Computer Aided Diagnosis
Assignment 5

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1 Assignment 1

1.1 Question 1

We investigated all techniques mentioned during the lecture. See below.

Dilation Dilation adds pixels around every pixel in the original image. This would cause the holes to at least shrink, and with a kernel equal to the radius of the biggest hole even close the holes. However, there is a side effect. Every object would grow since every border pixel is also surrounded with a number of pixels in every direction with a width of the radius of the biggest hole. This is not something that is desired, so we should look for an alternative.

Erosion Erosion removes pixels and thus cannot close holes. It might even connect two holes creating an even bigger one.

Hit or miss transformation This is a detection mechanism. It may be used to detect holes which can later be filled, so it is a candidate. The problem with this technique is that it is not straightforward and would need more engineering before it worked and even then it would be slowing as it combines multiple kernels and then the holes still need to be filled up!

Opening First applies erosion, which makes holes worse. Then applies dilation, which adds a border around the objects and might close some holes. This is not a good idea.

Closing This technique first applies dilation, which closes the holes but adds a border around the objects. Then it applies erosion which removes the border around objects. This means that in the end, holes are closed and the objects stay the same. This would be the best technique for closing holes.

In the end we can conclude that the best morphological technique for hole closing is **Closing**, which the name indicates as well.

Note, however that this only works for holes with a low intensity. If the holes instead are high intensity spots in a low intensity environment, we should opt for opening. Opening in this case, would lower the intensity of the holes by eroding them, after which dilation is applied to restore non-hole structures to their original shape. Thus it mimics closing in reversed conditions.

1.2 Implementation 1

See `mlErosionDilation.cpp`

1.3 Question 2

`We first applied dilation and then erosion, as this is equal to the closing technique we discussed in the answer to Question 1.`

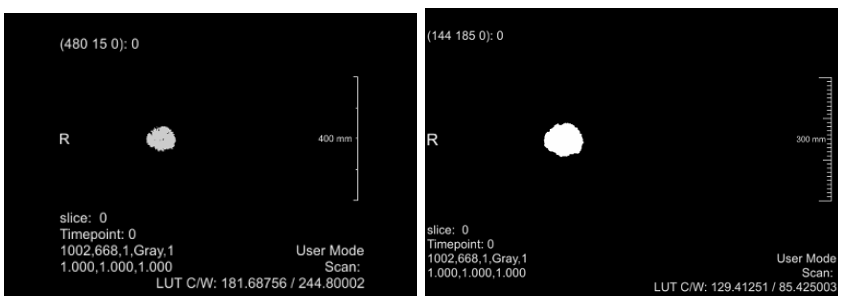

Figure 1: Thresholded red channel of retinal image on the left, with closing applied on the right.

1.4 Question 3

`The boundary is extracted by first eroding the image, then subtracting the eroded image from the original. For an original image, we use the result of the previous question. The results of this sequence of actions can be found in figure 2. The radius for both dilation and erosion is set to 5 pixels.`

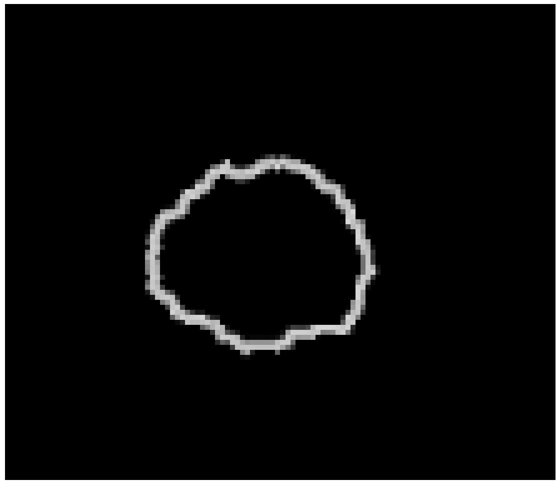

Figure 2: Border as extracted using subtraction of eroded image.

1.5 Question 4

Figure 3: Unwanted structures below the optic disc after applying a threshold of 230.

These structures can be removed by applying opening, i.e. first apply erosion then dilation. With erosion we remove the unwanted structures (under the assumption that the kernel size is larger than the unwanted structures), with dilation we restore the size of the optic disk.

2 Assignment 2

2.1 Question 5

We propose to use a black top-hat transform followed by appropriate thresholding on the resulting image. The reasoning for this proposal is that a black top-hat transform enhances dark figures in images and the vessels are dark in this picture. The thresholding step is important, since the top hat transform does not remove noise.

2.2 Question 6

The black top-hat transform shows the vessels as bright lines, while the white top-hat transform tends to enhance brightness that is close to dark spots. In figure 4 the black top-hat transform is shown on the left and the white top-hat is shown on the right. As can be seen, the black top-hat transform is better suited for vessel segmentation, since this transform highlights the vessels more clearly.

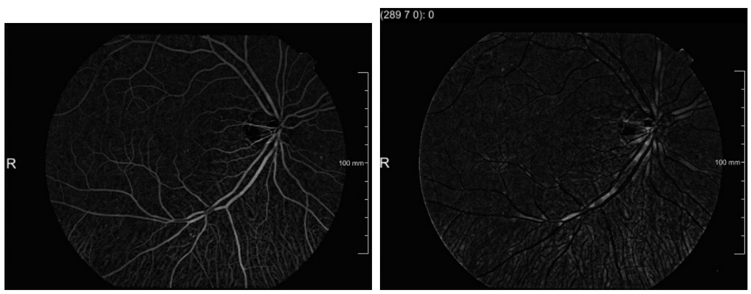

Figure 4: Black and white top-hat transform respectively applied to the retinal image

2.3 Question 7

Black tophat transform is used to extract black structures from an uneven background. It applies the following transformation to an image f: $(f \circ k) - f$ where k is the tophat kernel. The first step applies closing to the image with the kernel. This closes dark structures in light areas so that these structures are closed and the same colour as their surroundings. However, larger areas are not closed and remain black.

Then, the original image is subtracted from the closed image. This causes the areas that are white in the original image to become black in the resulting image, since $white - white = black$. The areas that were black in the original image but filled in the closed image (the dark structures we want to detect) remain white, since $white - black = white$. The larger black areas stay black since $black - black = black$. So all that remains in the resulting image are the black structures in the original image highlighted in white with the rest of the image in black.

2.4 Question 8

First a distance transform is performed on the the image calculating for all pixels of an object the distance to the edge. The points that lay the furthest are joined together to form the skeleton. We applied this to the result of the black top-hat, with a object minimum object value of 25 and a cavity volume of 10. The result of this is shown in figure 5

Figure 5: Skeleton of the vessels

3 Assignment 3

The steps for brain extraction in this assignment are different from the steps outlined in the morphology slides from last Monday's class. When using the steps in the assignment (with condition dilation as final step and using the thresholded image as a mask), the result is a mask with gaps in it since the mask contains gaps. When using the steps outlined in the slides (conditional dilation after the first erosion step, then performing closing) the result is a mask without gaps in it, resulting in a good mask for brain extraction. Since the method outlined in the slides results in a better mask, and it seems that that is the objective of this assignment, we have chosen to use the outline given in the slides.

3.1 Question 9

First, apply a binary threshold to the image. Then erode the image with a kernel such that the skull is removed from the image. Then perform conditional dilation with the eroded image as input and the thresholded image as mask, this is done to restore the shape of the brain's border. Since the conditionally dilated image still contains some gaps (since the thresholded image contained some as well), closing should be performed with a relatively small kernel size to both close the gaps in the brain and preserve as much of the brain border's shape as possible.

3.2 Question 10

We used a threshold value of 70 on the original image.The result of this threshold is shown in figure 6. With this threshold the skull and the brain are disconnected. The is desirable since the skull area's which are still connected to the brain won't be removed by erosion.

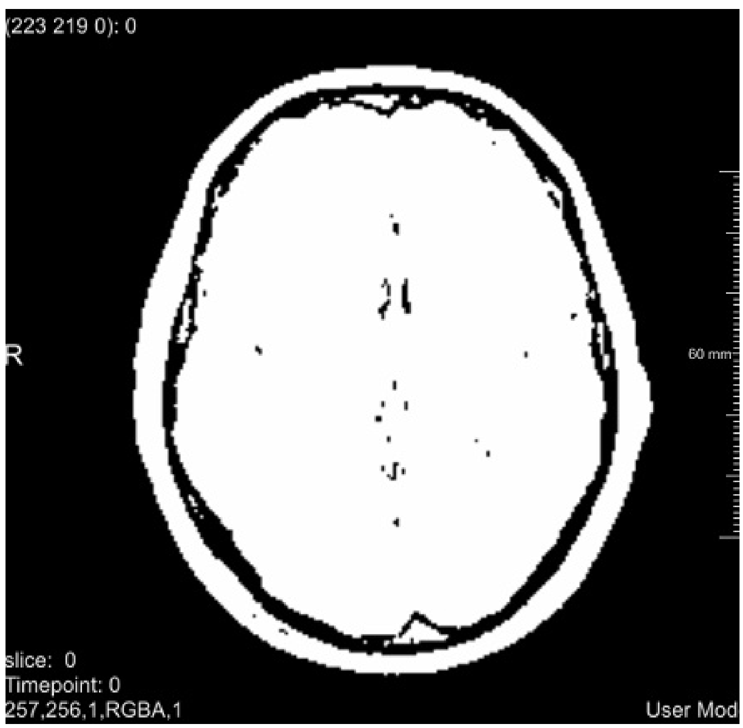

Figure 6: The thresholded image

3.3 Question 11

The goal of the erosion operation is to remove the skull from the image. To accomplish this, the kernel size needs to be sufficiently large, we used a circular kernel with a diameter of 13 pixels, resulting in the image shown in figure 7.

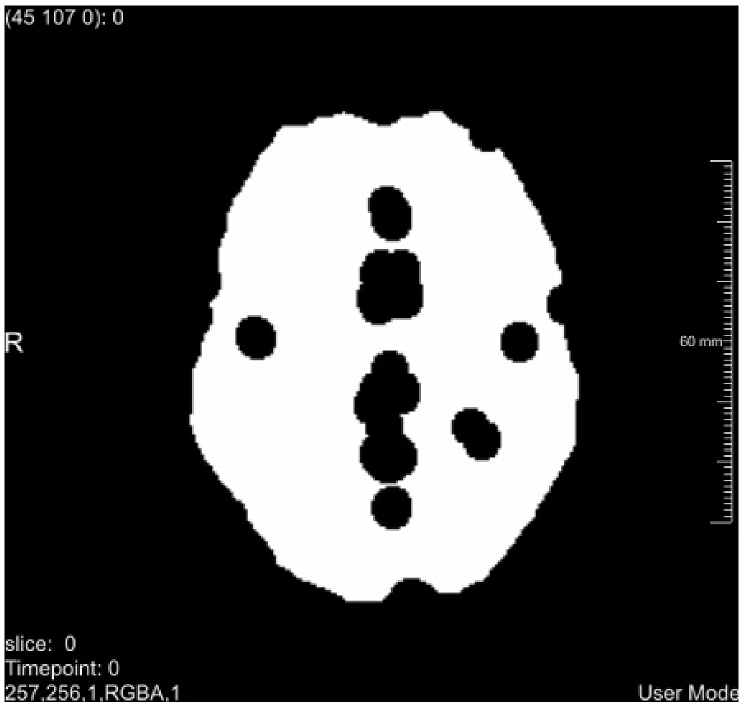

Figure 7: Thresholded image with the skull eroded out.

3.4 Question 12

We applied closing to to remove holes, using spherical filters of size 3 for both the dilation and the erosion step. The result of the operation is shown in figure 8. As we noted in the beginning of assignment 3 we applied this after the conditional dilation (which we will discuss more in question 13).

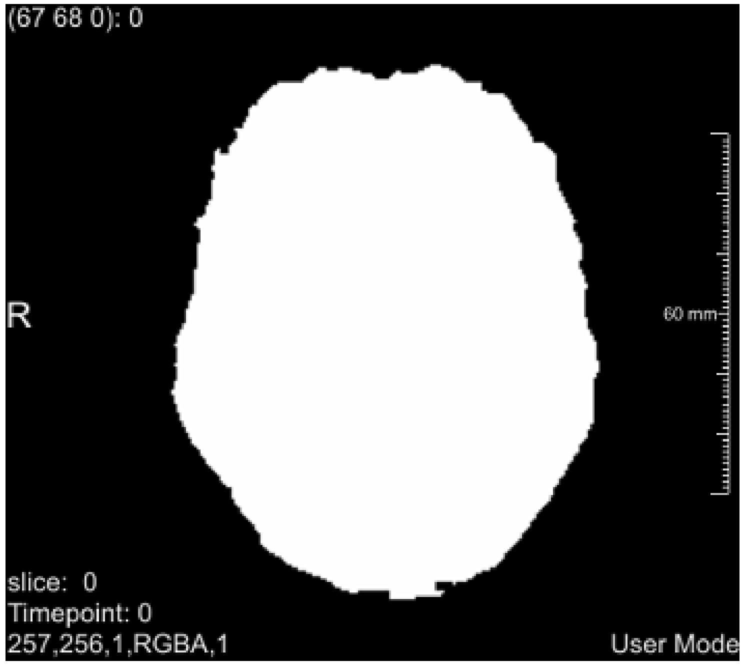

Figure 8: Result of the closing operation (after applying conditional dilation)

3.5 Question 13

The module consists of 5 terms: Grayscale, Geodesic, Dilate, Image and Filter. We will explain these terms and then explain how they are connected and what they accomplish. Grayscale and geodesic refer to the type of image that the module can be applied to: 1-channel 3D images. In our case the images are binary and not grayscale, but the same principles apply. Also, the image has only 2 dimensions so the geodesicity part is not useful.

Dilate Image refers to the first operation that is applied, namely dilation of the input image with a kernel. This kernel is a radius-one with face neighbors only (so 4 neighbors in 2 dimensions). Since the input image is a closed thresholded image, it simply increases the area of the region by a bit. This is to ensure that the area is larger than the original area (since it might have shrunk during closing). We will call this image the diluted image. The area is larger than the brain, but the skull is already removed.

Filter refers to the second operation, namely applying a mask to the image. This mask has to be supplied by the user. In the case of grayscale this mask will result in the minimum of the mask and the dilated image. In binary images, as we used for this assignment, this equals the logical AND operator. Thus the resulting image is the original image dilated and masked with the mask. Since we used the thresholded original image as the mask, the result is the overlap between the dilated image and the thresholded original image. This masking removes the excess area generated during closing and dilation. Since the diluted image does not contain the skull, the resulting image does not either. Since the thresholded original image does not contain anything other than the brain and the skull, and the skull is removed, all that remains is the brain.

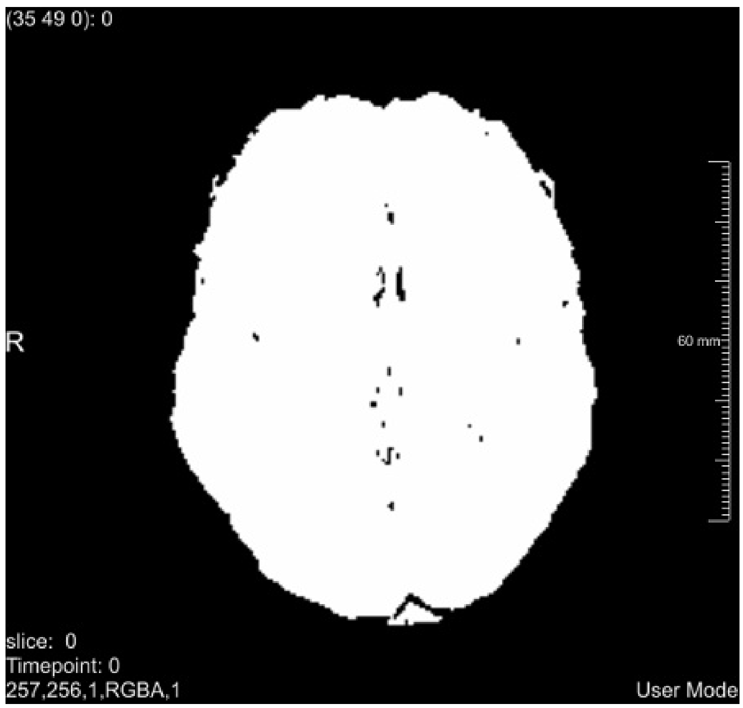

Figure 9: The result of conditional dilation (after the first erosion step)

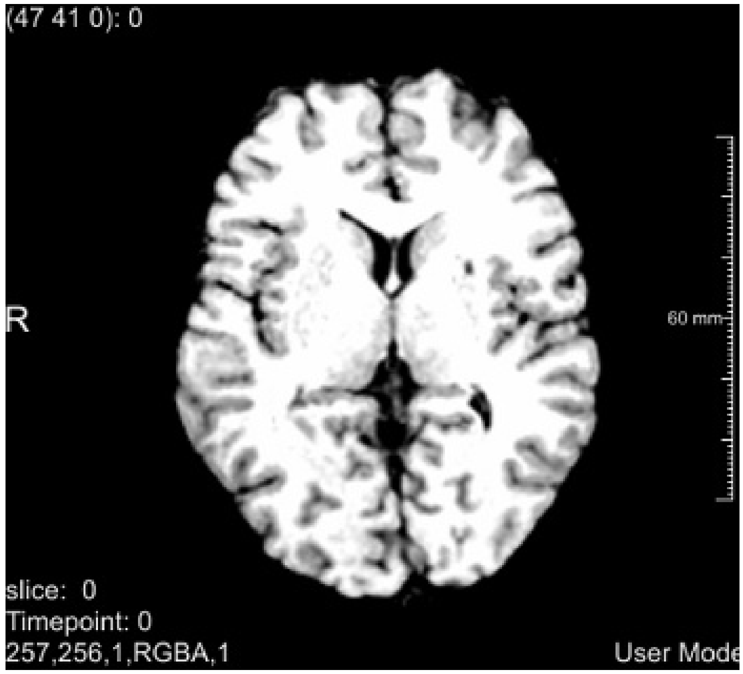

Figure 10: The result of the whole skull stripping process