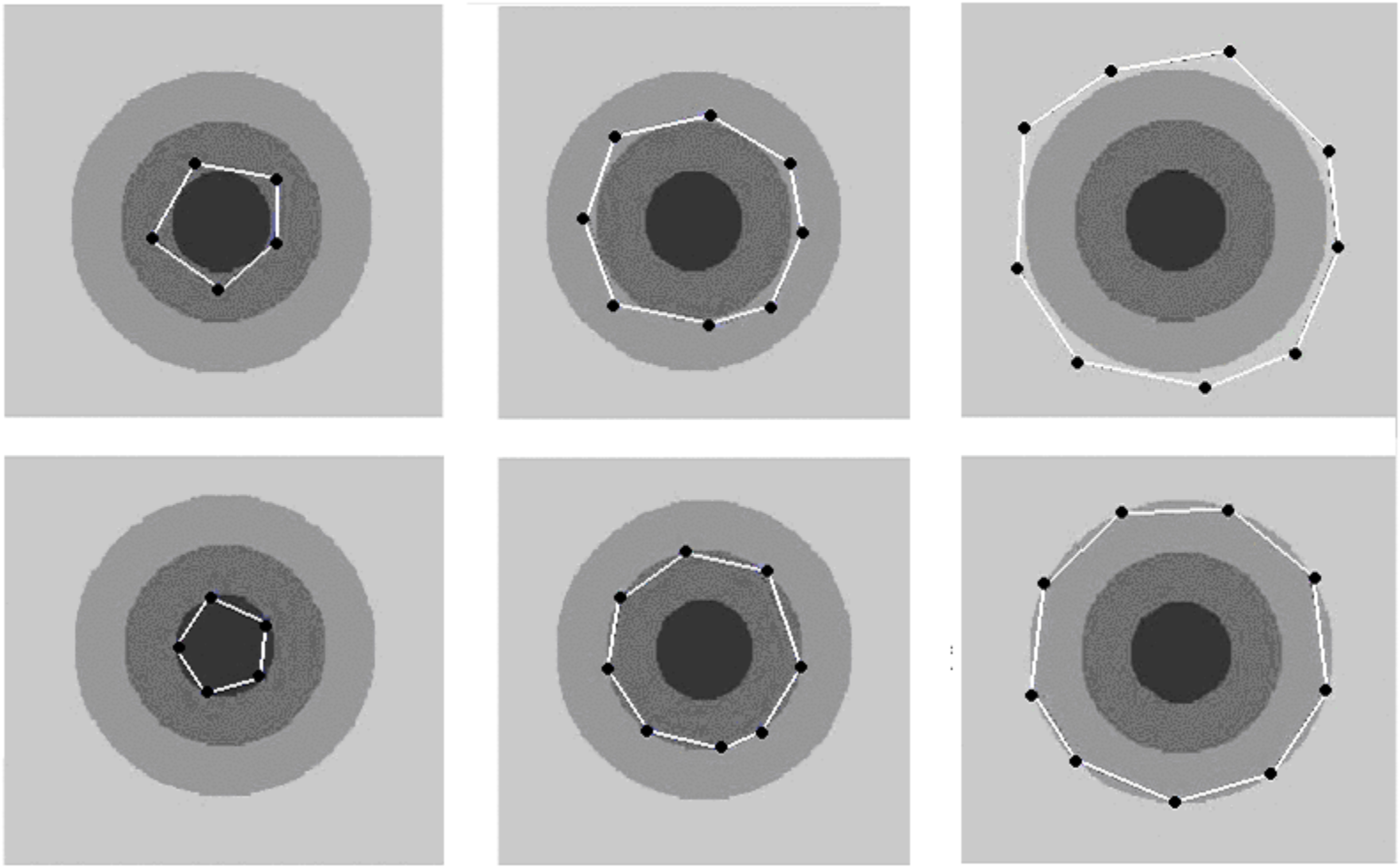
Gravitation Force Field (Cont.)



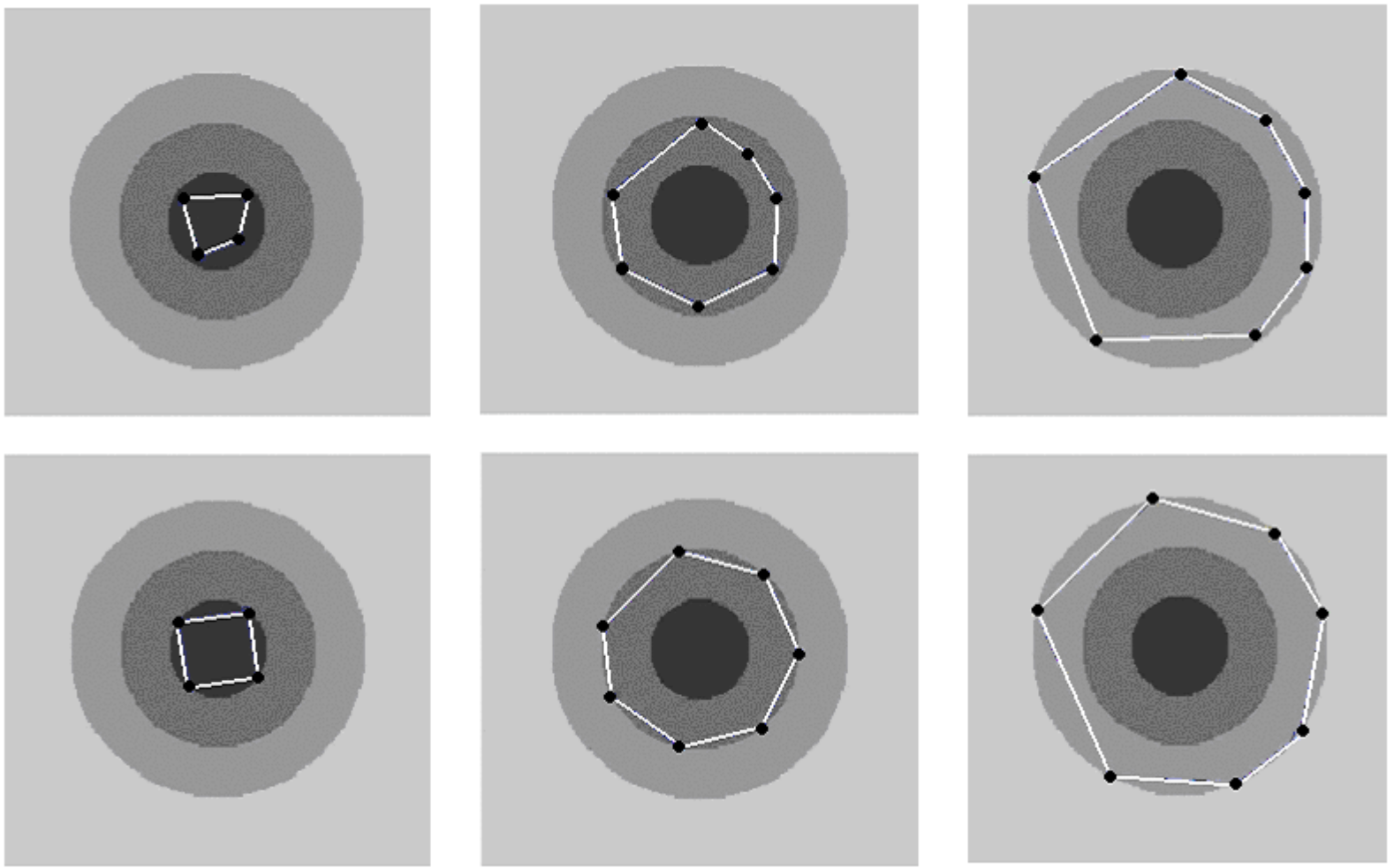
Gravitation Force Field (Cont.)



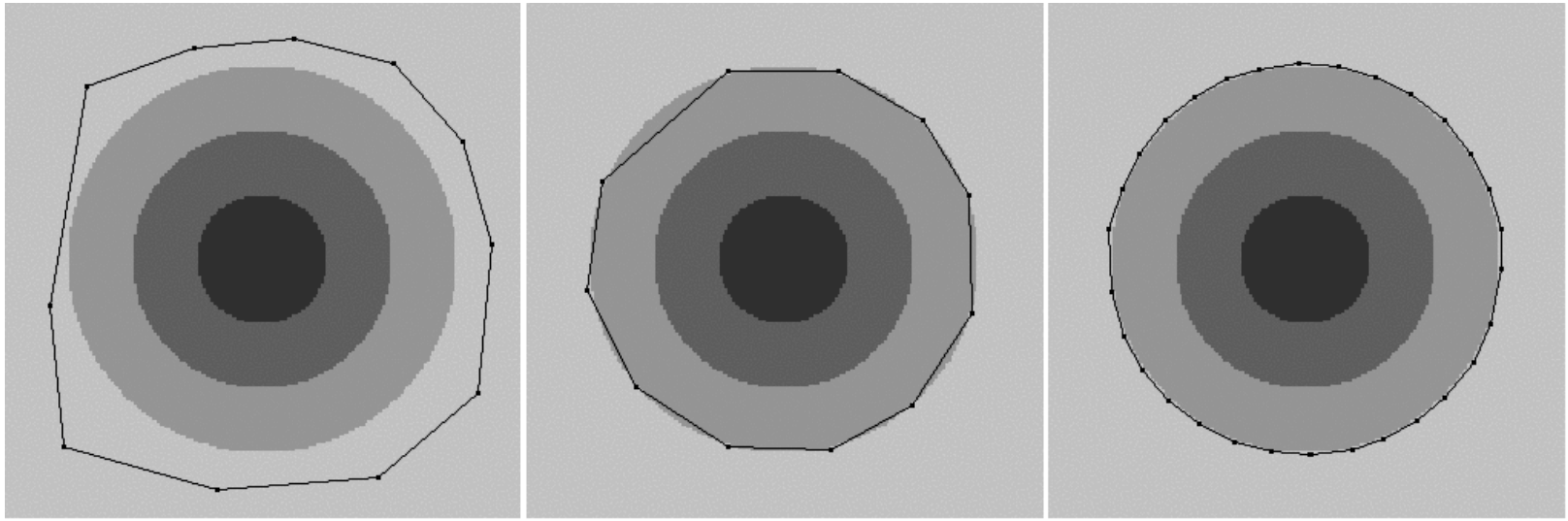
Experiment Results



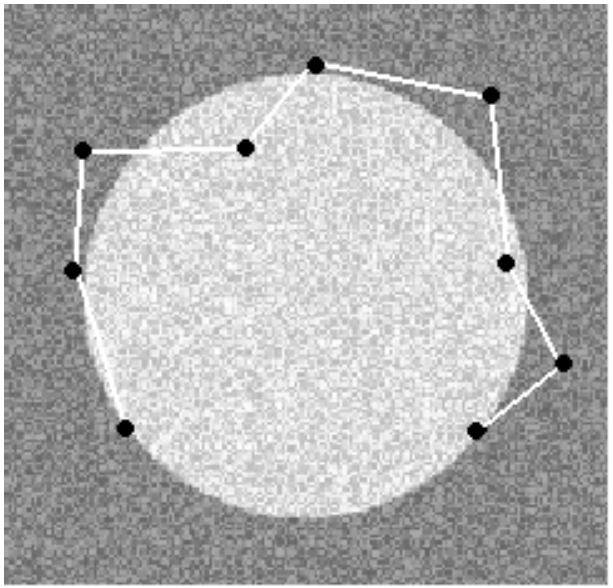
Experiment Results



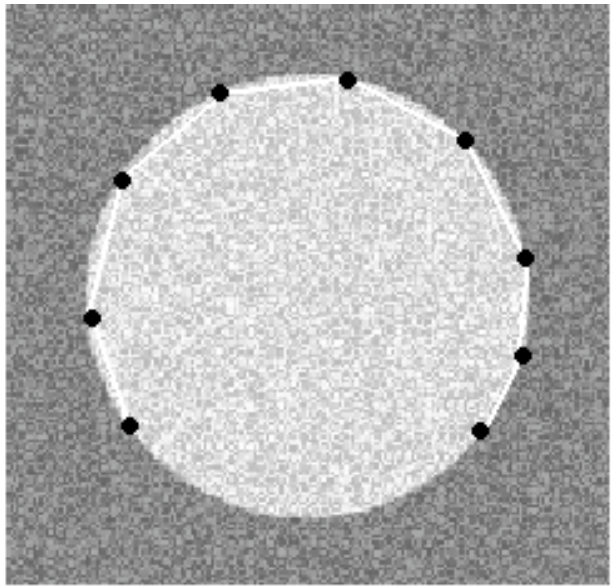
Applying Point Interpolation



Fixed-End Snake

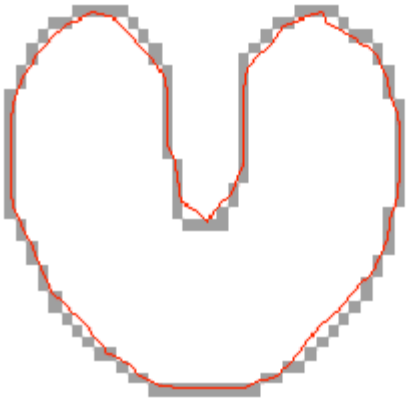


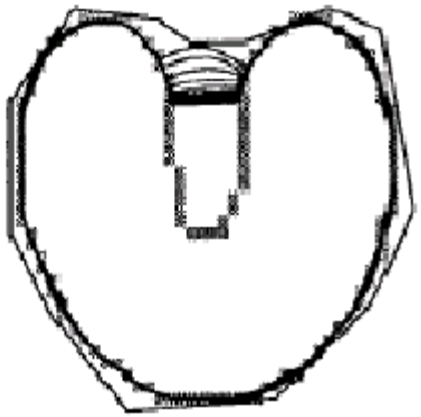
(a)



(b)

Applying to the Concavity





References

- [1] M. Kass, A. Witkin and D. Terzopoulos, “Snake: active contour model,” *International Journal of Computer Vision*, vol. 1, pp. 321-331, 1987.
- [2] D. J. Williams and M. Shah, “A fast algorithm for active contours and curvature estimation,” *CVGIP: Image Understanding*, vol. 55, no. 1, pp. 14-26, 1992.
- [3] C. Y. Xu and J. L. Prince, “Snakes, shapes, and gradient vector flow,” *IEEE Transactions on Image Processing*, vol. 7, no. 3, pp. 359-369, 1998.

[4] L. D. Cohen, “On active Contour Models and Balloons,” *CVGIP; Image Understanding*, vol. 53, pp. 211-218, 1991.