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COMP-2032

Introduction to Image Processing

Lecture 7

Segmentation

Learning Outcomes

IDENTIFY

1. What is Segmentation?
2. Region-based Segmentation
3. Edge-based Segmentation

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What is Segmentation?

Image Segmentation

?

A common task in image analysis & computer vision

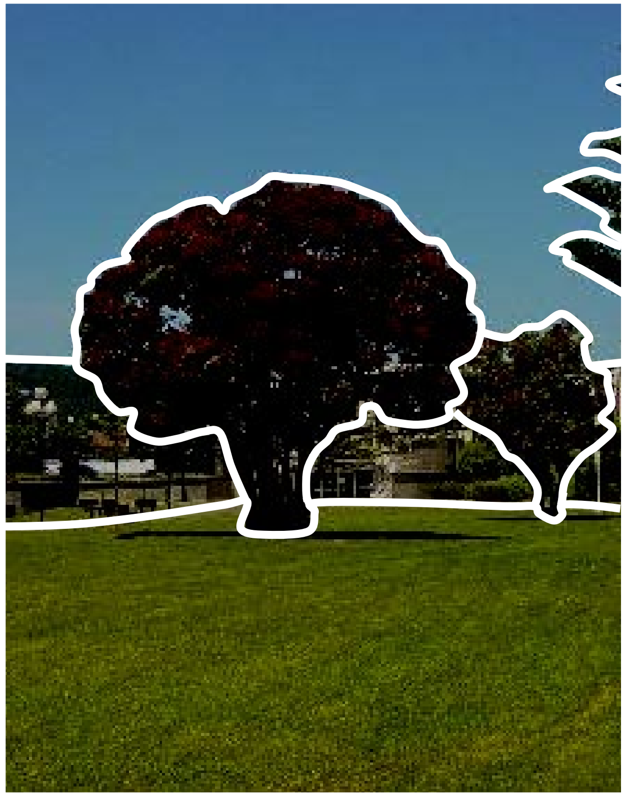
To identify **meaningful** regions

Why do it?

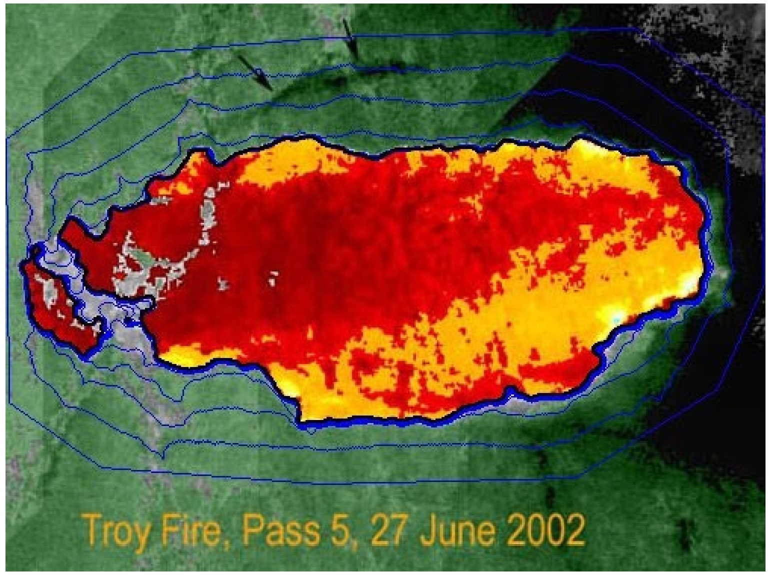
We can partition or group pixels according to local image properties

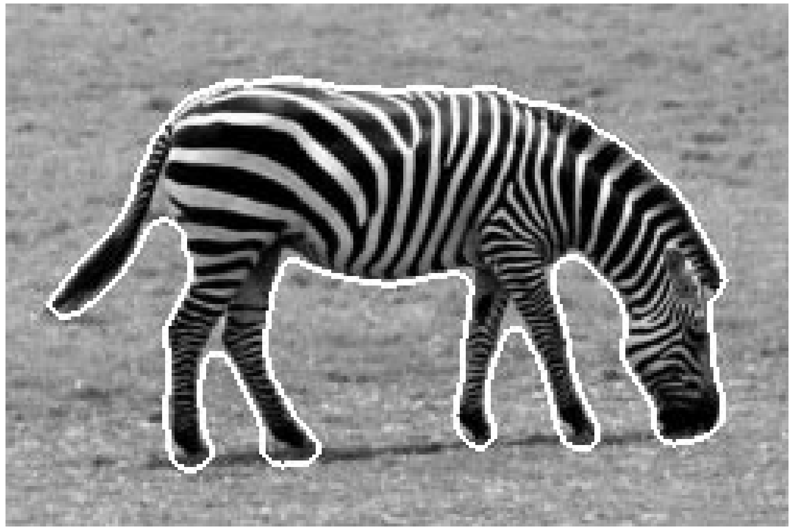
- Intensity or colour from original images, or computed values based on image operators
- Textures or patterns that are unique to each type of region
- Spectral profiles that provide multidimensional image data

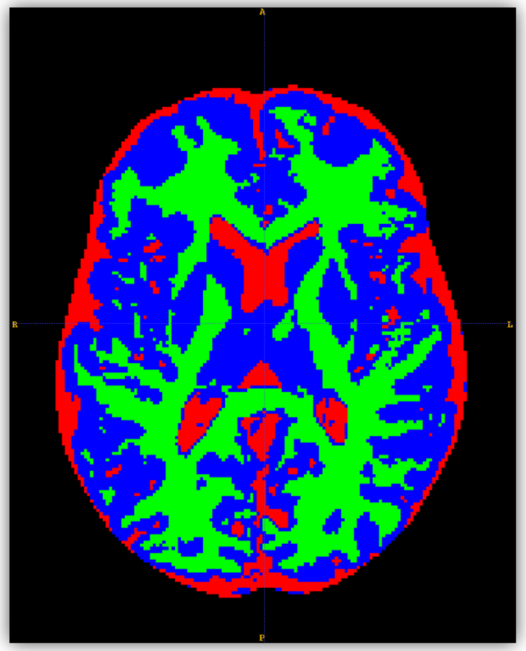
Elaborate systems may use a combination of properties

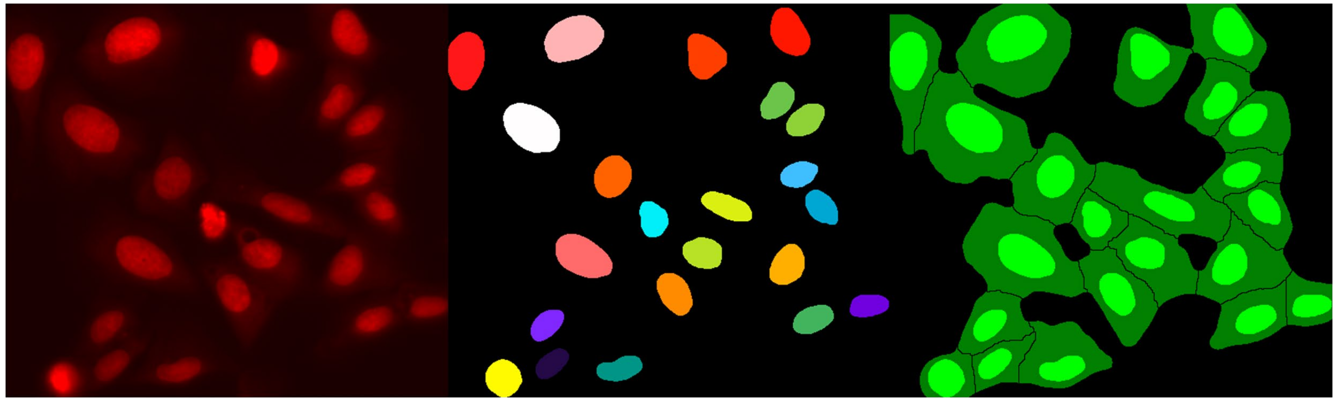


Applications









Approaches

Many different approaches have been taken to the segmentation problem

Seeks groups of similar pixels, with no regard for where they are – views images as uncorrelated data

Clustering

- Focus on finding physically connected sets of pixels
- E.g., region growing, split and merge

Region-based

- Emphasise the boundaries between regions
- E.g., watersheds

Edge-based

Thresholding + connected components is a form of segmentation, but treats grey/colour and spatial information independently

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Region-Based Segmentation

Region-based Segmentation

We want smooth regions in the image

- We still want the pixels in each region to be similar, and those in adjacent regions to be different
- One way to do this is to work with regions rather than pixels

Region Growing

Start with a small 'seed' and expand by adding similar pixels

Split & Merge

- Splitting divides regions that are inconsistent
- Merging combines adjacent regions that are consistent

Region Growing

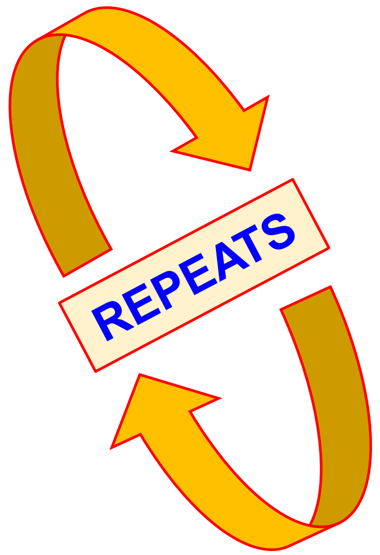
Region growing starts with a small patch of seed pixels

- Compute statistics about the region
- Check neighbours to see if they can be added
- Recompute the statistics

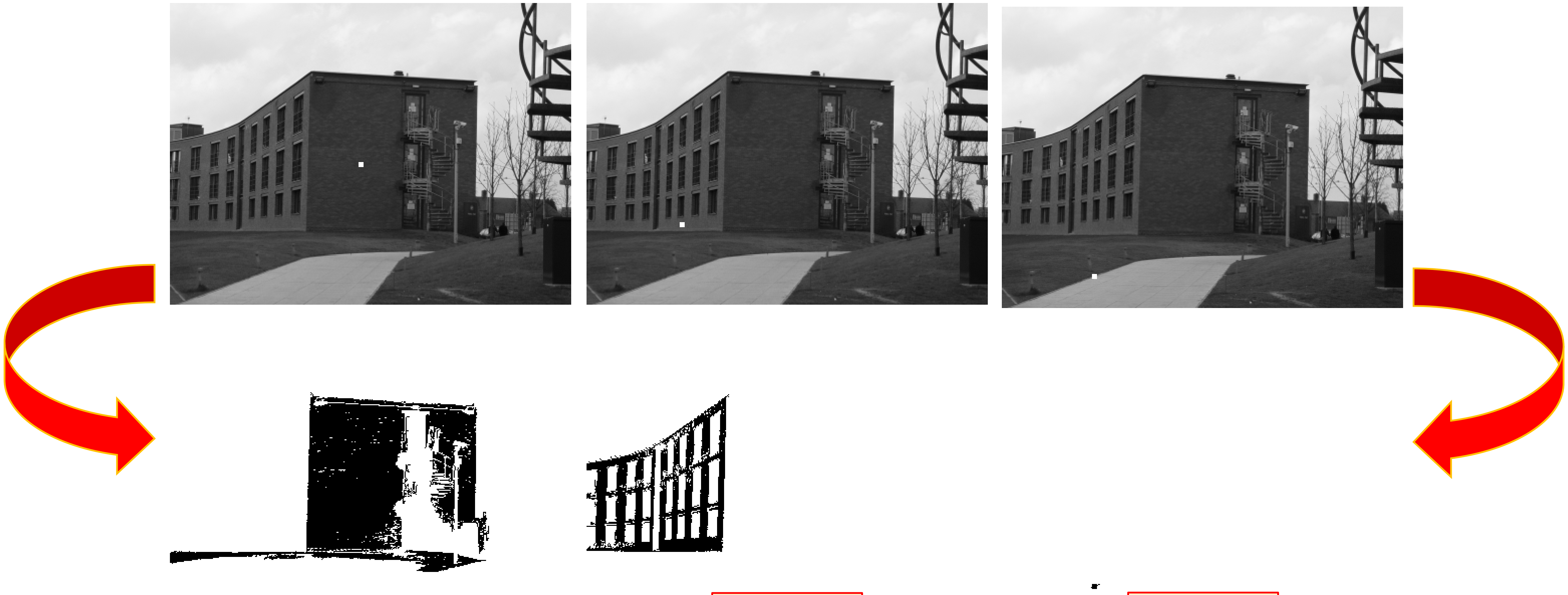
Algorithm

This procedure repeats until the region stops growing

- Simple example: *we compute the mean grey level of pixels in the region*
- Neighbours are added if their grey level is near the average



Region Growing Example



Split and Merge - Split

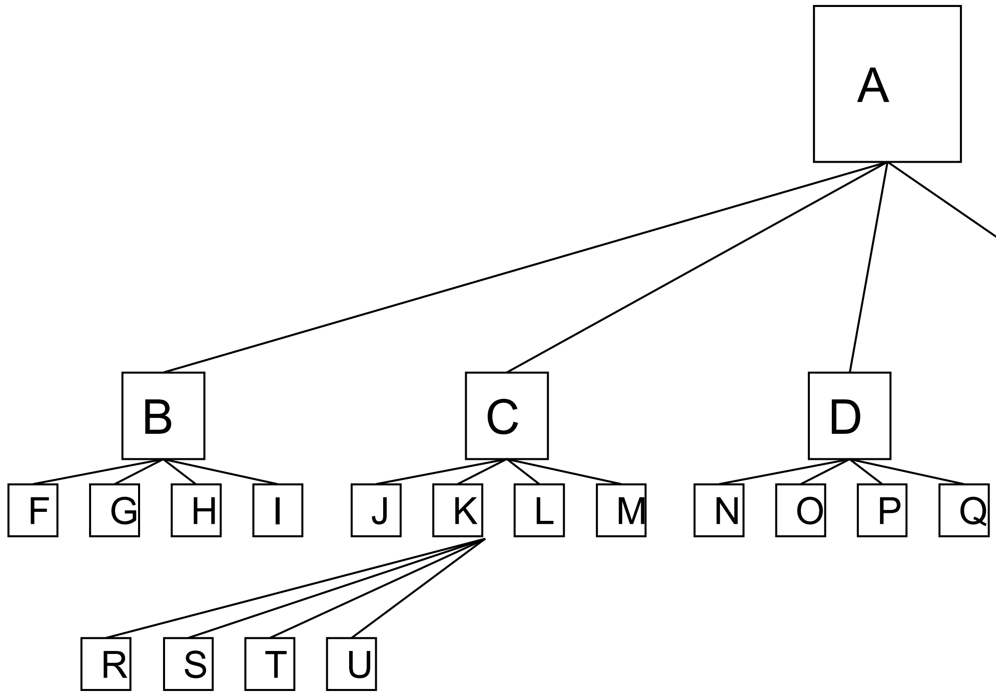
We start by taking the whole image to be one region

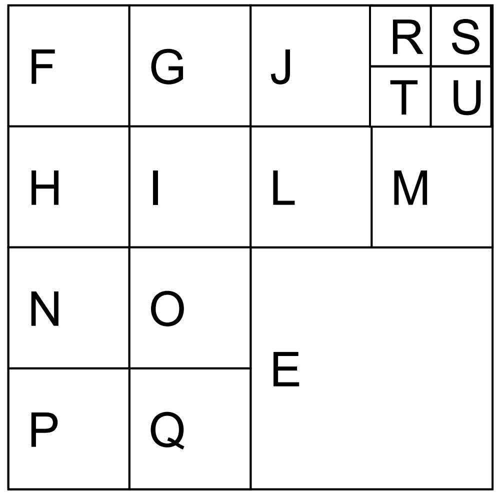
- We compute some measure of internal similarity
- If this indicates there is too much variety, we divide the region
- Repeat until no more splits, or we reach a minimum region size

Some details are needed

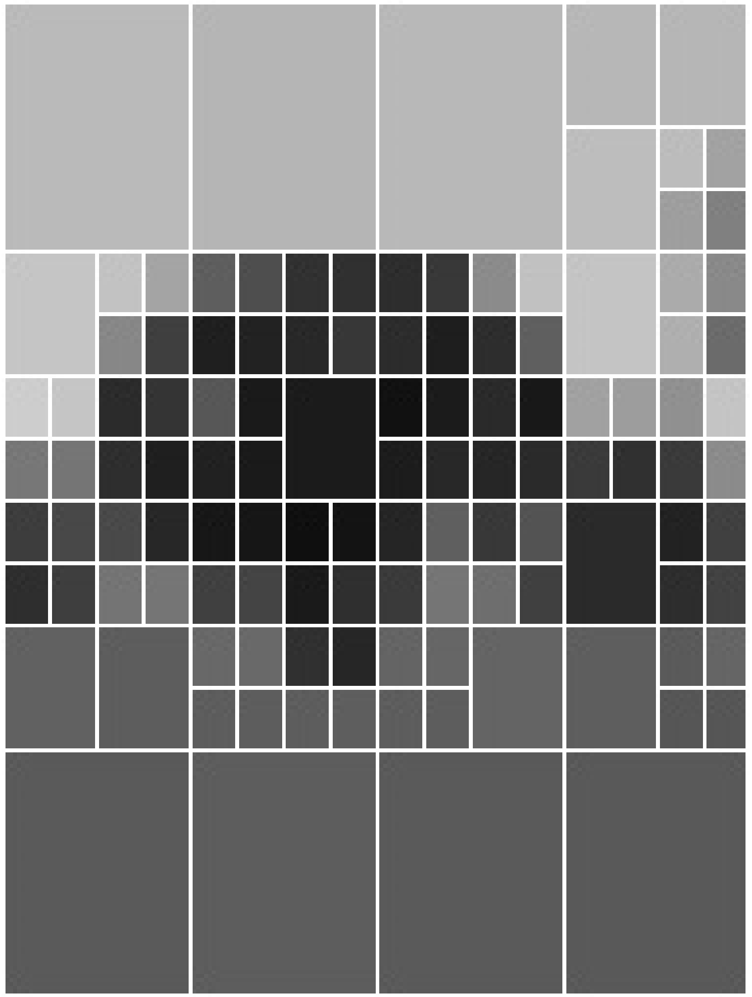
- How to we measure similarity? – standard deviation are commonly used
- How do we determine whether to split or not? – thresholding is easy
- How do we split regions? – *quadtrees* are a common method

Quadtrees





Example - Splitting



We'll use the tree image again

- Splitting based on intensity (*could use something else*)
- Splitting based on standard deviation, with a threshold of 25
- Split using quadtree with a maximum of 5 level

Split and Merge - Merge

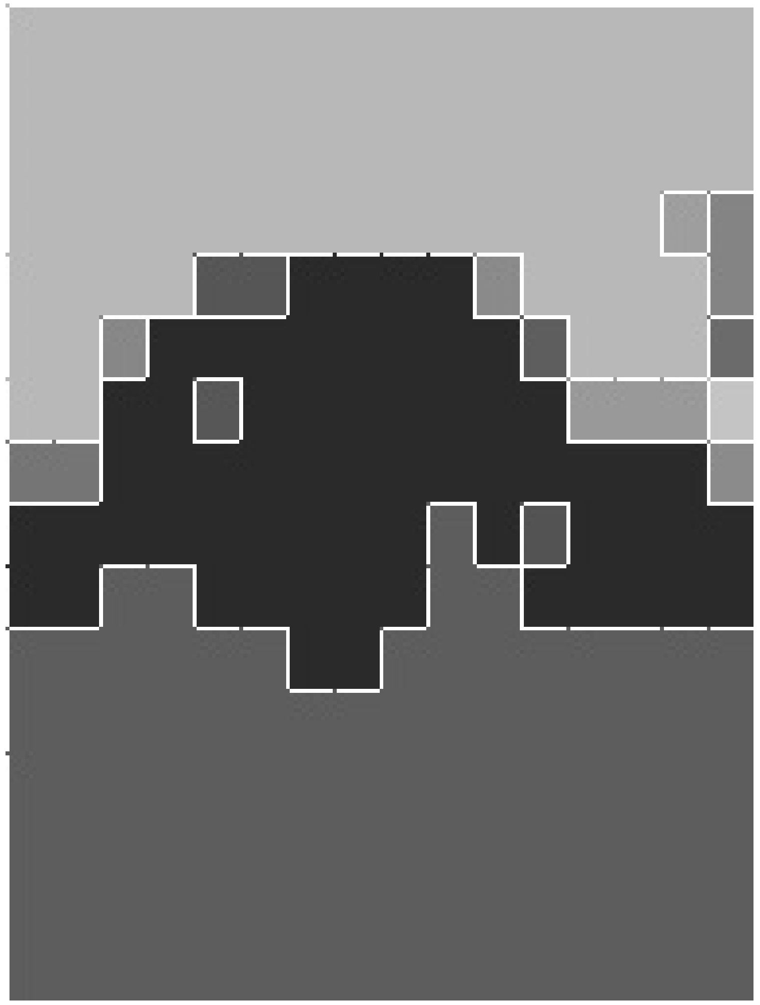
Splitting give us…

- Regions that are small, consistent, or both
- Rather too many regions, as adjacent ones may be very similar
- We can now combine adjacent regions to make bigger ones

Merging

- We merge two regions if they are adjacent and similar
- Need a measure of similarity – can compare their mean grey level, or use statistical tests
- Repeat the merging until you can do no more

Example - Merging



We consider merging adjacent regions

- Two regions are merged if their mean grey levels differ by less than 25
- This leads to less regularly shaped regions, but they are larger and still consistent

Break

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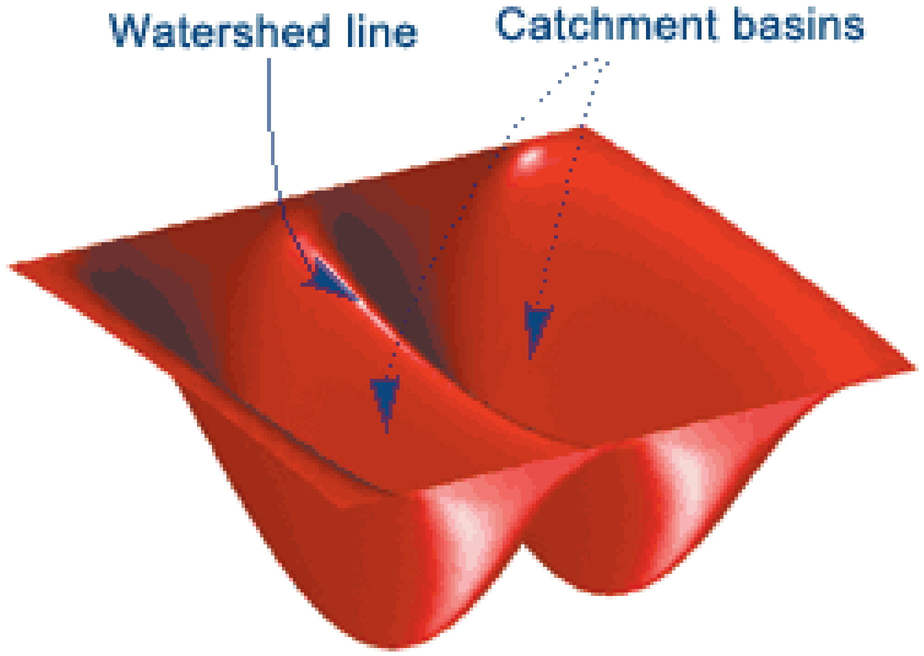
Edge-based Segmentation (*Watersheds*)

Edge-based Segmentation

- Do region-based methods focus too much on regions?
- Edge represent discontinuities in image intensity
- Regions should then be areas without edges, and should be bounded by edges
- One class of edge-based segmentation uses **watersheds**



In geography, a watershed is a ridge which divides rainfall into basins on either side

Catchments in images

We can view the ***gradient*** image as a terrain

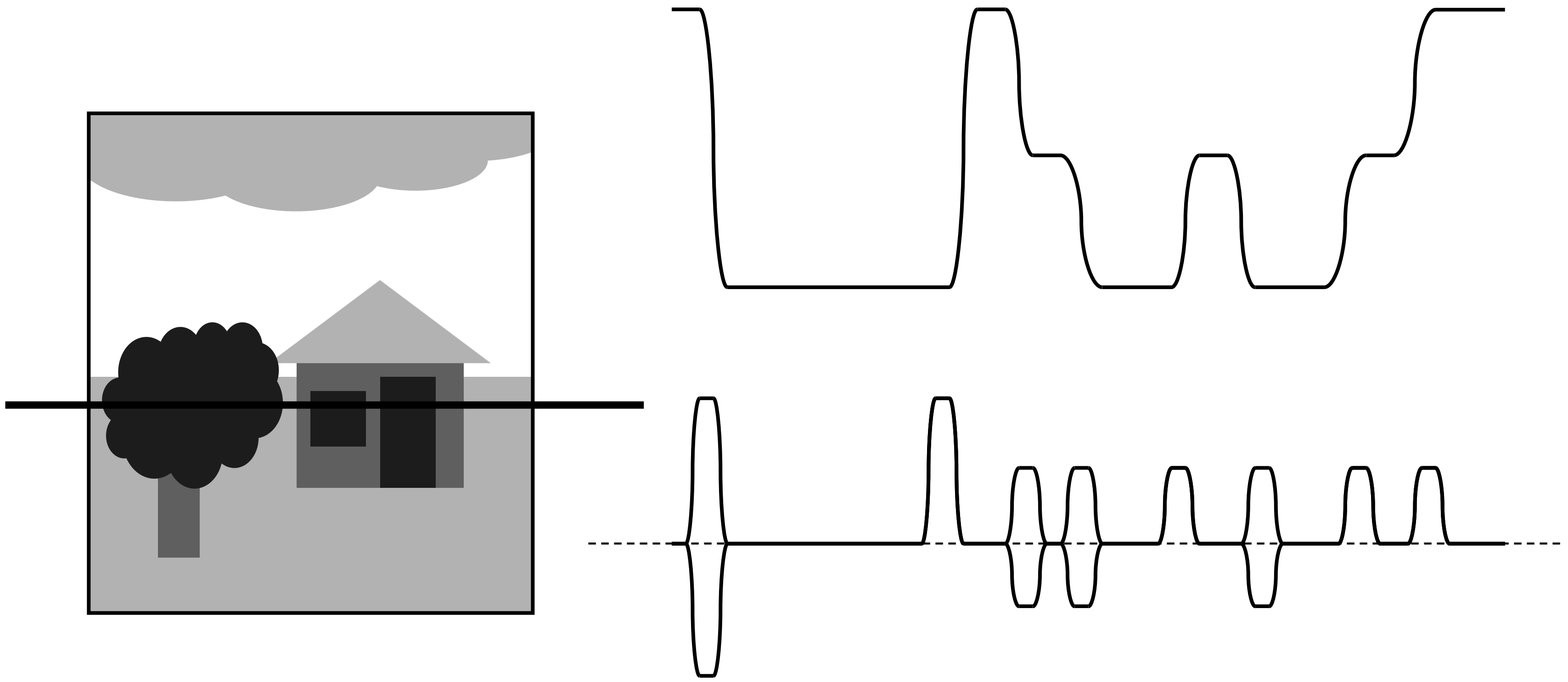
- Areas of high gradient are high points on the terrain
- Catchment basins are regions in the image
- Watersheds are the lines dividing them

We don't have to use the usual intensity gradient

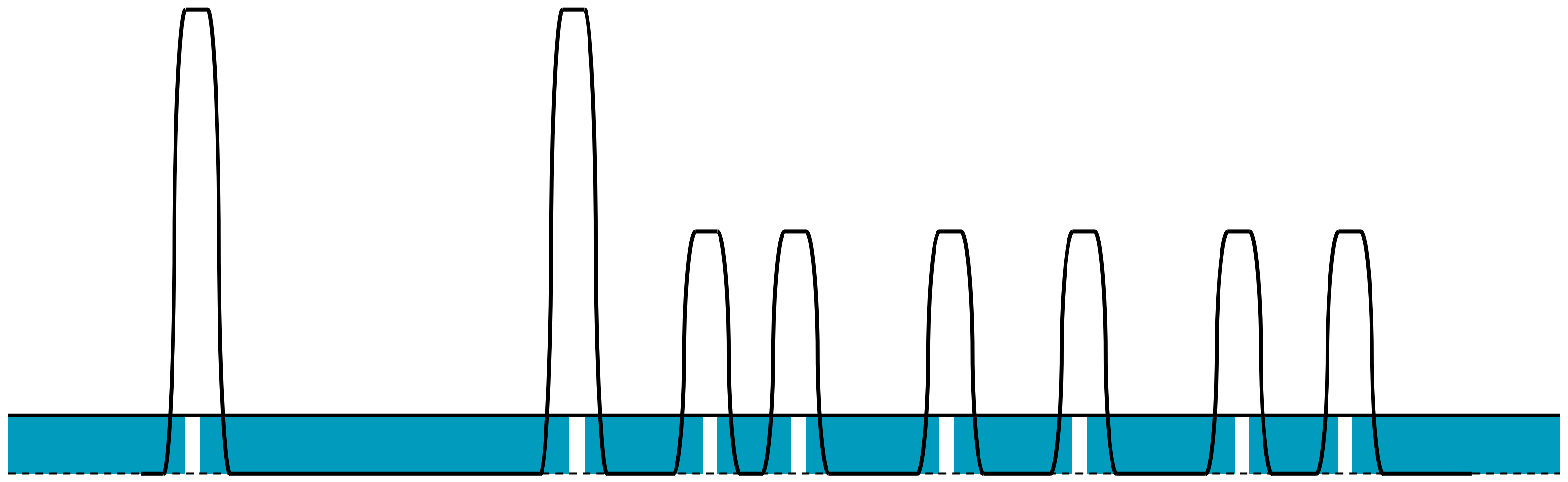
- Gradients can be computed from hue etc., if we want
- Any value that is low within a region and high at boundaries could be used

Using gradients is common, though….

Gradients in Highlight Edges



Immersion to Find Regions



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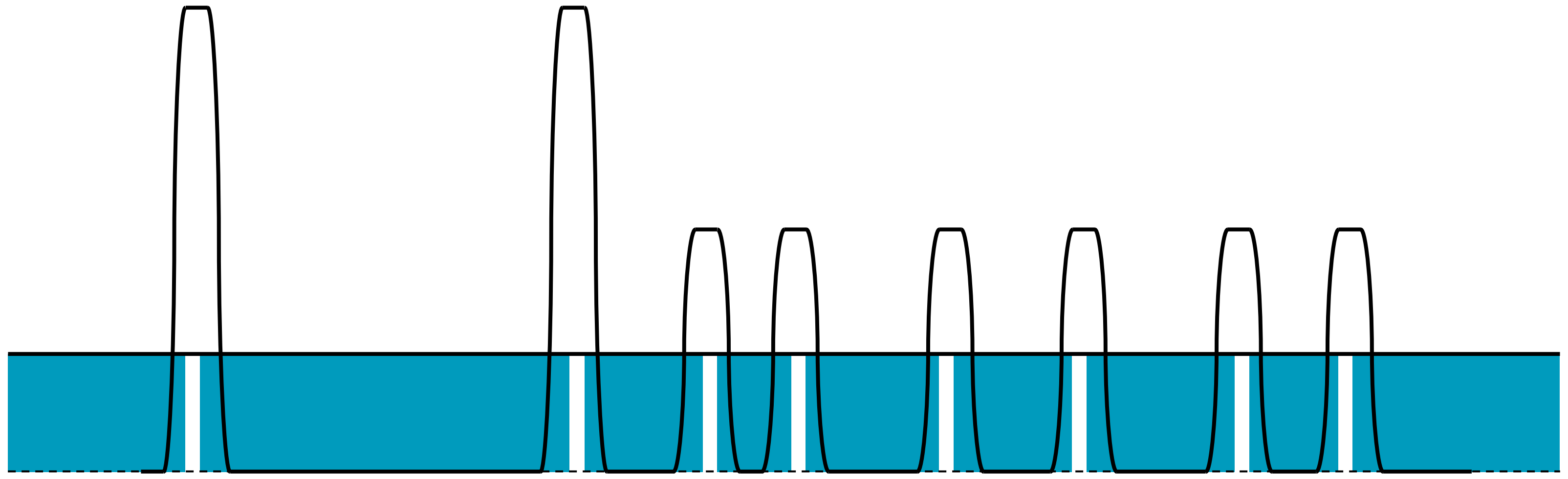

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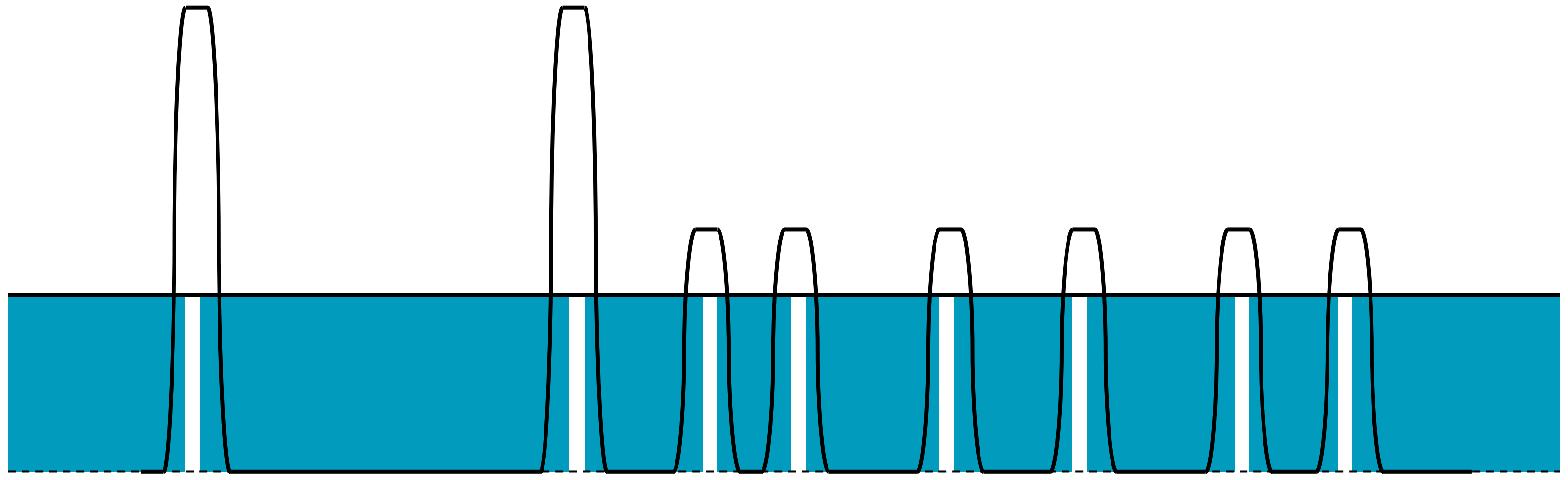

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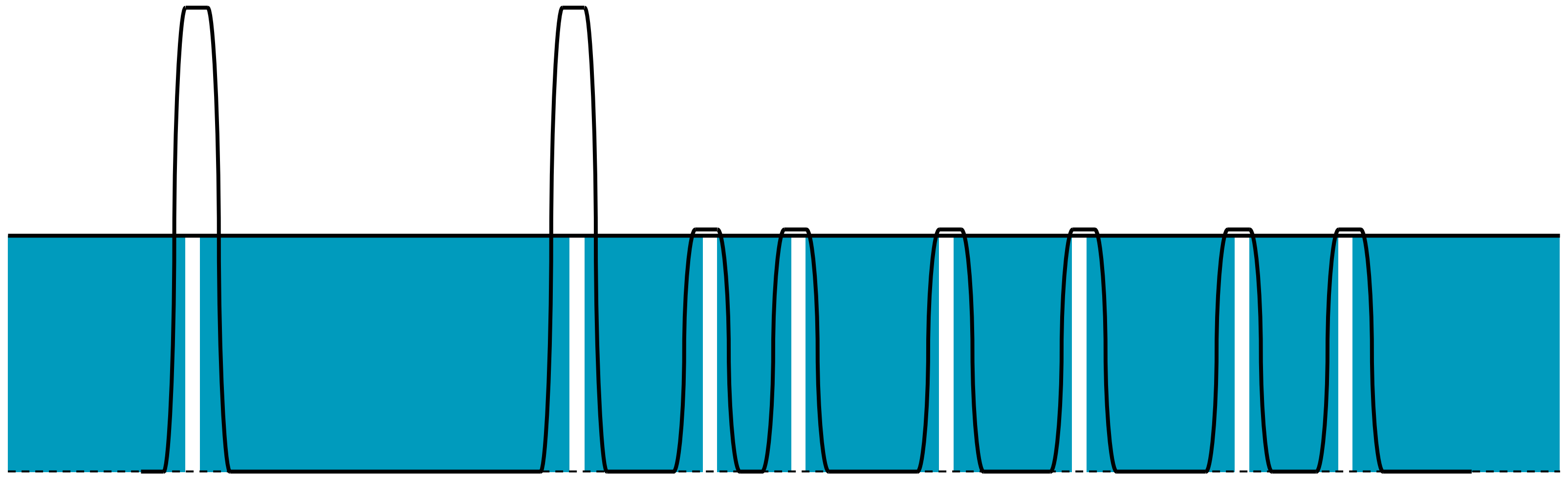

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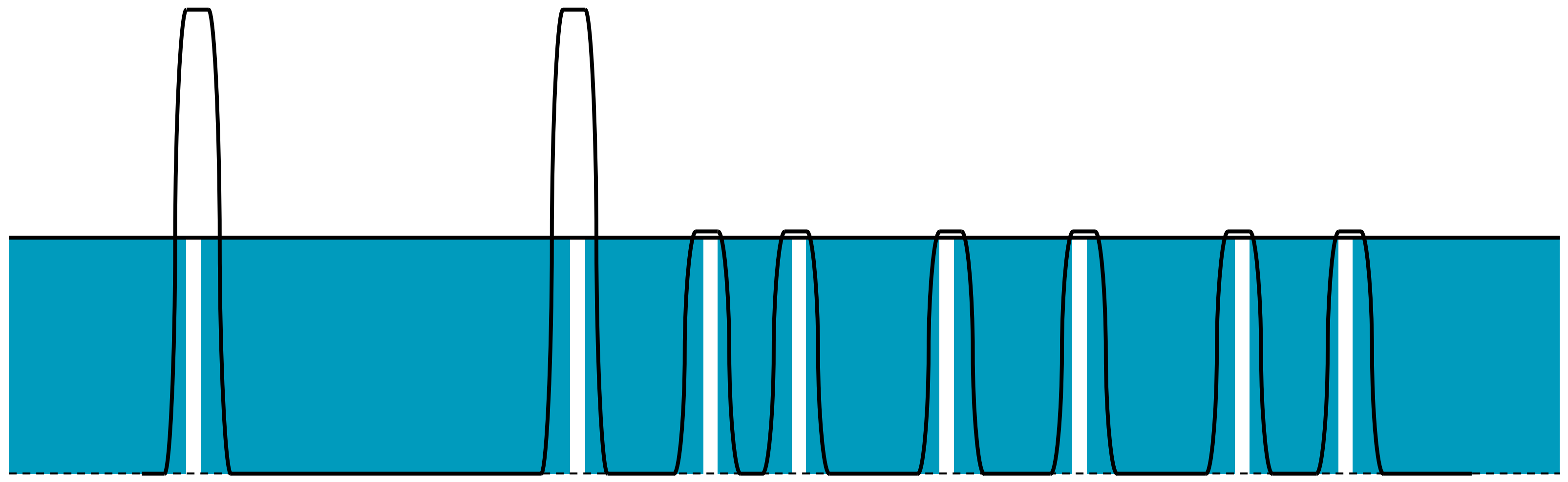

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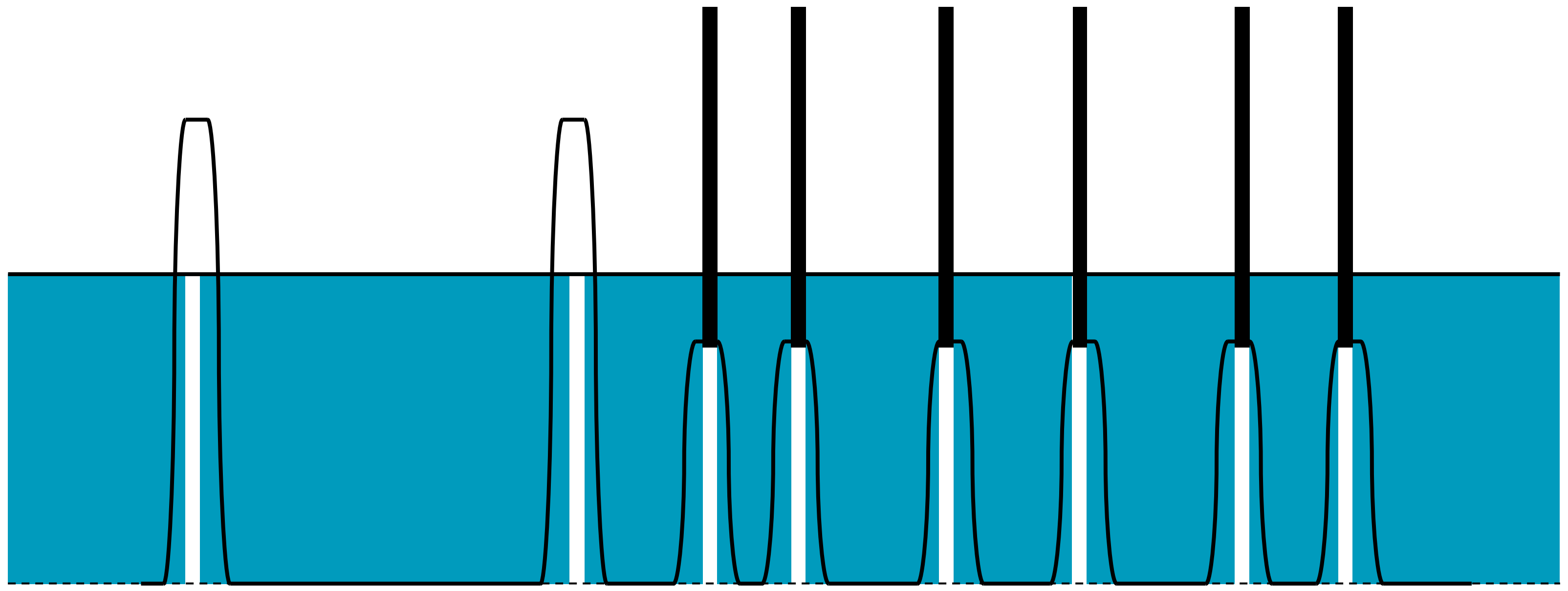

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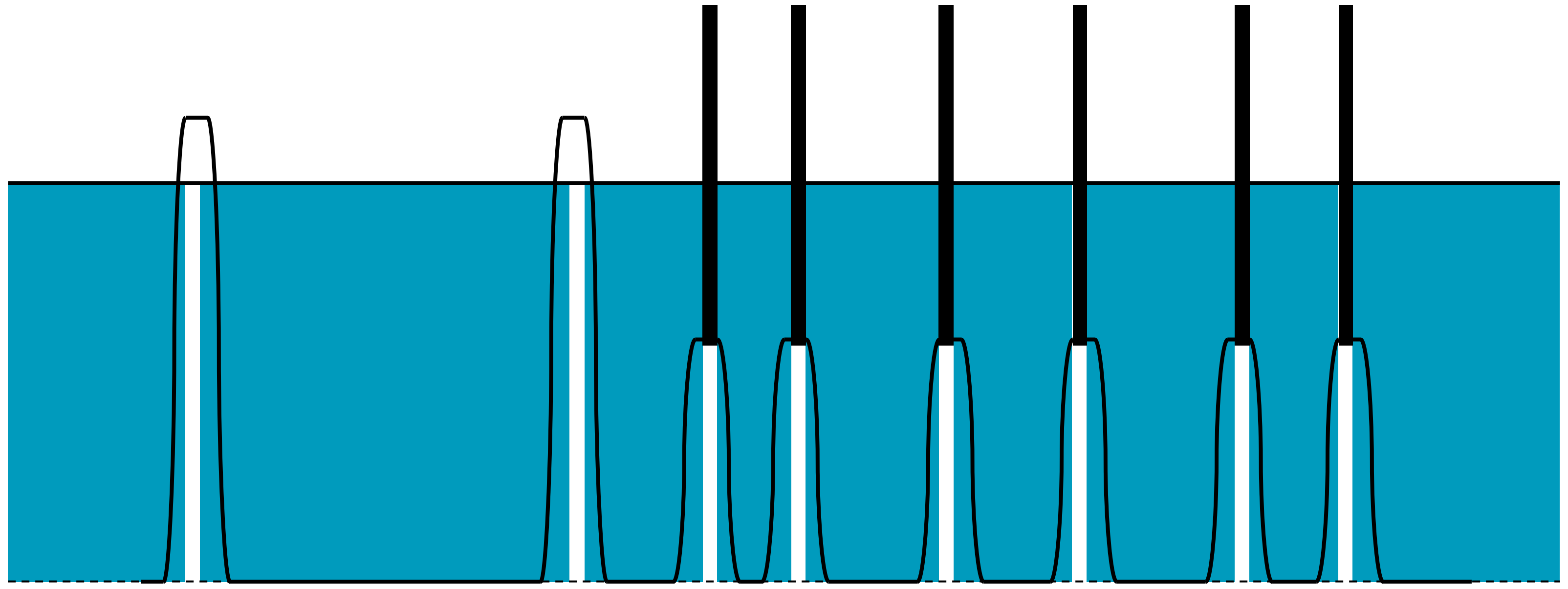

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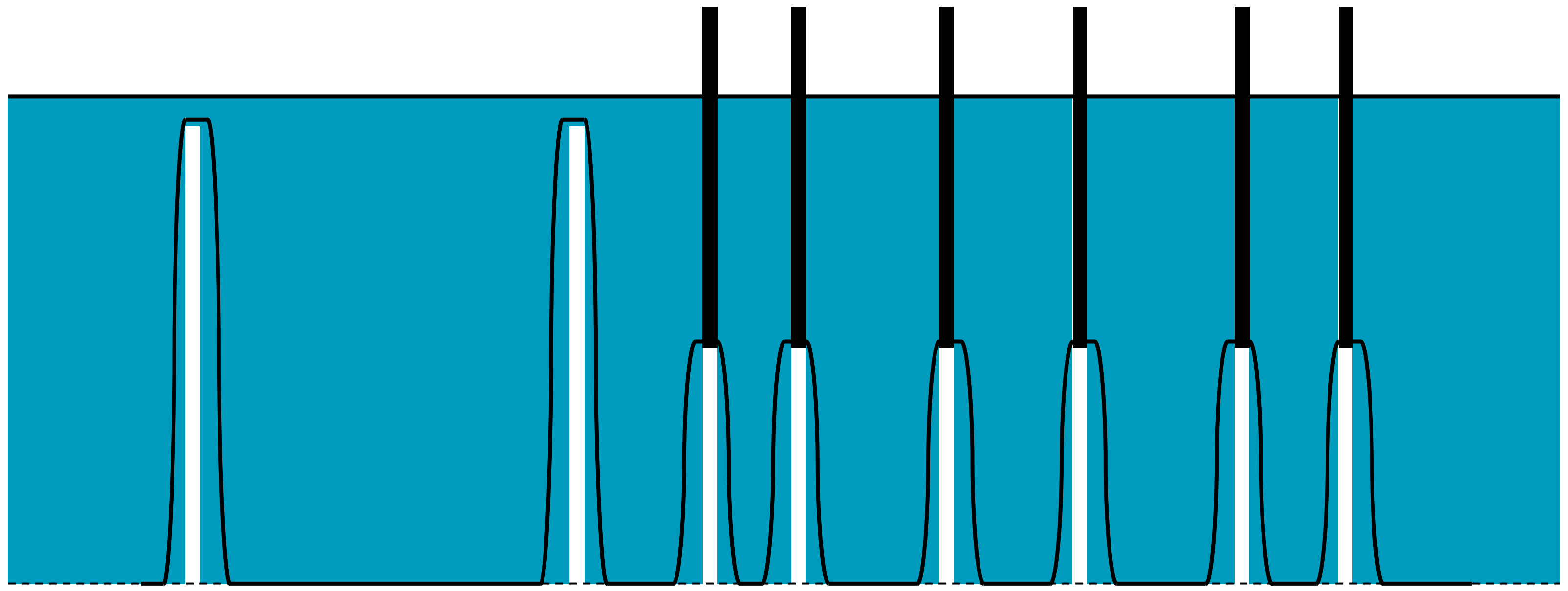

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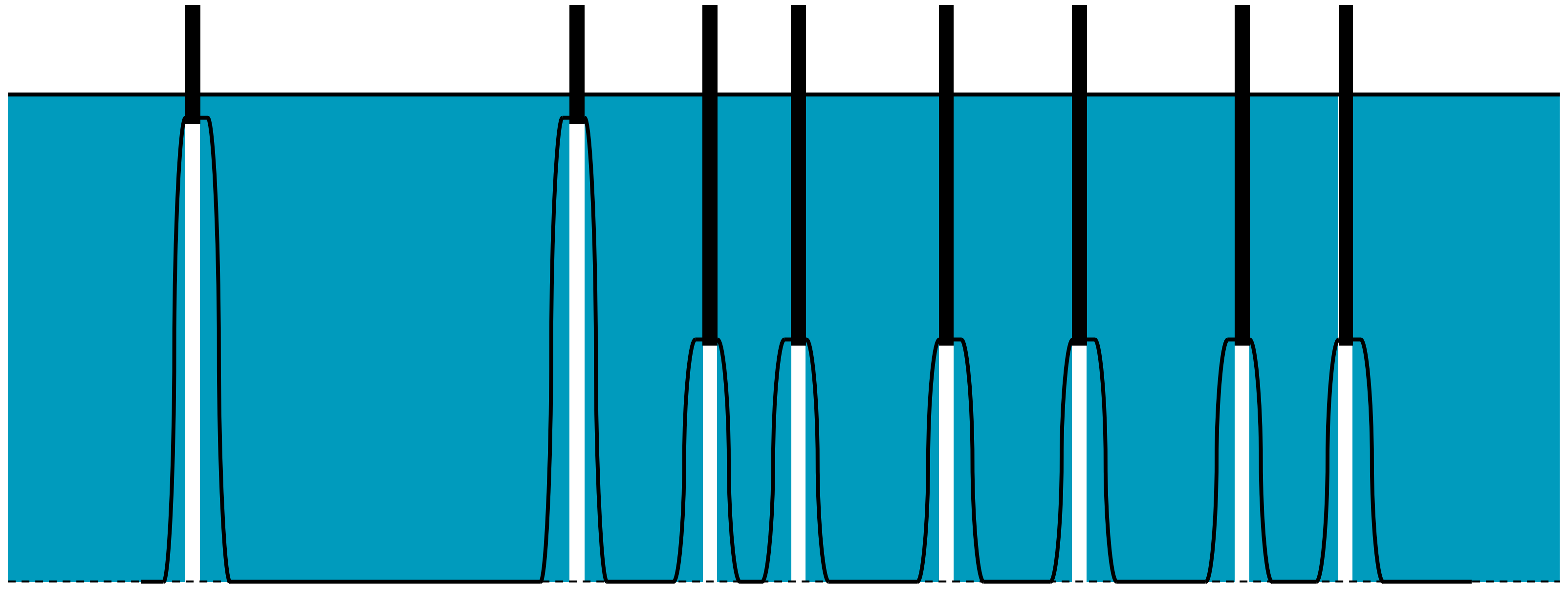
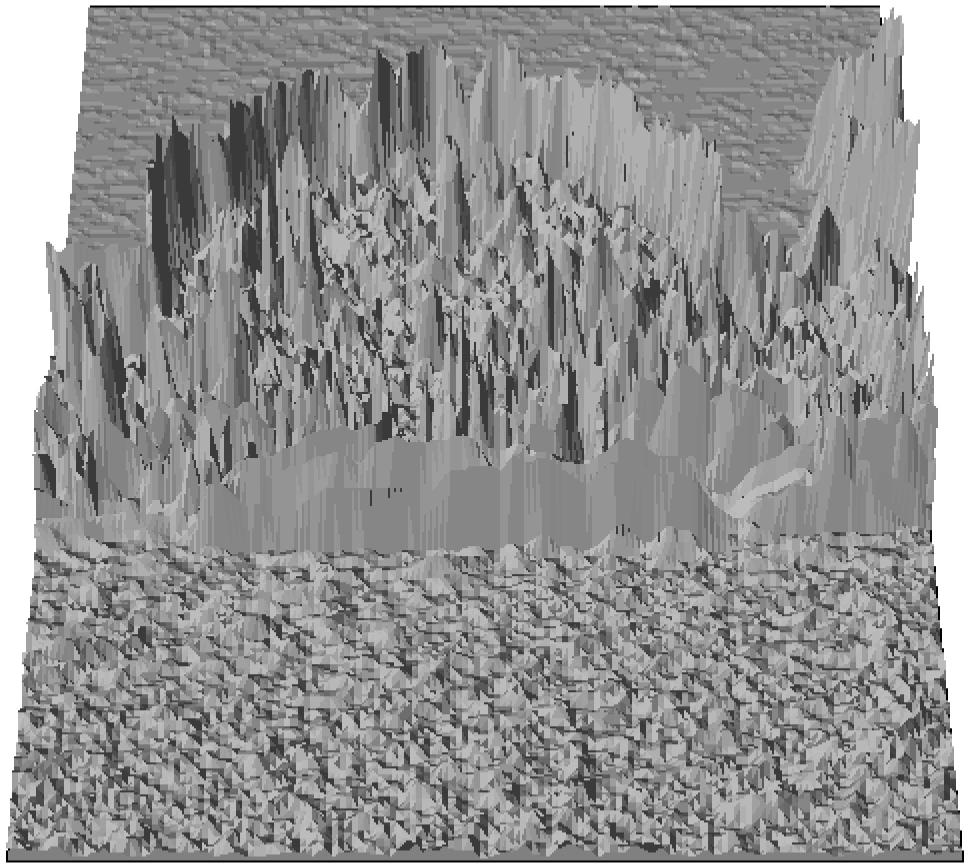


Watersheds in Images

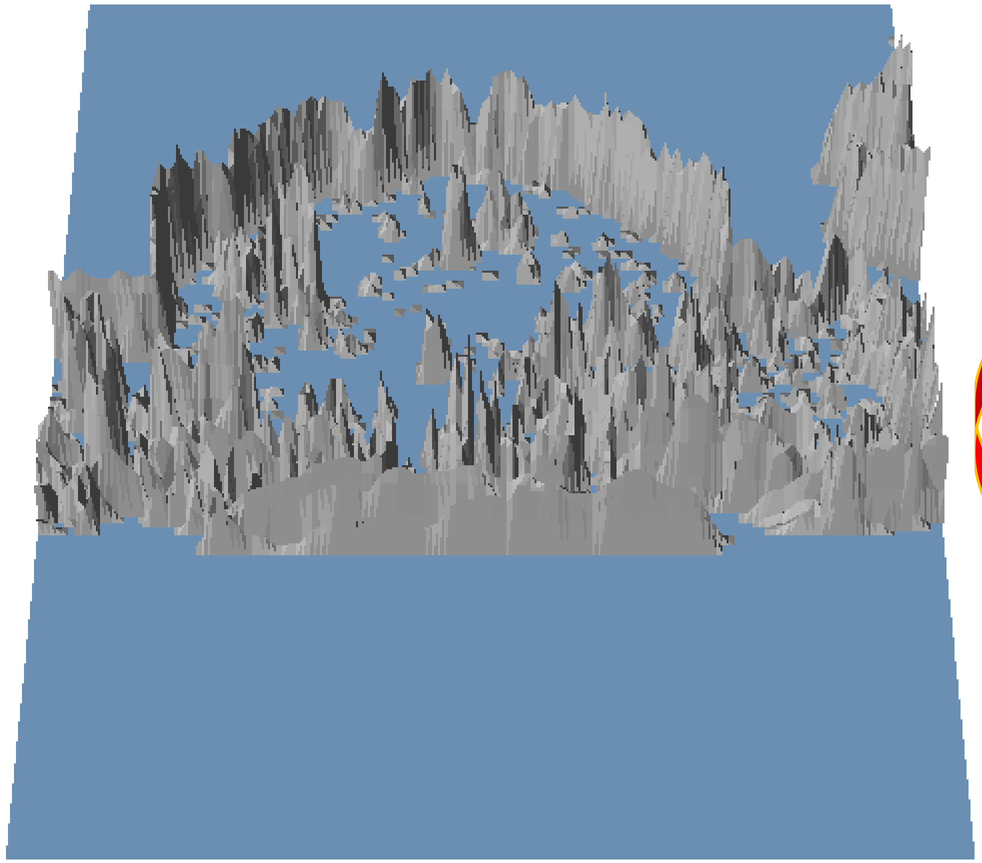


We start by finding images gradients

- Using methods like Sobel operators, we get a value for the gradient magnitude
- This can be viewed as a 3D 'terrain'

$$\sqrt{I_x^2 + I_y^2}$$

Watersheds in Images



We then slowly flood the terrain

- Flat areas of the image become areas of low gradient, so are valleys in the terrain
- Edges in the image have high gradient and so are ridges in the terrain

Watershed Algorithm

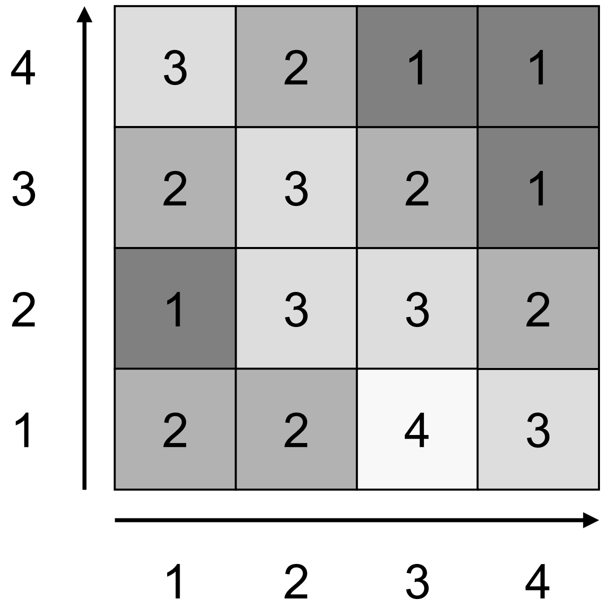
1. Sort the pixels: **low to high**
2. For each pixels

- If it's neighbours are all unlabelled, give it a new label
- If it has neighbours with a single label, it gets that label
- If it has neighbours with two or more labels, it is a watershed

This is a very basic version

- It has certain problems in that it can give 'thick' watersheds rather than fine lines
- It is sensitive to noise and so can generate lots of small regions
- It does show the basic plan, though

An Example



Sorted list:

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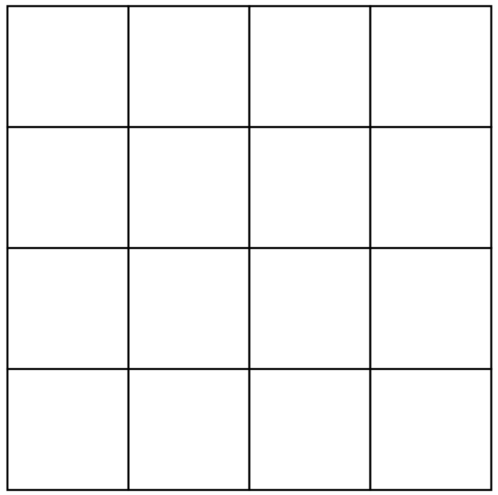
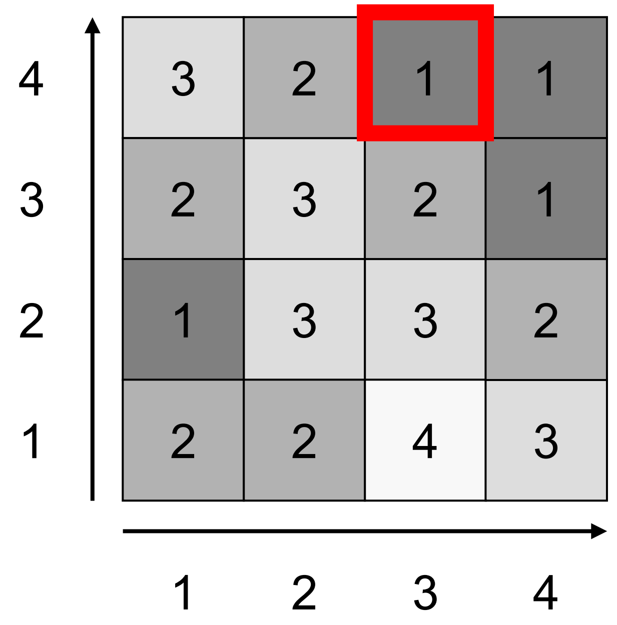


Labels

An Example



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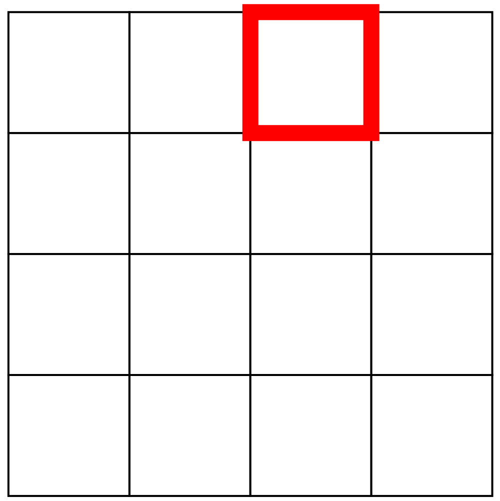

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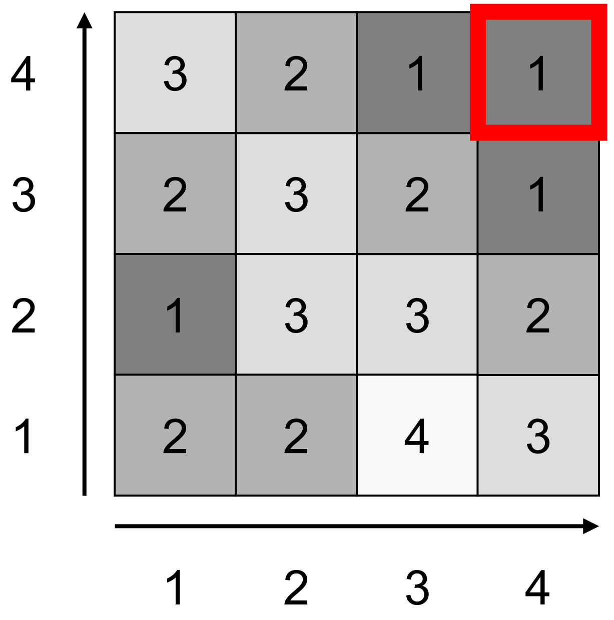

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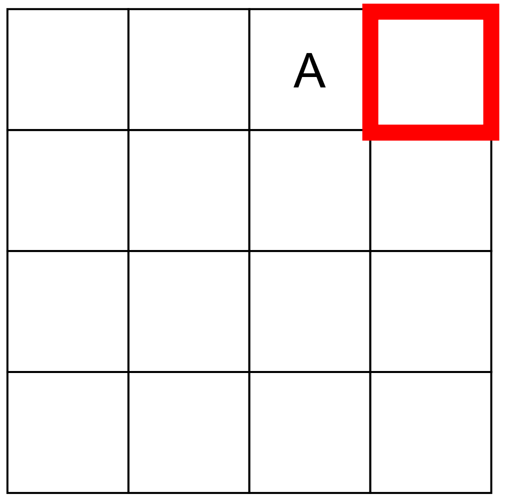

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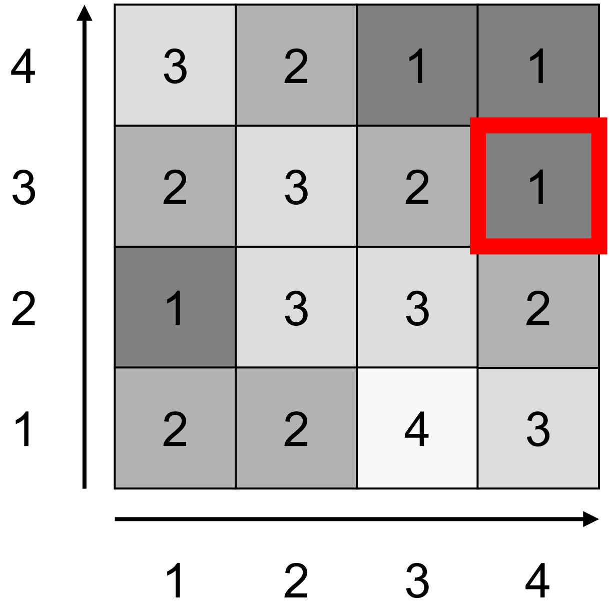

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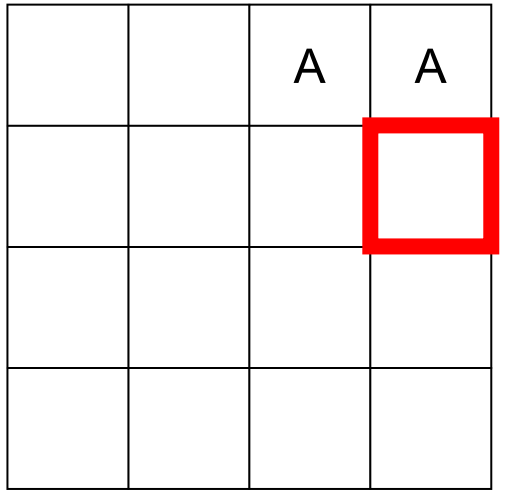

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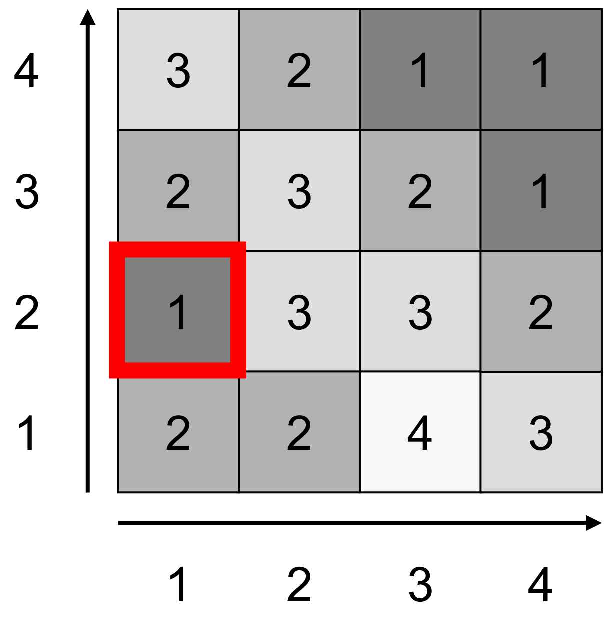

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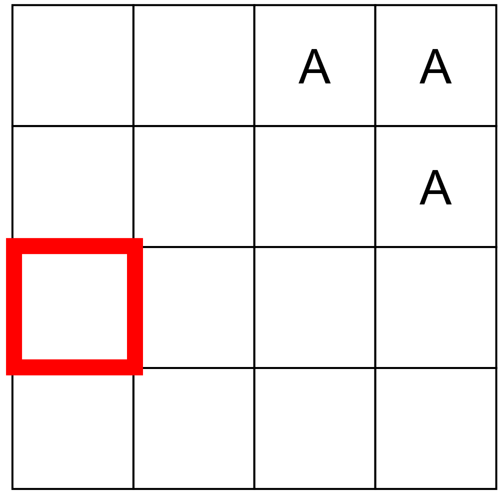

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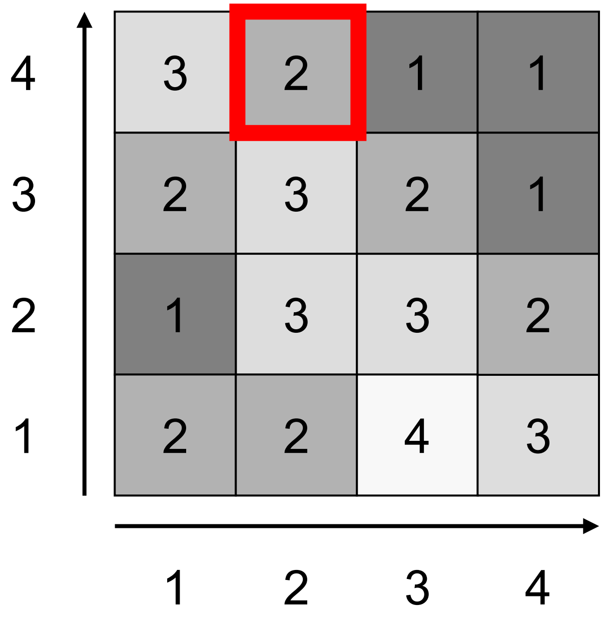

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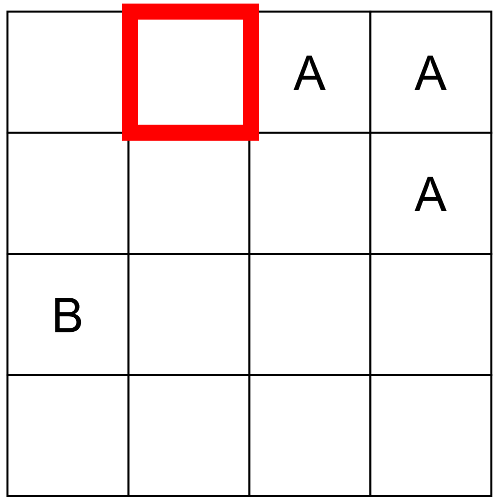

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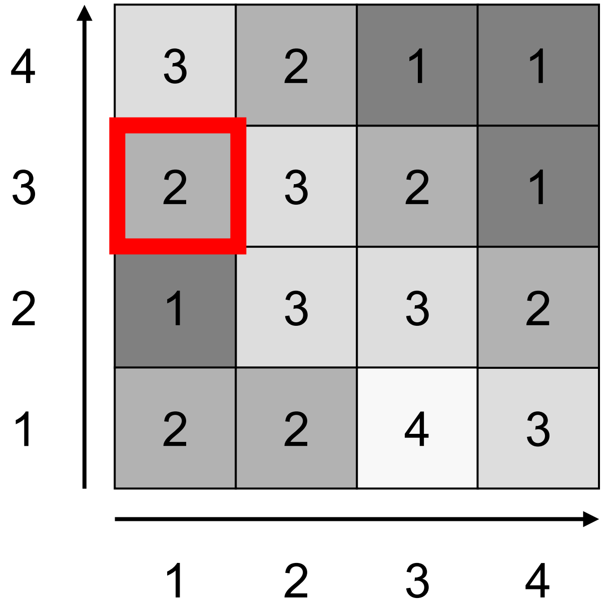

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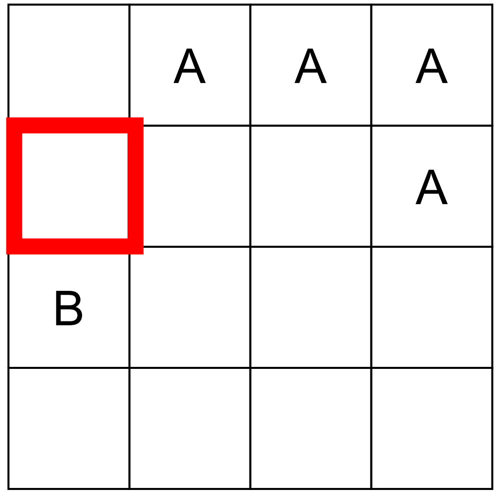

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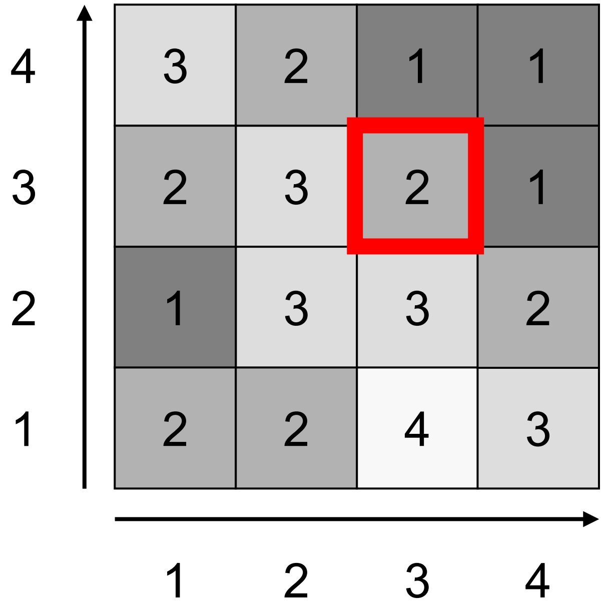

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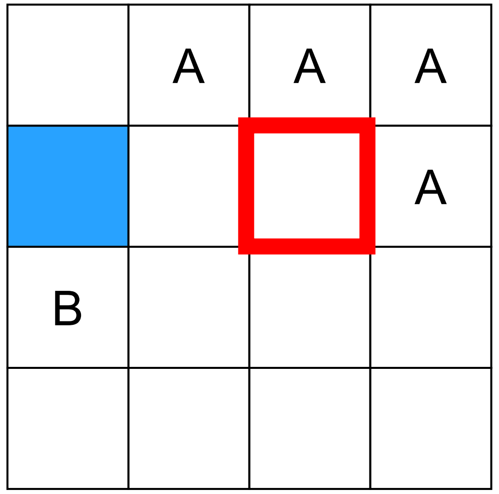

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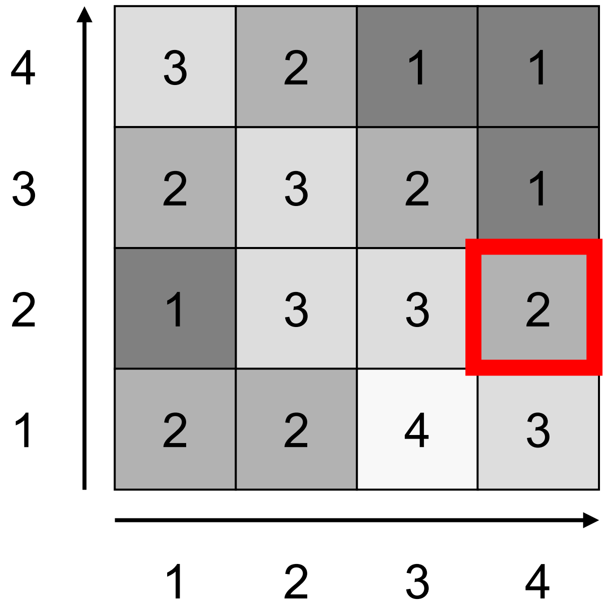

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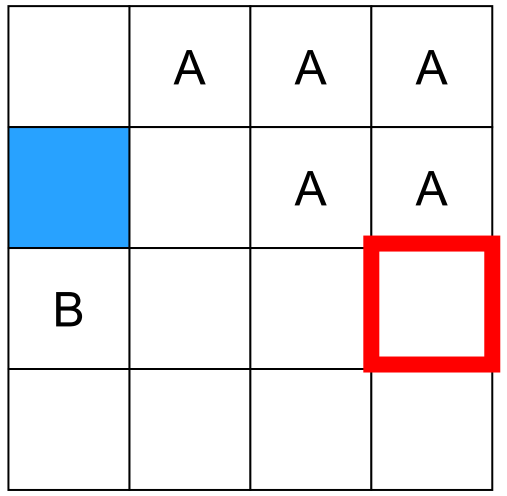

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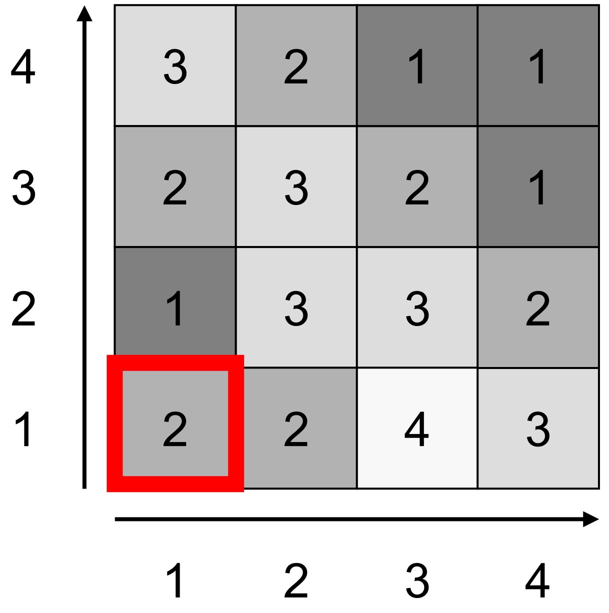

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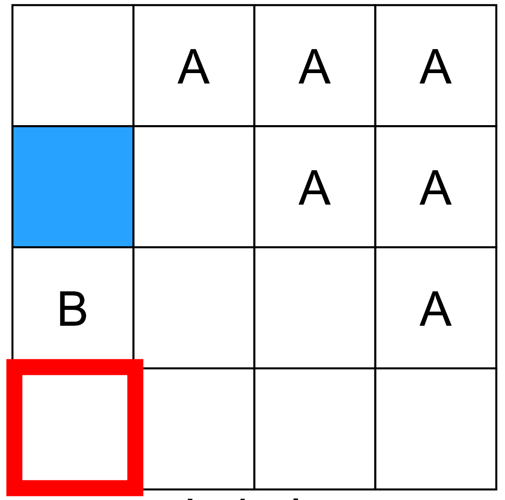

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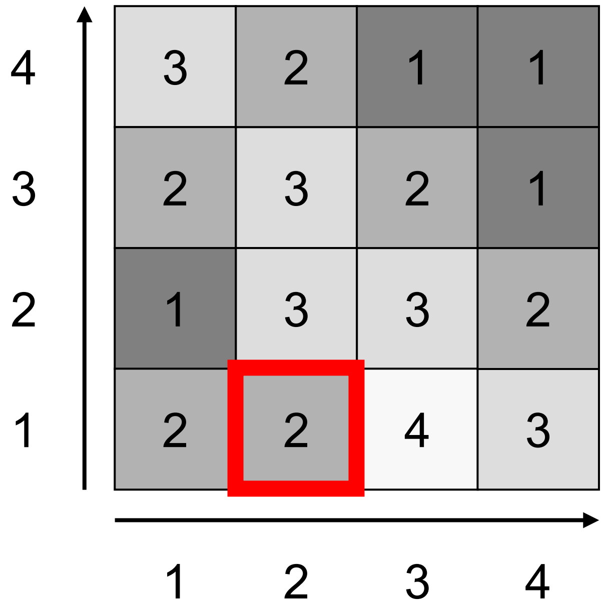

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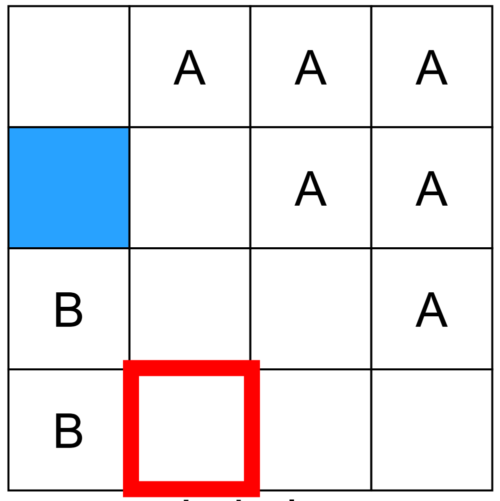
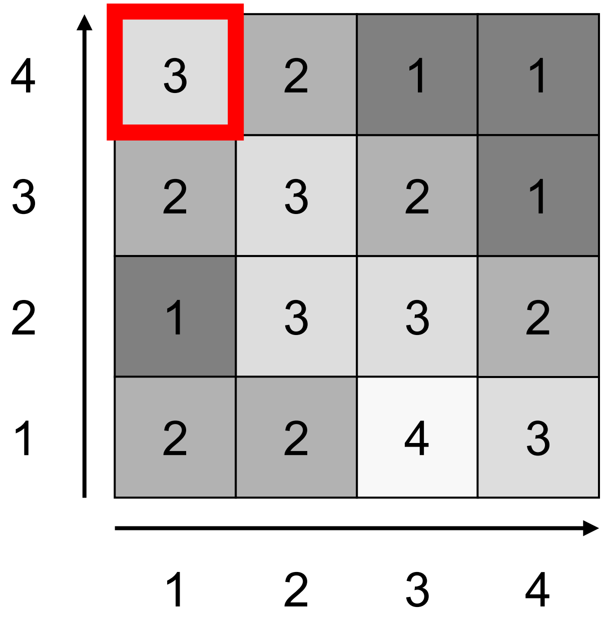


Labels

An Example



4	3	2	1	1
3	2	3	2	1
2	1	3	3	2
1	2	2	4	3
	1	2	3	4

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(4,4) = 1
(4,3) = 1
(1,2) = 1
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(1,3) = 2
(3,3) = 2
(4,2) = 2
(1,1) = 2
(2,1) = 2
(1,4) = 3
(2,3) = 3
(2,2) = 3
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(4,1) = 3
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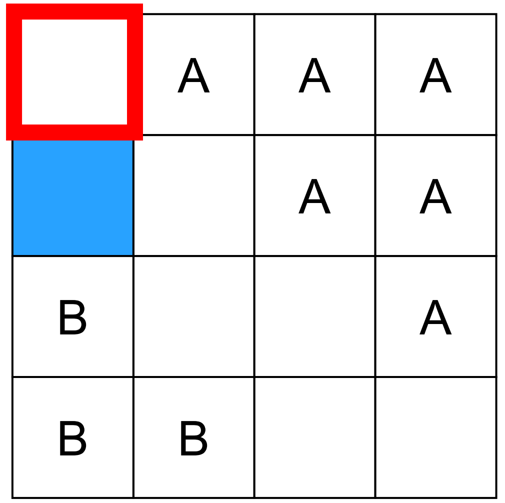
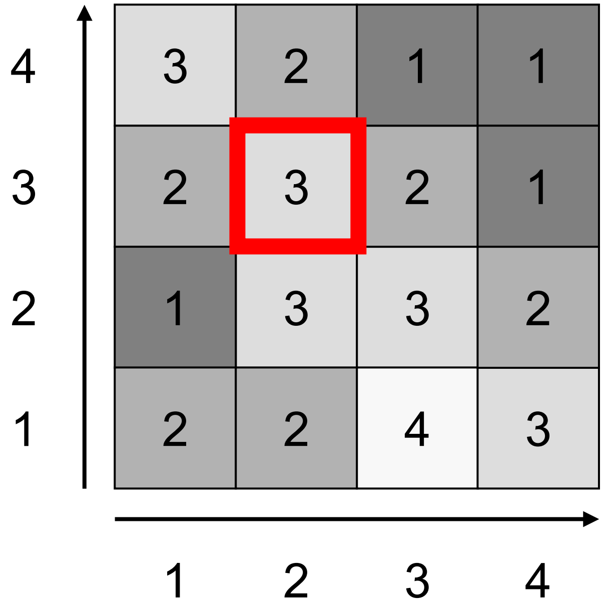


	A	A	A
🟦		A	A
B			A
B	B		

Labels

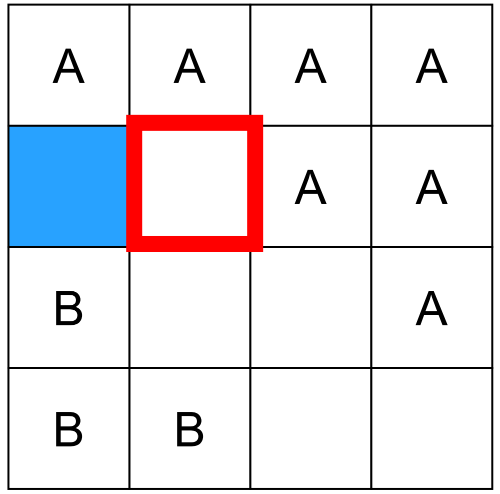
An Example



4	3	2	1	1
3	2	3	2	1
2	1	3	3	2
1	2	2	4	3
	1	2	3	4

Sorted list:

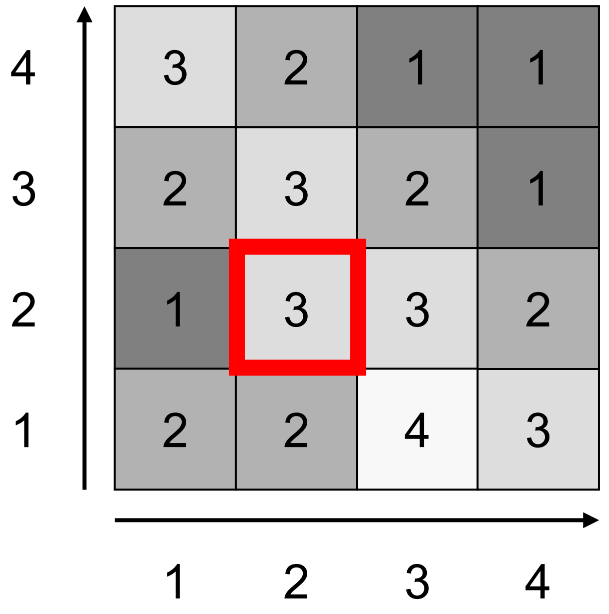
(3,4) = 1
(4,4) = 1
(4,3) = 1
(1,2) = 1
(2,4) = 2
(1,3) = 2
(3,3) = 2
(4,2) = 2
(1,1) = 2
(2,1) = 2
(1,4) = 3
(2,3) = 3
(2,2) = 3
(3,2) = 3
(4,1) = 3
(3,1) = 4



A	A	A	A
🟦		A	A
B			A
B	B		

Labels

An Example



Sorted list:

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(1,3) = 2
(3,3) = 2
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(3,2) = 3
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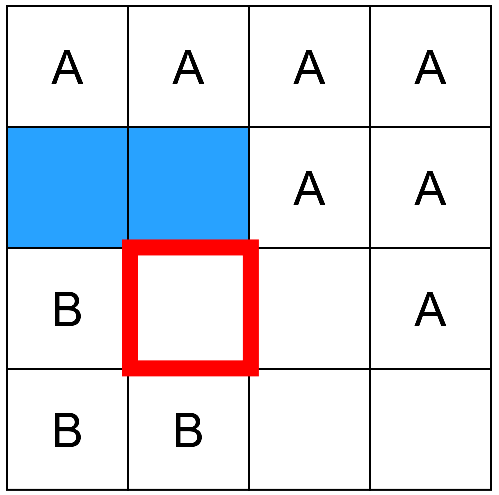
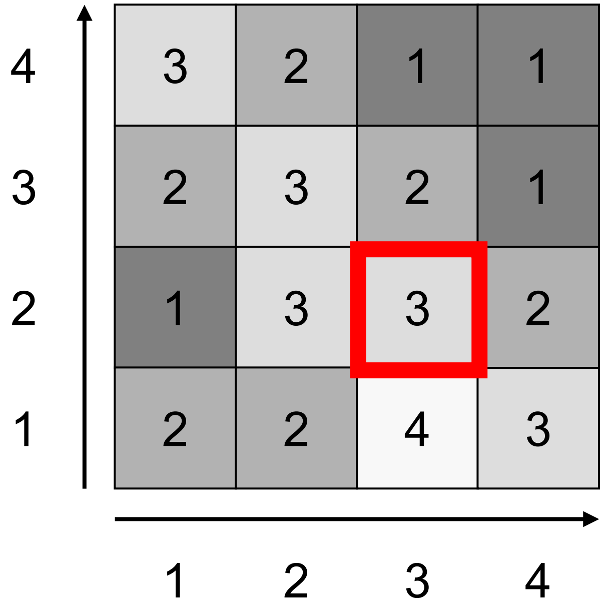
(3,1) = 4



Labels

An Example



Sorted list:

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(4,4)	= 1
(4,3)	= 1
(1,2)	= 1
(2,4)	= 2
(1,3)	= 2
(3,3)	= 2
(4,2)	= 2
(1,1)	= 2
(2,1)	= 2
(1,4)	= 3
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(2,2)	= 3
(3,2)	= 3
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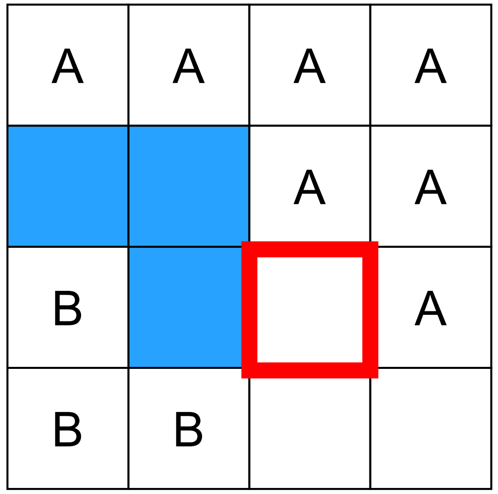
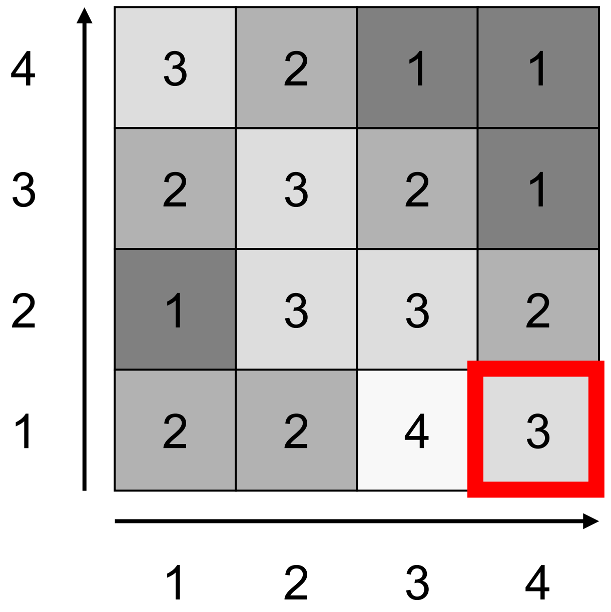


Labels

An Example



Sorted list:
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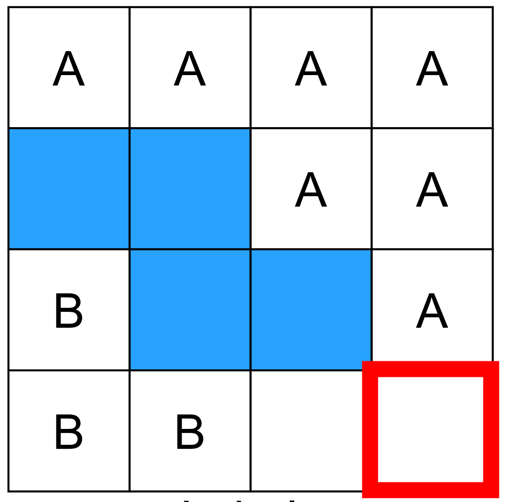
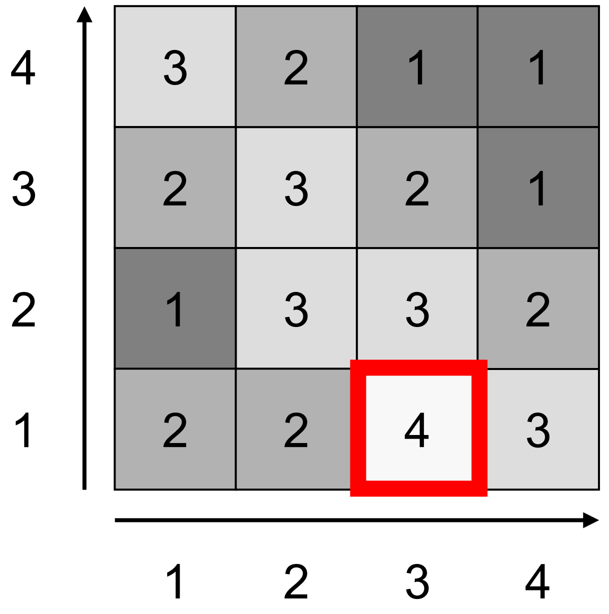


Labels

An Example



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(1,3) = 2
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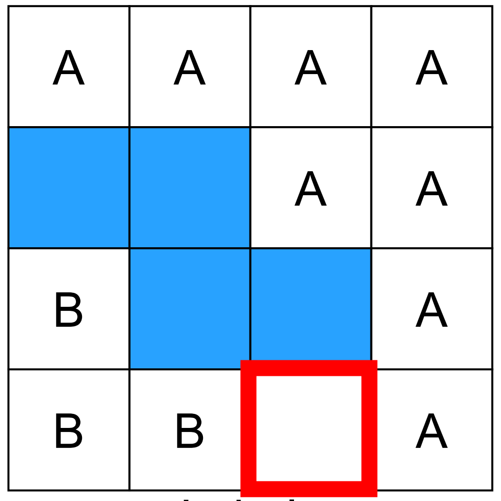
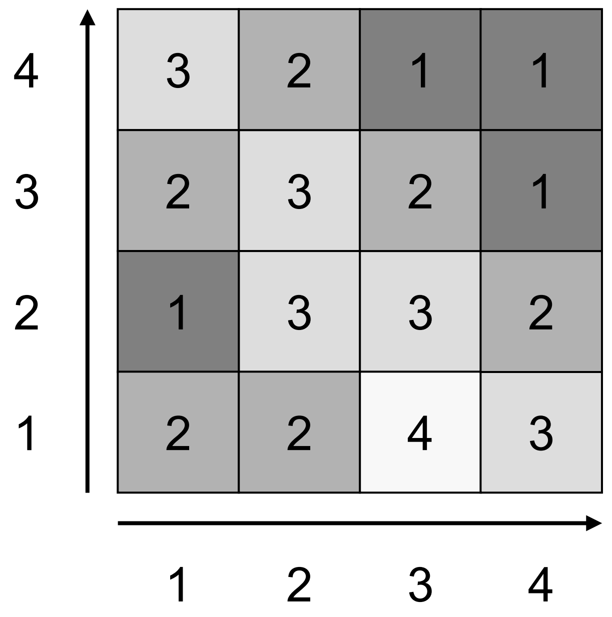
(3,1) = 4



Labels

An Example



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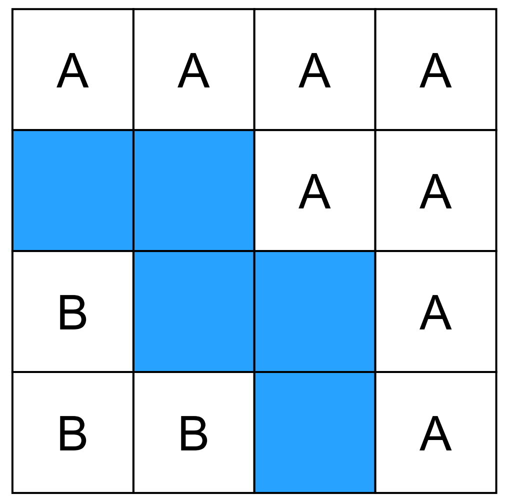


A	A	A	A
🟦	🟦	A	A
B	🟦	🟦	A
B	B	🟦	A

Labels

Computing Watersheds

Watershed based segmentations can be very efficient

- It is possible to implement it in *O(n)* time, where *n* is the number of pixels
- Since it takes *O(n)* time to read or write an image, this is as good as it can get in most situations

To implement watersheds we need to sort the pixels

- They need to be sorted from highest to lowest gradient
- Sorting is *O(n* log*(n))*, so how do we get an *O(n)* algorithm?

Sorting in Linear Time

In any situation where we have

- A large number of values, and
- Those values are drawn from a smaller set of possibilities

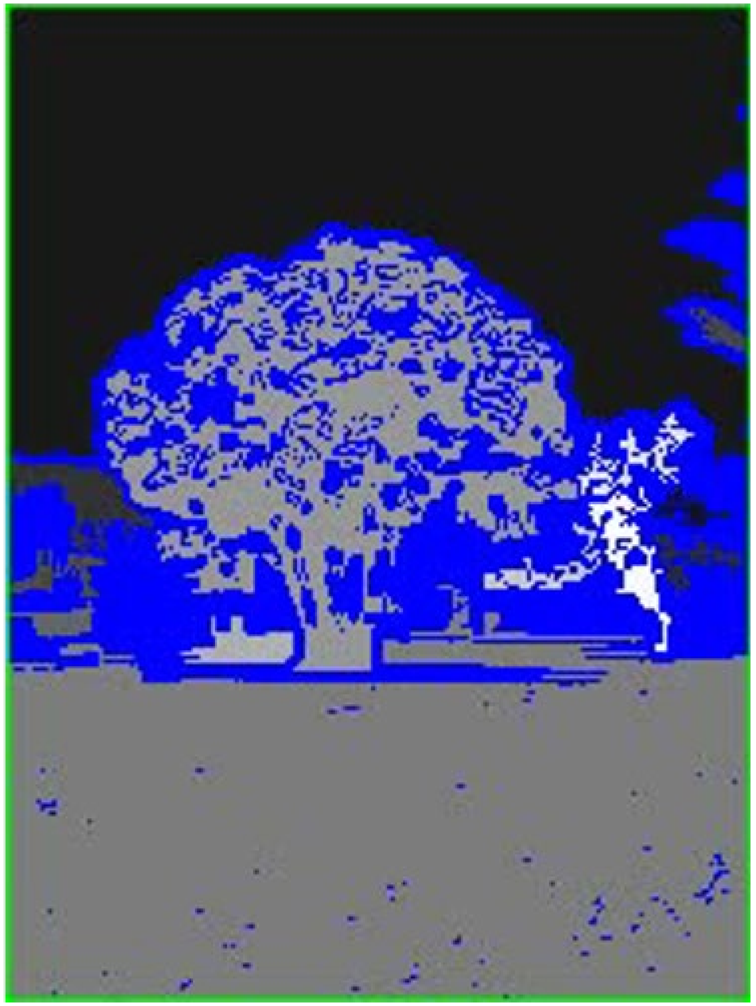
We can sort in linear time with a bin sort

1. Make a bin (*a list, queue or stack*) for each possible value
2. For each item: put it in the appropriate bin

Bin Sort

The items are now SORTED!

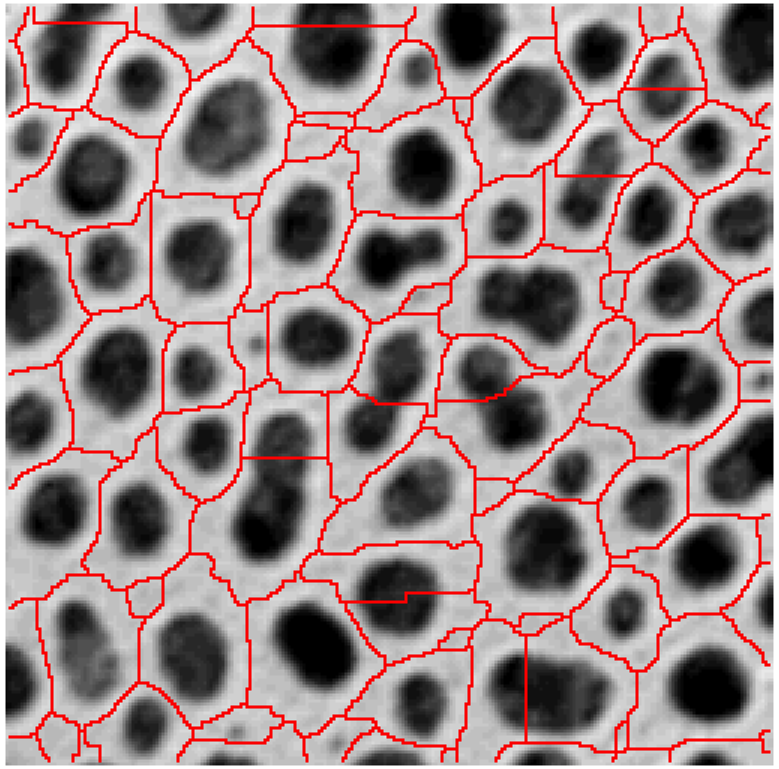
Example - Watershed



Segmenting the tree image

- The basic algorithm has been modified to avoid the effects of noise
- The gradient has been quantised to remove small variations
- Above a threshold water level, no more new segments are introduced as the water rises

Example - Watershed



- Watersheds can also be applied to some greyscale images directly
- For example, in many medical and biological images the regions are dark or light regions against a light or dark background

Summary

1. What is Segmentation?
2. Region-based Segmentation
3. Edge-based Segmentation

University of Nottingham
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Questions

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NEXT:

Interactive Segmentation