Baby-Snakes Model: A Modified Active Contour (Snake) Approach for Image Segmentation

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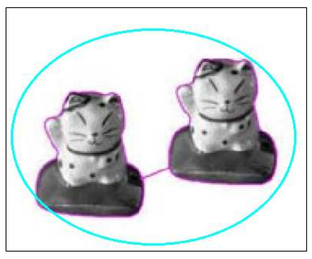
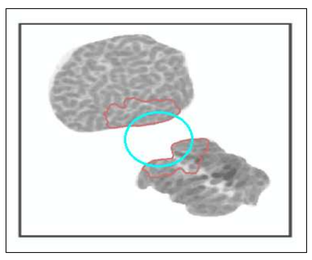
Why Baby-Snakes Model?

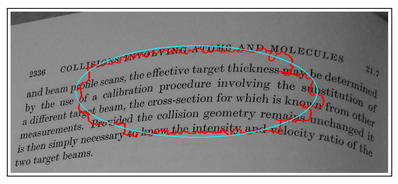
- Active contour (Snake) [1] and Level Set [2] are state-of-the-art image segmentation approaches in computer vision.
- **Drawbacks of Active Contour and Level Set:**
  - **Active Contour:** not possible to detect more than one objects
  - **Level Set:** sensitive to the number of evolution steps
  - **Both:** sensitive to the initial position of curve
  - **Both:** not directly applicable to other image segmentation areas, for example *Document Image Segmentation*
- **Goals of Baby-Snakes segmentation model are:**
  - Overcome the limitations of Active Contour (Snake) and Level Set.
  - Improve the segmentation results of already addressed areas.
  - Make it more general to apply on different image segmentation areas.



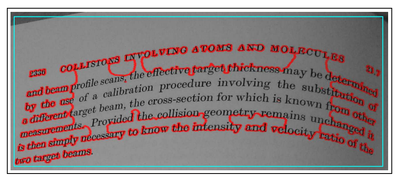
Active Contour's segmentation failure



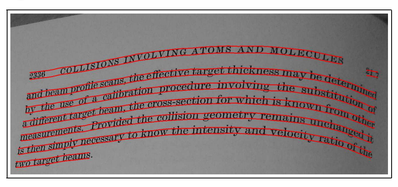
Level Set's initialization failure



Active Contour's textlines segmentation failure



Level Set's textlines segmentation failure



Baby-Snakes' adaptation for textlines segmentation

Baby-Snakes Model

Active Contour (Snake) Overview [1]

- Initial closed-curve contour, $S(s) = [x(s), y(s)]$, $s \in [0, 1]$
- Deformation of curve by minimizing the following energy function:

$$E = \int_0^1 \frac{1}{2}[\alpha\{S'(s)\} + \beta\{S''(s)\}] + E_{ext}(S(s))ds \quad (1)$$

- First term, referred as internal energy, tries to keep curve points together
- Second term, referred as external energy, attracts the curve towards object boundaries, which is gradient, gradient of Gaussian or gradient vector flow (GVF) [3] of an edge-map of image

Baby-Snakes Features

- **Not a closed-curve**
- **Multiple snakes at the same time**
- **Automated starting positions (image features, connected-components, etc)**
- **Restricted direction of deformation (horizontal, vertical or both, depends upon the application)**

References

[1] M. Kass and A. Witkin and D. Terzopoulos: Snakes: Active contour models. In International Journal of Computer Vision, **1**(4) (1988) 1162–1173

[2] S. Osher and J.A. Sethian: Fronts Propagating with Curvature-Dependent Speed: Algorithms Based on Hamilton-Jacobi Formulations. In Journal of Computational Physics, **79**(1) (1988) 12–49

[3] C. Xu and J. L. Prince: Snakes, Shapes, and Gradient Vector Flow. IEEE Transaction of Image Processing, **7**(3) (1998) 359–369

[4] S. S. Bukhari and F. Shafait and T. M. Breuel: Segmentation of Curled Textlines using Active Contours. In Proceedings of The Eight IAPR Workshop on Document Analysis Systems (DAS), 2008 270–277

[5] F. Shafait and T. M. Breuel: Document Image Dewarping Contest. In 2nd International Workshop on Camera-Based Document Analysis and Recognition (CBDAR), 2007 181–188

[6] S. S. Bukhari and F. Shafait and T. M. Breuel: Coupled Snakelet Model for Curled Textlines Segmentation of Camera-Captured Document Images. In Proceedings of the 10th International Conference on Document Analysis and Recognition (ICDAR), 2009 (*accepted for publication*)

[7] S. S. Bukhari and F. Shafait and T. M. Breuel: Script-Independent Handwritten Textlines Segmentation using Active Contours. In Proceedings of the 10th International Conference on Document Analysis and Recognition (ICDAR), 2009 (*accepted for publication*)

[8] B. Gatos and A. Antonacopoulos and N. Stamatopoulos: Handwriting Segmentation Contest. In Proceedings of the 9th International Conference on Document Analysis and Recognition (ICDAR), 2007 1284–1288

Adaptation of Baby-Snakes Model for Complex Textlines Segmentation

Challenges: Textlines segmentation is an important step for **Optical Character Recognition (OCR)**. Textlines segmentation from camera-captured and handwritten documents is a difficult task because of the following problems:

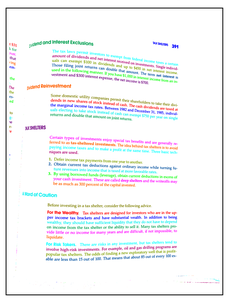
- Non-planar image shape, perspective distortion (camera-captured)
- Touching characters within consecutive textlines (handwritten)
- Multi-oriented textlines

Textlines Segmentation from Camera-Captured Documents [4, 6]

First Model [4]:

- Straight-line snakes are initialized over smeared words
- Orientation of snakes are same as slope of words
- External energy (GVF) is calculated from smeared image
- Snakes are deformed in vertical direction only
- Textlines segmentation is resulted by overlapping snakes
- **Results: 97.96%** match-score on CBDAR 2007 dataset [5]

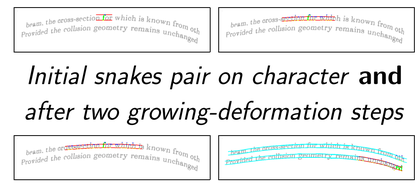
Initial snakes over smeared words **and** *Deformed overlapping snakes*



Textlines segmentation result

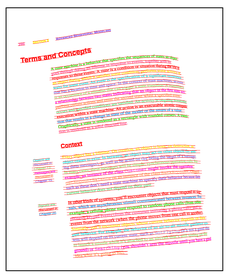
Second Model [6]:

- Opened-curve snakes pair is initialized over each character's top and bottom points
- Snake pairs are grown in length, with each iteration
- In each pair, top and bottom snakes are deformed in vertical direction with respect to the GVFs of top and bottom neighboring characters' points, respectively
- After each deformation, distances within a pair are adjusted to become equal
- Textlines segmentation is resulted by overlapping snakes pairs
- **Results: 90.76%** detection accuracy on CBDAR 2007 dataset [5]



Initial snakes pair on character **and** *after two growing-deformation steps*

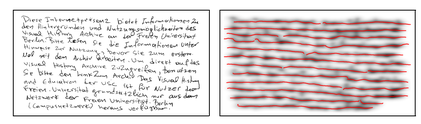
After four growing-deformation steps **and** *deformed overlapping snakes pairs*



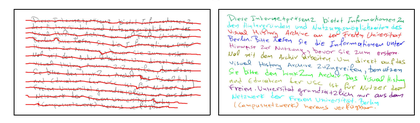
Textlines segmentation result

Textlines Segmentation from Handwritten Documents [7]

- Image is smoothed by multi-oriented multi-scale anisotropic Gaussian smoothing
- Ridges are detected from smoothed images; which are also used as initial opened-curve snakes with additional lengths
- GVF is calculated from ridges image
- Ridges having slope in between -45 to 45 are deformed using horizontal GFV and others using vertical GVF
- Textlines segmentation is resulted by overlapping snakes
- **Results: 96.3%** detection accuracy on ICDAR 2007 dataset [8]



Handwritten document **and** *Detected ridges*



Deformed overlapping snakes **and** *textlines segmentation result*

Textlines segmentation results

Conclusion

- Introduced **novel "Baby-Snakes Model" for image segmentation**, based on Active Contour (Snake).
- Overcome the drawbacks of Active Contour (Snake) and Level Set methods by:
  - using automated initialization of curves
  - making segmentation results insensitive to the number of deformation steps
- Baby-Snakes Model has a capability of:
  - improving the results of traditional photographic image segmentation
  - adaptation to the new image segmentation areas with respect to Active Contour and Level Set, like **document image segmentation**
- Achieved **above 90% textlines segmentation accuracy** for camera-captured and handwritten document images on standard datasets, using Baby-Snakes Model