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

Innovation

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.

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-Shah flows are examples

Hybrid Solution

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

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.

Interior local region

Exterior local region

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 \( h \) function is a free parameter

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

Acknowledgements

This work is part of the National Alliance for Medical Image Computing (NA-MIC), funded by the National Institutes of Health through the NIH Roadmap for Medical Research grant U54 EB005149. Information on the National Centers for Biomedical Computing can be obtained from http://nihroadmap.nih.gov/nccbrp/. This work was also funded in part by grants from NSF, AFOSR, ARCO, MUR, MRDDL, as well as by a grant from NIH (R01 GM-69155) through Brigham and Women’s Hospital.