TP6 : Image segmentation using K-means

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The aim of this lab session is to program and study the K-means method for image segmentation.

1. Dowload the file `.zip` and unarchive it
2. You should obtain
   - a directory named `data` containing pgm and ppm image files
   - a directory named `src` containing NewpixmapIO.h and NewpixmapIO.c files. Those files are new versions of the files pixmapIO.c and pixmapIO.c. The new versions can handle reading and writing color images (.ppm).

Once finished, you will have to send a pdf report within one week.

1 Remarks on color images

Image file formats PBM (Portable Bit Map), PGM (Portable Gray Map) and PPM (Portable Pixel Map) gives a simple solution to any programmer confronted with image file manipulation. In these formats, an image is viewed as a matrix where each value represents the illumination of each pixel: black or white (PBM), gray levels (PGM) or three level of colors RGB: Red Green Blue (PPM). The corresponding files contain the following elements:

1. A Magic number to identify the file type: P1 or P4 for PBM, P2 or P5 for PGM and P3 or P6 for PPM.
2. A space character (white space, or TABs or CRs, or LFs).
3. The width of the image (number of columns) followed by a space character and the height of the image (number of rows) followed by a space character.
4. For the PGM and PPM types only: the maximum intensity value between 0 and 255 followed by a space character.

5. width*height numbers. These numbers are either values coded with ASCII and separated by white spaces (for P1, P2 and P3) or, binary values on bytes (or bits) for P4, P5 and P6. In this case, there is no space between values.

Files PPM account for color images. To each pixel is associated 3 values (usually ranging from 0 to 255 as for grey levels), respectively for the red, green and blue channels (RGB coding). An exemple of a PPM ascii file is given below. It describes a 4×4 image.

```
P3
# feep.ppm
4 4
255
0  0 0  0 0  0 0 0  0 256 0 15
0  0 0  0 15 7 0 0  0 0  0 0
0  0 0  0 0  0 0 15 7 0  0 0
15 0 15 0 0  0 0 0  0 0  0 0
```

file PPM of a 4 ×4 image

2 K-means

K-means clustering algorithm was developed by J. MacQueen (1967) and then by J. A. Hartigan and M. A. Wong around 1975. Simply speaking K-means clustering is an algorithm to classify or to group the objects based on attributes/features into K groups. K is a positive integer number. The grouping is done by minimizing the distances between data and the corresponding cluster centroid. The distance that will be used here is the L^2 distance ($d(x, y) = (x - y)^2$).

The aim of clustering analysis is to group data in such a way that similar objects are in one cluster and objects of different clusters are dissimilar. The K-means algorithm basically consists of three steps:

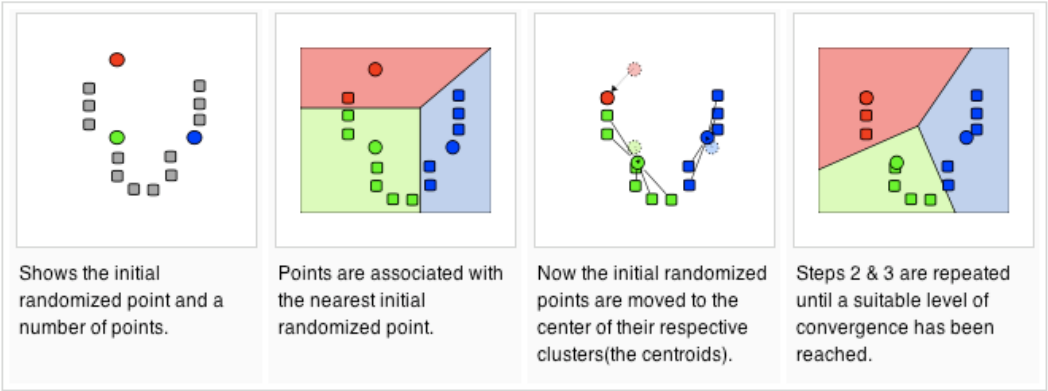
1. Initialization: K chosen, an initial set of K so-called centroids, i.e. virtual points in the data space is randomly created,

2. every point of the data set is assigned to its nearest centroid and

3. the position of the centroid is updated by the means of the data points assigned to that cluster. In other words, the centroid is moved toward the center of its assigned points.

Steps 2 and 3 are performed until no centroid was shifted in one iteration. In practice, the algorithm is stopped when the minimum shift is below a

threshold. The following images demonstrate the k-means clustering algorithm in action, for the two-dimensional case.



The k-means algorithm will then find the K groups of data that minimize the following objective fonction:

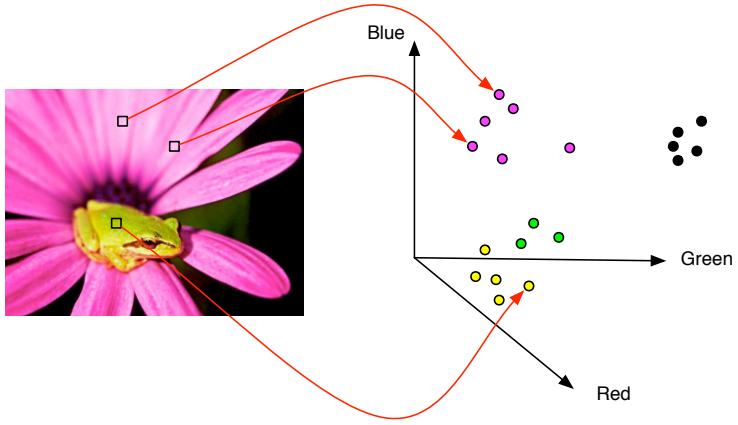
$$F = \sum_{i=1}^{K} \sum_{x_j \in S_i} (x_j - c_i)^t (x_j - c_i),$$

where there are K clusters S_i, $i = 1, 2, \ldots, K$, and c_i is the centroid or mean point of all the points $x_j \in S_i$.

3 Application to image segmentation

The k-means clustering algorithm is commonly used in computer vision as a form of image segmentation.

To each pixel of an image is associated its color described in RGB. The image to be segmented can then be represented as a set of points in a 3D data space, as illustrated in the following figure. In case of a grey-level image, the procedure is the same apart from the fact that the image is represented as a set of points in a 1D space.



4 Implementation

1. Implement the K-means method to segment the grey-level images.
2. Test on few images. Illustrate your results by showing the segmented images where the regions are displayed in different grey values.
3. Extent your algorithm to color images and test on few exemples.
4. Do initial centroid positions have an influence on the result ?
5. How does the choice of K influence the result ?
6. How does the choice of the stopping threshold influence the result ?
7. To improve the result, we propose to take into account the color of each pixel and its position. The color image is then represented in a 5D space (R,G,B, line, colomn). Implement and test the K-means method to segment the images with this new representation.