BeaulieuJM.ca/publi/Bea2000a

Hierarchical Segmentation of SAR Images with Shape Criteria

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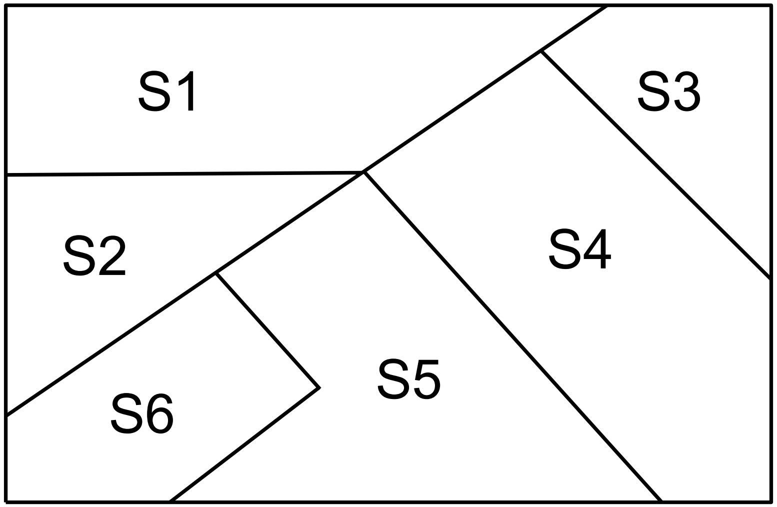
Image Segmentation is the division of the image plane into regions



Two basic questions:

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

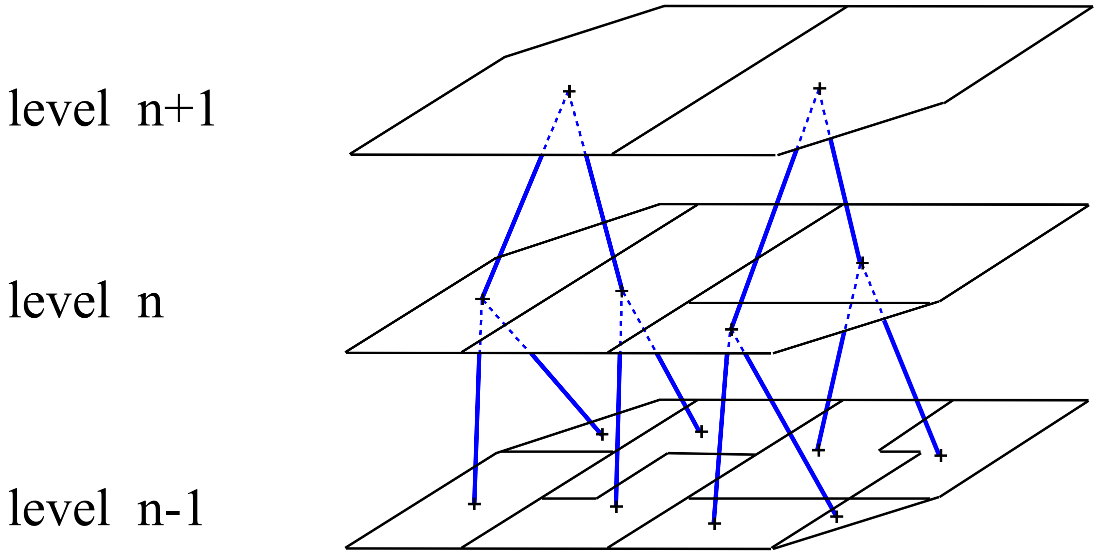
- Homogeneous regions
- Segment similarity

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

- Algorithm desing

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.

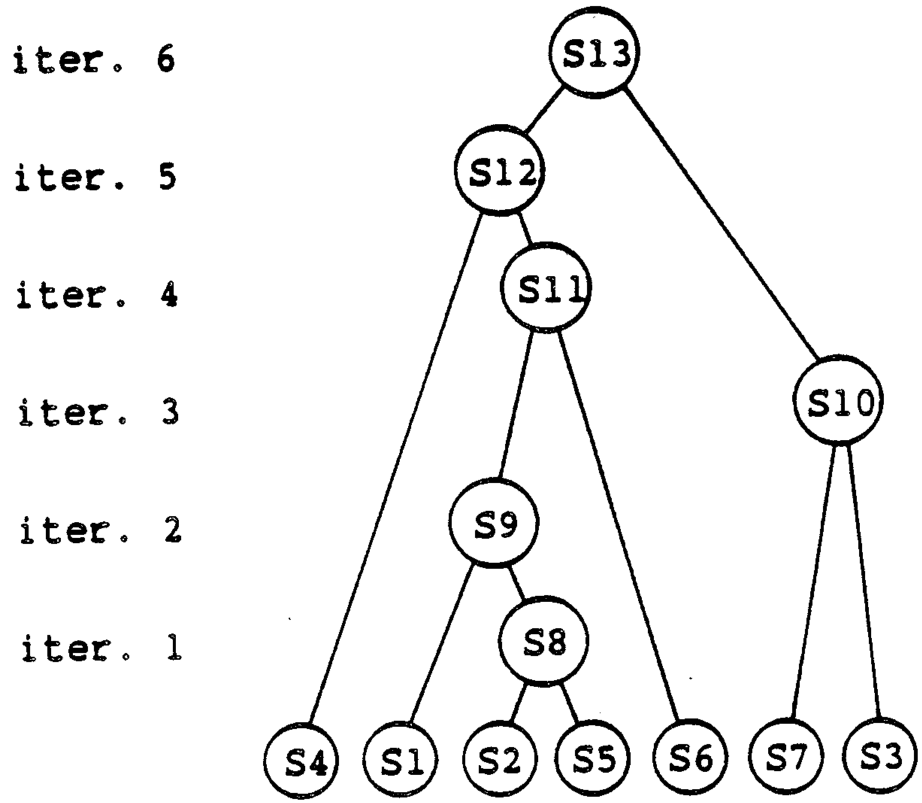


Segment tree

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.



Implantation aspects

- too many segments
- merge only neighbour segments
- avoid recalculation

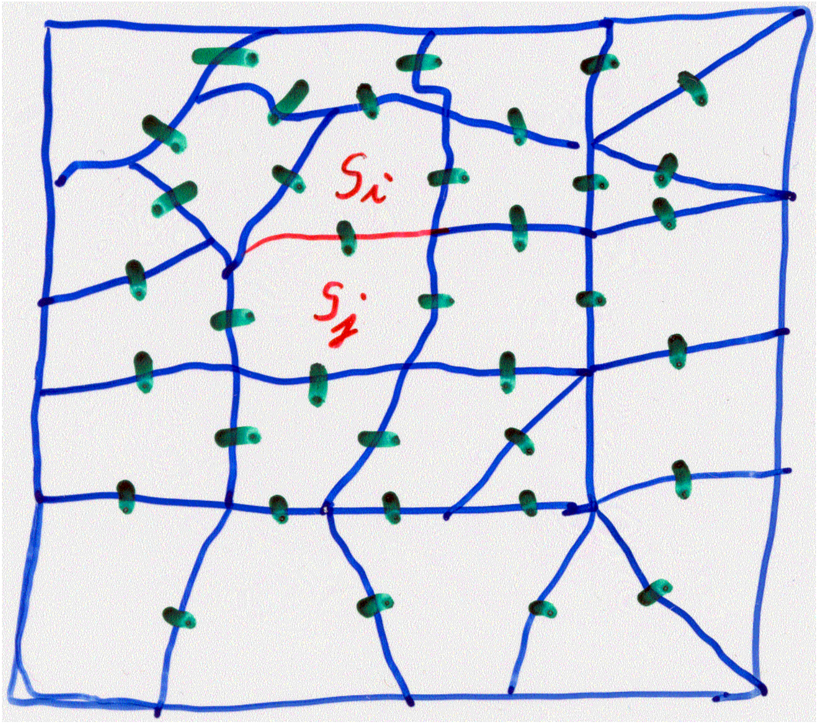
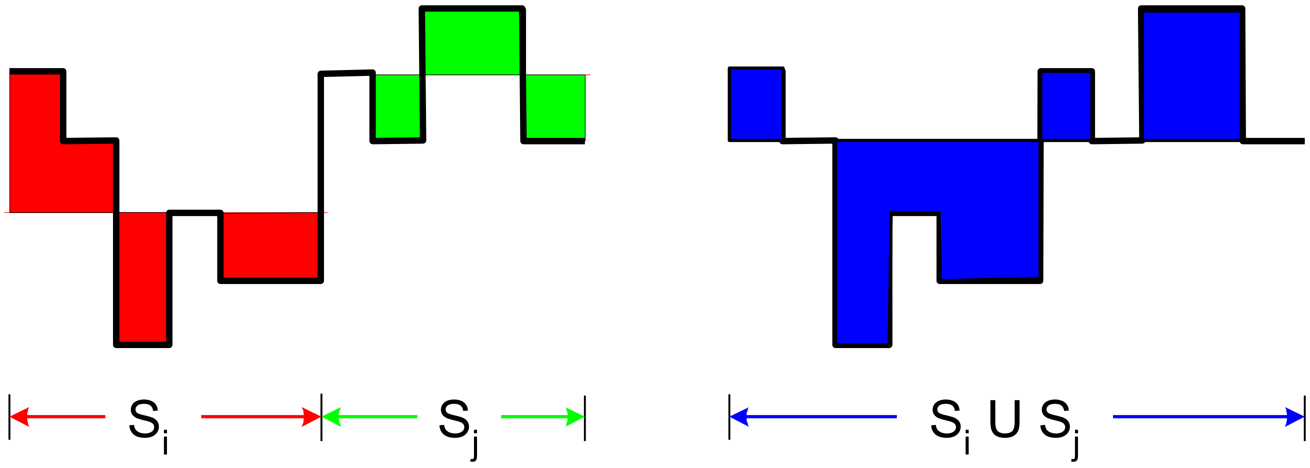


IMAGE APPROXIMATION

- Each segment, S_i, is represented by an approximation function, $r_i(x,y)$.
- The approximation error is defined as

$$H(S_i) = \sum_{(x,y)\varepsilon S_i} \left(f(x,y) - r_i(x,y) \right)^2$$



- The goal is to find the image segmentation that produces the lowest overall approximation error.

- In hierarchical segmentation, this results in sequentially merging the segments that produce the smallest increases in the approximation error.

- Thus, the step-wise criterion is

$$C_{i,j} = H(S_i \cup S_j) - H(S_i) - H(S_j)$$

- This assures that each iteration does its best to minimize the overall approximation error.

Constant value approximation

$$f_i(x,y) \simeq r_i(x,y) = \mu_i \quad (mean)$$

$$C_{i,j} = \frac{N_i \times N_j}{N_i + N_j} \left[\mu_i - \mu_j\right]^2$$

Multi-spectral image

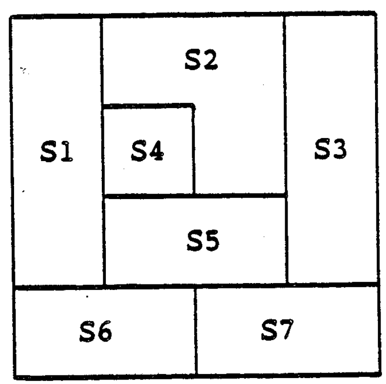
$$C_{i,j} = \frac{N_i \times N_j}{N_i + N_j} \sum_k w^k \left[\mu_i^k - \mu_j^k\right]^2$$

A SMALL EXAMPLE

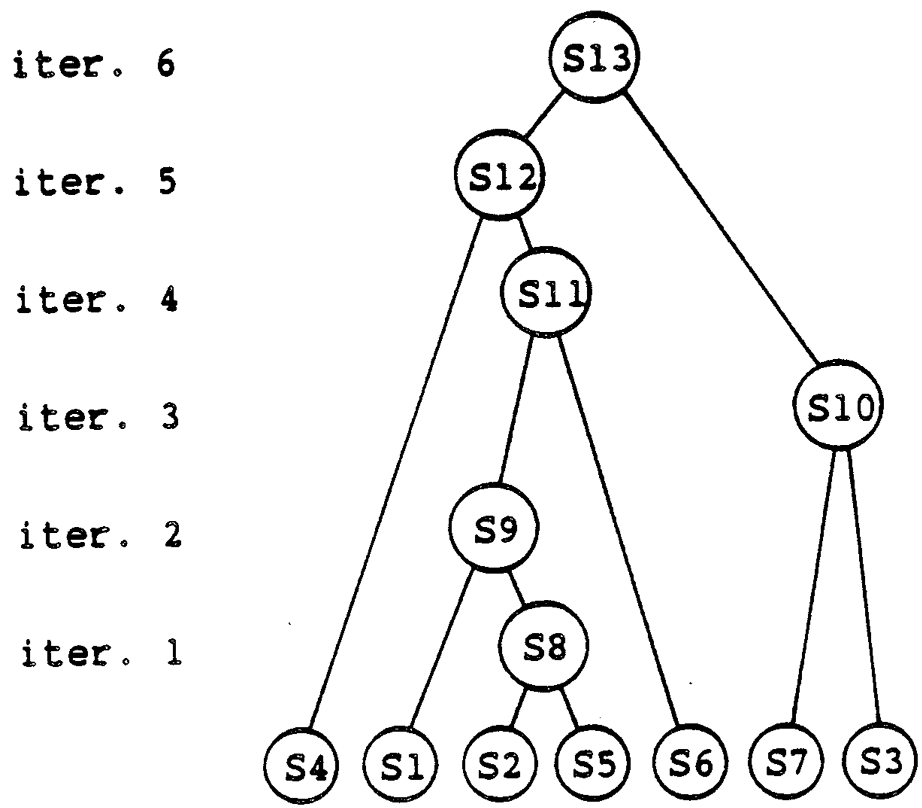
Gray level values

1	2	2	13
1	10	2	13
1	3	3	13
6	6	10	10

Initial partition



Sequence of segment merges.



Segment description parameters and neighbour lists.

	N_i	μ_i	B_i (neighbour lists)
S1	3	1.0	S2 S4 S5 S6
S2	3	2.0	S1 S3 S4 S5
S3	3	13.0	S2 S5 S7
S4	1	10.0	S1 S2 S5
S5	2	3.0	S1 S2 S3 S4 S6 S7
S6	2	6.0	S1 S5 S7
S7	2	10.0	S3 S5 S6

Make the information explicit.

Calcul of criteria from segment descriptors

		Lists of criteria at each iteration	
i, j	Ci,j	it. 1	it. 2
1, 2	1.5	1.5	
1, 4	60.7	60.7	
1, 5	4.8	4.8	
1, 6	30.0	30.0	
2, 3	181.5	181.5	
2, 4	48.0	48.0	
2, 5	1.2	1.2	
3, 5	120.0	120.0	
3, 7	10.8	10.8	
4, 5	32.7	32.7	
5, 6	9.0	9.0	
5, 7	49.0	49.0	
6, 7	16.0	16.0	

Update segment description and neighbour lists.

	N_i	μ_i	B_i (neighbour lists)
S1	3	1.0	S2 S4 S5 S6
S2	3	2.0	S1 S3 S4 S5
S3	3	13.0	S2 S5 S7
S4	1	10.0	S1 S2 S5
S5	2	3.0	S1 S2 S3 S4 S6 S7
S6	2	6.0	S1 S5 S7
S7	2	10.0	S3 S5 S6
S8	5	2.4	S1 S3 S4 S6 S7

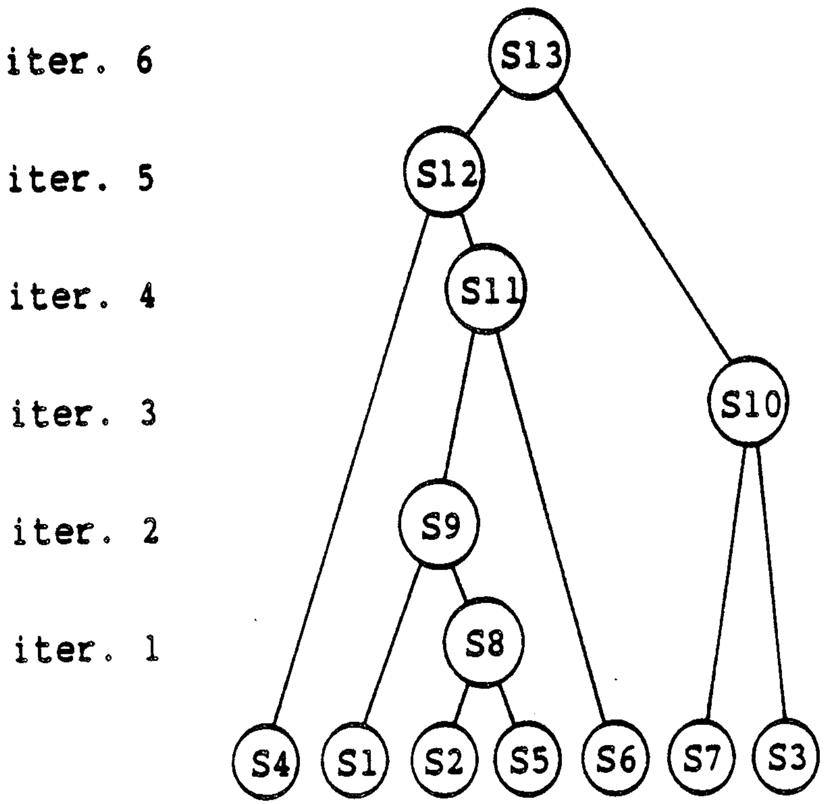
Recursive descriptor and criterion

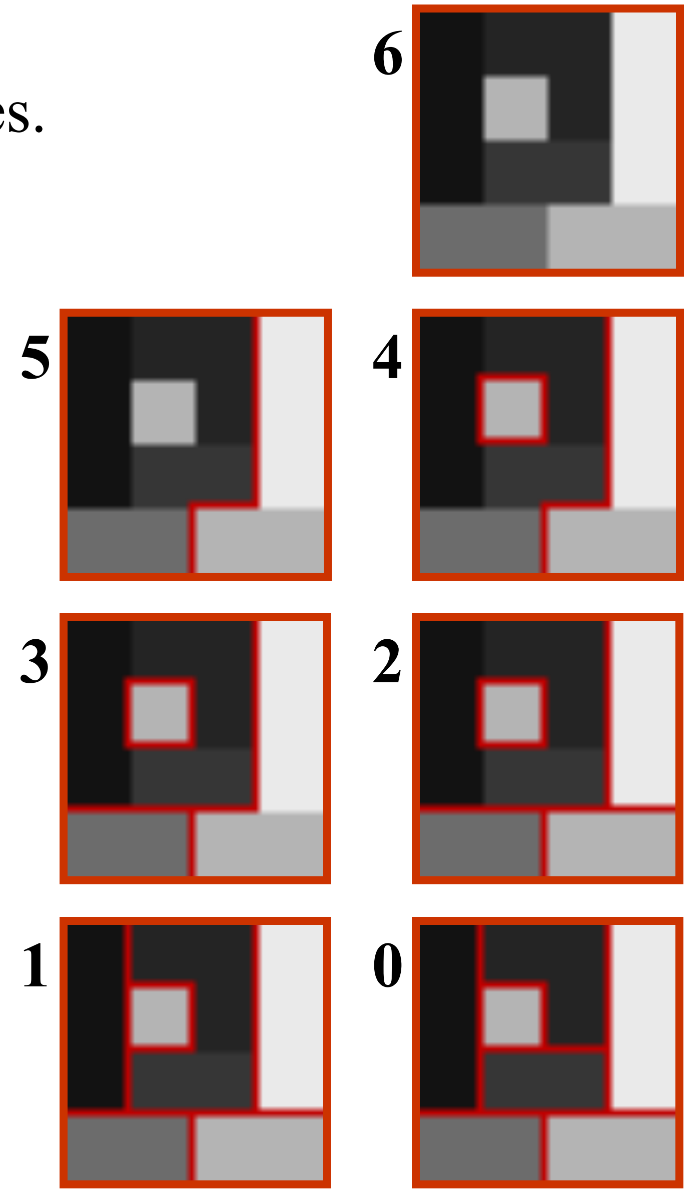
i, j	Ci,j	it. 1	it. 2	it. 3	it. 4	it. 5	it. 6
1, 2	1.5	1.5					
1, 4	60.7	60.7	60.7				
1, 5	4.8	4.8					
1, 6	30.0	30.0	30.0				
2, 3	181.5	181.5					
2, 4	48.0	48.0					
2, 5	1.2	1.2					
3, 5	120.0	120.0					
3, 7	10.8	10.8	10.8	10.8			
4, 5	32.7	32.7					
5, 6	9.0	9.0					
5, 7	49.0	49.0					
6, 7	16.0	16.0	16.0	16.0			
8, 1	3.7		3.7				
8, 3	210.7		210.7				
8, 4	48.1		48.1				
8, 6	18.5		18.5				
8, 7	82.5		82.5				
9, 3	270.0			270.0			
9, 4	58.7			58.7	58.7		
9, 6	27.2			27.2	27.2		
9, 7	105.6			105.6			
10, 6	48.1				48.1		
10, 9	303.1				303.1		
11, 4	48.4					48.4	
11, 10	277.0					277.0	
12, 10	244.6						244.6

Segment description parameters and neighbour lists.

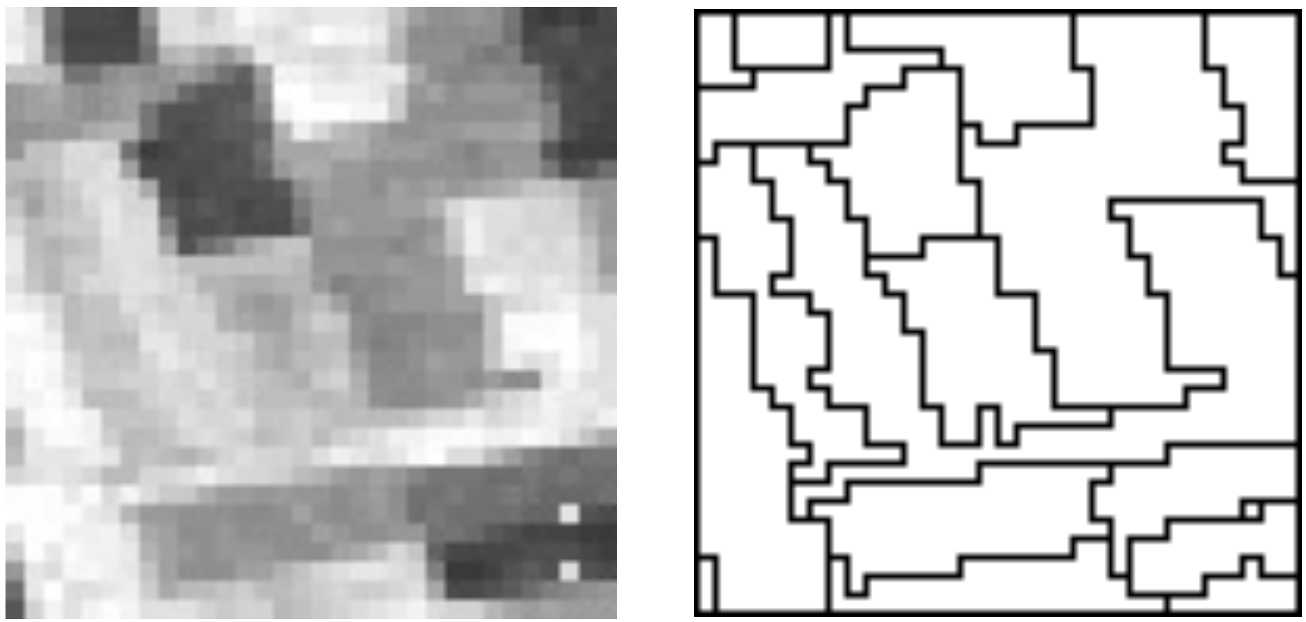
	N_i	μ_i	B_i (neighbour lists)
S1	3	1.0	S2 S4 S5 S6
S2	3	2.0	S1 S3 S4 S5
S3	3	13.0	S2 S5 S7
S4	1	10.0	S1 S2 S5
S5	2	3.0	S1 S2 S3 S4 S6 S7
S6	2	6.0	S1 S5 S7
S7	2	10.0	S3 S5 S6
S8	5	2.4	S1 S3 S4 S6 S7
S9	8	1.9	S3 S4 S6 S7
S10	5	11.8	S6 S9
S11	10	2.7	S4 S10
S12	11	3.4	S10
S13	16	6.0	

Sequence of segment merges.

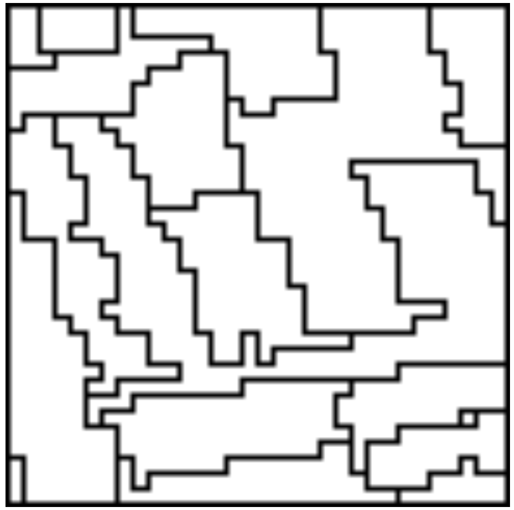


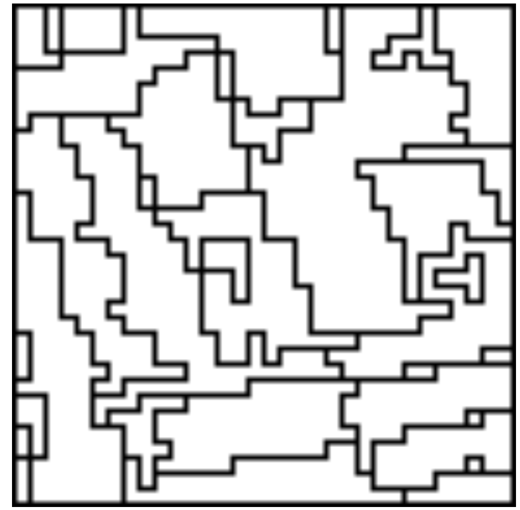


SEGMENTATION OF 32x32 LANDSAT IMAGES



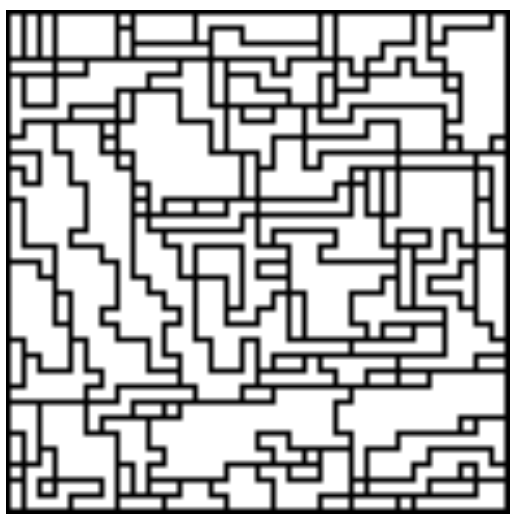
18
segments

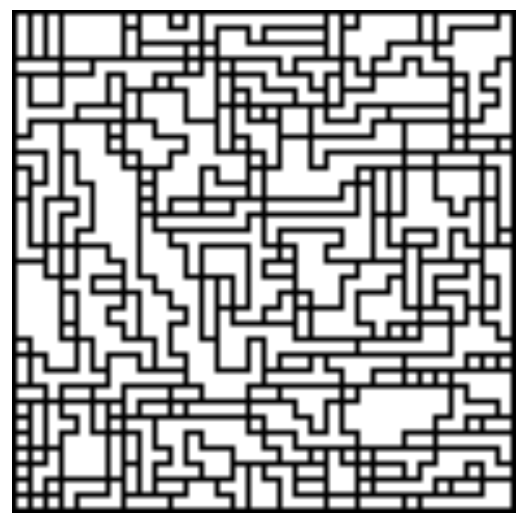




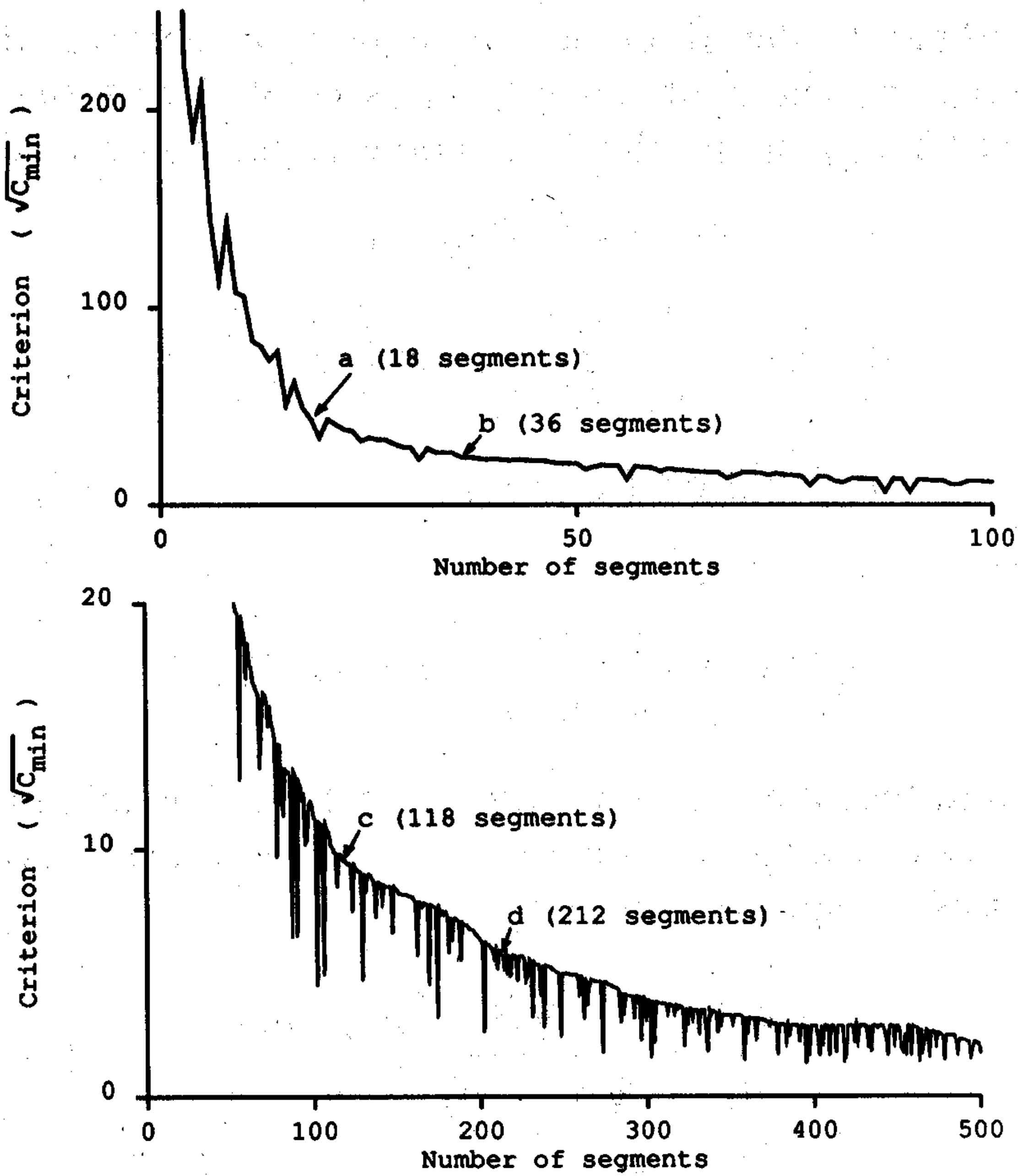
36
segments

118
segments

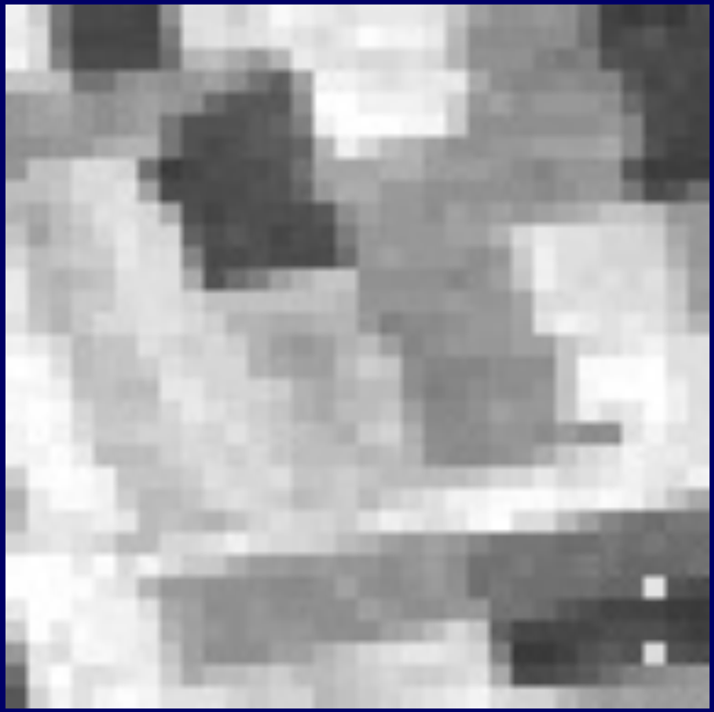
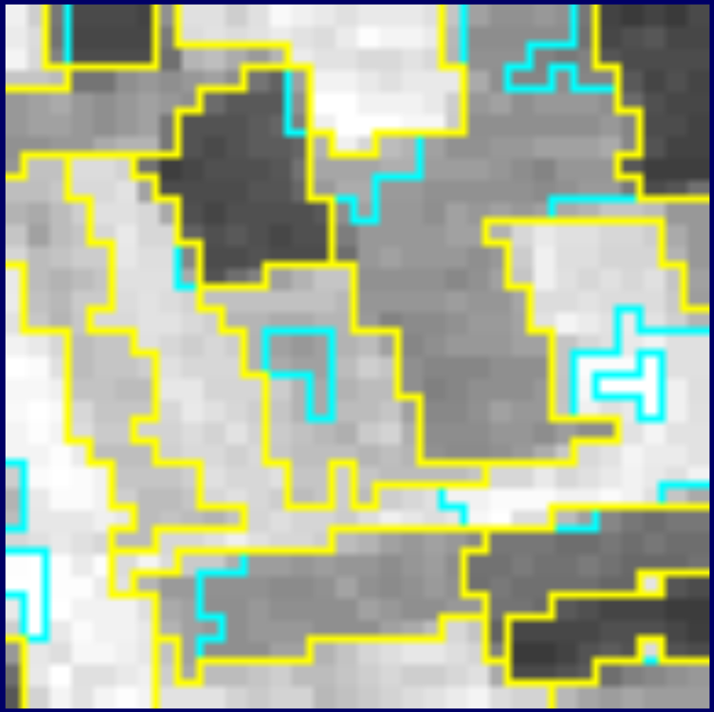




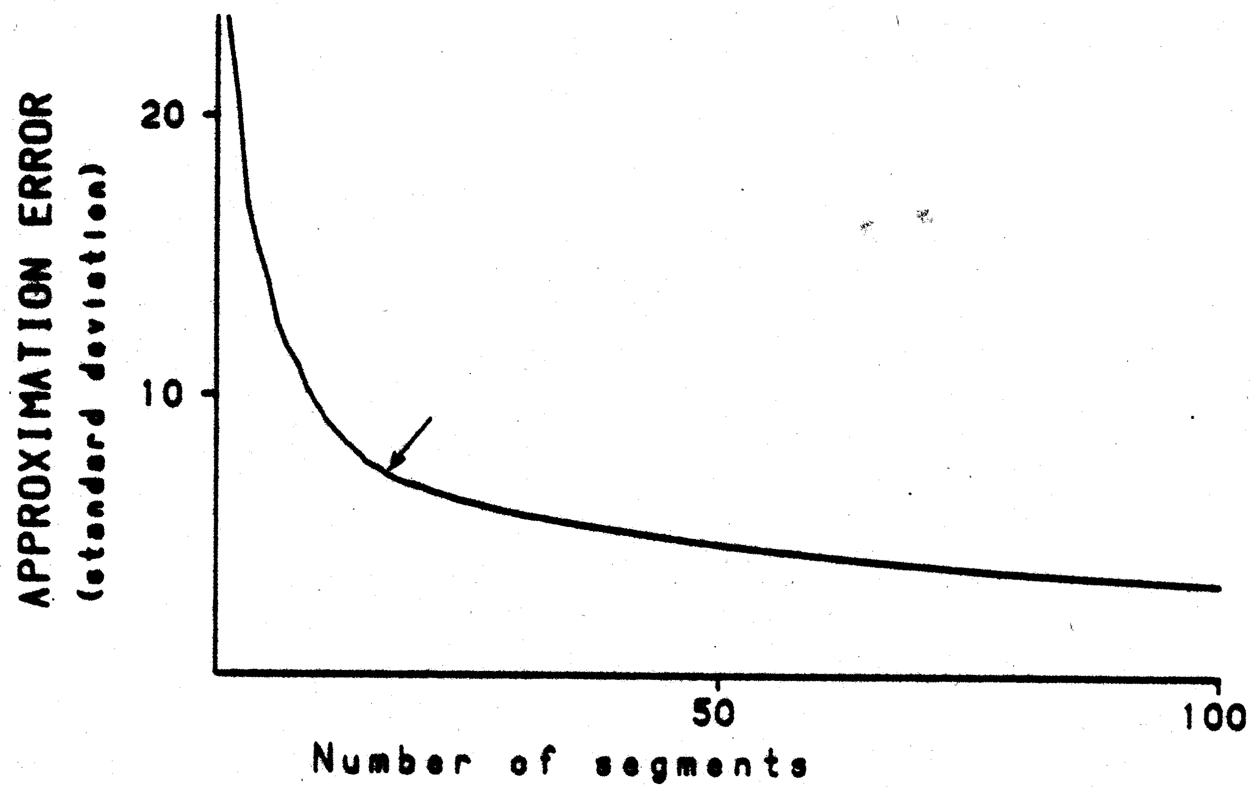
212
segments

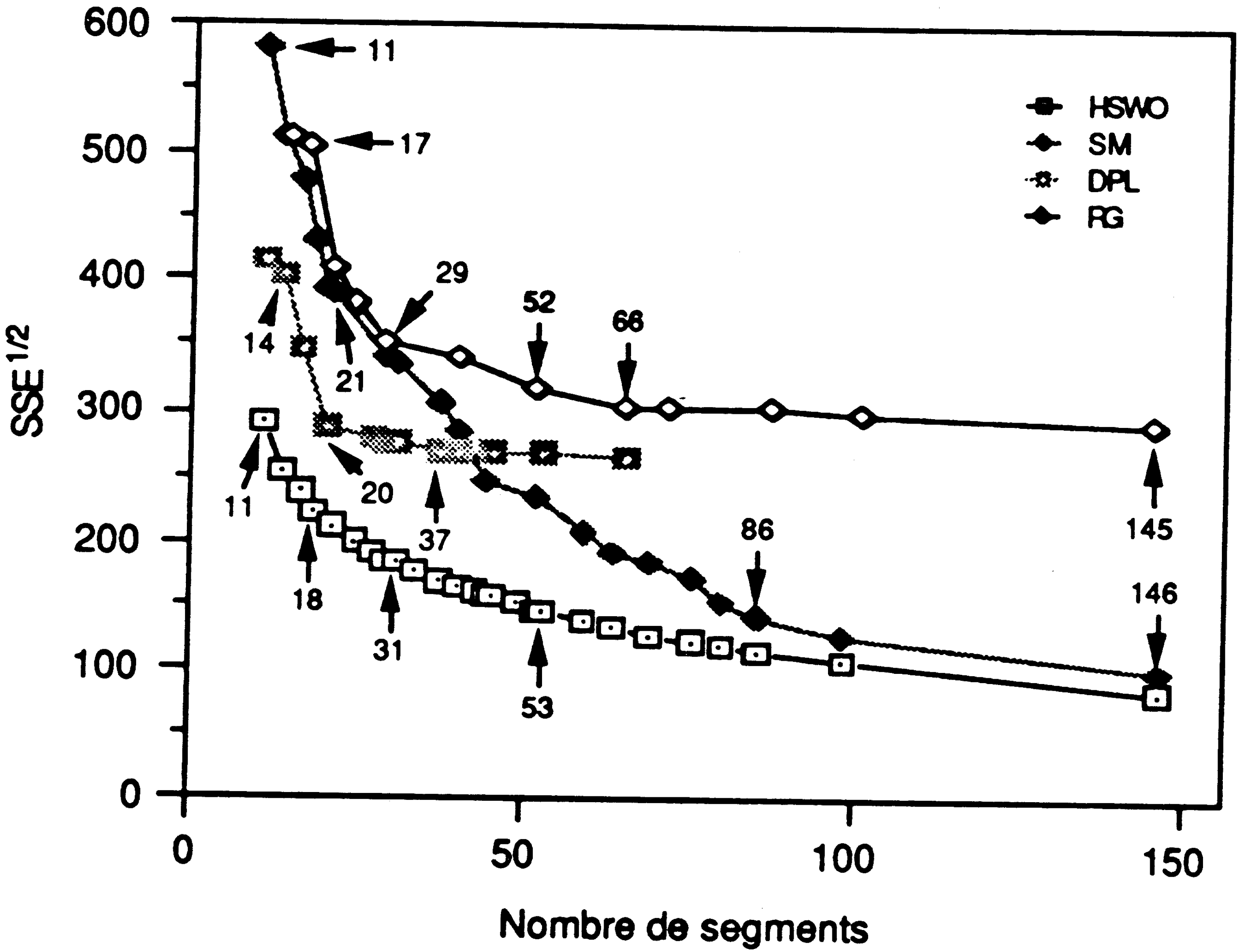


200
100
0
Criterion ($\sqrt{C_{min}}$)
a (18 segments)
b (36 segments)
0
50
100
Number of segments
20
10
0
Criterion ($\sqrt{C_{min}}$)
c (118 segments)
d (212 segments)
0
100
200
300
400
500
Number of segments

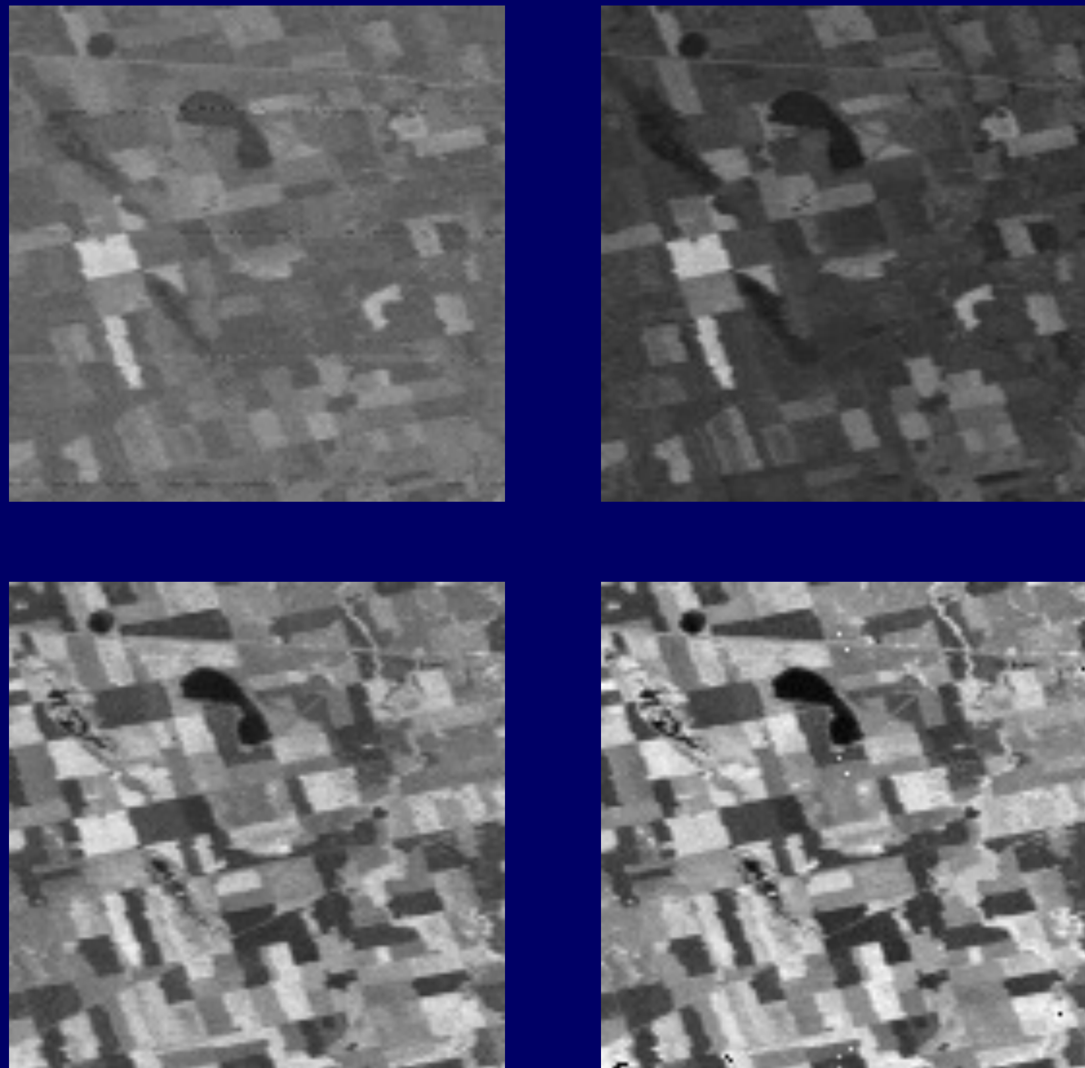
Sum of approximation error



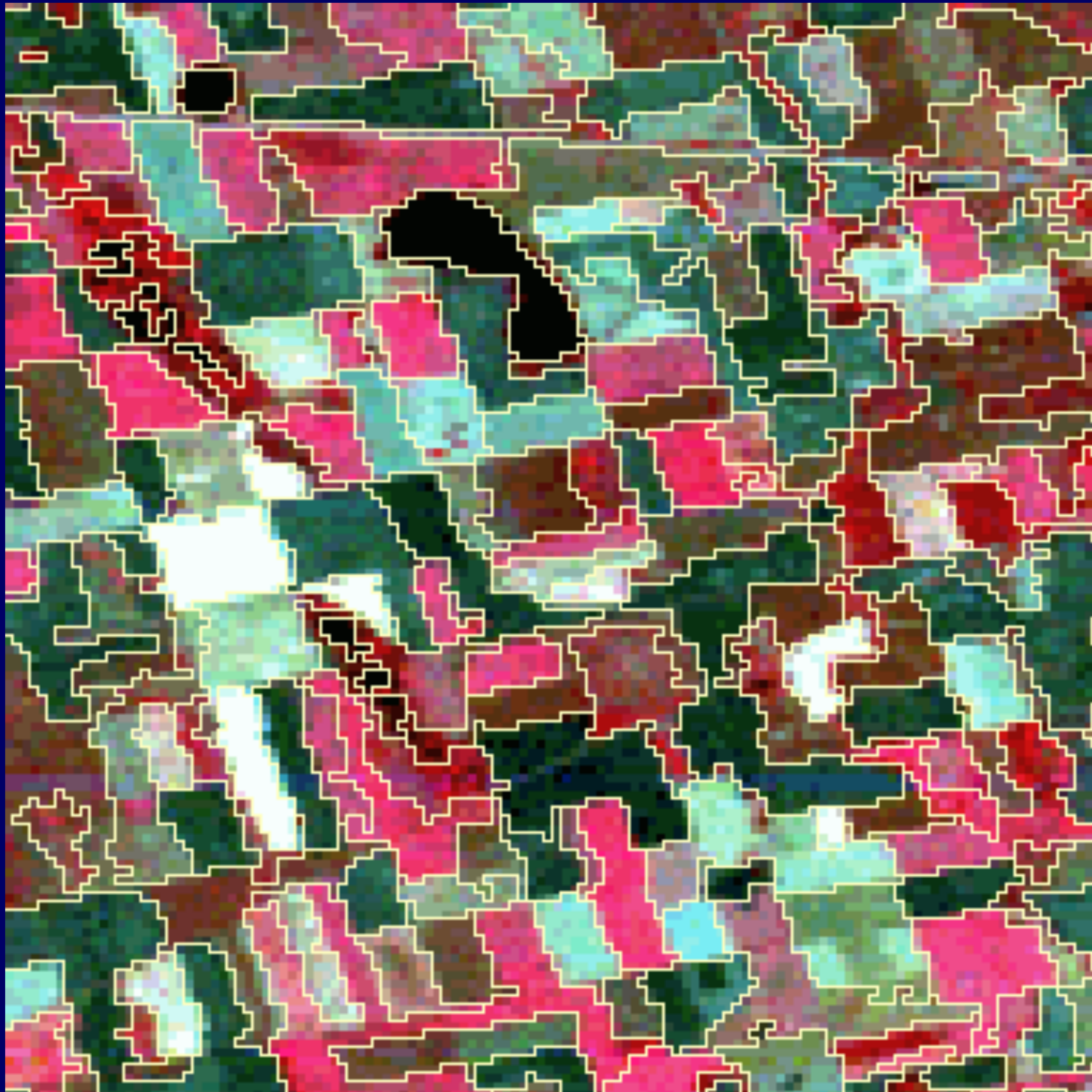


600
500
400
300
200
100
0
SSE 1/2
0
50
100
150
Nombre de segments
HSWO
SM
DPL
RG
11
17
29
52
66
14
21
20
11
37
18
31
53
86
145
146

SEGMENTATION OF 128x128x4 LANDSAT IMAGES



400 segments

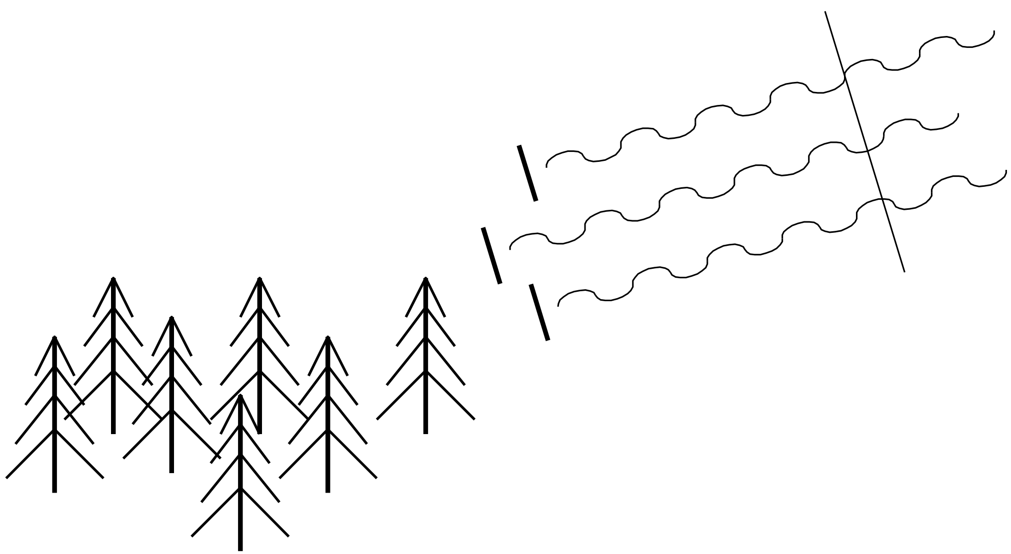


200 segments

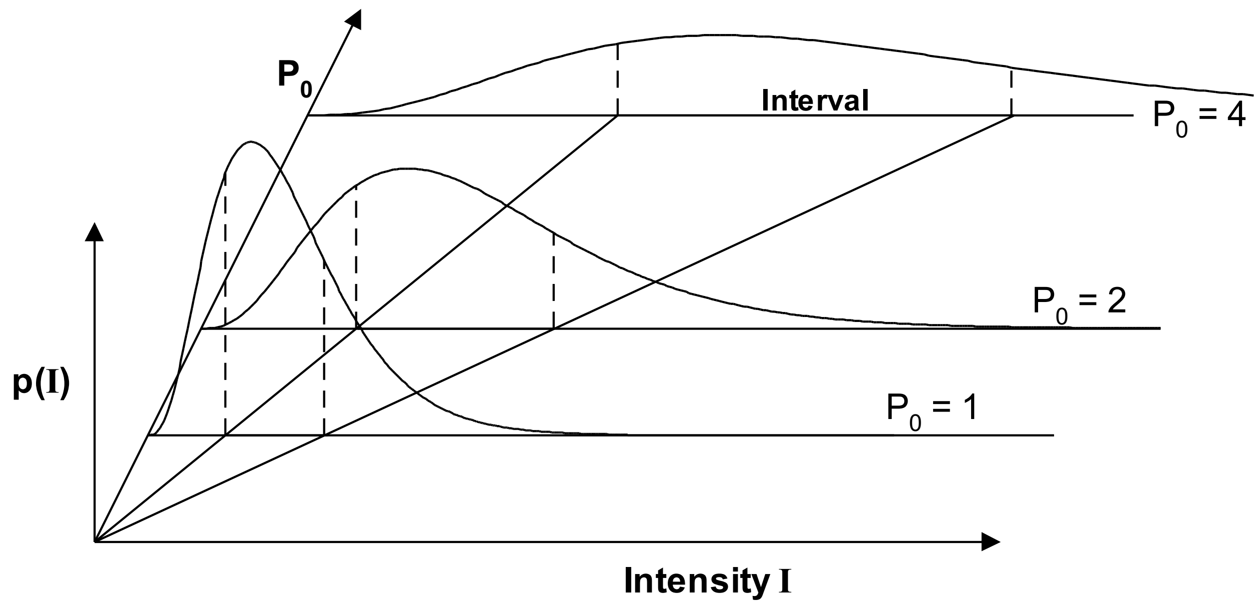
SEGMENTATION OF SAR IMAGE

SAR IMAGE → COHERENT SIGNAL (RADAR)

→ INTERFERENCE PATTERN



MULTIPLICATIVE NOISE



NOISE IS PROPORTIONAL TO THE AMPLITUDE

NEW CRITERION

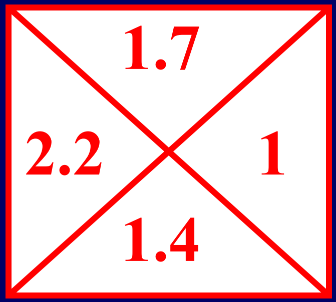
The segment dispersion (difference) is divided by the segment mean

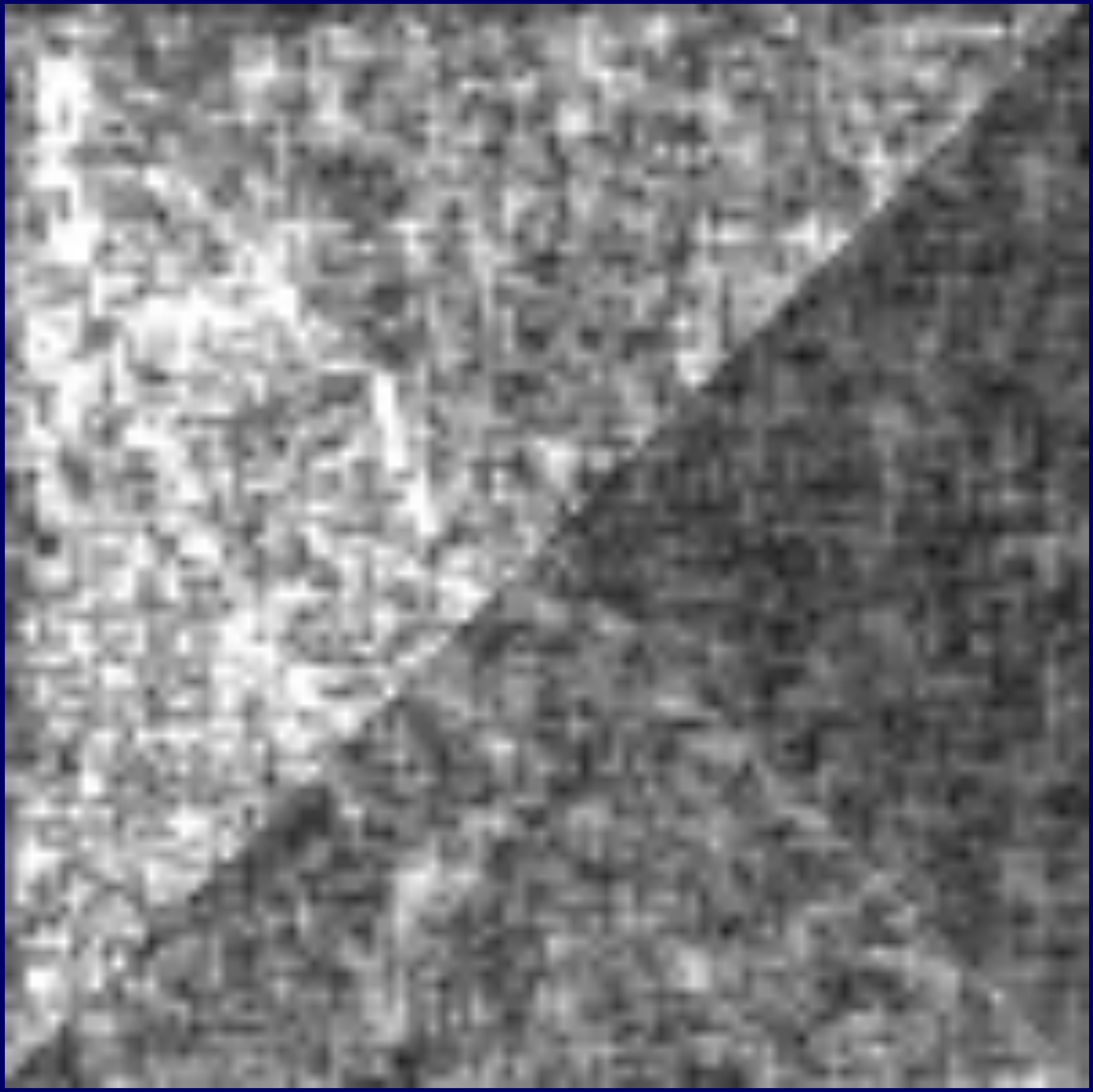
$$C_{i,j} = \frac{N_i \times N_j}{N_i + N_j} \left[\frac{\mu_i - \mu_j}{\mu_{i \cup j}} \right]^2$$

IMPORTANT NOISE

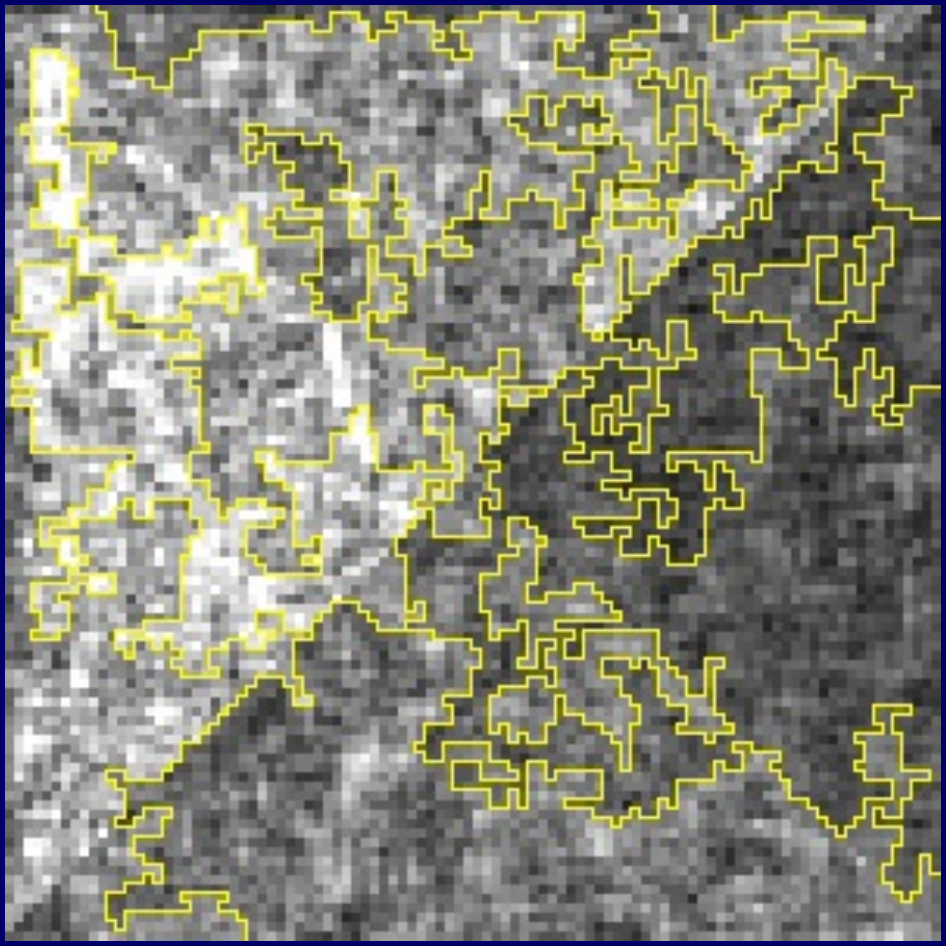
PROBLEM WITH THE FIRST MERGES

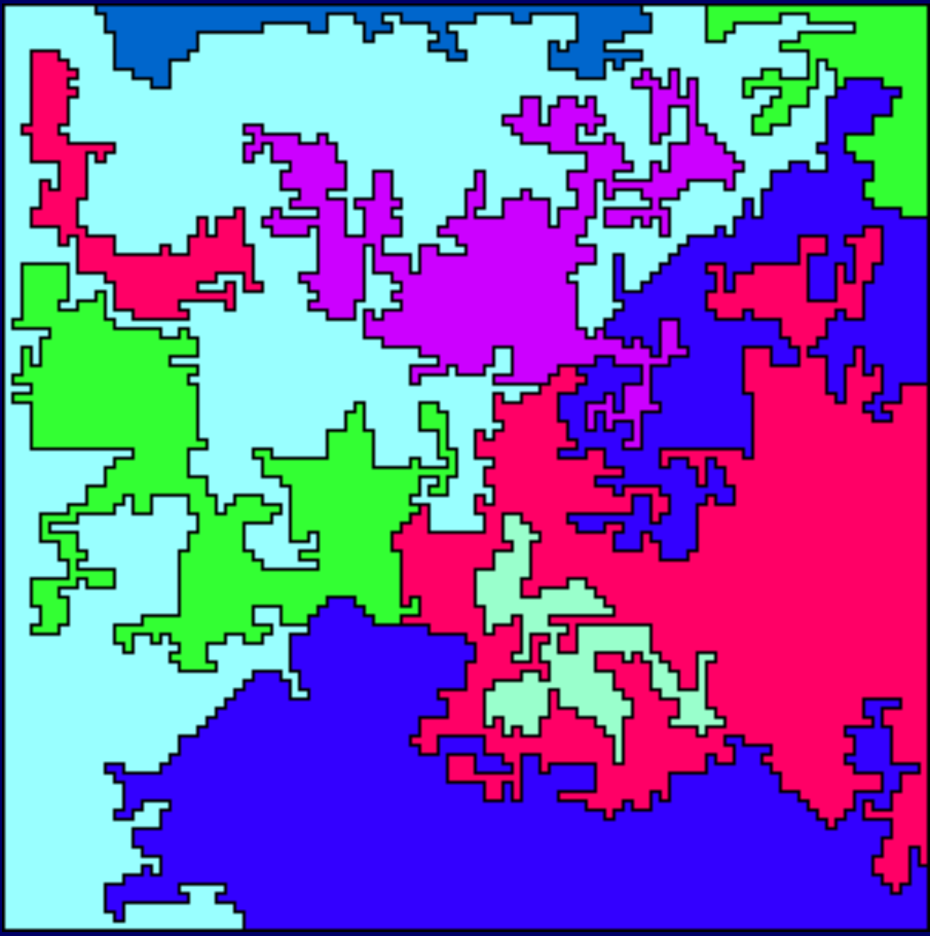
4 regions, 4 looks, 100x100



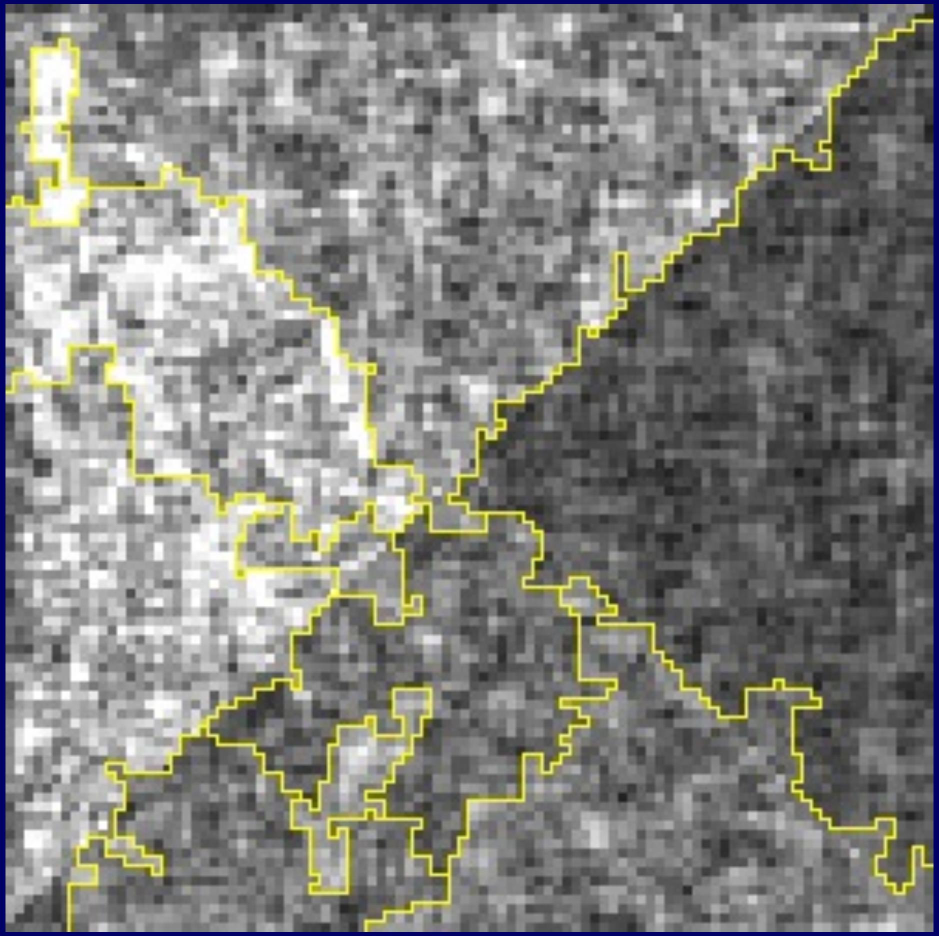


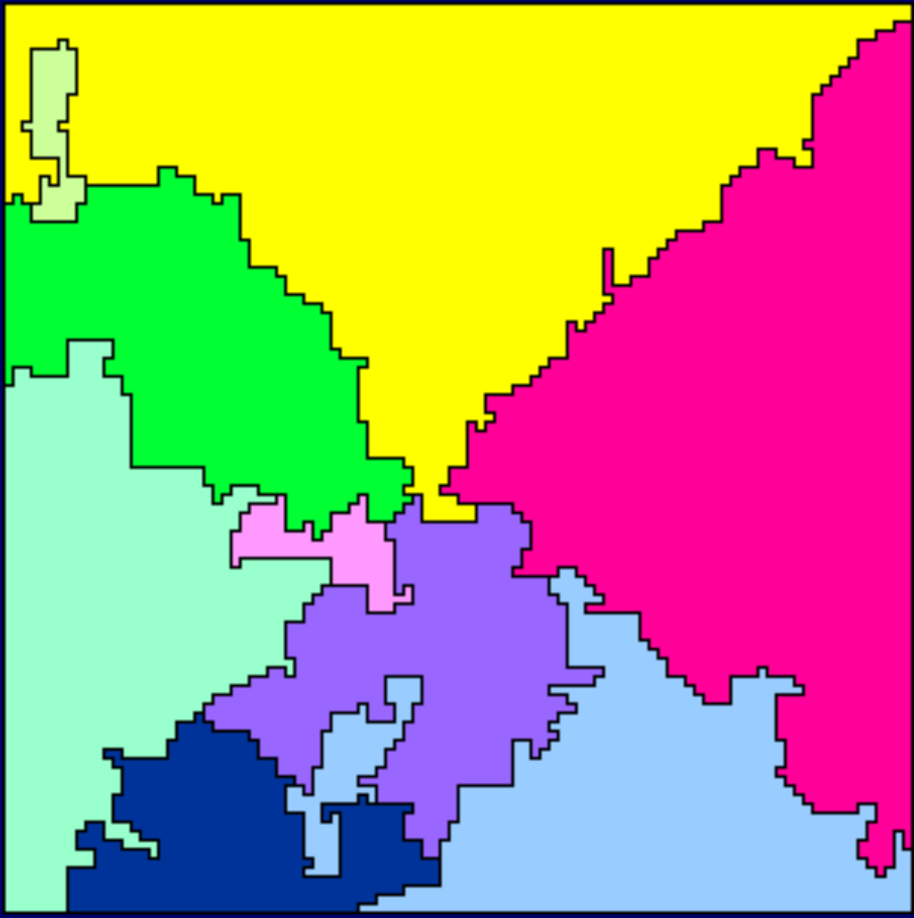
10 segments, standard criterion



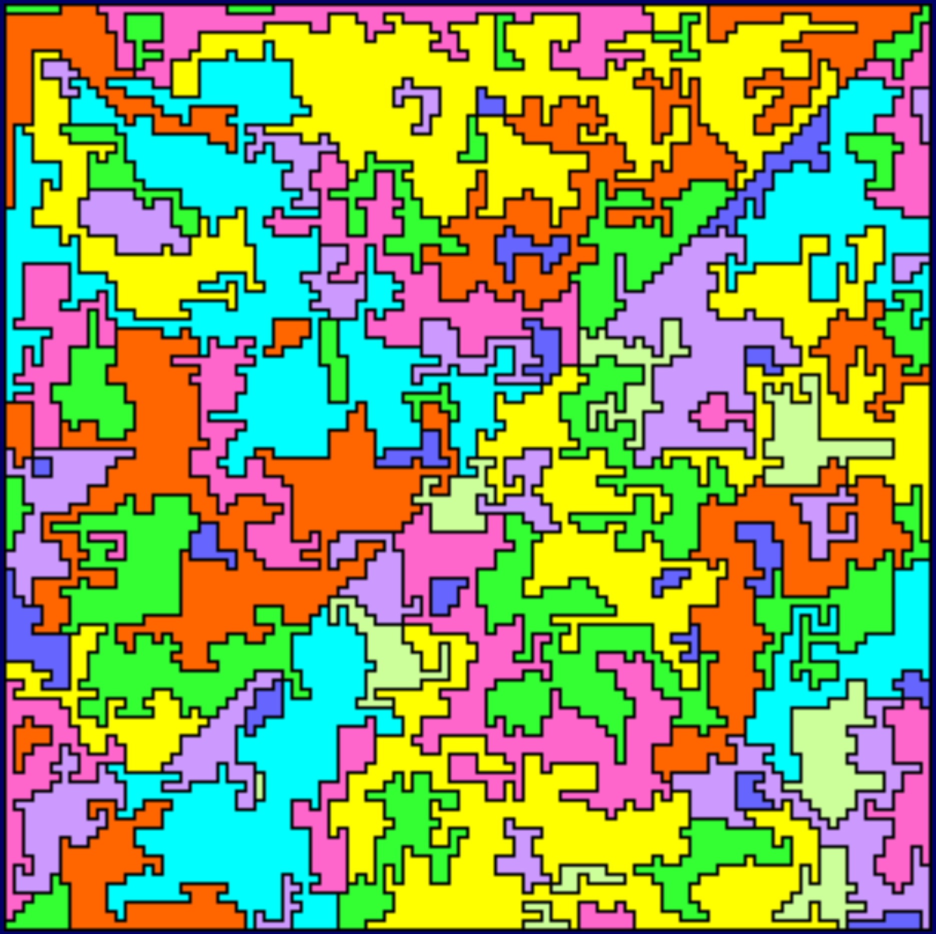


10 segments, shape criterion

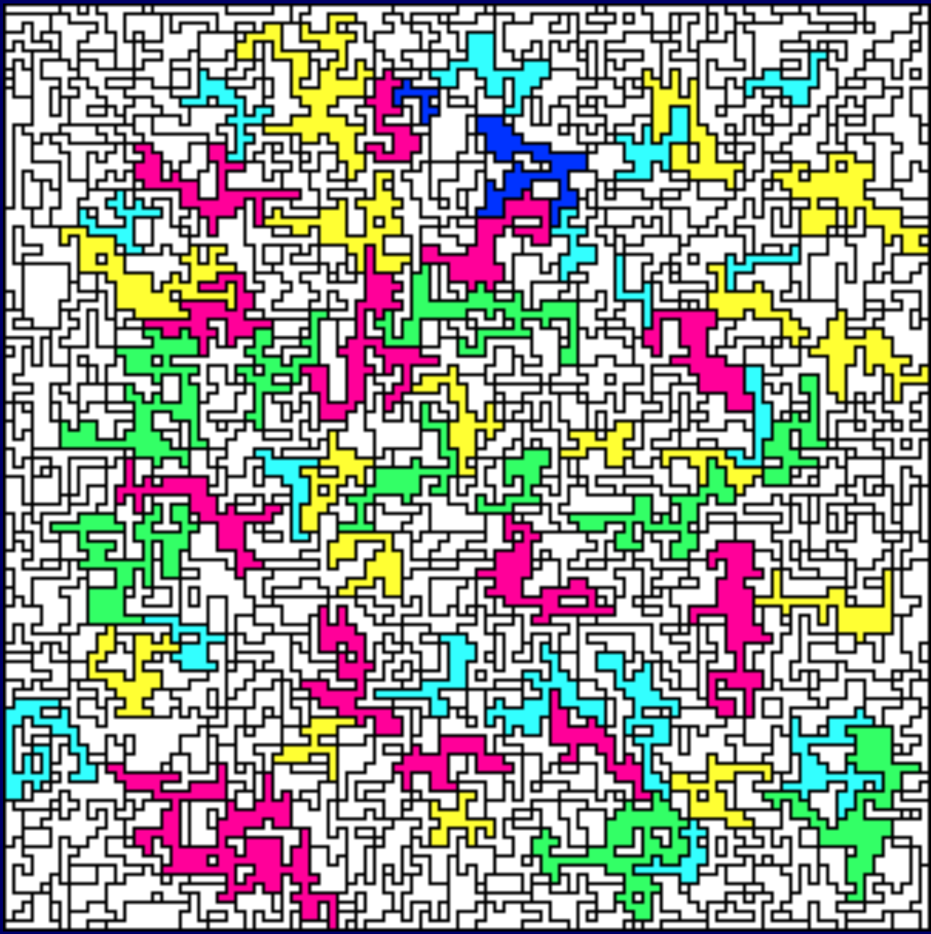




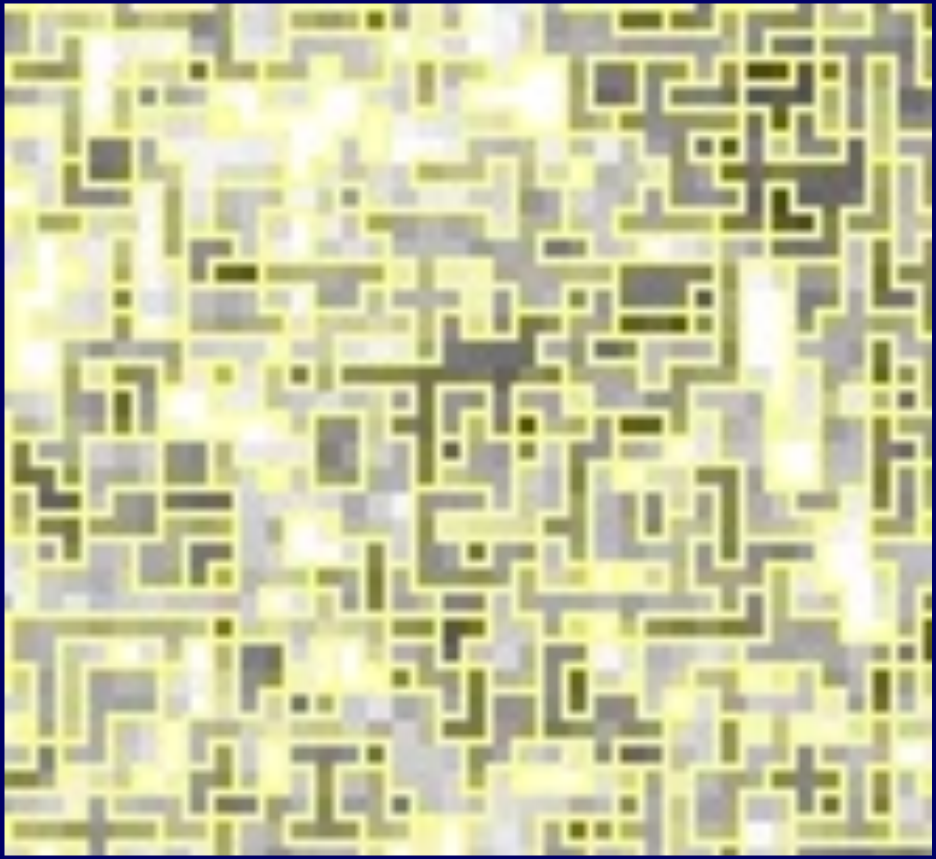
standard criterion

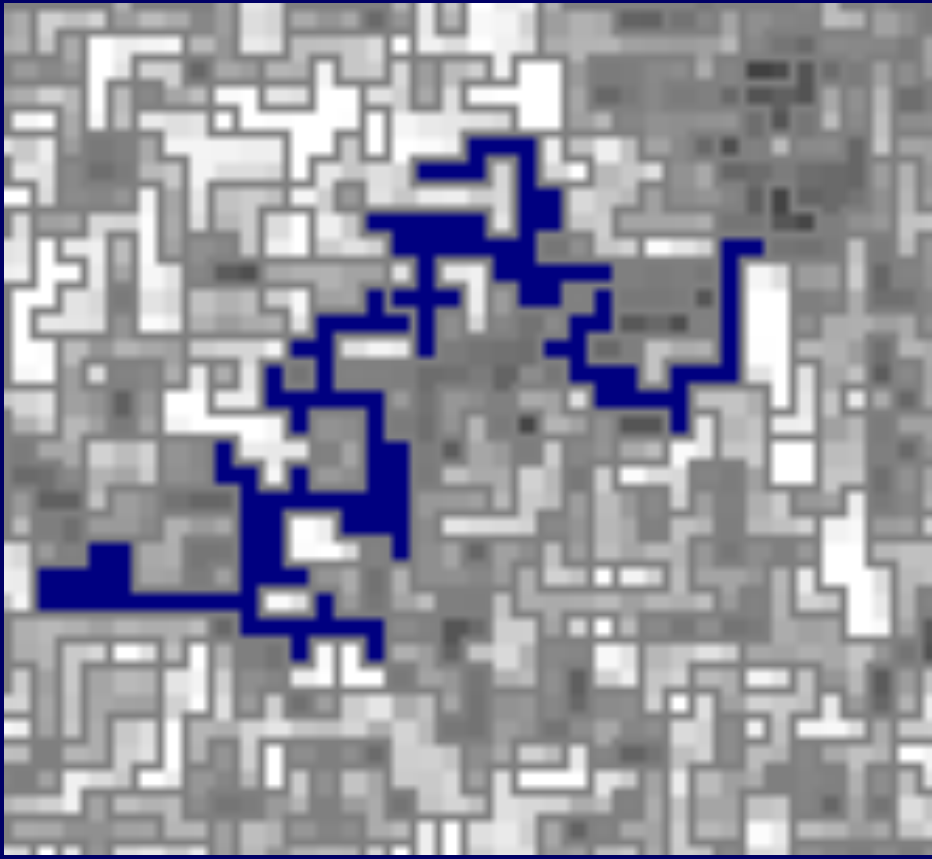


100 segments



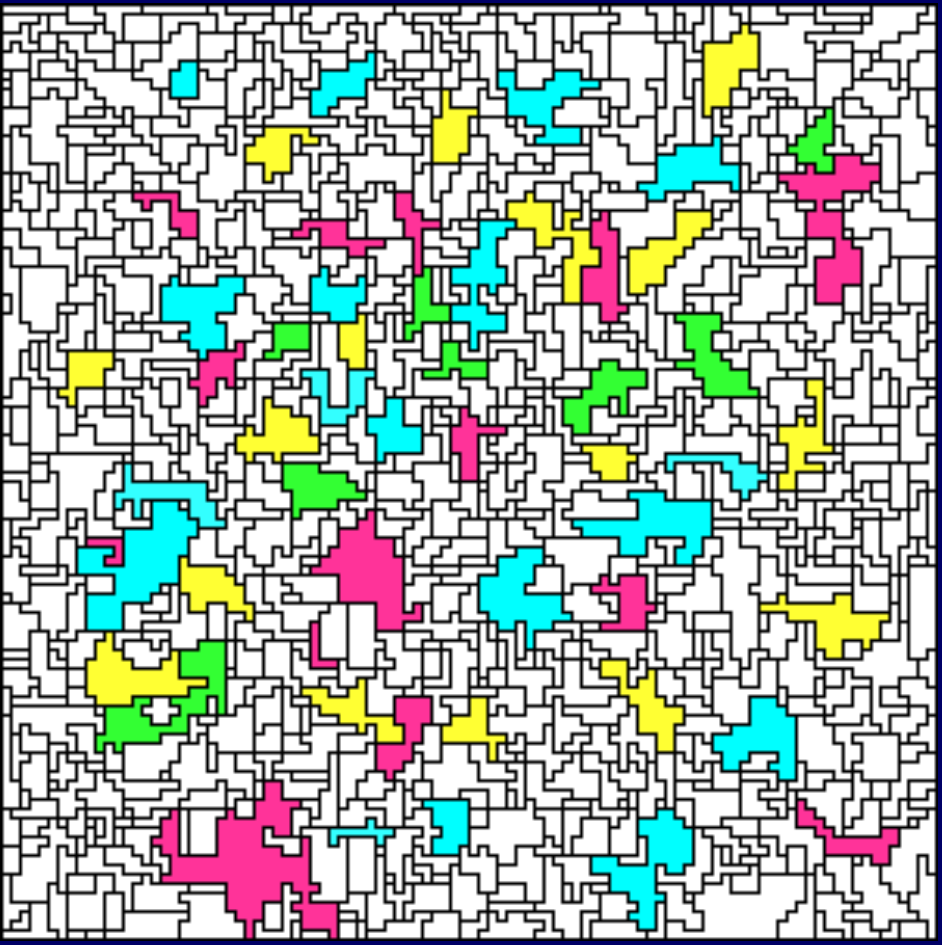
1000 segments



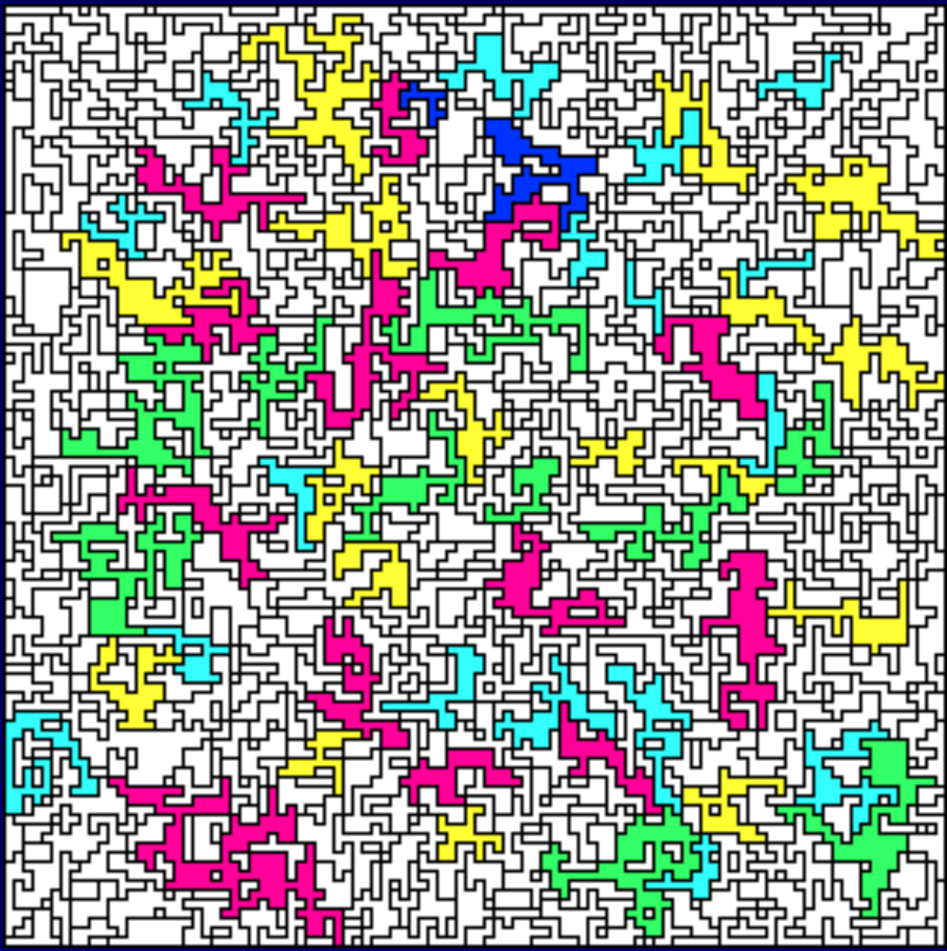


2000 **s**egments

Shape vs standard criterion, 1000 segments



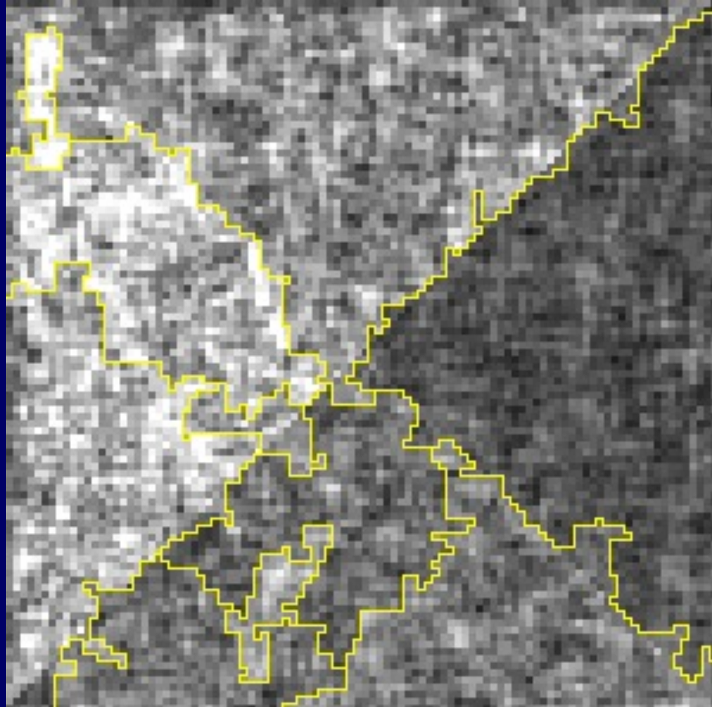
with shape criterion

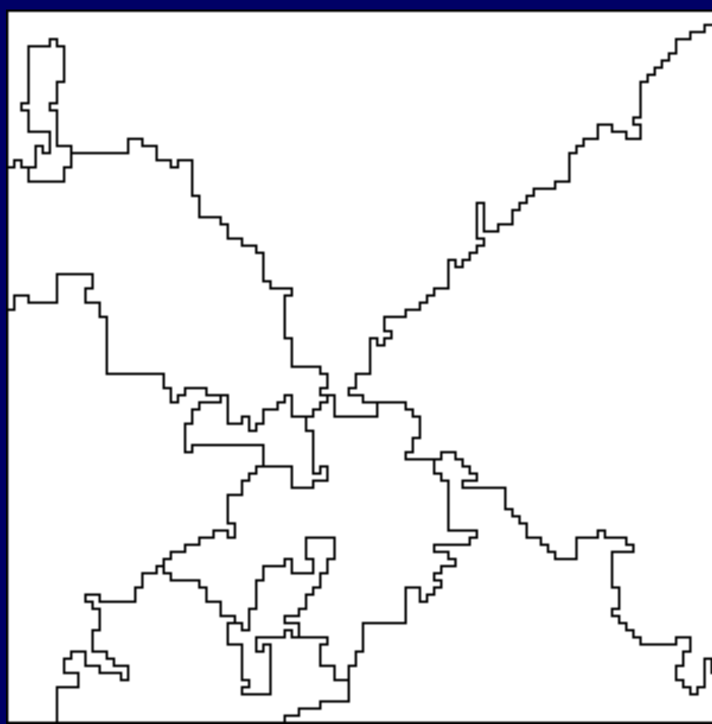


without shape criterion

10

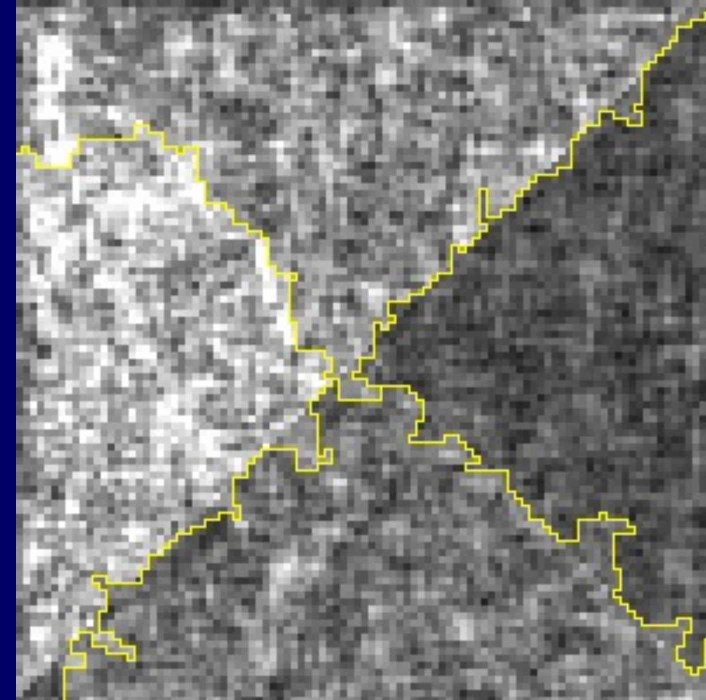
Segments

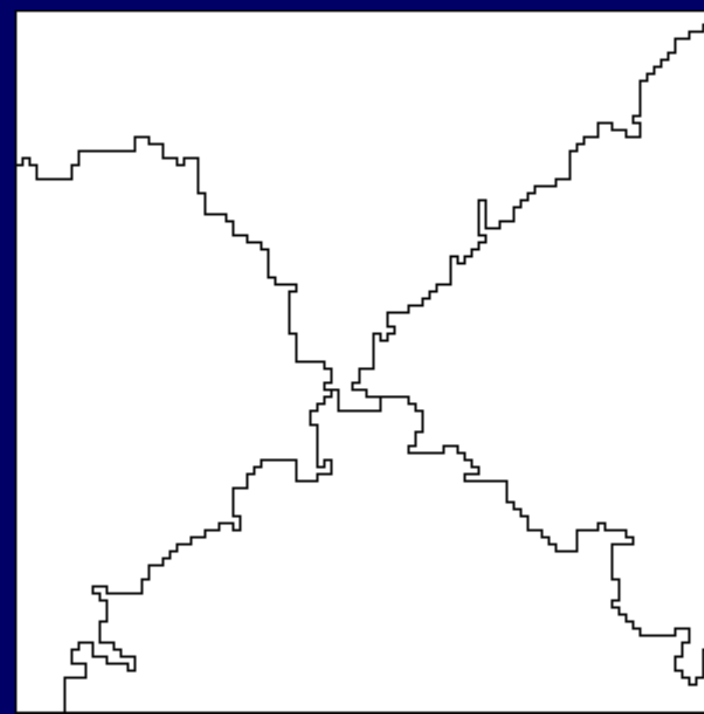




4

Segments





SHAPE CRITERIA

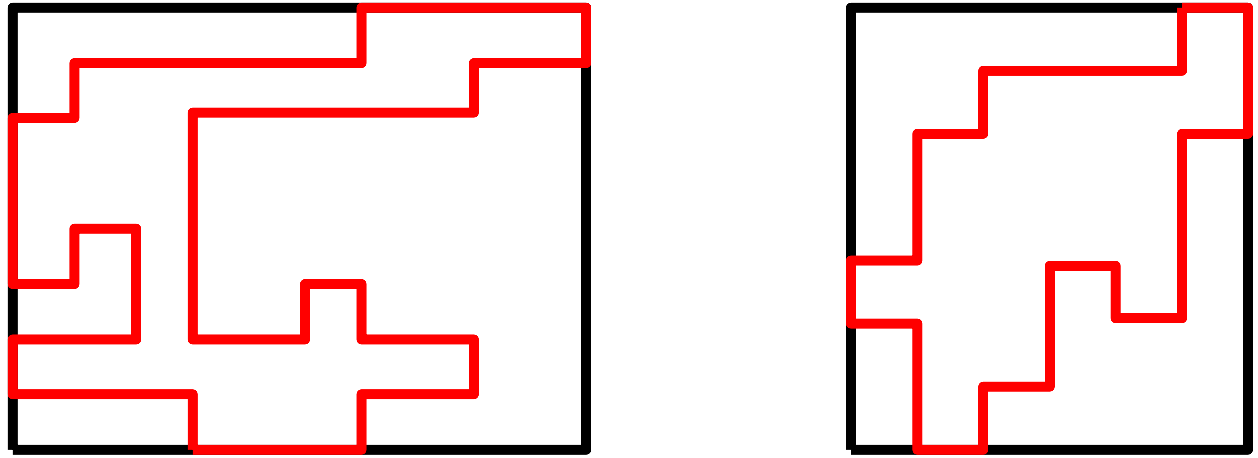
- Bonding box – perimeter Cp
- Bonding box – area Ca
- Contour length Cl

New criteria

$$Cs_{i,j} = C_{i,j} * Cp^2 * Ca * Cl$$

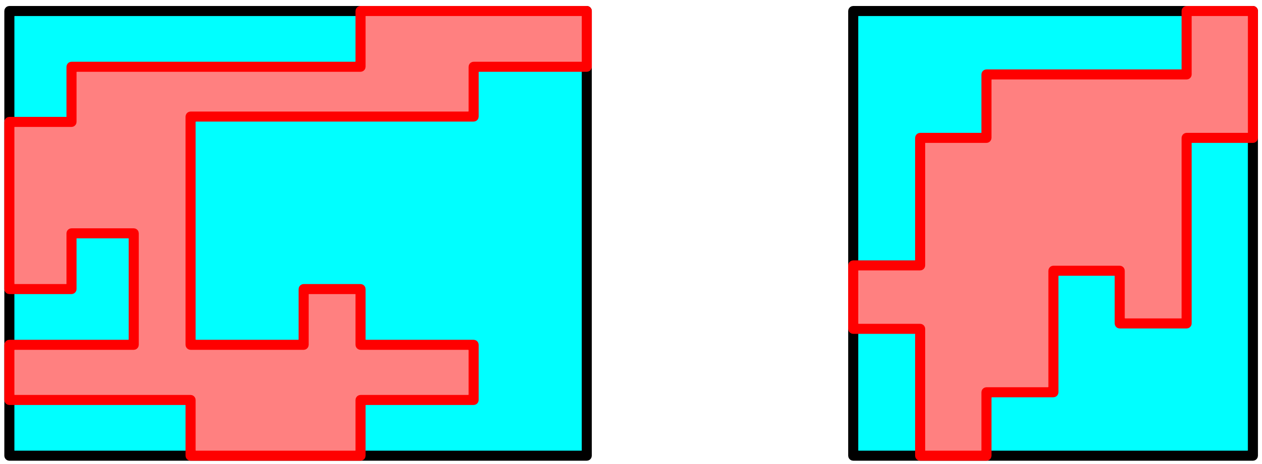
Bonding box – perimeter

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



Bonding box – area

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

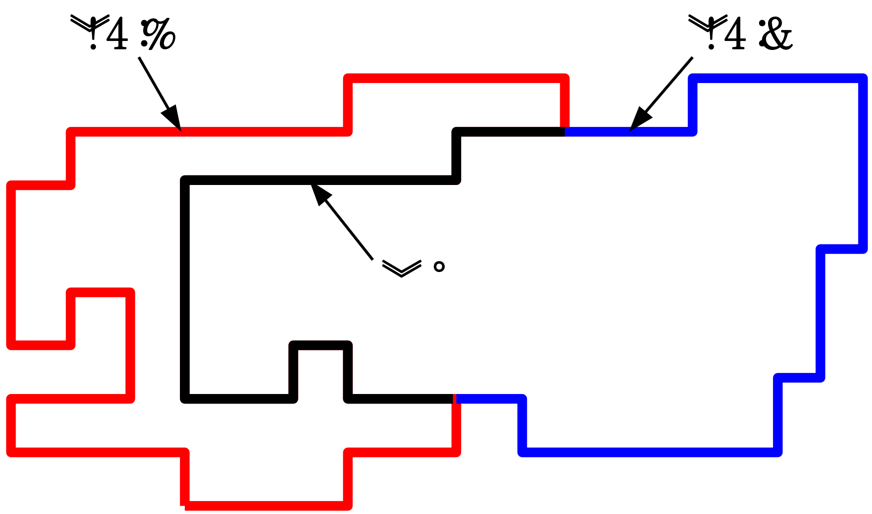


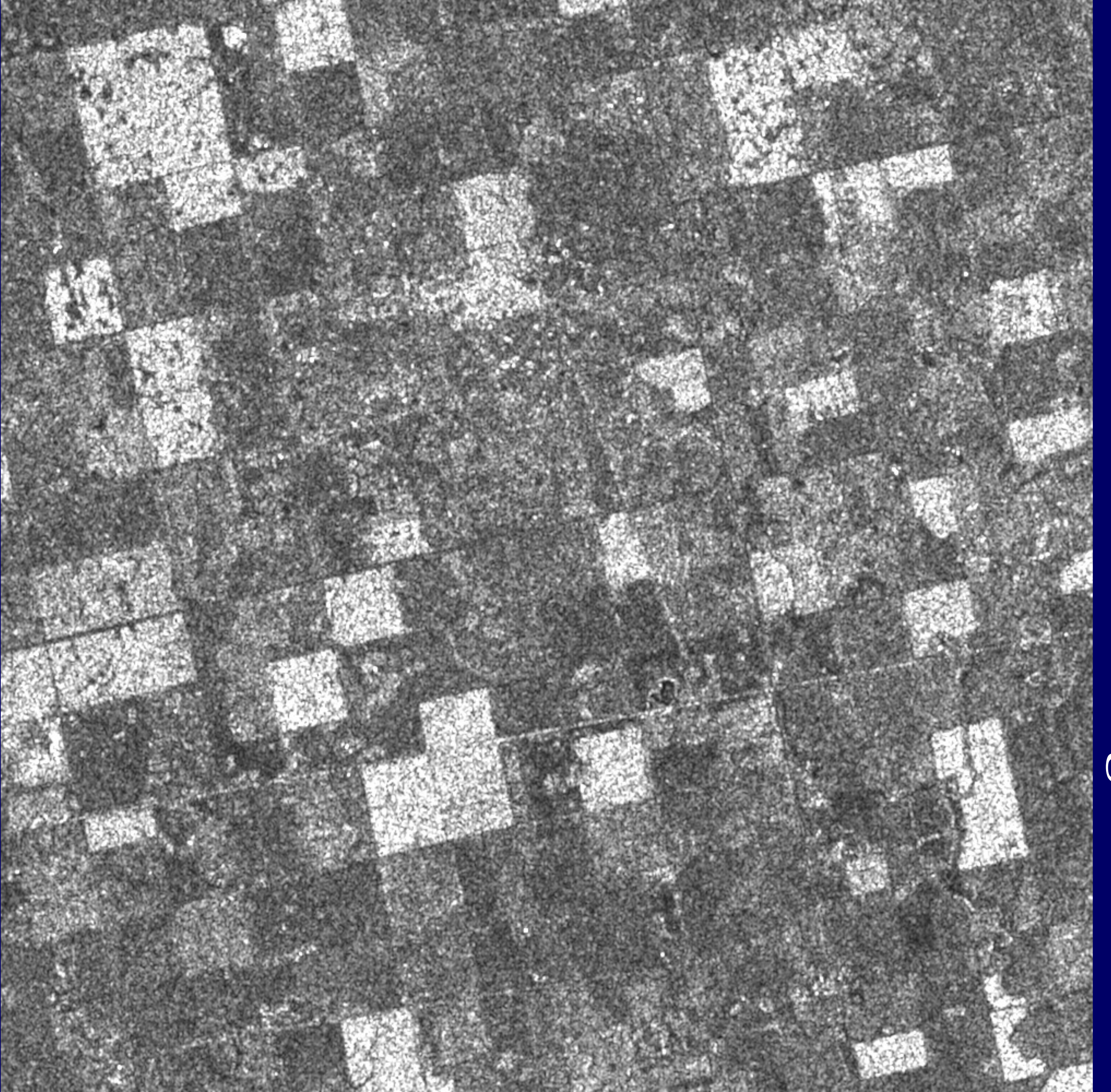
Contour length

$$Lc \quad = \quad length\ of\ common\ part\ of\ contours$$

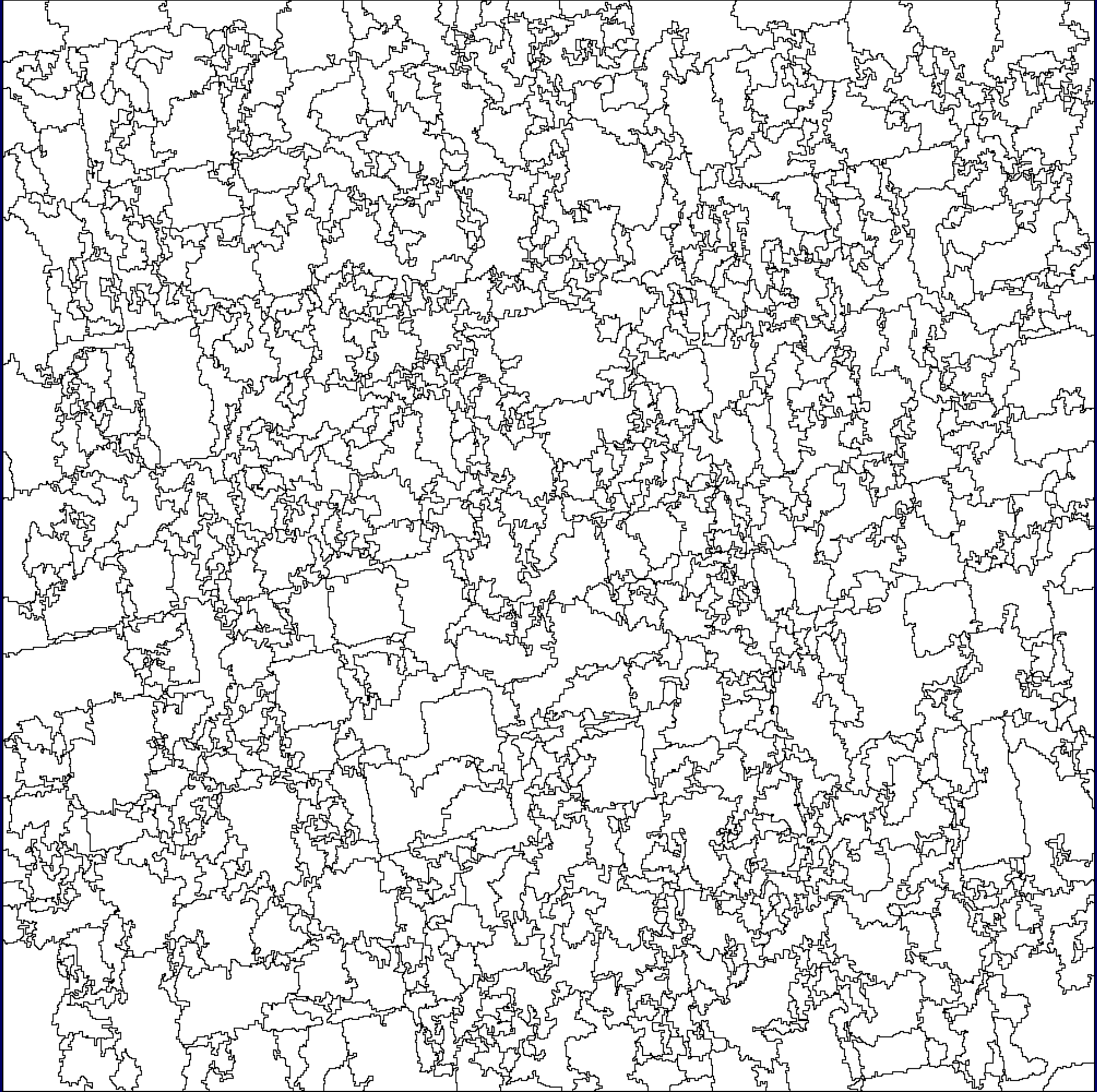
$$Lex\ i \quad = \quad length\ of\ exclusive\ part\ for\ S_i$$

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

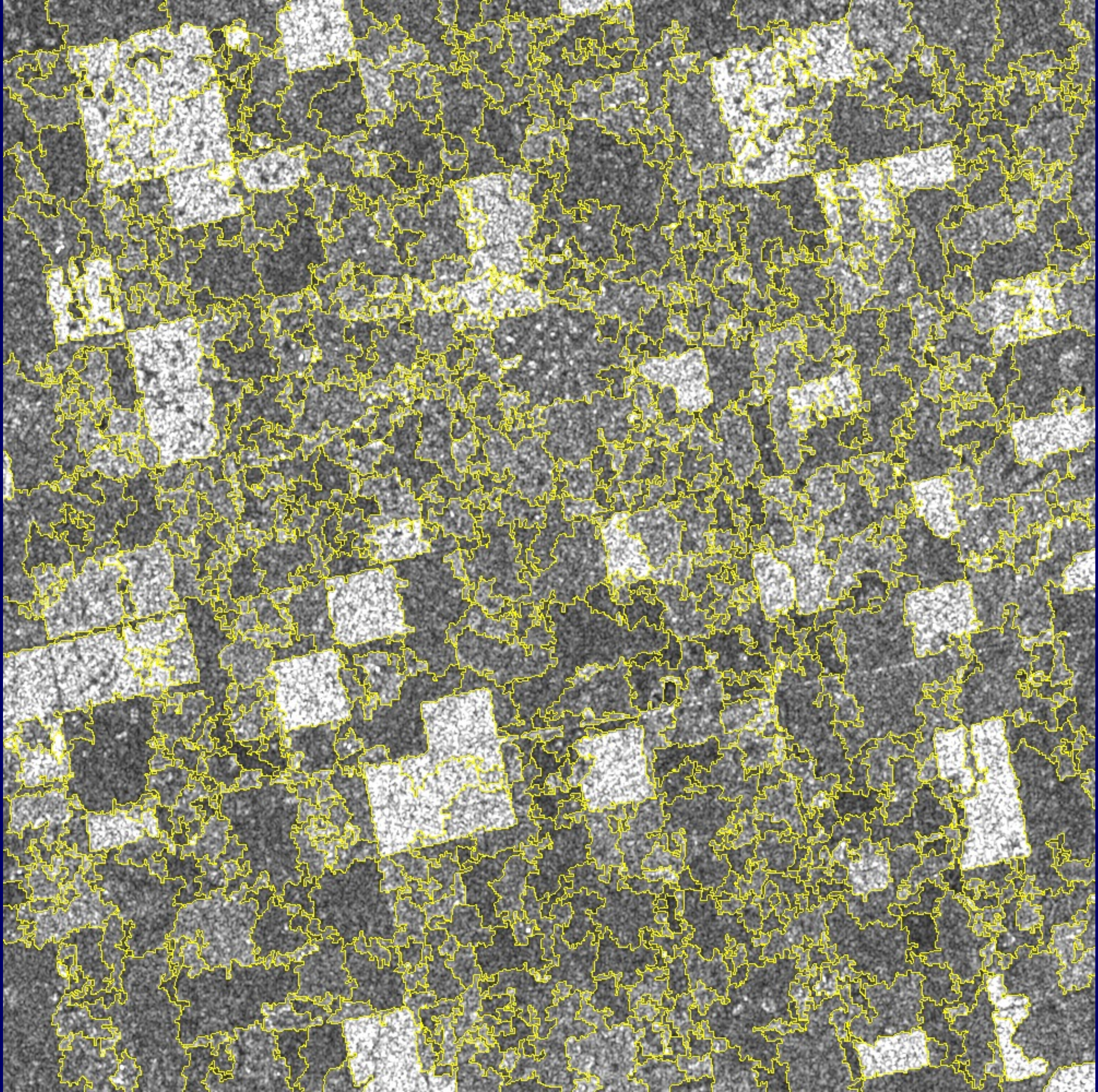




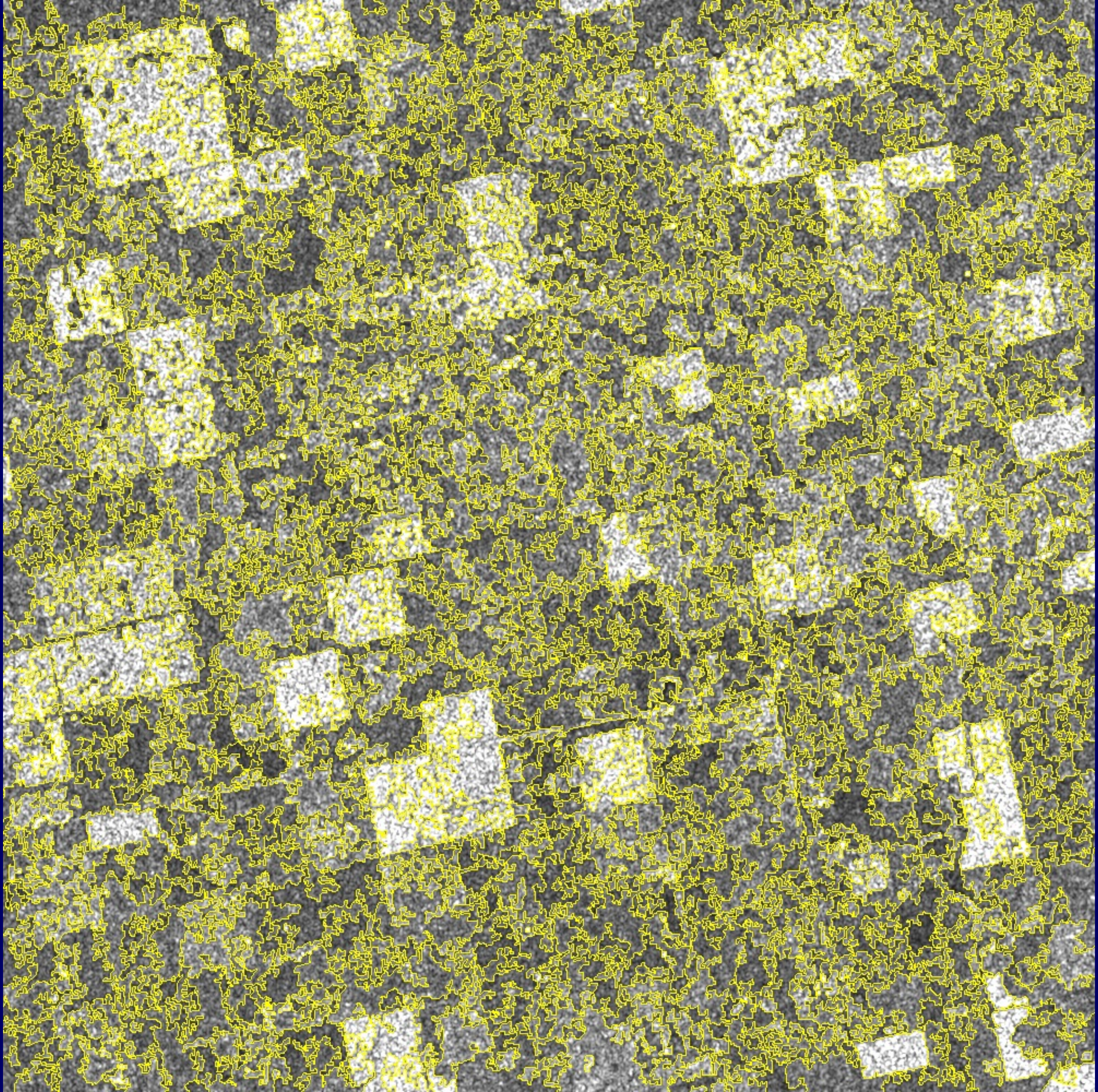
1000x1000 SAR image



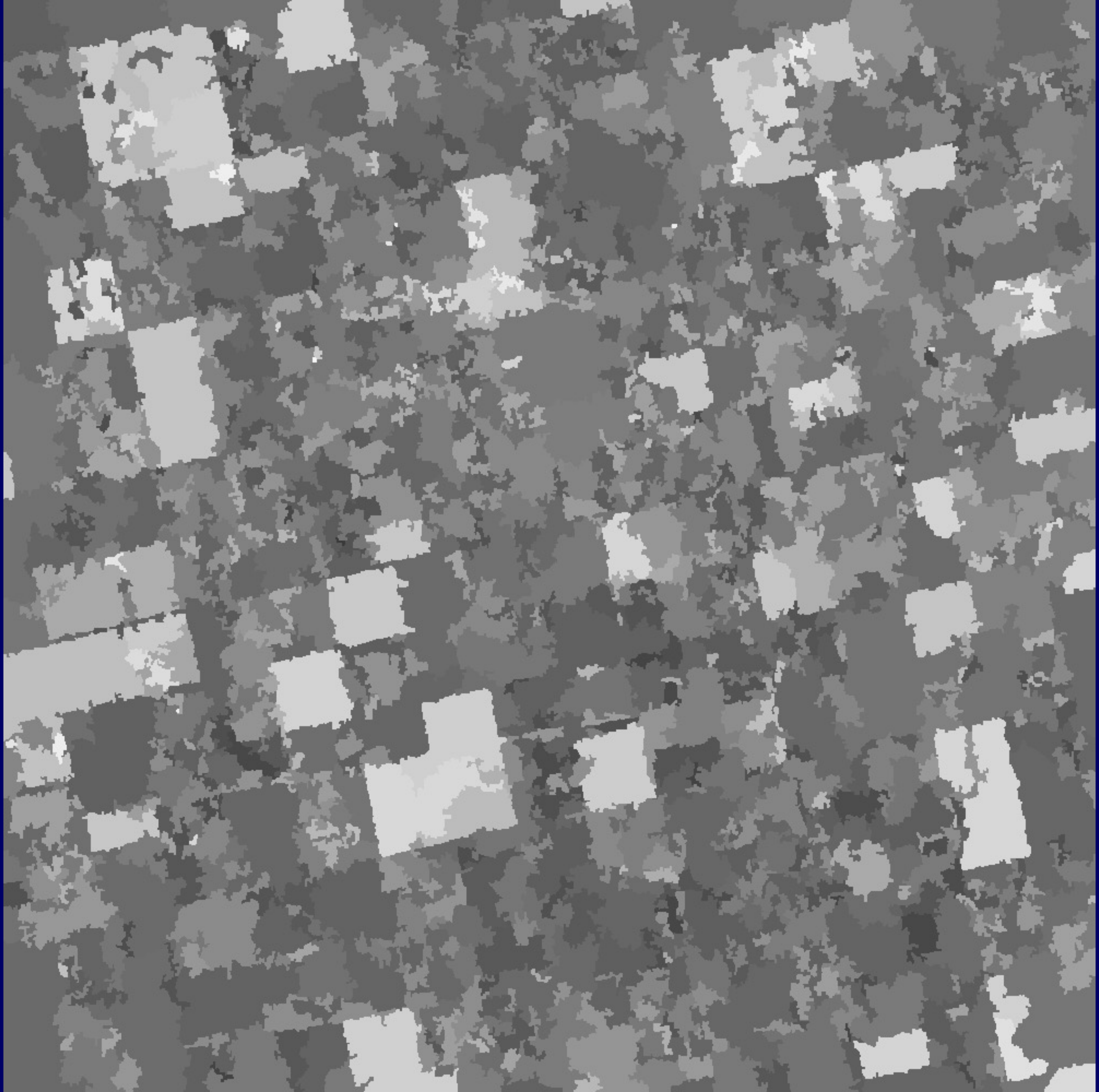
1000 segments

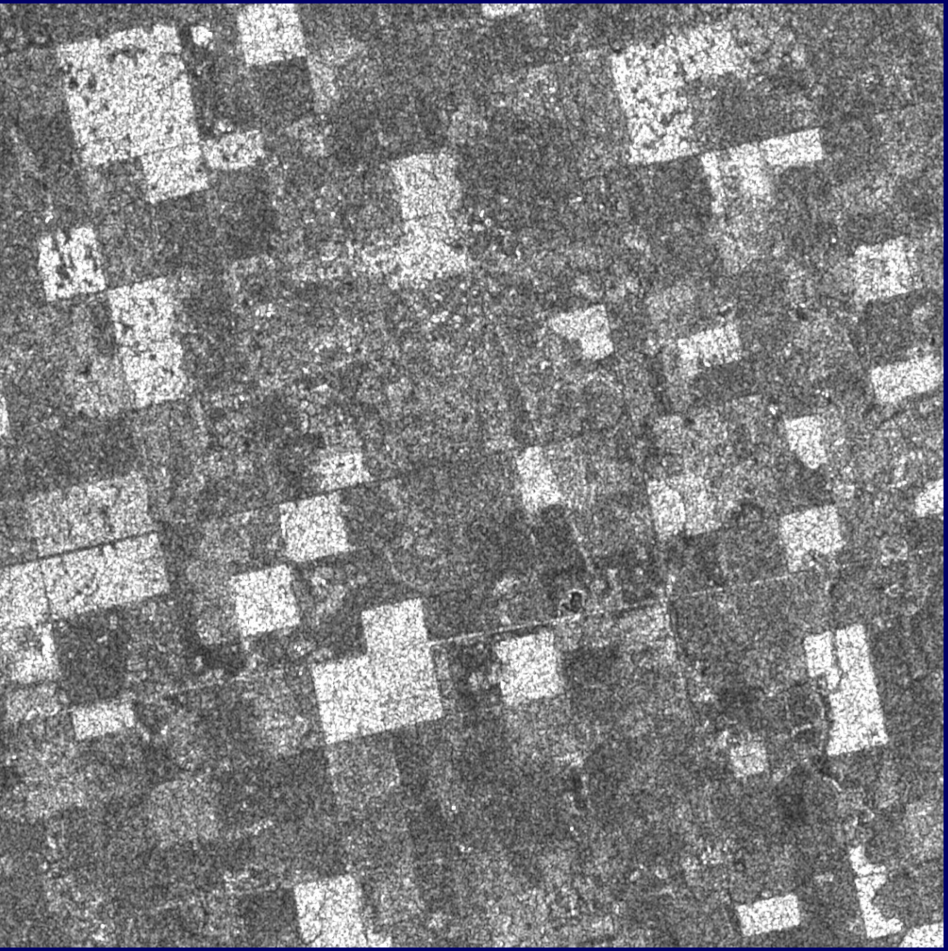


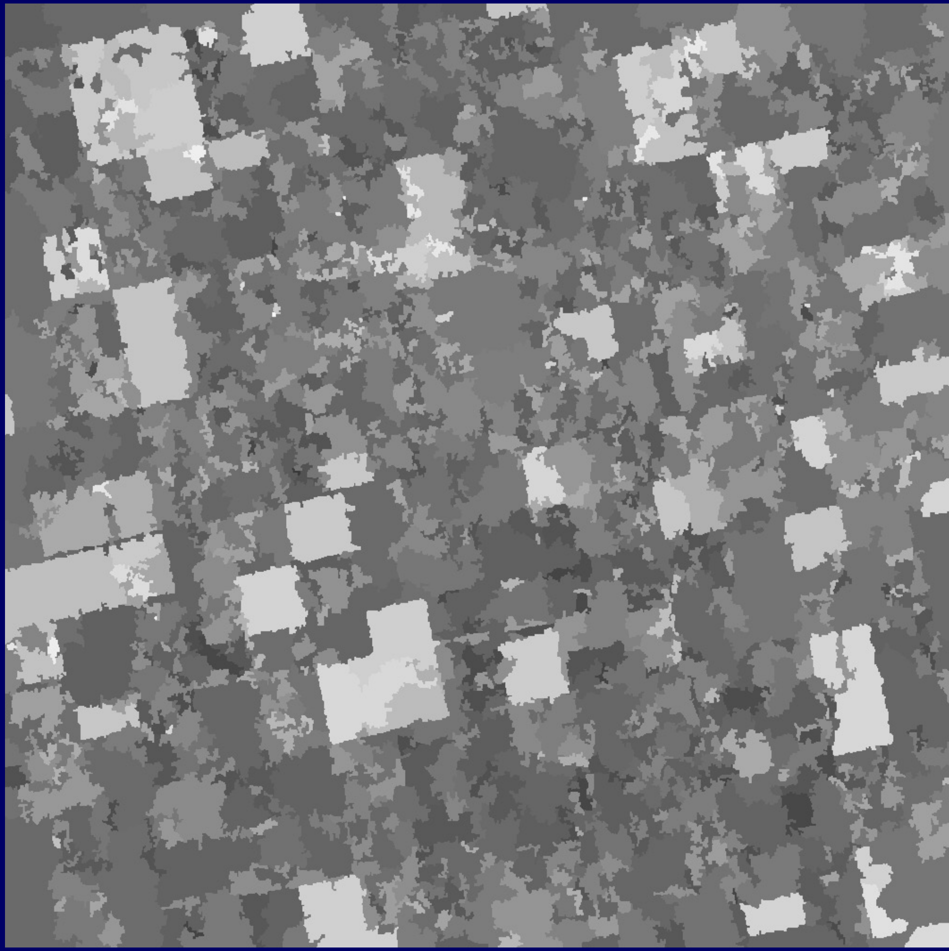
1000 segments



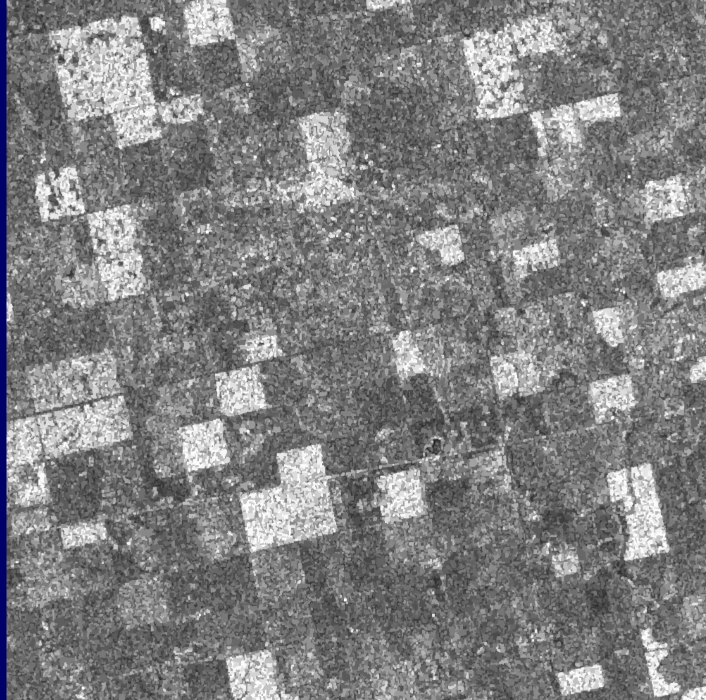
1000 segments

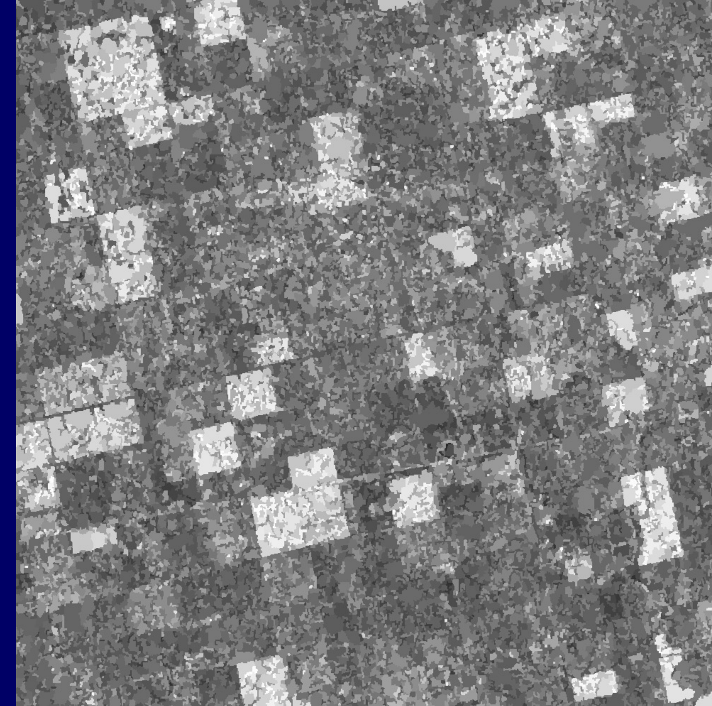






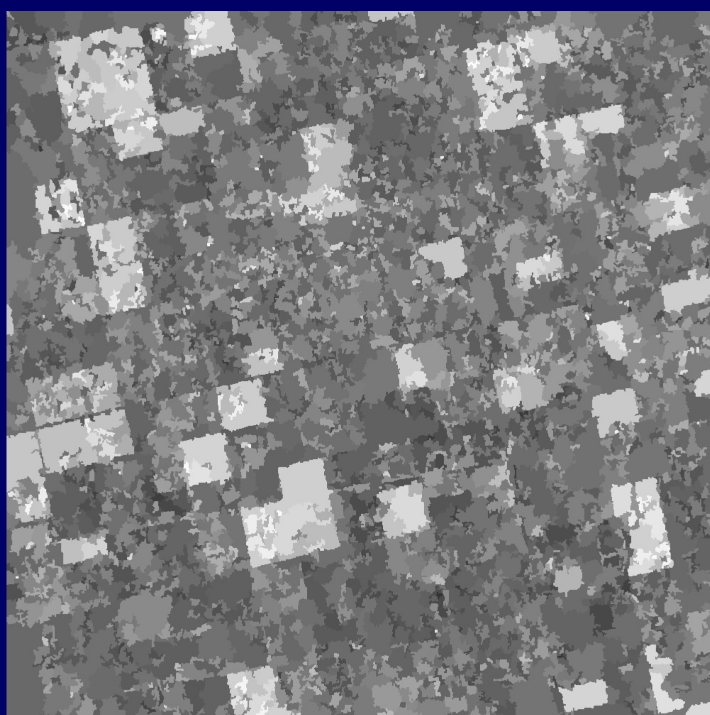
40K
Segments

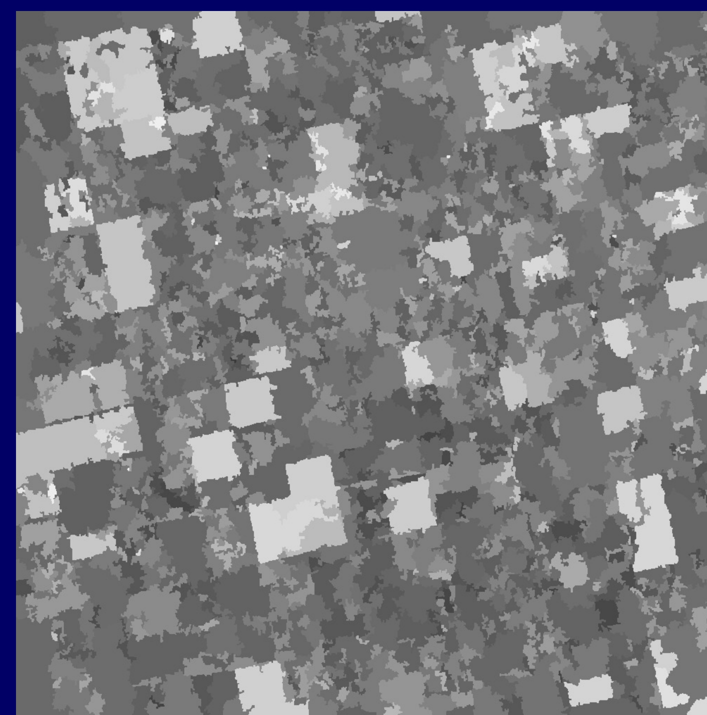




10K
Segments

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