Lecture 10 – Image segmentation III
Regions

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Agenda

- Regions growing
- Region splitting and merging

REGIONS GROWING

Regions growing

- ***f(x, y)*** is the input image;
- ***S(x, y)*** is an image containing seeds:
  - ***S*** is a binary image with the same size as image ***f***.
  - Pixels with a value of ***1*** indicate the seeds and ***0***s indicate the other locations;
- ***Q*** denotes ***some property*** to be applied at each position ***(x, y)***.

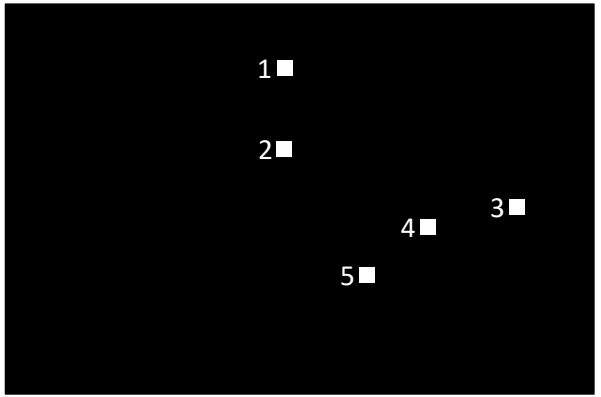
Regions growing

- ***f(x, y)*** is the input image;
- ***S(x, y)*** is an image containing seeds:
  - ***S*** is a binary image with the same size as image ***f***.
  - Pixels with a value of ***1*** indicate the seeds and ***0***s indicate the other locations;
- ***Q*** denotes ***some property*** to be applied at each position ***(x, y)***.

f(*x*, *y*)

Markers for the seeds

S(*x*, *y*)



Regions growing

- Basic region growth algorithm (based on connectivity-8):
  - Reduce each connected component in S(x, y) to a single pixel (morphological erosion).
    - Label all pixels, r = [1, 2, 3, ... N].
  - For each seed r, generate an image f_r where:
    - $f_r(x, y) = r$, if the input image pixel satisfies Q;
    - $f_r(x, y) = 0$, otherwise.
  - The output image g is formed by appending to each seed in S all the pixels labeled with the number r in f_r that are 8-connected to that seed.
    - In case of conflict, assign the lowest label. “The first one takes all”.

Regions growing

- (A) Original image f(x, y) with size 5 x 5, 3-bit depth (L = 8) and two seeds.

(A)

7	0	5	6	5
5	1	5	7	7
0	3	6	5	6
2	1	7	7	6
0	1	5	6	1

f(x, y)

Regions growing

- (B) Image with seeds S(x, y). The seeds have already been reduced to a single pixel and labeled.

(A)

7	0	5	6	5
5	1	5	7	7
0	3	6	5	6
2	1	7	7	6
0	1	5	6	1

f(x, y)

(B)

0	0	0	0	0
0	0	0	2	0
0	0	0	0	0
0	1	0	0	0
0	0	0	0	0

S(x, y)

- (C) Image with the absolute differences between the pixel under the seed labeled 1 and the other pixels.
  - Q property: absolute difference between pixels (T).

(A)

7	0	5	6	5
5	1	5	7	7
0	3	6	5	6
2	1	7	7	6
0	1	5	6	1

f(x, y)

(C)

6	1	4	5	4
4	0	4	6	6
1	2	5	4	5
1	0	6	6	5
1	0	4	5	0

$T_1 = |f(x, y) - 1|$

(B)

0	0	0	0	0
0	0	0	2	0
0	0	0	0	0
0	1	0	0	0
0	0	0	0	0

S(x, y)

Regions growing

- (D) Image with the absolute differences between the pixel under the seed labeled **2** and the other pixels.
  - Q property: absolute difference between pixels (T).

(A)

7	0	5	6	5
5	1	5	7	7
0	3	6	5	6
2	1	7	7	6
0	1	5	6	1

$f(x, y)$

(C)

6	1	4	5	4
4	0	4	6	6
1	2	5	4	5
1	0	6	6	5
1	0	4	5	0

$T_1 = |f(x, y) - 1|$

(B)

0	0	0	0	0
0	0	0	2	0
0	0	0	0	0
0	1	0	0	0
0	0	0	0	0

$S(x, y)$

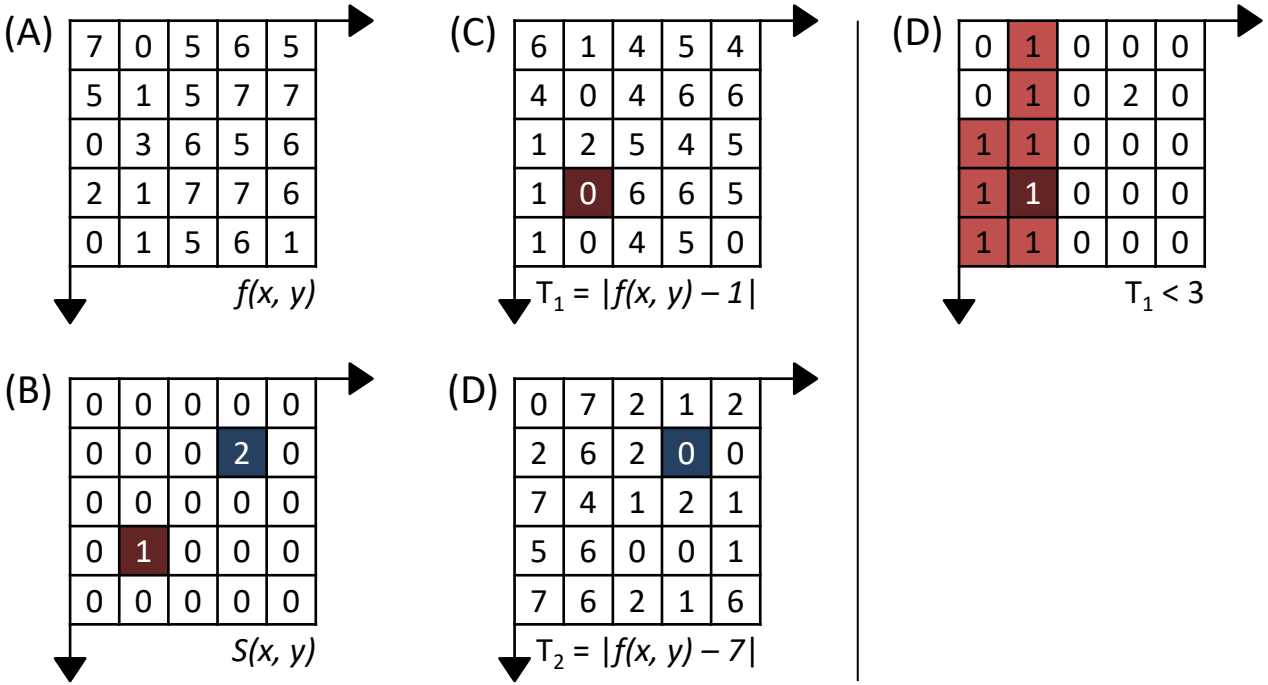
(D)

0	7	2	1	2
2	6	2	0	0
7	4	1	2	1
5	6	0	0	1
7	6	2	1	6

$T_2 = |f(x, y) - 7|$

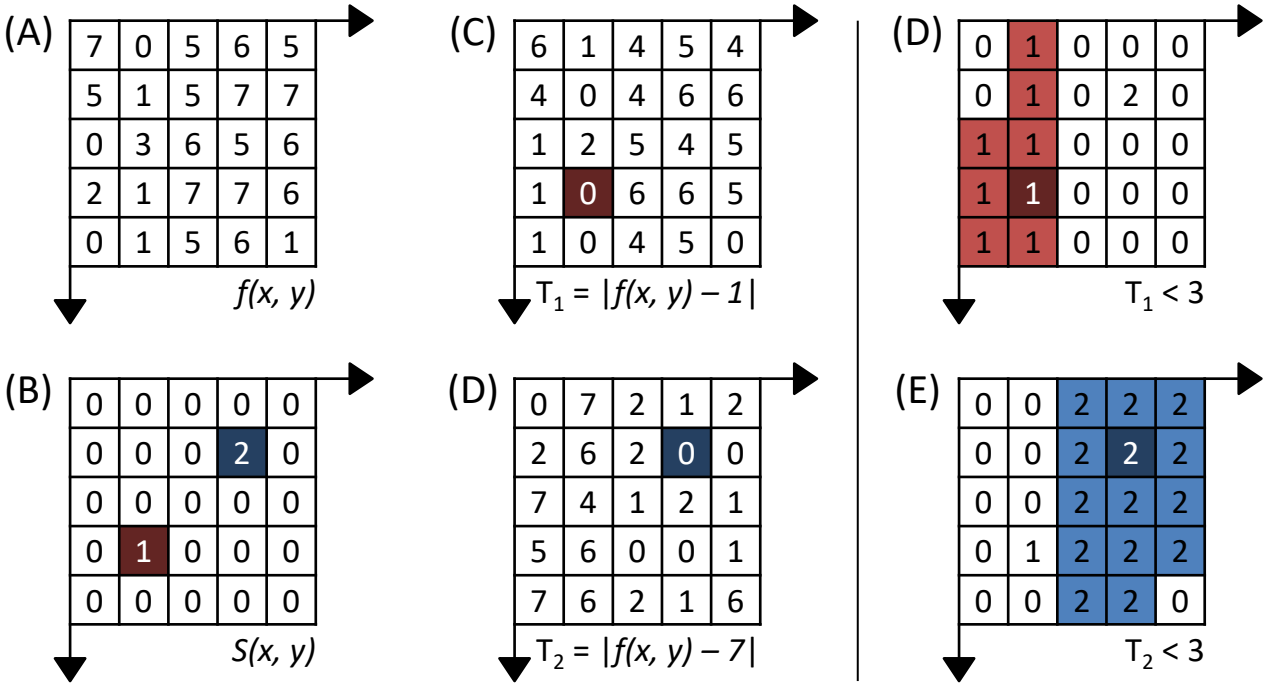
Regions growing

- (E) Segmentation of image f considering Q = T < 3.
  - Pixels in T_1 that satisfy Q and have an 8-connected path to the seed.



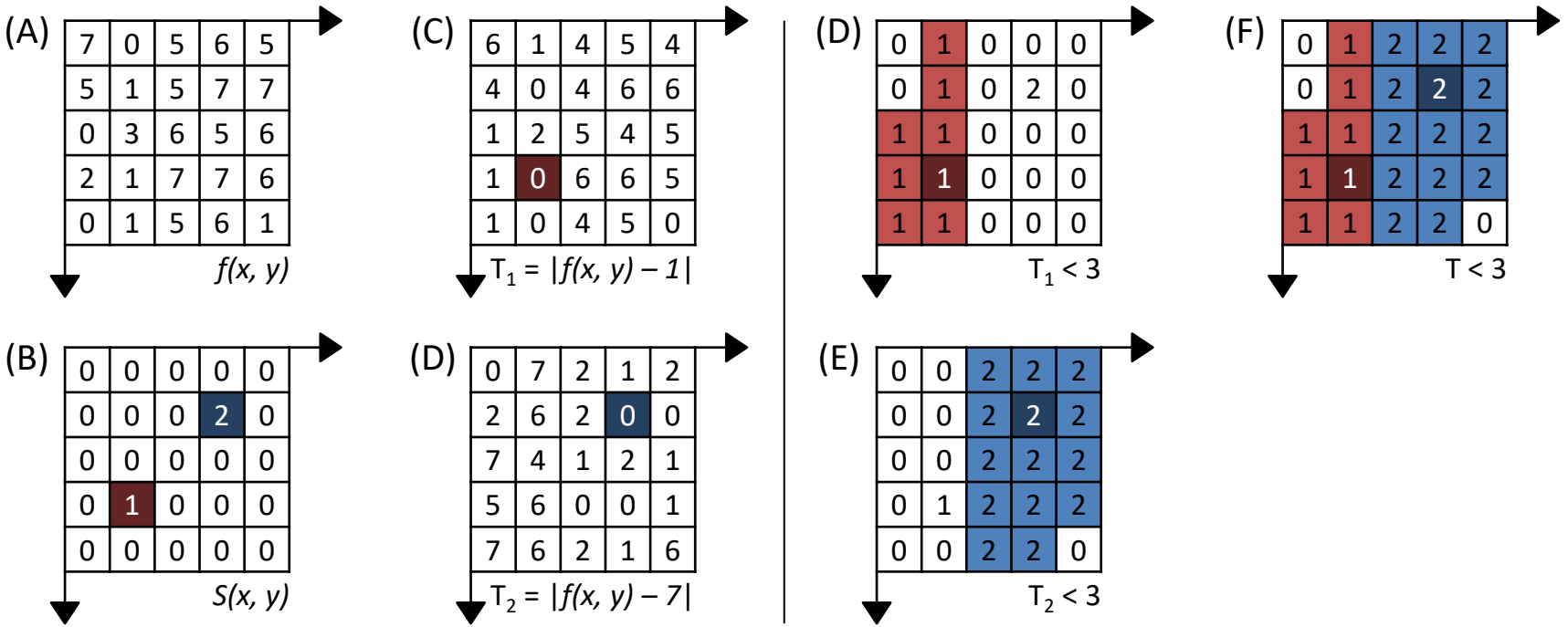
Regions growing

- (E) Segmentation of image f considering Q = T < 3.
  - Pixels in T_2 that satisfy Q and have an 8-connected path to the seed.



Regions growing

- (F) Segmentation of image f considering Q = T < 3.



Regions growing

- (G) Segmentation of image f considering Q = T < 5.
  - Pixels in T_1 that satisfy Q and have an 8-connected path to the seed.

(A)

7	0	5	6	5
5	1	5	7	7
0	3	6	5	6
2	1	7	7	6
0	1	5	6	1

f(x, y)

(B)

0	0	0	0	0
0	0	0	2	0
0	0	0	0	0
0	1	0	0	0
0	0	0	0	0

S(x, y)

(C)

6	1	4	5	4
4	0	4	6	6
1	2	5	4	5
1	0	6	6	5
1	0	4	5	0

$T_1 = |f(x, y) - 1|$

(D)

0	7	2	1	2
2	6	2	0	0
7	4	1	2	1
5	6	0	0	1
7	6	2	1	6

$T_2 = |f(x, y) - 7|$

(G)

0	1	1	0	0
1	1	1	2	0
1	1	0	1	0
1	1	0	0	0
1	1	1	0	0

$T_1 < 5$

Regions growing

- (H) Segmentation of image f considering Q = T < 5.
  - Pixels in T_2 that satisfy Q and have an 8-connected path to the seed.

(A)

7	0	5	6	5
5	1	5	7	7
0	3	6	5	6
2	1	7	7	6
0	1	5	6	1

f(x, y)

(B)

0	0	0	0	0
0	0	0	2	0
0	0	0	0	0
0	1	0	0	0
0	0	0	0	0

S(x, y)

(C)

6	1	4	5	4
4	0	4	6	6
1	2	5	4	5
1	0	6	6	5
1	0	4	5	0

$T_1 = |f(x, y) - 1|$

(D)

0	7	2	1	2
2	6	2	0	0
7	4	1	2	1
5	6	0	0	1
7	6	2	1	6

$T_2 = |f(x, y) - 7|$

(G)

0	1	1	0	0
1	1	1	2	0
1	1	0	1	0
1	1	0	0	0
1	1	1	0	0

$T_1 < 5$

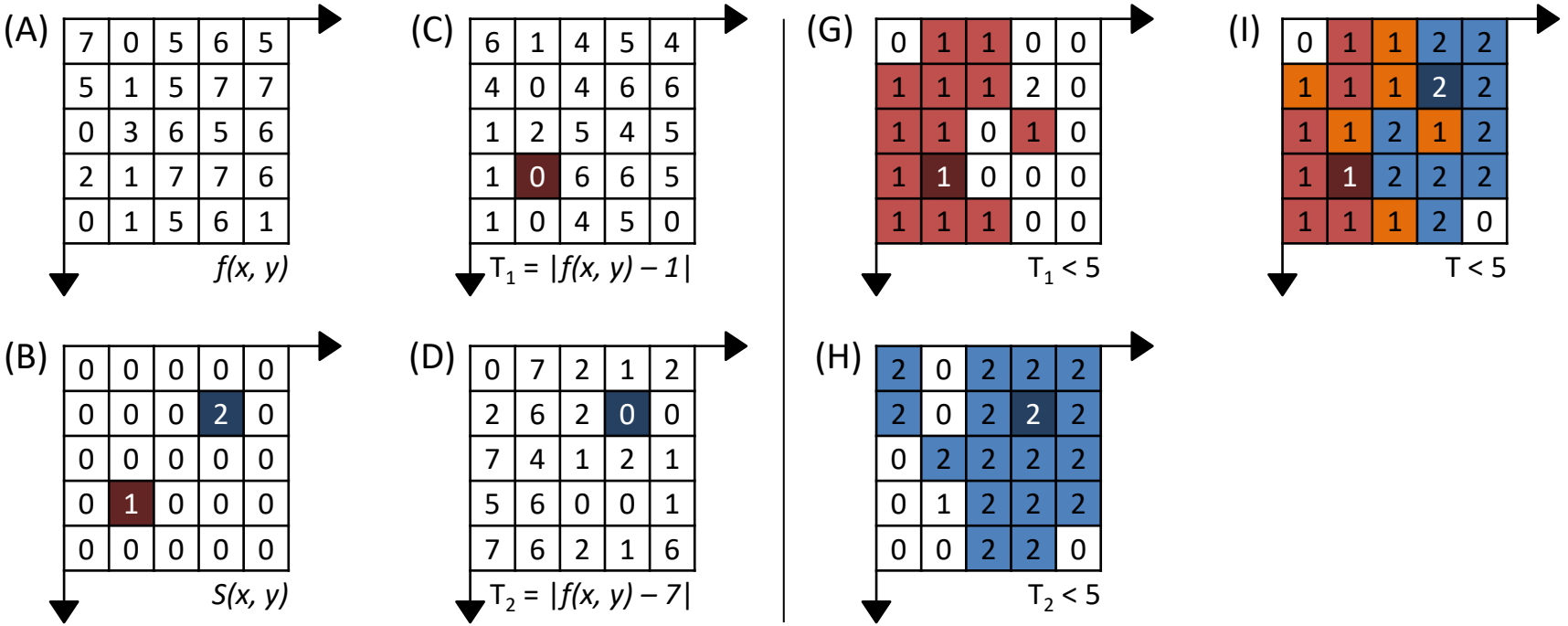
(H)

2	0	2	2	2
2	0	2	2	2
0	2	2	2	2
0	1	2	2	2
0	0	2	2	0

$T_2 < 5$

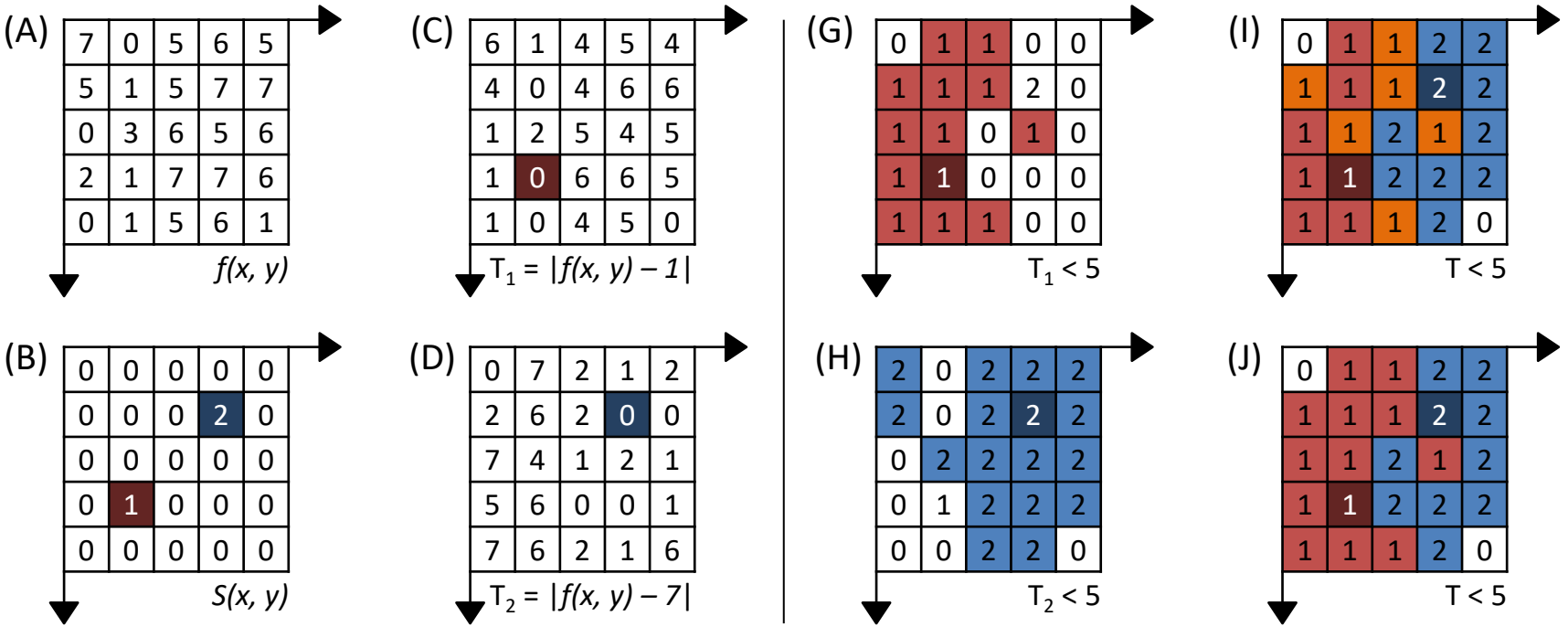
Regions growing

- (I) Segmentation of image f considering Q = T < 5.
  - In case of conflict, the pixel is arbitrarily assigned to the region with the smallest label.



Regions growing

- (J) Segmentation of image f considering Q = T < 5.



Regions growing

- (K) Segmentation of image f considering Q = T < 8.
  - Pixels in T_1 that satisfy Q and have an 8-connected path to the seed.

(A)

7	0	5	6	5
5	1	5	7	7
0	3	6	5	6
2	1	7	7	6
0	1	5	6	1

f(x, y)

(B)

0	0	0	0	0
0	0	0	2	0
0	0	0	0	0
0	1	0	0	0
0	0	0	0	0

S(x, y)

(C)

6	1	4	5	4
4	0	4	6	6
1	2	5	4	5
1	0	6	6	5
1	0	4	5	0

$T_1 = |f(x, y) - 1|$

(D)

0	7	2	1	2
2	6	2	0	0
7	4	1	2	1
5	6	0	0	1
7	6	2	1	6

$T_2 = |f(x, y) - 7|$

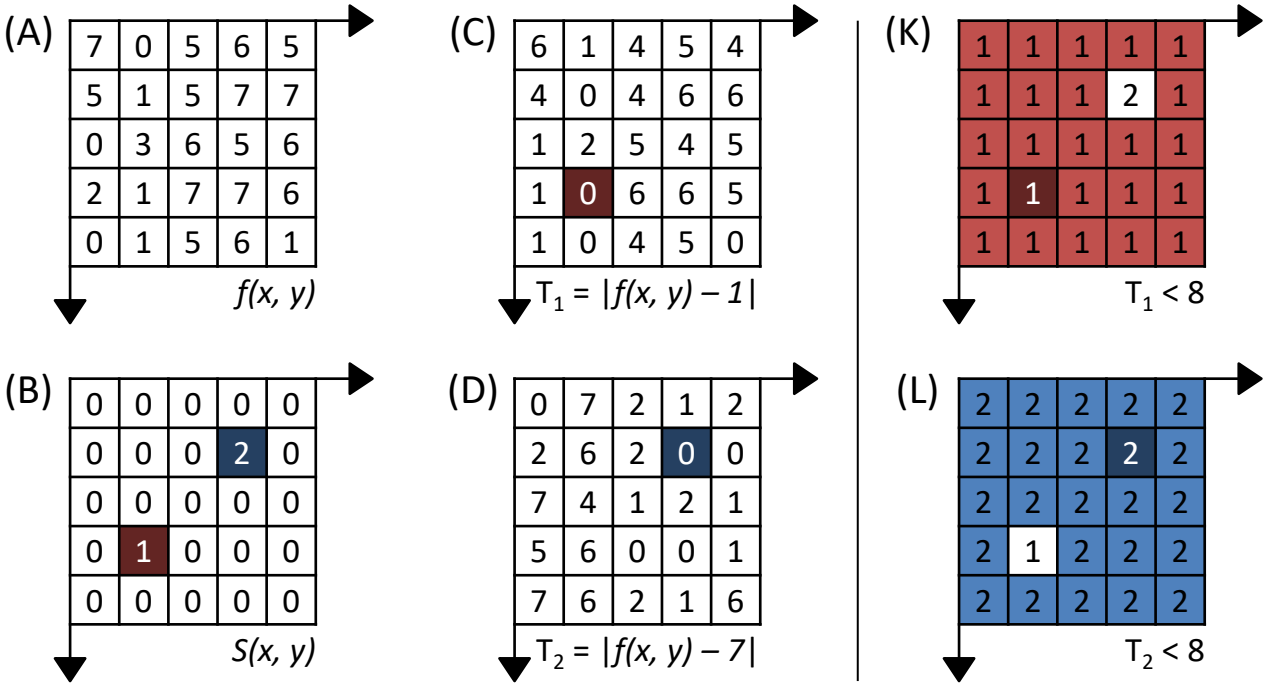
(K)

1	1	1	1	1
1	1	1	2	1
1	1	1	1	1
1	1	1	1	1
1	1	1	1	1

$T_1 < 8$

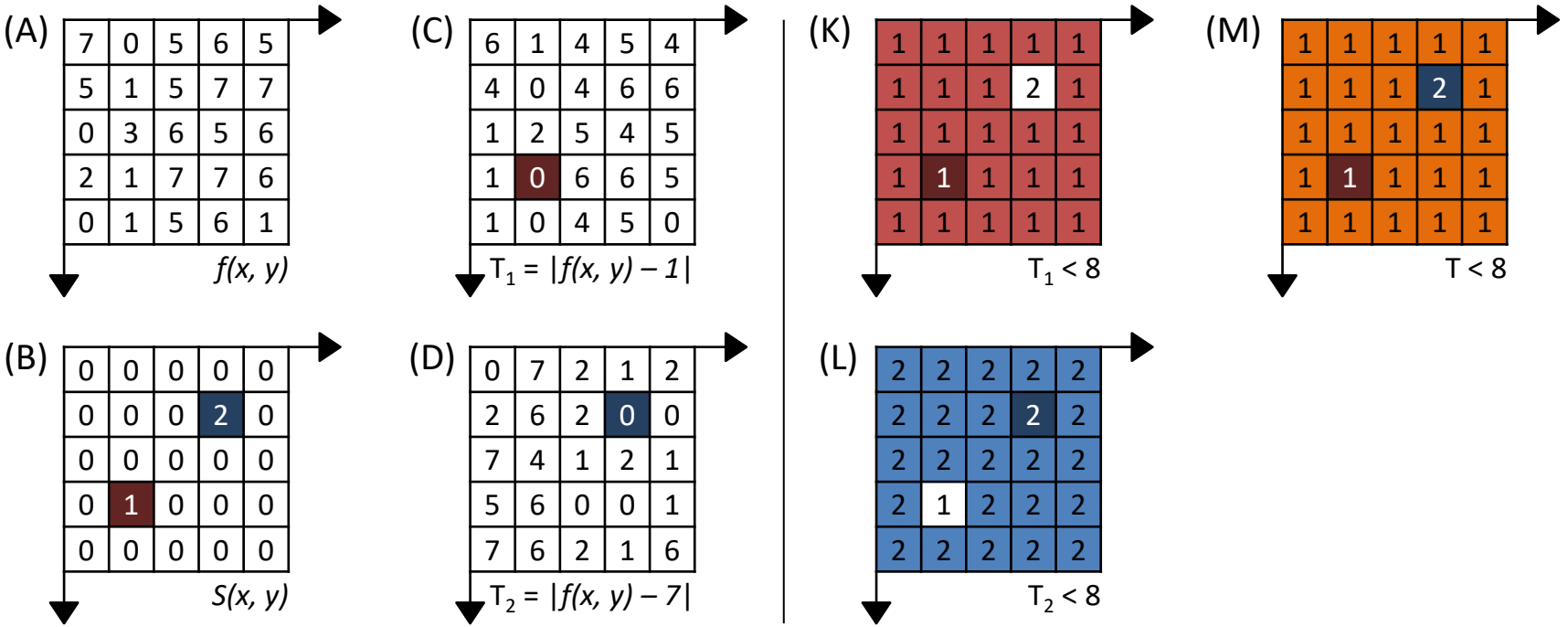
Regions growing

- (L) Segmentation of image f considering Q = T < 8.
  - Pixels in T_2 that satisfy Q and have an 8-connected path to the seed.



Regions growing

- (M) Segmentation of image f considering Q = T < 8.
  - In case of conflict, the pixel is assigned to the region with the smallest label arbitrarily.



Regions growing

- (N) Segmentation of image f considering Q = T < 8.
  - With T < 8, all pixels assigned to seed 1.

(A)

7	0	5	6	5
5	1	5	7	7
0	3	6	5	6
2	1	7	7	6
0	1	5	6	1

f(x, y)

(B)

0	0	0	0	0
0	0	0	2	0
0	0	0	0	0
0	1	0	0	0
0	0	0	0	0

S(x, y)

(C)

6	1	4	5	4
4	0	4	6	6
1	2	5	4	5
1	0	6	6	5
1	0	4	5	0

$T_1 = |f(x, y) - 1|$

(D)

0	7	2	1	2
2	6	2	0	0
7	4	1	2	1
5	6	0	0	1
7	6	2	1	6

$T_2 = |f(x, y) - 7|$

(K)

1	1	1	1	1
1	1	1	2	1
1	1	1	1	1
1	1	1	1	1
1	1	1	1	1

$T_1 < 8$

(L)

2	2	2	2	2
2	2	2	2	2
2	2	2	2	2
2	1	2	2	2
2	2	2	2	2

$T_2 < 8$

(M)

1	1	1	1	1
1	1	1	2	1
1	1	1	1	1
1	1	1	1	1
1	1	1	1	1

$T < 8$

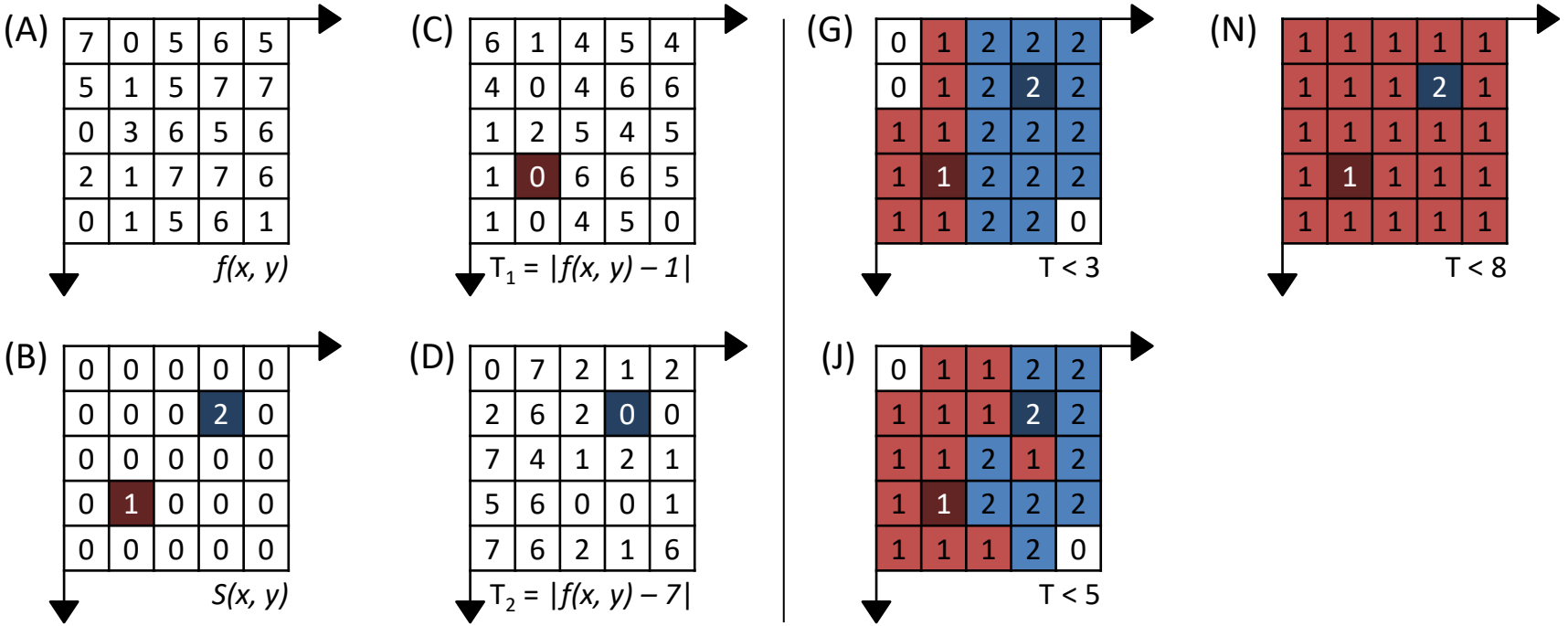
(N)

1	1	1	1	1
1	1	1	2	1
1	1	1	1	1
1	1	1	1	1
1	1	1	1	1

$T < 8$

Regions growing

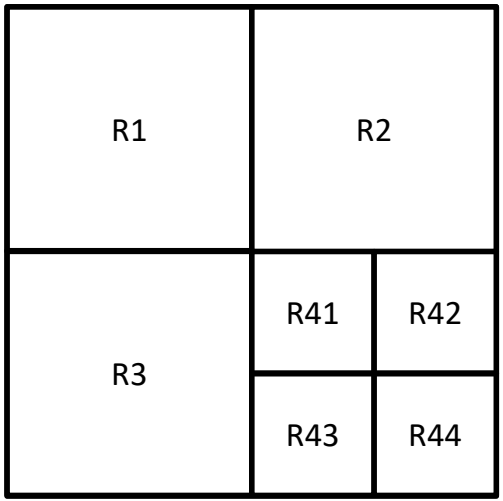
- Image segmentations f considering (G) Q = T < 3; (J) Q = T < 5; (N) Q = T < 8.

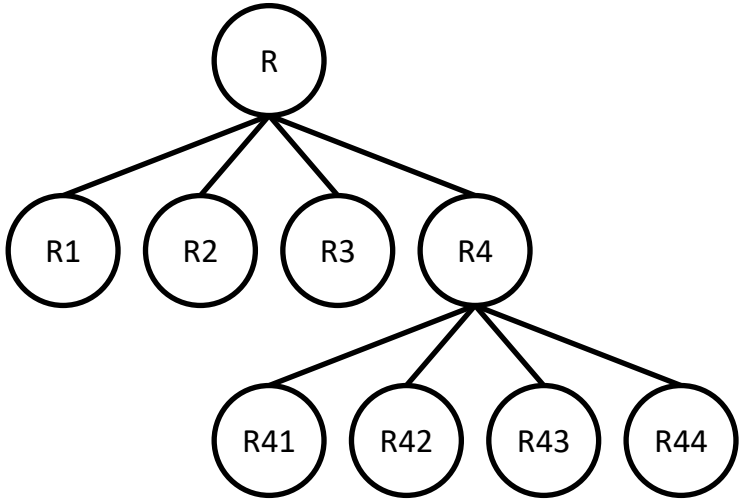


REGION SPLITTING AND MERGING

Divisão e fusão de regiões

- Region splitting and merging algorithm.
  1. Divide into four quadrants any region R_i in which $Q(R_i)$=False.
  2. When it is not possible to divide a region, merge the adjacent regions R_j and R_k where $Q(R_j \cup R_k)$ = Truth.
  3. Stop when merging is no longer possible.





Region splitting and merging

0	0	0	0	0	0	0	0
0	5	5	5	1	1	2	2
0	5	5	5	1	1	2	2
0	5	5	5	3	3	2	2
0	0	6	4	0	0	2	0
0	0	3	6	0	0	4	0
0	1	2	1	7	7	1	7
0	0	0	0	0	0	0	2

Q: $\mu > 2.5$ e $\sigma > 1.0$

Region splitting and merging

μ=1.88
σ=2.24

0	0	0	0	0	0	0	0
0	5	5	5	1	1	2	2
0	5	5	5	1	1	2	2
0	5	5	5	3	3	2	2
0	0	6	4	0	0	2	0
0	0	3	6	0	0	4	0
0	1	2	1	7	7	1	7
0	0	0	0	0	0	0	2

Q: $\mu > 2.5$ e $\sigma > 1.0$

Region splitting and merging

μ=1.88
σ=2.24

0	0	0	0	0	0	0	0
0	5	5	5	1	1	2	2
0	5	5	5	1	1	2	2
0	5	5	5	3	3	2	2
0	0	6	4	0	0	2	0
0	0	3	6	0	0	4	0
0	1	2	1	7	7	1	7
0	0	0	0	0	0	0	2

Q: μ > 2.5 e σ > 1.0

0	0	0	0
0	5	5	5
0	5	5	5
0	5	5	5

0	0	0	0
1	1	2	2
1	1	2	2
3	3	2	2

0	0	6	4
0	0	3	6
0	1	2	1
0	0	0	0

0	0	2	0
0	0	4	0
7	7	1	7
0	0	0	2

Region splitting and merging

μ=1.88
σ=2.24

0	0	0	0	0	0	0	0
0	5	5	5	1	1	2	2
0	5	5	5	1	1	2	2
0	5	5	5	3	3	2	2
0	0	6	4	0	0	2	0
0	0	3	6	0	0	4	0
0	1	2	1	7	7	1	7
0	0	0	0	0	0	0	2

Q: μ > 2.5 e σ > 1.0

μ=2.81
σ=2.48

0	0	0	0
0	5	5	5
0	5	5	5
0	5	5	5

μ=1.38
σ=0.99

0	0	0	0
1	1	2	2
1	1	2	2
3	3	2	2

μ=1.44
σ=2.09

0	0	6	4
0	0	3	6
0	1	2	1
0	0	0	0

μ=1.88
σ=2.69

0	0	2	0
0	0	4	0
7	7	1	7
0	0	0	2

Region splitting and merging

μ=1.88
σ=2.24

0	0	0	0	0	0	0	0
0	5	5	5	1	1	2	2
0	5	5	5	1	1	2	2
0	5	5	5	3	3	2	2
0	0	6	4	0	0	2	0
0	0	3	6	0	0	4	0
0	1	2	1	7	7	1	7
0	0	0	0	0	0	0	2

Q: μ > 2.5 e σ > 1.0

μ=2.81
σ=2.48

0	0	0	0
0	5	5	5
0	5	5	5
0	5	5	5

μ=1.38
σ=0.99

0	0	0	0
1	1	2	2
1	1	2	2
3	3	2	2

μ=1.44
σ=2.09

0	0	6	4
0	0	3	6
0	1	2	1
0	0	0	0

μ=1.88
σ=2.69

0	0	2	0
0	0	4	0
7	7	1	7
0	0	0	2

Region splitting and merging

μ=1.88
σ=2.24

0	0	0	0	0	0	0	0
0	5	5	5	1	1	2	2
0	5	5	5	1	1	2	2
0	5	5	5	3	3	2	2
0	0	6	4	0	0	2	0
0	0	3	6	0	0	4	0
0	1	2	1	7	7	1	7
0	0	0	0	0	0	0	2

Q: μ > 2.5 e σ > 1.0

μ=2.81
σ=2.48

0	0	0	0
0	5	5	5
0	5	5	5
0	5	5	5

μ=1.38
σ=0.99

0	0	0	0
1	1	2	2
1	1	2	2
3	3	2	2

μ=1.44
σ=2.09

0	0	6	4
0	0	3	6
0	1	2	1
0	0	0	0

μ=1.88
σ=2.69

0	0	2	0
0	0	4	0
7	7	1	7
0	0	0	2

0	0
0	5

0	0
5	5

0	5
0	5

5	5
5	5

0	0
0	0

6	4
3	6

0	0
0	0

2	0
4	0

0	1
0	0

2	1
0	0

7	7
0	0

1	7
0	2

Region splitting and merging

μ=1.88
σ=2.24

0	0	0	0	0	0	0	0
0	5	5	5	1	1	2	2
0	5	5	5	1	1	2	2
0	5	5	5	3	3	2	2
0	0	6	4	0	0	2	0
0	0	3	6	0	0	4	0
0	1	2	1	7	7	1	7
0	0	0	0	0	0	0	2

Q: μ > 2.5 e σ > 1.0

μ=2.81
σ=2.48

0	0	0	0
0	5	5	5
0	5	5	5
0	5	5	5

μ=1.38
σ=0.99

0	0	0	0
1	1	2	2
1	1	2	2
3	3	2	2

μ=1.44
σ=2.09

0	0	6	4
0	0	3	6
0	1	2	1
0	0	0	0

μ=1.88
σ=2.69

0	0	2	0
0	0	4	0
7	7	1	7
0	0	0	2

μ=1.25
σ=2.17

0	0
0	5

μ=2.50
σ=2.50

0	0
5	5

μ=2.50
σ=2.50

0	5
0	5

μ=5.00
σ=0.00

5	5
5	5

μ=0.00
σ=0.00

0	0
0	0

μ=4.75
σ=1.30

6	4
3	6

μ=0.00
σ=0.00

0	0
0	0

μ=1.50
σ=1.66

2	0
4	0

μ=0.25
σ=0.43

0	1
0	0

μ=0.75
σ=0.83

2	1
0	0

μ=3.50
σ=3.50

7	7
0	0

μ=2.50
σ=2.69

1	7
0	2

Region splitting and merging

μ=1.88
σ=2.24

0	0	0	0	0	0	0	0
0	5	5	5	1	1	2	2
0	5	5	5	1	1	2	2
0	5	5	5	3	3	2	2
0	0	6	4	0	0	2	0
0	0	3	6	0	0	4	0
0	1	2	1	7	7	1	7
0	0	0	0	0	0	0	2

Q: μ > 2.5 e σ > 1.0

μ=2.81
σ=2.48

0	0	0	0
0	5	5	5
0	5	5	5
0	5	5	5

μ=1.38
σ=0.99

0	0	0	0
1	1	2	2
1	1	2	2
3	3	2	2

μ=1.44
σ=2.09

0	0	6	4
0	0	3	6
0	1	2	1
0	0	0	0

μ=1.88
σ=2.69

0	0	2	0
0	0	4	0
7	7	1	7
0	0	0	2

0	0
0	5

0	0
5	5

μ=5.00
σ=0.00

0	5
0	5

5	5
5	5

μ=0.00
σ=0.00

0	0
0	0

6	4
3	6

μ=0.00
σ=0.00

0	0
0	0

2	0
4	0

μ=0.25
σ=0.43

0	1
0	0

μ=0.75
σ=0.83

2	1
0	0

7	7
0	0

1	7
0	2

Region splitting and merging

μ=1.88
σ=2.24

0	0	0	0	0	0	0	0
0	5	5	5	1	1	2	2
0	5	5	5	1	1	2	2
0	5	5	5	3	3	2	2
0	0	6	4	0	0	2	0
0	0	3	6	0	0	4	0
0	1	2	1	7	7	1	7
0	0	0	0	0	0	0	2

Q: μ > 2.5 e σ > 1.0

μ=2.81
σ=2.48

0	0	0	0
0	5	5	5
0	5	5	5
0	5	5	5

μ=1.38
σ=0.99

0	0	0	0
1	1	2	2
1	1	2	2
3	3	2	2

μ=1.44
σ=2.09

0	0	6	4
0	0	3	6
0	1	2	1
0	0	0	0

μ=1.88
σ=2.69

0	0	2	0
0	0	4	0
7	7	1	7
0	0	0	2

0	0
0	5

0	0
5	5

μ=5.00
σ=0.00

0	5
0	5

5	5
5	5

μ=0.00
σ=0.00

0	0
0	0

6	4
3	6

μ=0.00
σ=0.00

0	0
0	0

2	0
4	0

μ=0.25
σ=0.43

0	1
0	0

μ=0.75
σ=0.83

2	1
0	0

7	7
0	0

1	7
0	2

Region splitting and merging

μ=1.88
σ=2.24

0	0	0	0	0	0	0	0
0	5	5	5	1	1	2	2
0	5	5	5	1	1	2	2
0	5	5	5	3	3	2	2
0	0	6	4	0	0	2	0
0	0	3	6	0	0	4	0
0	1	2	1	7	7	1	7
0	0	0	0	0	0	0	2

Q: μ > 2.5 e σ > 1.0

μ=2.81
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0	0	0	0
0	5	5	5
0	5	5	5
0	5	5	5

μ=1.38
σ=0.99

0	0	0	0
1	1	2	2
1	1	2	2
3	3	2	2

μ=1.44
σ=2.09

0	0	6	4
0	0	3	6
0	1	2	1
0	0	0	0

μ=1.88
σ=2.69

0	0	2	0
0	0	4	0
7	7	1	7
0	0	0	2

0	0
0	5

0	0
5	5

μ=5.00
σ=0.00

0	5
0	5

5	5
5	5

μ=0.00
σ=0.00

0	0
0	0

6	4
3	6

μ=0.00
σ=0.00

0	0
0	0

2	0
4	0

μ=0.25
σ=0.43

0	1
0	0

μ=0.75
σ=0.83

2	1
0	0

7	7
0	0

1	7
0	2

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```
@misc{mari_im_proc_2023,
       author = {João Fernando Mari},
       title = {Image segmentation III - Regions},
       year = {2023},
       publisher = {GitHub},
       journal = {Introduction to digital image processing - UFV},
       howpublished = {\url{https://github.com/joaofmari/SIN392_Introduction-to-digital-image-processing_2023}}
}
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THE END