Practical work on mathematical morphology

The aim of this work is to experiment with the main mathematical morphology operations, and to understand their behavior and their properties.

Before starting the work

Copy the files in one of your directories. The directory TP-morpho contains a python code (tp_morpho.py), and a directory with images. You have to use python3 (e.g. in the anaconda distribution). You can then use spyder for instance, to launch the code:

```
spyder tp_morpho.py &
```

Move then to the Images directory. There are examples that can be useful to illustrate the various operations, but you can work with other images of your choice as well.

Execute SECTIONS 1 and 2 of tp_morpho.py in order to have all necessary packages included. SECTION 2 defines some useful functions for this work. SECTION 3 contains examples of functions that will help you to do the work.

Structuring element

The structuring element is defined using function `strel`. It is possible to choose its shape: `‘diamond’`, `‘square’`, `‘disk’`, `‘line’`, and its size. For instance

```
se = strel(‘square’,11)
```

a square structuring element of size 11×11 pixels (note that what we usually call the size, or the “radius”, is 5 in this case).

1 Mathematical morphology on gray-scale images

The following images can be used:

- `bat200.bmp`
- `bulles.bmp`
- `cailloux.png`
- `cailloux2.png`
- `laiton.bmp`
- `retina2.gif`

An image can be read and visualized using:

`im=skio.imread(‘bat200.bmp’)`

`plt.imshow(im,cmap="gray")` (or `viewimage(im)` if you have gimp installed).

1. Apply dilation, erosion, opening and closing with various structuring elements, by varying the shape and the size (functions `morpho.dilation, morpho.erosion, morpho.opening, morpho.closing`[1]).
   What is the influence of the size and the shape of the structuring element?

2. Illustrate the properties of these four operations on examples.

3. What is the operation equivalent to the succession of a dilation by a square of size 3×3 and a dilation by a square of size 5×5? Same question for opening. What are the properties of these operations that explain the result?

4. Apply a top-hat transform (difference of the original image and its opening), for instance on image `retina2.gif`. Comment the result, according to the size and shape of the structuring element. What would be the dual operation (that you can illustrate on image `laiton.bmp`)?

5. Define segments in several directions, apply an opening with each of them as structuring element, and compute the point-wise maximum of the results. Conclusion?

2 Alternate sequential filters

Define an alternate sequential filter, for instance as the following sequence:

```
se1=strel('disk',1)
se2=strel('disk',2)
se3=strel('disk',3)
se4=strel('disk',4)
se5=strel('disk',5)...
fas1=morpho.closing(morpho.opening(im,se1),se1)
fas2=morpho.closing(morpho.opening(fas1,se2),se2)
fas3=morpho.closing(morpho.opening(fas2,se3),se3)
fas4=morpho.closing(morpho.opening(fas3,se3),se3)
fas5=morpho.closing(morpho.opening(fas4,se3),se3)...
```

Use different shapes for the structuring element and vary the maximum size. Comment the results.

What will be obtained if the sequence is continued with larger and larger structuring elements?

3 Reconstruction

Reconstruction makes several operations more robust. The reconstruction by dilation is obtained by the following sequence of operations (m is the marker, I the image, or mask, and B_1 an elementary structuring element, of size 1):

$$m_0 = m \wedge I$$

$$m_1 = D(m_0, B_1) \wedge I$$

[1]Here functions of skimage.morphology are used, and renamed morpho for clarity.

...

$$m_i = D(m_{i-1}, B_1) \wedge I$$

...

where this sequence is iterated until convergence (i.e. $m_n = m_{n-1}$).

1. As an example, the reconstruction of an image from its opening allow recovering small details of objects that are partially kept by the opening. Test for example (you can change the structuring element):

   ```
   im=skio.imread('retina2.gif');
   se4 = strel('disk',4);
   open4 = morpho.opening(im,se4);
   reco=morpho.reconstruction(open4,im);
   ```

   Comment the results.

2. Write the sequence of operators for a reconstruction by erosion. How could this reconstruction be derived from a reconstruction by dilation using duality principle?

3. Add a reconstruction operation at each step of the alternate sequential filter (reconstruction by dilation after each opening and reconstruction by erosion after each closing).

   Comment the results.

4 Segmentation

1. Compute the morphological gradient (dilation - erosion with an elementary structuring element, of size 1), for instance on image `bat200.bmp`. Comment the results.

2. Compute the watershed on this gradient image (see the corresponding section in the code).

   Comment the results. For the visualization, the watershed lines (having value 0 in the result) can be superimposed on the original image.

3. Try to improve the result by filtering the original image by an appropriate morphological filter and/or by filtering the gradient image by a closing, before computing the watersheds.

4. Eliminate regional minima with a dynamic less that some value before applying the watershed. Explain the sequence of operations and comment the results.

5. Define markers (manually or using a dedicated pre-processing), inside the object to be segmented, and outside of it (e.g. on the image border). Let m be the marker, such that m takes value 0 in the marked regions and 255 elsewhere. Compute $I' = I \wedge m$, where I is the image on which we want to compute the watershed (e.g. gradient, or the inverted image in the case of `laiton.bmp`, etc.). Reconstruct I' by erosion from m. The reconstructed image should have minima only in the regions defined by m. Compute the watersheds of the reconstructed image. Comment the results.

6. How could the watersheds be used to segment the black lines in image `bulles.bmp` or `laiton.bmp`? Discuss the different steps of the method you propose.