

Hybrid geodesic region-based curve evolutions for image segmentation

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Motivation

Challenges of medical images:

- Heterogeneous intensity profiles
- Poor edge information
- Proximity to other structures

Existing Approaches:

- Edge-based: "There will be strong gradients on the borders of objects"
- Region-based: "The object and background can be modeled easily"

Our contribution:

Development of a new class of algorithms and supporting mathematics capable of hybridizing these two existing approaches

Inspiration

Edge-based Geodesic Active Contours

- Find a local minimum "length" curve on an imposed Metric
- Can get trapped in insignificant local minima
- Only examines data on the contour
- Uses gradients of image (very noisy), smooths image to compensate
- Classically presented by Caselles et. al.

$$E = \oint_{C(s)} \frac{1}{1 + \|\nabla I\|^2} ds$$

Region-based Geometric Active Contours

- Minimizes an energy related to global image data and position of curve
- Very robust to noise and curve placement
- Makes global assumptions about image makeup
- Popular Chan-Vese and Mumford-Shaw flows are examples

$$E = \int_{x \in \Omega} (I - u)^2 dA + \int_{x \in \bar{\Omega}} (I - v)^2 dA$$

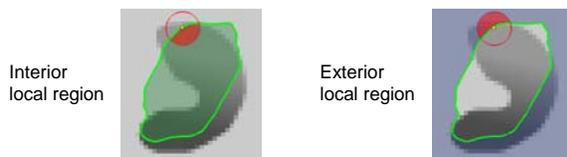
Hybrid Solution

$$E = \underbrace{\oint_{C(s)} \int_{x \in \Omega} (I\chi(x, s) - u_\ell(s))^2 + \int_{x \in \bar{\Omega}} I\chi(x, s) - v_\ell(s))^2 ds}_{\text{Region-based component over local regions}}$$

Edge-based component over every point on the curve

Concept

- Edge-based energy where each point's cost is based on a local region.
- Each point on the contour moves such that regions of nearby pixels just inside and just outside the contour are modeled optimally by their mean intensities.

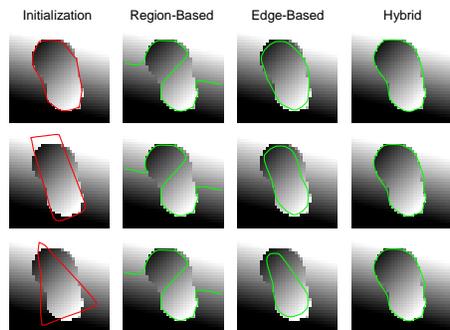


Implementation

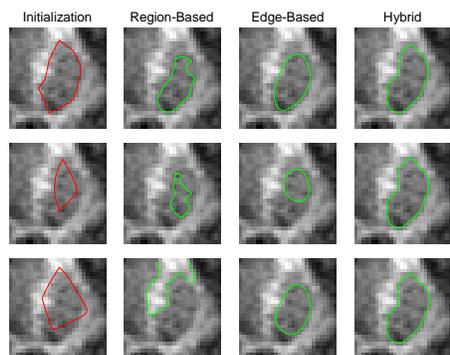
- Gradient descent to find local minimum
- Level sets used to embed evolving contour
- Pre-computation of statistics to speed algorithm

Experiments

Synthetic Images



Medical MRI Images



Results

- **Region-based** finds an incorrect way to model regions by mean intensities
- **Edge-based** finds some strong edges, but usually finds a (wrong) local minima
- **Hybrid methods** find the correct outline of the object

Discussion

Benefits:

- Weak assumptions about image makeup
- Robust to noise and initial curve placement
- Extensible mathematical framework, proposed algorithm is a simple example

Limitations:

- Subject to initial curve placement, as with all geometric active contours
- The radius of the χ function is a free parameter

Future work:

- Automatic or adaptive setting of the radius of χ
- Incorporation of higher order statistical moments
- Extension to vector-valued images and 3D images

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