Image Segmentation

Lecture 5

Region Based Segmentation

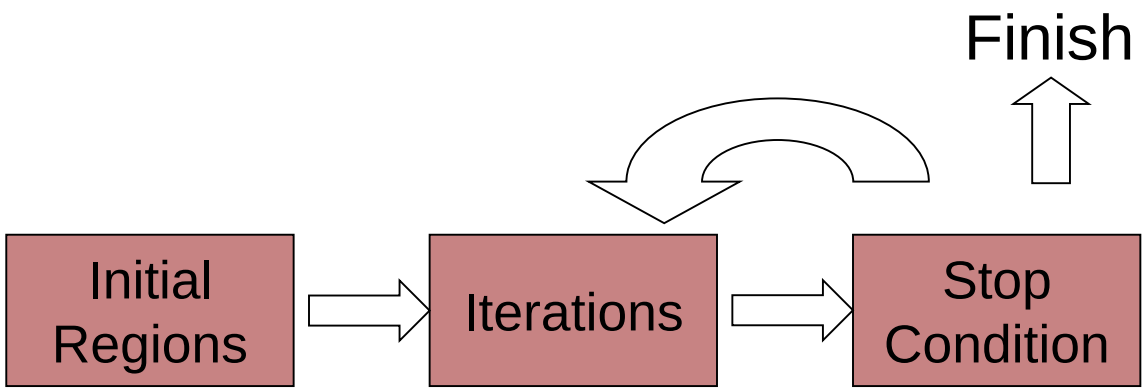
Region Based Segmentation

- Segmentation may be regarded as **spatial clustering:**
  - *clustering in the sense that pixels with similar values are grouped together, and*
  - *spatial in that pixels in the same category also form a single connected component.*
- Region Growing (Bottom-up approach)
- Region Split-and-merge (Top-down approach)

Region growing

- Groups pixels into larger regions.
- Starts with a **seed** region.
- **Grows** region by **merging** neighboring pixels.

- Iterative process
  - How to start?
  - How to iterate?
  - When to stop?



Region Growing

Let: $f(x, y)$ denote an input image array; $S(x, y)$ denote a *seed* array containing 1s at the locations of seed points and 0s elsewhere; and Q denote a predicate to be applied at each location (x, y). Arrays f and S are assumed to be of the same size. A basic region-growing algorithm based on 8-connectivity may be stated as follows.

1. Find all connected components in $S(x, y)$ and erode each connected component to one pixel; label all such pixels found as 1. All other pixels in S are labeled 0.
2. Form an image f_Q such that, at a pair of coordinates (x, y), let $f_Q(x, y) = 1$ if the input image satisfies the given predicate, Q, at those coordinates; otherwise, let $f_Q(x, y) = 0$.
3. Let g be an image formed by appending to each seed point in S all the 1-valued points in f_Q that are 8-connected to that seed point.
4. Label each connected component in g with a different region label (e.g., $1, 2, 3, \ldots$). This is the segmented image obtained by region growing.

Region Growing

1. Region growing is a procedure that groups pixels or sub-regions into larger regions.

2. The simplest of these approaches is ***pixel aggregation***, which starts with a set of "seed" points and from these grows regions by appending to each seed points those **neighboring pixels** that have **similar properties** (such as gray level, texture, color, shape).

3. Region growing based techniques are better than the edge-based techniques in noisy images where edges are difficult to detect.

Suppose that we have the image given below.

(a) Use the region growing idea to segment the object. The seed for the object is the center of the image. Region is grown in horizontal and vertical directions, and when the difference between two pixel values is less than or equal to 5.

Table 1: Show the result of Part (a) on this figure.

10	10	10	10	10	10	10
10	10	10	69	70	10	10
59	10	60	64	59	56	60
10	59	10	60	70	10	62
10	60	59	65	67	10	65
10	10	10	10	10	10	10
10	10	10	10	10	10	10

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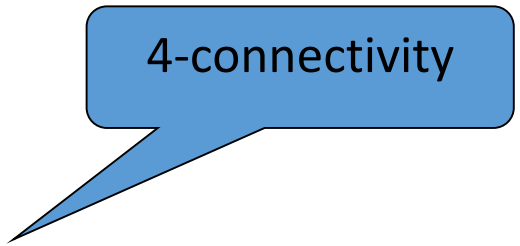
10	59	10	60	70	10	62
10	60	59	65	67	10	65
10	10	10	10	10	10	10
10	10	10	10	10	10	10



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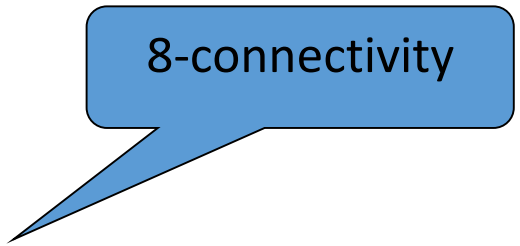
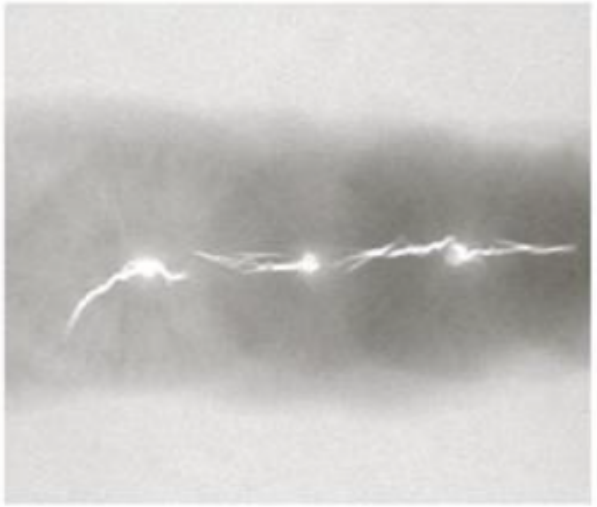
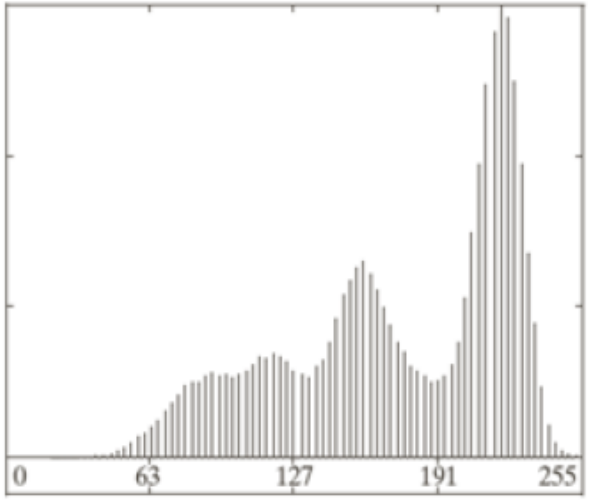
10	60	59	65	67	10	65
10	10	10	10	10	10	10
10	10	10	10	10	10	10



Region Growing Example



X-Ray image of weld with a crack we want to segment.

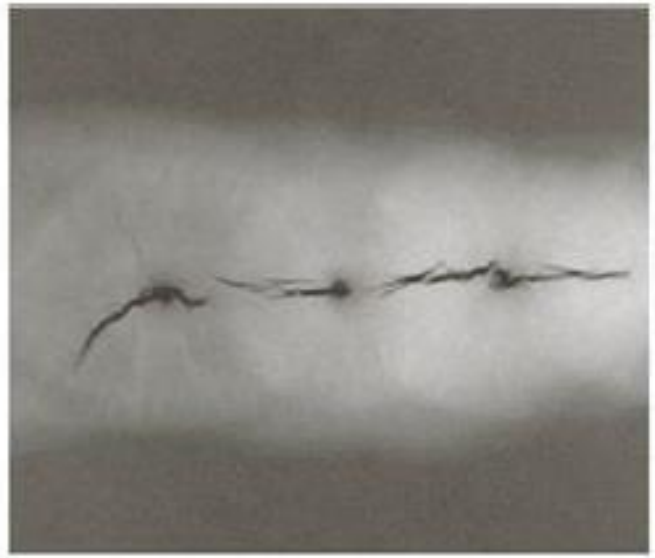


Histogram

Seed image (99.9% of max value in the initial image).
Crack pixels are missing.

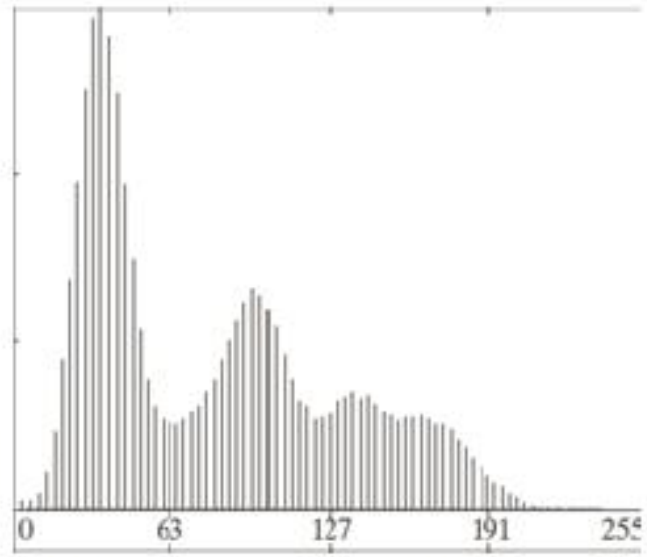
The weld is very bright. The predicate used for region growing is to compare the absolute difference between a seed point and a pixel to a threshold. If the difference is below it we accept the pixel as crack

Seed image eroded to 1 pixel regions.

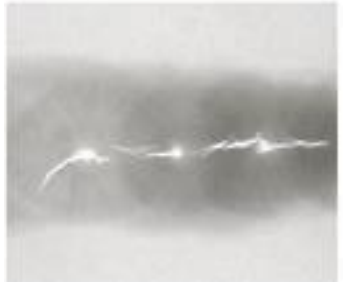


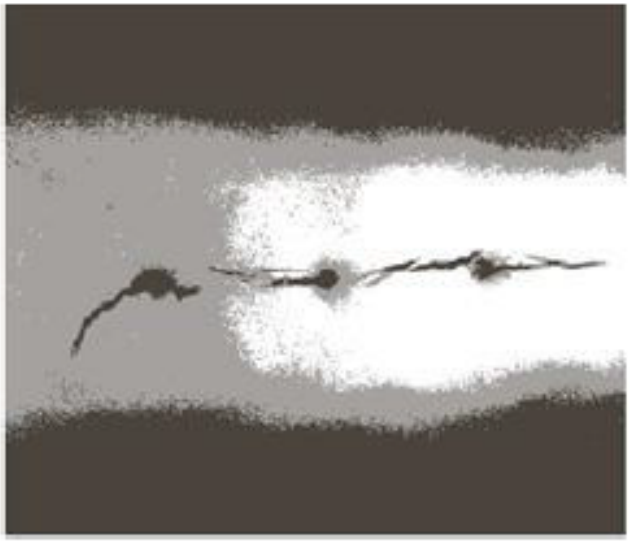
Difference between the original image and the initial seed image.

The pixels are ready to be compared to the threshold.



Histogram of the difference image. Two valleys at 68 and 126 provided by Otsu.





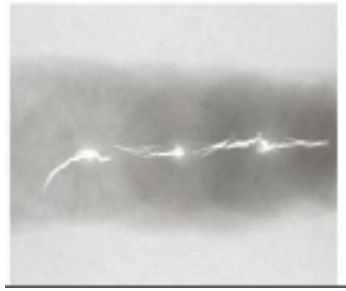
Otsu thresholding of the difference image to 3 regions (2 thresholds).

Thresholding of the difference image with the lowest of the dual thresholds.

Notice that the background is also considered as crack.

Segmentation result by region growing.

The background is not considered as crack.
It is removed as it is not 8-connected to the seed pixels.

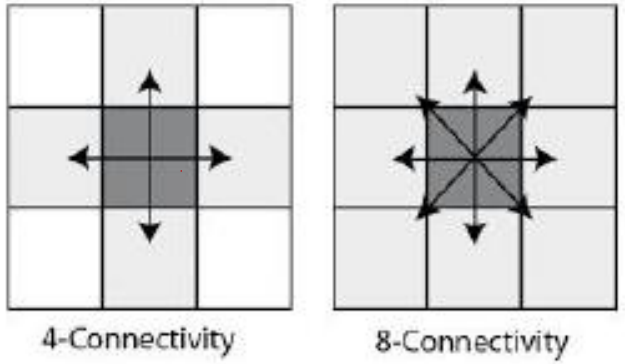


Q= difference between seed and pixel intensity should be zero.

8-connectivity

1	1	9	9	9
1	1	9	9	9
5	1	1	9	9
5	5	5	3	9
3	3	3	3	3

1	1	9	9	9
1	1	9	9	9
5	1	1	9	9
5	5	5	3	9
3	3	3	3	3



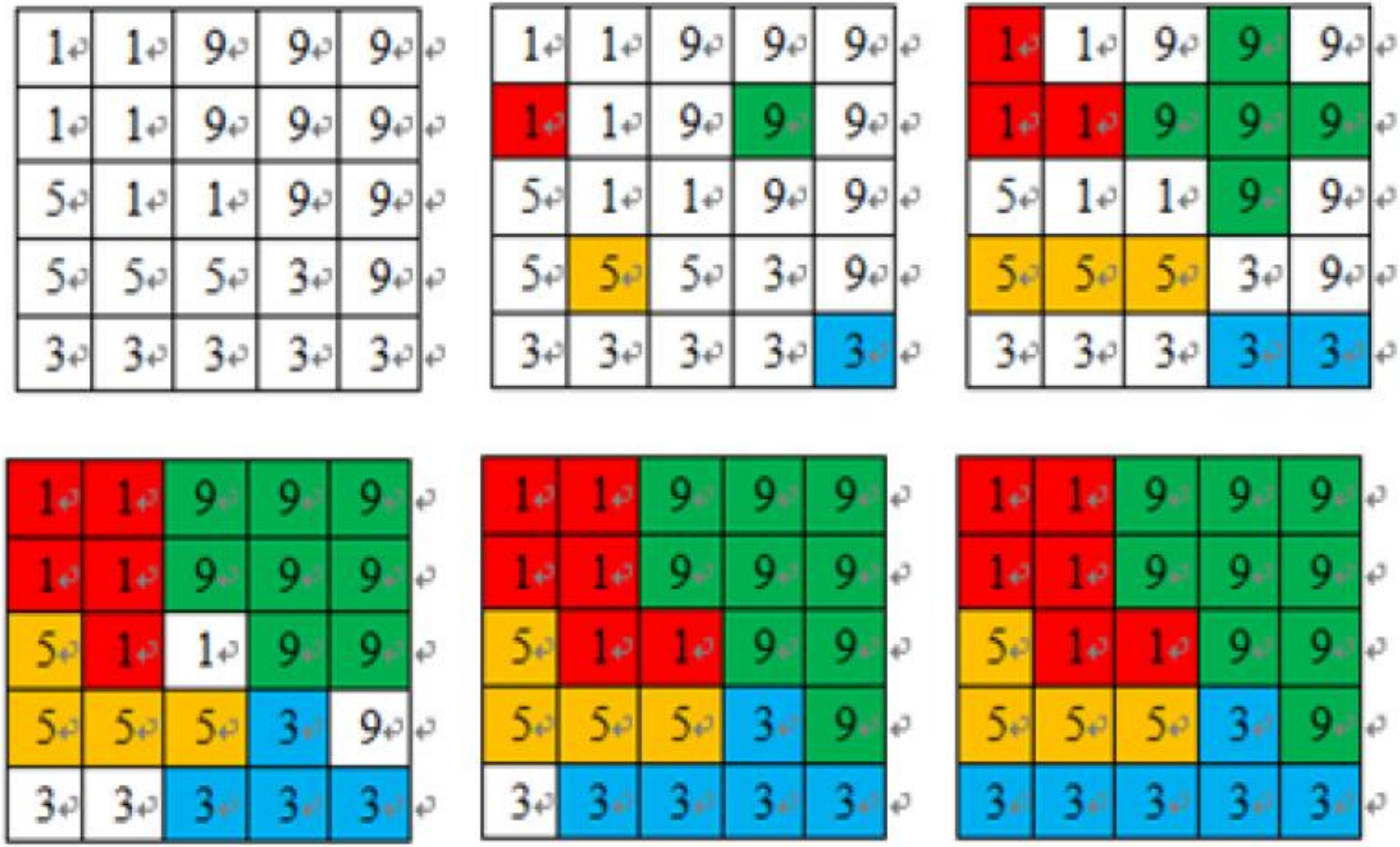
1	1	9	9	9
1	1	9	9	9
5	1	1	9	9
5	5	5	3	9
3	3	3	3	3

1	1	9	9	9
1	1	9	9	9
5	1	1	9	9
5	5	5	3	9
3	3	3	3	3

1	1	9	9	9
1	1	9	9	9
5	1	1	9	9
5	5	5	3	9
3	3	3	3	3

Q= difference between seed and pixel intensity should be zero.

4-connectivity



Example :

4	5	9	9
3	3	1	5
4	2	2	5
10	3	6	9
9	9	4	6
9	5	8	7
6	6	3	8
4	5	5	7
10	11	9	7

- For image of size 9 x4 , segment foreground and background using region growing method if seed pixel is the pixel with intensity '1' and condition for similarity is

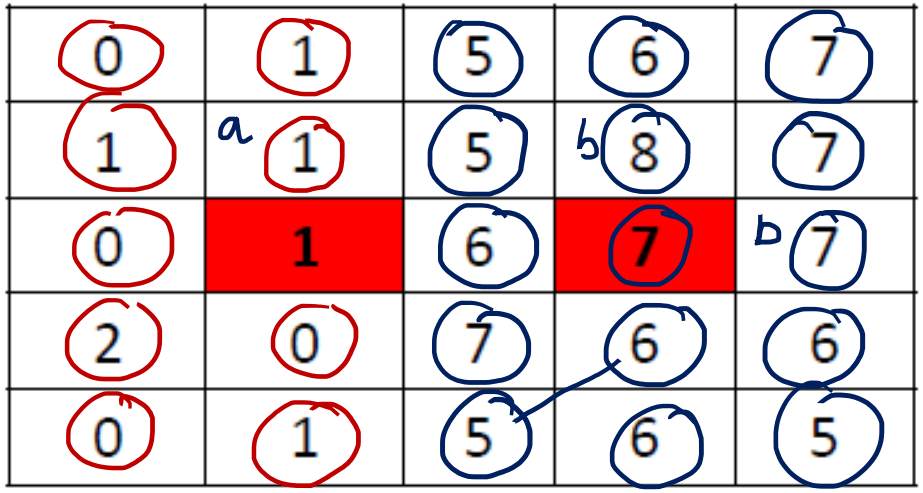
  |seed-f(x,y)|<=1

  Use 8-connectivity in the algorithm.

4	5	9	9
3	3	1	5
4	2	2	5
10	3	6	9
9	9	4	6
9	5	8	7
6	6	3	8
4	5	5	7
10	11	9	7

4	5	9	9
3	3	1	5
4	2	2	5
10	3	6	9
9	9	4	6
9	5	8	7
6	6	3	8
4	5	5	7
10	11	9	7

- Consider a following image. Segment the image using the Region growing procedure. Let Q(Ri)=TRUE if |seed-f(x,y)|<=1. Seed pixels are highlighted in image. Use 8 connectivity for algorithm



- Consider a following image. Segment the image using the Region growing procedure. Let Q(Ri)=TRUE if |seed-f(x,y)|<=7. Seed pixels are highlighted in image. Use 8 connectivity for algorithm

0	1	5	6	7
1	1	5	8	7
0	**1**	6	**7**	7
2	0	7	6	6
0	1	5	6	5

Region Splitting and Merging

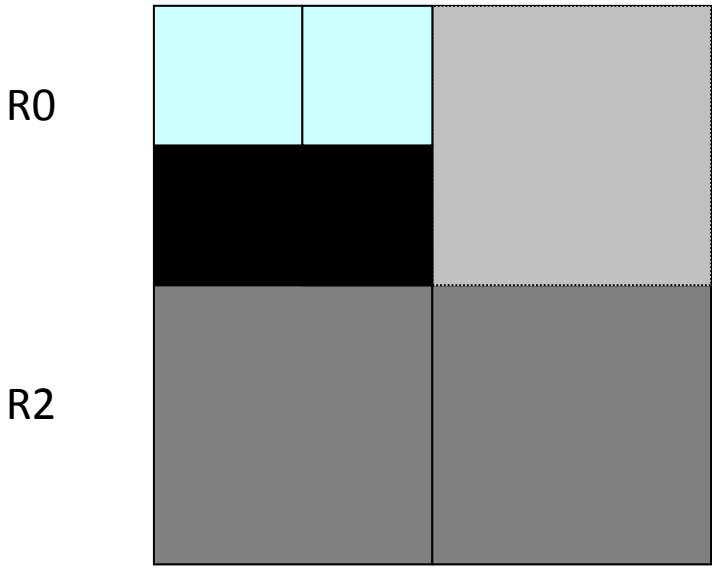
Split

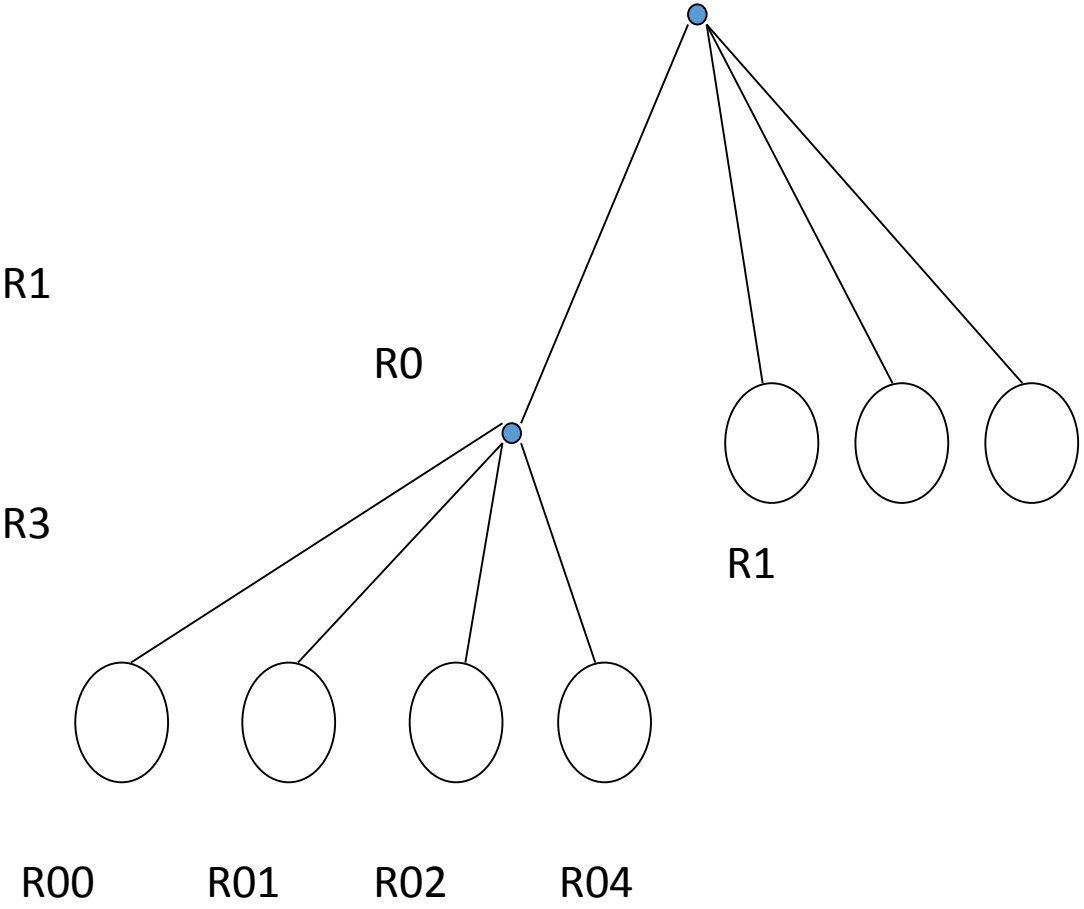
- The opposite approach to region growing is region splitting.
- It is a top-down approach and it starts with the assumption that the entire image is homogeneous
- If this is not true, the image is split into four sub images
- This splitting procedure is repeated recursively until we split the image into homogeneous regions

- If the original image is square N x N, having dimensions that are powers of 2(N = 2n):
- All regions produced but the splitting algorithm are squares having dimensions M x M , where M is a power of 2 as well.
- Since the procedure is recursive, it produces an image representation that can be described by a tree whose nodes have four sons each
- Such a tree is called a Quadtree.

Split

Quadtree



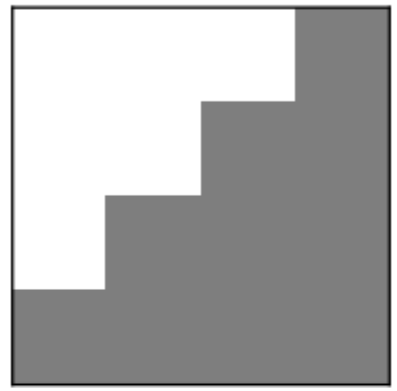


Split / Merge

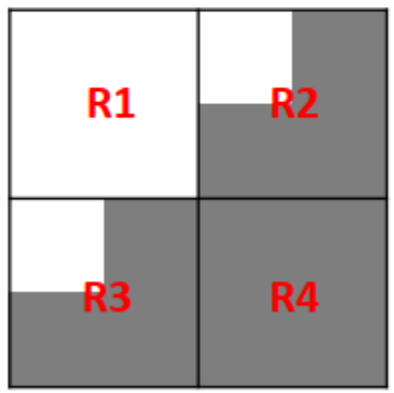
- If a region R is inhomogeneous (P(R)= False) then it is split into four sub regions
- If two adjacent regions Ri, Rj are homogeneous (P(Ri U Rj) = TRUE), they are merged
- The algorithm stops when no further splitting or merging is possible
- The split and merge algorithm produces more compact regions than the pure splitting algorithm

1. Split into four disjoint quadrants any region R_i for which $Q(R_i) = \text{FALSE}$.
2. When no further splitting is possible, merge any adjacent regions R_j and R_k for which $Q(R_j \cup R_k) = \text{TRUE}$.
3. Stop when no further merging is possible.

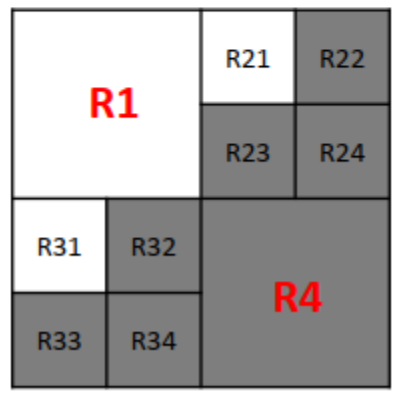
Example



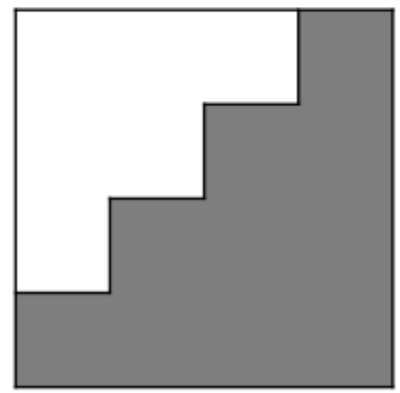
Input image



Split

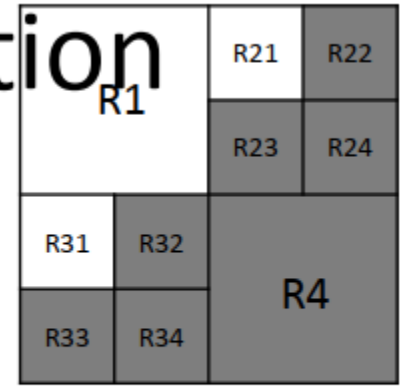


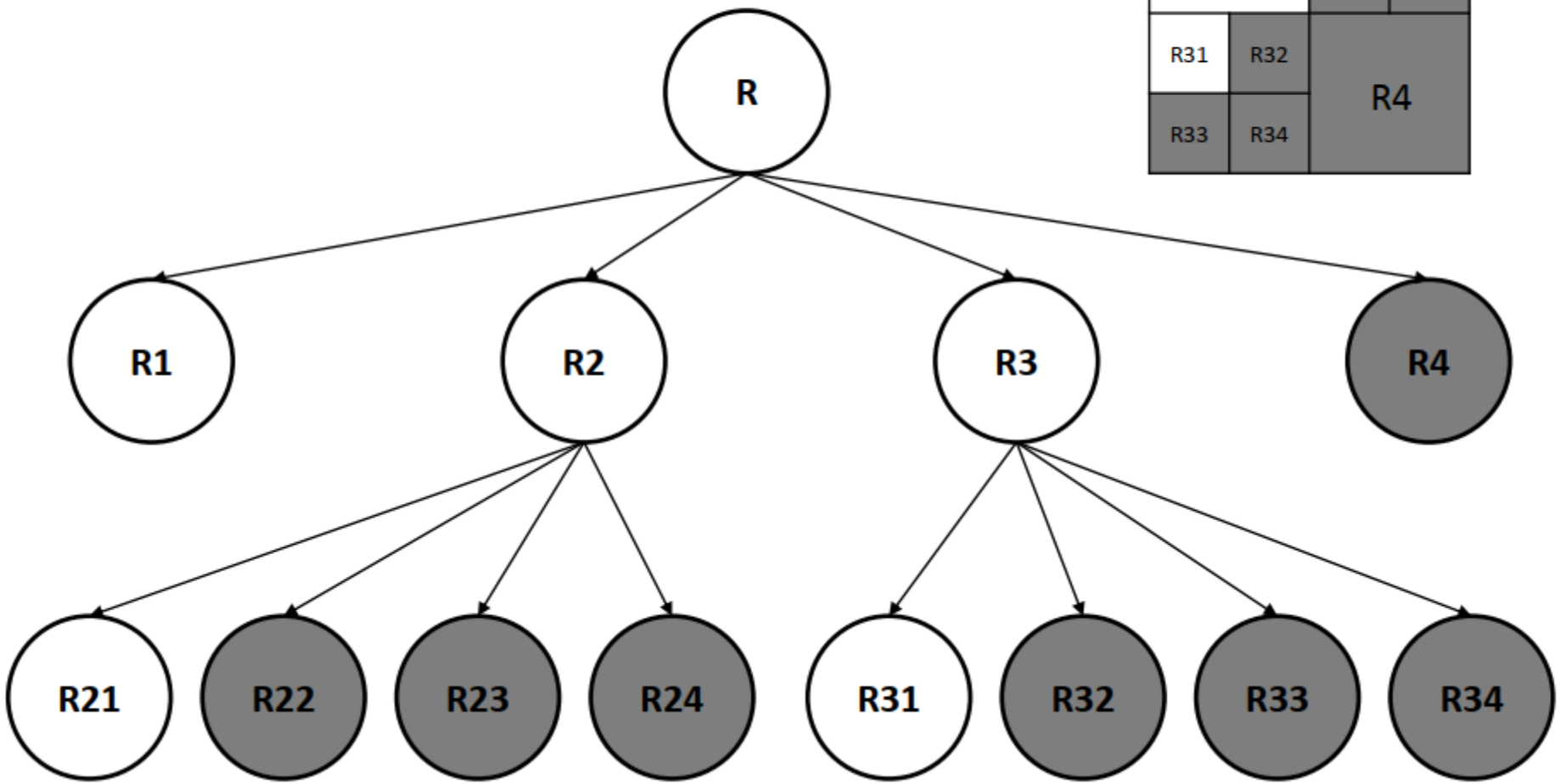
Split

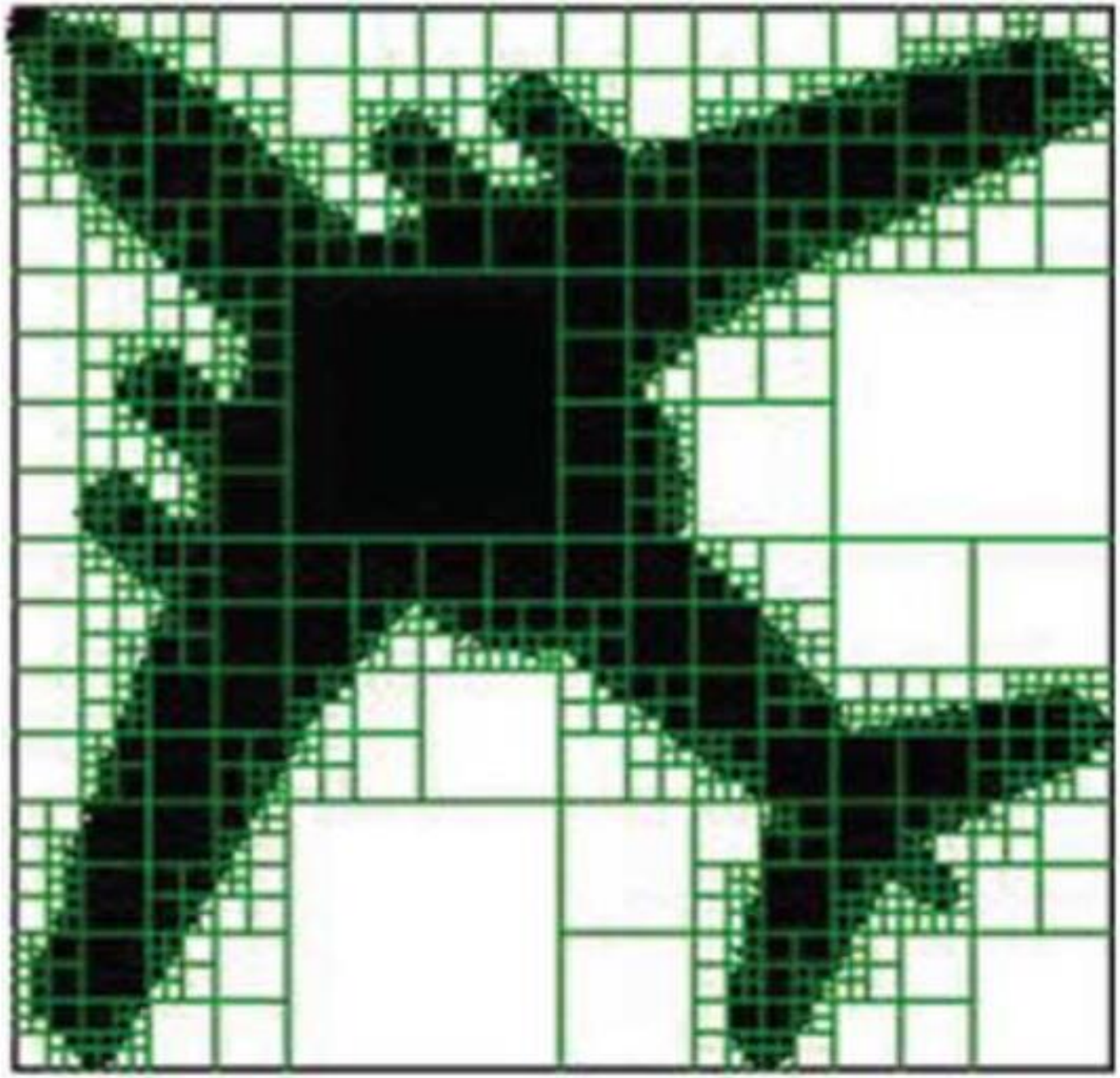


Merge

Quadtree representation

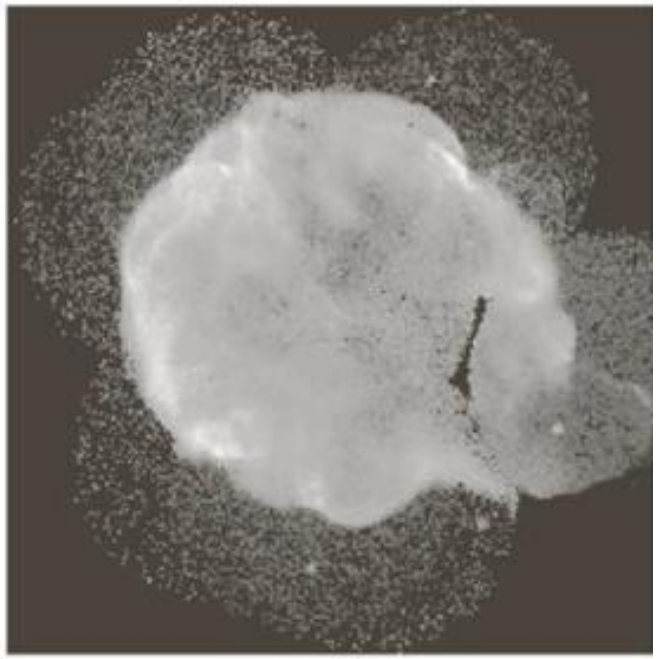






Region Splitting and Merging

- We want to segment the outer ring of less dense matter.
- Characteristics of the region of interest:
  - Standard deviation grater than the background (which is near zero) and the central region (which is smoother).
  - Mean value greater than the mean of background and less than the mean of the central region.

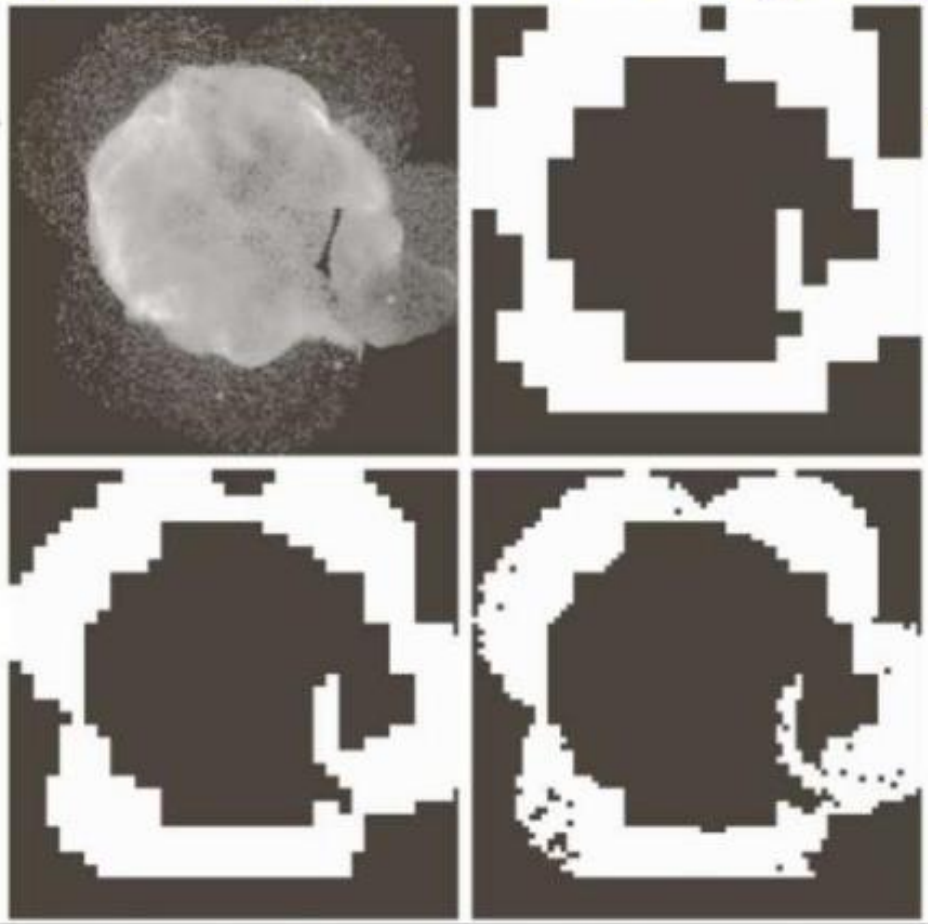


- Predicate:

$$Q = \begin{cases} \text{true} & \sigma > \alpha \; AND \;\; 0 < m < b \\ \text{false} & \text{otherwise} \end{cases}$$

Region splitting and merging

Original image



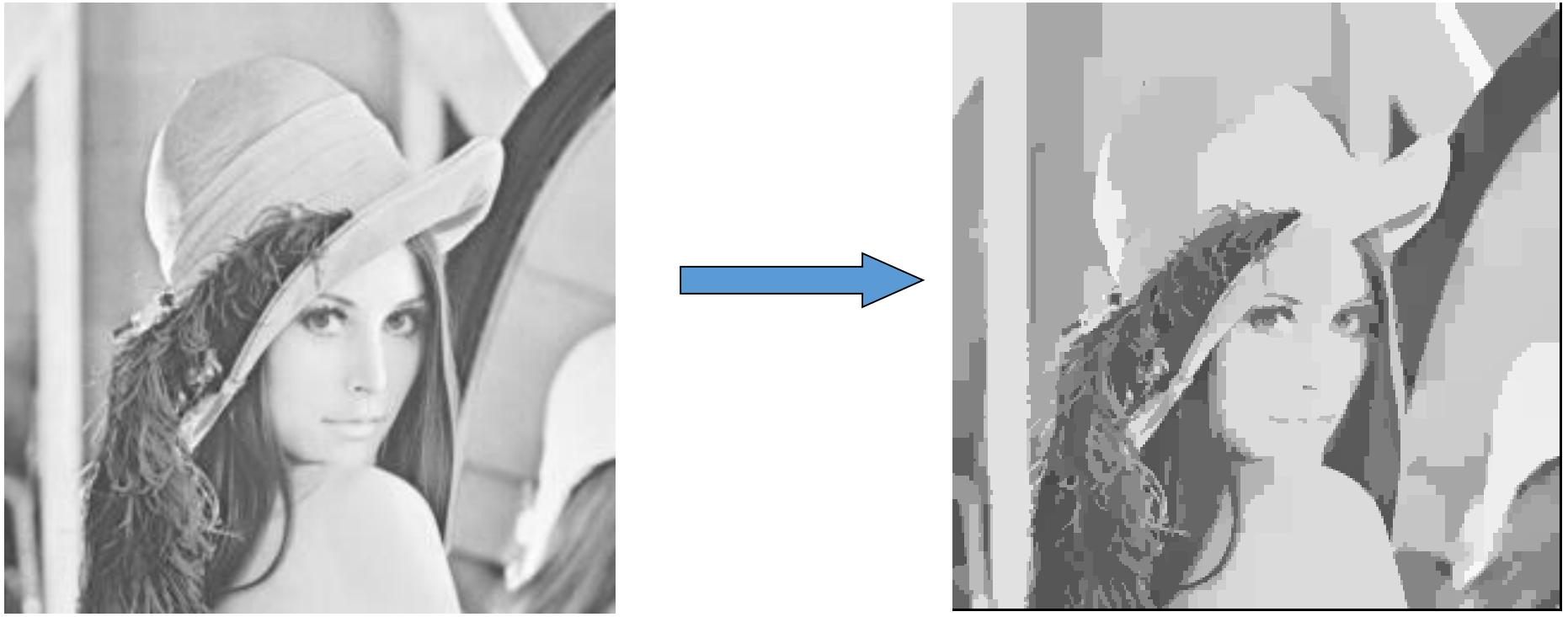
Smallest Quad-Region: 32x32

Smallest Quad-Region: 16x16

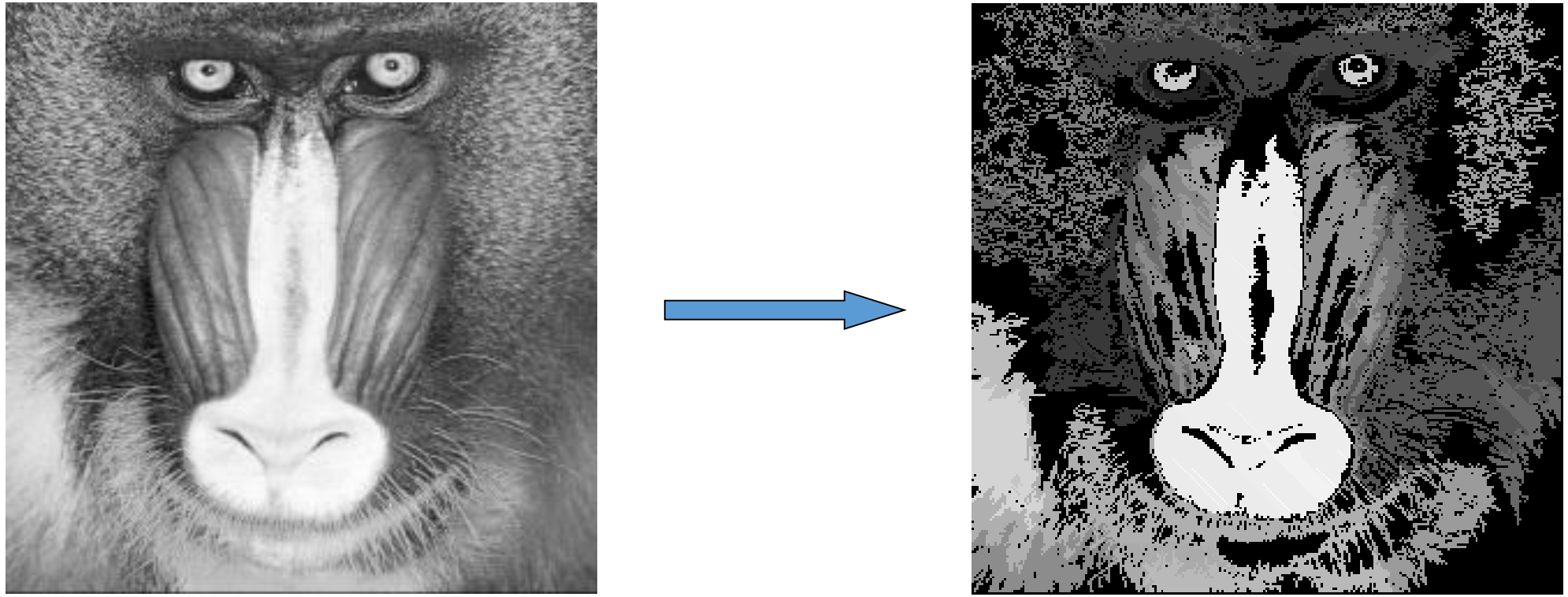
Smallest Quad-Region: 8x8

$$Q = \begin{cases} \text{TRUE}, & \text{if } \sigma(std) > a \text{ AND } 0 < m(\text{mean}) < b \\ \text{FALSE}, & \text{otherwise} \end{cases}$$

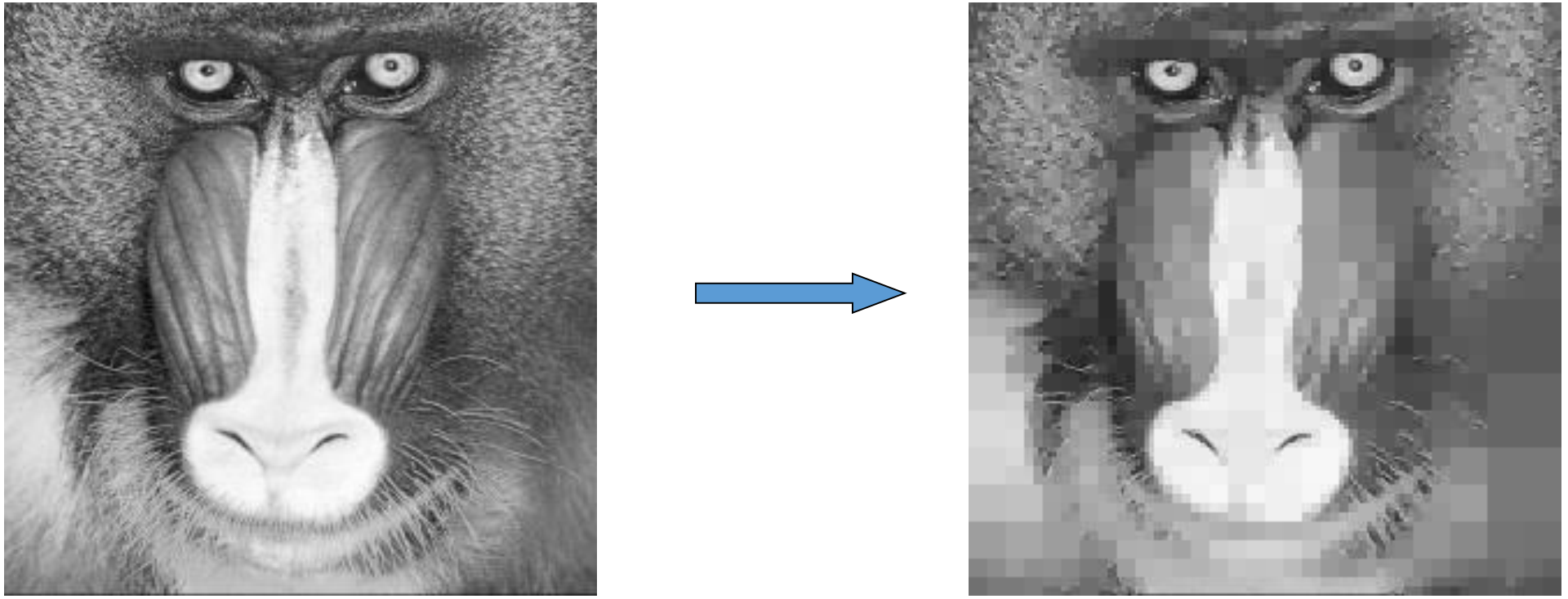
Results – Region Split and Merge



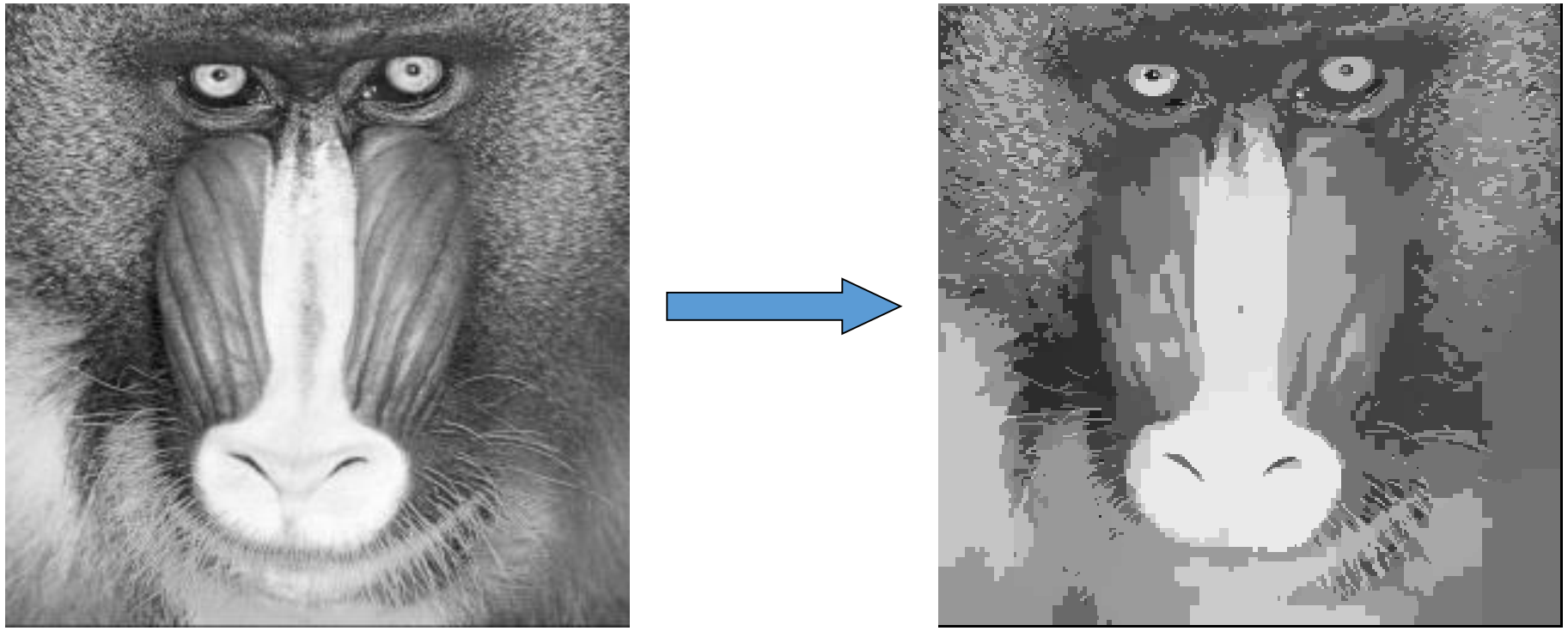
Results – Region growing



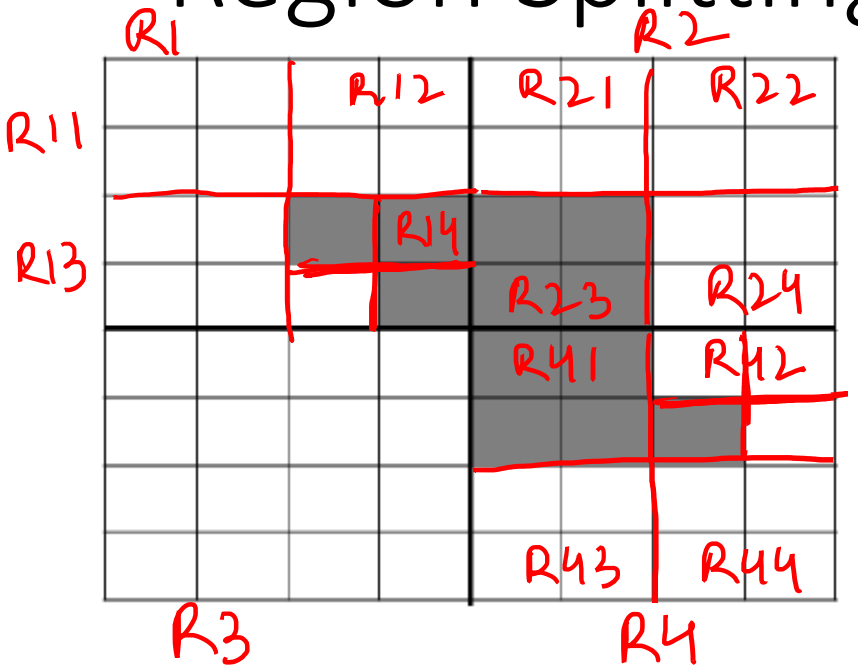
Results – Region Split

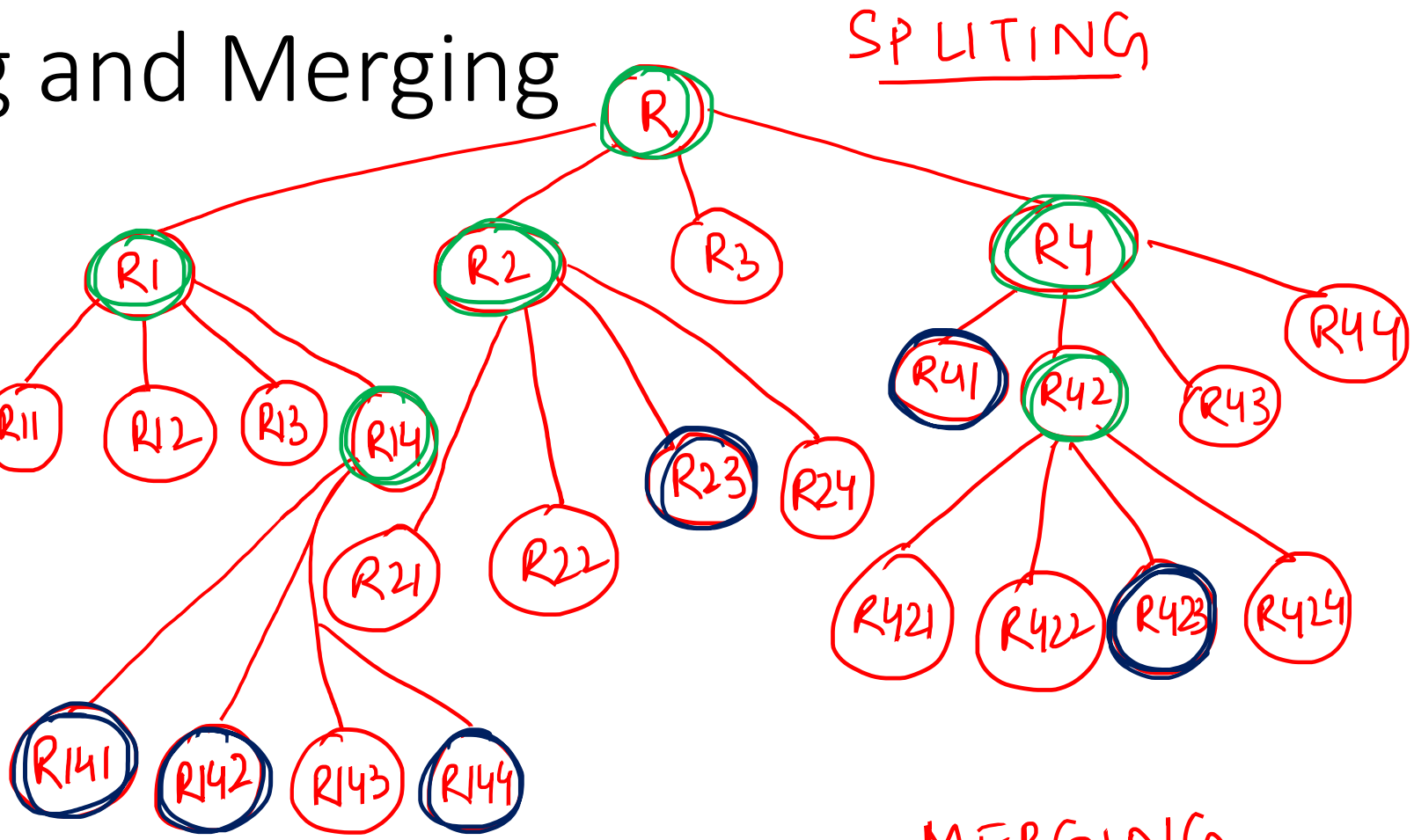


Results – Region Split and Merge

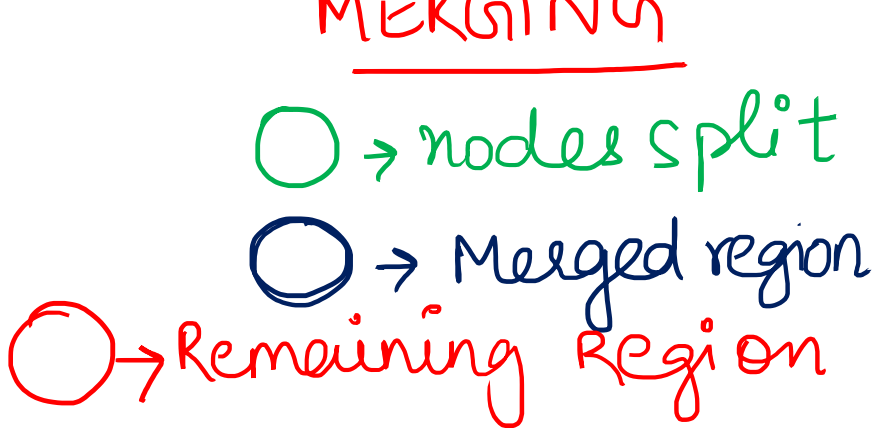


Region Splitting and Merging

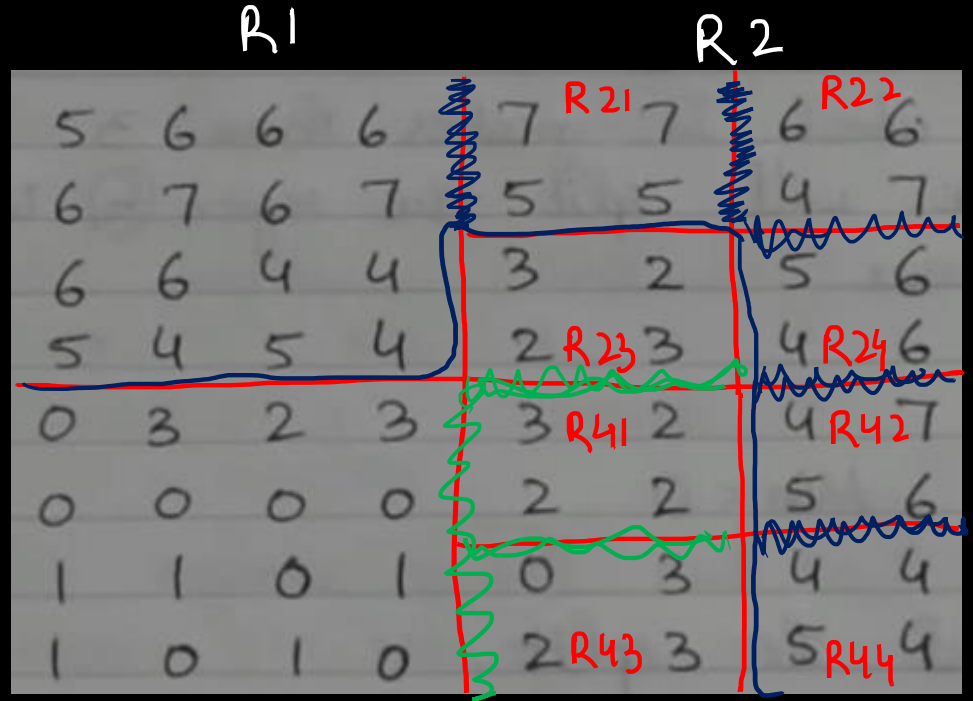


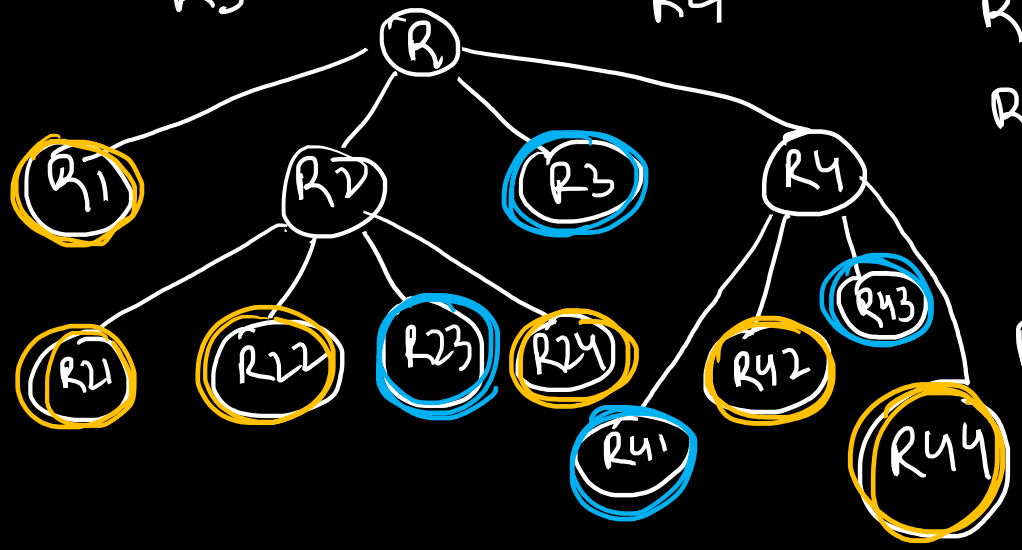


- Consider a 8 x 8 image. Segment the image using the splitt and merge procedure. Let Q(Ri)=TRUE if all pixels in Ri have the same intensity. Show quad tree corresponding to your procedure.



Apply splitting & merging on following image & threshold value = 3





Max - Min

$7 - 0 = 7 > 3$ → Divide into 4 Quads

→ For R1 max - min = 7 - 4 = 3 Don't split

→ For R2 max - min = 7 - 2 = 5 > 3 SPLIT

→ For R3 max - min = 3 - 0 = 3 Don't SPLIT

→ For R4 max - min = 7 - 0 = 7 > 3 SPLIT

Check new regions → no more splits

MERGE : check all adjacent regions

R1 & R3 → max - min = 7 - 0 > 3 NO MERGE

R1 & R21 → 7 - 4 = 3 ≯ 3 MERGE

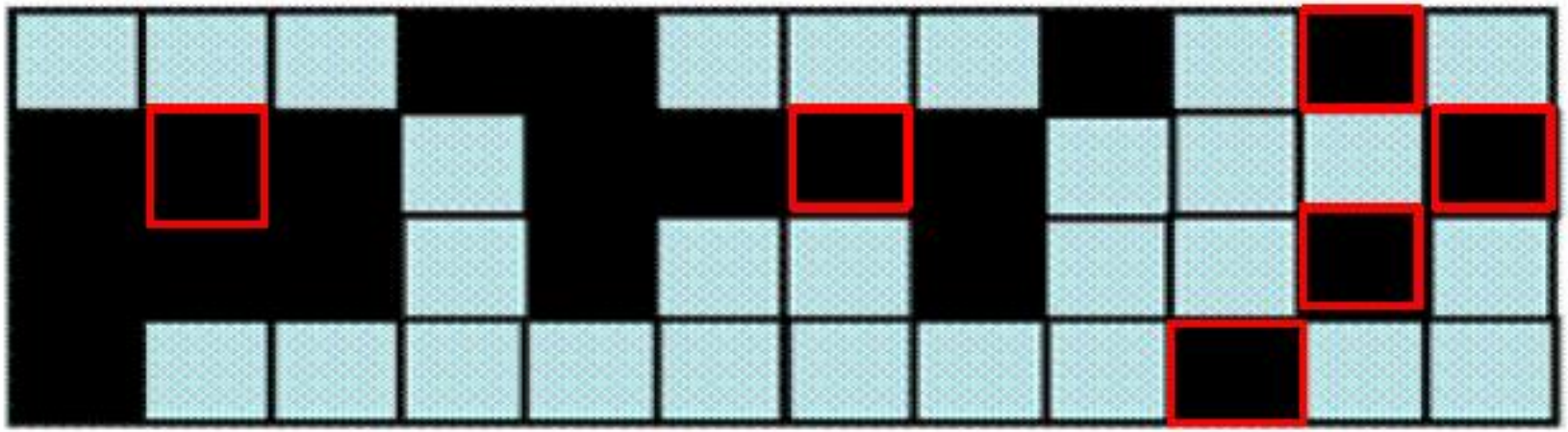
R21 & R22 MERGE

R1 & R23 → 7 - 2 > 3 Don't MERGE

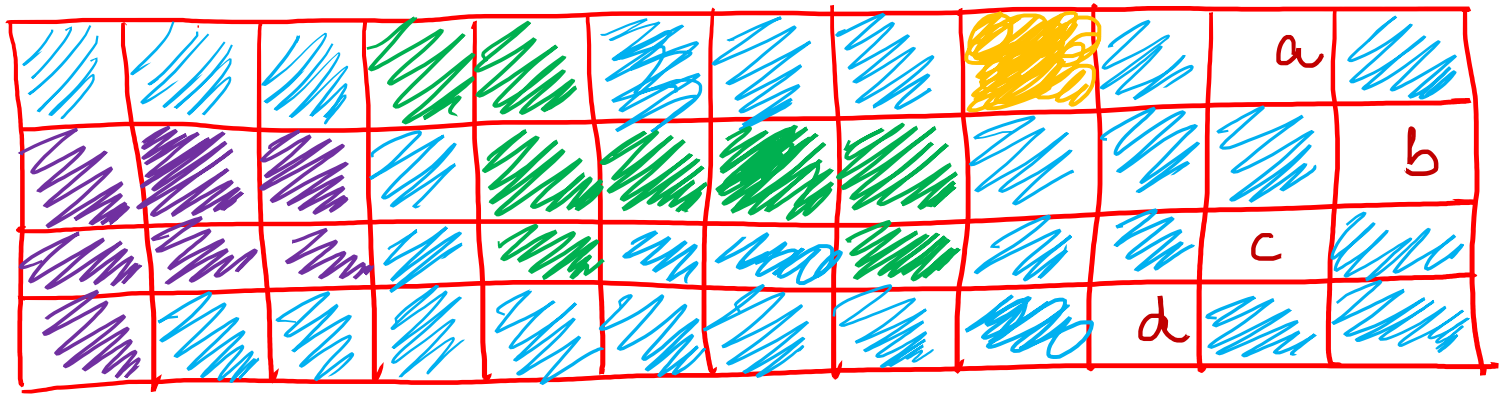
R22 & R24 & R42 & R44 → MERGE

Same way R3, R23, R41, R43 MERGE

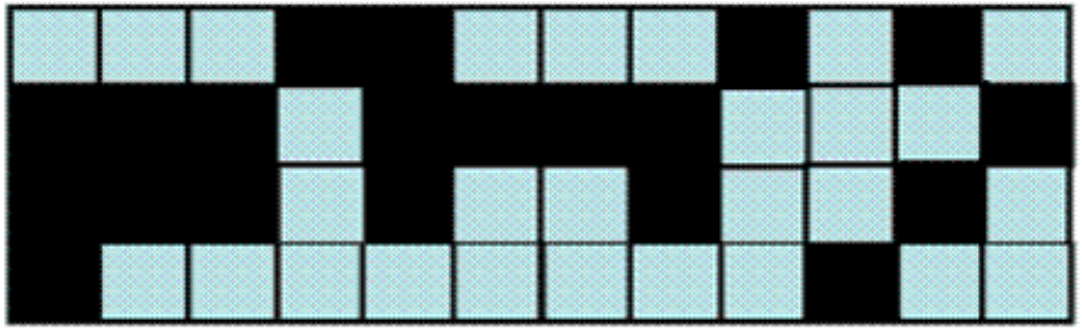
- For image of shown in figure below , segment foreground and background using region growing method. Seed pixels are shown with red boundary and condition for similarity is |seed-f(x,y)|<1
- Show your results for 1) 8 connectivity 2) 4- connectivity



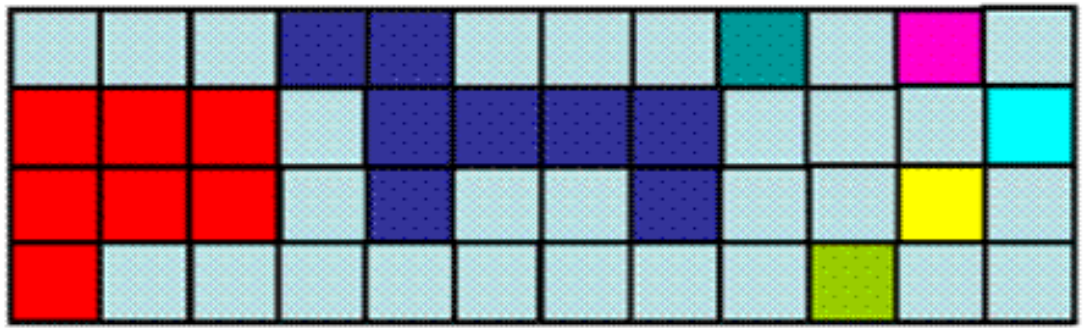
Binary image:
0 - objects;
1 -background



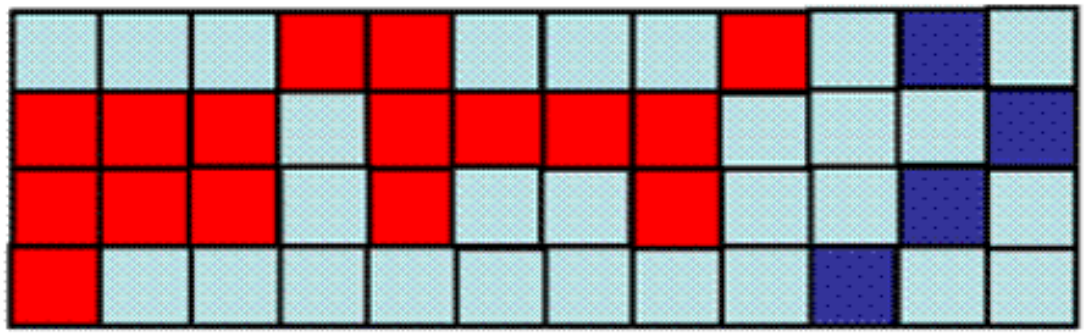
Solution:



Binary image:
0 - objects;
1 -background

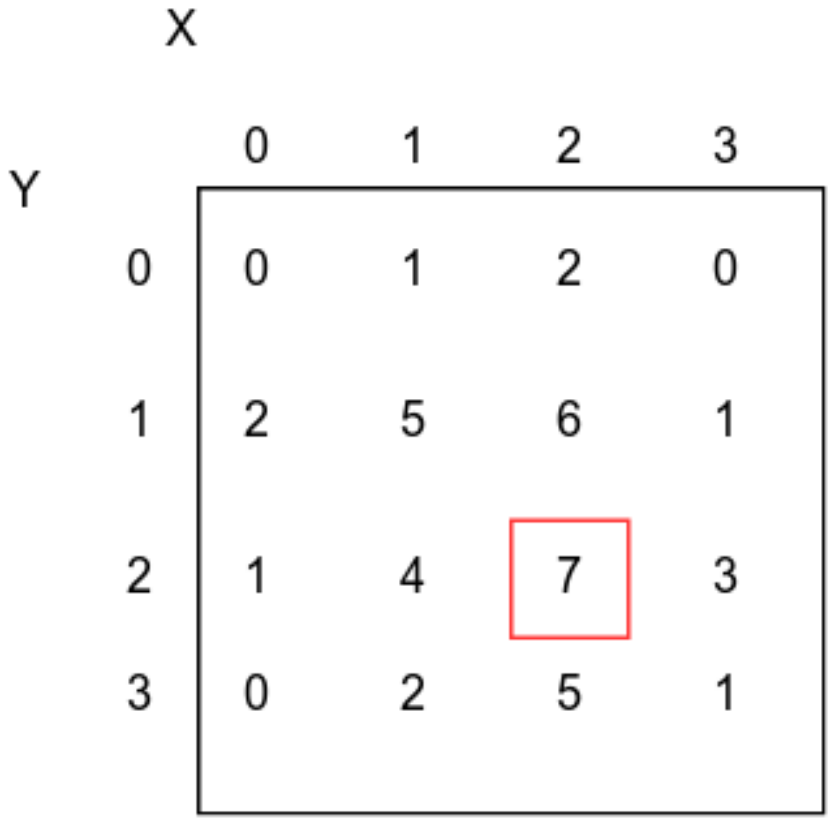


4-connected
objects +
8-connected
background



8-connected
objects +
8-connected
background

Q2. Apply region growing on the following image. Initial point at (2,2). Threshold is 2. Use 4 connectivity.



Y \ X	0	1	2	3
0	0	1	2	0
1	2	5	6	1
2	1	4	7	3
3	0	2	5	1

Practice Questions

Q1. A 3 bits/pixel image of size 5x5 is given below. Find the following: (a) the output of a 3x3 averaging filter at (1,1), (b) the output of a 3x3 median filter at (1,1) and (c) the gradient magnitude at (1,1) using the Sobel masks shown below.

IMAGE

y ↓ x →	0	1	2	3	4
0	3	7	6	2	0
1	2	4	6	1	1
2	4	7	2	5	4
3	3	0	6	2	1
4	5	7	5	1	2

a) $\frac{1}{9}$

1	1	1
1	1	1
1	1	1

at (1,1) R = $(3+7+6+2+4+6+4+7+2)/9$

$= 4.55 \cong 5$

b) Median filter → 2 2 3 4 **4** 6 6 7 7

$(6-3) + (12-4) + (2-4)$

$= 9$

Horizontal G_y

-1	-2	-1
0	0	0
1	2	1

G_x

-1	0	1
-2	0	2
-1	0	1

$(4-3) + (14-14) + (2-6)$

$1 + 0 - 4 = -3$

Vertical

$Mag = \sqrt{G_x^2 + G_y^2}$

$= \sqrt{9+81}$

$= \sqrt{90}$

$= 9.48 \cong 9$

Q3. Histogram of a 3 bit image is shown in the following table

Gray level	0	1	2	3	4	5	6	7
number of pixels	2	3	2	1	2	3	2	1

Find optimal threshold using Otsu.

$P1 = 2/16 + 3/16 + 2/16 + 1/16 = 8/16 = 1/2$

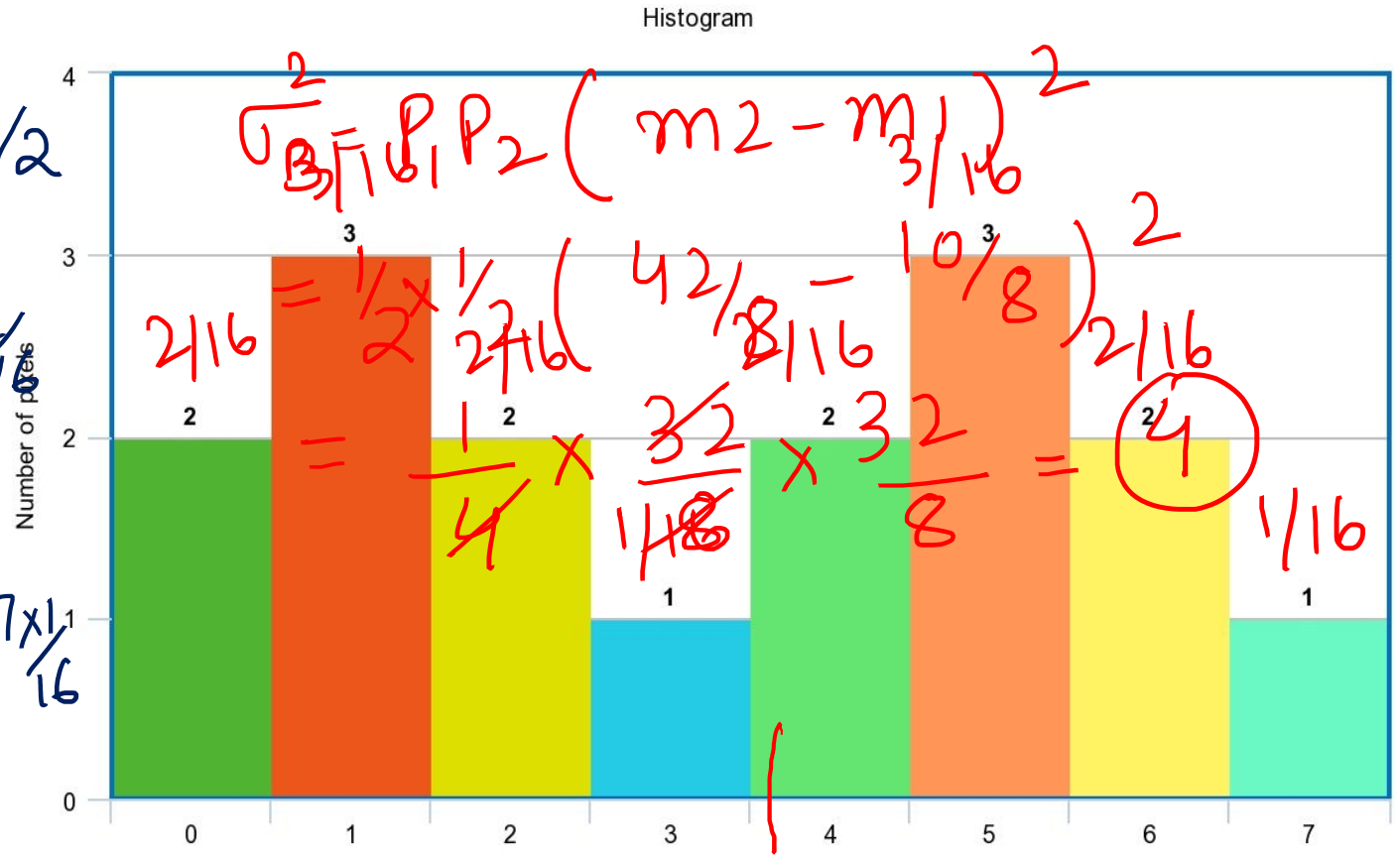
$P2 = 1 - 1/2 = 1/2$

$m1 = \sum_{i=0}^{3} iPi / P1 = (0\times2/16 + 1\times3/16 + 2\times2/16 + 3\times1/16)/1/2$

$= 10/16 \times 2/1 = 10/8$

$m2 = \sum_{i=4}^{7} iPi / P2 = 4\times2/16 + 5\times3/16 + 6\times2/16 + 7\times1/16$

$= \frac{42}{16} \times \frac{2}{1} = 42/8$



$\sigma_B^2 = P1P2(m2 - m1)^2$

$= 1/2 \times 1/2 (42/8 - 10/8)^2$

$= 1/4 \times 32/8 \times 32/8 = 4$