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Utilisation of Contour Criteria in Micro-Segmentation of SAR Images

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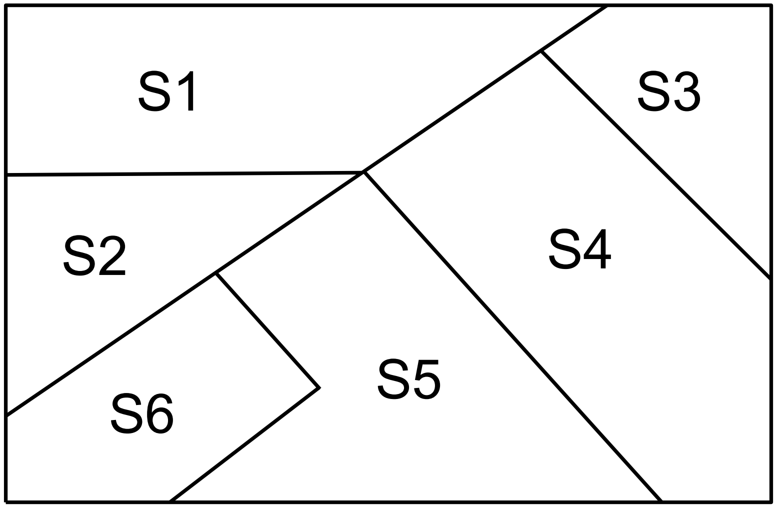
Image Segmentation is the division of the image plane into regions



Two basic questions:

1- **What** kind of regions do we want ?

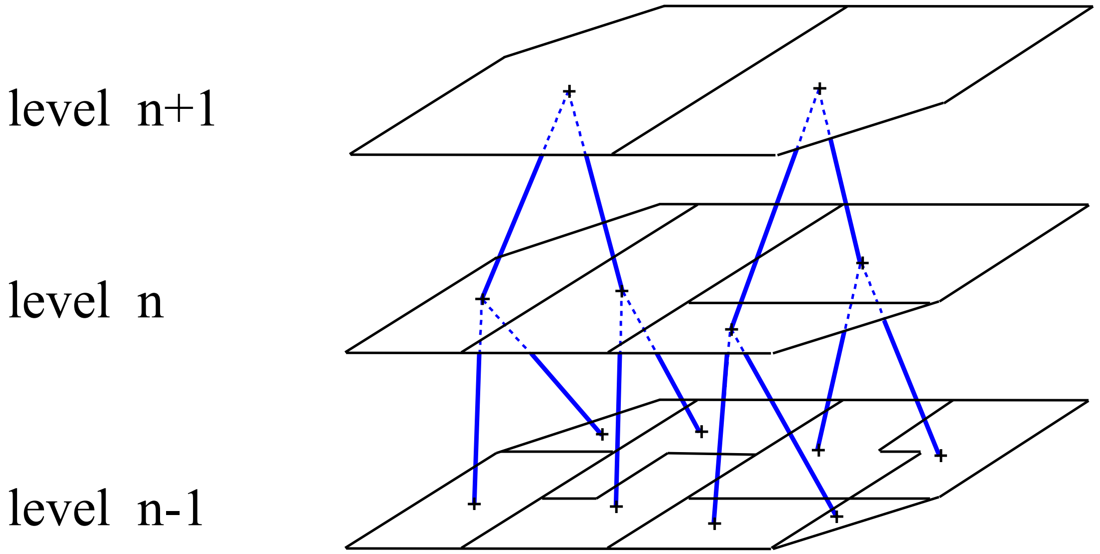
- Homogeneous regions
- Segment similarity

2- **How** can we obtain them ?

- Algorithm design

HIERARCHICAL SEGMENTATION BY STEP-WISE OPTIMISATION

A hierarchical segmentation begins with an initial partition P^0 (with N segments) and then sequentially merges these segments.

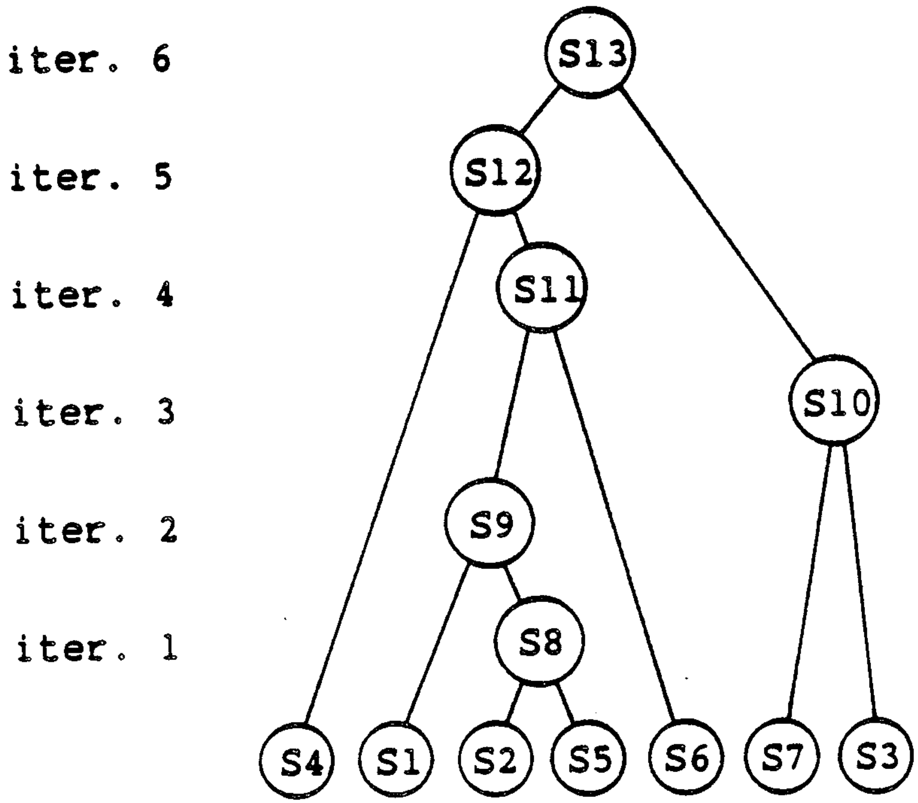


Segment tree

STEP-WISE OPTIMISATION

- A criterion, corresponding to a measure of segment similarity, is used to define which segments to merge.
- At each iteration, an optimization process finds the two most similar segments and merges them.
- This can be represented by a segment tree, one node per iteration, where only the two most similar segments are merged.

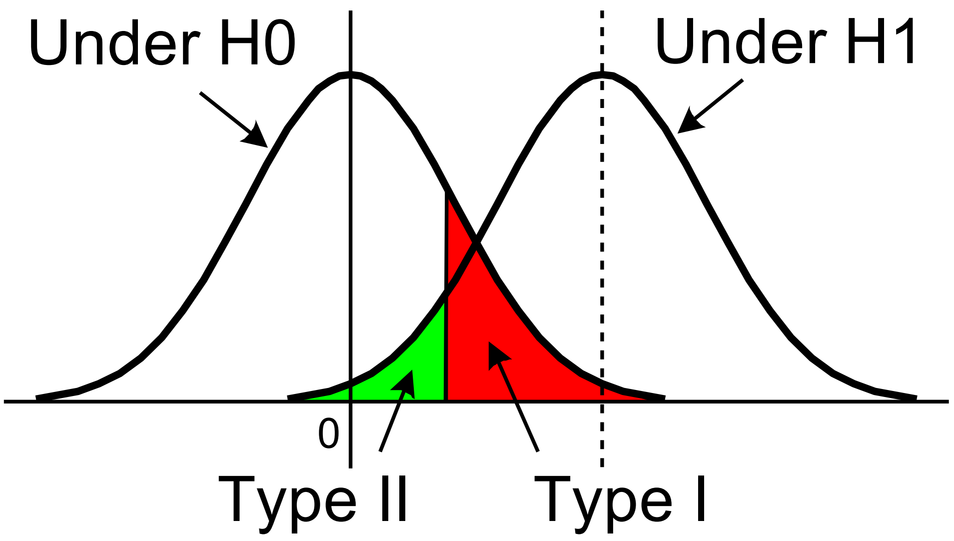
Sequence of segment merges.



Segmentation by hypothesis testing

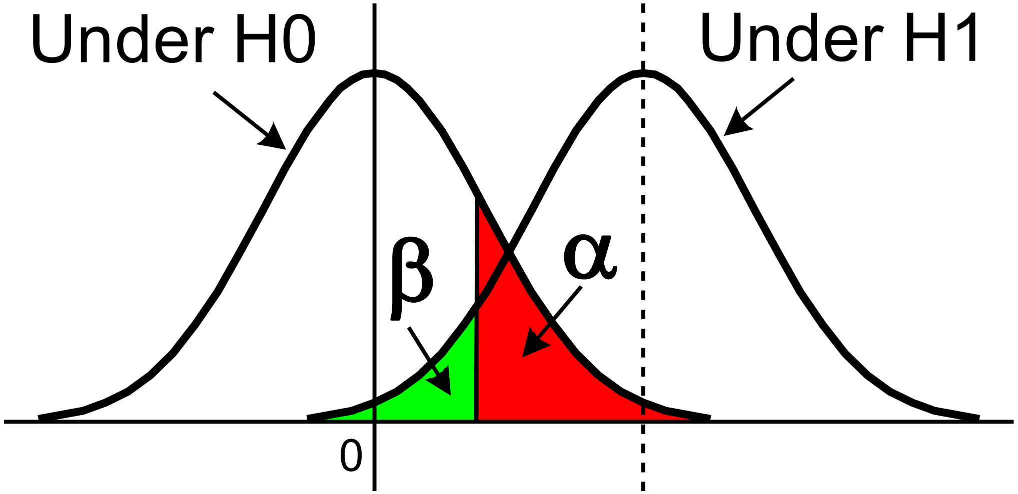
Two hypothesis
H0: segments are similar
H1: segments are different

Distributions of the statistic d under H0 and H1



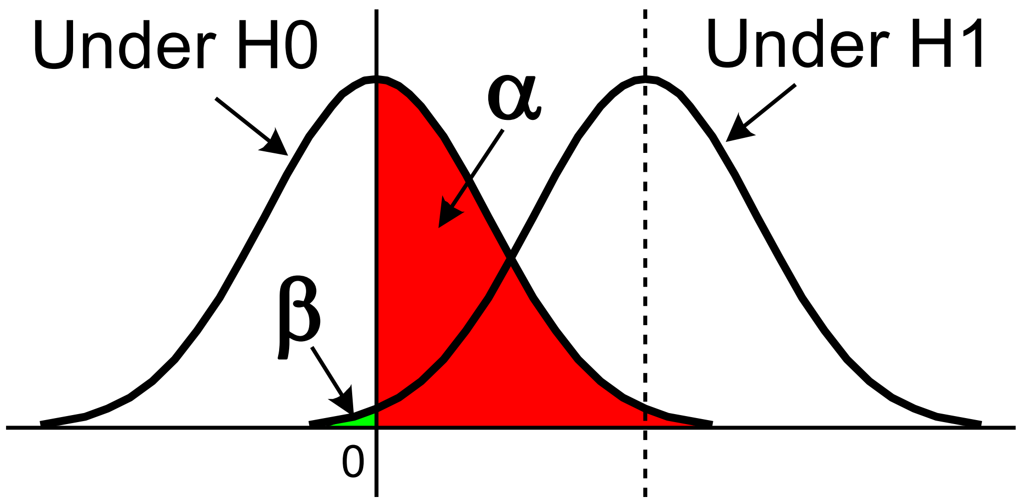
Two types of errors
Type I: not merging similar segments
Type II: merging different segments

α = Prob(Type I errors)
β = Prob(Type II errors)



Select the threshold to minimise α or β, but not both simultaneously

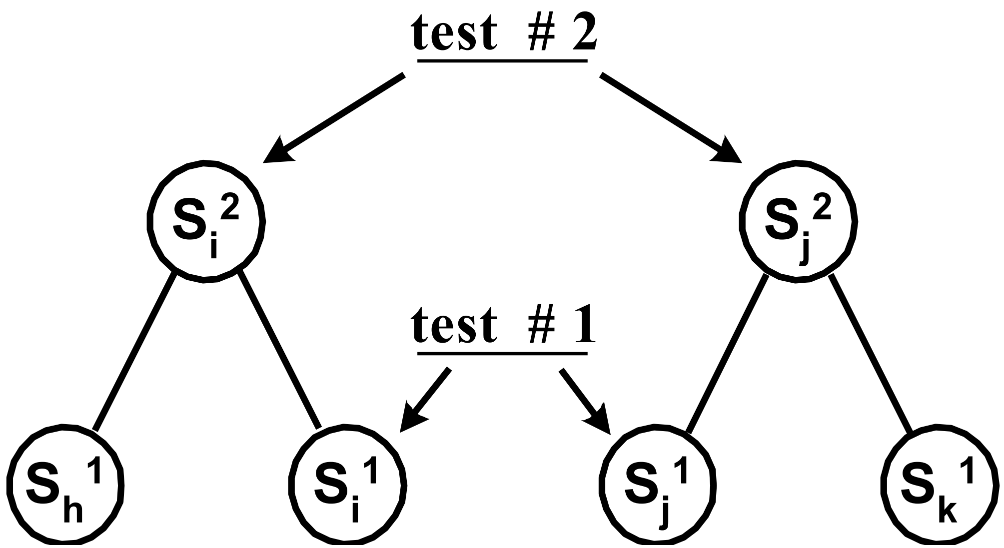
In hierarchical segmentation, type II errors (merging different segments) can not be corrected, while type I errors can be corrected later on.



The distribution of H1 and β are unknown.
Reduce β by increasing α.

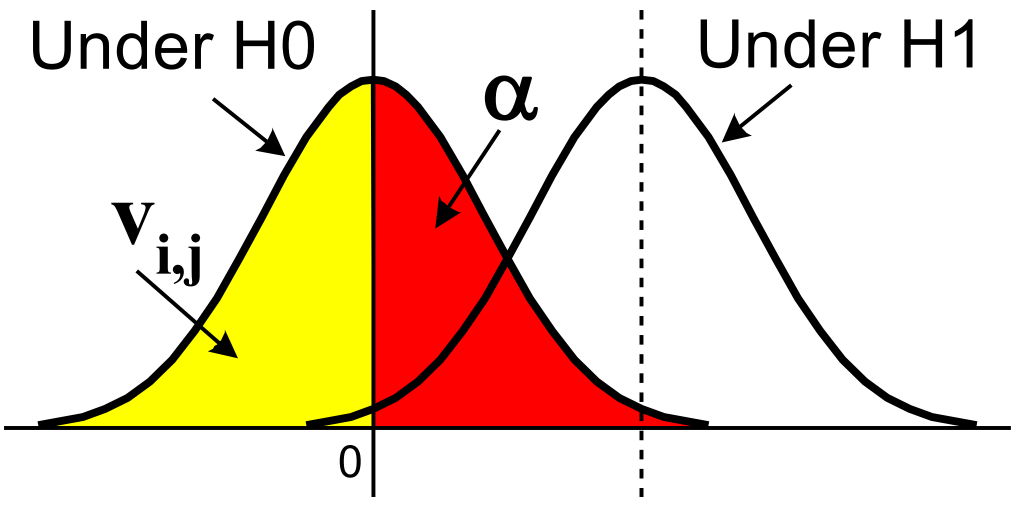
Sequential testing:
α will be reduced as segment sizes increase.

$$\alpha_{1+2+\ldots} \le \text{minimum}(\ \alpha_1, \alpha_2, \ldots\ )$$
$$\beta_{1+2+\ldots} \ge \text{maximum}(\ \beta_1, \beta_2, \ldots\ )$$



Stepwise criterion

Find and merge the segment pair (i, j) that minimises $V_{i,j}$ (= 1 - α).



$$V_{i,j} = \text{Prob}(d \leq d_{i,j} \; ; H0) \quad (= 1 - \alpha).$$

Constant value region with uniform additive noise

$$\text{Region } R_k \quad \propto \quad N(m_k, \sigma^2)$$

$$d_{i,j} \quad = \quad \left| \mu_i - \mu_j \right|$$

$$v_{i,j} \quad = \quad \text{prob}(d \le d_{i,j} \,;\, H0)$$

$$v_{i,j} \quad = \quad \int_{-d_{i,j}}^{d_{i,j}} \frac{1}{\sqrt{2\pi}\;\;\sigma_d} \;\exp\left(\frac{-x^2}{2\sigma_d^2}\right)\; dx$$

$$v_{i,j} \quad = \quad 2\,\text{erf}(d_{i,j}/\sigma_d)$$

$$\text{where} \quad \sigma_d{}^2 = \left(1/N_i + 1/N_j \right) \sigma^2$$

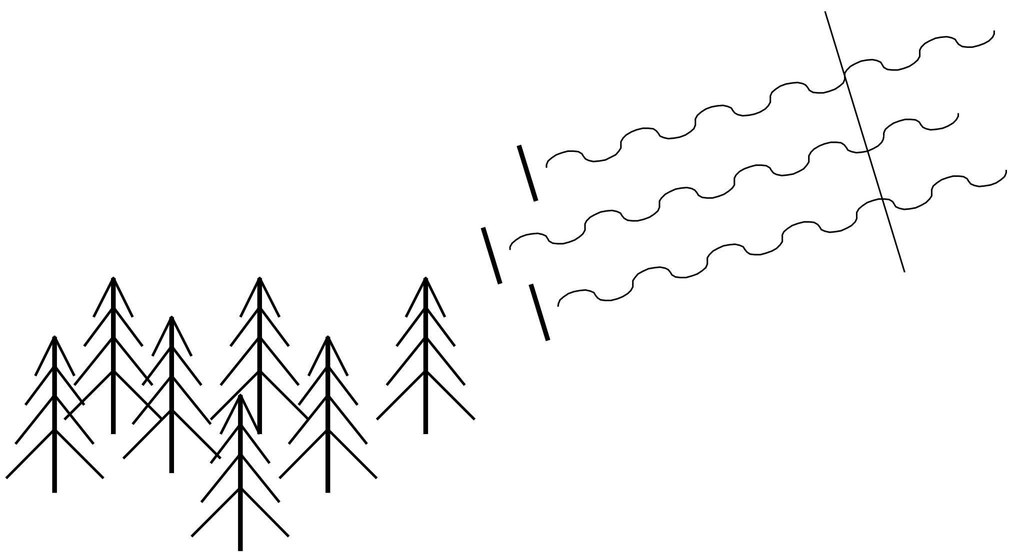
Constant value region

$$C_{i,j}^{ward} = \frac{d_{i,j}}{\sigma_d} = \sqrt{\frac{N_i N_j}{N_i + N_j}} \frac{|\mu_i - \mu_j|}{\sigma}$$

SEGMENTATION OF SAR IMAGE

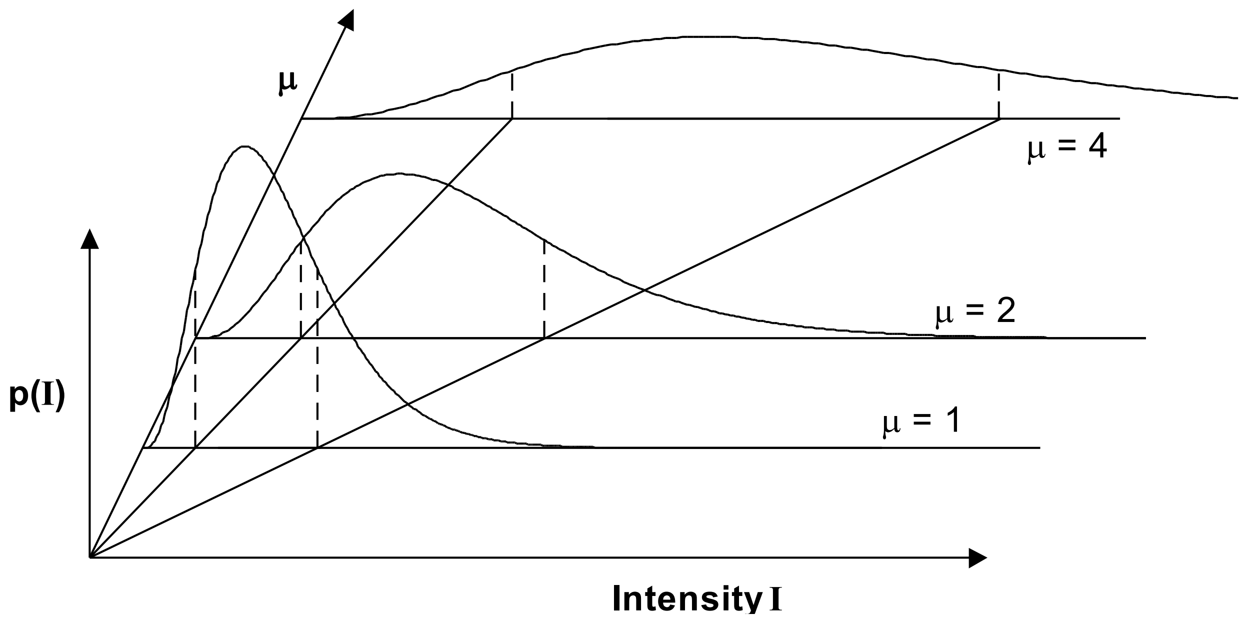
SAR IMAGE → COHERENT SIGNAL (RADAR)

→ INTERFERENCE PATTERN



MULTIPLICATIVE NOISE

$$p(I) = \frac{1}{\Gamma(L)} \left(\frac{L}{\mu}\right)^{L} I^{L-1} \exp\left(-L\, I/\mu\right)$$



Noise is proportional to the amplitude

SAR criterion

Using a Gaussian approximation for large NL value, we have:

$$\sigma_d^{\,2} = \left(1/N_i + 1/N_j \right) \mu_{i+j}^2 / L$$

$$C_{i,j}^{sar} = \frac{d_{i,j}}{\sigma_d} = \sqrt{\frac{N_i N_j}{N_i + N_j}} \; \frac{\left|\mu_i - \mu_j\right|}{\mu_{i+j}} \; \cancel{\sqrt{L}}$$

The segment dispersion (difference) is divided by the segment mean

IMPORTANT NOISE

PROBLEM WITH THE FIRST MERGES

SHAPE CRITERIA NEEDED

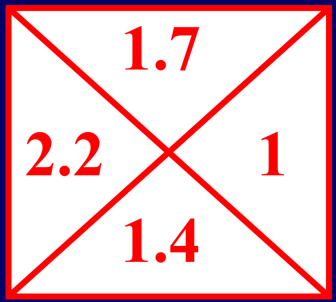
SHAPE CRITERIA

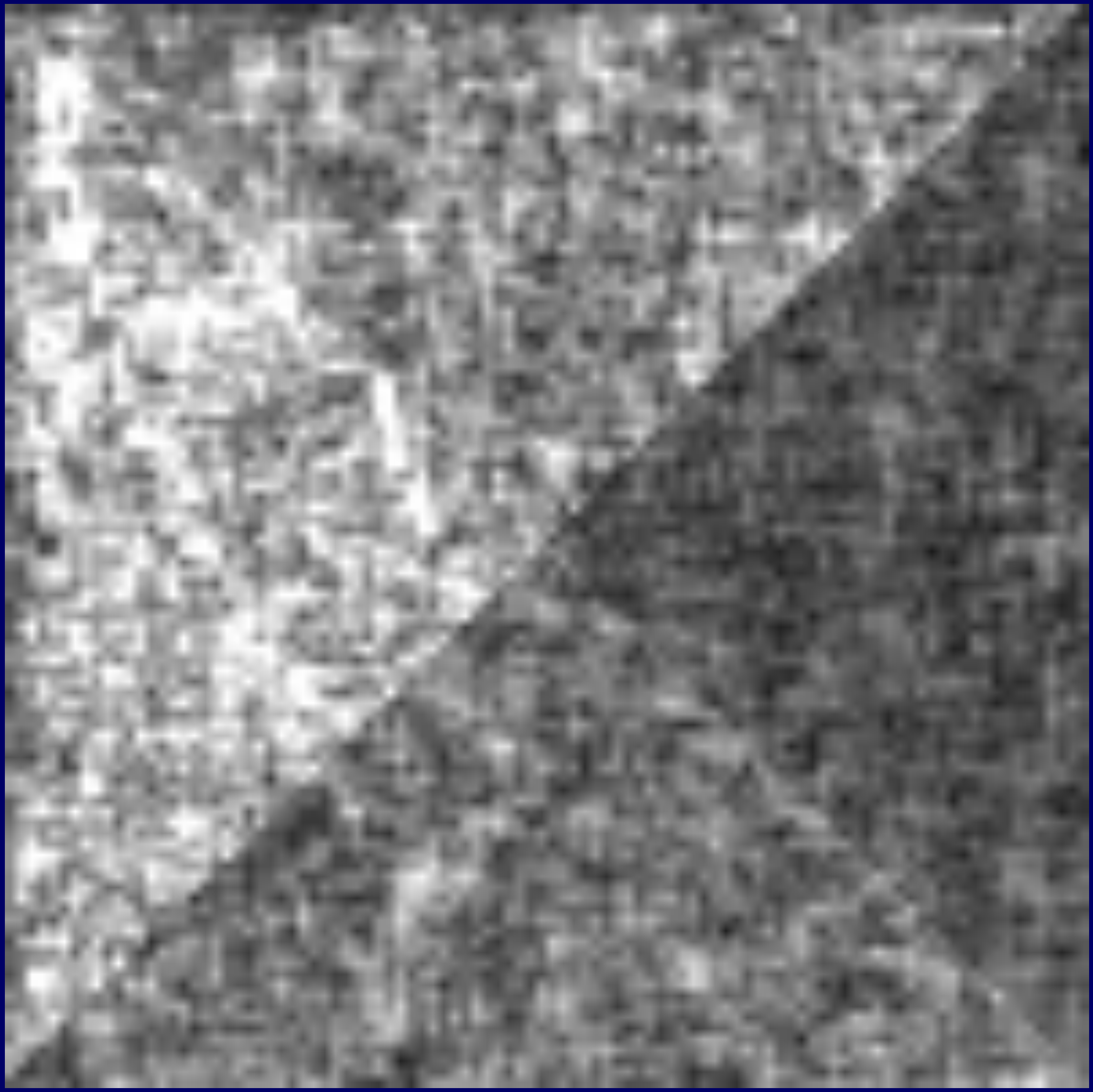
- Bonding box – perimeter Cp
- Bonding box – area Ca
- Contour length Cl

New criteria

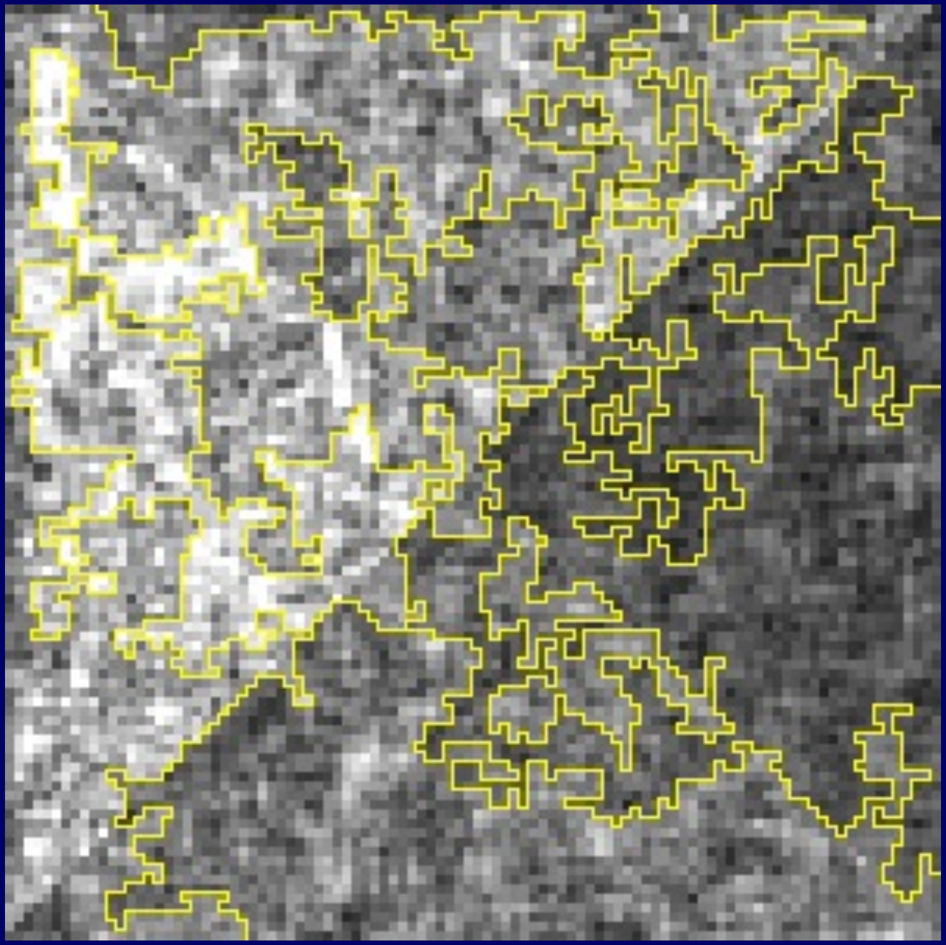
$$C_{i,j}^{contour} = {C_{i,j}^{sar}}^2 \times Cp^2 \times Ca \times Cl$$

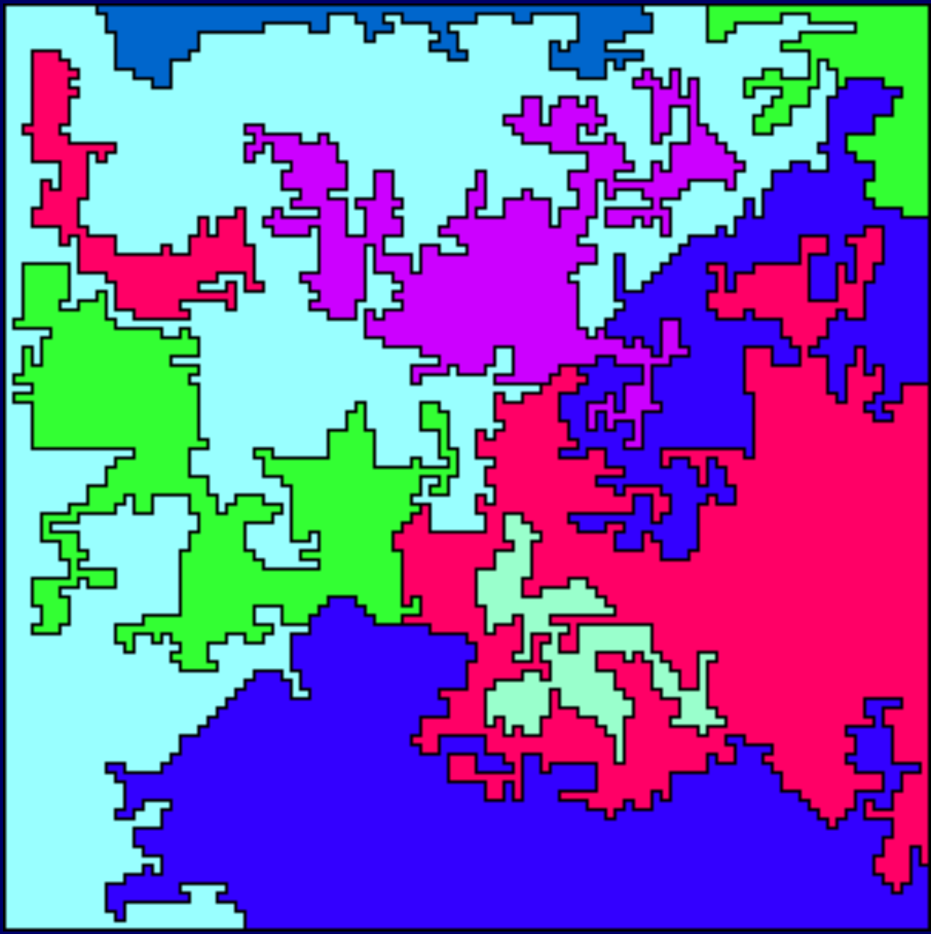
4 regions, 4 looks, 100x100



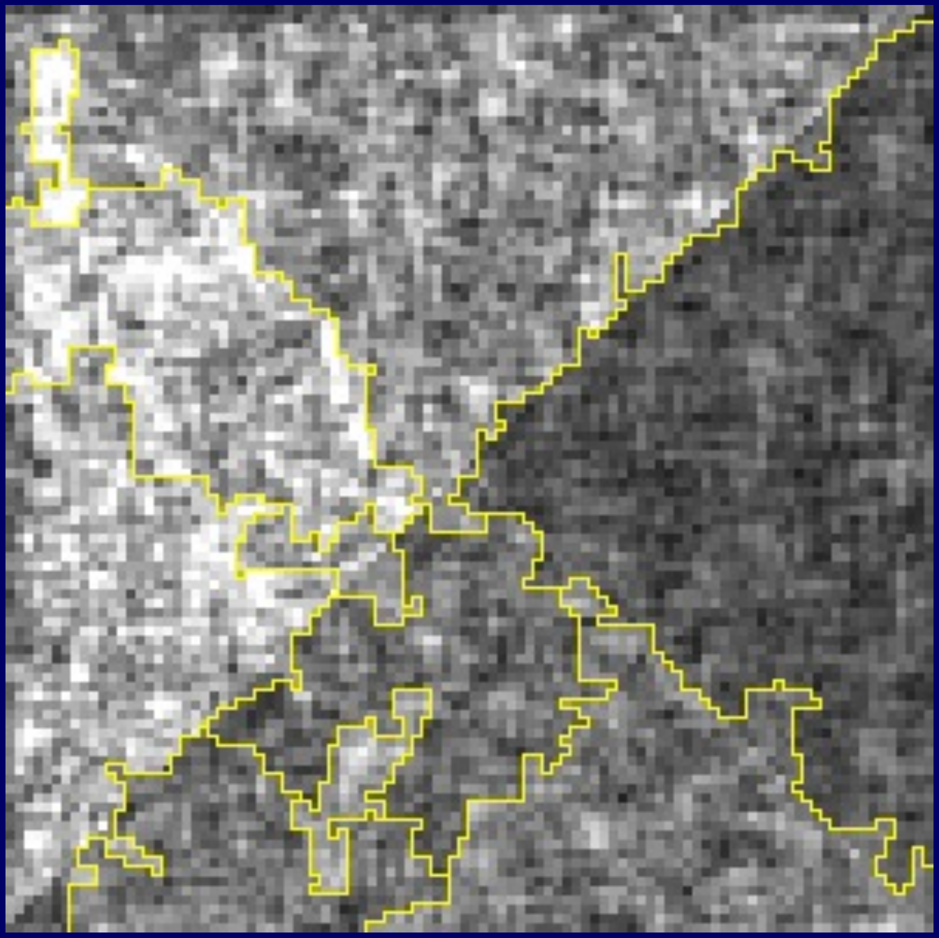


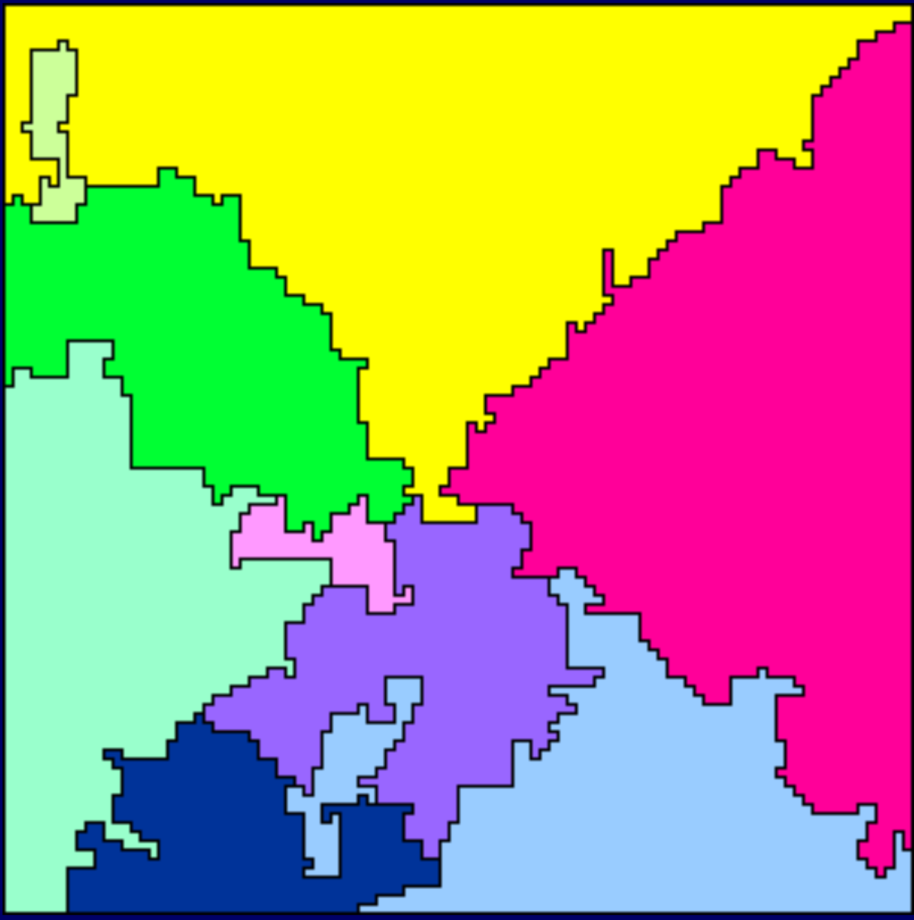
10 segments, standard criterion



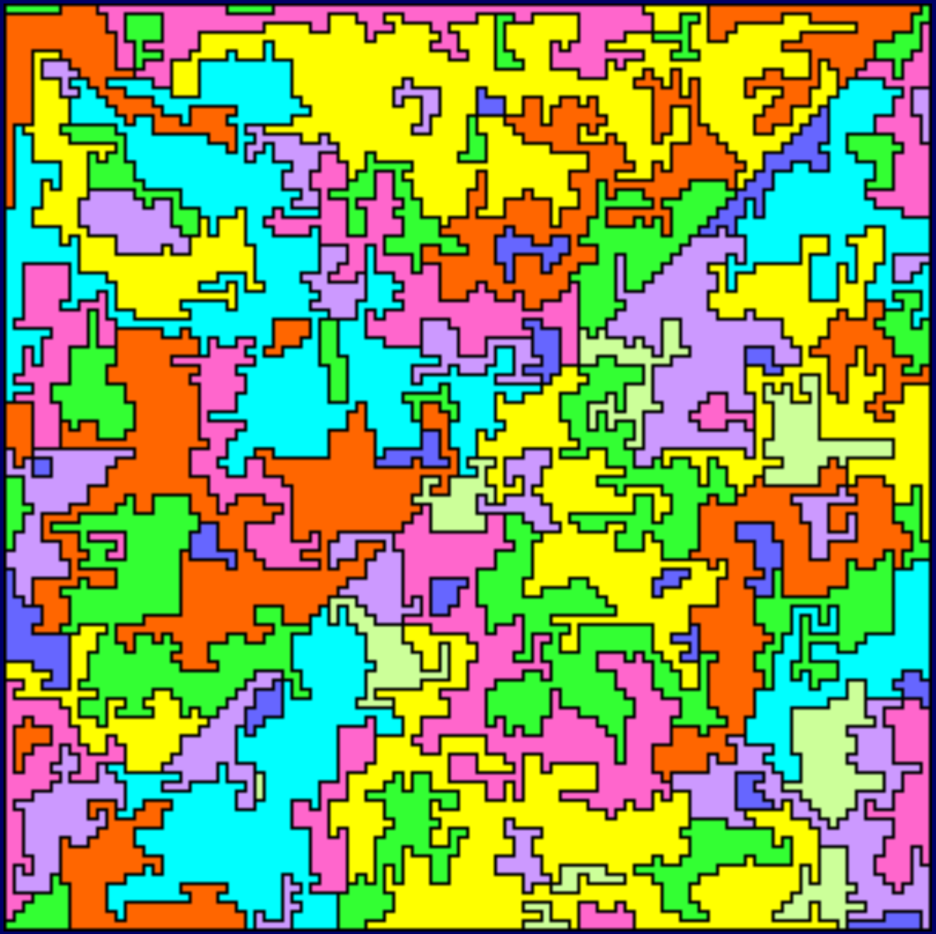


10 segments, shape criterion

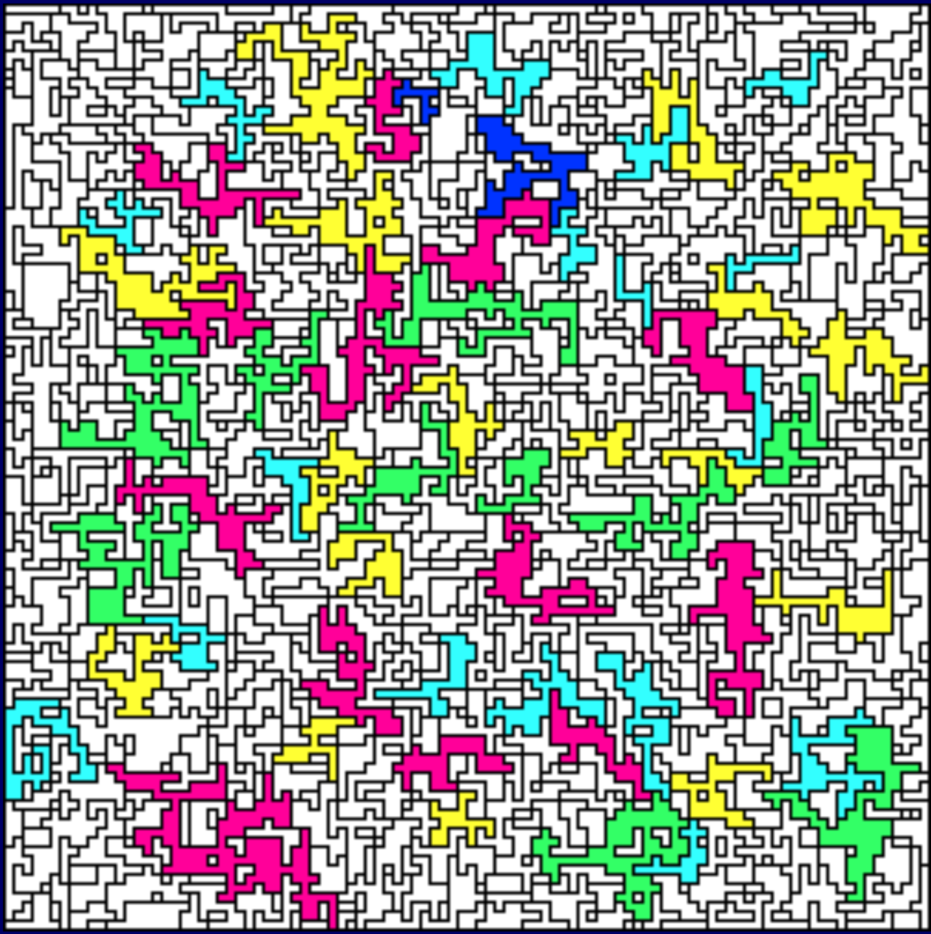




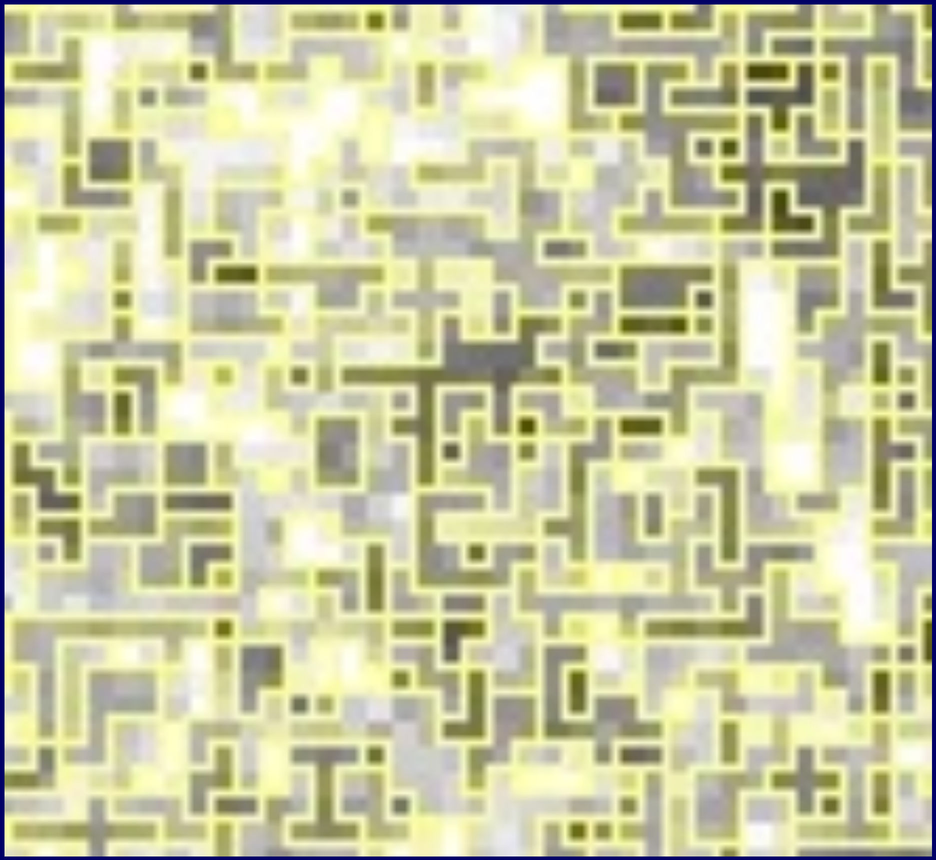
standard criterion

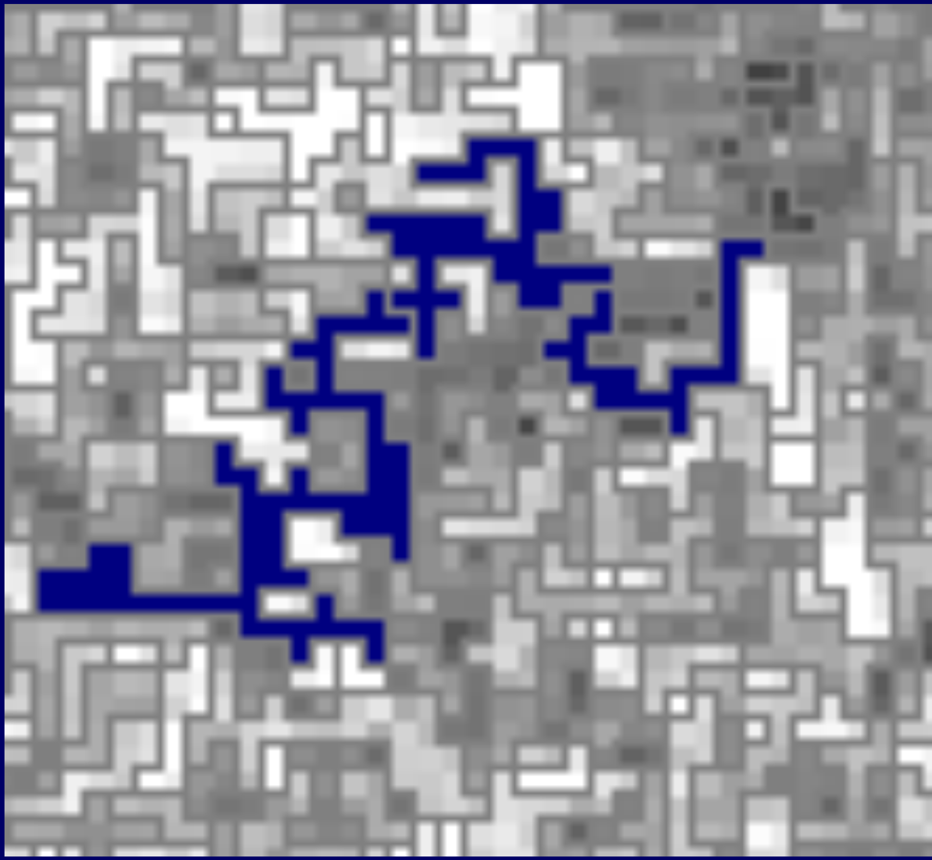


100 **s**egments



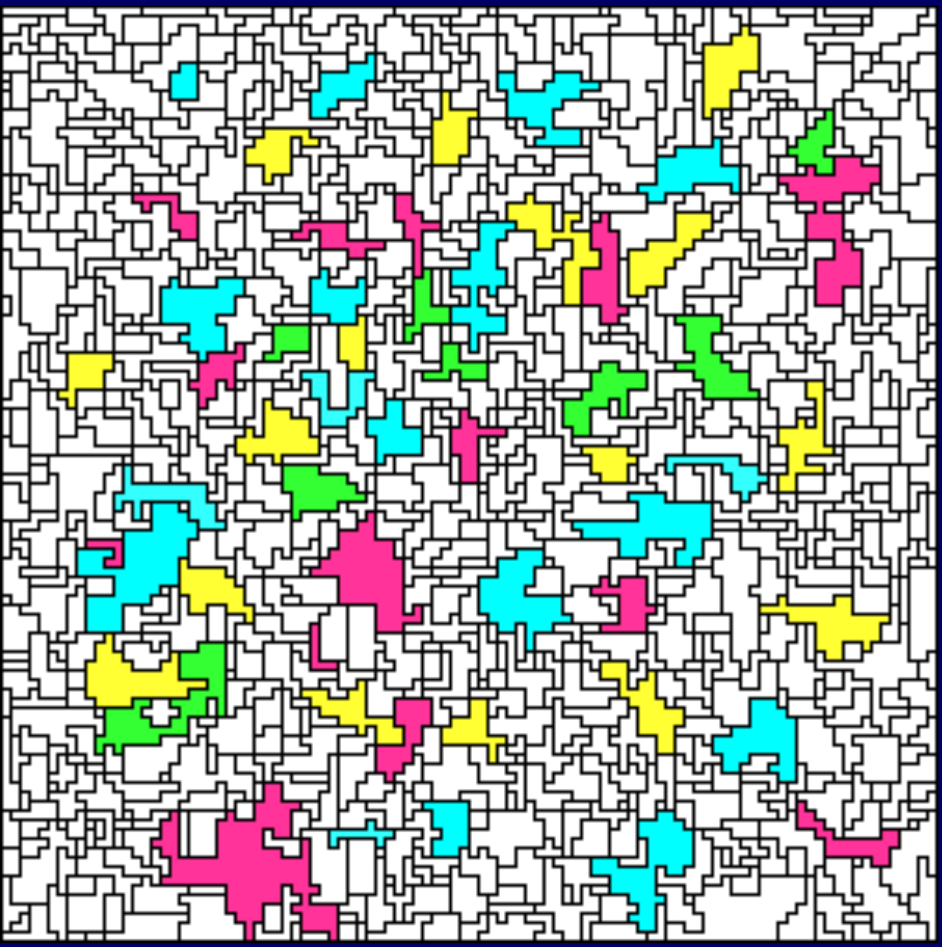
1000 **s**egments



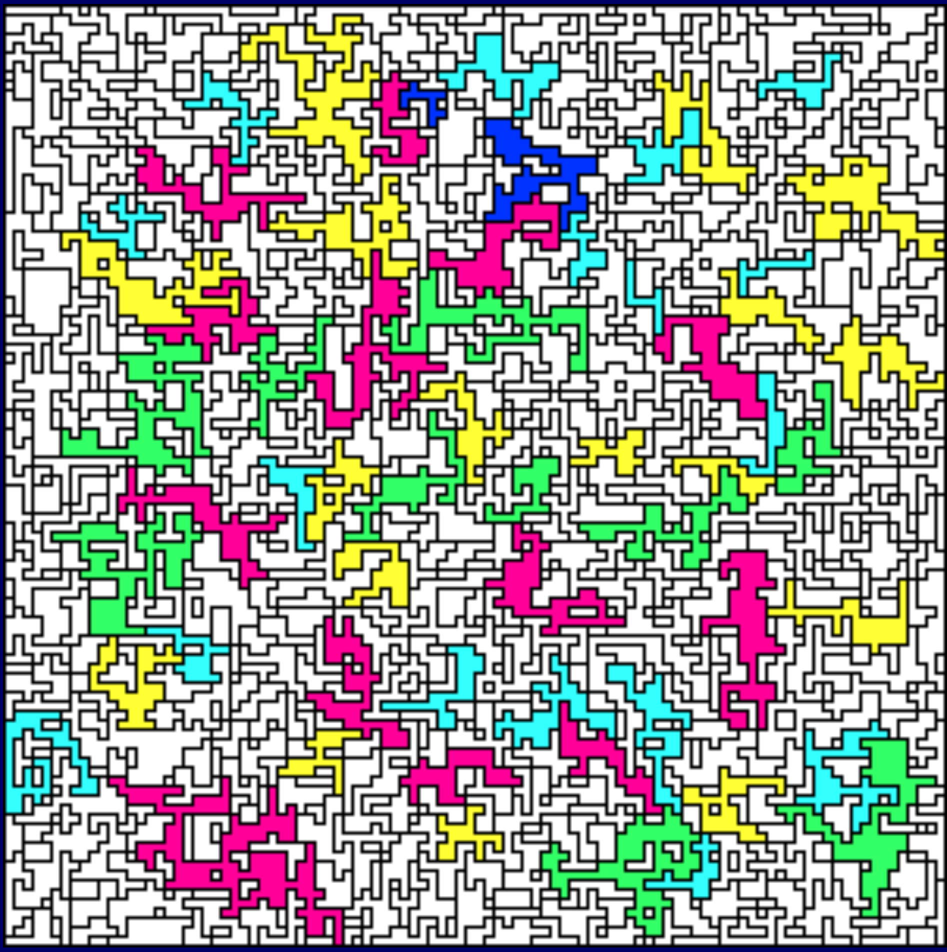


2000 **s**egments

Shape vs standard criterion, 1000 segments



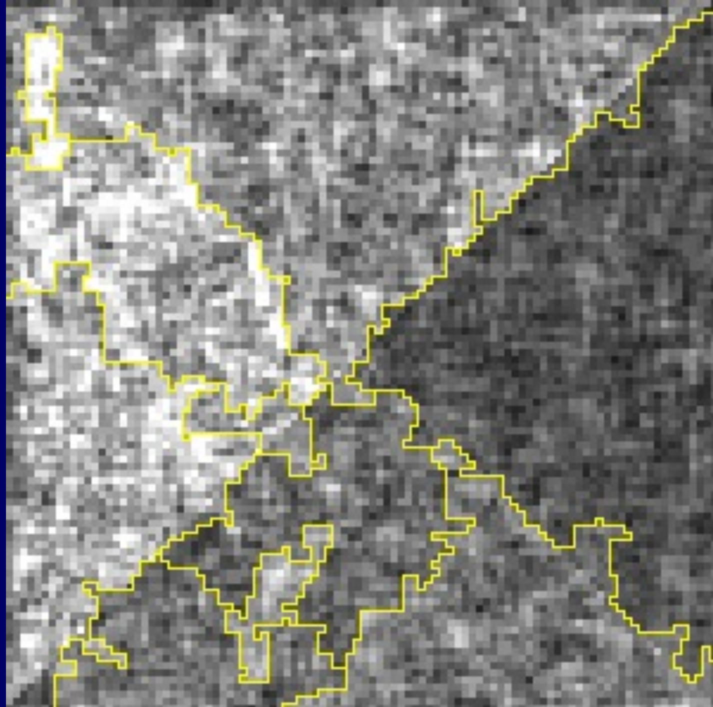
with shape criterion

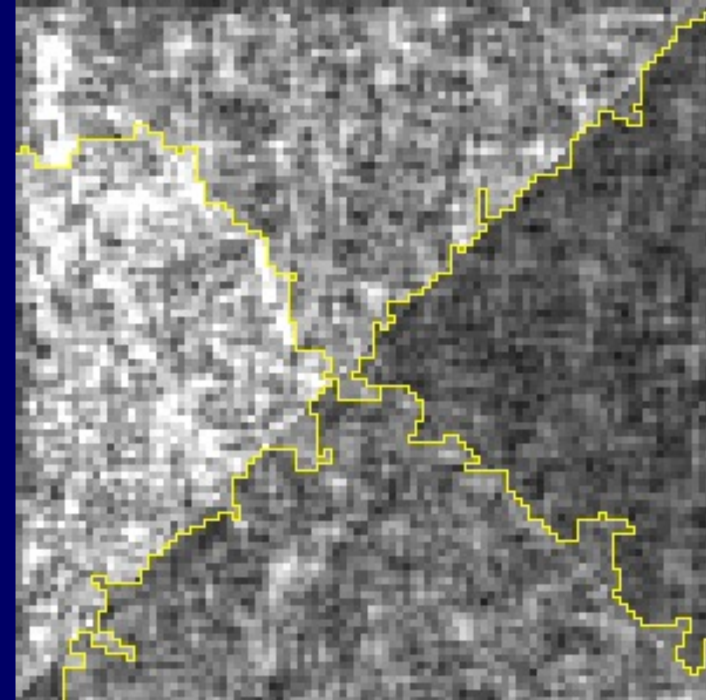


without shape criterion

10

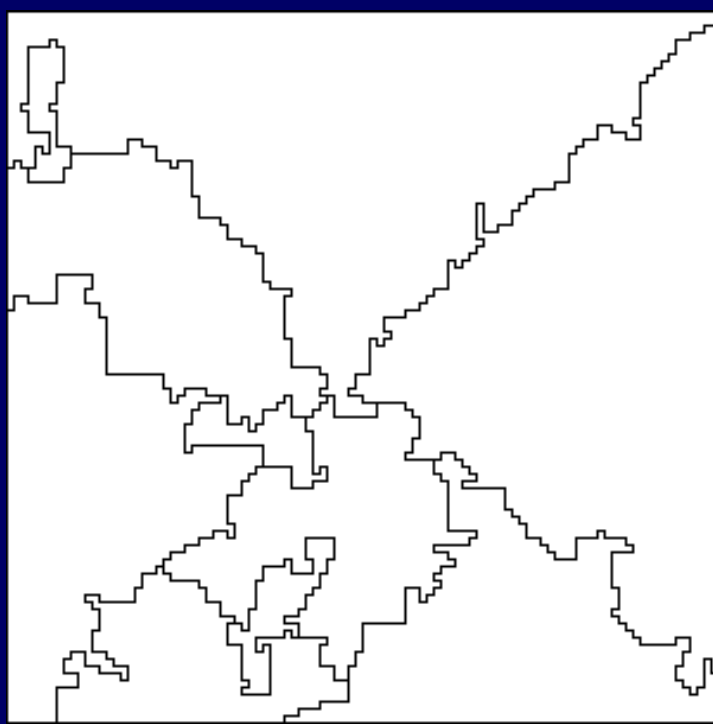
Segments

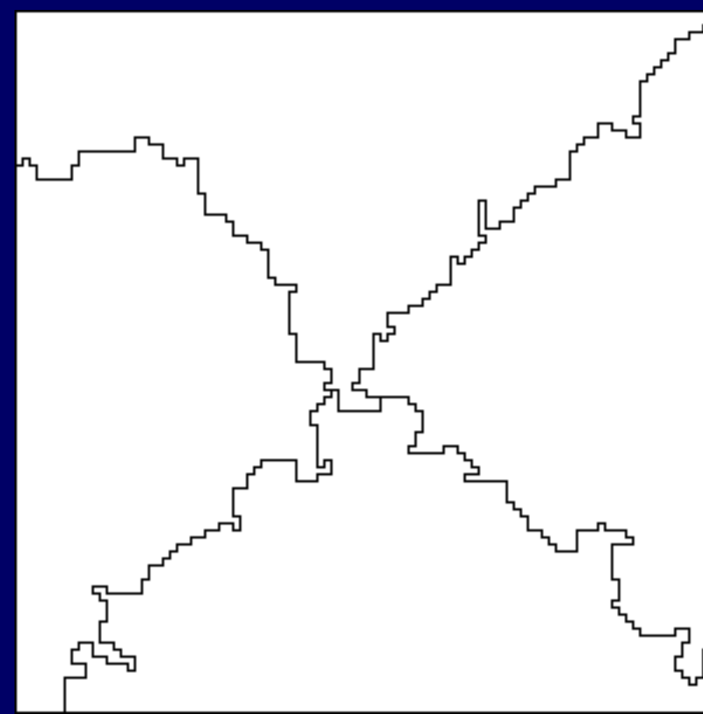




4

Segments





SHAPE CRITERIA

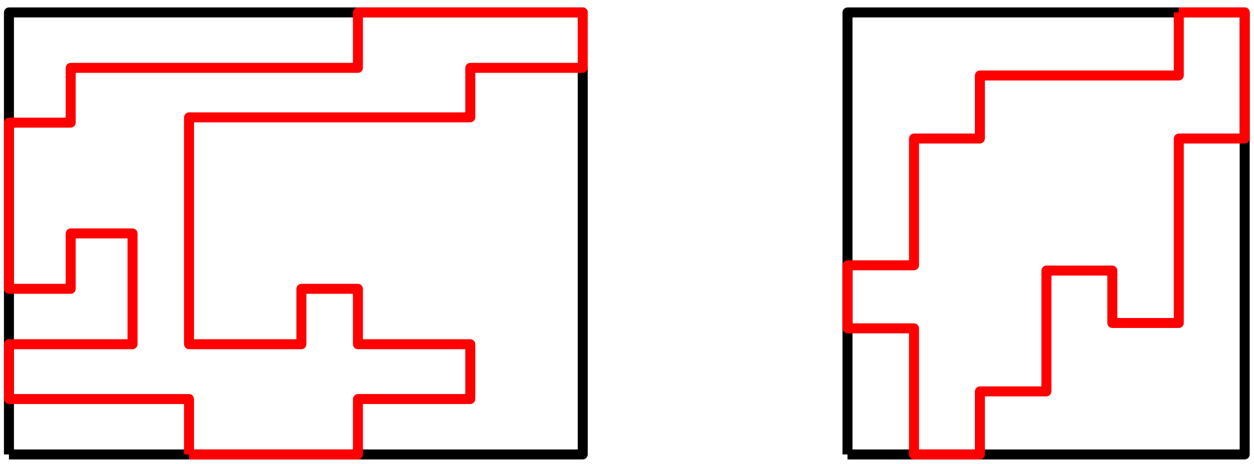
- Bonding box – perimeter   Cp
- Bonding box – area   Ca
- Contour length   Cl

New criteria

$$C_{i,j}^{contour} = {C_{i,j}^{sar}}^2 \times Cp^2 \times Ca \times Cl$$

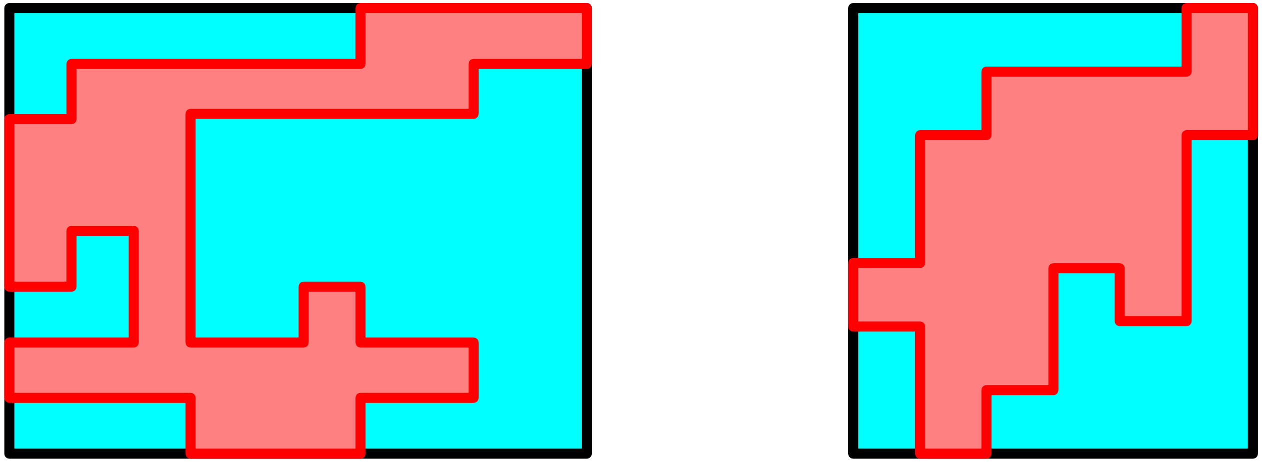
Bonding box – perimeter

$$Cp = \frac{perimeter\ of\ S_i \cup S_j}{perimeter\ of\ bonding\ box}$$



Bonding box – area

$$Ca = \frac{area\ of\ bonding\ box}{area\ of\ S_i \cup S_j}$$

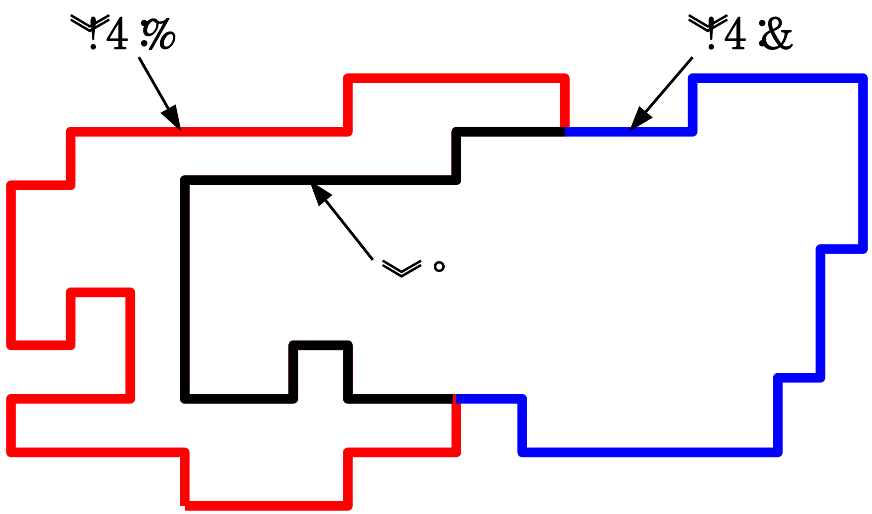


Contour length

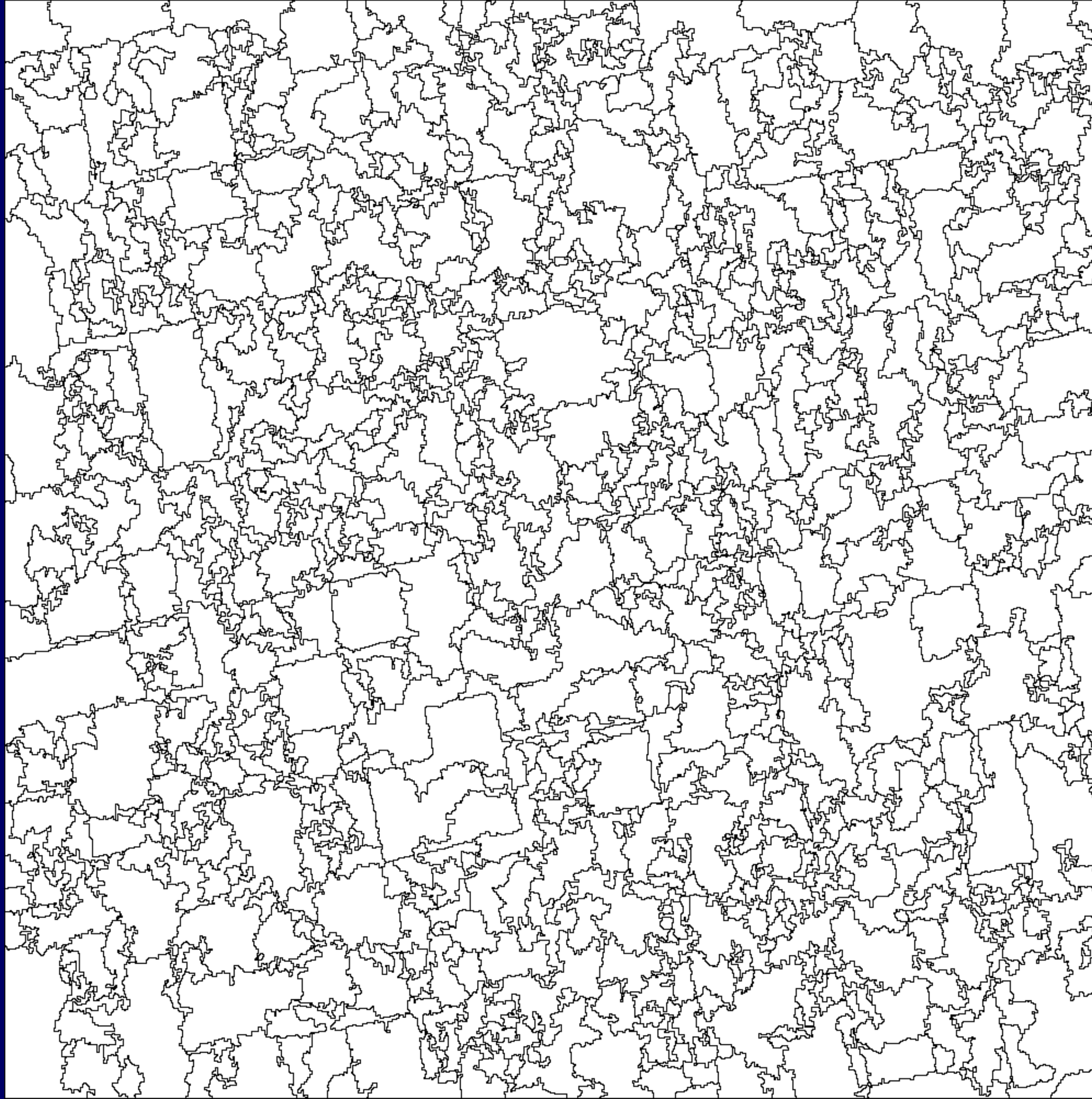
$$Lc \quad = \quad \text{length of common part of contours}$$

$$Lex\ i \quad = \quad \text{length of exclusive part for } S_i$$

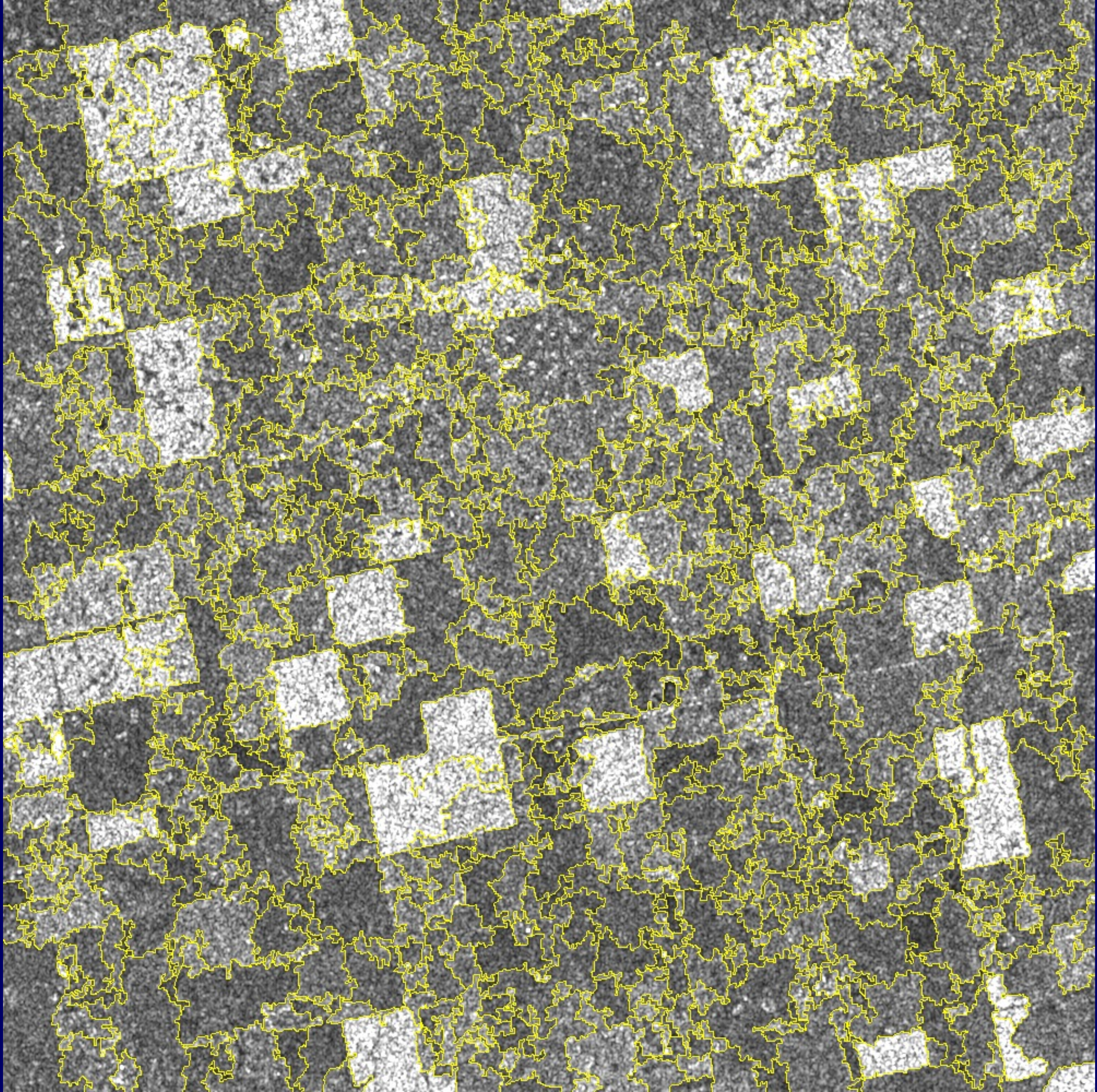
$$Cl \quad = \quad Min\left\{ \frac{Lex\ i}{Lc}, \quad \frac{Lex\ j}{Lc} \right\}$$



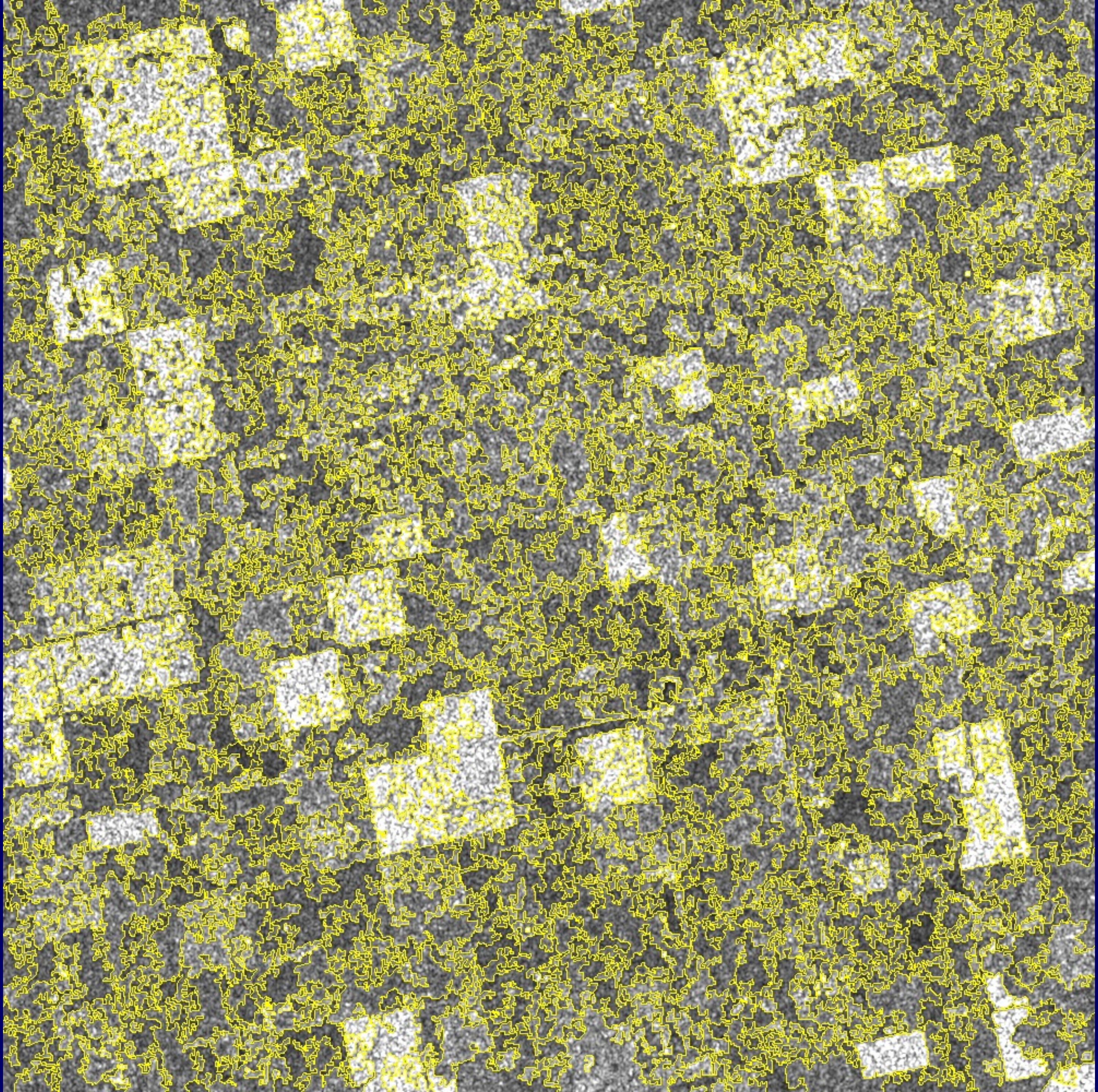
1000x1000 SAR image



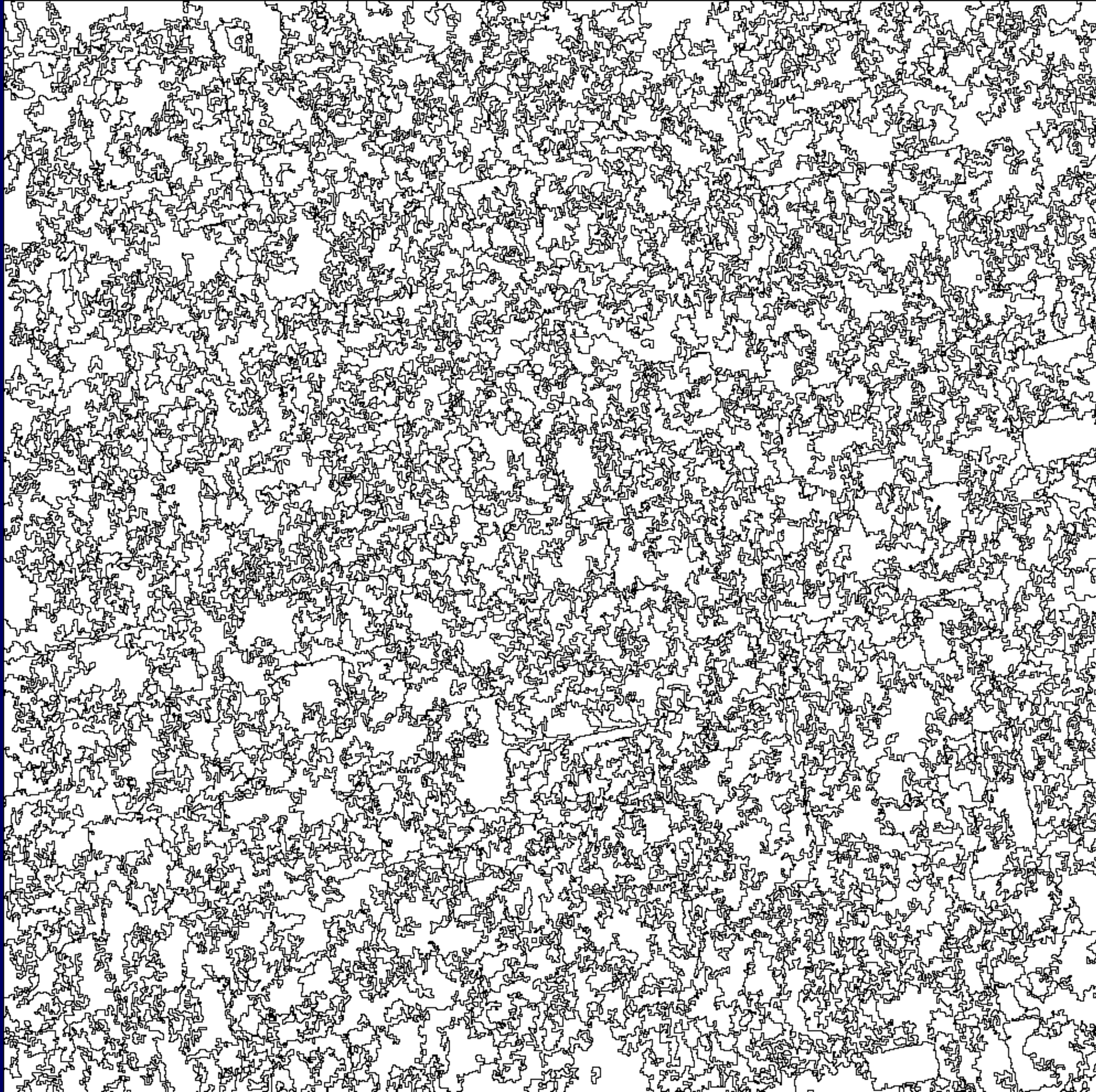
1000 segments



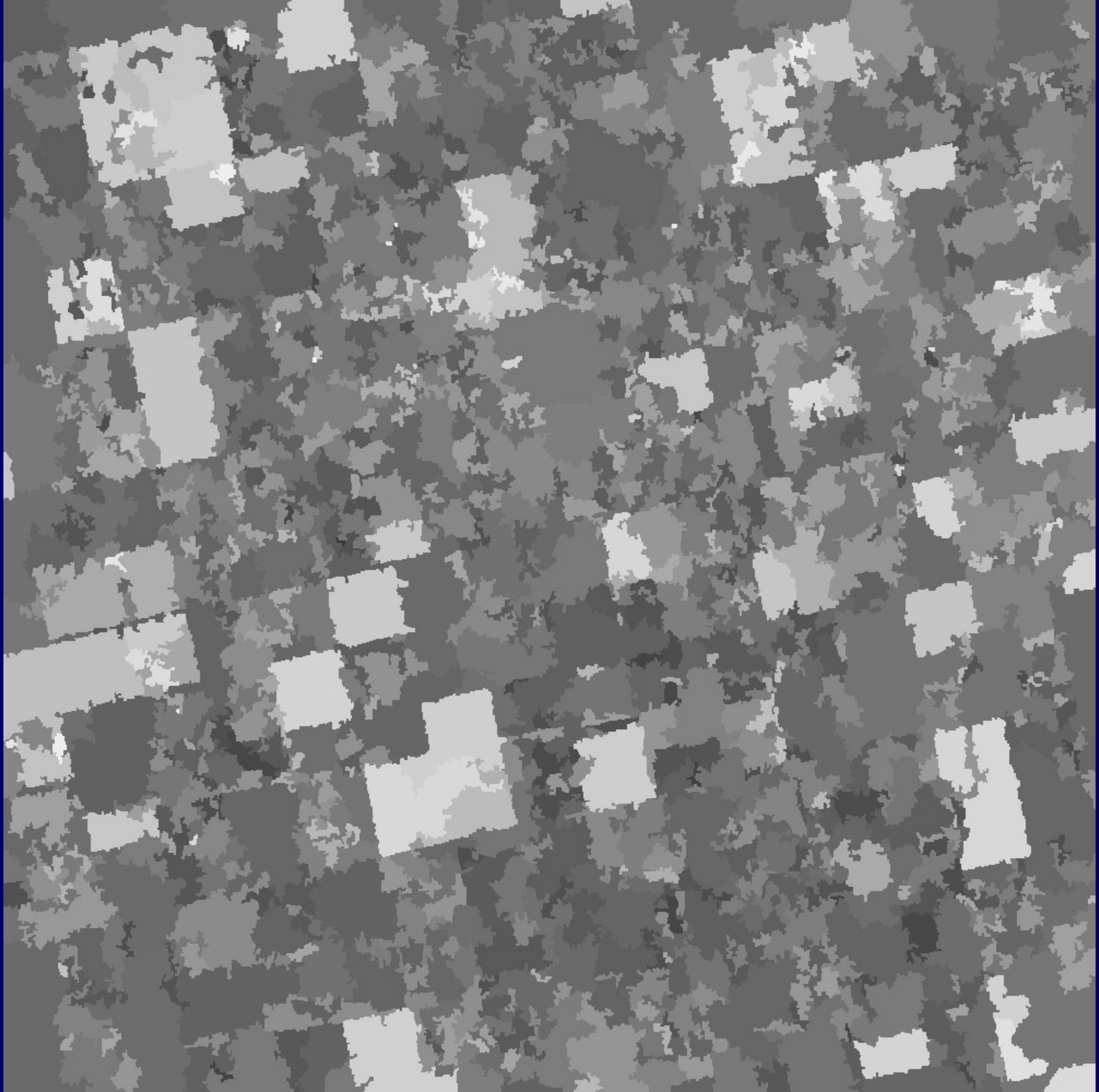
1000 segments



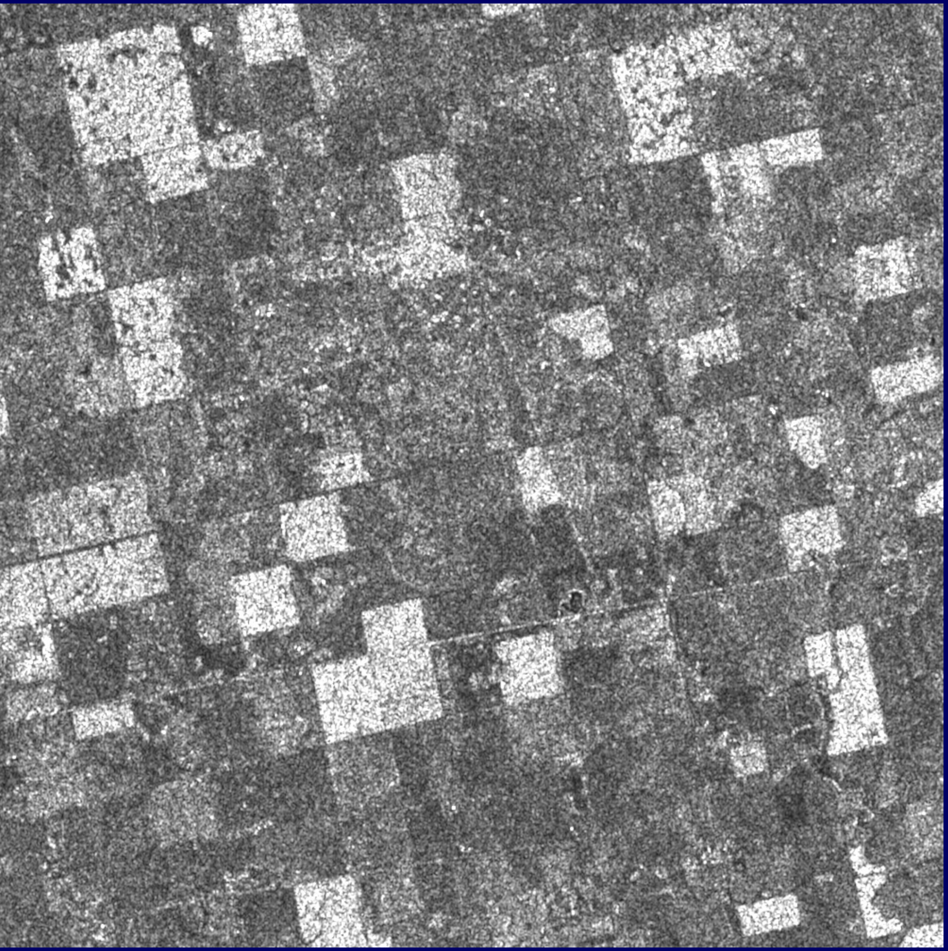
1000 segments



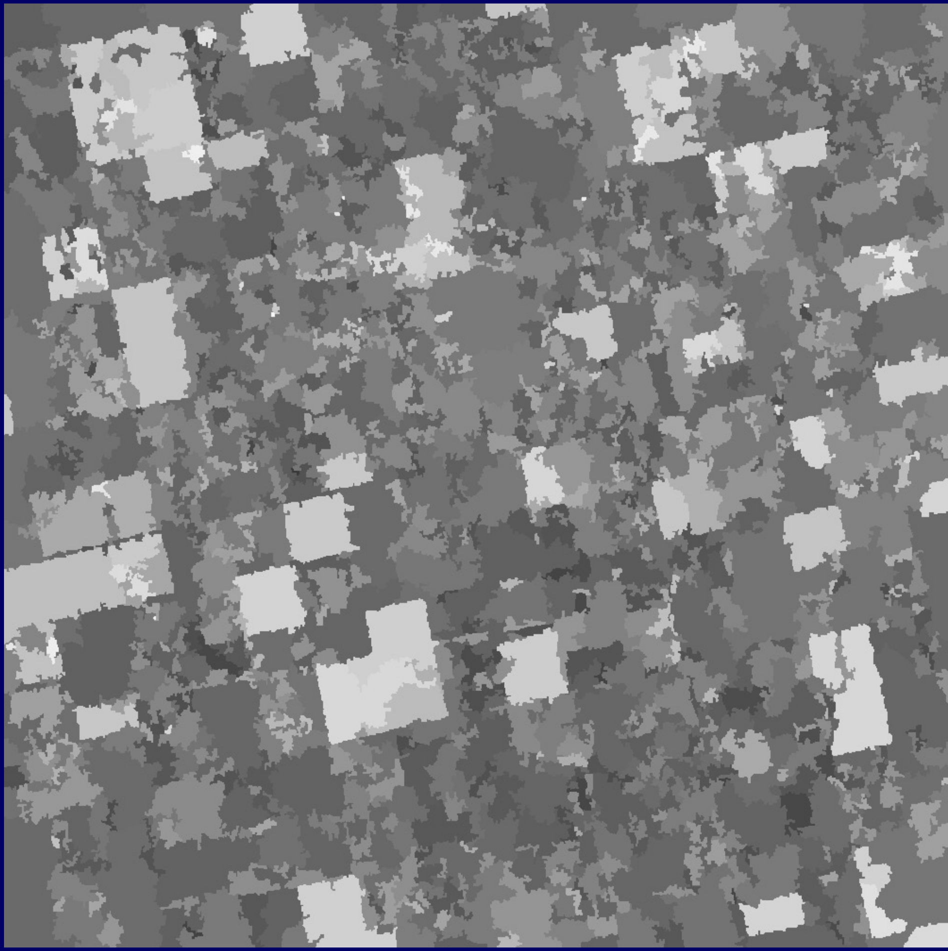
1000 segments



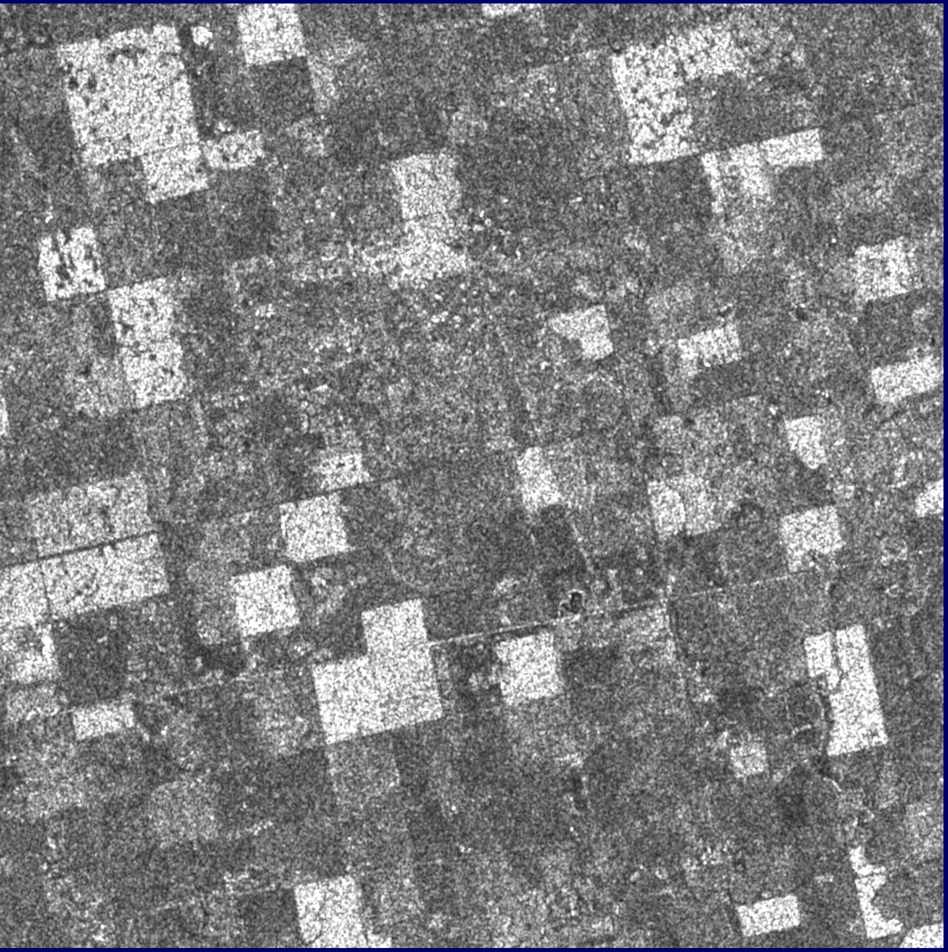
SAR image



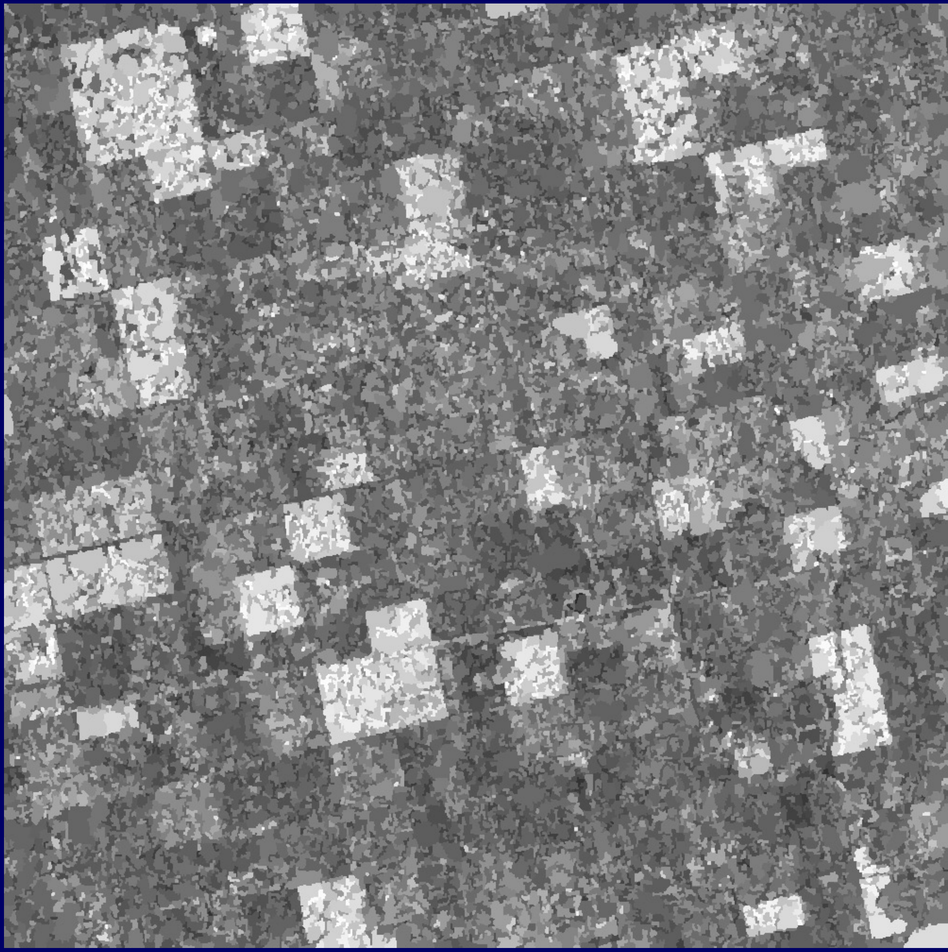
1000 segments



SAR image

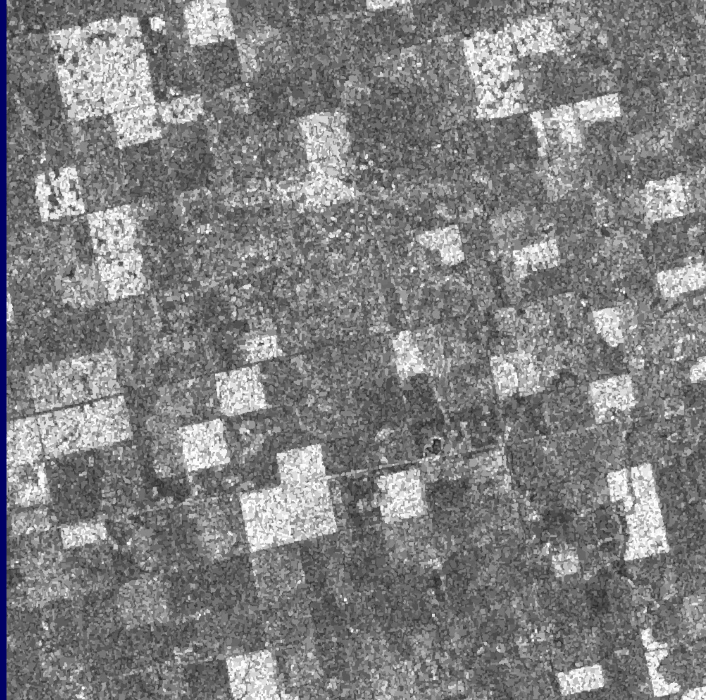


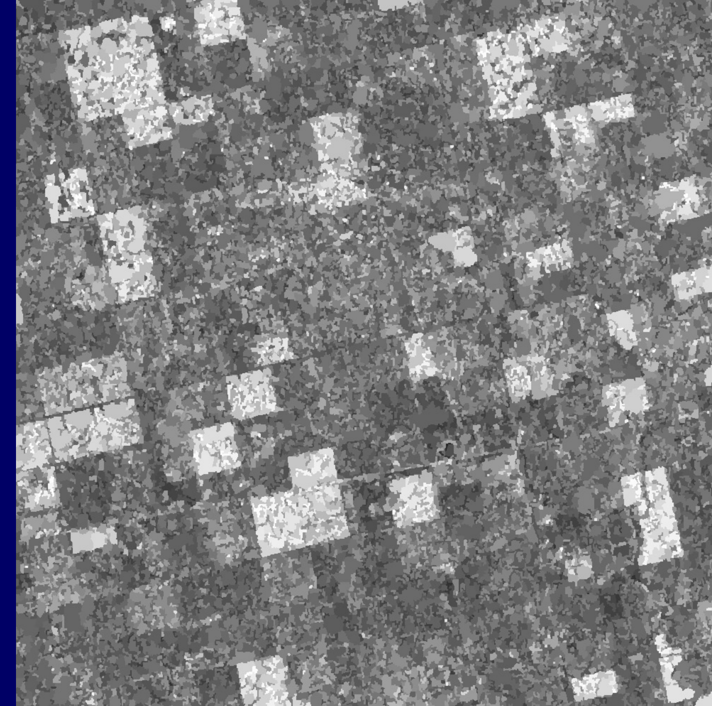
10 K segments



40K

Segments



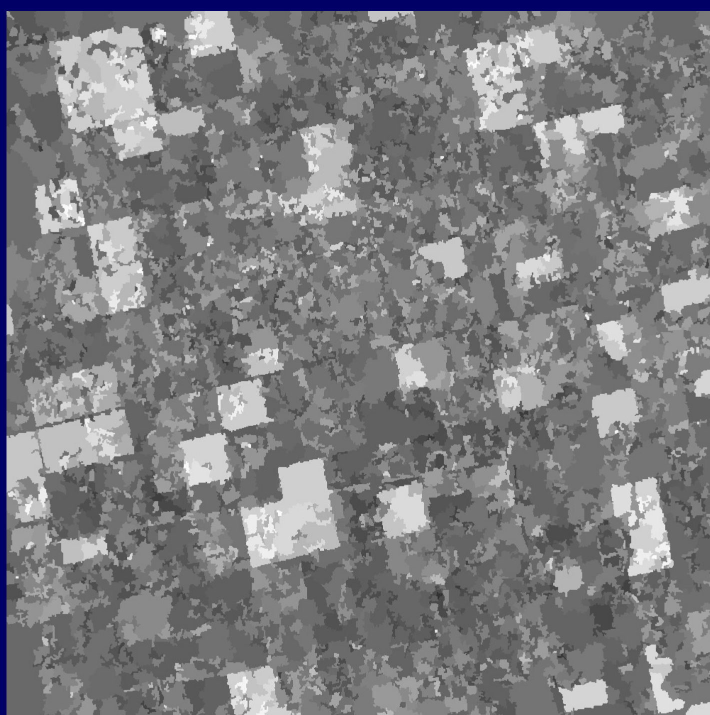


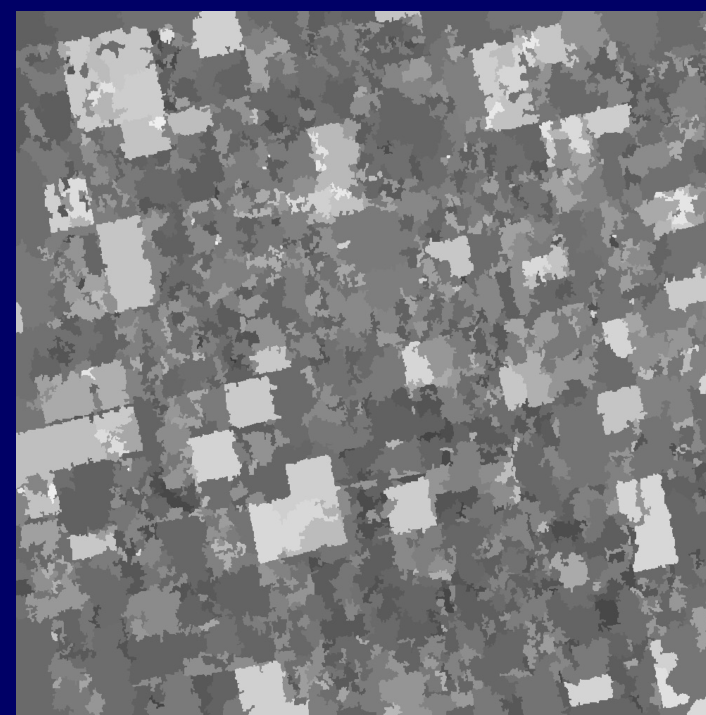
10K

Segments

2.5K

Segments





1K

Segments

CONCLUSION

- Hierarchical segmentation produces goods results
- Criterion should be adapted to the application
- The first merges should be done correctly
- Shape criteria are useful