Norsk Regnesentral
NORWEGIAN COMPUTING CENTER

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Image segmentation beyond thresholding (or how to understand Andy Warhols inspiration)

An introduction

Lars Aurdal,

Norsk Regnesentral,

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Plan

1. Region and edge based approaches.
2. Region based approaches:
   a. Region similarity.
   b. Region merging techniques.
   c. Region splitting techniques.
   d. Region splitting and merging techniques.
   e. Homogeneity criteria.

Region and edge based approaches

1. A region in an image can be defined by its border (edge) or its interior, the two representations are equivalent.
2. If you know the interior you can always define the border and vice versa.
3. Because of this, image segmentation approaches can typically be divided into two categories, edge and interior based.

Region and edge based approaches

1. The edge of a region can often be hard to find because of noise or occlusions.
2. Among the simpler segmentation approaches the interior based methods are arguably the most robust.

Region and edge based approaches

1. The robustness is due to many factors:
   a. Regions cover more pixels than edges and thus you have more information available in order to characterize your region.
   b. When detecting a region you could for instance use texture which is not easy when dealing with edges.

Region based approaches

1. What is a region?
2. A region R of an image f is defined as a connected homogenous subset of the image with respect to some criterion such as gray level or texture.
3. Let P denote a logical predicate for the homogeneity measure defined on R.

Region based approaches

1. We define the predicate P as follows:

$$P(R) = \begin{cases} \textbf{true}, \; if\ H(R) \in \mathcal{D} \\ \textbf{false}, \; otherwise \end{cases}$$

   where H is a function for evaluating the homogeneity of a region R and D is some predefined range of values for H.

2. A segmentation of an image f is a partition of f into several homogenous regions R_i, i=1,2,…,m

Region based approaches

1. The relationships among these regions are defined as follows:

$$1)\ f = \bigcup_{i=1}^{m} R_i$$

$$2)\ R_i \bigcap R_j = \emptyset,\ 1 \le i, j \le m\ and\ i \ne j$$

$$3)\ P(R_i) = \textbf{true}\ for\ all\ i$$

$$4)\ P(R_i \bigcup R_j) = \textbf{false},\ 1 \le i, j \le m\ and\ i \ne j\ and$$

$$R_i, R_j\ are\ adjacent$$

Region merging techniques

1. One region based type of segmentation methods is the so called region merging method.
2. Very simple method. Initialization is done as follows:
   a. Start by giving all the pixels a unique label (a possible variation is to give groups of 2 and 2 or 4 and 4 pixels a unique label).
   b. Thus conditions 1 and 2 in the previous slide are satisfied.
   c. Condition 3 is assumed to be satisfied.

Region merging techniques

1. The rest of the algorithm is as follows:
   a. In some predefined order, examine the neighbor regions of all regions and decide if the predicate evaluates to true for all pairs of neighboring regions.
   b. If the predicate evaluates to true for a given pair of neighboring regions then give these neighbors the same label.
   c. Continue until no more mergings are possible.
   d. Upon termination all 4 criteria will be satisfied.

Region merging techniques

1. The function H can be defined in many ways:
   a. It can measure the variance of a given region.
   b. It can measure the difference between the smallest and the largest pixel value associated with a region.
   c. More on this later.

Region merging techniques

1. A variant of this method is the so called region growing method.
2. Instead of assigning labels to all pixels only one or a few pixels are initially assigned labels (these are often referred to as seeds).
3. Based on these seed regions neighboring pixels are added as long as some predicate evaluates to true (the variance within certain bounds for instance).

Region merging techniques

1. One problem with these methods is the choice of starting point (seed).
2. One strategy is to start in a single point a grow from there, with this strategy you will not label all pixels (and if you did the result would not be very interesting).
3. Another strategy is to pick a number of random starting points, you are still not certain of labeling all pixels.

Region merging techniques

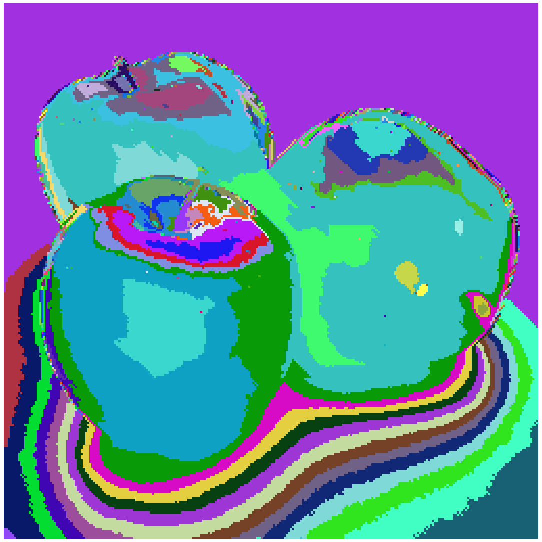
1. In the exercises you will be trying out a simple implementation of region merging.
2. The algorithm is implemented in the file region_grow1.m
3. Commands for running it are given in region_2006.m
4. Matlab example.

Region merging techniques

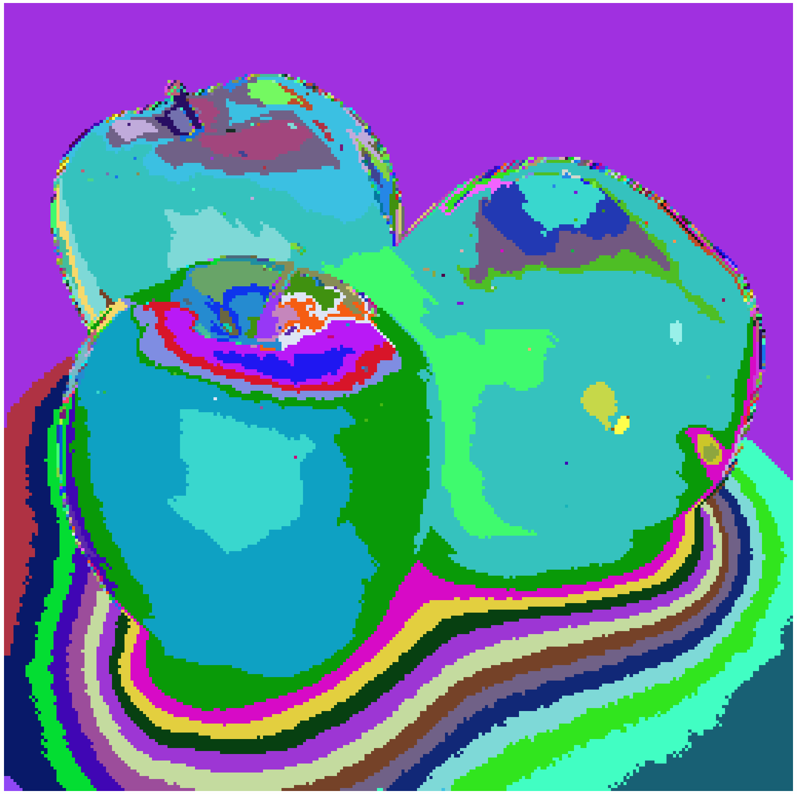
1. An interesting case for region merging is the image to the right.
2. The aim is to separate the apples from the background.
3. This image poses more of a challenge than you might think.
4. This image can be downloaded from the course web site.

Region merging techniques

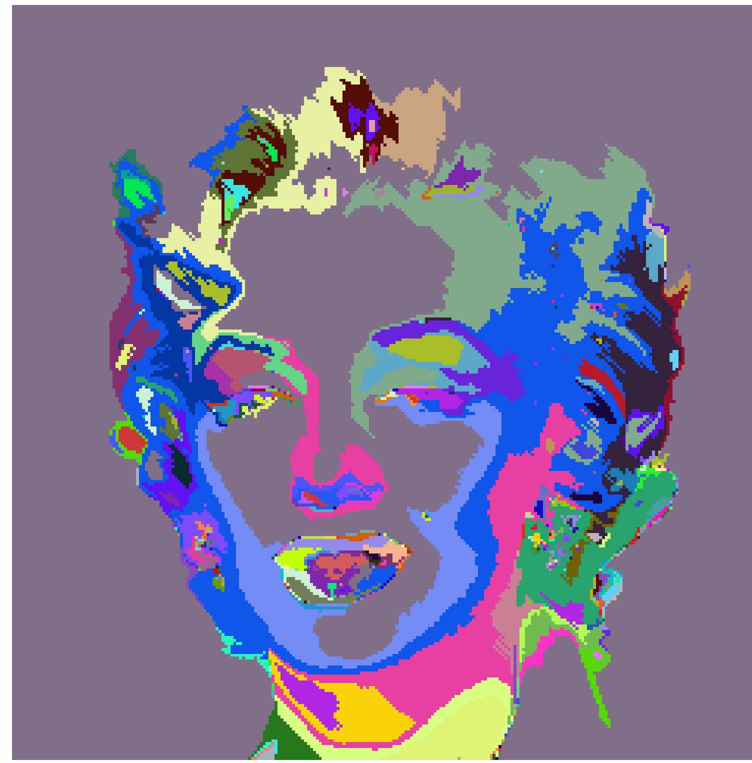
1. We run a standard region merging procedure where all pixels initially are given a unique label.
2. If neighboring regions have mean values within 10 gray levels they are fused,
3. Regions are considered neighbors in 8-connectivity.



Region merging techniques



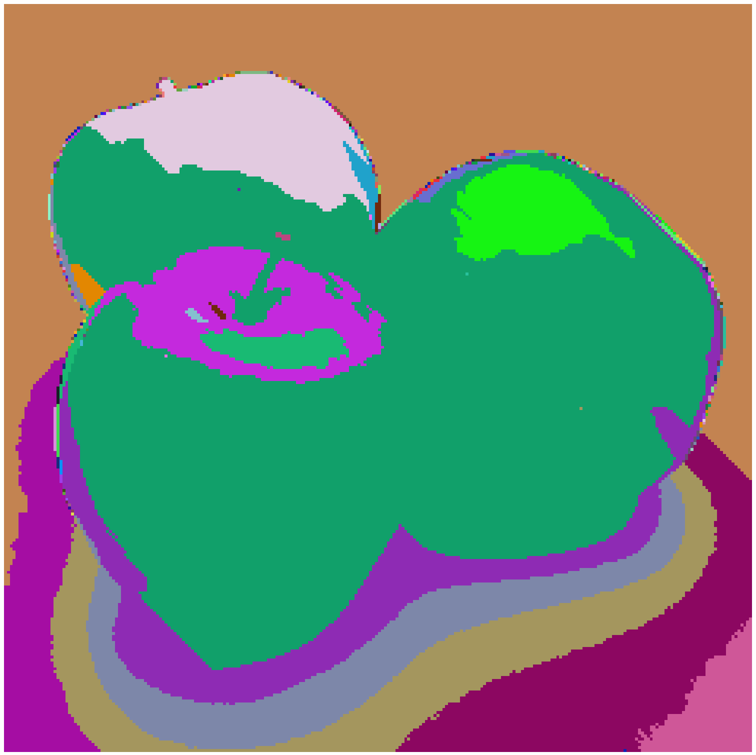
How Andy Warhol really did it…



Region merging techniques

1. A caveat:
2. Remember that initialization is critical, segmentation results will in general depend on the initialization.
3. The order in which the regions are treated will also influence the result, in the images in the next slide the right image was flipped upside down before it was fed to the merging algorithm.

Region merging techniques



The right image was flipped upside down before being fed to the region merging algorithm, notice the differences between the two.

Region splitting techniques

1. Another region based type of segmentation methods is the so called region splitting method.
2. Also a very simple method. Initialization is done as follows:
   a. Start by considering the segmented image to consist of a single region covering all of the image.
   b. Thus conditions 1 and 2 in the previous slide are satisfied.
   c. Condition 3 is almost certainly not satisfied.

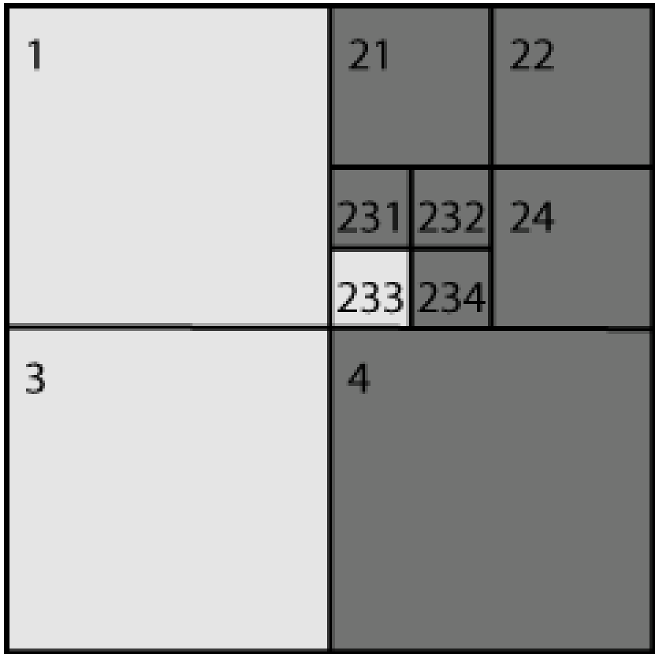
Region splitting techniques

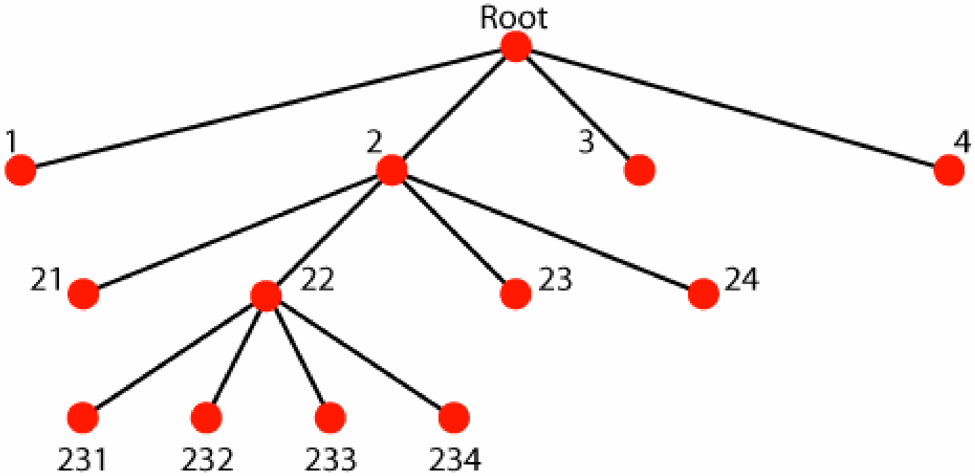
1. The rest of the algorithm is as follows:
   a. Split the image in parts, typically four equal parts.
   b. Check if the predicate evaluates to true for any of the new regions.
   c. Continue until all regions satisfy the predicate.
   d. Upon termination all 4 criteria will be satisfied.

Region splitting techniques

1. The function H can again be defined in many ways:
   a. It can measure the variance of a given region.
   b. It can measure the difference between the smallest and the largest pixel value associated with a region.
   c. More on this later.

Region splitting techniques



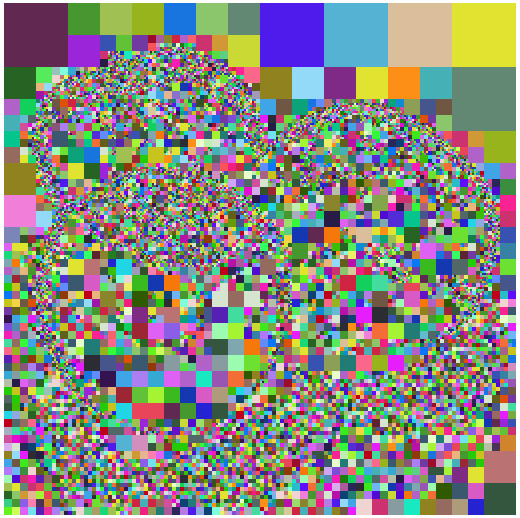


Region splitting techniques

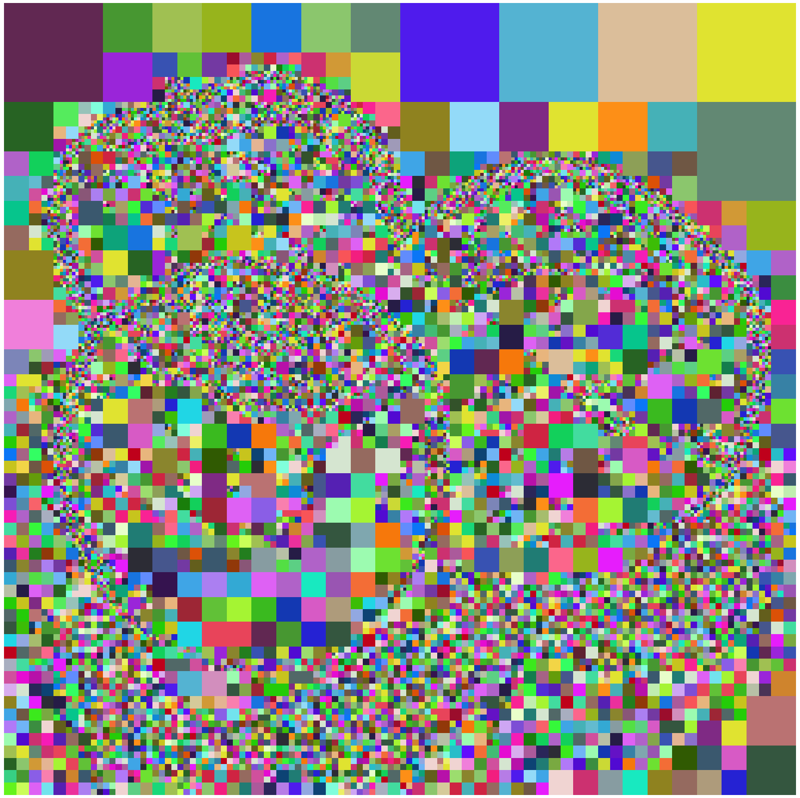
1. In the exercises you will be trying out a simple implementation of region splitting.
2. The algorithm is implemented in the file region_split1.m
3. Commands for running it are given in region_2006.m
4. Matlab example.

Region splitting techniques

1. We run a standard region splitting procedure.
2. If the difference between the max and the min value of a region is more than 10 the region is split.



Region splitting techniques



Region splitting techniques

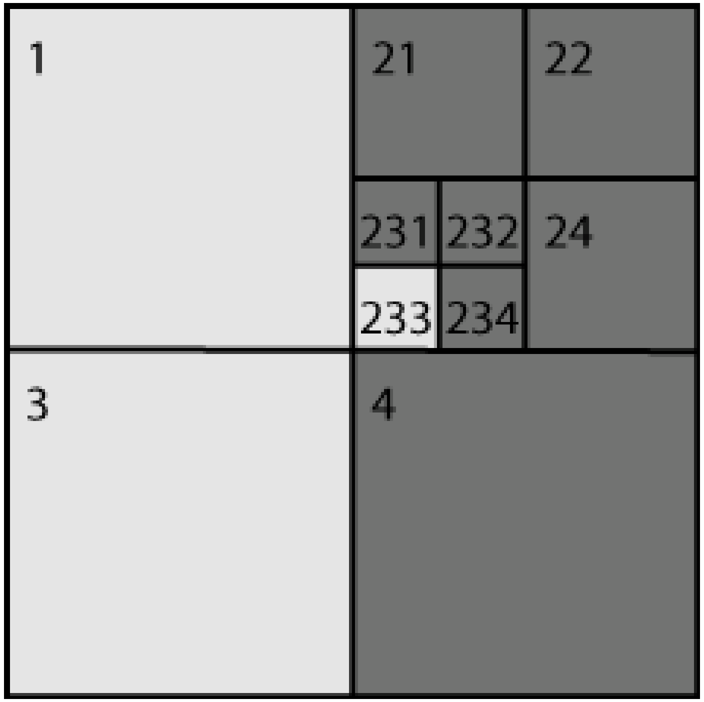
1. One particularity of this algorithm is that is cries out for a recursive implementation.
2. Matlab example.
3. Study this carefully in the matlab example.

Region split and merge techniques

1. It should come as no surprise that the region splitting technique has a very limited field of application.
2. There is however a simple way of improving on its performance.
3. This rests upon the observation that once the splittings are terminated there can be many neighboring regions that should actually have the same label.

Region split and merge techniques

1. In the example to the right it is easy to see that all the regions that are light gray should be merged, so should all the dark gray regions.
2. A simple splitting will however give unique labels to all the regions 1, 21, 22, 231, 232, 233, 234, 24, 3 and 4.



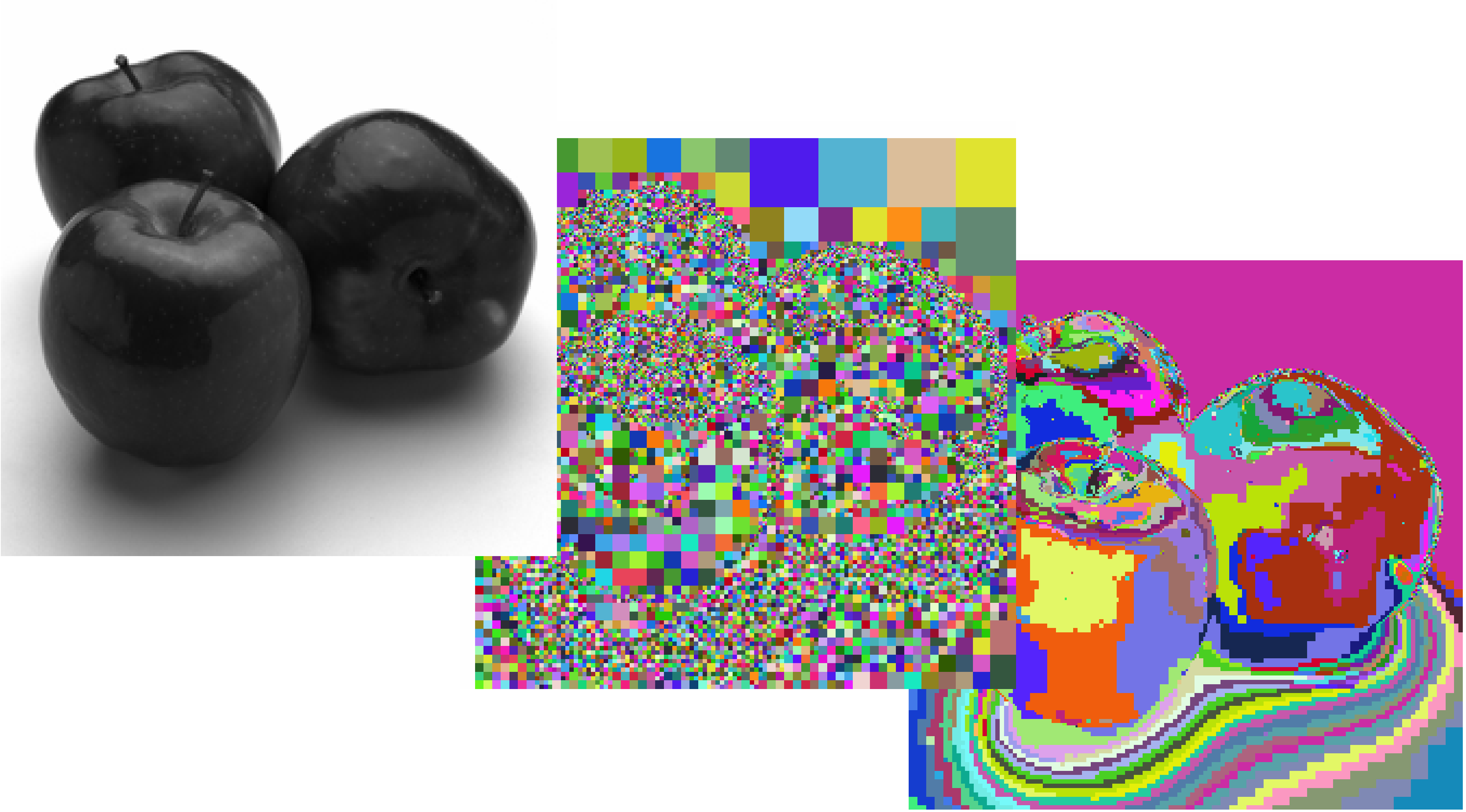
Region split and merge techniques

1. There are many ways to implement such a remerging of the split regions.
2. Many approaches are based on an analysis of what's called an adjacency graph.
   a. In an adjacency graph the nodes are the different segments resulting from the splitting process.
   b. The nodes connected by an edge represent segments sharing a common border (or corner depending on connectivity).

Region split and merge techniques

1. These are often complicated and inelegant algorithms.
2. One simple solution is the following:
   a. You'll need a separate region merging and splitting algorithm.
   b. Run the region splitting algorithm first. Make it return both the segments and the values of the criterion calculated on every segment.
   c. Then run region merging with these segments as an initial segmentation of the image containing the criterion values.

Region split and merge techniques



Region split and merge techniques

1. In the exercises you will be trying out a simple implementation of region splitting and merging.
2. Commands for running it are given in region_2006.m
3. Matlab example.

Homogeneity criteria

1. So far we haven't said much about the function H, that is the function that measure the homogeneity of the regions under study.
2. Remember that the value of H determines if the predicate is true or false:

$$P(R) = \begin{cases} \textbf{true}, \; if \; H(R) \in \mathcal{D} \\ \textbf{false}, \; otherwise \end{cases}$$

Homogeneity criteria for splitting

1. The difference between the maximal and minimal value measured over a given region.
   a. Measures the homogeneity of the regions gray-levels, a small difference means similar gray-levels.
   b. Simple to compute.
   c. Very sensitive to noise.
   d. A small difference means that you do not want to split the region.
   e. Not interesting for textures.

Homogeneity criteria for splitting

1. Region variance
   a. Another measure of the homogeneity of the regions gray-levels, a small variance means similar gray-levels.
   b. More expensive to compute.
   c. Very sensitive to noise.
   d. A small variance means that you do not want to split the region.
   e. There are other, higher order moments that can be used to.
   f. Interesting for segmentation of textures.

Homogeneity criteria for splitting

1. Histogram-based methods:
    a. Measures the distribution of the region gray-levels.
    b. Expensive to compute.
    c. Less sensitive to certain types of noise.
    d. If the histogram for a given region is unimodal then it may be reasonable to assume that it represents a single object with noise. Splitting is probably not wise.
    e. On the other hand, if the histogram is bi- or multimodal it probably overlaps several objects and a splitting of the region can be called for.
    f. Not interesting for textures.

Homogeneity criteria for merging

1. Region mean
   a. Measures the average intensity of a region.
   b. Simple to compute
   c. Less sensitive to noise
   d. If neighboring regions have the same mean then they should probably be merged
   e. Does not necessarily work with textures (unless the textures have different means).

Homogeneity criteria for merging

1. Cooccurrence matrices
   a. Measures global textural properties.
   b. Expensive to compute
   c. Less sensitive to noise
   d. If neighboring regions have the same cooccurence matrices then they should probably be merged.