OPTIMIZING SHAPE PARTICLE FILTERS FOR THE DETECTION AND SEGMENTATION OF MEDICAL IMAGES

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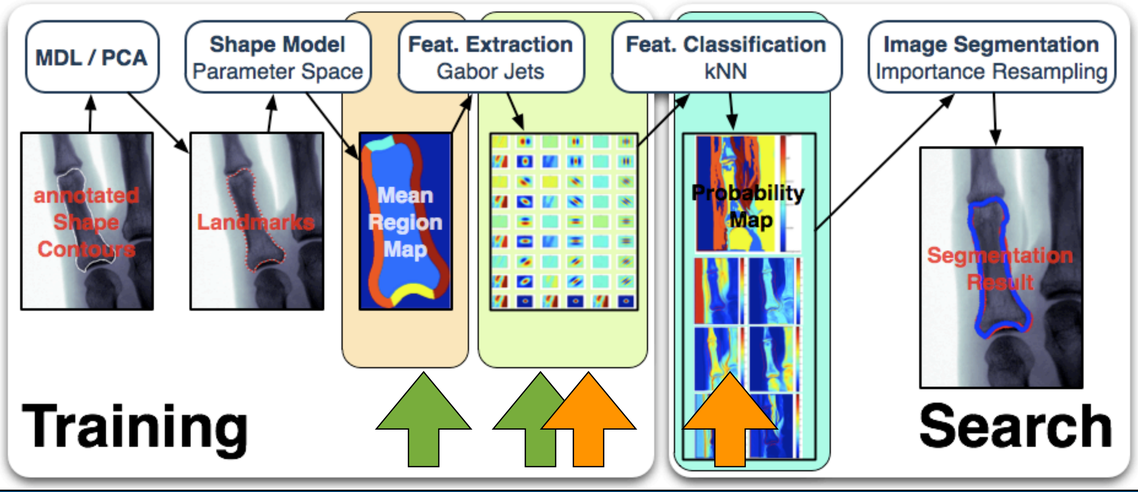
Motivation

Shape Particle Filters introduced in [deBruijne04b] offer promising results for the segmentation of medical images e.g. vertebræ, lungs and hearts.

Based on a global shape model a **region map** for the following feature extraction is defined. The **number** and **location** of these regions was previously defined **manually**.



Existing approaches suffer from **2 major drawbacks**:

- Computational Performance
- Segmentation Accuracy

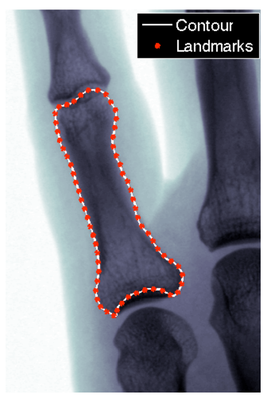
Contribution

- **Refined region maps** for more accurate results.
- **Monogenic Signal** based appearance features.
- **Elimination of classification** step for performance increase.

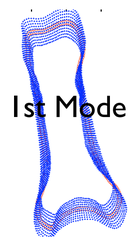
Method

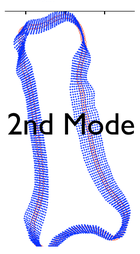
Shape Model

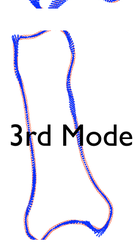
- Obtain Landmarks from annotated contour using **Minimum Description Length** (MDL)
- Align shapes and reduce their dimensionality using **Principle Component Analysis** (PCA)
- Generate **shape model**

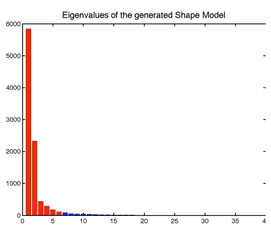


Contour and Landmarks







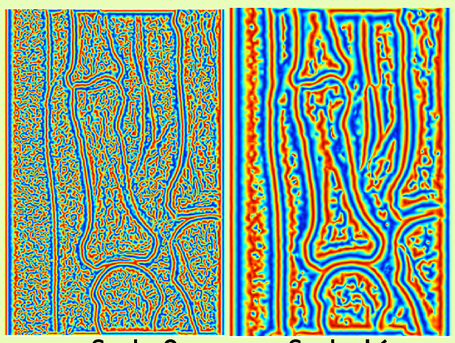


Eigenvalues

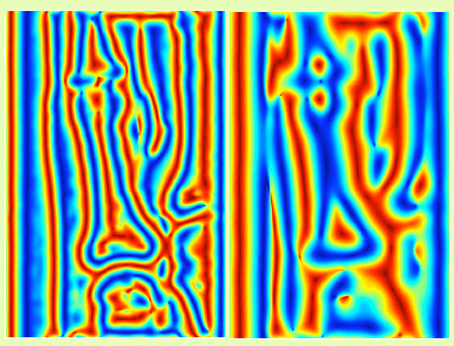
Feature Extraction

Replacing Gabor Jets with **Monogenic Signal based features** [Felsberg01]

$$A_f(x_1,x_2) = \sqrt{f^2 + (h_1 * f)^2 + (h_2 * f)^2}$$
$$\varphi(x_1,x_2) = acos(\frac{f(x_1,x_2)}{A_f(x_1,x_2)}), \varphi \in [0,\pi)$$
$$\theta(x_1,x_2) = atan2(h_2 * f, h_1 * f), \theta \in [-\pi,\pi)$$



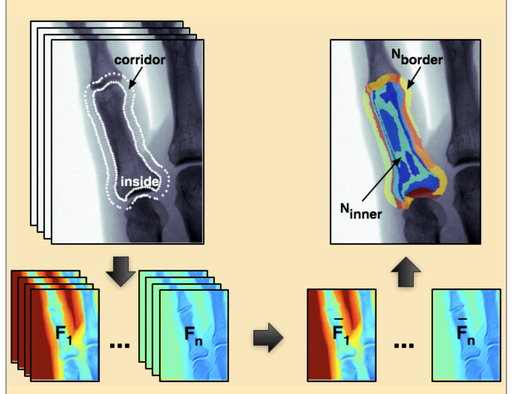
Scale 8 Scale 16



Scale 32 Scale 64

Region Map

Automatic Region Map
Replacing manual region maps by automatic regions determined by clustering mean feature vectors.



Per-Pixel Region Map
Based on the mean shape of the training set all or a certain percentage of pixels inside are used for hypothesis confidence computation. The confidence is computed pixel-wise, so no region clustering is necessary.
In contrast to automatic region maps only pixels within the mean shape contours are used. Furthermore the computational costly image classification step can be omitted.

Feature Classification

Speed Comparison
3 algorithms were compared in terms of computational performance:

- k-NN
- k-NN with a kd-tree
- linear SVM

	k-NN	kd-tree	SVM	speed gain vs. k-NN	speed gain vs. kd-tree
Synth.	32,6	20,5	4,2	7,8x	4,8x
Hearts	240	134,8	19,9	12,1x	6,8x
Metacarp. Bones	641	363,1	70,5	9,1x	5,2x

The linear SVM yielded the fastest classification result and was therefore used in all consequent experiments.

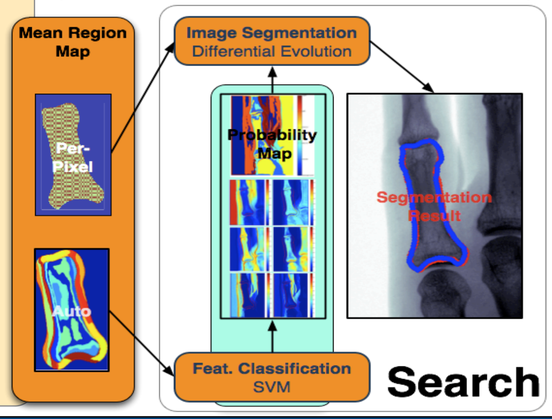
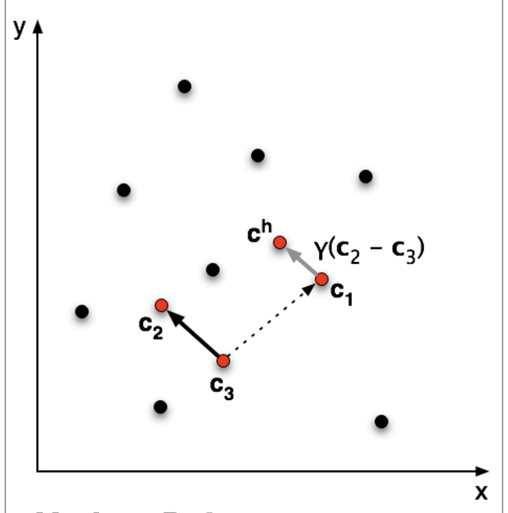


Image Segmentation

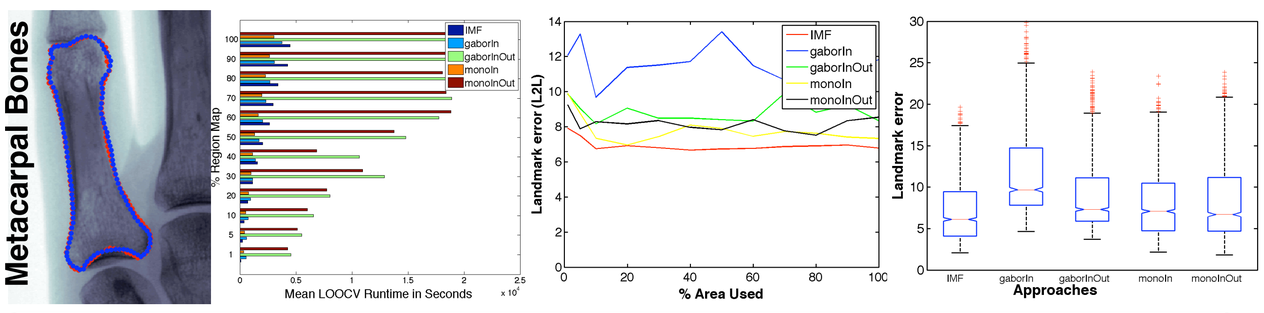
Differential Evolution
It is a genetic algorithm and aims at optimizing functions based on populations in parameter space, which in this case is the subspace (restricted to plausible models) of the model parameters c_i.

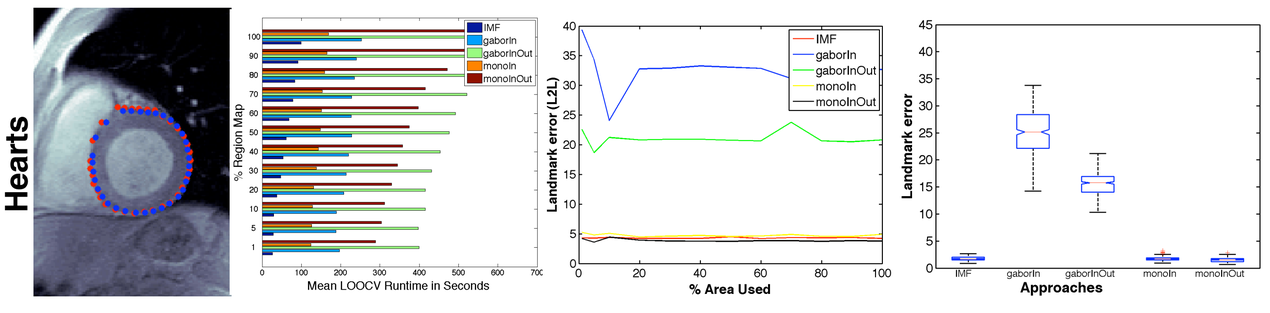


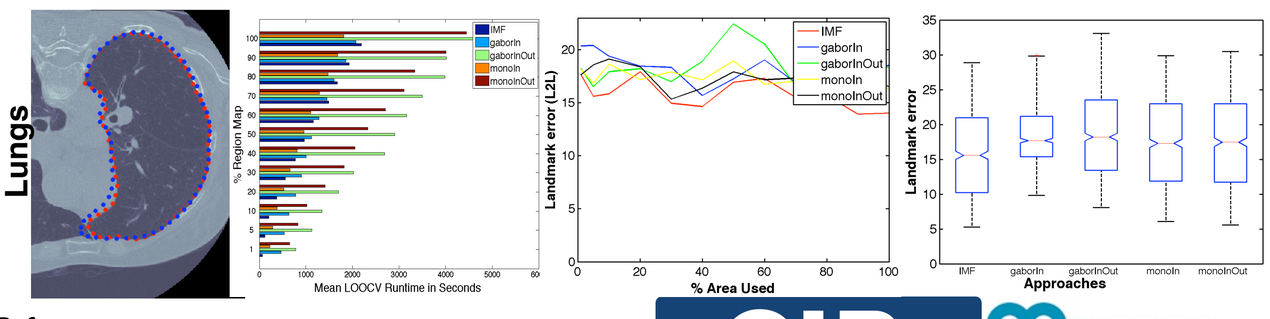
Update Rule:

$$\mathbf{c}^h = \mathbf{c}_1 + \gamma(\mathbf{c}_2 - \mathbf{c}_3)$$
$$\pi(\mathbf{c}^h) < \pi(\mathbf{c}_1)?$$

Results







Conclusion

- The **optimized Shape Particle Filter outperforms** the previous version in terms of **computational performance** and provides **equal** or even **better segmentation accuracy**.
- Especially the use of **Monogenic Signal based features** showed **promising results** on the scientific data sets.
- The **automatically derived region maps** yield regions describing the underlying image features and providing an **accurate representation** of the spacial representation of the object of interest
- By using **Per-Pixel region maps** the costly classification step can be omitted resulting in an **increase** in **computational performance**.

References:
[deBruijne04b]: M. de Bruijne, M. Nielsen. Shape Particle Filtering for Image Segmentation. Proc. MICCAI 2004, vol. 3216:pp. 168–175, 2004.

[Felsberg01]: M. Felsberg, G. Sommer. The monogenic signal. IEEE transactions on signal processing, vol. 49(12):pp. 3136–3144, 2001.

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