Estimating the Ground Truth From Multiple Individual Segmentations Incorporating Prior Pattern Analysis with Application to Skin Lesion Segmentation

X. Li, B. Aldridge, L. Ballerini, R. Fisher, J. Rees
University of Edinburgh

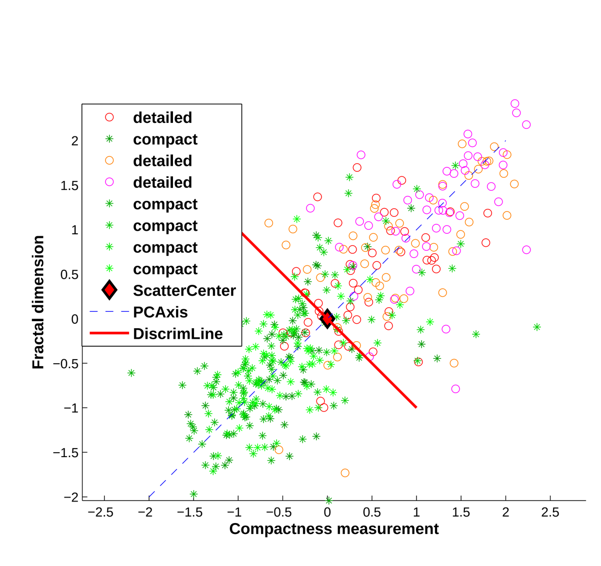
Claim

A proper lesion boundary ground truth estimation approach should take into account and compensate for the inter-rater variation.

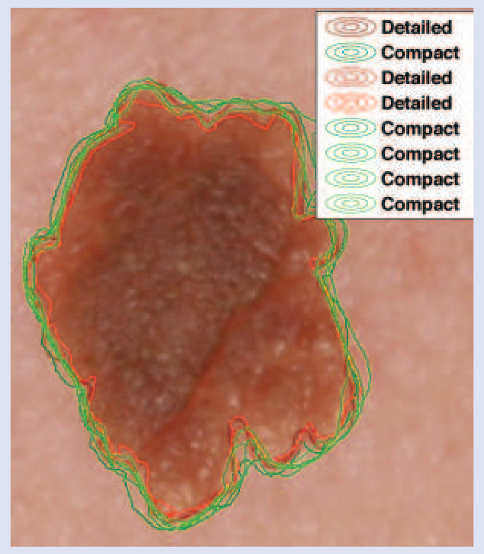
Manual Segmentation Patterns

Question: Are there different segmentation patterns?

- **Subject:** Inter-rate variation
- **Object:** 50 lesion images / 8 dermatologists
- **Pattern analysis features:** Compactness Measurement (CM) and Fractal Dimension (FD)
- **Result:** two segmentation patterns (**detailed** and **compact**) exist because of different segmentation policies



The scatter plot of FD and CM



Manual segmentations categorized using the above analysis

Ground Truth Estimation Methods Solved using Level-set approach

- **Maximize the *a posteriori* (MAP) probability based energy function (LSML)**

$$E_{LSML} = -\sum_{n}\sum_{x\in\Omega_n} \log p(T(x)|D_{\{1,2,\dots,J\}}(x)) \quad (1)$$

(2)

- **Segmentation pattern information based energy function**

$$E_{shape} = \int_{\Omega} [T(x) - SPM(x)]^2 dx \quad (3)$$

(4)

- **The ground truth estimation energy function (LSMLP)**

$$E = E_{LSML} + E_{shape}. \quad (5)$$

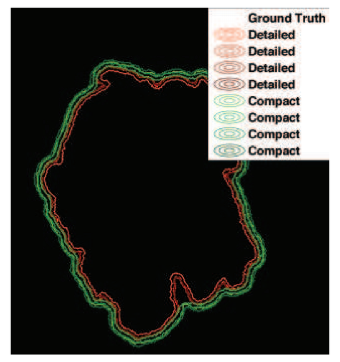
- **The ground truth calculation equation: maximizing the energy function**

$$\frac{\partial\phi}{\partial t} = -\frac{\partial E(\phi)}{\partial\phi} = \delta(\phi)\left(\log\frac{W}{V} + \gamma \times (2 \times SPM(x) - 1)\right). \quad (6)$$

- **Notations:** $D_{\{1,2,\dots,J\}}(x)$: manual segmentations at pixel positation x; $T(x)$: the estimated ground truth; SPM: shape prior model learnt from manual seegmentation pattern (see paper for details); γ weights the importance of the shape prior energy; W and V are the joint conditional probability that pixel x belongs to the lesion and skin, respectively.

Experiments

- **Evaluation metrics:** XOR and FOM
- **Generate synthetic data for testing**



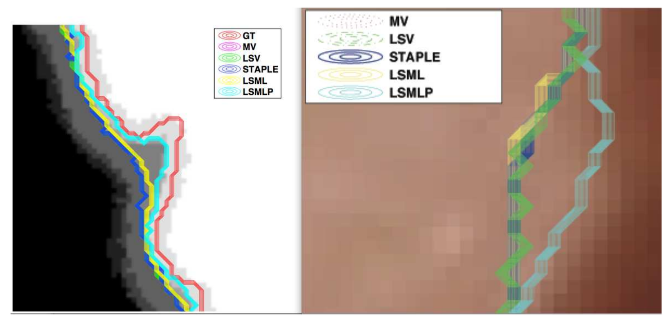
The synthetic segmentations

- **Comparisons:** LSMPL has the best performance.

	Methods				
Metrics	**MV**	**LSV**	**STAPLE**	**LSML**	**LSMLP**
XOR (%)	3.8409	3.8409	3.7212	3.2733	2.1615
FOM (%)	8.9026	8.9026	10.6596	13.1484	26.7412
Sensitivity	1.0000	1.0000	1.0000	1.0000	1.0000
Specificity	0.9709	0.9709	0.9719	0.9754	0.9839

The performance of different ground truth estimation methods

Notations: MV: majority vote method; LSV: variation minimization based approach (which is proved to be identical to MV, see details in paper); STAPLE [Warfield2004].



Comparison on synthetic image (Left) and real image (Right)

Conclusion

- Experiments on both synthetic and real data show that segmentation style prior information helps to find a more accurate estimate of the ground truth.
- LSMLP uses this prior information to produce a ground truth that has smaller error.

Reference

Simon K Warfield, Kelly H Zou and William M Wells. Simultaneous truth and performance level estimation (staple): an algorithm for the validation of image segmentation. IEEE Transactions on Medical Imaging, 23(7):903 921, 2004.

School of informatics