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Feature quarrels: The Dempster-Shafer Evidence Theory for Image Segmentation Using a Variational Framework

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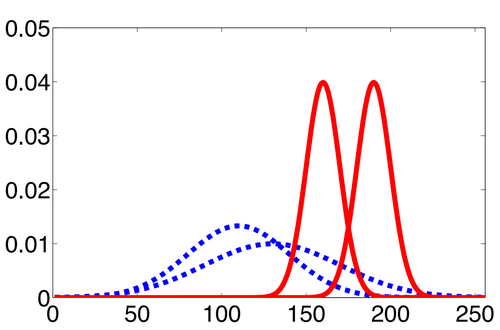
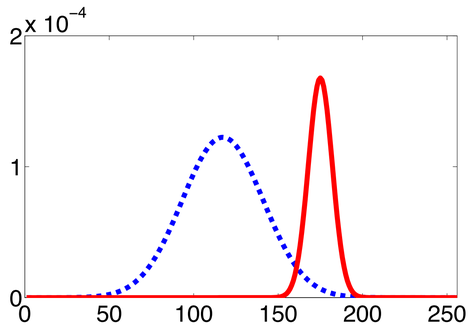
Problem statement:

Image segmentation using a variational framework [1]

$$E(\varphi) = -\int_\Omega H(\varphi) \sum_{j=1}^{m} \log p_{1,j}\, d\Omega - \int_\Omega (1 - H(\varphi)) \sum_{j=1}^{m} \log p_{2,j}\, d\Omega + \nu \int_\Omega |\nabla H(\varphi)|\, d\Omega$$



two feature channels (blue BG, red FG)



product of the two densities (Bayesian model)

➡ fusing feature channels in a Bayesian framework favours small probabilities

Contribution:

Dempster-Shafer evidence theory [2] for Image Segmentation

➡ define mass functions:

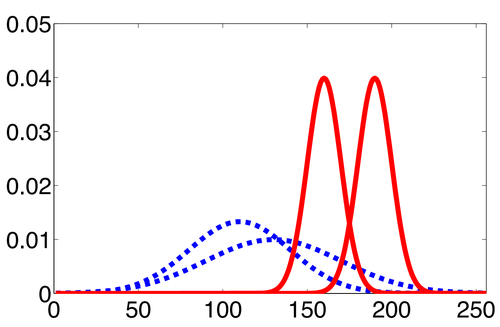
$$m_j(\Omega_1) = p_{1,j}(I(x)), \quad m_j(\Omega_2) = p_{2,j}(I(x)),$$
$$m_j(\emptyset) = 0, \quad m_j(\Omega) = 1 - (p_{1,j}(I(x))) + p_{2,j}(I(x))),$$

➡ fuse mass functions according to Dempster's rule:

$$m(A) = m_1(A) \otimes m_2(A) = \frac{\sum_{B \cap C = A} m_1(B) m_2(C)}{1 - \sum_{B \cap C = \emptyset} m_1(B) m_2(C)}$$

➡ proposed energy functional:

$$E(\varphi) = -\int_\Omega H(\varphi) m(\Omega_1)\, d\Omega - \int_\Omega (1 - H(\varphi)) m(\Omega_2)\, d\Omega + \nu \int_\Omega |\nabla H(\varphi)|\, d\Omega$$



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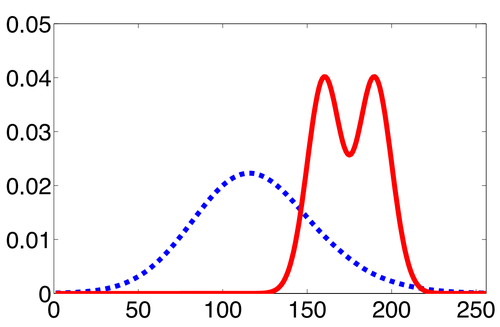
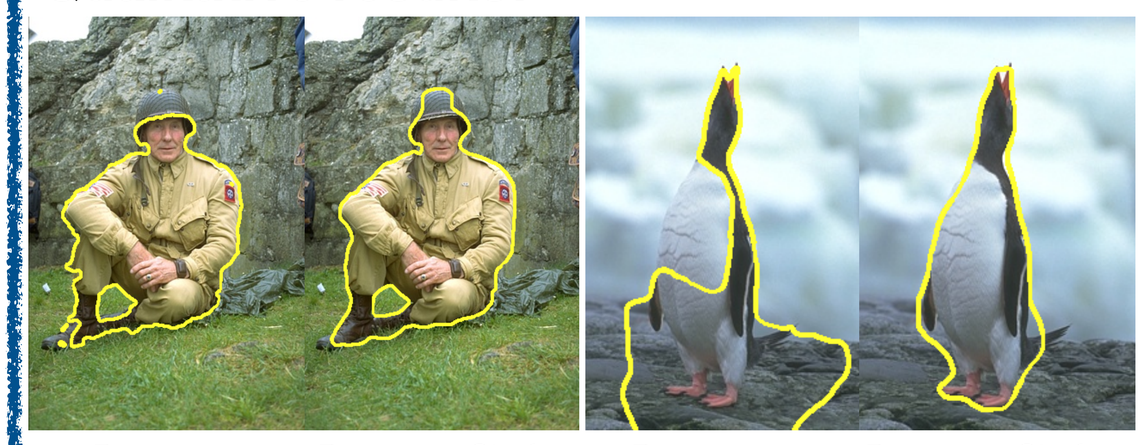


mass function fused with DS (proposed model)

➡ proposed method favours high probabilities
➡ separates much better the semantically interesting and different regions
➡ in some cases the proposed method leads to slightly worse segmentations

Qualitative results:

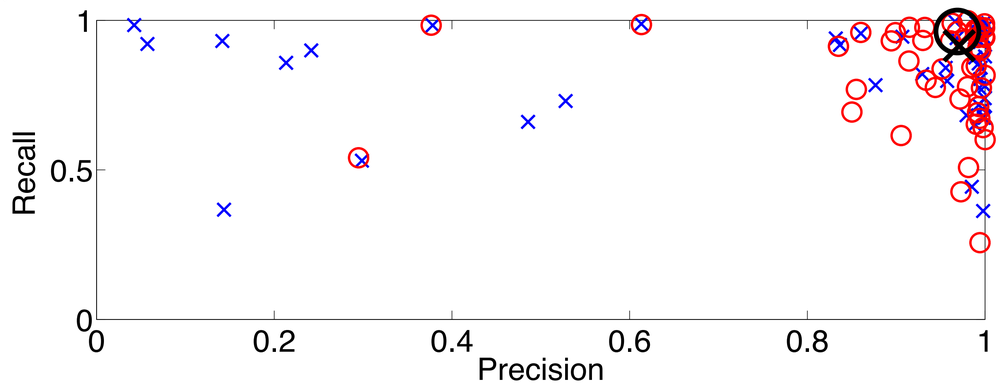


Bayes | Dempster-Shafer | Bayes | Dempster-Shafer

Bayes | Dempster-Shafer | Bayes | Dempster-Shafer

➡ the Bayesian framework using level-sets does not provide satisfying results
➡ feature fusion with Dempster's rule of combination outperform the standard approach

Quantitative results:



➡ Precision-Recall-Diagramm of 47 images from the Berkeley segmentation dataset [3]. The DS theory of evidence (circles) outperform the Bayesian framework (x)

Conclusion:

➡ proposed DS as an extension to the Bayesian framework of level-set based image segmentation
➡ combine feature channels by modeling inaccuracy and uncertainty at the same time

References:

[1] Chan, T., Vese, L.: Active contours without edges. IEEE Transactions on Image Processing 10 (2001) 266–277
[2] Shafer, G.: A mathematical theory of evidence. Princeton university press (1976)
[3] Martin, D., Fowlkes, C., Tal, D., Malik, J.: A database of human segmented natural images and its application to evaluating segmentation algorithms and measuring ecological statistics. In: Proc. 8th Int'l Conf. Computer Vision. Volume 2. (2001) 416–423

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