Digital image processing and analysis

9. Segmentation

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Previous lecture:

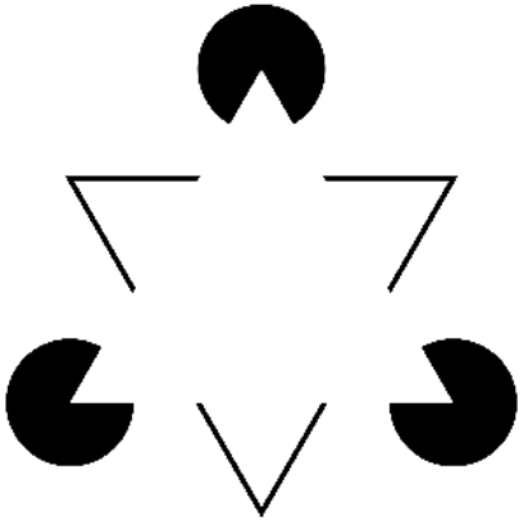
- Edge detection filters
  - Their types
  - How and why they work
  - How they can be combined
  - Where they can be found in the brain
- Median, min and max filters
- Edge preserving smoothing

In this lecture we shall find out about:

- What is image segmentation
- Principles of the region-based segmentation
- Global methods: pixel classification
  - Thresholding
  - Multi-object classification
  - Feature spaces
- Local methods
  - Bottom up: region growing
  - Top down: image partitioning

Edge detection in the brain
Visual illusions

Previous lecture



Hypothesis:
Orientation-sensitive cells in the visual cortex generate perception of the edges that would be expected in the real 3-dimensional world.

Low-level grouping mechanisms for contour completion

Alison G. Todman *, Ela Claridge

Examples of filters

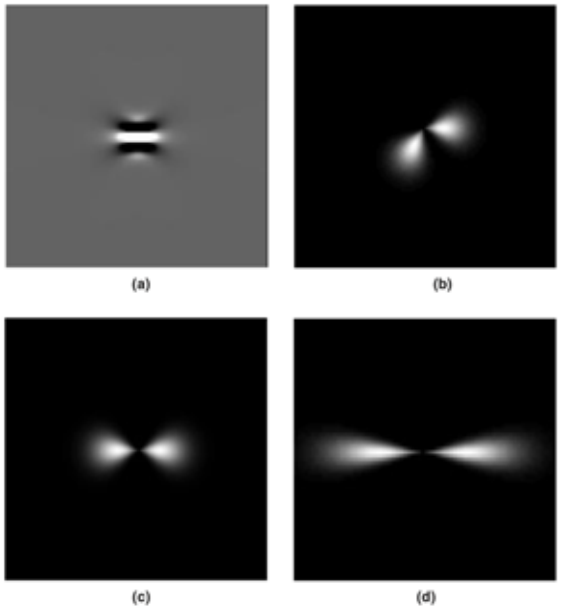
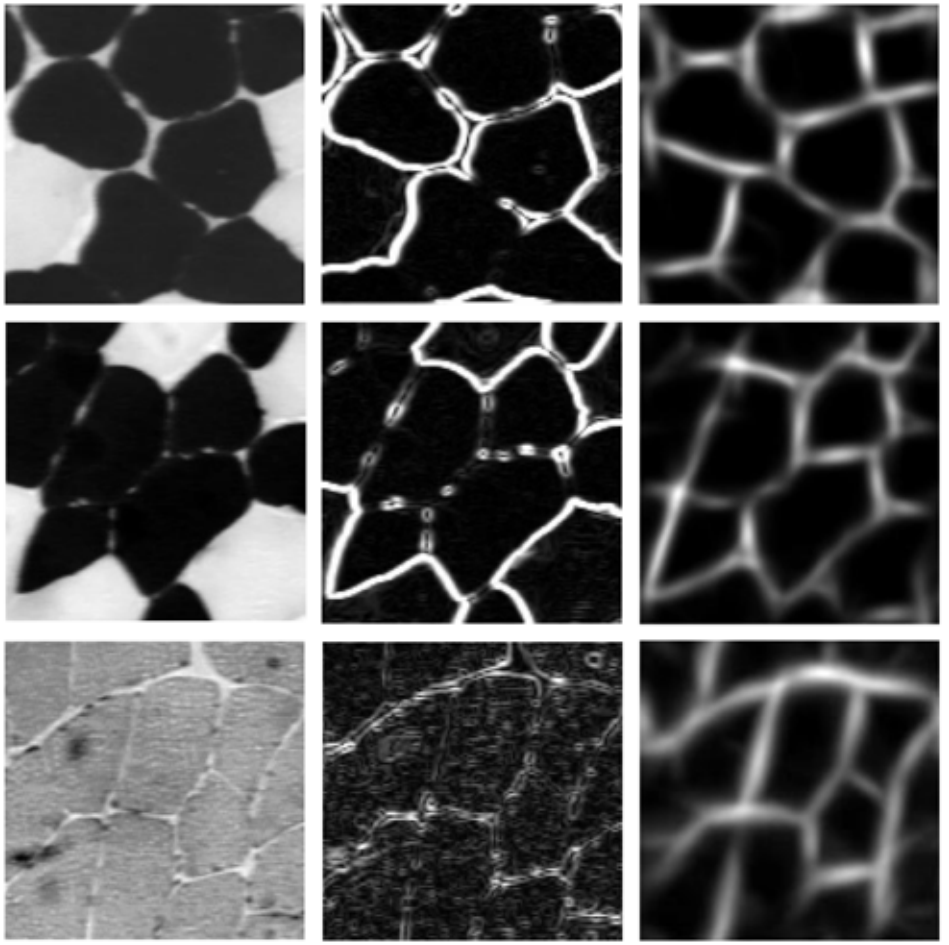


Image | Standard edge detection filter | Edge completion method

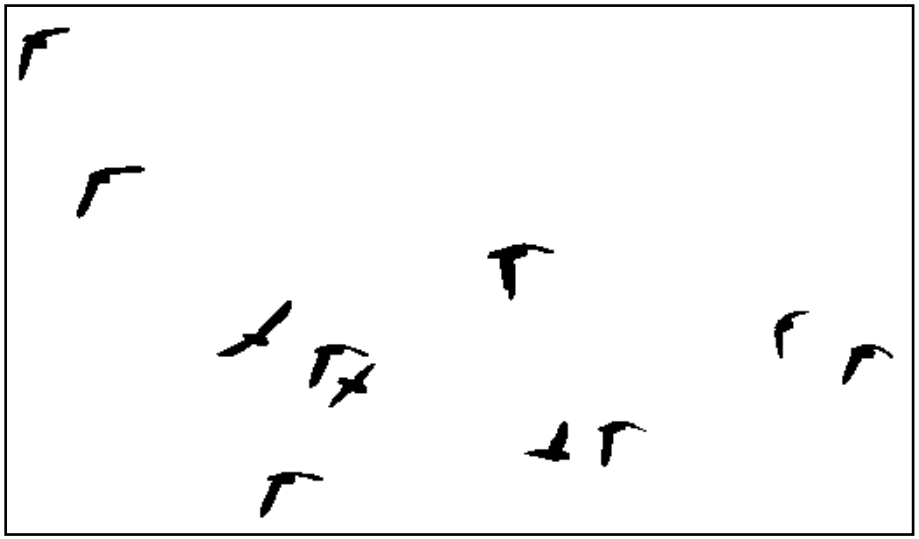


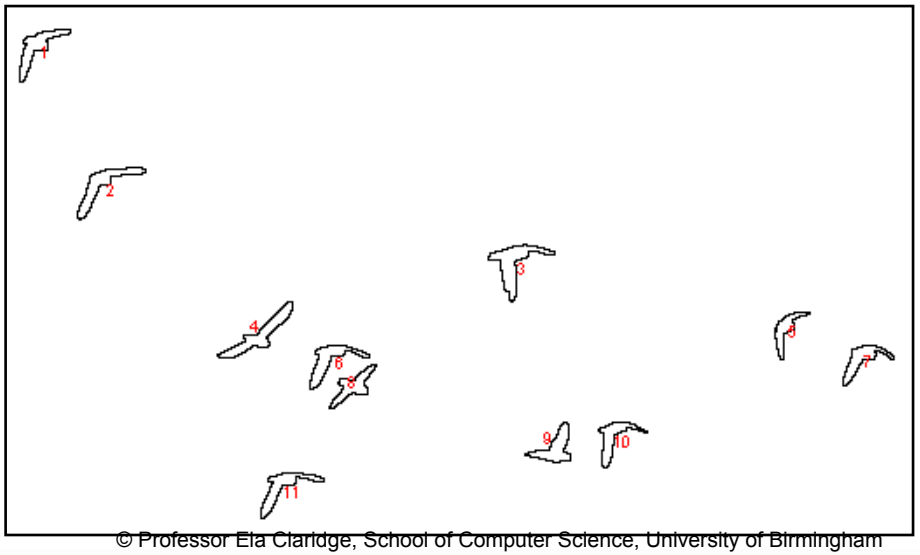
What is segmentation?

- Human vision tends to organise the observed scene into *meaningful units* as a significant step towards image understanding. Further processing is necessary to *group* edge elements or groups of pixels into structures suited to *interpretation.*
-
- *"The goal of segmentation is to partition an image into disjoined regions which correspond to objects or their parts."*

(T. Pavlidis)

What is segmentation?

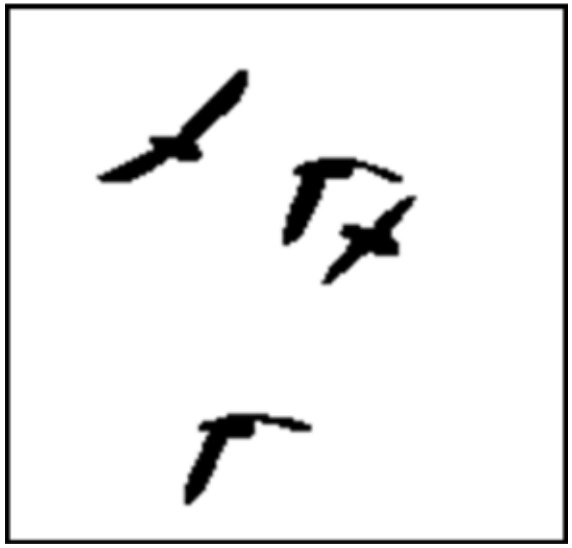




Two main approaches

- Through extracting boundaries of regions
  - Based on discontinuities (e.g. in grey levels or statistical properties)
- Through extracting regions
  - Based on similarities
-
- The two approaches are equivalent - one representation can be converted into the other.

Two main approaches



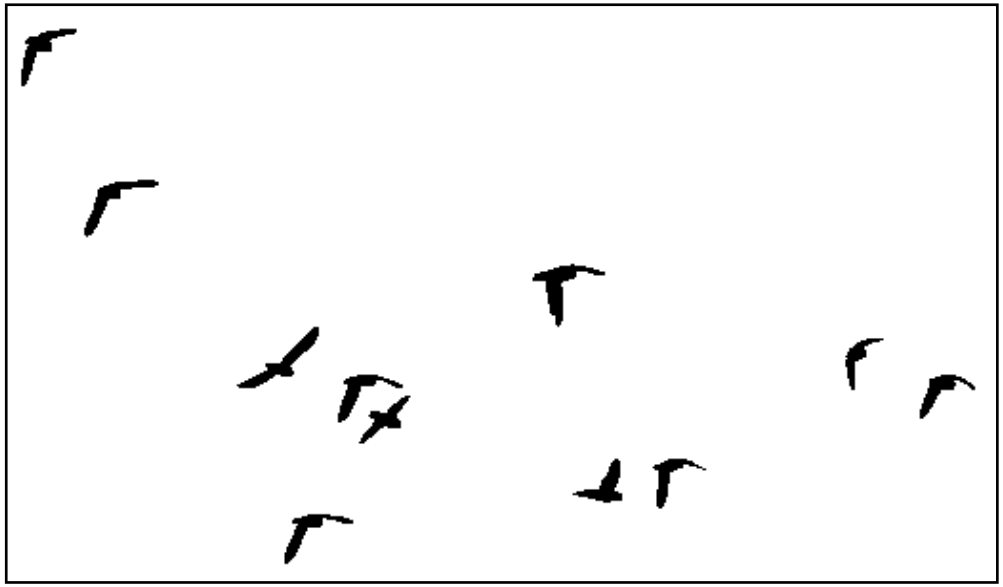
Similarity of pixel values

Dis-similarity of pixel values

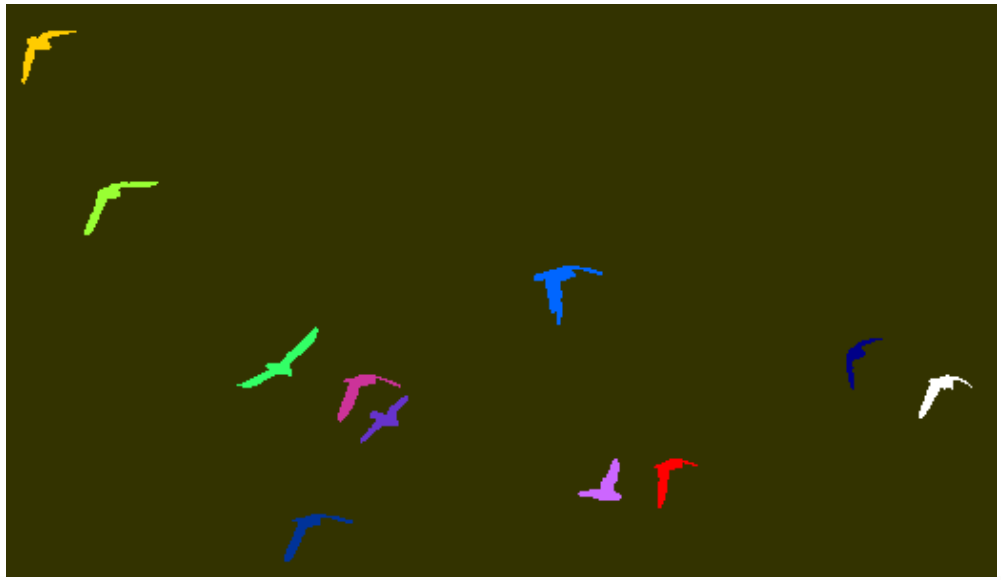
Representations for segmented image

- Input to segmentation is an image
- Output of the segmentation can have several forms:
  - An *image* where a pixel value indicates whether the pixel belongs to edge/region or to the background (a binary image).
  - An *image* where a pixel value is a region ***label***
    - e.g. if there are five different regions in the image, there will be five different labels; all pixels belonging to the same region will have the same value in the label image
  - A *data structure* which describes the results of segmentation, for example a list of coordinates of the outline of a region.

Representations for segmented image



Binary image:
pixel value = 0 for the background
pixel value = 1 for (any) object

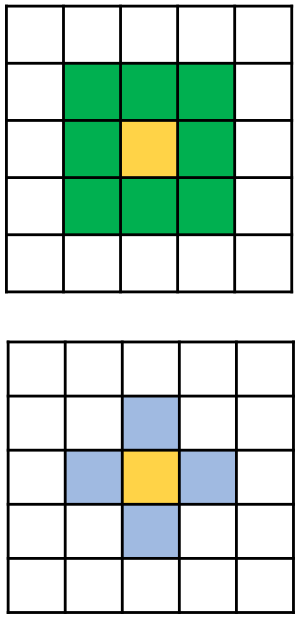


Label image:
pixel value = 0 for the background
pixel value = object number
(each colour represents different number)

Region based segmentation
Formal definition

- The partitioning of an image into set of mutually non-overlapping regions, each of which is maximum connected uniform region.
  - ***Connected region*** - each element of the region is adjacent to at least one other element of this region.
  - ***Uniform region*** - every subset of that region is uniform according to the same criterion
  - ***Maximum connected uniform region*** - no other pixel, adjacent to the region, can be added to it without the region becoming non – uniform.
  - ***Uniformity*** - homogeneity (of the same kind; consisting of parts of the same kind; uniform); e.g. constant grey level

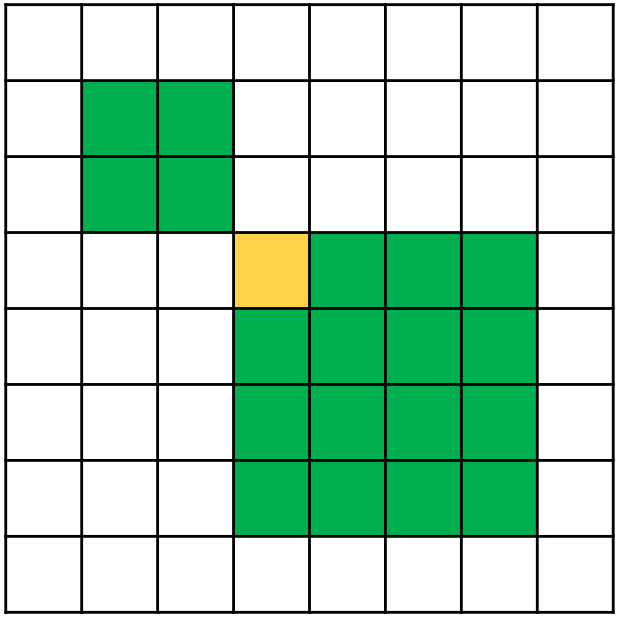
Region based segmentation
4- and 8-connectivity



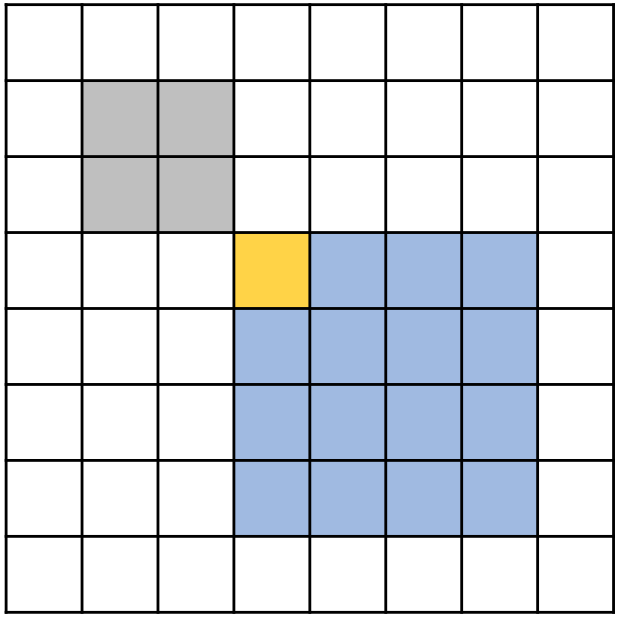
Current pixel

8-connected pixels

4-connected pixels

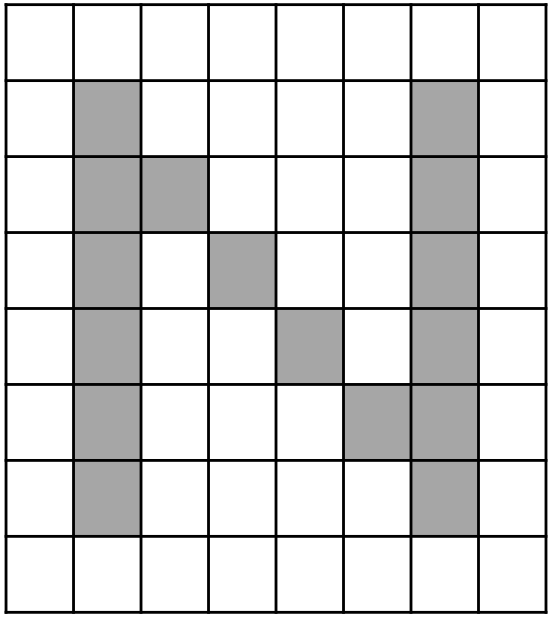


8-connected pixels:
All the pixels belong to the same region as the current pixel.

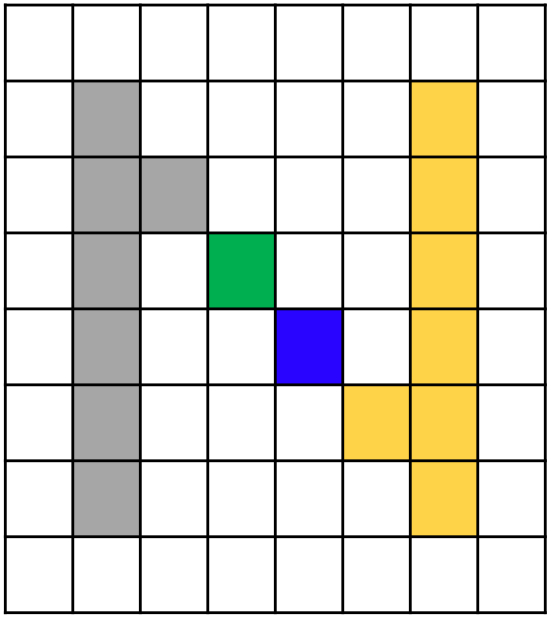


4-connected pixels:
Only pixels highlighted blue belong to the same region as the current pixel.

Region based segmentation
4- and 8-connectivity



8-connected pixels:
One region is detected.



4-connected pixels:
Four regions are detected.

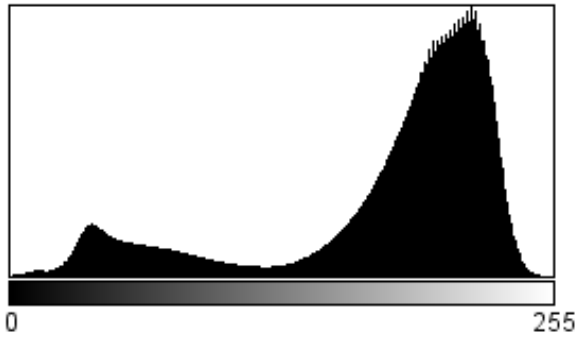
Region based segmentation methods

- Global - pixels are grouped into regions on the basis of the properties of a large population of pixels (image statistics).

- Local - pixels are assigned to regions on the basis of their close neighbours properties.

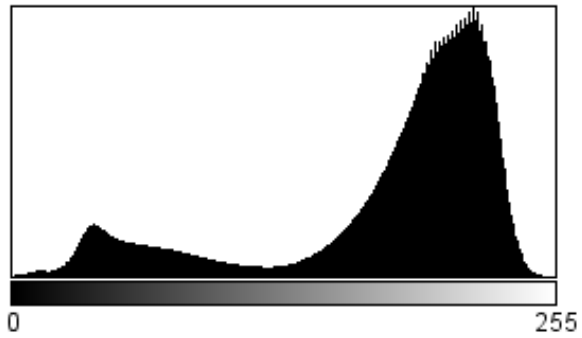
Global methods
Pixel classification

- Region segmentation can be regarded as process of pixel classification.
- The picture is segmented into subsets by assigning the individual pixels to classes.
- The choice of the class depends on the global properties (statistics) of the image, e.g. image histogram.

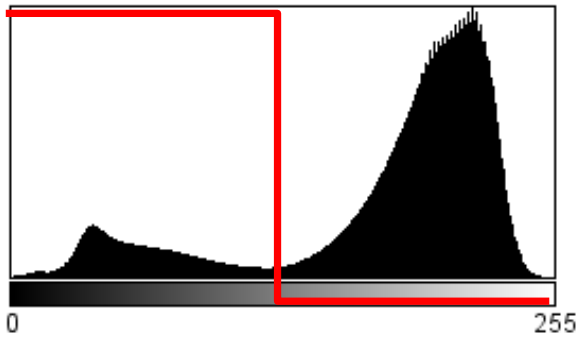


Global methods
Pixel classification: thresholding

- **Thresholding** uses a single property and assigns pixels into one of the two classes.
- The classes are typically object(s) and a background
- The property is typically a grey level value.

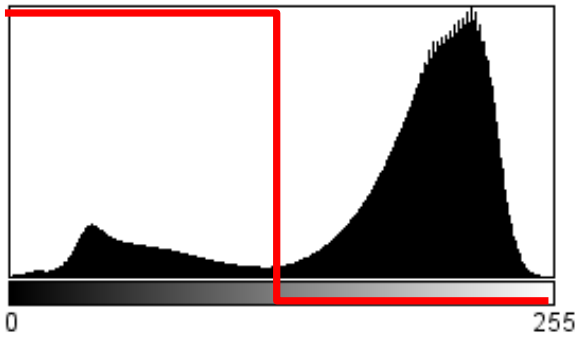


Global methods
Pixel classification: thresholding

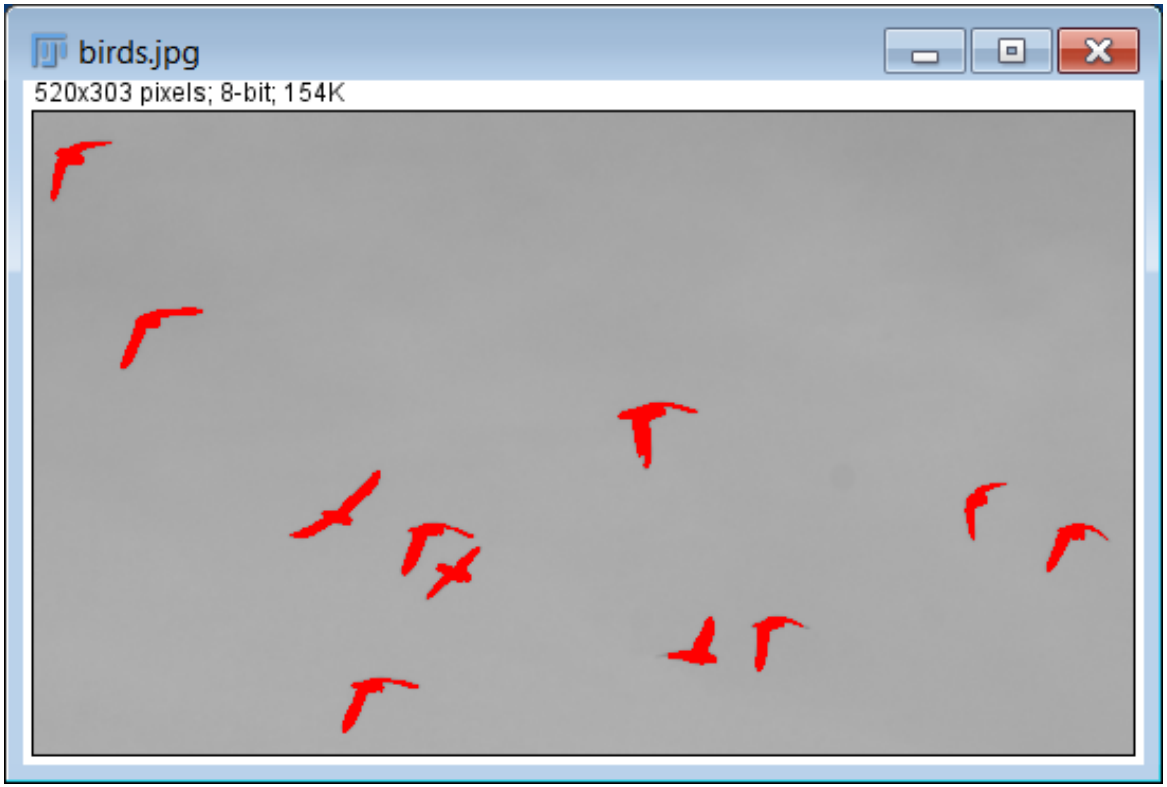


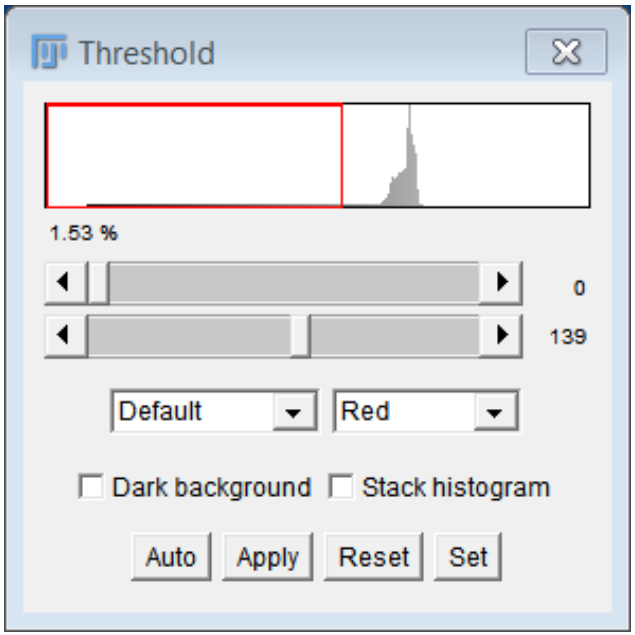
Global methods
Pixel classification: thresholding

- The main problem is to find a threshold value which would separate the two classes.
- The simplest solution:- build a histogram and find the valley between two peaks (why? – see Exercise 9).
- There exist methods for automatic threshold selection (see "Further reading and exploration").



Global methods
Pixel classification: thresholding





Global methods
Pixel classification: thresholding

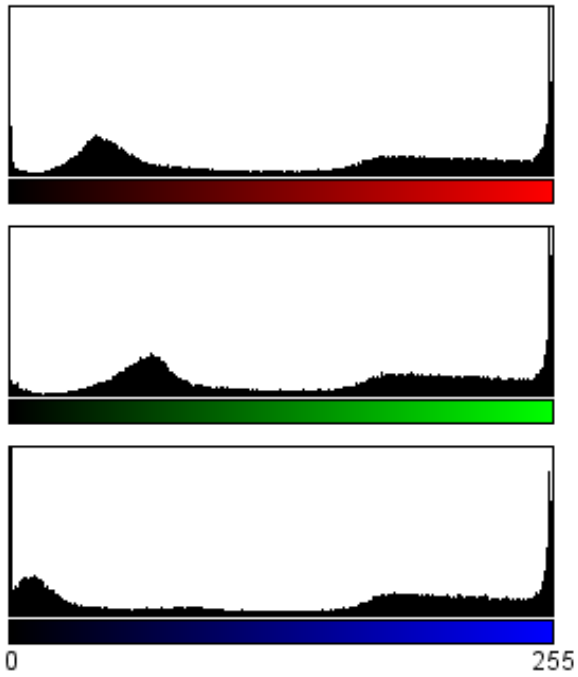
- Thresholding uses a single property and assigns pixels into one of the two classes.
- The classes are typically object(s) and a background
- The property is typically a grey level value.

How is image segmentation computed for bright objects on a dark background?

```
Decide on a threshold value T
Create a new empty image I'
For every pixel in the original image I
        if I(x,y) > T
                set I'(x,y) to 1
        otherwise
                set I'(x,y) to 0
```

Beyond simple thresholding
Single property, several classes

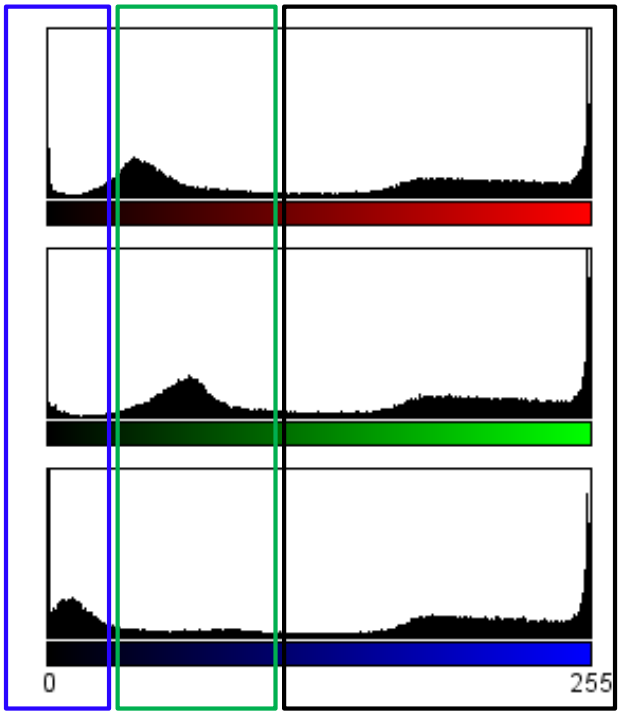
- Multi-level thresholding is segmentation into more than two classes.



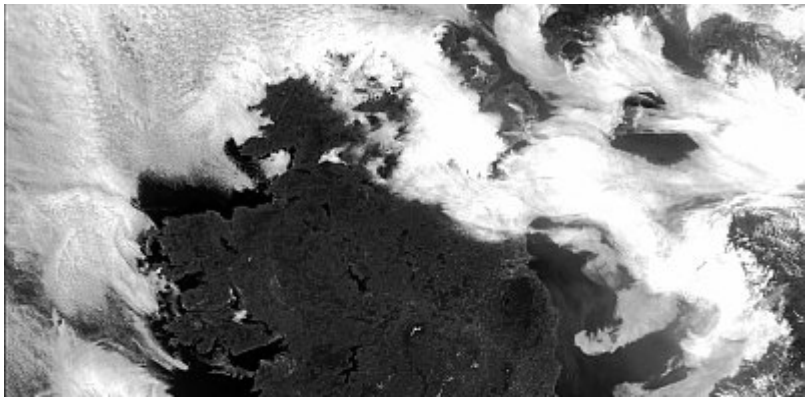
Colour histograms

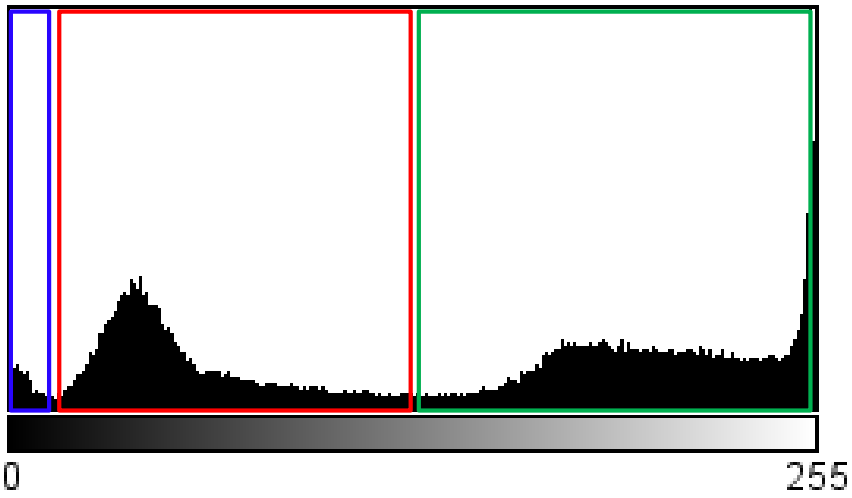
Beyond simple thresholding
Single property, several classes

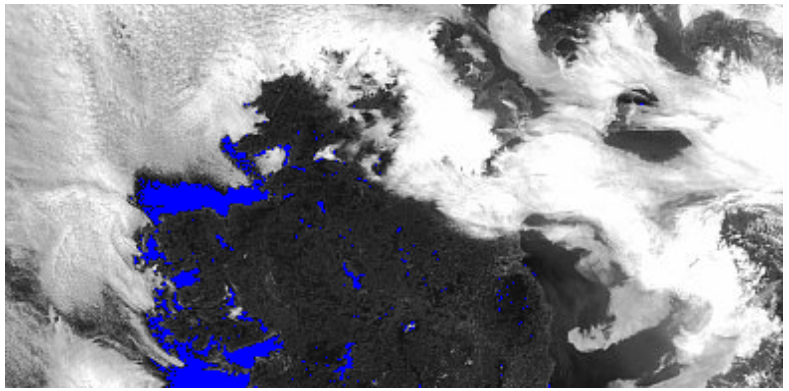
- Multi-level thresholding is segmentation into more than two classes.

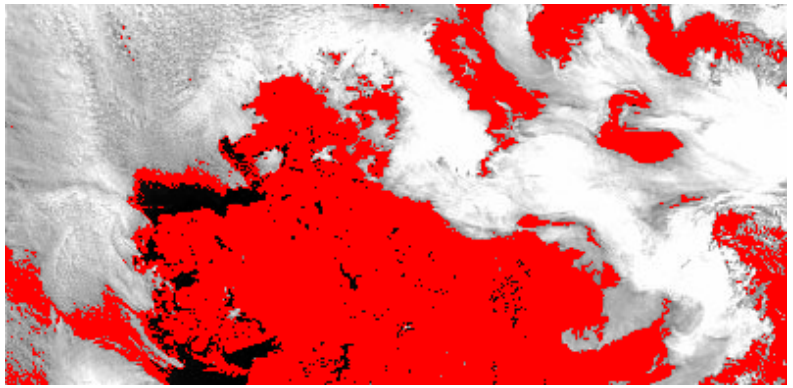


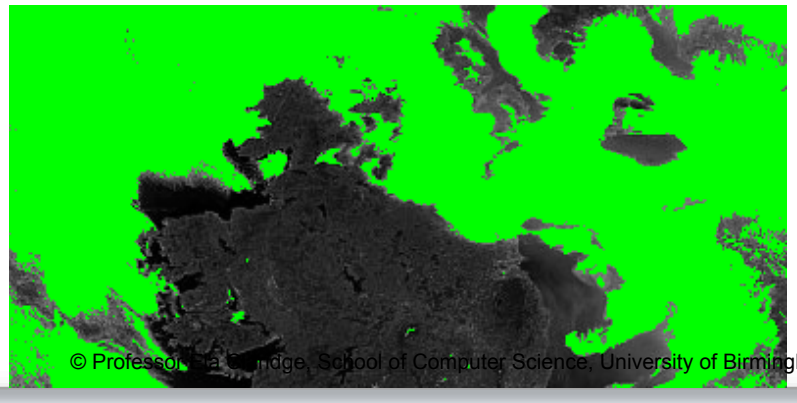
Beyond simple thresholding
Single property, several classes







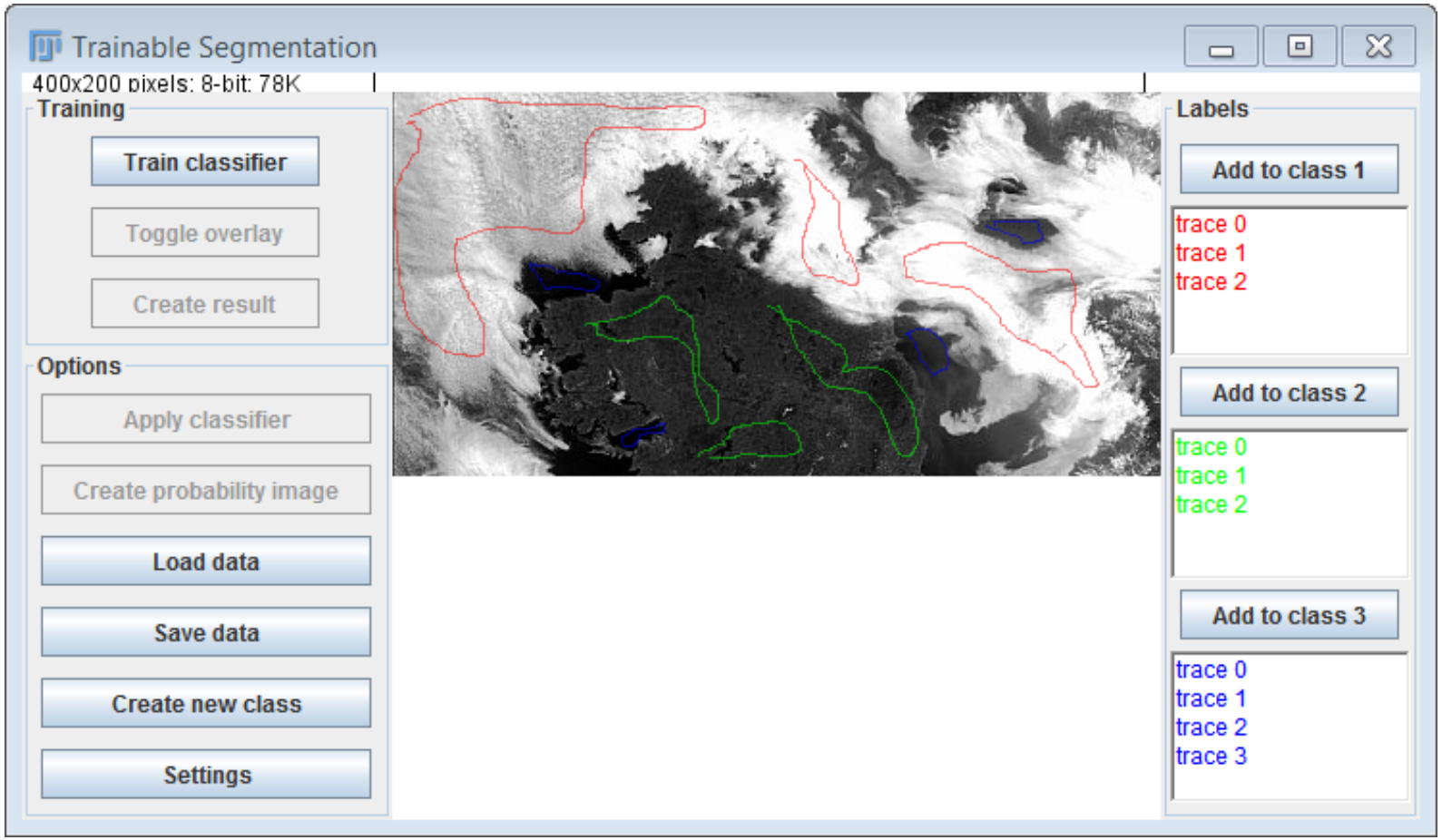




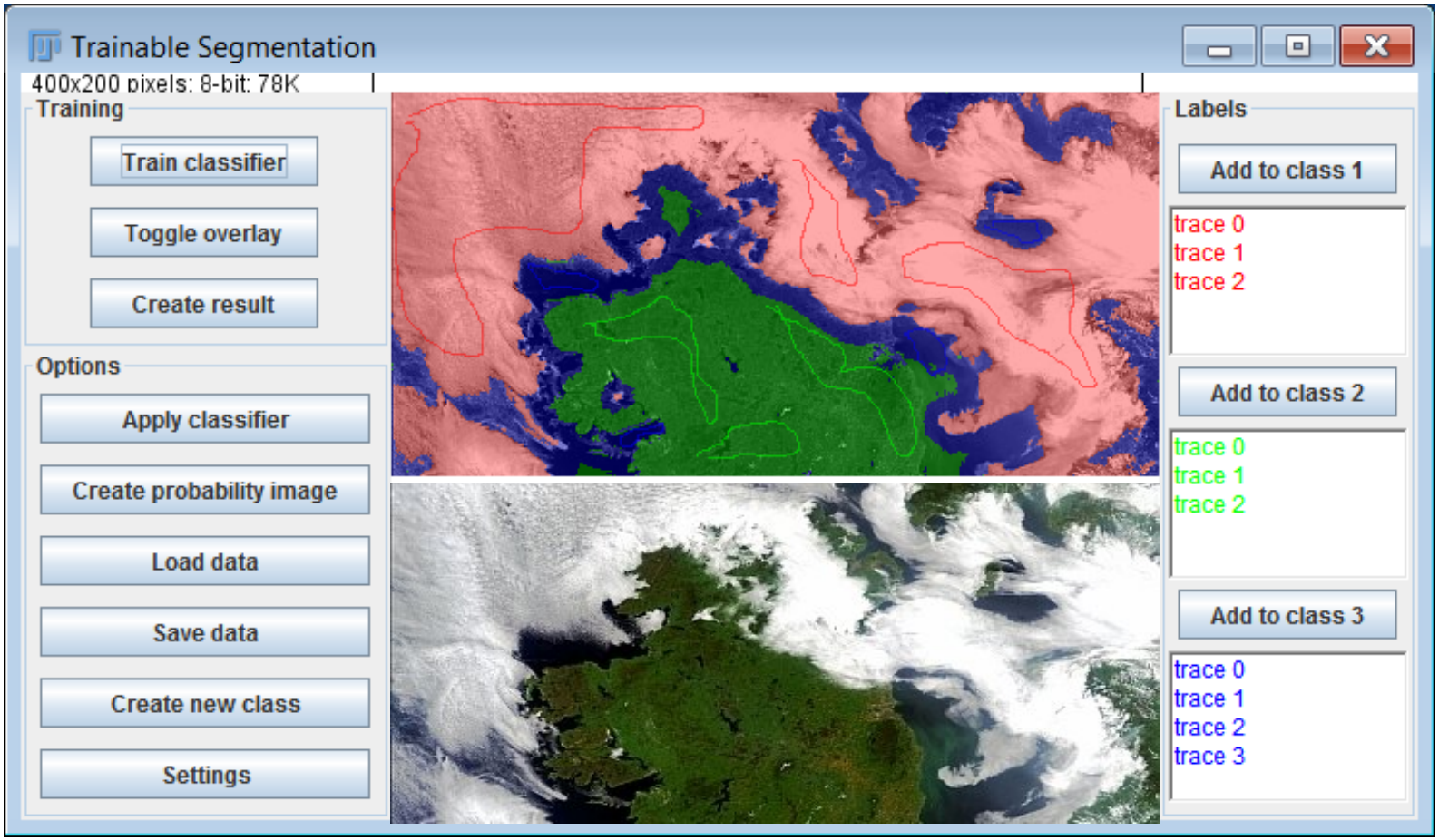
Beyond simple thresholding
Several properties, several classes

- General statistical classification methods are used.
- **Supervised classification**
  - Classes are known in advance.
  - User selects initially some pixels from each possible class.
  - Classification algorithm determines characteristics of each class.
  - Each pixel is then assigned to a most likely class.
  - Stages: training and classification.

Beyond simple thresholding
Several properties, several classes



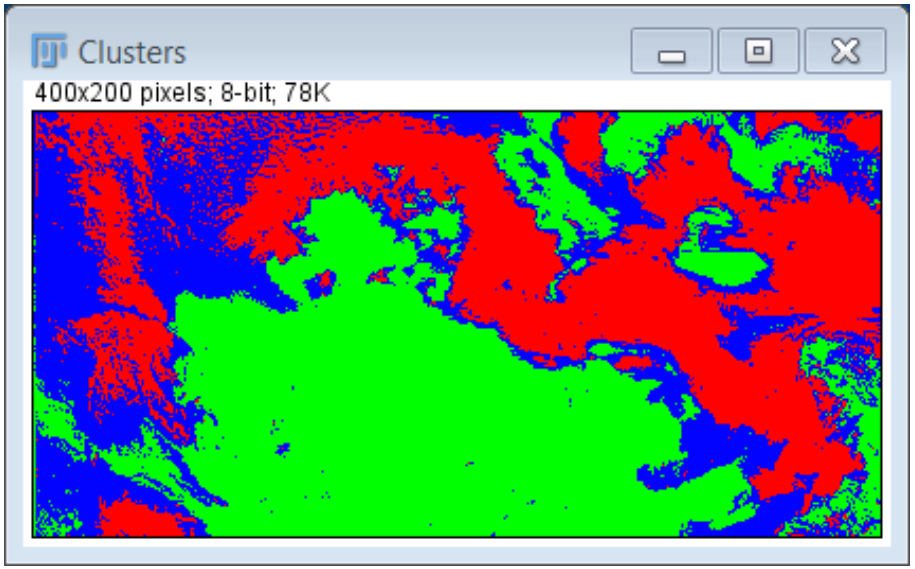
Beyond simple thresholding
Several properties, several classes



Beyond simple thresholding
Several properties, several classes

- General statistical classification methods are used.
- **Unsupervised classification**
  - Classes are not known in advance.
  - The classes are determined by the algorithm by locating clusters in a feature space.
  - Each cluster is assumed to correspond to a class.
  - Each pixel is then assigned to a most likely class.

Beyond simple thresholding
Several properties, several classes



Region based segmentation methods

- **Global** - pixels are grouped into regions on the basis of the properties of a large population of pixels (image statistics).

- **Local** - pixels are assigned to regions on the basis of their close neighbours properties.

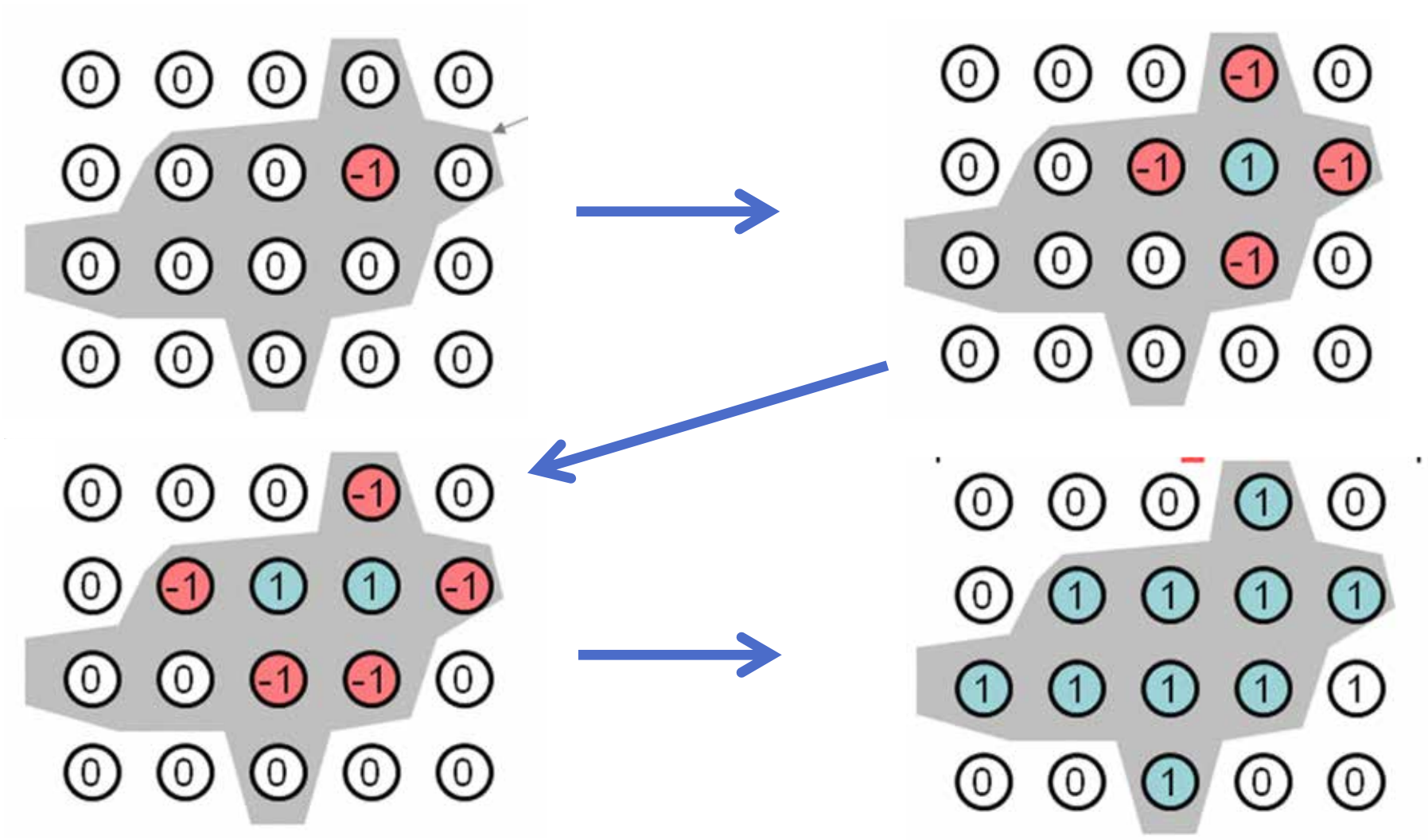
Local methods
Sequential segmentation

- Global methods classify all pixels simultaneously, on the basis of the statistics of the whole population of pixels.
- Local methods classify pixels or their groups sequentially.
- Classification of a given pixel can take into account the result of classification of the pixels already classified.
- Sequential segmentation can proceed either “bottom-up” or “top-down”.

Local methods
Bottom-up: region growing

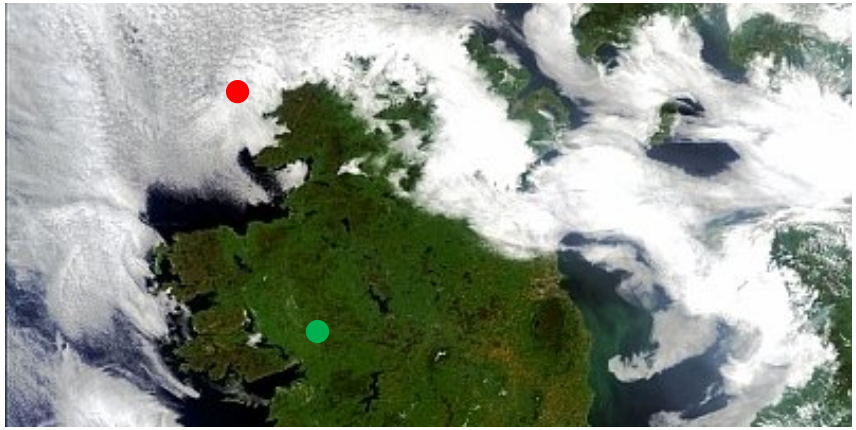
- Typical steps
  - Find starting pixels (these are normally pixels in the centre of the identified objects).
  - Examine all the pixels adjacent to those already selected.
  - Incorporate those adjacent pixels for which a similarity criterion is met.
  - Terminate if no more candidates found.

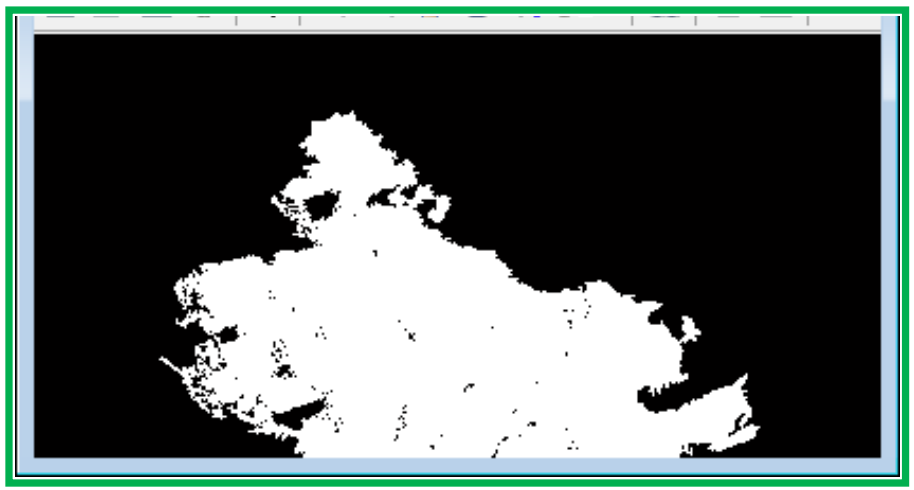
Local methods
Bottom-up: region growing



Source: www.csd.uwo.ca

Local methods
Bottom-up: region growing

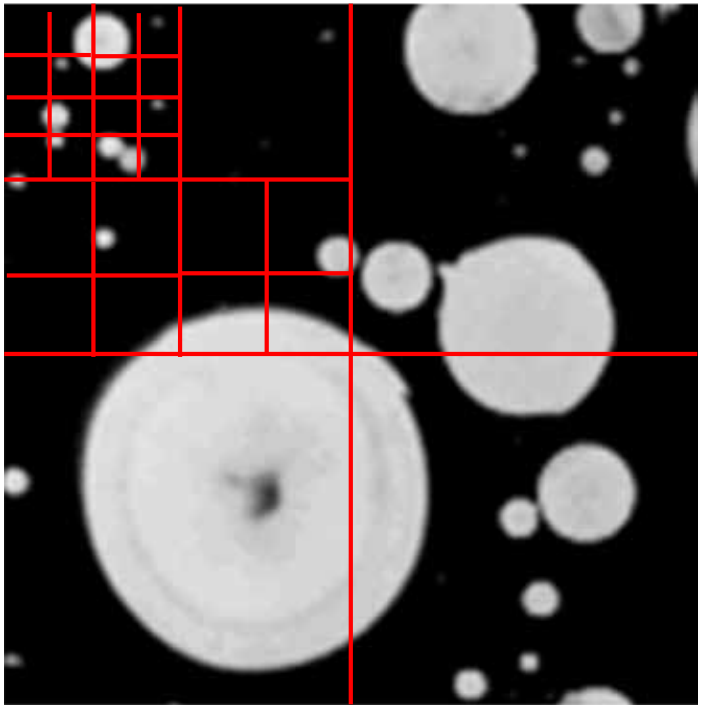


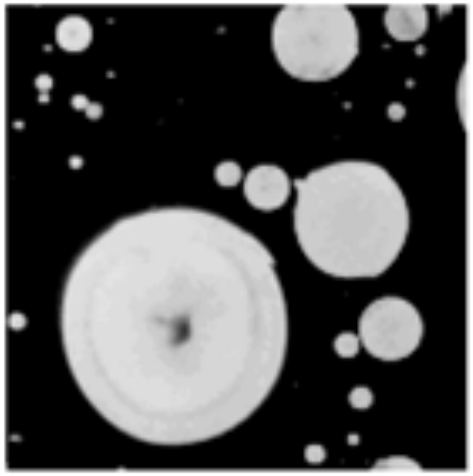


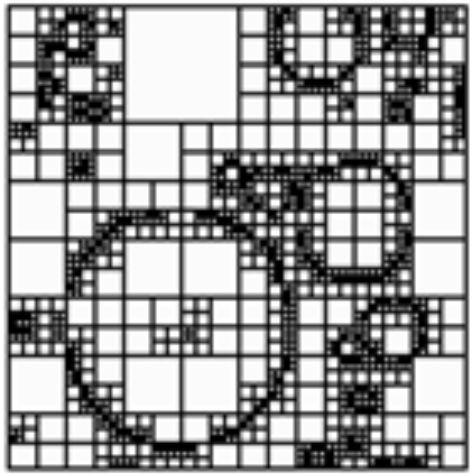
Local methods
Top down: image partitioning

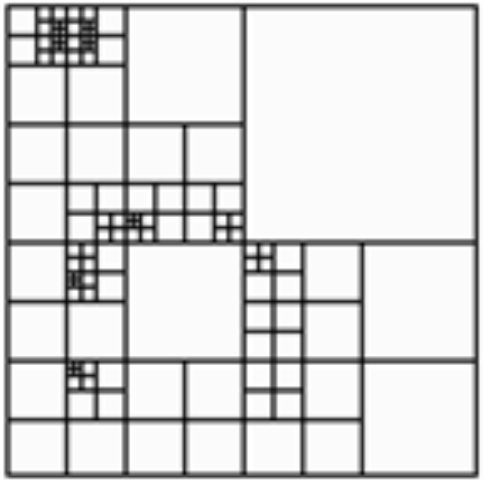
- Start from an entire image and *partition* (split) it into uniform regions.
- Typical steps
  - For each partition determine if it meets a similarity criterion.
  - If it does not, partition it further.
  - If it does, terminate and move to the next one.
- Partitioning uses usually regular sub-divisions, e.g. a region is split into four further sub-regions.

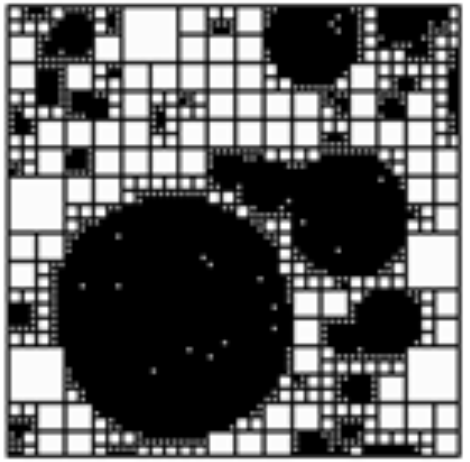
Local methods
Top down: image partitioning











http://article.sapub.org/image/10.5923.j.biophysics.20120203.01_001.gif

Segmentation
Post-processing

- Segmentation often produces objects with irregular boundaries and spurious “holes”, and “noise” in the background.
- These can be corrected with various post-processing methods.

In this lecture we have covered:

- What is image segmentation
- Principles of the region-based segmentation
- Global methods: pixel classification
  - Thresholding
  - Multi-object classification
  - Feature spaces
- Local methods
  - Bottom up: region growing
  - Top down: image partitioning

Next lecture:

- Post-processing methods
  - Mathematical morphology – basic operations
- Feature extraction
  - Mathematical morphology – combined operations

Further reading and experimentation

- **Book chapters**:
- Gonzalez, R.C. & Woods, R.E. Digital Image Processing, Addison-Wesley (various editions), 7.3.
- Sonka, M. Hlavac, V. Boyle, R. (various editions) Image Processing, Analysis and Machine Vision, Chapman & Hall Computing, 5.
- Umbaugh, S.E. Computer vision and image processing : a practical approach using CVIPtools , Prentice Hall International (various editions), 2.4.

- **Otsu thresholding**
- https://en.wikipedia.org/wiki/Otsu's_method

- *HIPR2 resources*
- **Pixel classification**
- http://homepages.inf.ed.ac.uk/rbf/HIPR2/classify.htm
- **Pixel labelling**
- http://homepages.inf.ed.ac.uk/rbf/HIPR2/label.htm