Image Analysis

Lab 4: Mathematical Morphology

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Date: 06 March 2020

Introduction: The objective of this lab work is to understand how to use mathematical morphology for purposes including extracting features of an image.

Preparation before the lab:

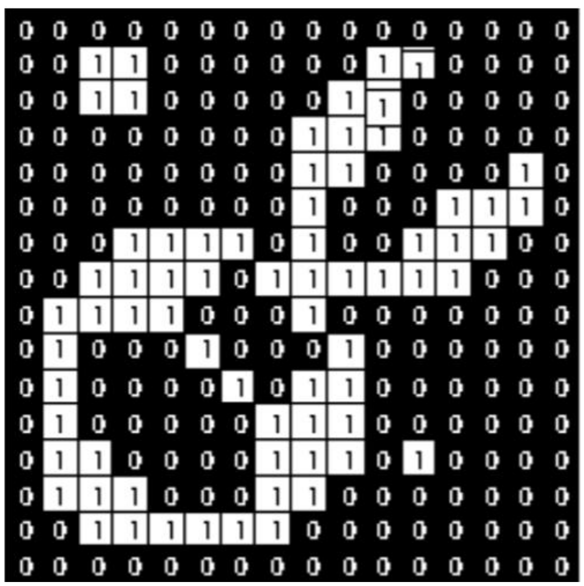

Figure 1. The scissors image

A **structure element** (SE) is a matrix that identifies the pixel in the image being processed and defines the neighborhood used in the processing of each pixel.

Dilation is a process that is done by overlapping the SE and the image and add pixels whenever the SE hits the image. It can make images become continuous, fill holes, extend structure,…

Erosion will delete the pixel in the case the SE hits the image, unless the SE fits the image. It is the opposite of dilation which can separate objects in an image, enlarge holes, and eliminate narrow shapes.

Opening is the dilation of the erosion of an image. Objects smaller than the SE disappear and other objects remain unchanged. As a result, opening removes small objects from the foreground of an image, placing them in the background.

Closing is the erosion of the dilation of an image. Holes smaller than the SE disappear and other objects remain unchanged. As a result, closing removes small holes in the foreground, changing small islands of background into foreground.

These are the results of the 4 operations on the scissors image:

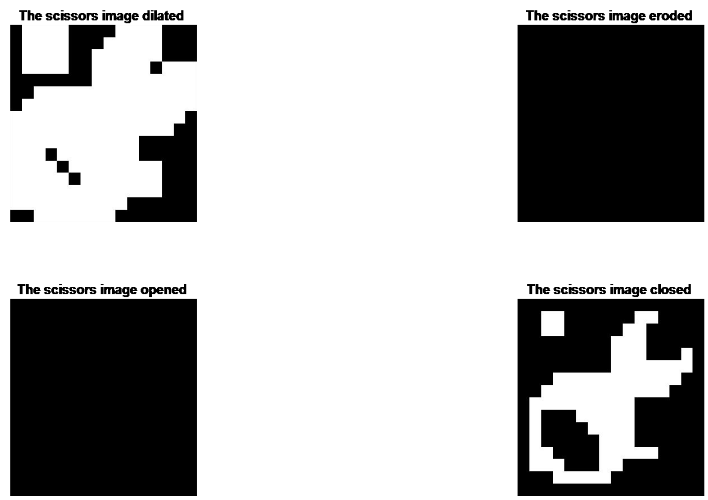

Figure 2. The dilation, erosion, opening, and closing of the scissors image

For the 1st case, we see that the scissor has been extended and the holes are reduced or even eliminated. For the 2nd case, the scissor disappeared as we have no position where the SE fits the object (not thick enough). As a consequent, the 3rd case gives an empty image as we are dilating an empty one. Lastly, the 4th image shows us that the hole smaller than the SE was eliminated while the other objects did not change much.

Computer session:

I. Familiarize yourself with the tools:

1. Structuring element:

The command *strel* is used to design a SE when we give it a shape and the numbers corresponding to the sizes of the shape. I tried with 3 different SEs with diamond, line, and octagon shapes respectively.

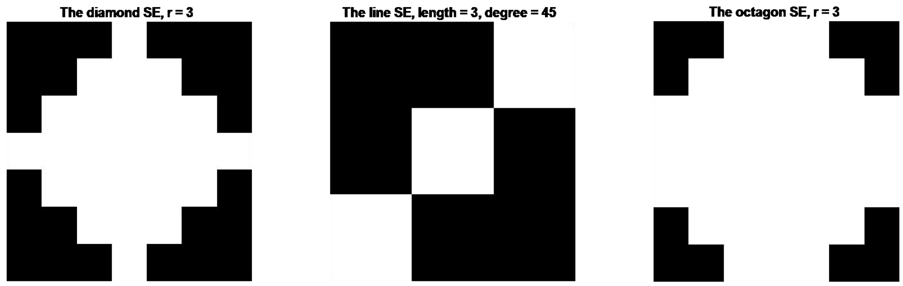

Figure 3. The different SE of various shapes and sizes

We will see that the choice of SE plays a very important role in mathematical morphology. If we do not find a suitable SE for the image, it is likely that we will not achieve our goal. The chosen SE usually has a shape and size identical with those of the objects in the image.

2. Morphological operators:

I applied 6 different operators on the cameraman image, using a square 3x3 SE.

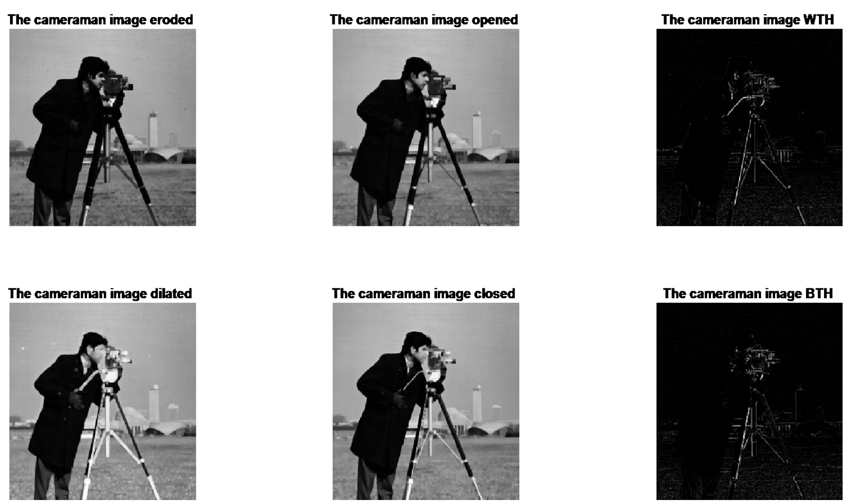

Figure 4. Six different operators applied to the cameraman image

We already saw the effects of the first 4 operators. The dilation extended the white spaces while the erosion narrowed them. The opening did make the tower behind appear sharper and the closing made the vertical holes in the house behind clearer to see.

The white top hat transform is defined as the difference between the input image and its opening, while the black top hat transform is defined as the difference between the closing and the input image. The former returned an image where the main features appear brighter than the surrounding, and the latter did the opposite. So they can be used to extract the objects from the background.

3. Other useful operators:

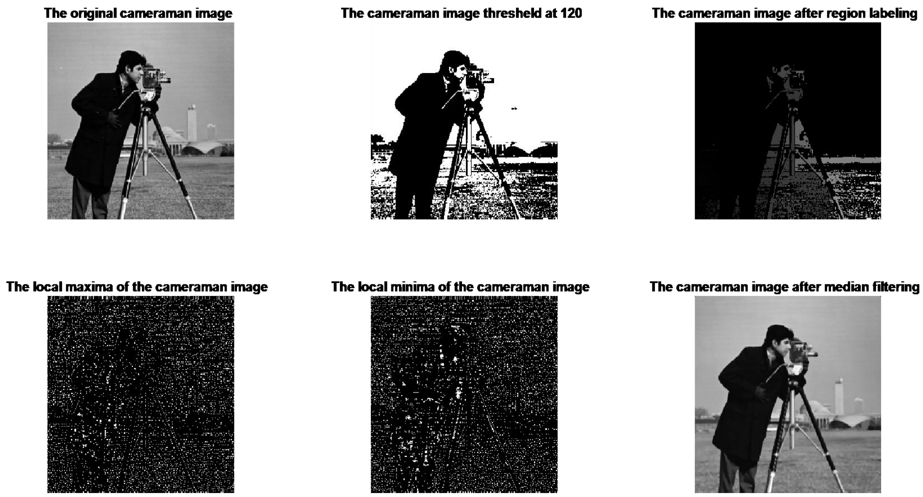

Figure 5. Some other useful operators applied to the cameraman image

Thresholding made the intensity values lower than a certain value go to 0 and the other ones go to 1. This can be used to highlight some objects while deleting other ones, which we will see later.

The local maxima and minima operators can help to find zones with high and low intensities locally.

Median filtering was shown in the last Lab to be effective against salt & pepper noise. It smoothes the difference between zones in an image.

Regions labeling was used to label the different zones in the image.

II. Image processing:

1. Extracting the tablets:

Our goal is to detect the missing tablet. I experimented with 2 approaches. For the first one, thresholding is applied at the beginning to eliminate the case around the tablets. This will cause some noises as some isolated pixels have high values of intensity.

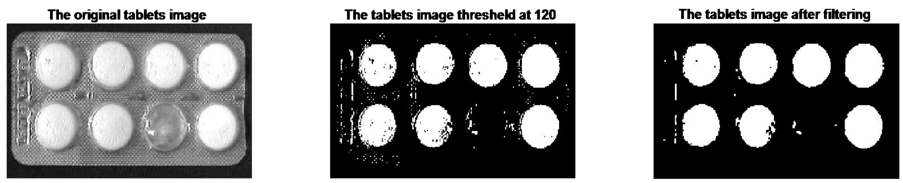

Figure 6. Extracting the tablets with mathematical morphology - 1st approach

To get rid of the noise, which is salt & pepper, I then applied a median filter as we saw in the last Lab that this type of filters is suitable for this kind of noise. We can now locate the missing tablet easily.

Then, for the second approach, I opened the image with a disk-shaped SE of radius 20 pixels in order to take the main objects to the foreground and eliminate the box behind.

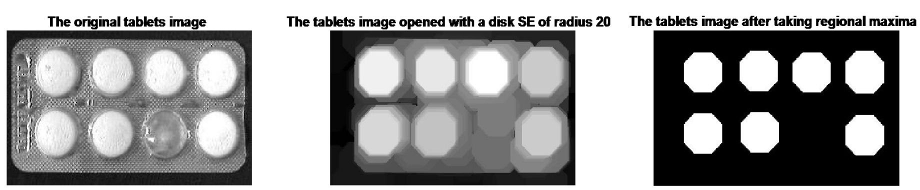

Figure 7. Extracting the tablets with mathematical morphology - 2nd approach

Then, by finding the local maxima, we can locate the tablets as well as the missing one.

2. Broken cookies:

Our goal is to detect the broken cookies. We want to locate these. First, thresholding at intensity 50 was used to separate the cookies from the background. Then, I applied White Top Hat with a disk-shaped SE of radius 60 pixels.

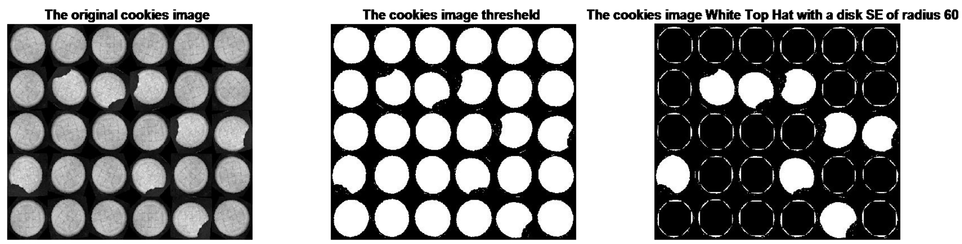

Figure 8. Locating the broken cookies with mathematical morphology

The white top-hat transform is defined as the difference between the input image and its opening. So the similarities (the unbroken cookies) are removed while the difference (the broken ones) are kept. We are now able to detect the broken cookies.

3. Area of choccolates:

Our goal is to find the average area (in number of pixels) occupied by the chocolates. First, we need to locate the chocolates in 2 steps. Thresholding (for intensity values smaller than 40) was used to pick out the chocolates and the box, and to later count the pixels occupied by the chocolates. Then, I used opening with a square SE of size 9 pixels to keep the chocolates and delete the box.

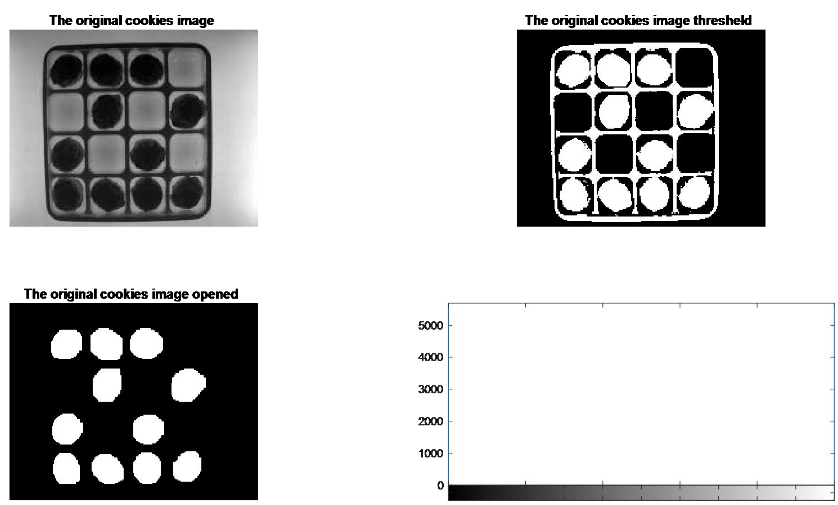

Figure 9. Calculating the average area occupied by chocolates

To find the area of chocolates, I obtained the histogram of the opened image. This has only 2 columns due to the thresholding. I counted the number of pixels with an intensity of 1, which correspond to the chocolates, and got a result of 7597 pixels. We have 11 chocolates in total, so on average, each of the chocolates has an area of approximately 690 pixels.

4. Caps of bottles:

Our goal is to keep only the bottle caps while deleting the box. First, I used opening with a disk-shaped SE of radius 5 to separate the caps from the background. Then I thresheld the image at 217 to obtain the final result:

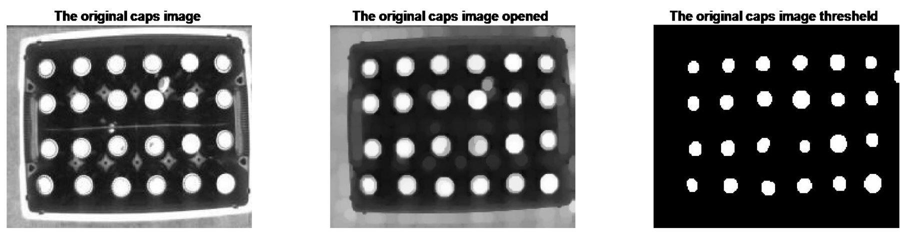

Figure 10. Extracting the bottle caps with mathematical morphology

We see that the bottle caps have been successfully extracted using the series of algorithms proposed.

5. Retina:

Our first goal here is to extract the vessels. For this, I applied the White Top Hat with a disk-shaped SE of radius 6 pixels to extract the vessels from the background using a SE. The vessels are still not very clear so thresholding of value 4000 was used next and this left some salt & pepper noise.

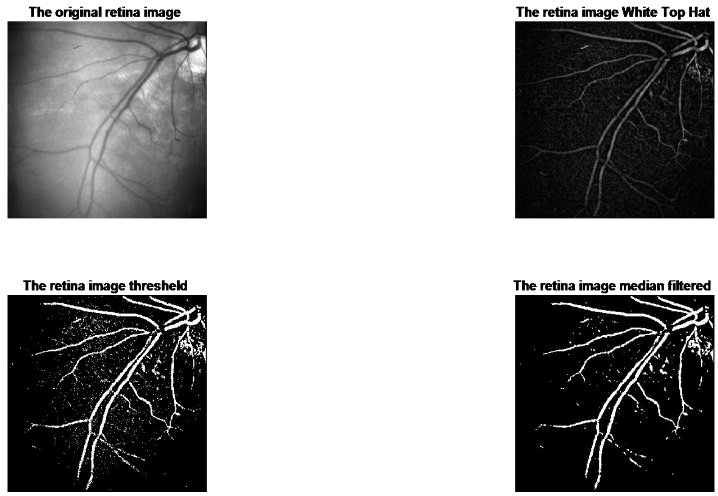

Figure 11. Extracting the vessels

To get rid of the salt & pepper noise, I applied a median filter. Finally in the last image we can see the vessels clearly.
Our next goal is to extract the optical nerve. The similarly procedure was used, but this time the SE was a disk of radius 100 pixels as the nerve is much bigger in size than the vessels.

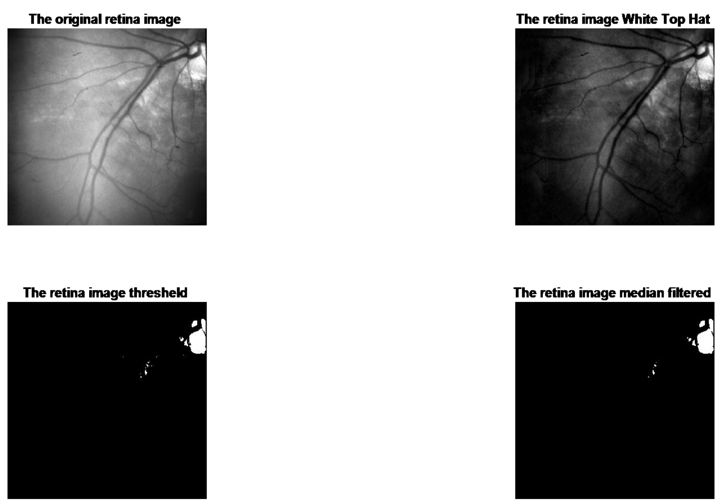

Figure 12. Extracting the optical nerve

After the final filtering step, we are now able to see the nerve. This case shows us the importance of choosing the right SE according to the targeted objects in the image. We had the same procedure but it was the SE that defines the object to be extracted. So to apply mathematical morphology, we would want to adapt the SE to the shapes and sizes of the desired objects.
The last goal is to enhance the image. I obtained the inverse of its background using thresholding (below 20000) and added it to the image (this equals obtaining the background and subtracting it from the image) to remove the dark zones around the image.

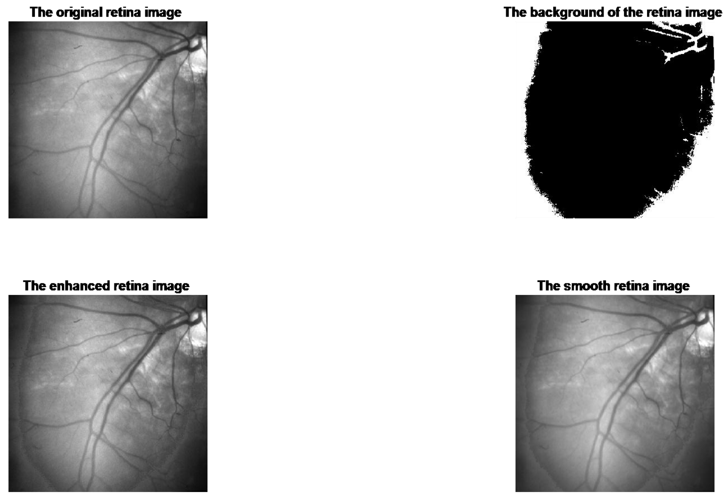

Figure 13. Enhancing the retina image

We see that the dark zones have been improved, but there is a sudden change in the intensity which makes the image unnatural. I then applied a median filter that redistributes these values to smooth the image. The last result is significantly better and to further enhance the image we can experiment and choose again other values for the thresholding.

6. Aligned cookies:

Our goal is to detect if the cookies are not aligned during mass production. By our eyes we see that the second and fourth columns each has one cookie that is out of line and we need to point out these columns. I closed the image with a disk-shaped SE of radius 33 pixels and this connected the cookies together. I then opened it with a rectangular SE of size [550 25] and it gave the lines which end where the out-of-line cookies are located.

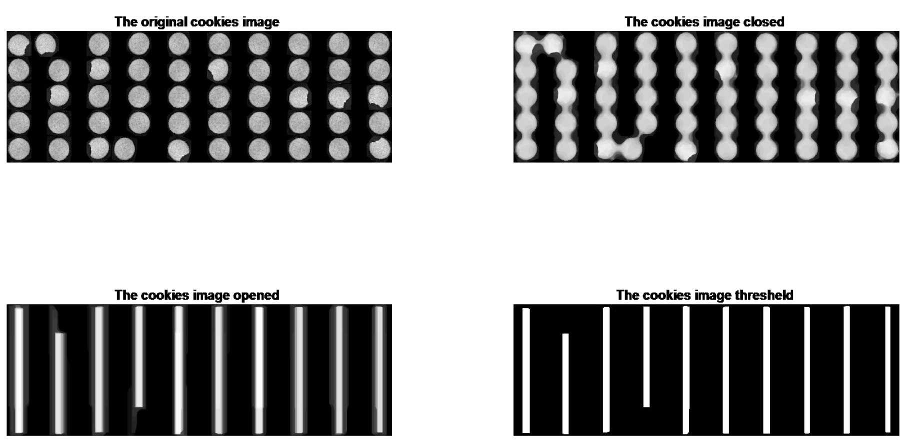

Figure 14. Detecting the out-of-line cookies

To make the result clearer, I thresheld the image at 125 and obtained a better result. We were able to not only locate the lines with the out-of-line cookies, but also where these cookies are.

Conclusion: This Lab helped understand the use of mathematical morphology to extract features of an image. After the Lab I understood the different operations using a SE to process an image, from object detection to image enhancement. Also, I learned the importance of choosing the suitable SE for processing a particular image.