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

Inspection

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), smoothes image to compensate
• Classically presented by Caselles et. al.

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

Hybrid Solution

\[ E = \int_{C(s)} \frac{1}{1 + |\nabla \hat{I}|^2} ds \]

Region-based component over local regions

\[ E = \int_{\Omega} (I - u)^2 dA + \int_{\Omega} (I - v)^2 dA \]

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

- Initialization
- Region-Based
- Edge-Based
- Hybrid

Medical MRI Images

- Initialization
- Region-Based
- Edge-Based
- Hybrid

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 \( X \) function is a free parameter

Future work:
• Automatic or adaptive setting of the radius of \( X \)
• Incorporation of higher order statistical moments
• Extension to vector-valued images and 3D images

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