RAGS: Region-aided Geometric Snake
—— A new approach to snake segmentation

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Snake, a powerful active contouring method

- Snake:
  - Deformable curves within image domain to recover object shapes.

- Implementations:
  - Shape description
  - Object localisation
  - Motion tracking
  - Segmentation (e.g. colour/texture)

- Two general types: parametric and geometric snakes
- One example: a geometric snake

Parametric snake models

- Parametric snake
  - Introduced by Kass et al. (1987);
  - Represented explicitly as parameterized curves;
  - Snake evolves to minimize the internal and external forces (Let $C(q)$ be a parameterized plane curve);

  $$\frac{\partial C}{\partial t} = \lambda \nabla I(C(q)) - \beta \frac{\partial}{\partial u} \left( \frac{\partial C}{\partial u} \right)$$

  - Initialisation problem;
  - Concavity convergence problem;
  - Topological problems.
    - Non-intrinsic, parameterisation dependent;
    - Hard to detect multiple objects simultaneously.

Geometric snake models

- Geometric snake
  - Introduced by Caselles et al. and Malladi et al. (1993);
  - Based on the theory of curve evolution
  - Numerically implemented via level set methods;
  - Snake evolves to minimize the weighted length in a Riemannian space with a metric derived from the image content;

  - Brief introduction to curve evolution and level set methods ...

Curve evolution

- Curvature flow
  - The curvature measures how fast each point moves along its normal direction;
  - A simple closed curve will evolve toward a circular shape and disappear;
  - It is indeed smoothing.

- Constant flow
  - Each point moves at a constant speed along its normal direction;
  - It can cause a smooth curve to a singular one.

Level set method

- A computational technique for tracking a propagating interface over time.

  - The snake is embedded as a zero level set of a 3D surface.
Standard geometric snake

- Geometric snake formulation:
  \[ C = \|\nabla \phi \| \kappa + \epsilon \| \nabla \phi \| \cdot \n\]
  - \( \epsilon \) represents a decreasing function such that \( \epsilon(x) \to 0 \) as \( x \to \infty \);
  - \( \kappa \) is curvature, \( N \) is the unit inward normal.
- Level set representation:
  \[ \phi = \| \nabla \phi \| \kappa + \epsilon \| \nabla \phi \| \cdot \n \]
  - \( \phi \) is a level set function, which embeds the snake contours.
- Advantages:
  - Much larger capture area;
  - Good convergence quality;
  - Totally intrinsic, automatically handle topological changes.

Standard geometric snake problems

- Weak-edge leakage problem
  - The weighting function is based on the gradient;
  - When the object boundary is indistinct or has gaps, the snake tends to leak through the boundary;
  - The second term of the geometric snake formulation is not strong enough to prevent from leaking through weak-edges.
- Lack of global information
  - Sensitive to local minima;
  - Only use local information.

Improvements in the literature world

- Area-length minimisation snake
  - Combine the weighted length functional with a weighted area functional.
  \[ C = \|\nabla \phi \| \kappa + \epsilon \| \nabla \phi \| \cdot \n\]

- GVF and Generalised GVF (GGVF) snakes
  - A new external force field \( V(u, v) \) (GVF) is used to attract the snake;
  - \( V = \int \| \nabla \phi \| \kappa + \epsilon \| \nabla \phi \| \cdot \n \)
  - GGVF can be fit into geometric framework;
  - Better convergence quality, larger capture area;
  - Preserve perceptual edge property of snake.

Improvements in the literature world (cont.)

- Region-based snakes
  - \( C = \alpha N \cdot (F_{\text{ext}} + W_{\text{reg}}) \)
  - \( R \) is a region function, \( W_{\text{reg}} \) is a positive weighting parameter;
  - The region force acts as signed pressure force, which replaces the constant force in standard geometric snake;
  - A refinement of region segmentation;
  - Can be powerful when dealing with textured images.

Still problems

- Area-length minimisation snake
  - The weighting function is still based on the gradient, i.e. still suffer from leakage problem.
- GVF/GGVF snakes
  - Topological problems, although GGVF can be fit into geometric framework;
  - Difficult to neighbouring weak/strong edges.
- Region-based snakes
  - Needs prior-knowledge;
  - Purely based on segmentation, have problem with object segmentation.

RAGS, the proposed method

- Goals
  - Make the geometric snake much more tolerant towards weak edges and image noise.
- The proposed method
  - Integrate the gradient flow forces with diffused region constrains;
  - Region vector flow is obtained through the diffusion of segmentation map;
  - The gradient flow forces supply local object boundary information;
  - Region force is based on the global features; Segmentation independent.
RAGS, region force diffusion

- Segmentation gives the region map \( R \);
- \( \forall z \) gives region constraints in the vicinity of the region boundaries;
- Region vector flow is derived from diffusing the region force (equilibrium state of following equation).

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RAGS, snake formulation

- The geometric snake can be represented as:
- \( C = [(f_1, f_2)] \)
- The original internal and external forces:
- \( f_i = g_i |f_i| \)
- Add the diffused region force to the external term:
- \( f_i = g_i |f_i| + e \cdot \langle \nabla f_i, \nabla \psi_i \rangle \)
- RAGS formulation:
- \( C = [(f_1, f_2)] \)
- Level set representation:
- \( \delta = \langle \nabla f_i, \nabla \psi_i \rangle \)

RAGS on vector-valued images

- Let \( \rho(.) \) be edge indicator, then the stopping function \( g(.) \) can be any decreasing function of \( f(.) \): \( g(.) = \frac{1}{1 + f(.)} \).
- Let \( \partial u_i (u_i) \) be a m-band image. The eigenvalues are given by:

\[
\lambda_j = \frac{u_i + u_j}{2} \quad \text{and} \quad \mu_j = \frac{u_i - u_j}{2}
\]

- The strength of the edge is given by the difference between the extremums;

\[
f_i = \lambda_j - \lambda_i, \quad g_i = \frac{g_i + f_i}{2}
\]

- Then colour RAGS is given by:

\[
C = g_i \langle |f_i| \rangle \quad \nabla = \langle \nabla \psi_i \rangle
\]

Implementations

- Testing on weak-edges
- Testing on noisy images
- Different region-forces
- More RAGS examples

Preventing weak-edge leakage

- The test object is a circular shape with a small blurred area on the upper right boundary.

Neighbouring weak/strong edges

- Standard geometric snake failed because of weak-edge;
- GGVF snake failed because of presence of strong edge;
- RAGS correctly converged.

From left: geodesic snake, GGVF snake, and RAGS.
Testing on noisy images

- Row 1: original image with added noise (0%-60%); row 2: geodesic snake result; row 3: GGVF snake result; row 4: RAGS result.

Testing on noisy images (cont.)

- MRE comparison for the Harmonic Shapes in previous figure

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<th>20</th>
<th>30</th>
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<td>9.00</td>
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<td>2.24</td>
<td>7.07</td>
<td>10.00</td>
<td>11.31</td>
<td>21.16</td>
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<tr>
<td>RAGS Error</td>
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</tbody>
</table>

Different region forces

- RAGS is segmentation independent;
- Mean shift algorithm is implemented to generate region map;
- RAGS works well both on under-segmentation and on over-segmentation.

RAGS on gray level images

- Rags in comparison to the standard geometric and GGVF snakes on gray level image.

Brain MRI (corpus callosum) image – from left to right: standard geometric snake, GGVF snake, and RAGS.

RAGS on colour images

- Convergence quality comparison;
- Weak-edge and GGVF problems demonstration.

More RAGS examples
Summary

- A novel method, RAGS, was proposed;
- It integrates the gradient flow with region vector flow;
- The theory is stand-alone;
- Better performance towards weak-edges and noise in images;
- Applicable in a variety of fields:
  - Shape modeling, recovery;
  - Object localisation;
  - Medical applications;
- Shortcomings:
  - Not suitable for highly textured images;
  - Dependent on reasonable segmentation.

Publications

- RAGS Website: [http://www.cs.bris.ac.uk/~xie/rags.html](http://www.cs.bris.ac.uk/~xie/rags.html)
- Xianghua Xie and Majid Mirmehdi, Geodesic Colour Active Contour Resistant to Weak Edges and Noise, submitted to BMVC2003, April 2003;

Questions

- ? …