Multi-region active contours with a single level set function

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Existing approaches

• Unsupervised methods
  - Active contours (AC)
  - Probabilistic clustering
  - Greedy algorithms
  - Graph-cut based methods
  - Convex relaxation methods

• Learning approaches
  - Supervised contour detection
  - Deep neural networks
Image segmentation using active contours

- Minimize the energy functional (segmentation criterion)

\[ E(C) = E_{data}(C) + E_{regularization}(C) \]

\[ C_0 \]

\[ \phi(x, y) \]

\[ C_t = F n \]

\[ F \triangleq -\frac{\delta E(C)}{\delta C} \]

\[ \phi_t = F |\nabla \phi| \]

Object

Background
Multi-region segmentation using level sets

- Images with 2 regions

  \[
  \text{Object} = \{ \text{Level set function} > 0 \} \\
  \text{Background} = \{ \text{Level set function} < 0 \}
  \]

- Generalization to \textit{multiple} / \textit{overlapping} regions is not immediate!
The proposed approach

- Boundaries of multiple / overlapping regions described by a **single level set function** $\phi \geq 0$
- Arbitrary $E(C)$
- Reduced computational complexity

\[ C = \{ (x, y) | \phi(x, y) = 0 \} \]

\[ \minimize E(C) = E_{\text{data}}(C) + E_{\text{regularization}}(C) \]

by

\[ \phi_t = F|\nabla \phi| \]
The proposed approach

- Multi-region level set function evolution
  - “Voronoi Implicit Interface Method (VIIM) for multi-phase level set evolution”, R. Saye and J. Sethian, *PNAS’11*

\[
C(p; t = 0) \quad \phi(x, y) \geq 0 \quad \phi(x, y; 0) = \varepsilon \quad C(p; t_0 + \Delta t)
\]

- Main observation: evolving contour is bounded by its adjacent \(\varepsilon\)-level sets.
The proposed approach

- Multi-region level set function evolution

- Generic segmentation model
  - Multi-region piecewise constant model (Mumford-Shah’89, Chan-Vese’01)
  - Region competition model (Zhu&Yuille’96)
  - Region dissimilarity models (Bertelly et al.’08, Jung et al.’12)

\[
E(C) = \sum_{i=1}^{N} E_{data}(C | \Omega_i) + \frac{\mu}{2} \sum_{i=1}^{N} E_{reg}(C | \partial \Omega_i)
\]

Data term

Regularization term

“Multi-region active contours with a single level set function”, D., Rosman, Kimmel, *TPAMI’15*
Segmentation results – the Berkeley Segmentation dataset

Piecewise constant and region competition models

Piecewise-constant model, different algorithm parameters
Evaluation using the Berkeley Segmentation benchmark

Proposed method
3D segmentation using the Active Surface Model

White matter exterior boundary
Thank you for your attention!