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# Interactive Image Segmentation Using Level Sets and Dempster-Shafer Theory of Evidence

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## Problem statement:

Image segmentation using a variational framework [1,2]

$$E(\varphi) = \underbrace{-\int_\Omega H(\varphi)\log m_{im}(\Omega_1)\,d\Omega - \int_\Omega (1-H(\varphi))\log m_{im}(\Omega_2)\,d\Omega}_{\text{data term}} + \lambda_1 \underbrace{\int_\Omega |\nabla H(\varphi)|\,d\Omega}_{\text{curve constraint}},$$

- fusing feature channels with Dempster-Shafer [3] models inaccuracy and uncertainty at the same time [1]
- does not allow much user interaction

## Contribution:

- user input $L : \Omega \to \{-1, 0, 1\}$ marking object or background regions
- shape constraint defined by the user [4]

$$E_{user-shape} = -\frac{1}{2}\int_\Omega L_\sigma(x)\mathrm{sign}(\varphi(x))\,d\Omega$$

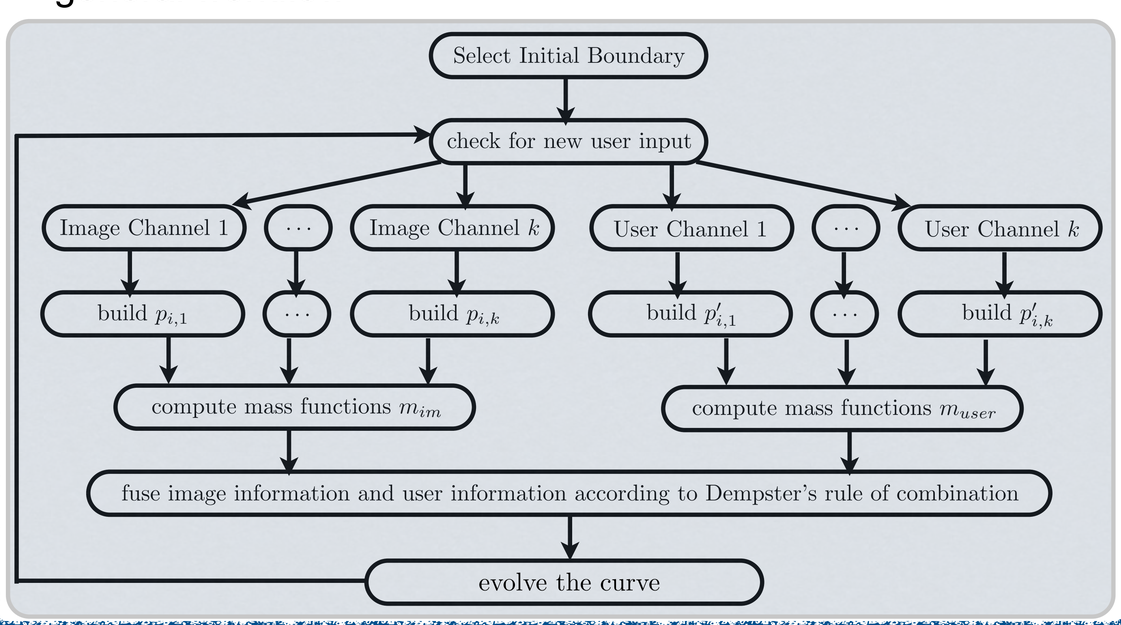
- with a Gaussian-smoothed user input
- novel term inspired by the image energy

$$E_{user-image} = \int_\Omega H(\varphi)\log m_{user}(\Omega_1)\,d\Omega - \int_\Omega (1-H(\varphi))\log m_{user}(\Omega_2)\,d\Omega$$

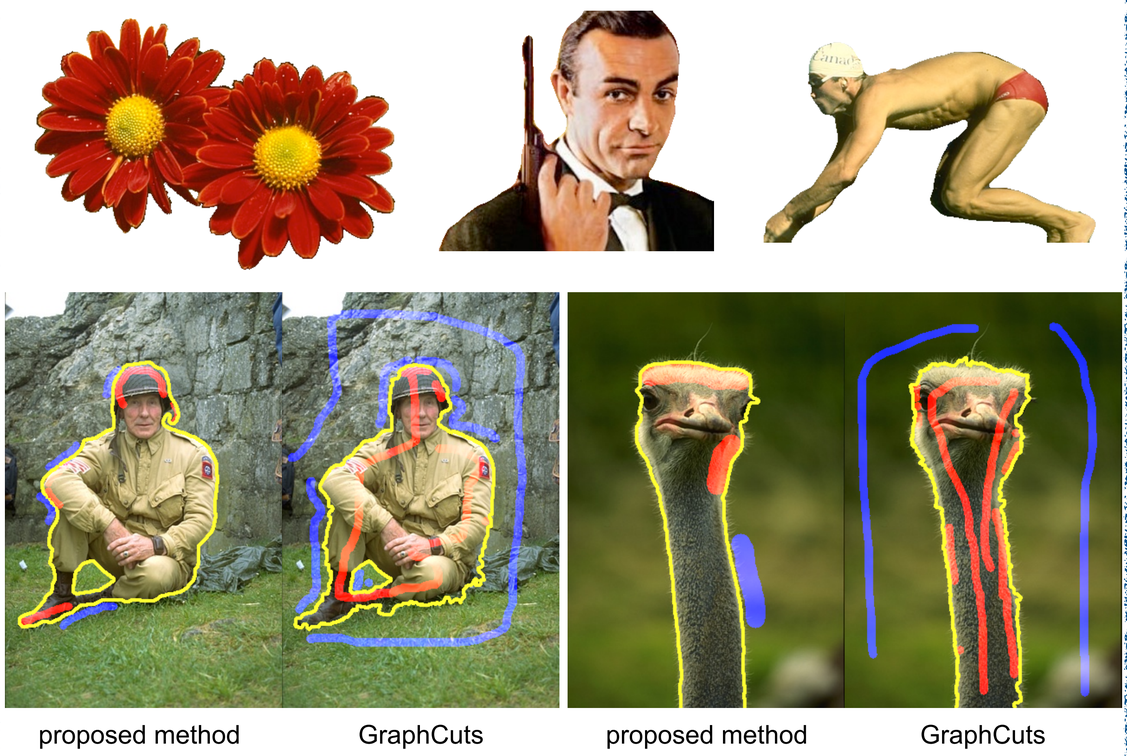
- new mass-function is defined on the (sparse) marked regions
- can be interpreted as an indicator for the appearance of a region
- fusion with Dempster-Shafer theory of evidence leads to

$$E(\varphi) = \underbrace{-\int_\Omega H(\varphi)\log m(\Omega_1)\,d\Omega - \int_\Omega (1-H(\varphi))\log m(\Omega_2)\,d\Omega}_{\text{data term + user defined term}} + \lambda_1 \underbrace{\int_\Omega |\nabla H(\varphi)|\,d\Omega}_{\text{curve constraint}} - \lambda_2\nu \underbrace{\int_\Omega L_\sigma H(\varphi)\,d\Omega}_{\text{user-shape}}$$

- where $m = m_{im} \otimes m_{user}$ fuses image and user data according to Dempster's rule of combination
- general workflow




## Qualitative results:




- proposed interactive segmentation utilizing Dempster-Shafer theory of evidence for feature fusion outperform standard approaches

## Quantitative results:

| Image | GraphCuts | $F_1$ | [4] | $F_1$ | proposed method | $F_1$ |
|---|---|---|---|---|---|---|
| Lady Bug | 4.33 str. | 0.94 | 1.3 str. + 2 klicks | 0.89 | 1.3 str. + 2 klicks | 0.90 |
| Eagle | 9.33 str. | 0.97 | 7 str. + 2 klicks | 0.93 | 5.5 str. + 2 klicks | 0.95 |
| Bird | 7.83 str. | 0.96 | 2.3 str. + 2 klicks | 0.95 | 1.83 str. + 2 klicks | 0.96 |
| Flowers | 7.17 str. | 0.98 | 6.6 str. + 2 klicks | 0.99 | 4 str. + 2 klicks | 0.99 |
| Soldier | 9.33 str. | 0.98 | 10.3 str. + 2 klicks | 0.98 | 7.33 str. + 2 klicks | 0.97 |

- user study with 6 persons and 5 images
- mean $F_1$ measure is comparable
- proposed method needed significantly fewer user-interactions

## Conclusion:

- proposed method extends the traditional framework by means of user-interactivity
- local influence by a user-defined shape-prior
- global influence by a user-defined appearance model
- allows more precise segmentations

## References:

[1] Scheuermann, B., Rosenhahn, B. Feature quarrels: The Dempster-Shafer evidence theory for image segmentation using a variational framework. In: Asian Conference on Computer Vision (2010)
[2] Chan, T., Vese, L.: Active contours without edges. IEEE Transactions on Image Processing 10 (2001) 266–277
[3] Shafer, G.: A mathematical theory of evidence. Princeton university press (1976)
[4] Cremers, D., Fluck, O., Rousson, M., Aharon, S.: A probabilistic level set formulation for interactive organ segmentation. Proc. of the SPIE Medical Imaging (2007)

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