Lab 10 – Image Retrieval

Deadline: +1 week

1 Motivation & Web structure mining

People are not only interested in finding text information but also in finding multimedia, e.g., images, videos, or music. For instance:

- **Web pages**: Web pages contain many pictures today. Some web browsers, like Google, support image retrieval. The user may enter a query in the form of a description (i.e., "black swan") or an image (image of a black swan). Then, the browser seeks for the most similar/relevant images and presents the results.
- **Astronomy**: NASA and ESA collect an astonishing amount of data every day. In particular, they use satellites and telescopes to take photos (x-ray, ultraviolet, gamma, etc.) of the space. Gathered data can be processed and analyzed to get some knowledge. However, an image retrieval system must be built first. It allows exploring a large database of images efficiently.
- **Medical imaging**: Medical imaging plays an important role in modern medicine. By generating images (e.g., X-ray, CT Scans, MRI) of the interior of a body, a disease may be diagnosed and treated. A system for image retrieval is required.

2 Example method for image retrieval

- **Manually**: Images are organized manually. The user may select some categories/-subcategories to find a relevant image. Such a system is very intuitive to use but challenging to build and maintain. What is more, it does not support complex queries (e.g., "cat and dog").

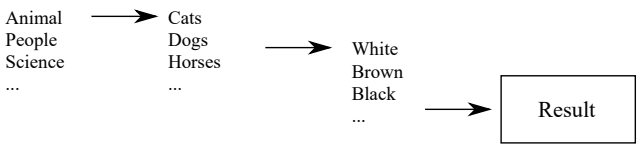

Figure 1: Manual selection

- **Using keywords**: easy to implement but the images must be annotated. Usually, annotations are very general ("dog" but not "black fluffy dog").

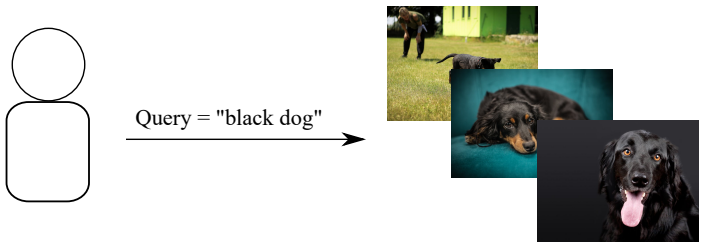

Figure 2: Using keywords

- **Based on similarity**: query is a reference object (i.e., an image, video, etc.). Some characteristics of the object are derived. Similar objects are found in a database and are presented to the user.

Using an image as a query:

- It is easy to find images that are very similar to the provided query.
- On contrary, if the system compares images using irrelevant features, the answer may not be satisfactory. E.g., consider the below example. The obtained picture is very black as well as the query image. However, the breed is different.

Figure 3: Using an image

Using a sketch as a query:

- Allows providing very specific queries.
- However, it may be difficult for someone to draw a picture (or sing a song, etc.).

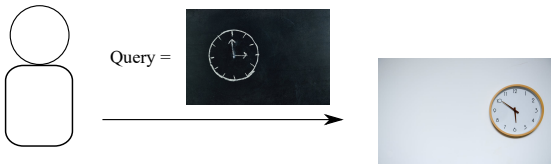

Figure 4: Using a sketch

3 Image features

The characteristics that one may derive from an image can be roughly divided into three categories:

- **Color** Color is an essential characteristic of (almost) every image. One may, e.g., compute such features like mean, standard deviation, skewness, or kurtosis of a particular color. These features are also referred to as color moments. What is more, a whole histogram may be derived to account for a distribution of color. It is worth remembering that one may derive image properties using different color spaces (e.g., RGB, HSV – see Figure 5). Figure 6 illustrates an exemplary ranking of images for a provided query image. The pictures are sorted according to a cosine similarity between feature vectors. Each vector consists of mean values of colors (RGB).

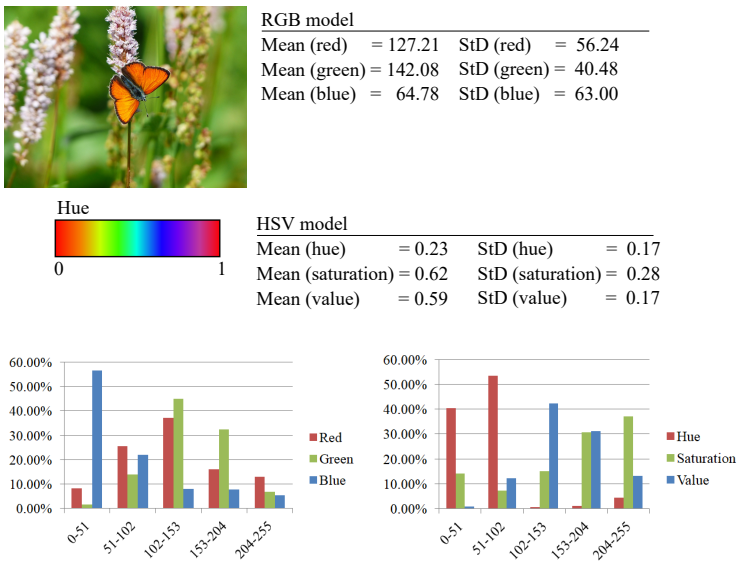

Figure 5: Some image and its characteristics

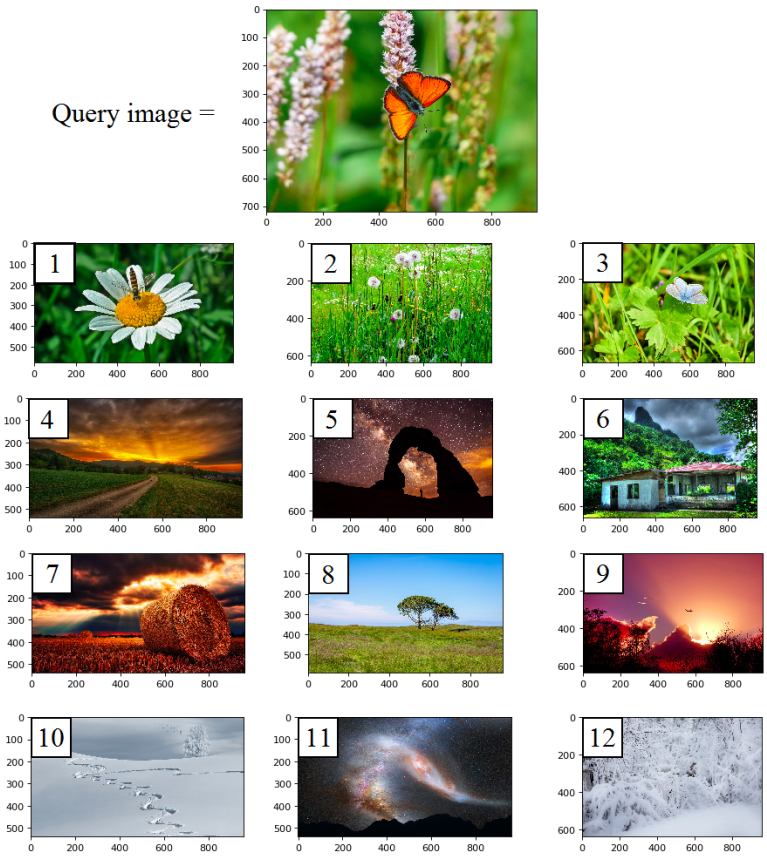

Figure 6: Ranking of images based on mean values of a color

- **Shape**: Apart from the color, a shape of an object in a picture is an important aspect. Characteristics of the shape can be used to seek the same object in different pictures. However, the size, position, or orientation of such an object may be much different (see Figure 7). Thus, measures that directly account for shape properties usually are not helpful in object detection.

Figure 7: Same objects but different position, scale, and orientation

- **Texture:** Images may also differ in terms of texture. The texture is an essential aspect of a picture because it is related to its physical attributes. Different objects may have the same color and even shape, but they may be different with respect

to the texture. For instance, consider Figure 8. It can be assumed that a horse and a zebra have the same shape (and sometimes even color). However, it is almost certain that they have different textures, i.e., a zebra has stripes :). Figure 9 depicts a piece of paper, a piece of wood, and ice. Obviously, the colors of these three objects are the same, but they have different textures. A measure that accounts for the object's pattern is of great importance for object detection.

Figure 8: Two animals that have similar shapes but different textures

Figure 9: Three images that share color properties but have different textures

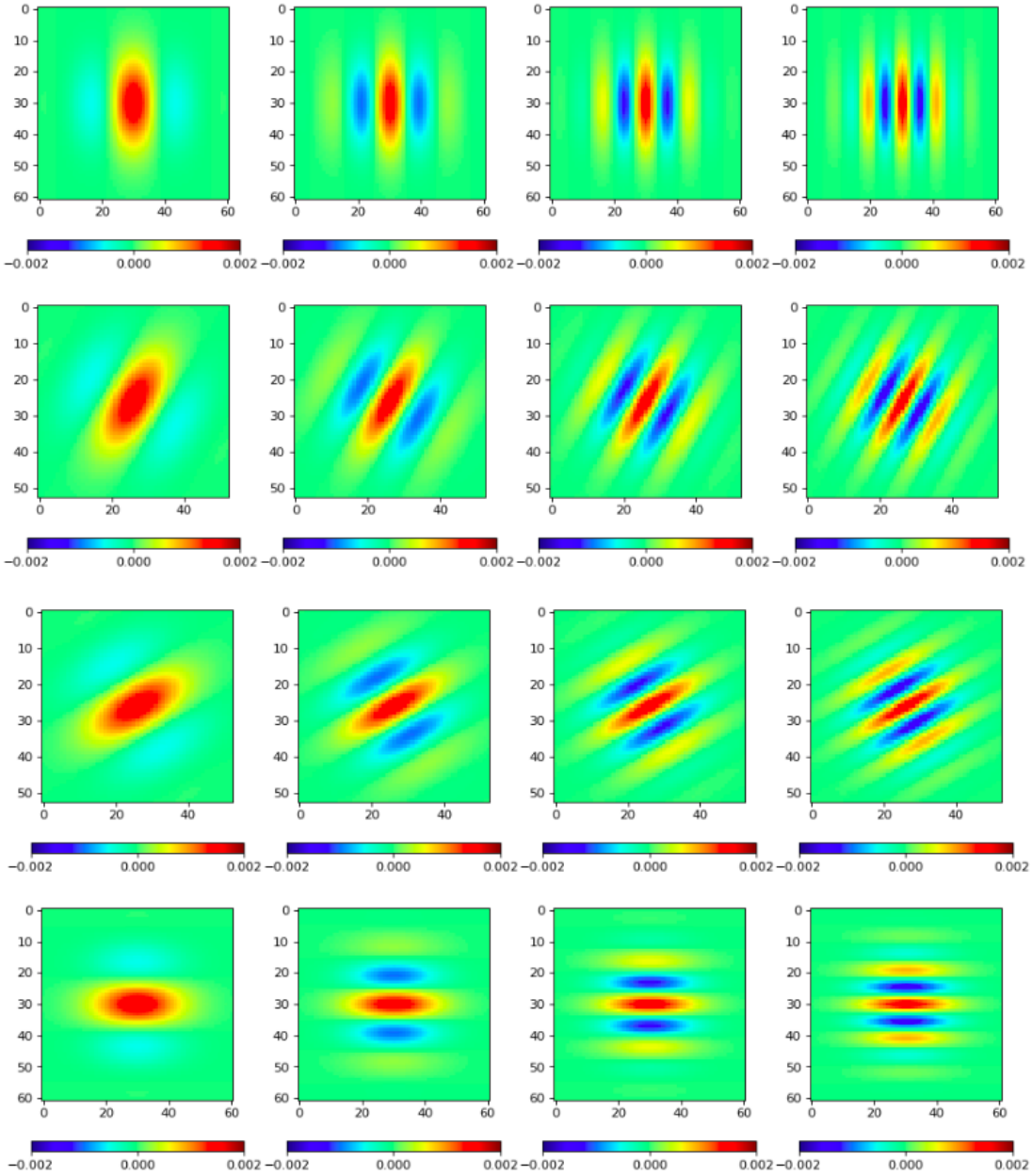

Figure 10: Different Gabor filters

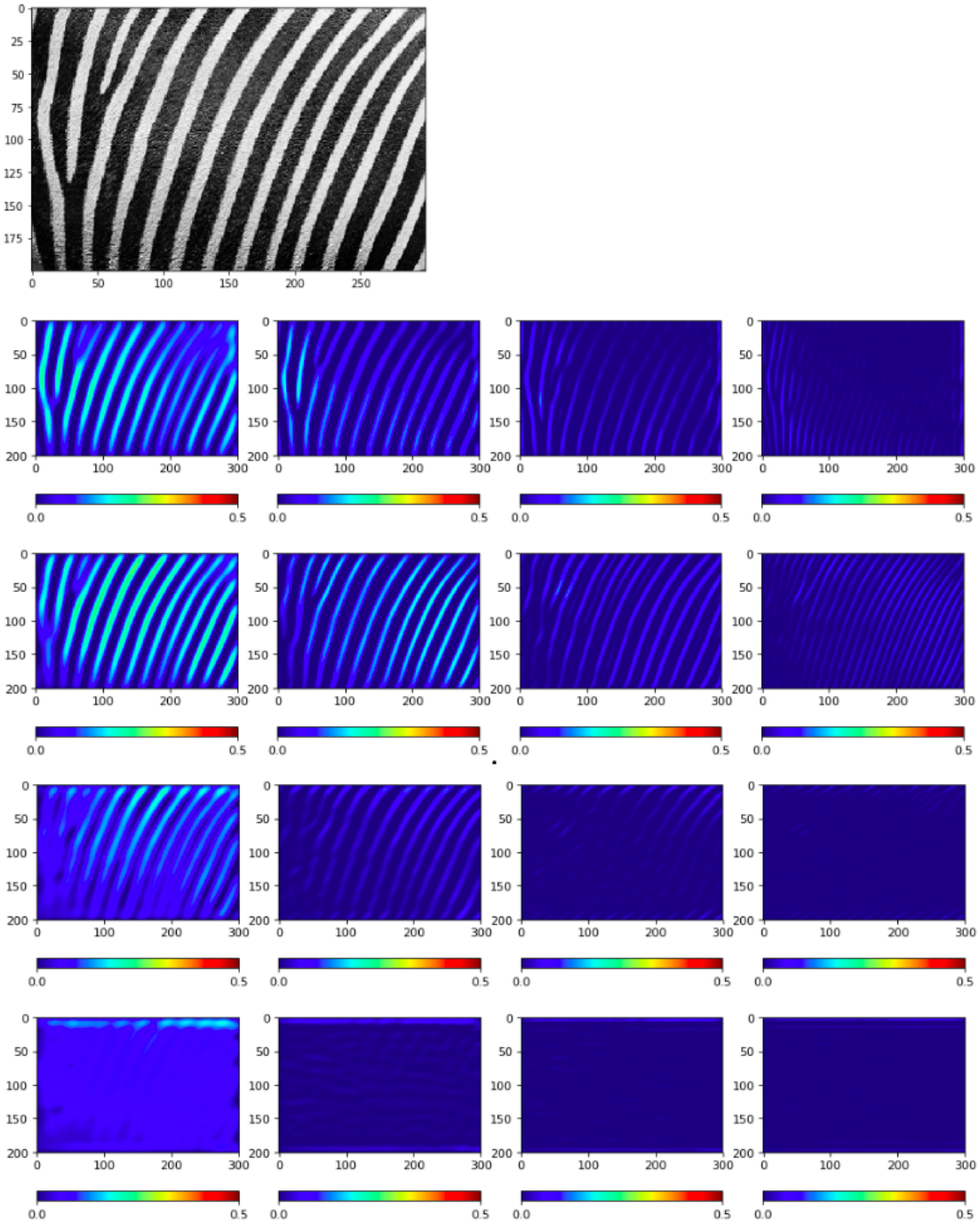

Figure 11: Convolution of the image and the Gabor filters (kernels).

4 Programming assignment (Python notebook)

Use the notebook **Lab10Images.ipynb** provided in the files bundle. To complete this assignment, finish all the exercises and present and discuss the results.