Snakes

Active contours models for boundary detection

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Introduction

General points

- Developed by Kass et al. in 1987 [Kass 1987]
- Adjusts a contour on an object

Characteristics

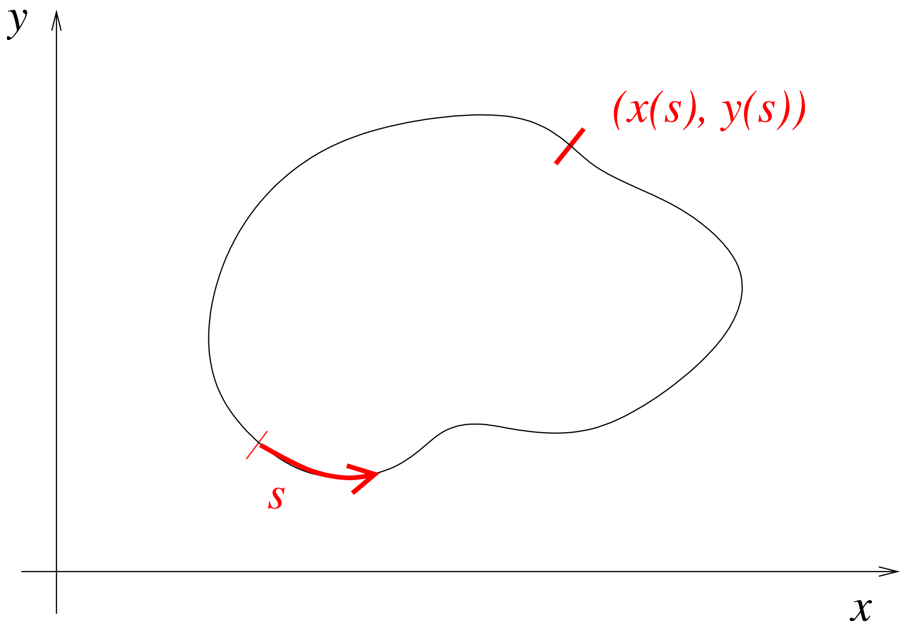
- Edge-based method
- Refine the results of an initial segmentation

Outline

- Definition
- Snakes equations
- Design
- Applications

Definition

- Evolving contour
- Defined parametrically as: $v(s) = [x(s), y(s)]$, where s is the curvilinear abscissa



Definition 2/2

- Each state of the snake is associated with an *energy*

- Analogy with physics:

  $\longrightarrow$ Evolution towards stationary state of minimal energy

Procedure

1. **Initialization**
   Place the snake near the contour of interest

   - Discrete initialization $\Rightarrow$ Control points (e.g. *spline*)
   - Enough control points

2. **Evolution**
   Snake *shape* and *location* affected by *forces* iteratively

   - Internal forces
   - Image forces
   - External constraint forces

Forces applied to the snake

Internal contour forces

Make the snake tend to be more *continuous* and *smooth*

Image forces

Draws the contour towards the closest image edges.

External forces

Force the snake in some *a priori* known direction or shape.

Snake equations

- Continuous case:

Minimize

$$E_S = \int_0^1 E_{Internal}(v(s))\,ds + \int_0^1 E_{Image}(v(s))\,ds + \int_0^1 E_{External}(v(s))\,ds \quad (1)$$

- Discrete case:

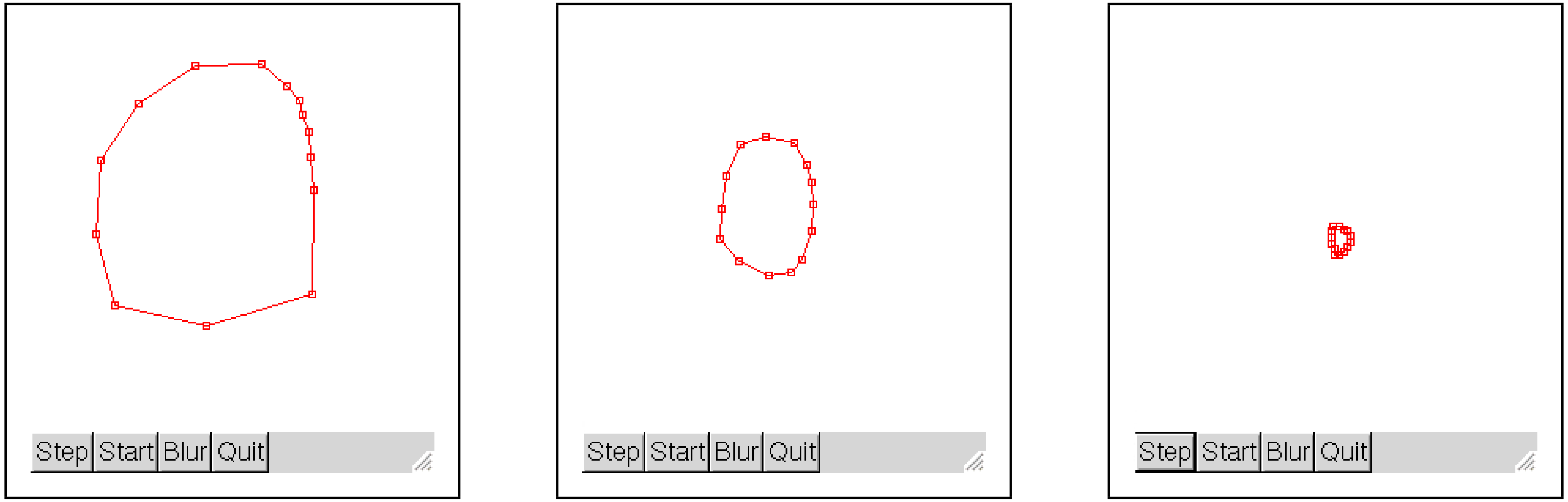
Minimize

$$E_S = \sum_{n=1}^{N} E_{Internal}(v_n) + \sum_{n=1}^{N} E_{Image}(v_n) + \sum_{n=1}^{N} E_{External}(v_n) \quad (2)$$

Internal energy

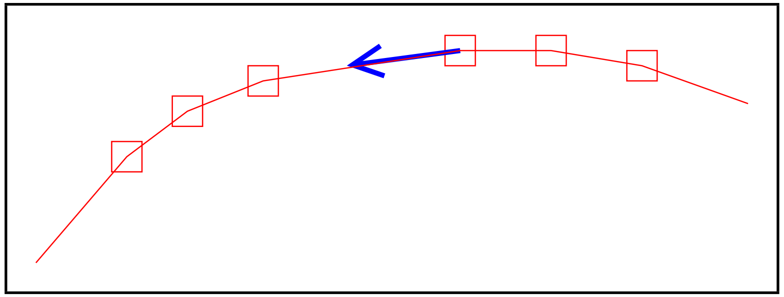
- The snake should be *continuous* and *smooth*

⇒ Tends to become circular

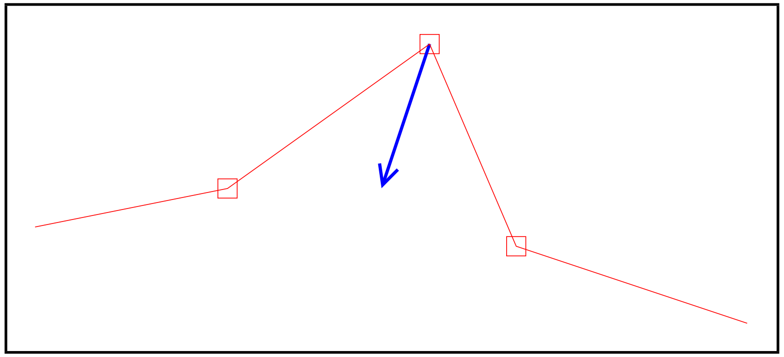


Continuous and smooth

- Internal energy is composed of two energies:
  - Continuity energy



  - Curvature energy



Internal :: The Continuity term

- The continuity energy is expressed by the first derivative:

$$E_{Continuity} = |\frac{dv}{ds}| \quad (3)$$

- Discrete case expressed by a finite difference:

$$E_{Continuity} = |v_n - v_{n-1}| \quad (4)$$

Tries to minimize the distance between the points...
... but the contour shrinks.

Internal :: The Continuity term 2/2

- Spread the points equally along the snake:

$$E_{Continuity} = \bar{d} - |v_n - v_{n-1}| \tag{5}$$

where $\bar{d}$ is the average distance between the points of the snake

- Normalization:

$$E_{Continuity} = \frac{\bar{d} - |v_n - v_{n-1}|}{MAX\{\bar{d} - |v_n(j) - v_{n-1}|\}} \tag{6}$$

where $v_n(j)$ represents the neighbors of a point v_n

Internal :: The Curvature term (smoothness term)

- To enforce smoothness and avoid oscillations of the snake

⇒ Penalizing high contour curvatures

- The curvature energy is expressed by the second derivative:

$$E_{Curvature} = |\frac{d^2v}{ds^2}|^2 \quad (7)$$

- Discrete case:

$$E_{Curvature} = \frac{|v_{n-1} - 2v_n + v_{n+1}|^2}{MAX\{|v_{n-1} - 2v_n(j) + v_{n+1}|^2\}} \quad (8)$$

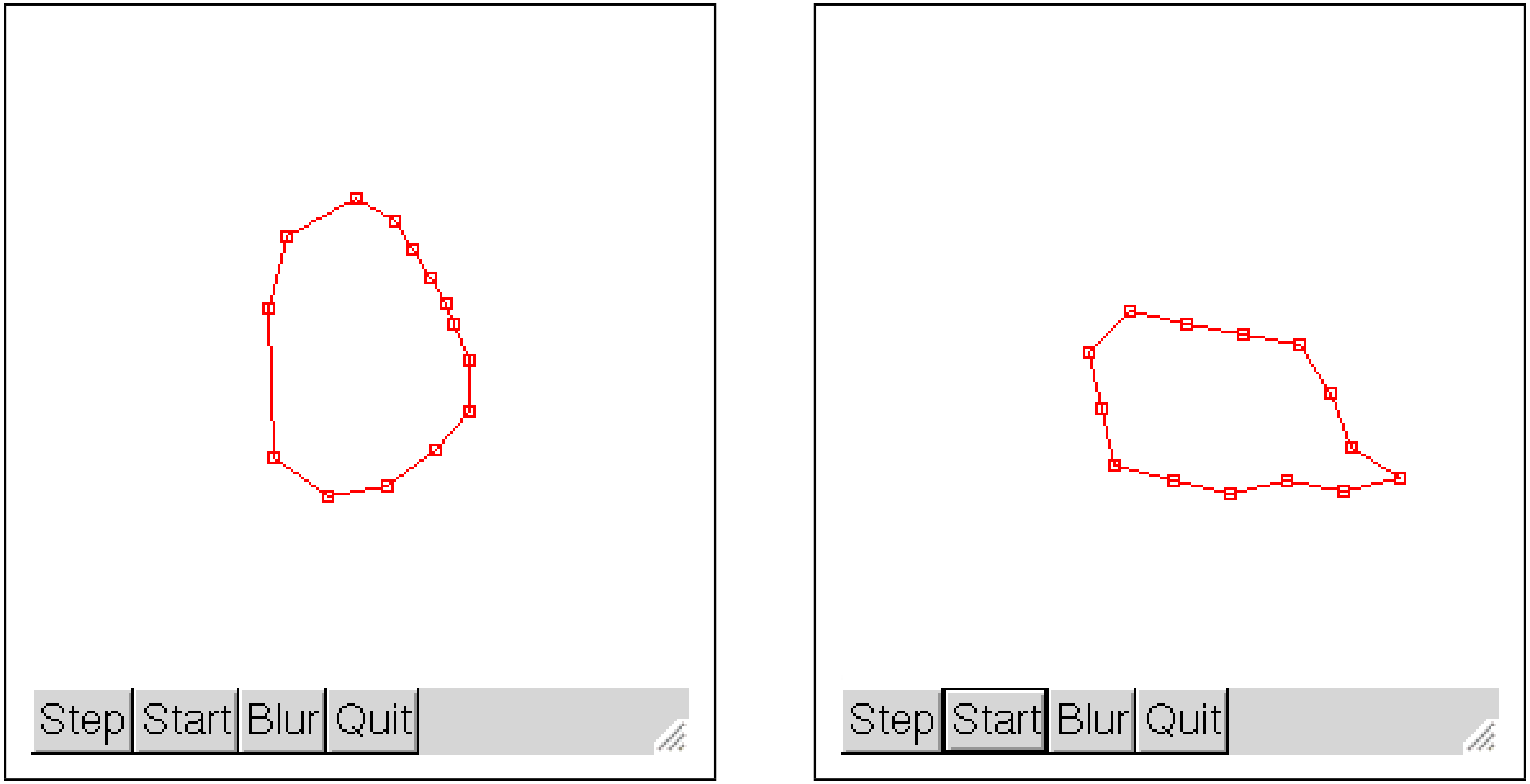
Let's play with Internal energy

$$E_{Internal} = \alpha(n)E_{Continuity}(v_n) + \beta(n)E_{Curvature}(v_n) \tag{9}$$

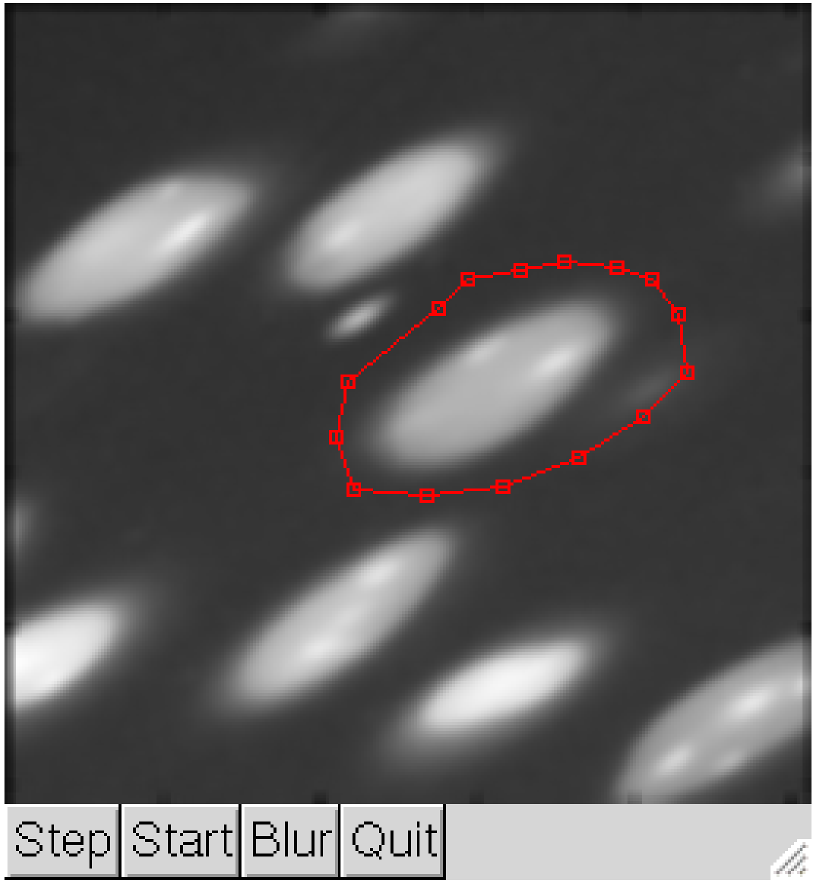
- But in general, α and β are chosen constant.

$\Rightarrow$ There are various ways to combine those energies, depending on the values of α and β

Example with $\alpha \neq 0$ and $\beta = 0$



Example with $\alpha \neq 0$ and $\beta \neq 0$



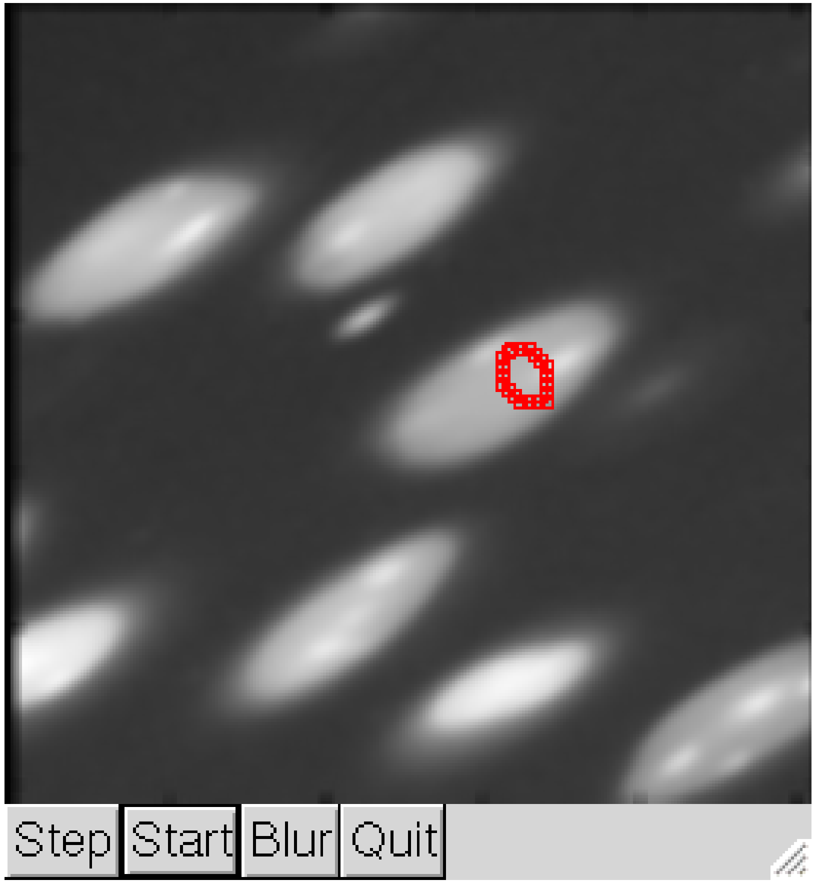
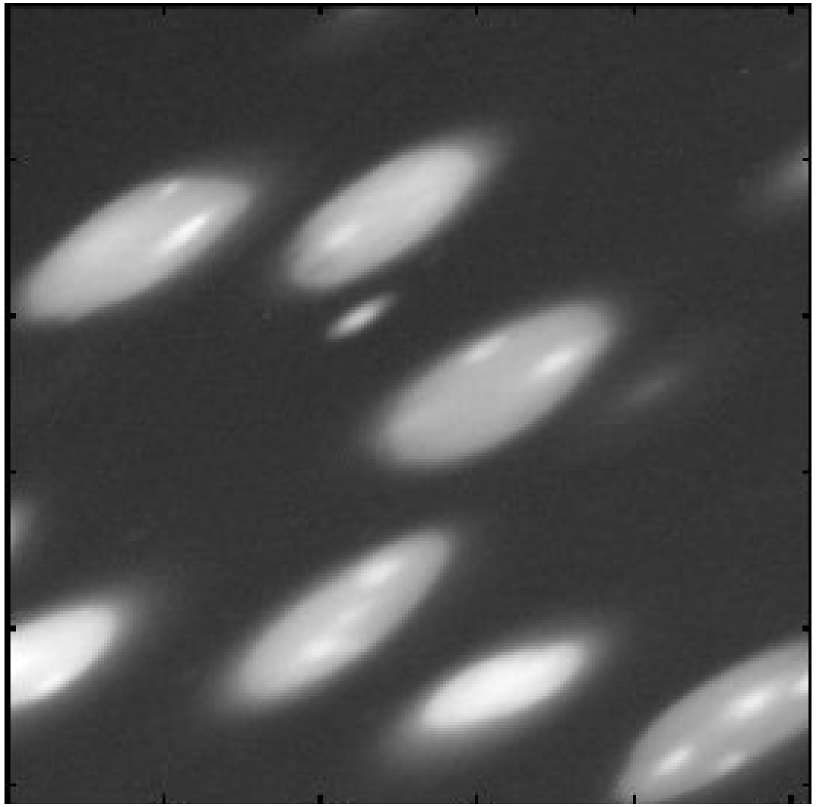


Image energy



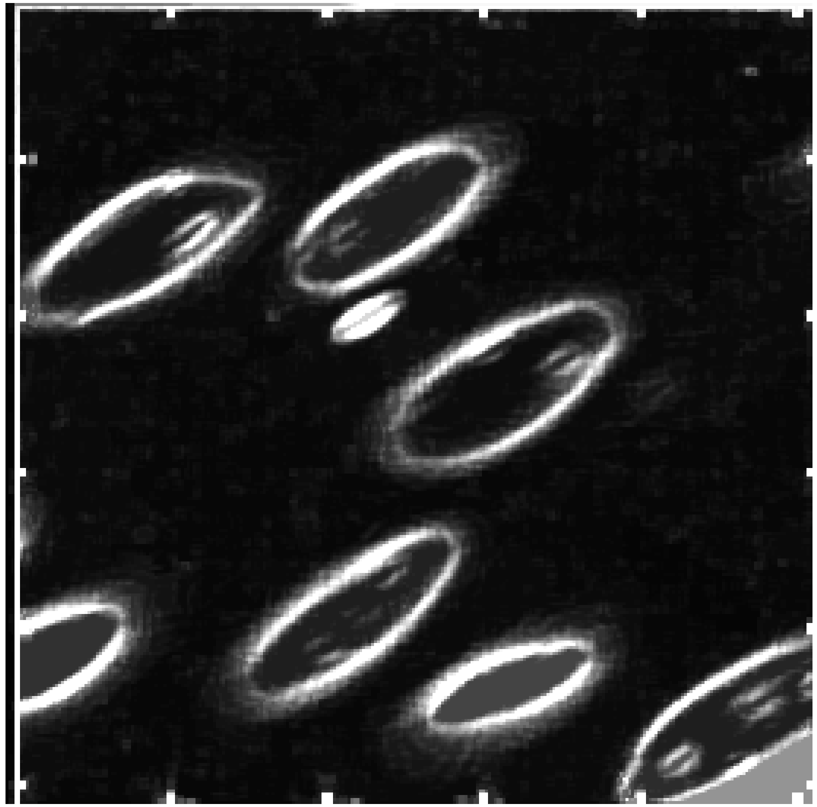


Image energy 2/2

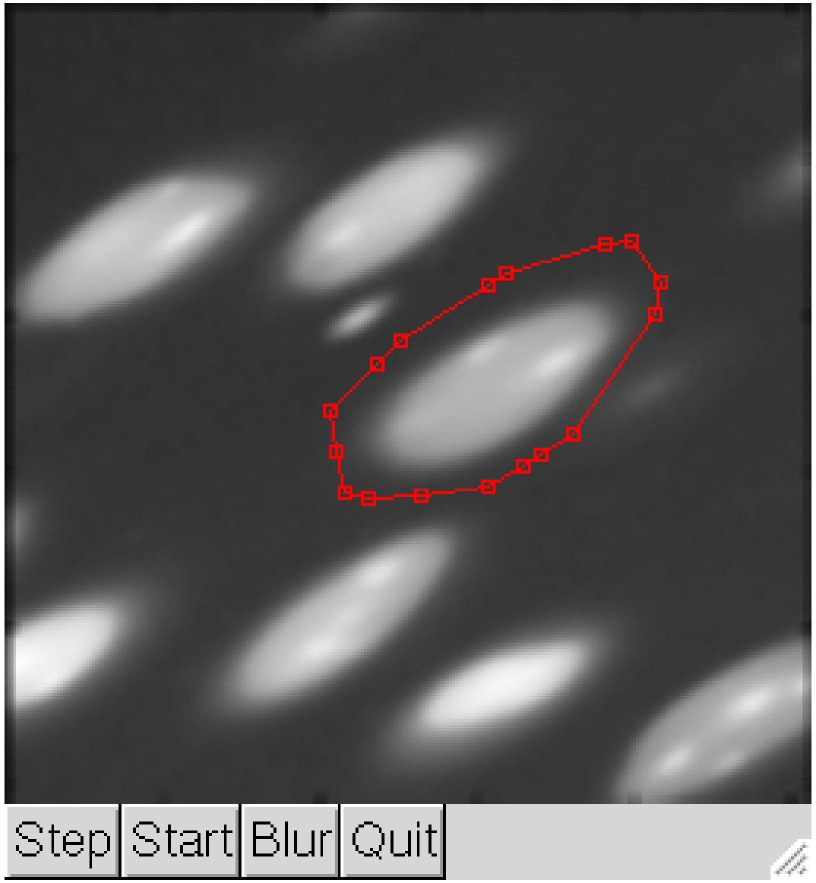
- Gradient intensity computed at each snake point

$$E_{Image} = -|\nabla I| \qquad (10)$$

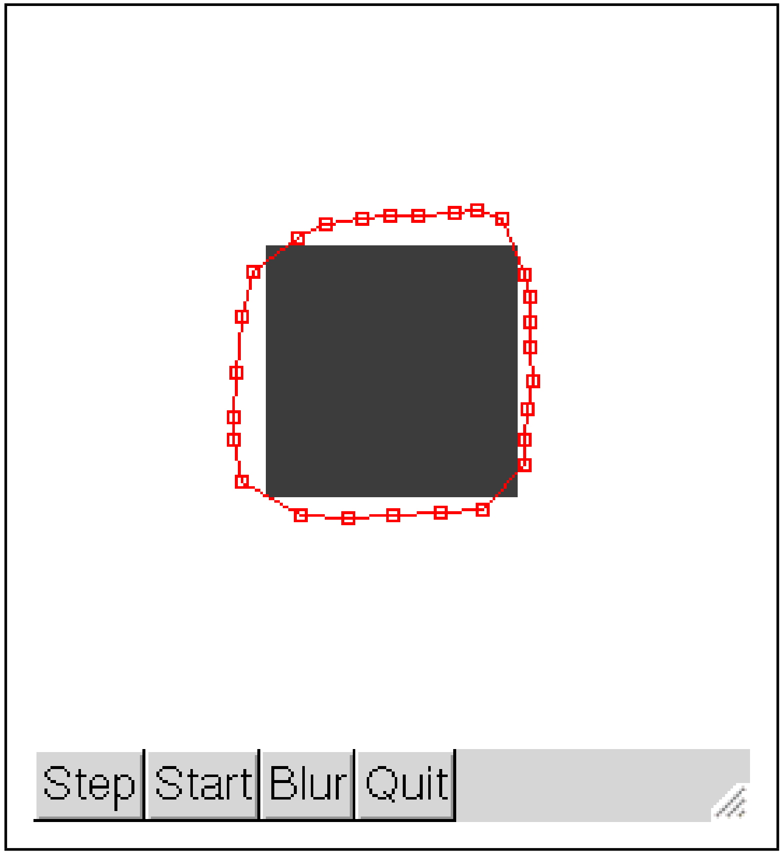
- Normalization:

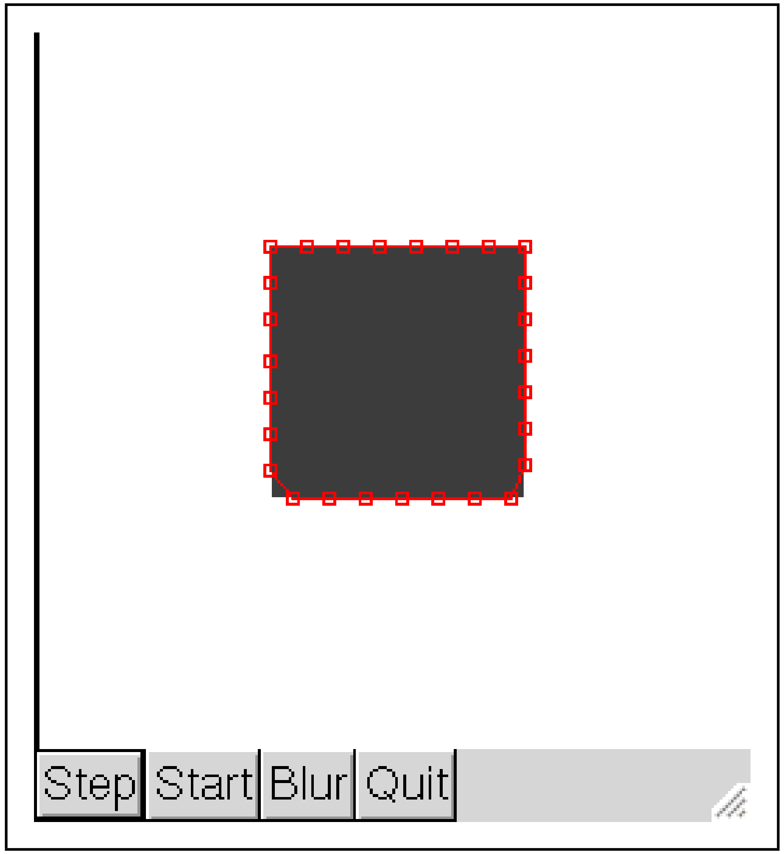
$$E_{Image} = \frac{\nabla_{min} - \nabla_j}{\nabla_{max} - \nabla_{min}} \qquad (11)$$

Example with $\alpha \simeq \beta$



Example with $\beta \ll \alpha$





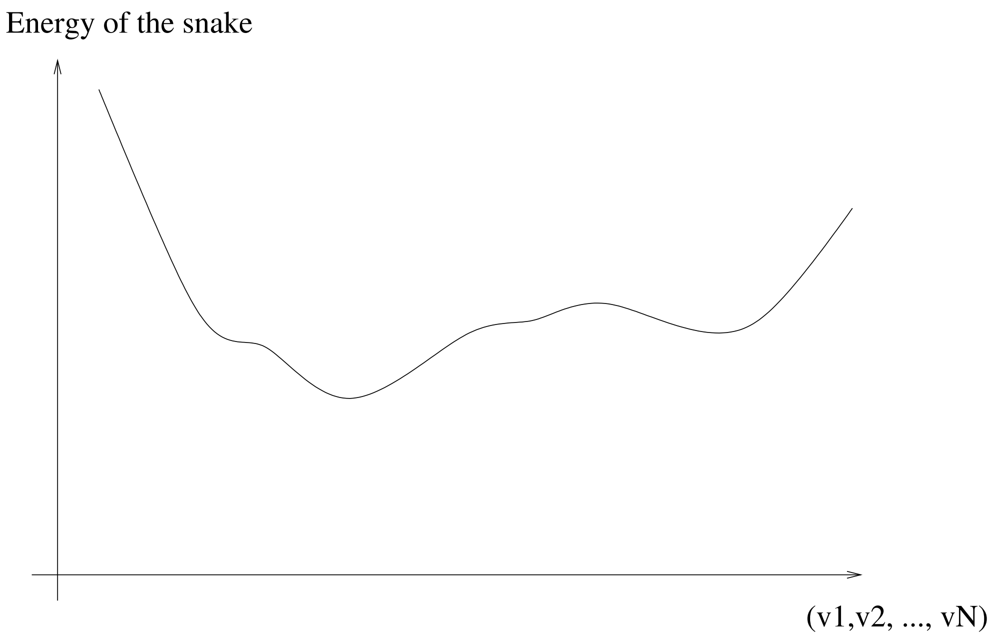
External energy

- High-level a priori information on the object:
  - Global shape of the object
  - Directional gradient
  - Should the snake blow or shrink ?

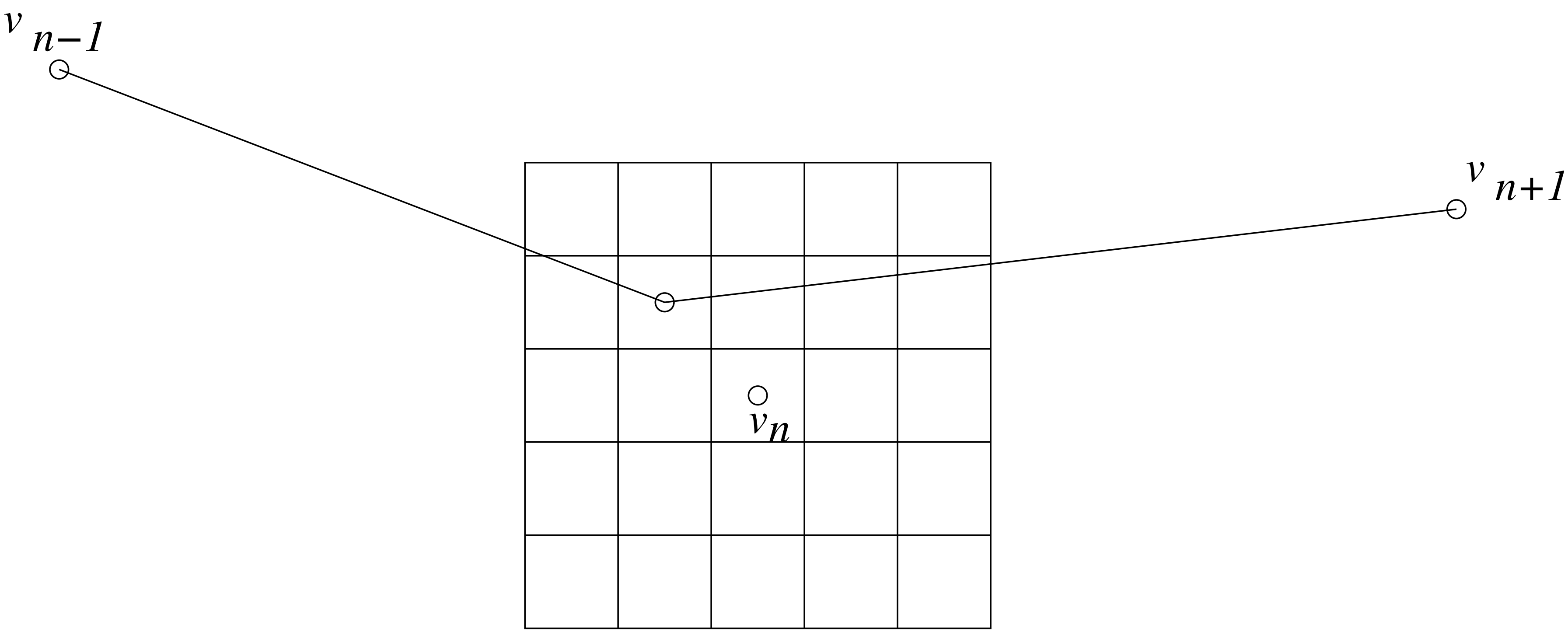
Design

- Minimization problem

⇒ Find a local or global minimum to the *snake energy*.



Greedy algorithm



Snakes applications

- Numerous biomedical applications:
  - Analysis of images of the retina
  - Automatic heart detection
  - Detection of malignant cells
  - Detection of arteries

  ...

- Automatic tracking of an object in an image sequence

...

Use case

- Snakes are noise-sensitive

  $\Rightarrow$ Need a textureless environment to evolve in
  $\Rightarrow$ The closest initialization, the better

- Inability to mold a contour to severe object concavities

- Can't be cut into two pieces

Conclusion

- Implementation in the image processing library *Olena*
- A basic GUI
- Still some (many ?) things to change to make it work better
  - Automatic initialization
  - Automatic finding of α and β coefficients
  - Avoid the creation of unwanted contour loops [Ji 1999]
- Include snakes in AdHoc project ?

References

- Seminar Report:
  http://www.lrde.epita.fr/cgi-bin/twiki/view/Publications/20030514-Seminar-Wang-Report

- Articles

[Kass 1987] M. Kass, A. Witkin, and D, Terzopoulos. “Snakes: Active Contour Models”. IEEE First International Conference on Computer Vision, 1987.

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– J.-P. Cocquerez and S. Philipp, et al. “Analyse d’images : filtrage et segmentation”. Masson, 1995.
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