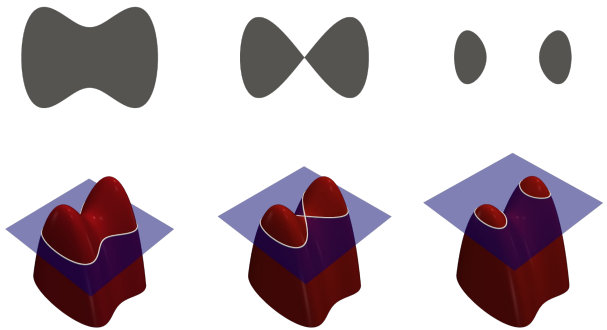
BM 4302 Medical Image Processing

Active Contours and Level Set Segmentation



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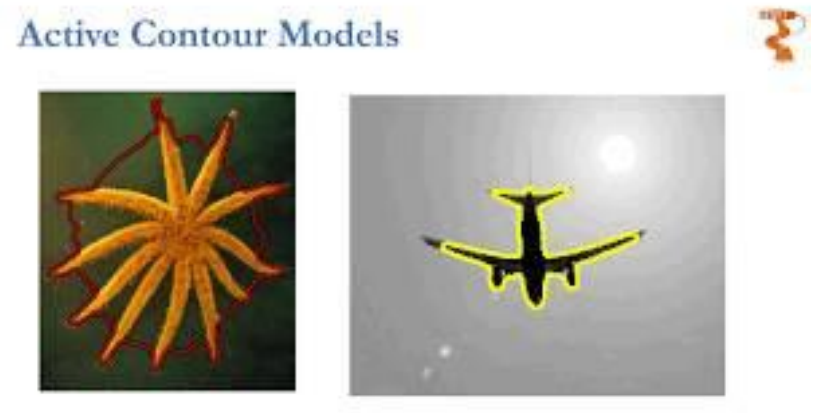
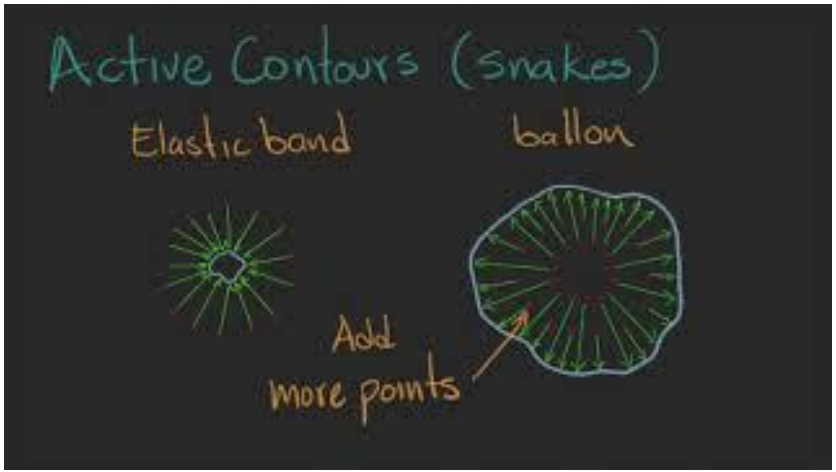
Snakes / Active Contour Models

Snakes

- An Energy Minimizing Spline.
- The Snake's energy depends on its shape and location with the image.



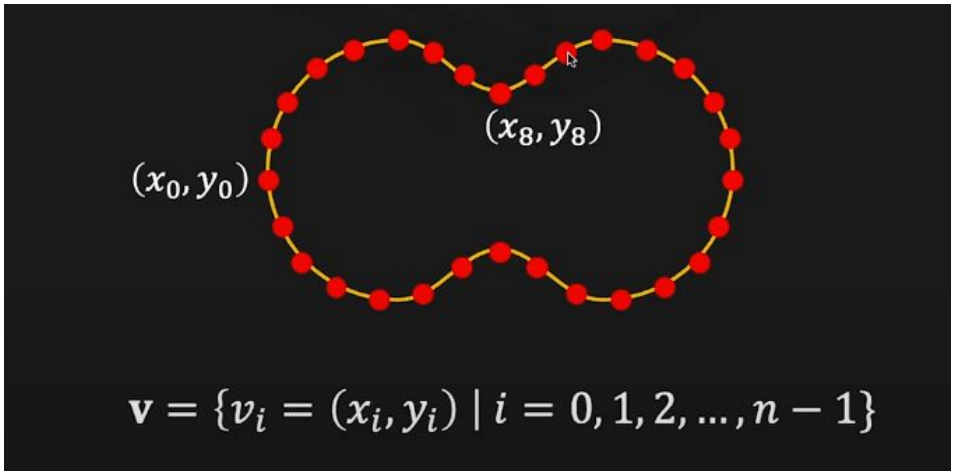


Sample Active Contours

Snakes / Active Contour Models

Contours

- An ordered list of 2D vertices (Control Points) connected by straight lines of fixed length.



Parameterizing Contours

Snakes / Active Contour Models

Objective

- Our Objective will be Maximizing the sum of gradient magnitude squares of all the points of the contour
- In other terms minimizing the negative value of the above expression.

Algorithm

- For each contour point, move the points to a position within a window W where the Objective function (Energy function) is minimized.

$$E_{ex}(c) = -|\nabla I(c)|^2 = -|\nabla I(x,y)|^2$$

Snakes / Active Contour Models

Regularization

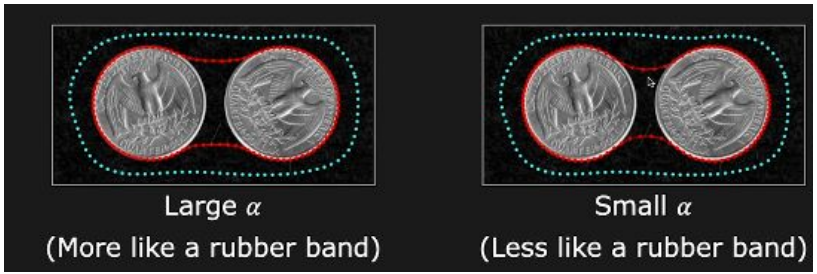
- The above convergence often fails due to noisy gradients.
- Therefore we need to calculate the energy of this contours with another perspective.
- Our contour should be elastic as a rubber band, as well as smooth as a bent metal plate.

$$E = E_{\text{in}} + E_{\text{ex}}.$$

$$E_{\text{ex}}(c) = -\left|\nabla I(c)\right|^2 = -\left|\nabla I(x,y)\right|^2$$

$$E_{\text{in}} = \underbrace{\alpha(s)\left|\frac{dC}{ds}\right|^2}_{\text{Elasticity (stretching)}} + \underbrace{\beta(s)\left|\frac{d^2C}{ds^2}\right|^2}_{\text{Bending}}$$

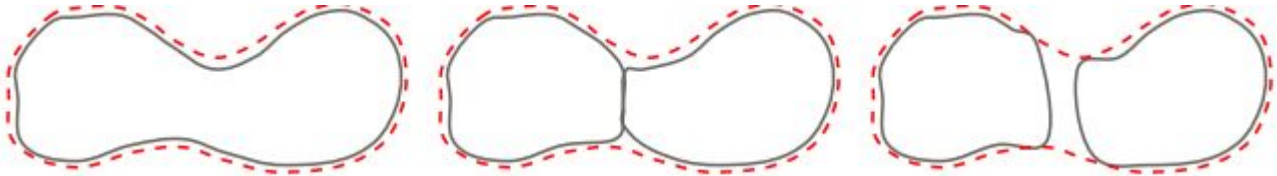
Snakes / Active Contour Models



Effect of internal energy components

Problems

- Sensitive to initialization.
- Numerical Instability.
- Struggles to follow-up topological changes of objects.



Scenarios where snakes fail

Level Sets

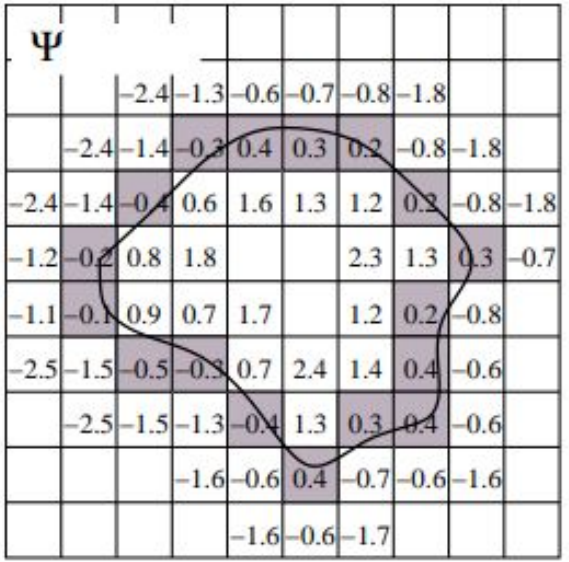
- Instead of parameterizing curve by a set of ordered points, discretize the whole image plane and define a function ψ(x,y). Evolve this entire function; pixels where ψ(x,y)=0 implicitly define the object contour we care about.

Level Sets

- The filters in ITK makes use of a generic level set equation to compute the update to the solution ψ of the partial differential equation.

$$\frac{d}{dt}\psi = -\alpha \mathbf{A}(\mathbf{x}) \cdot \nabla\psi - \beta P(\mathbf{x}) \mid \nabla\psi \mid + \gamma Z(\mathbf{x})\kappa \mid \nabla\psi \mid$$

- Where ,
  - A(x): Advection term; Simulating how a surface or field moves through space.
  - P(X): Propagation term: Controls the propagation speed of the front.
  - Z(x): Mean Curvature term; Regularizing the surface by smoothing it out, reducing sharp variation through the mean curvature.

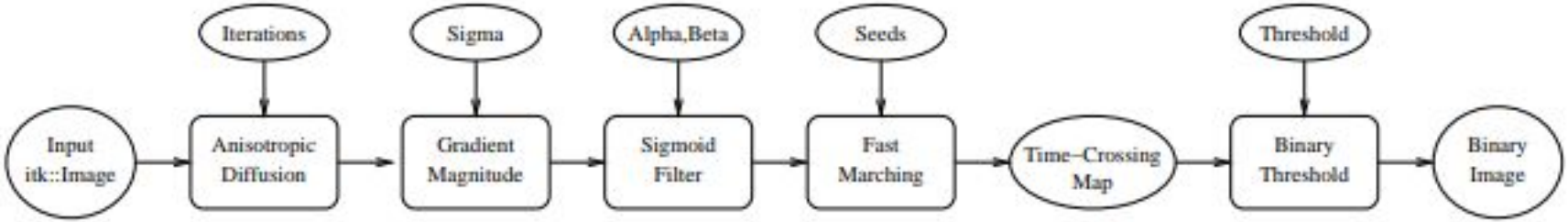


Available Filters in ITK

- Fast Marching Segmentation
- Shape Detection Segmentation
- Geodesic Active Contours Segmentation
- Threshold Level Set Segmentation
- Laplacian Level Set Segmentation
- Canny-Edge Level Set Segmentation

Available Filters in ITK

- Fast Marching Segmentation

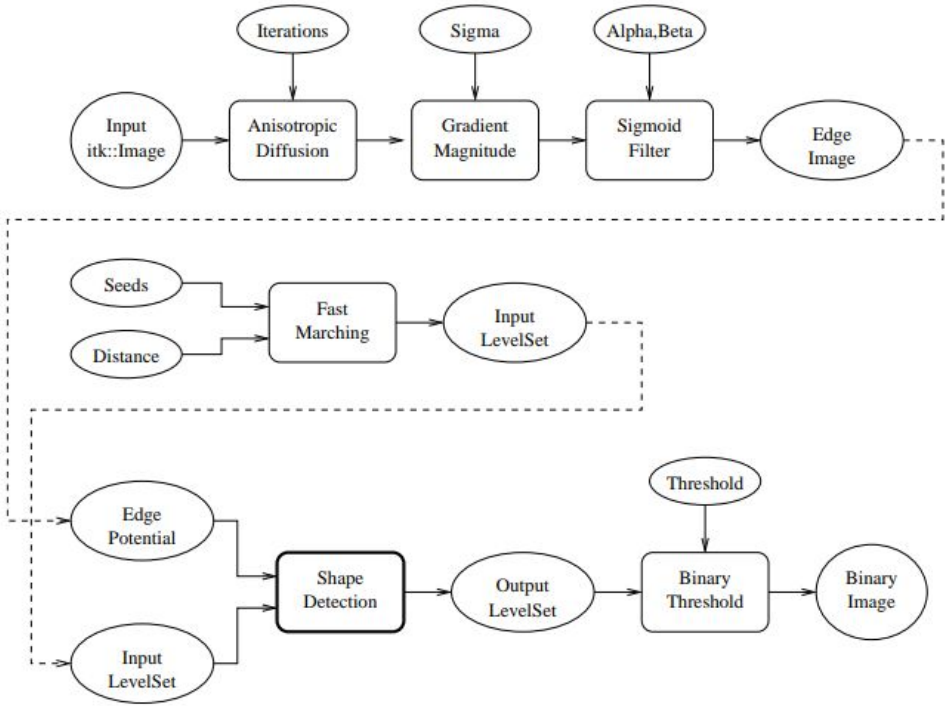


- Used When the differential equation governing the level set evolution has a very simple form.
- The output of the itk.FastMarchingFilter is a time-crossing map that indicates, for each pixel how much time it would take for the front to arrive at the pixel location.

Available Filters in ITK

- Shape Detection Segmentation

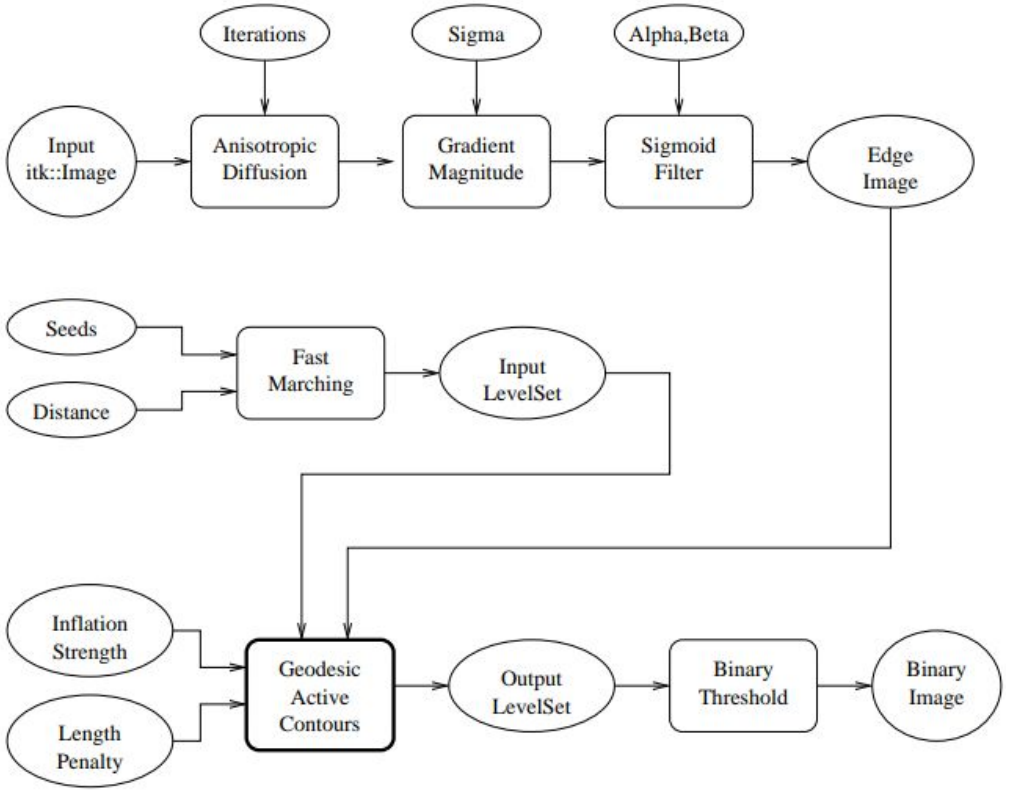
- Used When the governing differential equation has an additional curvature-based term which is used for smoothing areas with high curvature.



Available Filters in ITK

- Geodesic Active Contours Segmentation

- Extends the functionality of the previou filter by adding a third advection term which attracts the level set to the objec boundaries.

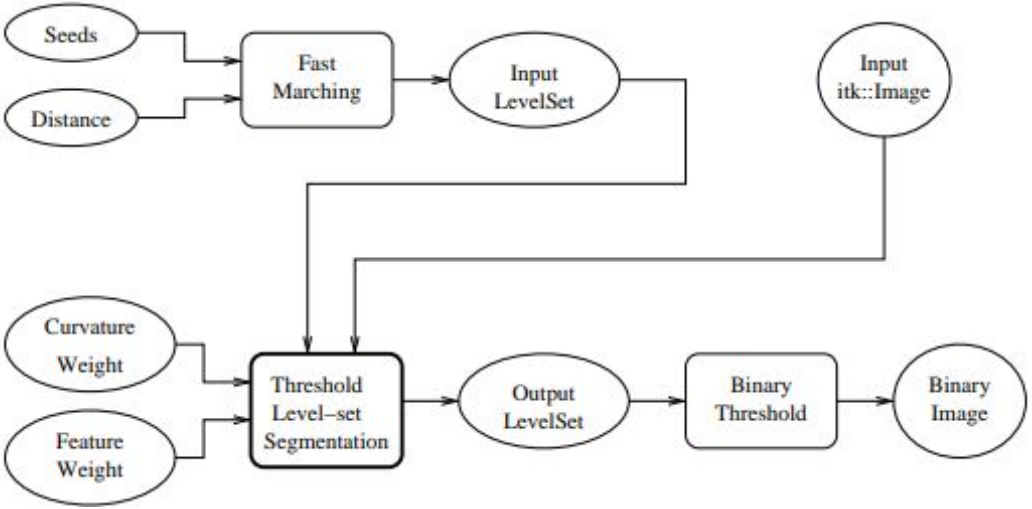


Available Filters in ITK

- Threshold Level Set Segmentation

- Extension of the threshold connected component segmentation framework.
- The goal is to define a range of intensity values that classify the tissue type of interest and then base the propagation term on the level set equation for that intensity range.

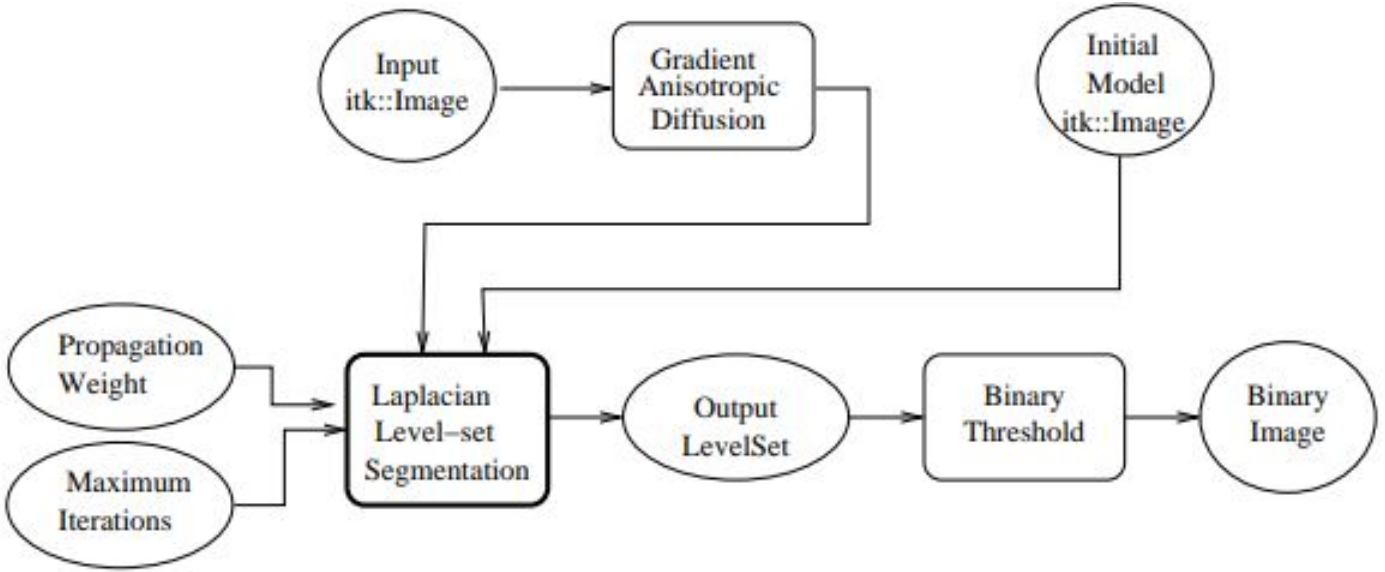
$$P(\mathbf{x}) = \begin{cases} g(\mathbf{x}) - L & \text{if } g(\mathbf{x}) < (U-L)/2 + L \\ U - g(\mathbf{x}) & \text{otherwise} \end{cases}$$



Available Filters in ITK

- Laplacian Level Set Segmentation

- Defines the speed term based on second derivative of the image.
- Goal is to attract the evolving level set surface to local zero-crossings in the laplacian image.



Resources

ITK Documentation: https://docs.itk.org/en/latest/
ITK Software Guide: https://itk.org/ItkSoftwareGuide.pdf

CMake Documentation: http://www.cmake.org/
Publicly Available Test Data: https://github.com/InsightSoftwareConsortium/
https://www.nlm.nih.gov/research/visible/visible_human.html
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