Snakes: a technique for line smoothing and displacement in map generalisation

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1. Motivation
2. The snakes model
3. Line smoothing with snakes
4. Combined line smoothing and displacement using snakes concept
motivation  snakes  smoothing  combination

**foundation:**
Snakes for **line** smoothing developed by Burghardt (2002)
(conventional snakes model by Kass et al. 1987)

**results of evaluation:**
already good results, but refinement needed..
- knowledge of parameters / smoothing control
- observation of cartographic constraints

bad parametrisation
motivation
snakes
smoothing
combination

**Further aims:**
- other approach using TAFUS (Borkowski et al. 1999)
- combination with known displacement model

**Tools:** Matlab R12
Snakes – an energy minimizing spline function

- developed in graphics domain for image recognition
- smooths „signals“ (lines) like a spline
- speciality: smoothing can be controlled locally
- snakes energy integral defined by two terms

\[ E_{ges} = \int_{0}^{1} (E_{ext} + E_{int}) ds \Rightarrow Min \]

- internal energy: describing the line „shape“ itself
- external energy: describing external forces

- the overall energy will be minimized
- solution in an iterative process
motivation  snakes  smoothing  combination

**models**

conventional snakes (based on x,y coordinate representation)

Tangent Angle Function Snakes (based on tangent angle representation s,φ)

\[ \varphi(s) = \arctan \frac{\dot{y}(s)}{\dot{x}(s)} \]

remark on curvature:

\[ \ddot{\varphi} = \frac{1}{R} \]
Line smoothing with snakes

internal energy (smoothing spline)

\[ E_{\text{int}} = \frac{1}{2} \left( \alpha \dot{y}^2 + \beta \dot{y}^2 \right) \]

variation of external energy (interaction, 2nd control)

\[ \frac{\partial E_{\text{ext}}}{\partial x} = \frac{\partial E_{\text{ext}}}{\partial y} = 0 \]

\[ \dot{\dot{\nu}} = \begin{bmatrix} \ddot{x} \\ \ddot{y} \end{bmatrix} \]

\[ \dot{\nu} = \begin{bmatrix} \dot{x} \\ \dot{y} \end{bmatrix} \]

\[ \frac{\partial E_{\text{ext}}}{\partial \phi} = -\phi_0 \]

\[ \alpha, \beta \quad : \text{control parameters (1st control)} \]

\[ \phi \quad : \text{tangent angle} \]

\[ \text{dotted} : \text{partial differentiation with respect to arc length s} \]

snakes approach: spline -- tafus approach: controlled by curvature

3rd control: number of iterations
model refinement for use in generalisation

- maintain constraint points (landmarks)
  by curvature controlled line segmentation

fixing translated border points of a line
by changed weights in the snakes filter matrix and mirror last points (green)
model refinement for use in generalisation

fixing translated border points of a line
by changed weights in the snakes filter matrix
and mirror last points (green)

maintain constraint points (landmarks)
by curvature controled line segmentation

preserve shape characteristics (meander, serpentines)
by curvature controled param. effect only up to 5 iterations

tafus $\alpha = 1, \beta = 2$, iteration stopped by curvature threshold

ICA workshop on generalisation and multiple representation, Leicester
Finally we recommend:

- conventional snakes (robust + faster than tafus)
- fix parameter $\alpha=1$, only $\beta$ variable
- iteration process to obtain desired smoothing deg.
  stopping criterion: curvature threshold
- segmentation
Combined line smoothing and displacement

- snakes displacement algorithms by Burghardt & Meier 1997
tafus displacement algorithms by Borkowski et al. 1999

- same structure of energy integral

- differences to smoothing:
  ▪ internal energy used to preserve original line shape
  ▪ external energy defined by displacement forces
basic methods of (batch like) combination:

- **alternating method**
  - **switching** between both algorithms after defined number of steps
  - both processes can have different parameter values (variable $\beta$ useful to prevent side effects of smoothing on displacement)

- **integrative method**
  - combination of formulas in a **linear fashion**
  - a new weighting parameter $\gamma$ arises (equal weight: $\gamma = 0.5$)
  - only **one system matrix** exists: no local control of $\alpha, \beta$
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motivation
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original lines
- conflicts
- vertex

snakes
alternating method
5 iterations

snakes
integrative method
$\gamma = 0.5$
5 iterations

grey: original lines
black: smoothed and displaced lines
$\Rightarrow$ only small differences in results
**preliminary results:**

- Higher processing time for displacement (reason: conflict evaluation)

- A larger number of iterations does not show big differences among constant and variable parameters $\alpha, \beta$

- Snakes $\Leftrightarrow$ tafus: negligible time cost differences; snakes are robust

- Further tests required: stopping criterion for not solvable displacement situations
Thank you for listening!

..questions are welcome

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interference of smoothing and displacement