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COMP-2032

Introduction to Image Processing

Lecture 8

Segment and Superpixels

Learning Outcomes

IDENTIFY

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

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

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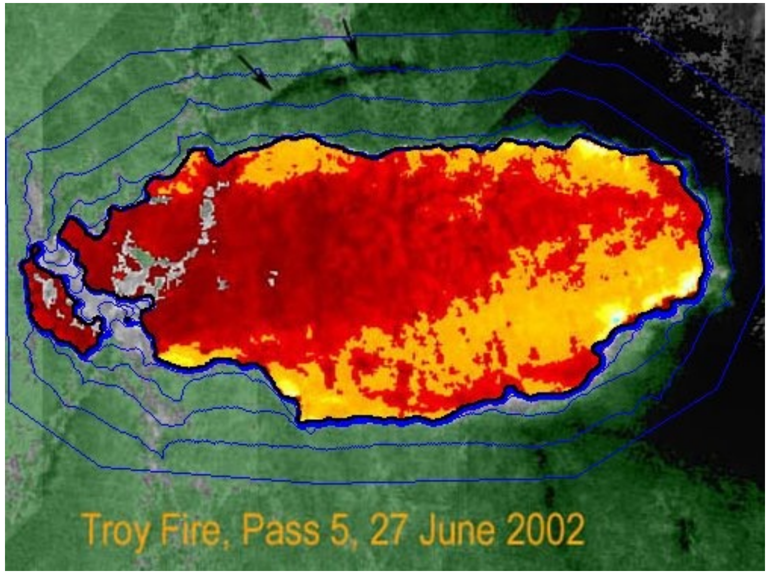
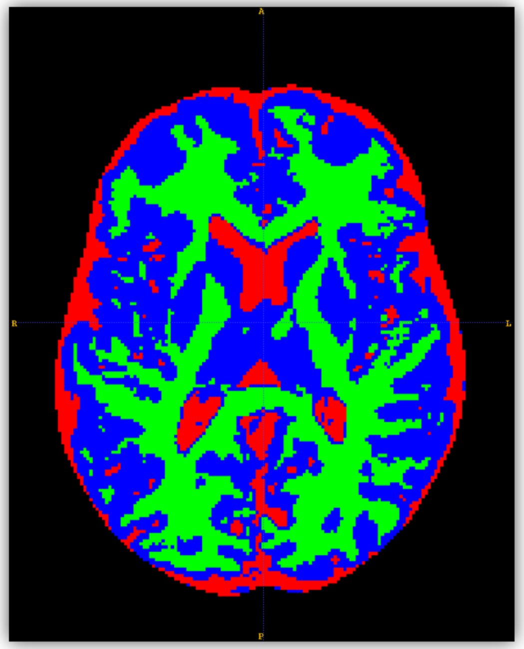
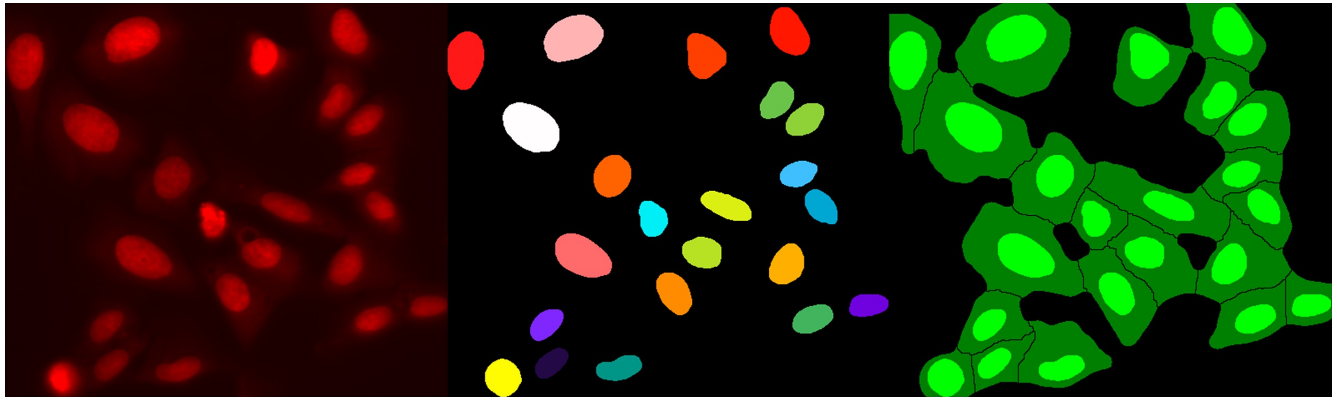
Applications







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Approaches

Many different approaches have been taken to the segmentation problem

Clustering

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

Region-based

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

Edge-based

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

Note

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

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Region Growing

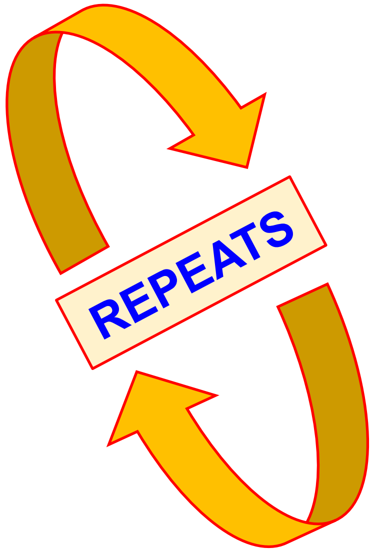
Region growing starts with a small patch of seed pixels

- 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



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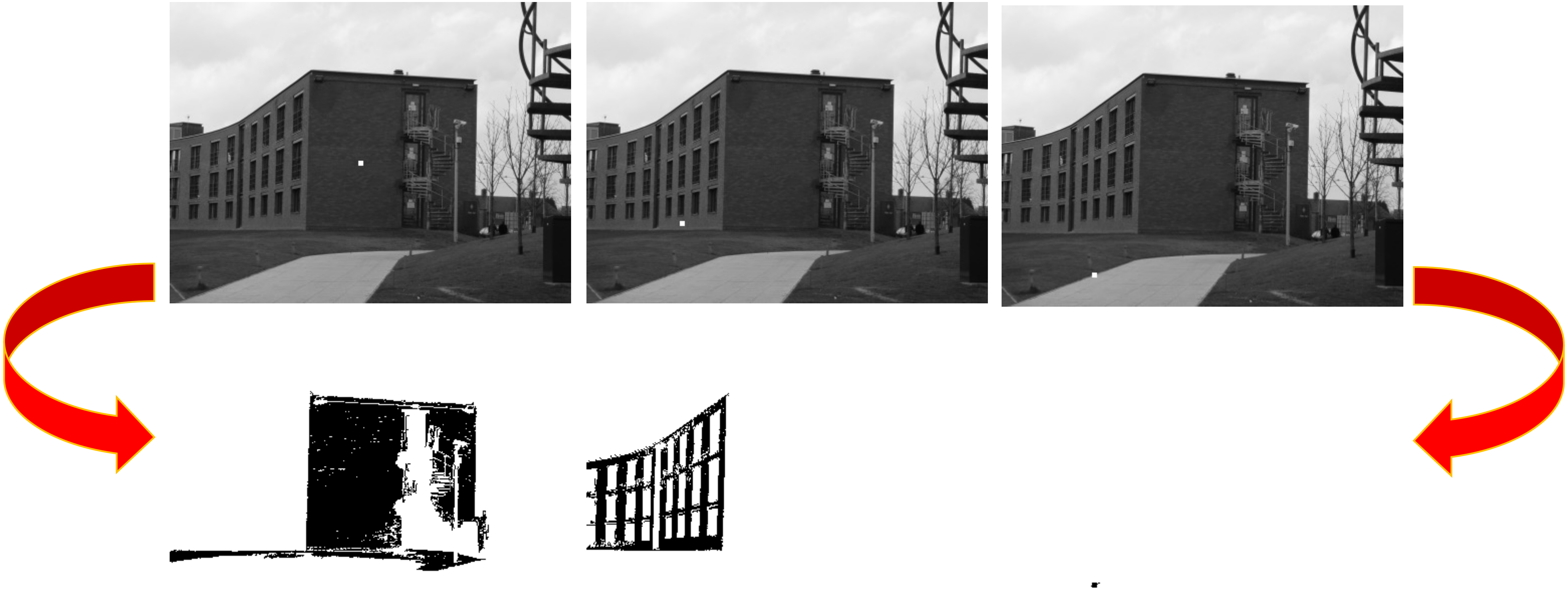
Region Growing Example



Output 1

Output 2

Output 3

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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

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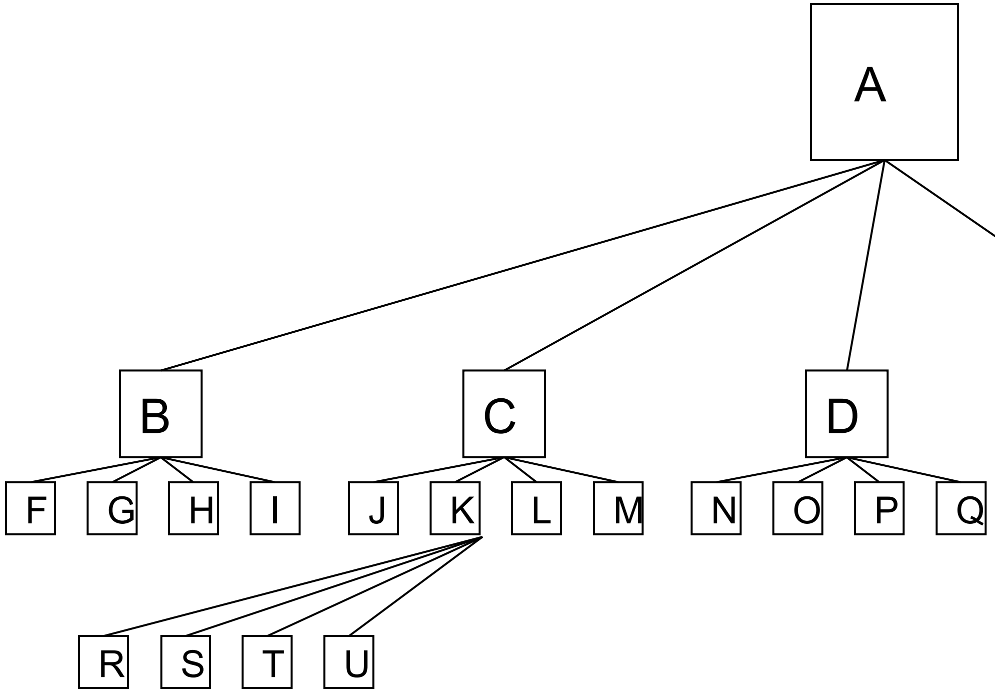
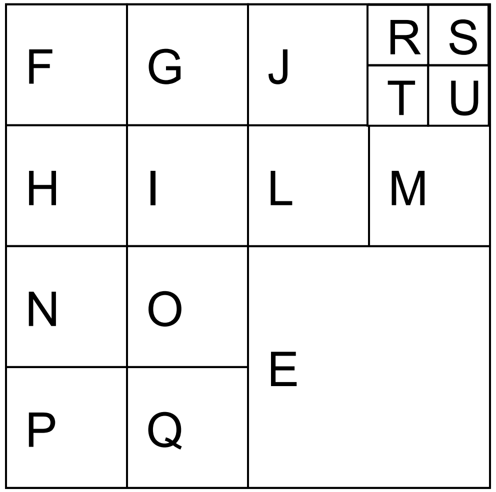
Quadtrees





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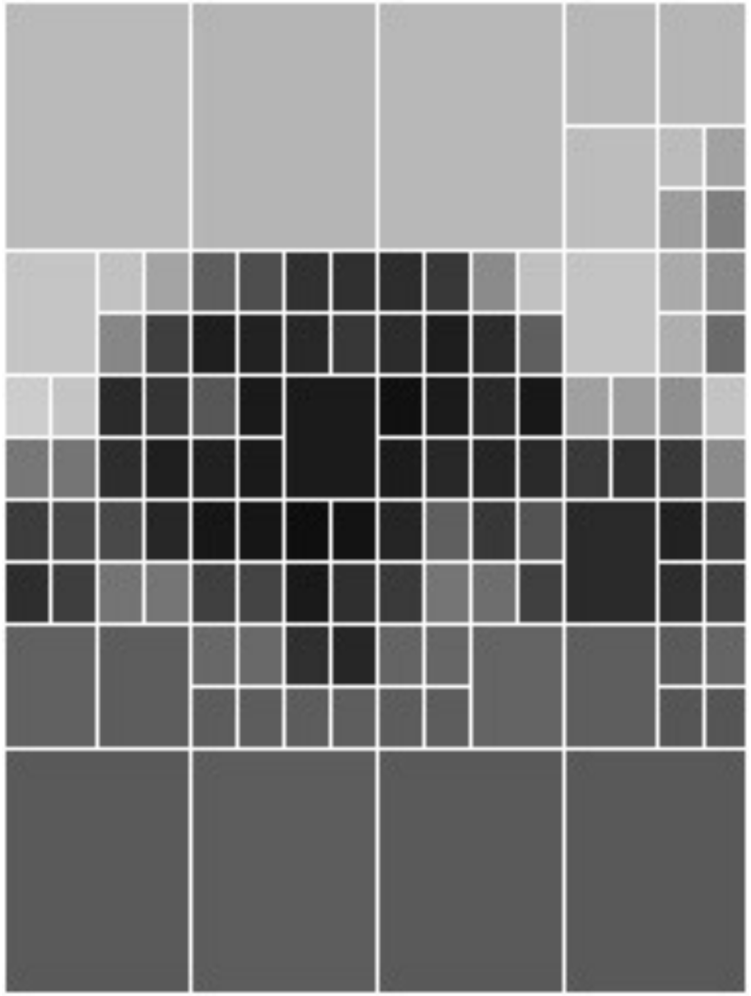
Example - Splitting



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

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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

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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

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Break

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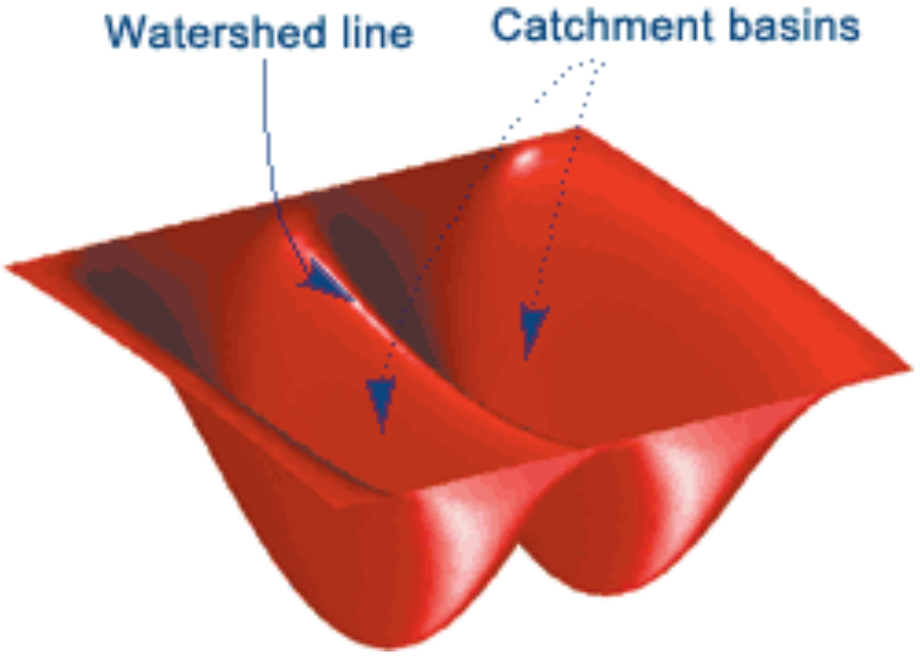
Edge-based Segmentation (*Watersheds*)

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

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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….

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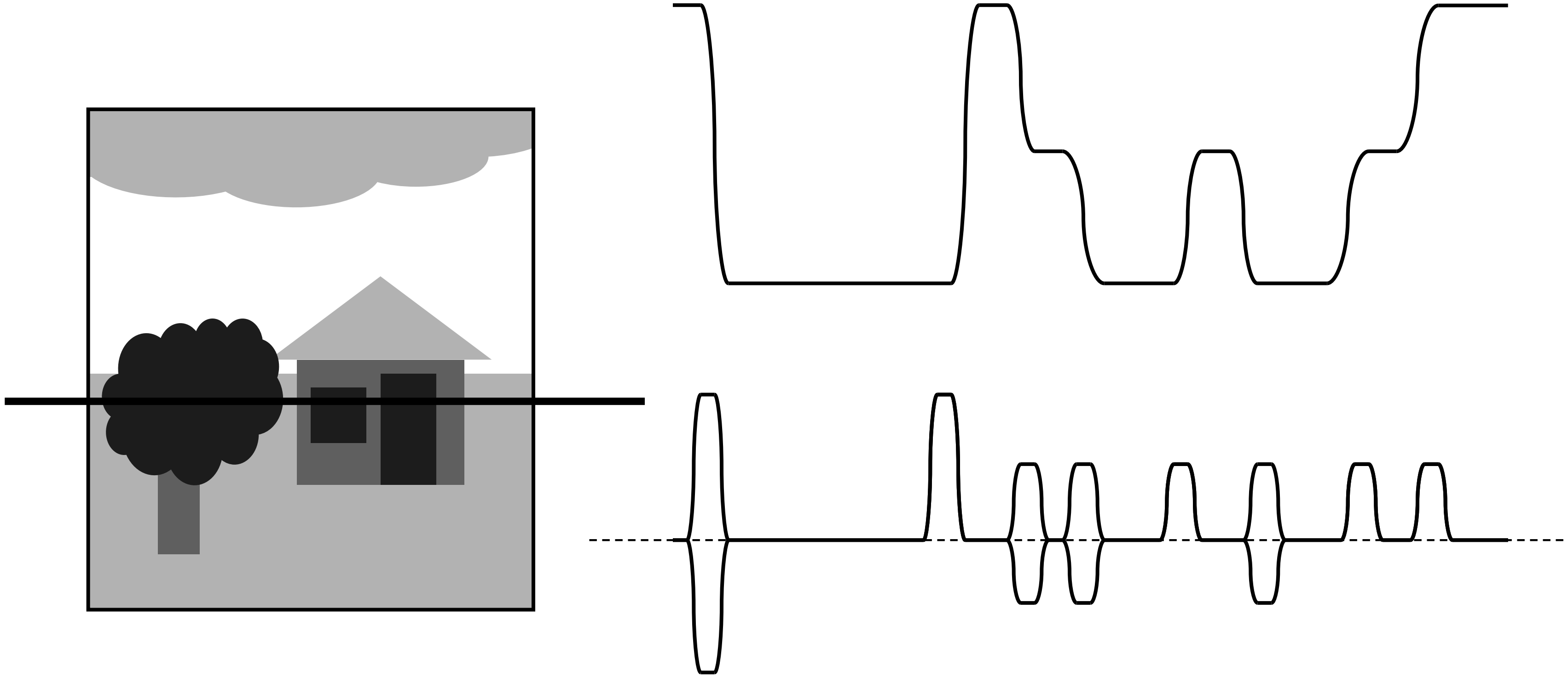
Gradients in Highlight Edges



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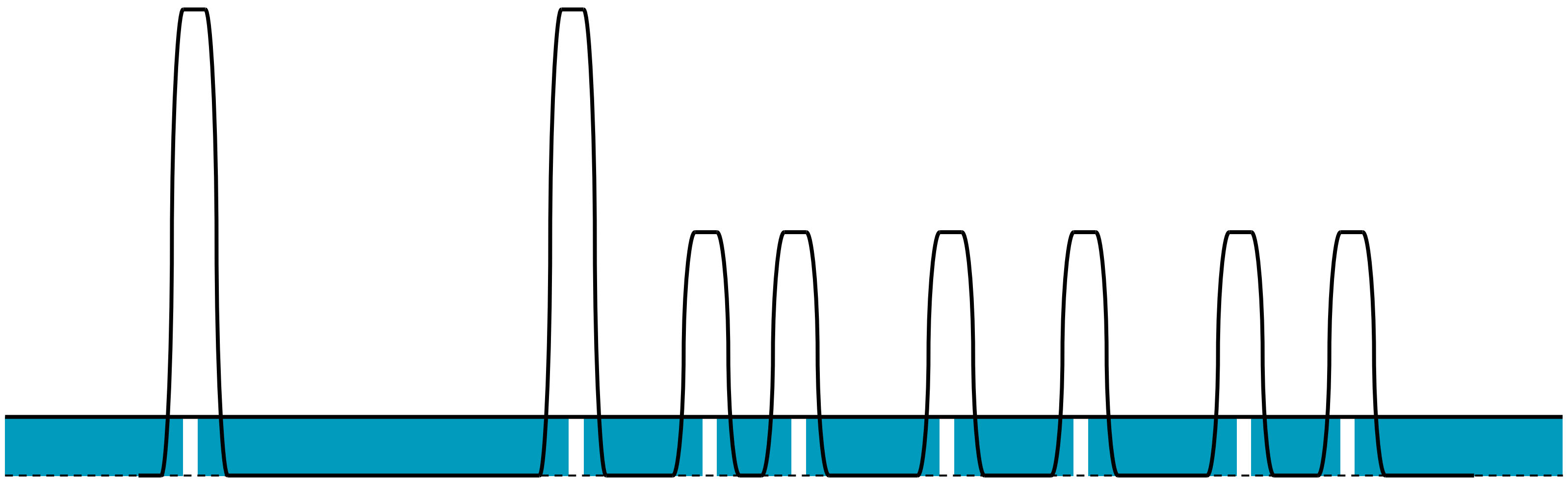
Immersion to Find Regions



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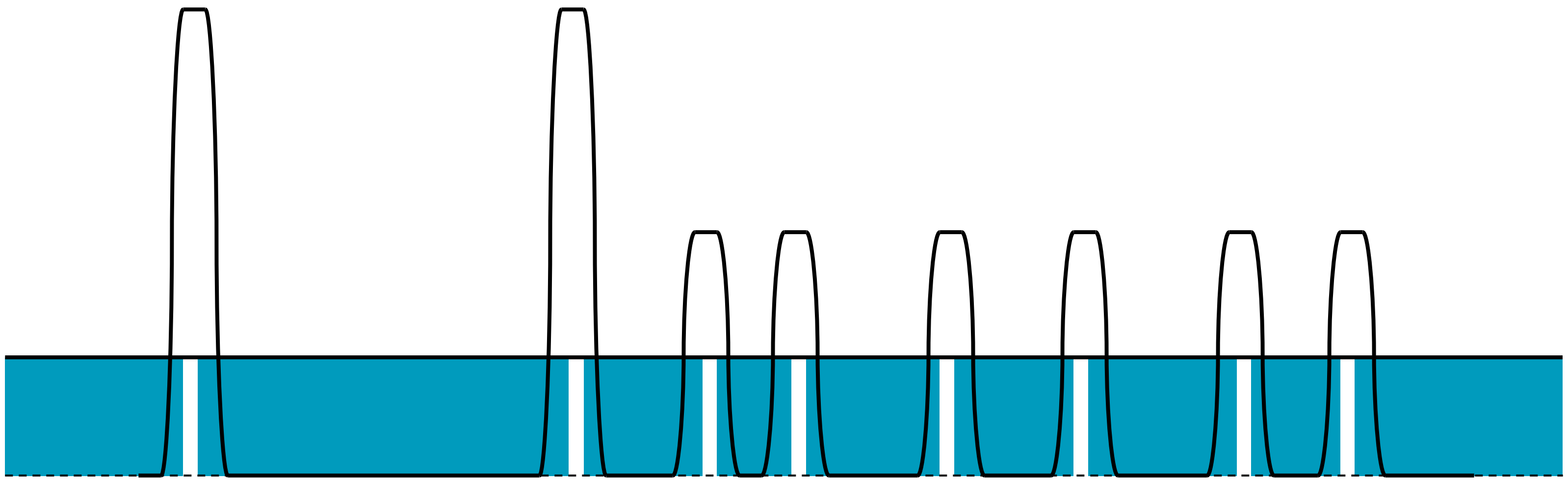

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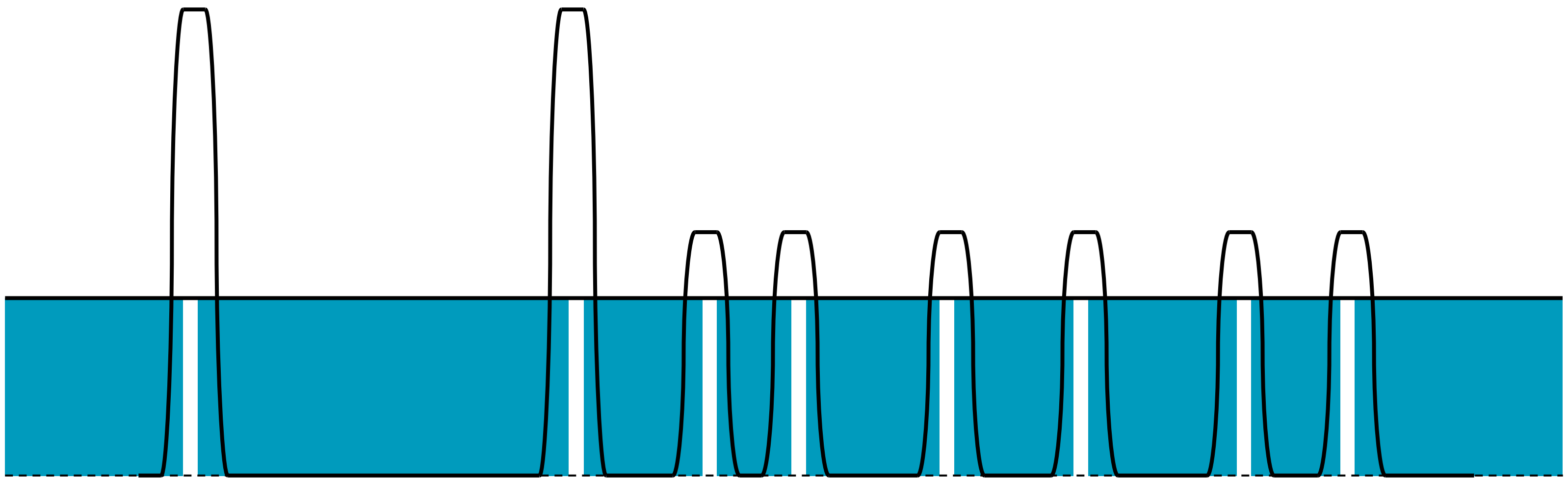

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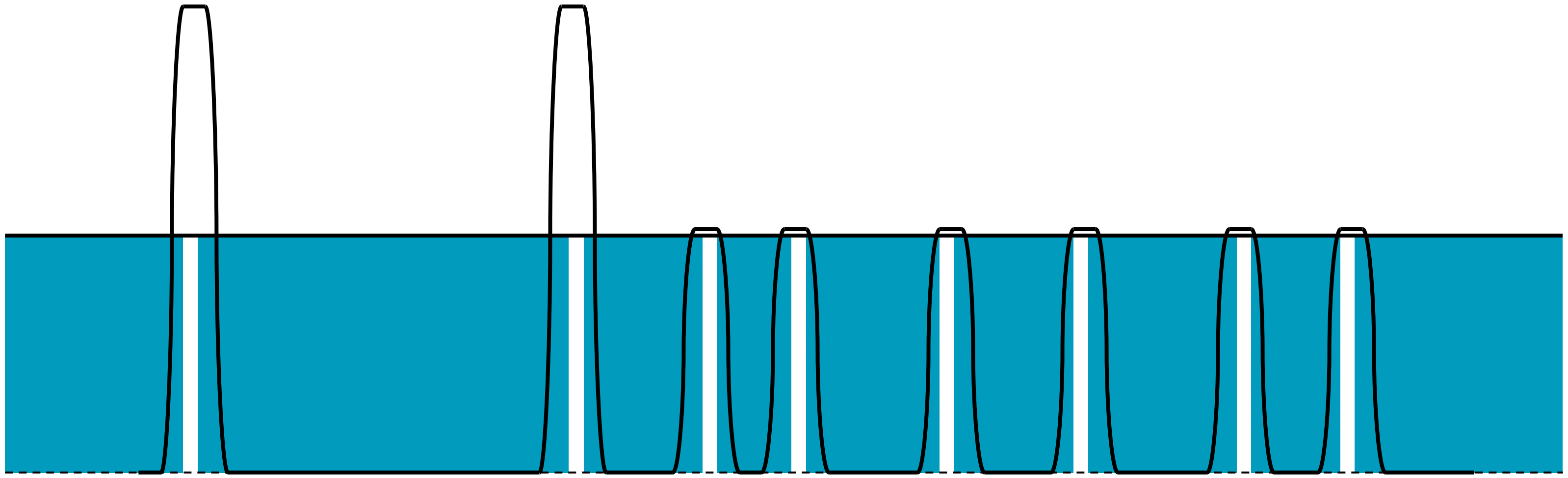

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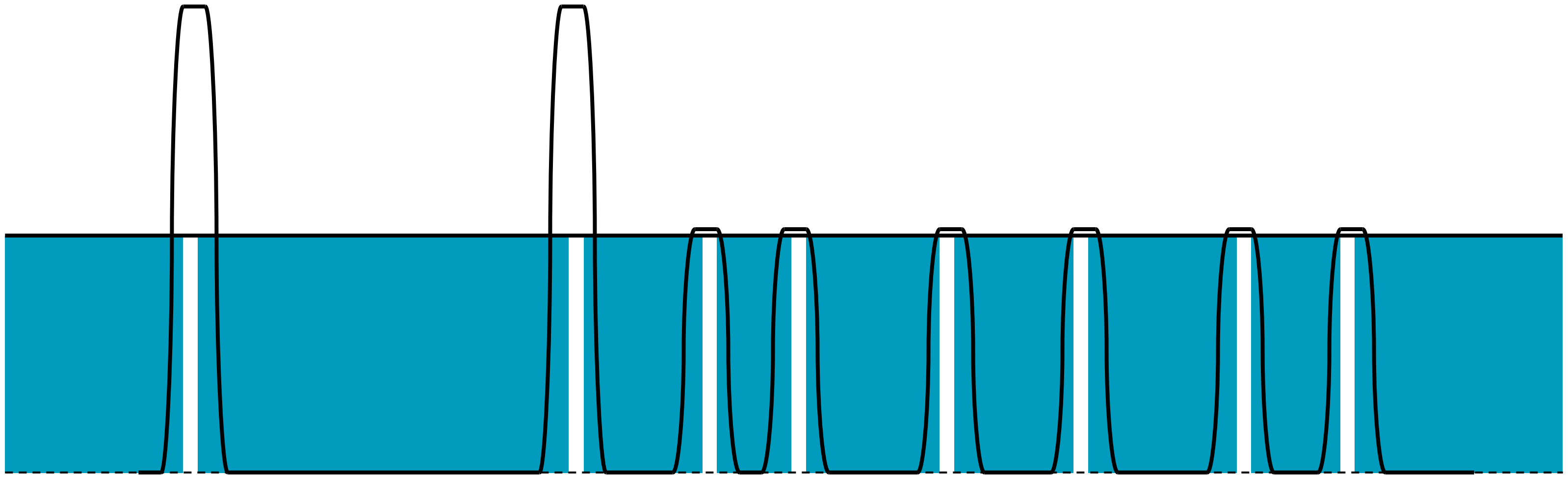

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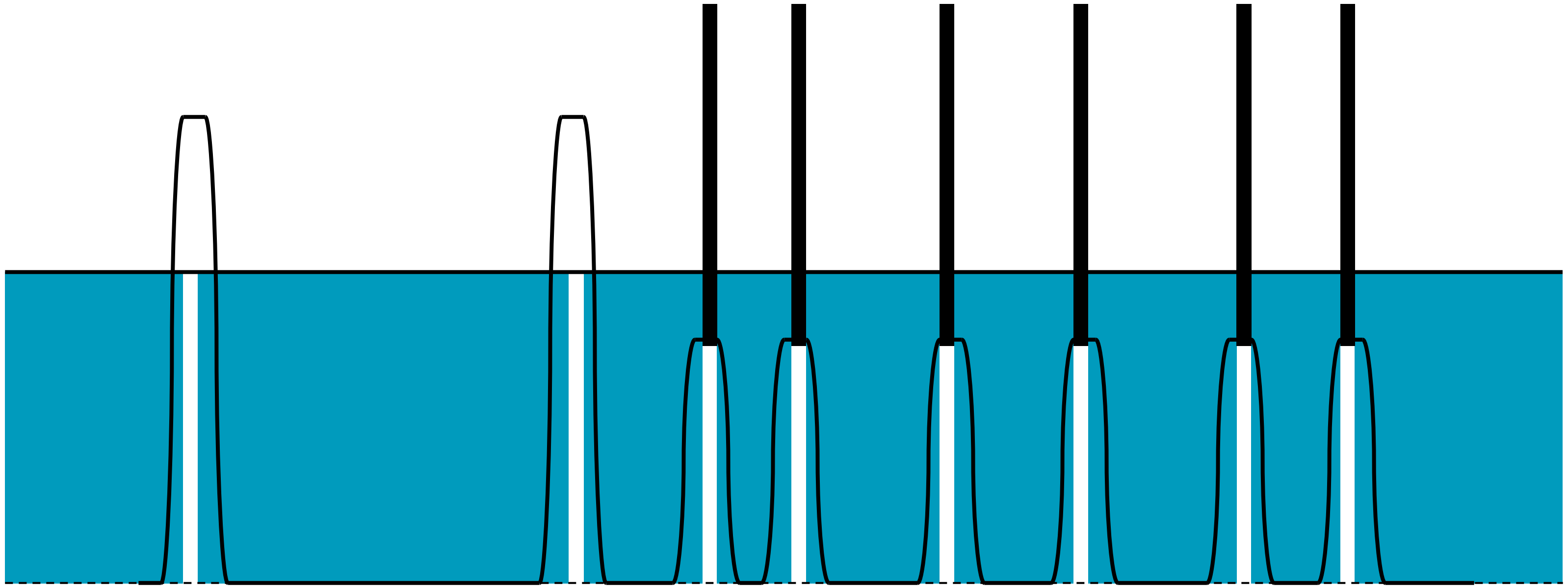

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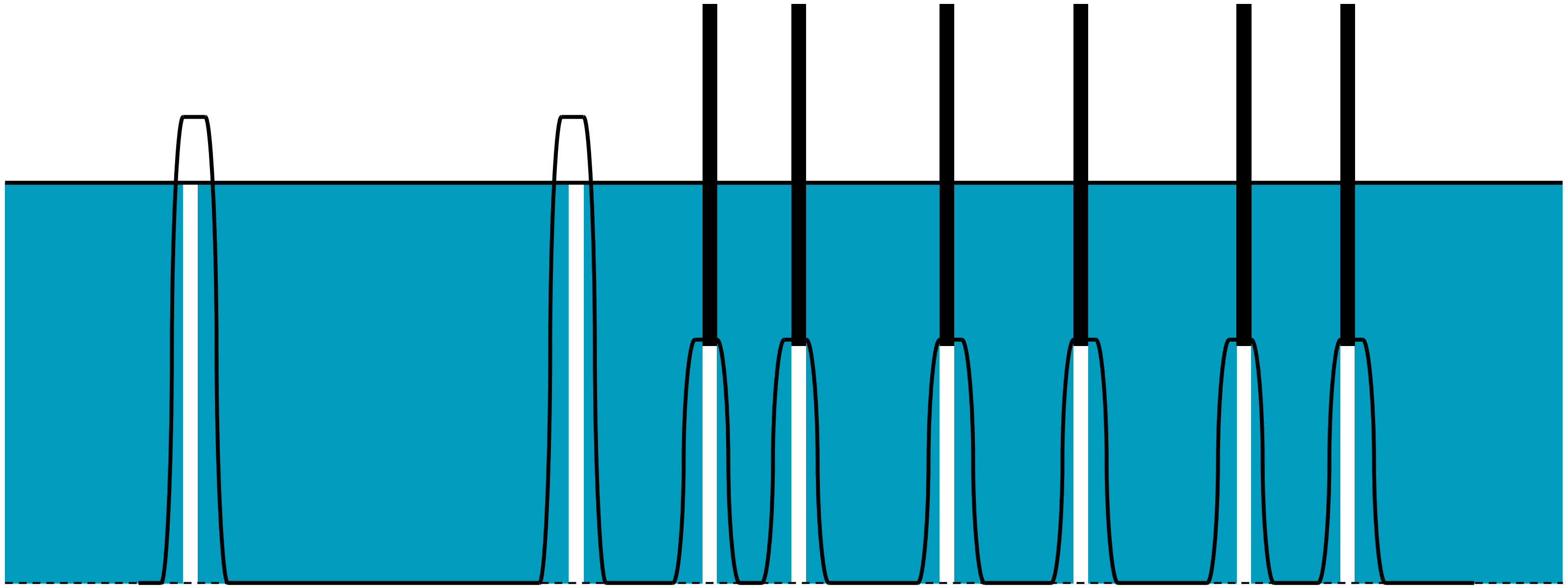

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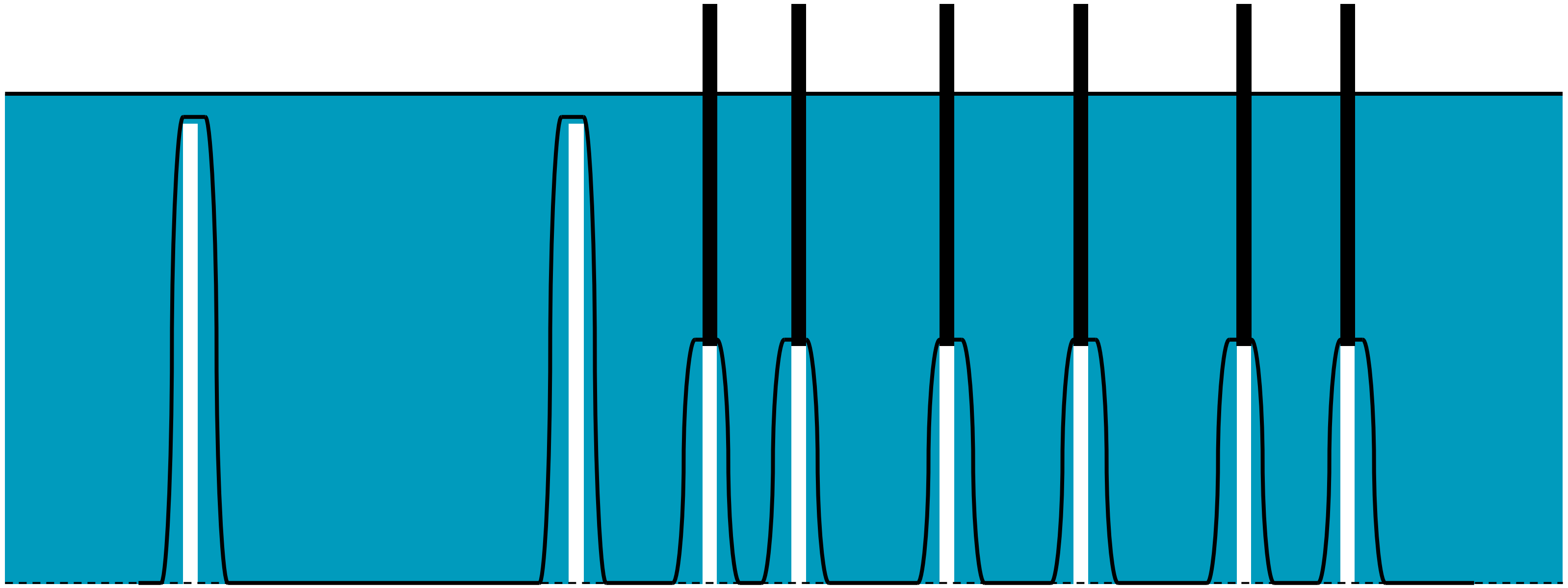

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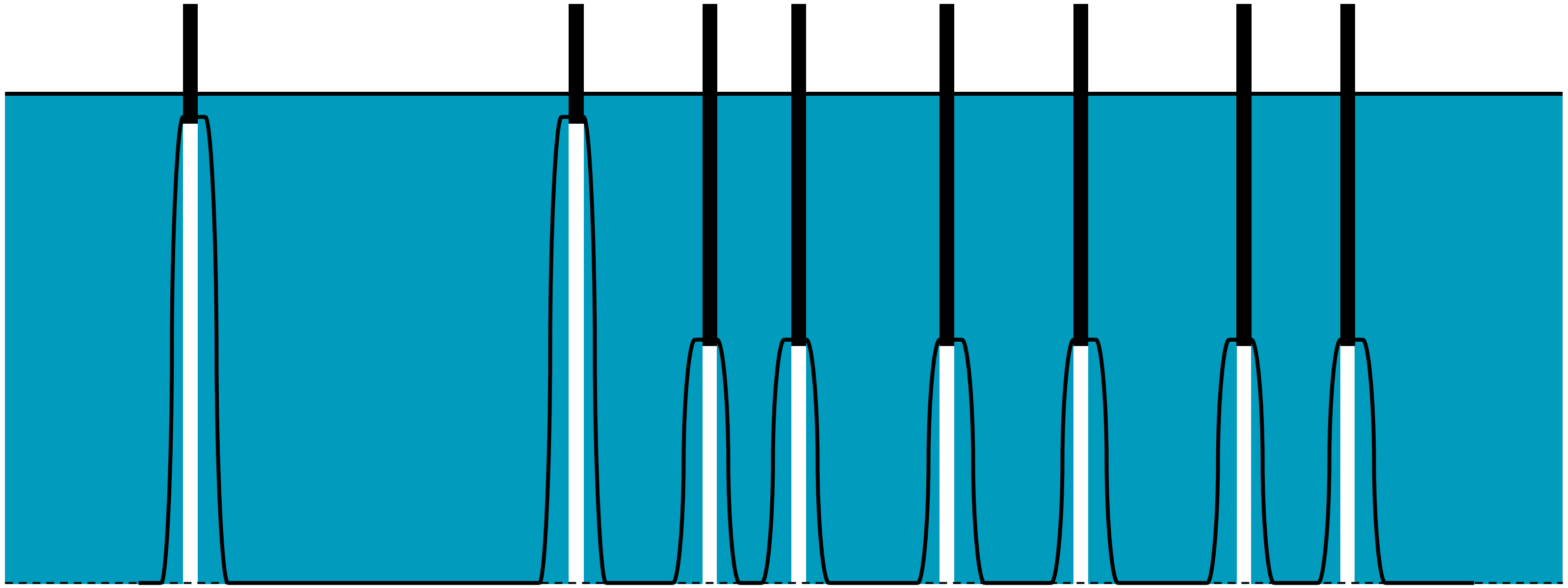

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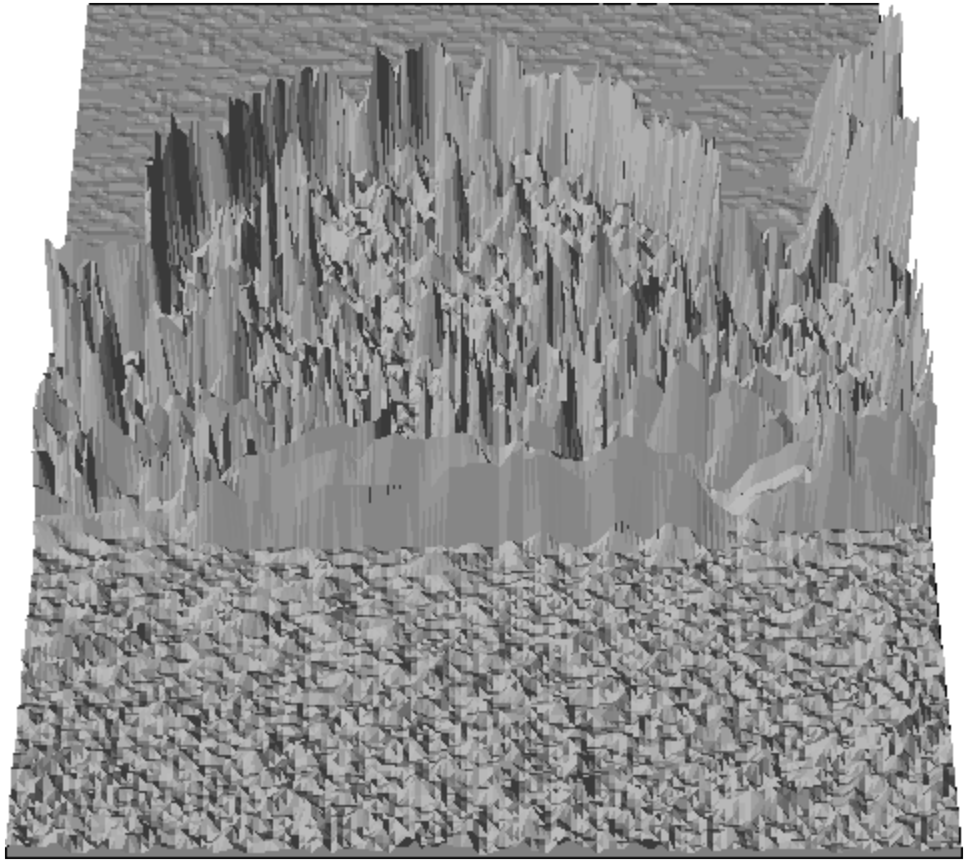
Watersheds in Images



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'

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

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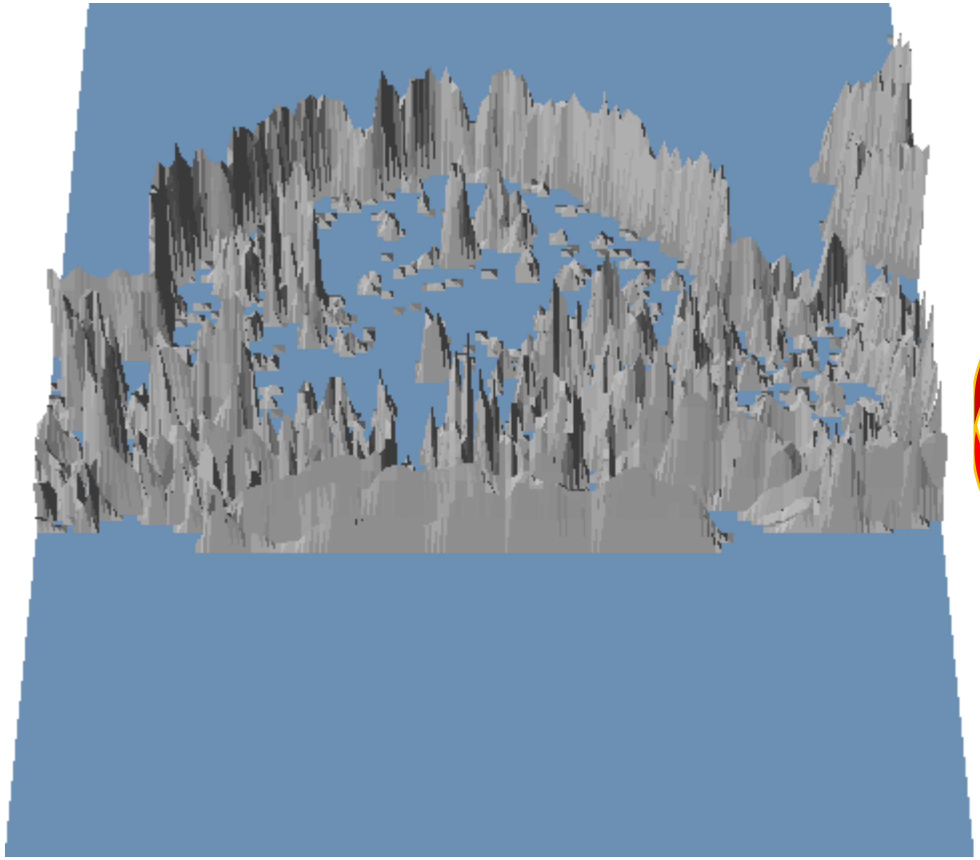
Watersheds in Images



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

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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

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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
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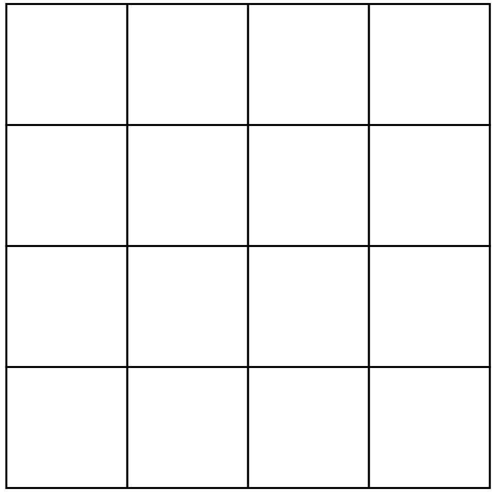
Labels

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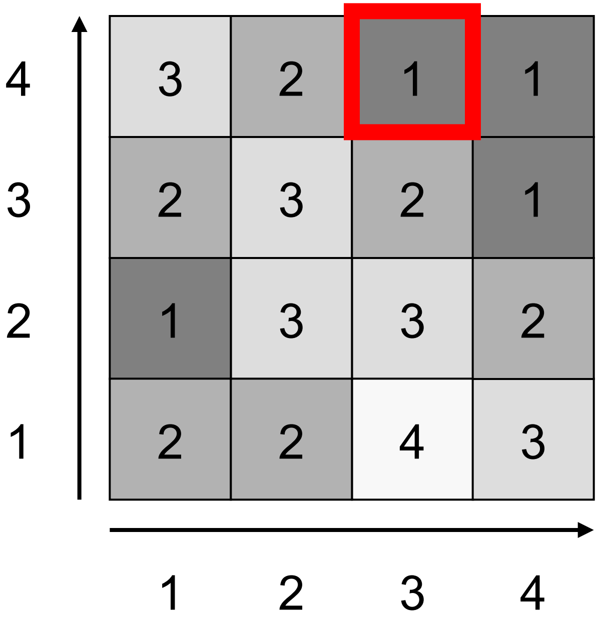

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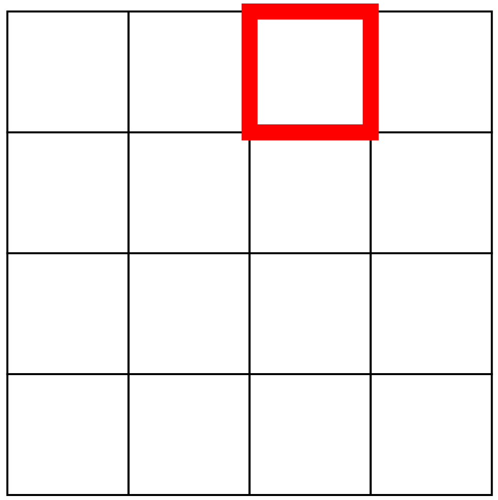

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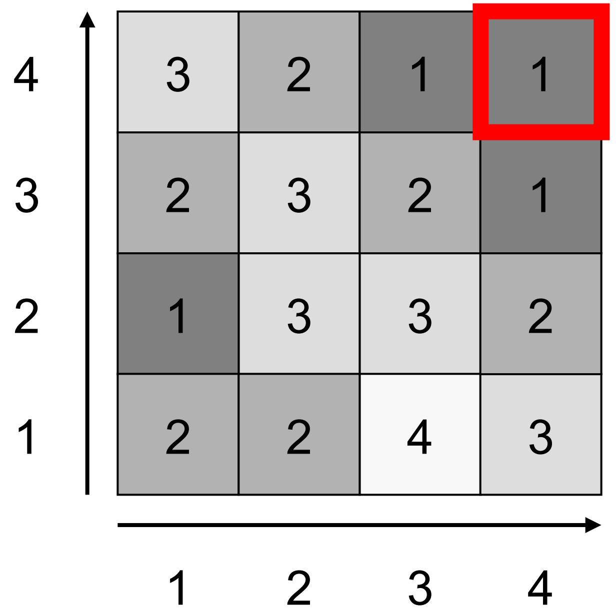

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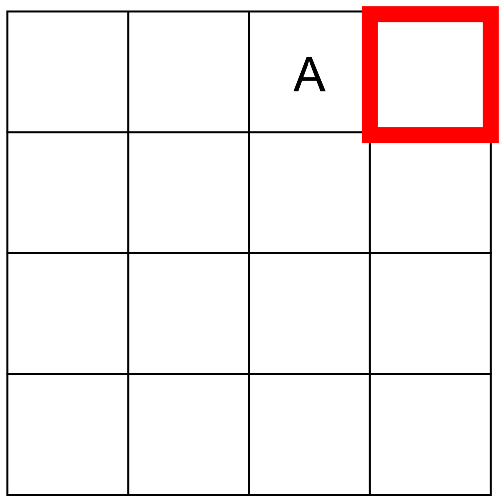

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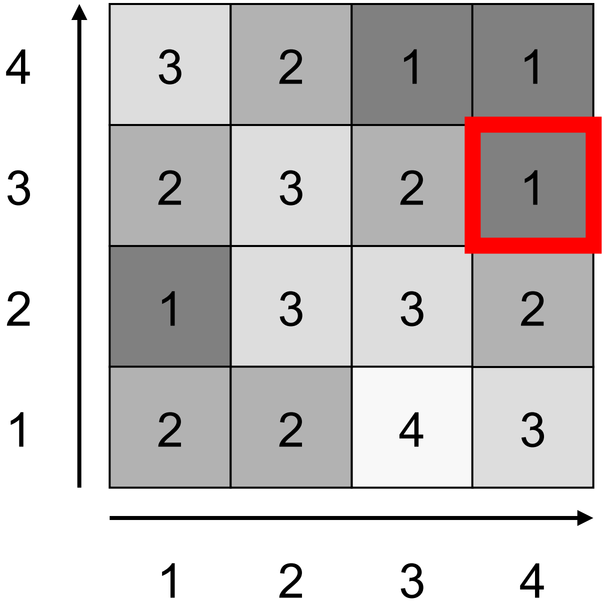

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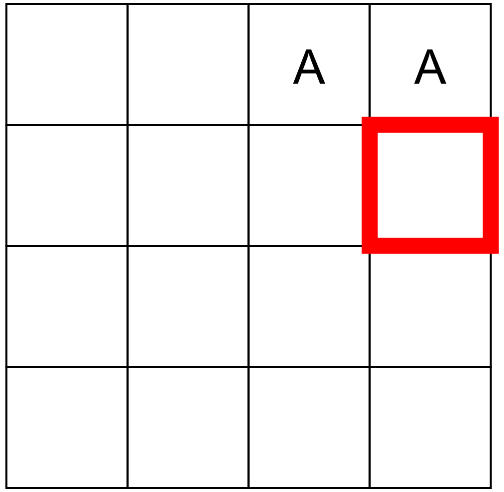

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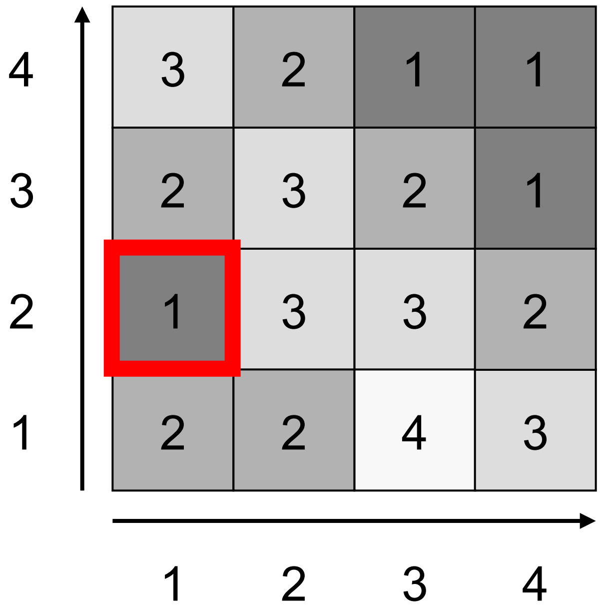

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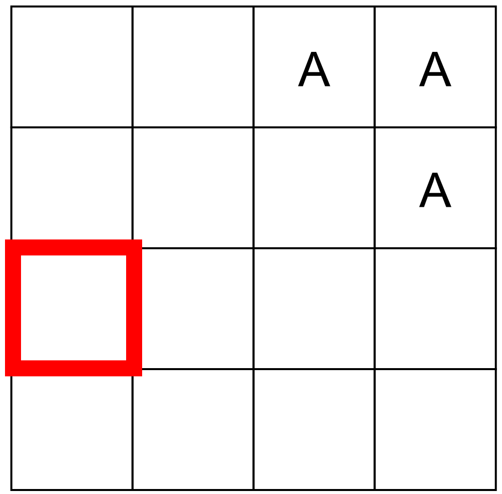

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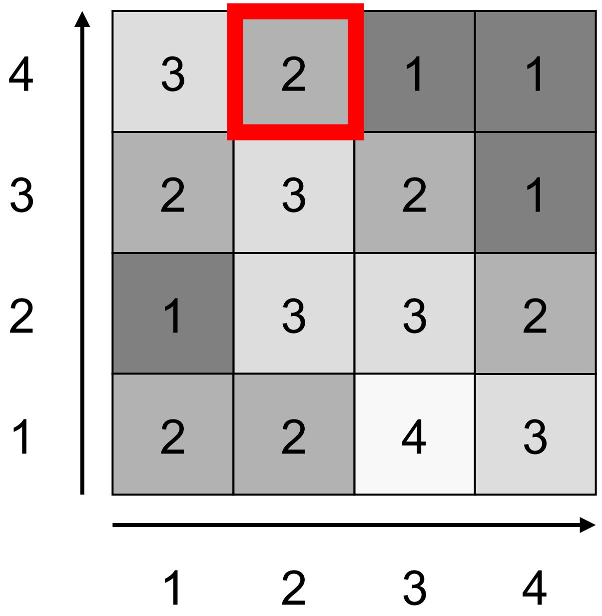

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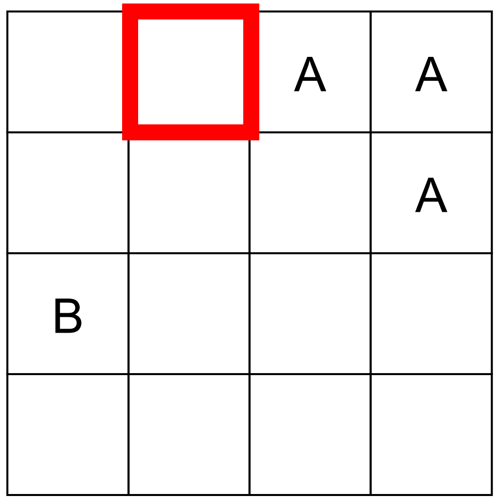

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	A	A	A
			A
B			

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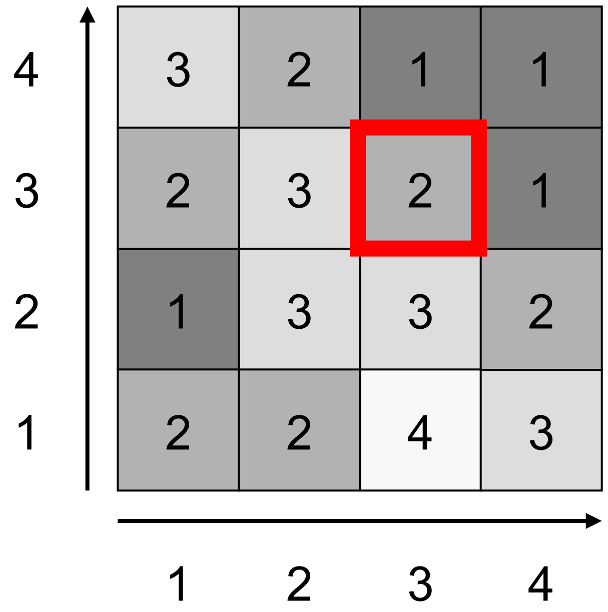
An Example



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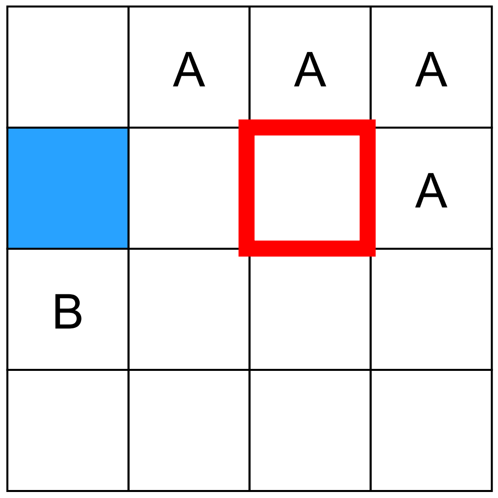

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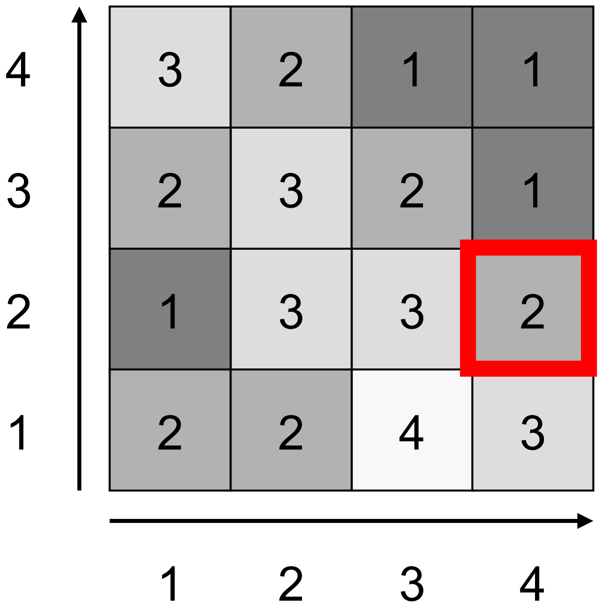

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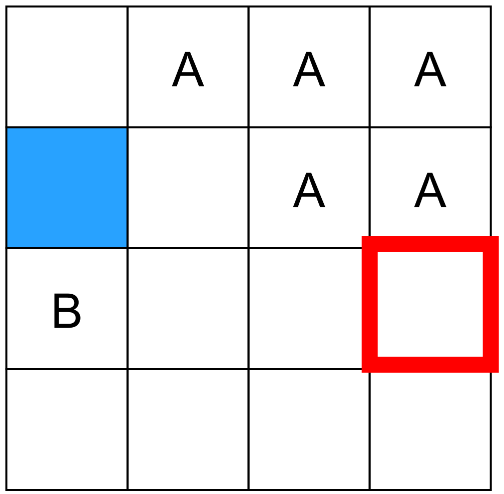

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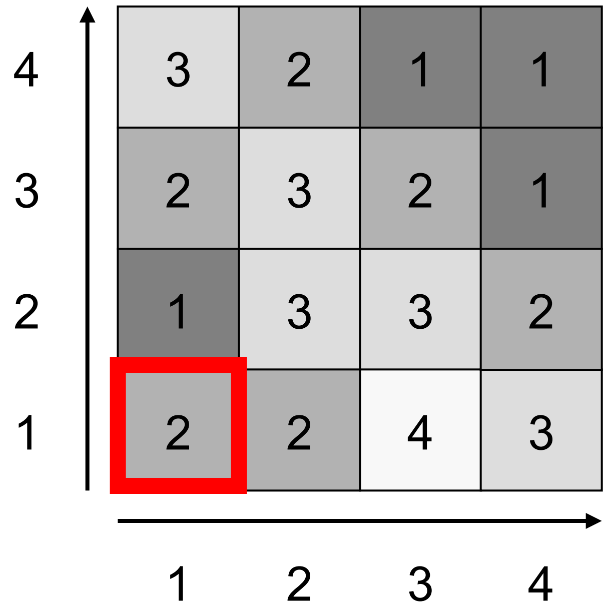

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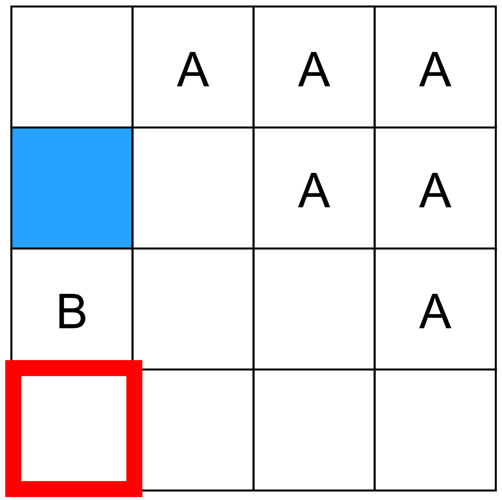

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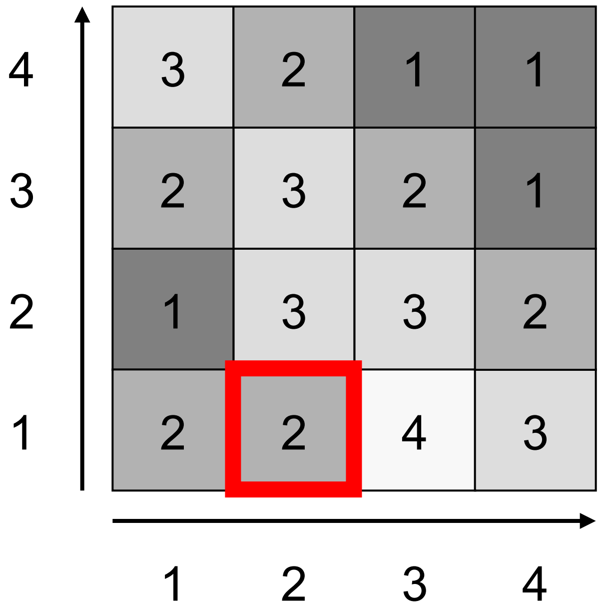

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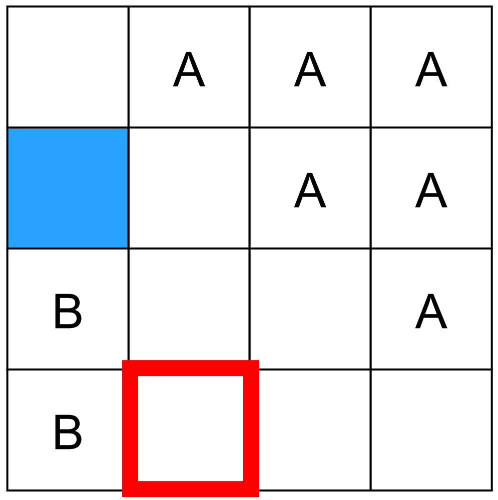

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(3,1) = 4

	A	A	A
		A	A
B			A
B	B		

Labels

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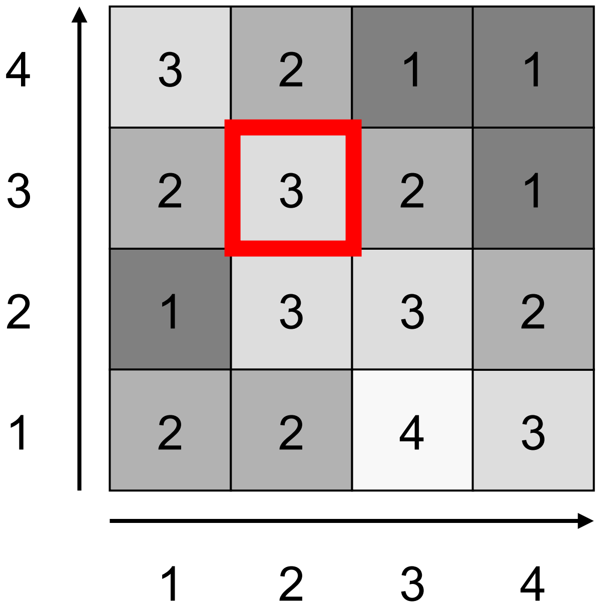
An Example



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
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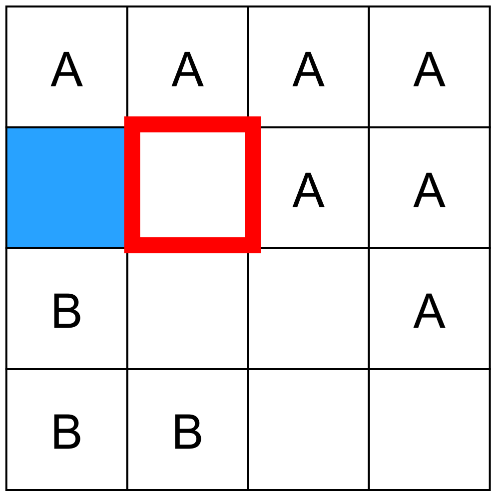
(3,1) = 4



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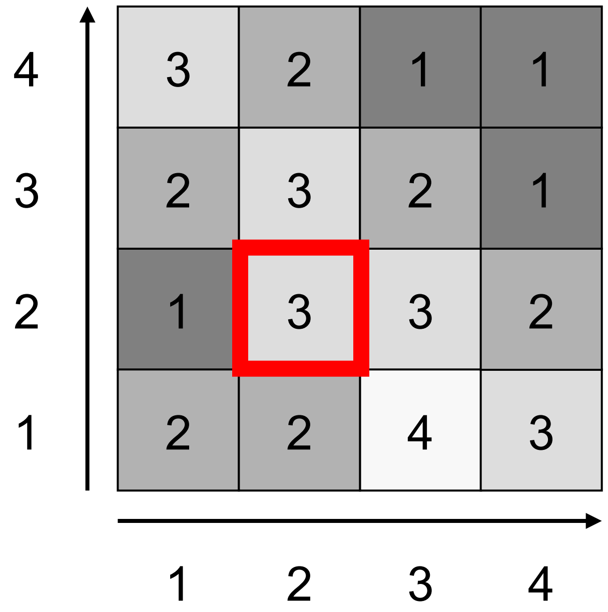
An Example



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(3,4) = 1
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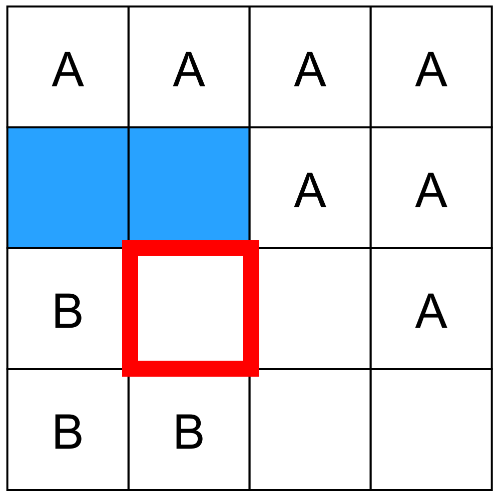

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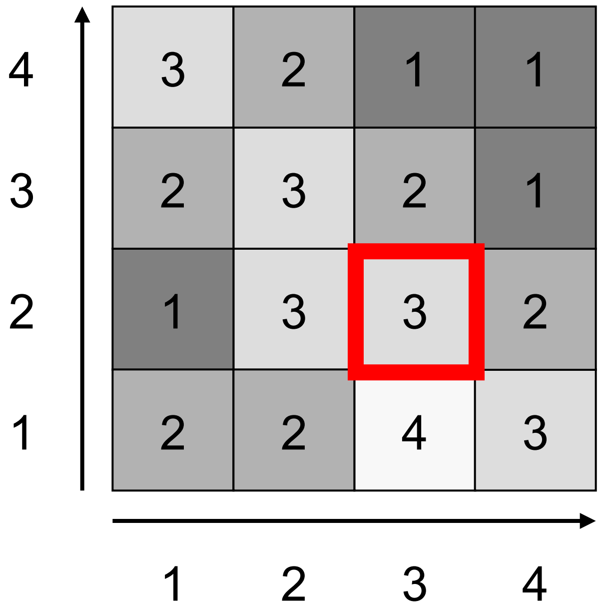
An Example



Sorted list:
(3,4) = 1
(4,4) = 1
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(1,3) = 2
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(1,4) = 3
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(2,2) = 3
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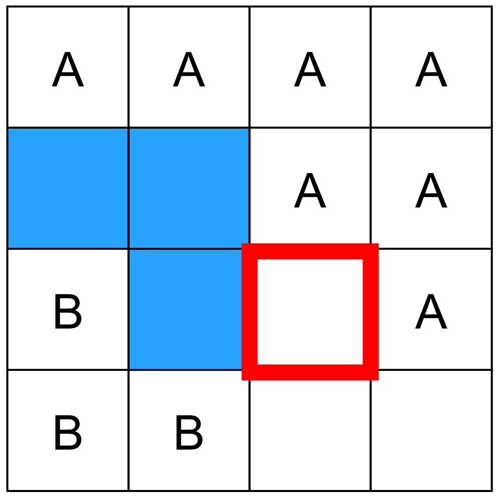
(4,1) = 3
(3,1) = 4



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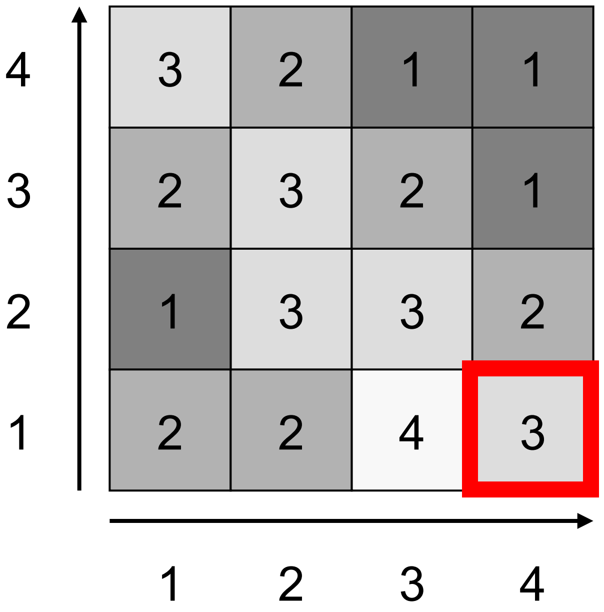
An Example



Sorted list:

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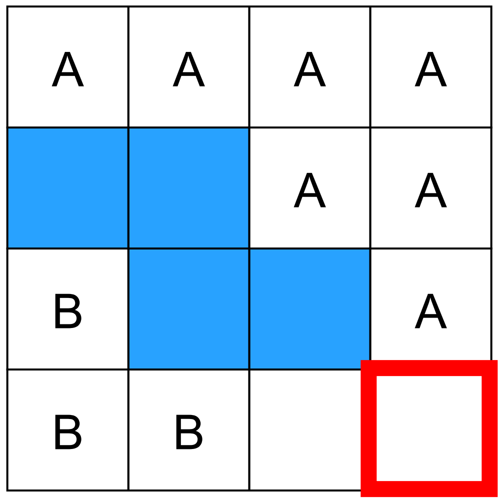
(3,1) = 4



Labels

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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
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(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		A

Labels

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An Example

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

Sorted list:

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

A	A	A	A
		A	A
B			A
B	B		A

Labels

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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?

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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!

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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

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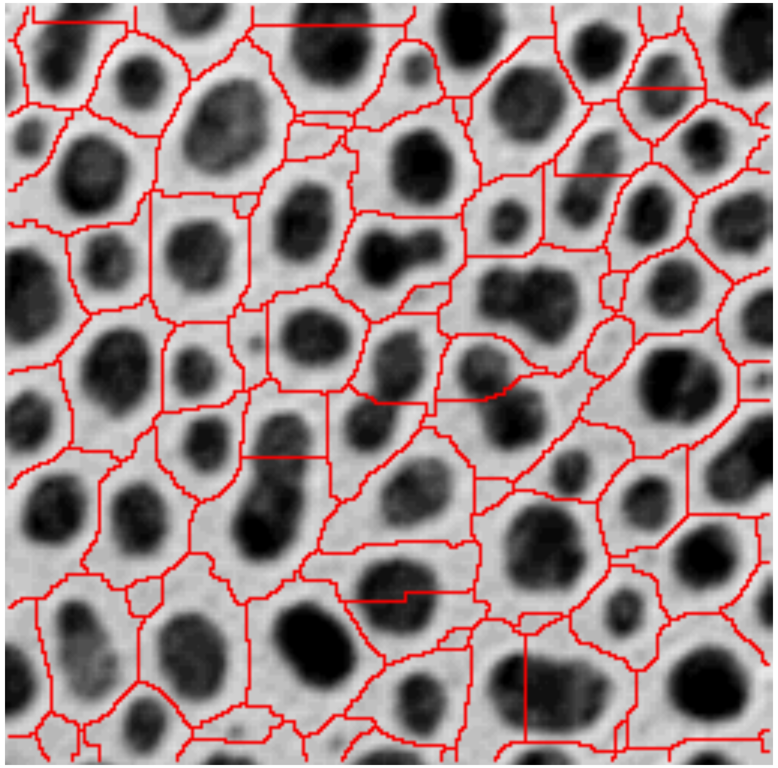
Example - Watershed



- 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

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Segmentation and Superpixels

An Alternative? Superpixels

Segmentation has motivated development of some useful techniques, **BUT**:

- 'segmentation' is poorly defined
- Trying to achieve meaningful, semantically correct results without knowledge of the application domain is optimistic at best
- Segmentation methods really just divide the image into similar regions

So let's accept that and forget the semantics…

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Simple Linear Iterative Clustering

- High-quality, compact, nearly uniform superpixels
- Simple, efficient algorithm based on **K-means**
- Only parameter is number of superpixels required (**K**)

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Simple Linear Iterative Clustering

1 Initialise cluster centres on pixel grid in steps S

- Image has N pixels, you want K superpixels
- Each superpixels is roughly square area of roughly N/K pixels
- Each superpixels is roughly sqrt(N/K) by sqrt(N/K)
- S = sqrt(N/K)

2 Move centres to the position in a 3x3 window with the smallest intensity (or colour) gradient

- Move centres away from edges, onto flattest area available
- Only a small move, these are still initial positions

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Simple Linear Iterative Clustering

3

Compare each pixel to all cluster centres within 2S pixels and assign it to the best matching centre

- Best matching = nearby and similar in colour
- Distance measure is sum of colour distance and image plane distance. ***See the paper on Moodle for details***

4

Recompute the cluster centres as mean colour and position of the pixels belonging to each cluster

5

Repeat 3 and 4 until total change made to position and colour of centres is below a threshold, or for a fixed number of iterations

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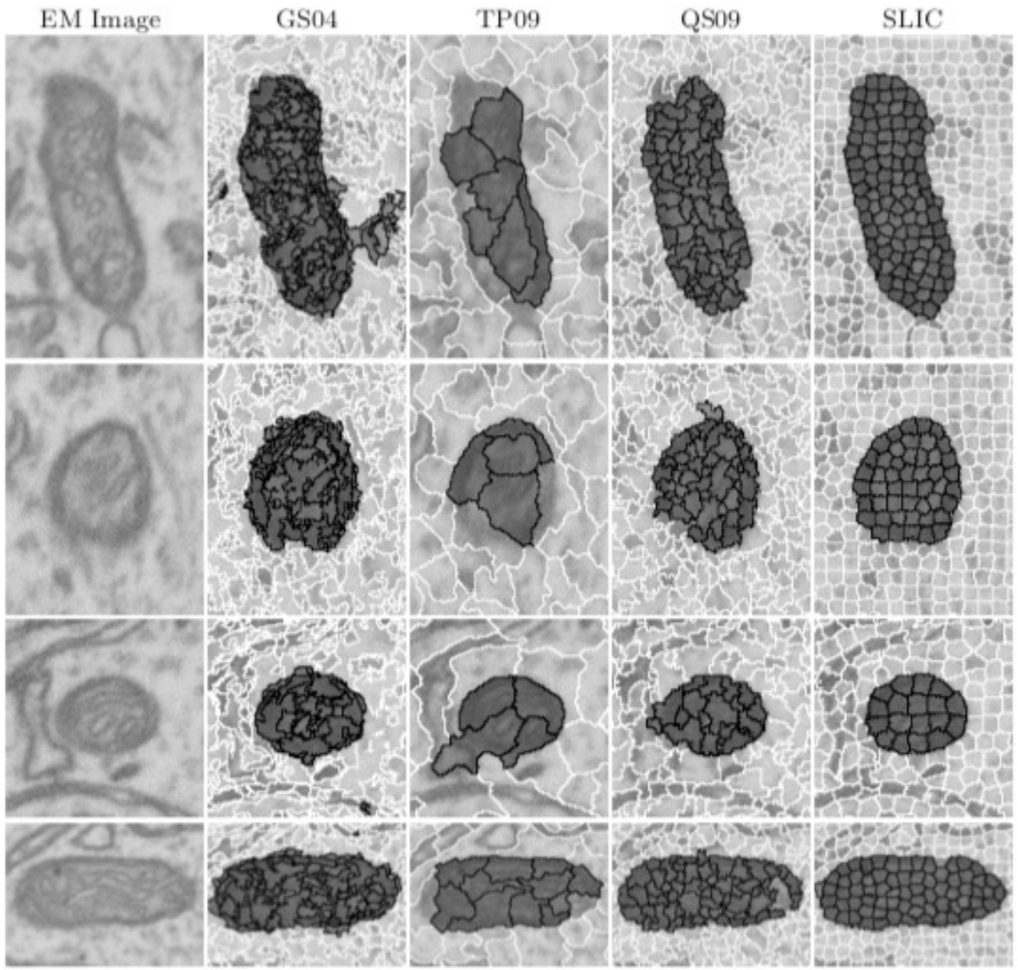
SLIC



Evaluated on

- Similarity of pixels in superpixels vs variation of values between adjacent superpixels
- Proportion of object boundaries marked by a superpixel boundary

- e.g., EM image of brain mitochondria (linked to degenerative diseases)
- Segmentation meets edge detection?

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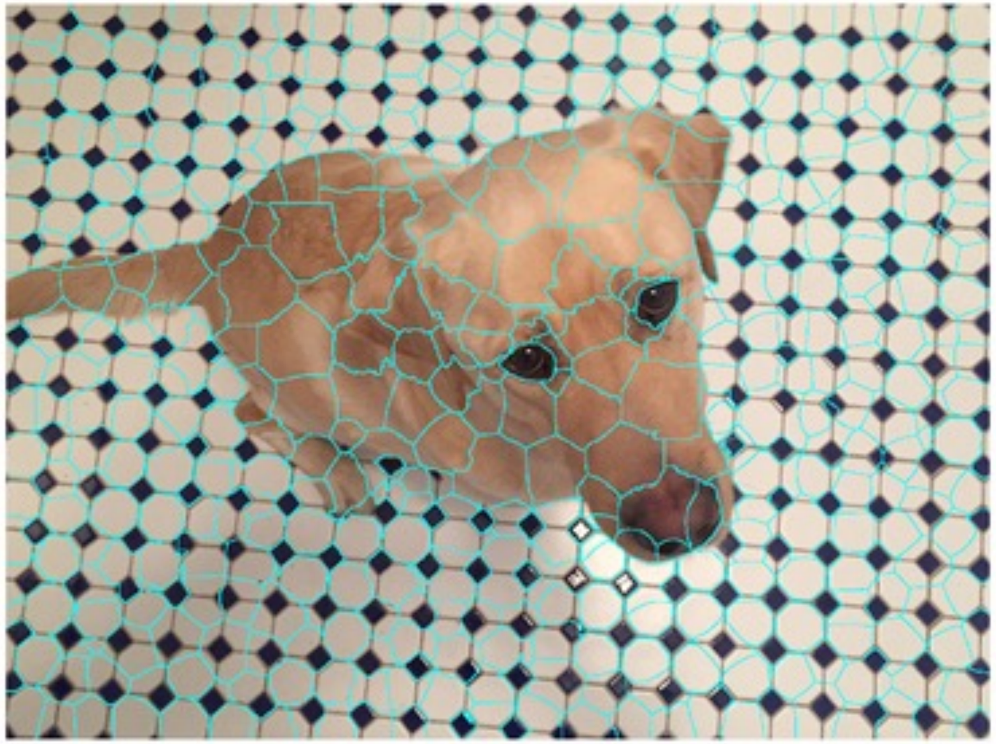
SLIC in MATLAB

```
A = imread('kobi.png');
[L,N] = superpixels(A,500);
    // L is a label image
    // N number of superpixels actually produced
figure
BW = boundarymask(L);
    // marks transitions from one label to another
imshow(imoverlay (A,BW,'cyan'), 'InitialMagnification',67);
    //overlays boundary mask on original image in cyan
```



https://www.mathworks.com/help/images/ref/superpixels.html

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Summary

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

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Questions

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NEXT:

Hough Transform & Frequency Domain