EE475 HW#6 SEZEN PERÇİN

1. **Opening to find the correct connected components:**

	1	1	1						
	1	1	1	1					
	1				2	2	2	2	
					2	2	2	2	
	3	3	3		2	2	2	2	
	3	3	3		2	2	2		
					2				
		4	4	4	2	2	2	2	
			4	4	2	2	2		

Connected components before

	1	1	1						
	1	1	1	1					
	1				2	2	2	2	
					2	2	2	2	
	3	3	3		2	2	2	2	
	3	3	3		2	2	2	2	
					2				
		2	2	2	2	2	2	2	
			2	2	2	2	2		

Connected components after

I checked every pixel on every row one by one, therefore first there were 4 components detected. However, as the operation continued it was seen that 4 is equal to 2.

		1							
		1	1						
						1	1		
						1	1		
		1				1	1		
		1				1	1		
			1	1	1	1	1		
				1	1	1			

$A \ominus B$

	1	1	1						
	1	1	1	1					
					1	1	1	1	
					1	1	1	1	
	1	1	1		1	1	1	1	
	1	1	1		1	1	1	1	
		1	1	1	1	1	1	1	
			1	1	1	1	1		

$(A \ominus B) \oplus B$

		0							
		0	0						
						0	0		
						0	0		
		0				0	0		
		0				0	0		
			0	0	0	0	0		
				0	0	0			

$(A \ominus B)^C$

1	1	1	1	1	1	1	1	1	1
1	1	0	1	1	1	1	1	1	1
1	1	0	0	1	1	1	1	1	1
1	1	1	1	1	1	0	0	1	1
1	1	1	1	1	1	0	0	1	1
1	1	0	1	1	1	0	0	1	1
1	1	0	1	1	1	0	0	1	1
1	1	1	1	1	1	1	1	1	1
1	1	1	0	0	0	0	0	1	1
1	1	1	1	0	0	0	1	1	1
1	1	1	1	1	1	1	1	1	1

$(A \ominus B)^C$ with 1's extending outside

	0	0	0						
	0	0	0	0					
	0				0	0	0	0	
					0	0	0	0	
	0	0	0		0	0	0	0	
	0	0	0		0	0	0	0	
					0				
		0	0	0	0	0	0	0	
			0	0	0	0	0		

A^C with only zeros

1	1	1	1	1	1	1	1	1	1
1				1	1	1	1	1	1
1					1	1	1	1	1
1		1	1	1					1
1	1	1	1	1					1
1				1					1
1				1					1
1	1	1	1	1		1	1	1	1
1	1								1
1	1	1						1	1
1	1	1	1	1	1	1	1	1	1

A^C with only ones

1	1	1	1	1	1	1	1	1	1
1	1	0	1	1	1	1	1	1	1
1	1	0	0	1	1	1	1	1	1
1	1	1	1	1	1	0	0	1	1
1	1	1	1	1	1	0	0	1	1
1	1	0	1	1	1	0	0	1	1
1	1	0	1	1	1	0	0	1	1
1	1	1	1	1	1	1	1	1	1
1	1	1	0	0	0	0	0	1	1
1	1	1	1	0	0	0	1	1	1
1	1	1	1	1	1	1	1	1	1

$A^C \oplus B$ which is the same as $(A \ominus B)^C$

A musical sheet processing algorithm

The note heads can be extracted from the image by performing erosion and dilation operations with the proper structural elements.

First thing to do would be converting the image to a binary image. Since the objects we desire and the ones that we wanted to erase are not represented as 1s but 0s, the binary complement of the can be took in order to perform erosion and dilation operations.

After the conversion, the staff lines can be found by applying the erosion with a horizontal structural element e.g [1 1 1 1 1 1]. Then a dilation can be applied to the resultant image with the only staff line components. For the dilation, the structure element could be chosen to have 2 dimensions in order to make the elements sharper e.g [1 1 1 1 1; 1 1 1 1 1]. After the detection of the staff lines, they can be removed by subtracting the resultant image from the converted binary image we obtained at the beginning.

For the vertical line components, the staff lines, the same procedure with a vertical structure element can be applied.

If the image is investigated, it can be seen that the note heads can be estimated by a disc with radius of 2. To perform another dilation operation the complement of the image is taken again so that the remaining elements will have the value of 0 and the background has the value 1.

Then a dilation operation with a structural element that is disc-shaped will be applied. Although the note heads can be estimated by a disc with radius 2, it is better to choose r as 1 since a clear information of the position of the center pixels that belong to the head notes are desired.

As a result, the regions can be found, where no pixel with the value of 1 are present in the neighborhood. Those regions could be taken as the position of the center pixels that belong to note heads.

Since there would be no homogeneous region on the clefs that are disc-shaped (with r =1) they would be eliminated on the previous step. But if they are not more specific algorithms could be used where the shape of the clefs is searched and deleted from the image (e.g. the HW question where we found the letter of a in the text). The same specific algorithms can be applied to find the full notes.

After the position of the note heads are calculated and no other distinct element are presented in the image, the complement of the last step is taken where center pixels (of the note heads) are 1 and others 0. This image can be dilated by using a structure element of a disc with radius

2 (the general size of the note heads is considered) and the final result would be the note heads at their true position and estimate by a disc with radius 2.

More morphology:

1		1
	1	

1		1
	1	
		1

		1
	1	1
		1

	1	1									1	1		
	1	1	1	1	1	1	1	1	1	1	1	1		
	1	1									1	1		

		1
	1	1
		1

	1										1			
	1	1	1	1	1	1	1	1	1	1	1			
	1	1	1	1	1	1	1	1	1	1	1			
	1	1								1	1			

1		1
	1	

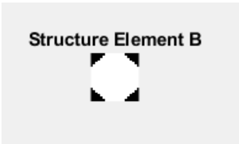
	1	1	1								1	1	1	
	1	1	1	1	1	1	1	1	1	1	1	1	1	
	1	1	1	1	1	1	1	1	1	1	1	1	1	
	1	1	1	1	1	1	1	1	1	1	1	1	1	
	1	1	1								1	1	1	

	1										1			
	1	1	1	1	1	1	1	1	1	1	1			
	1									1	1			

1		1
	1	
		1

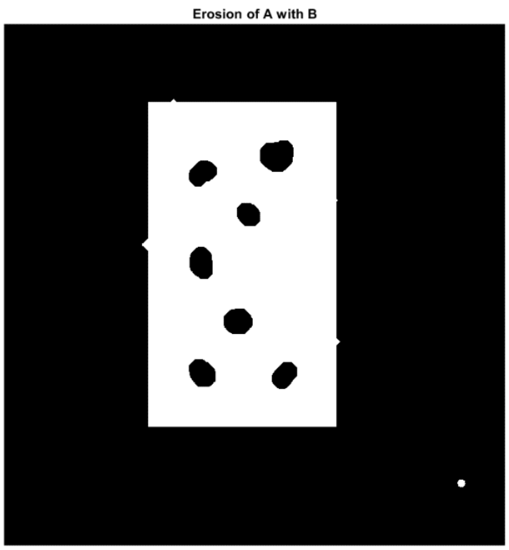
Fig. 9.3

Prob. 9.23 Clean the debris:



For this question I constructed the structural element which has radius of 11 by using the function strel('disk', 11). The resultant disk is not perfectly smooth and can be seen on the left. Also, for the code zero padding in used to check if the pixels on the edges contain or intersect with the foreground.

Erosion of A with B:



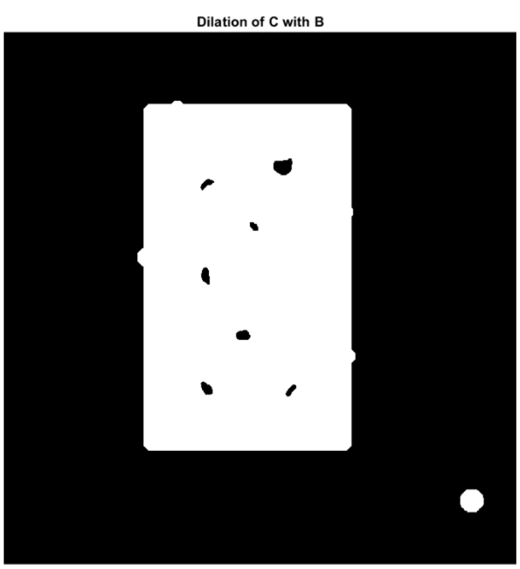
After the erosion is applied to A with structural element B, since the small pieces (debris) on the background do not completely contain the entire structural element (region with 1s), they would get the value of 0 and be erased.

In opposition to that, the foreground debris became larger since the regions that were in touch with the white areas also would not contain the entire structural element. They would also have the shape of curves which are similar to a disk since the structural element is disk-shaped (even though it is not smooth). The rectangular region area also became smaller.

There are a few regions where the white background region touches the foreground and intersect with the white debris. On these regions the side of the rectangles are distorted since those pixel neighborhoods contain the whole structural element and have the value of 1.

Lastly there is an another region with white pixels on the right below because the structural element was represented there.

Dilation of C with B resulting in D:

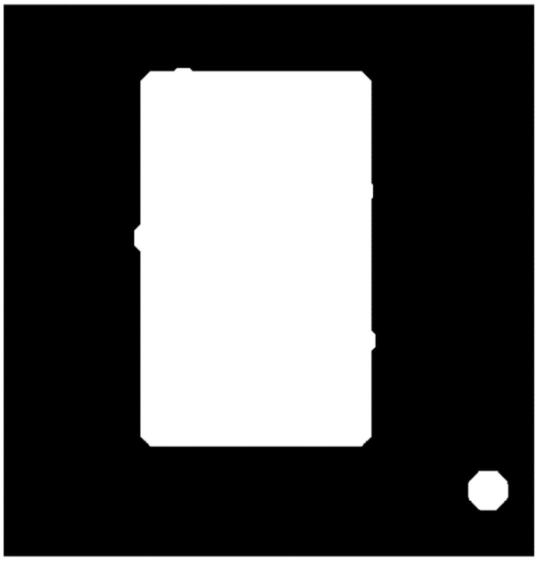


After the dilation operation is applied to image C from the previous step, the debris became smaller since all the points which have an intersection with the nonzero neighborhood determined by the structural element will have the value of 1.

In previous step, the rectangle boundaries (corners) were sharp since they were only determined by the center pixel. In this case for every center pixel, a disk shape is introduced causing the corners to have curve-shapes. The sides are still sharp because they were determined by the pixels that are tangent to the structural element.

Dilation of D with B resulting in E:

Dilation of D with B



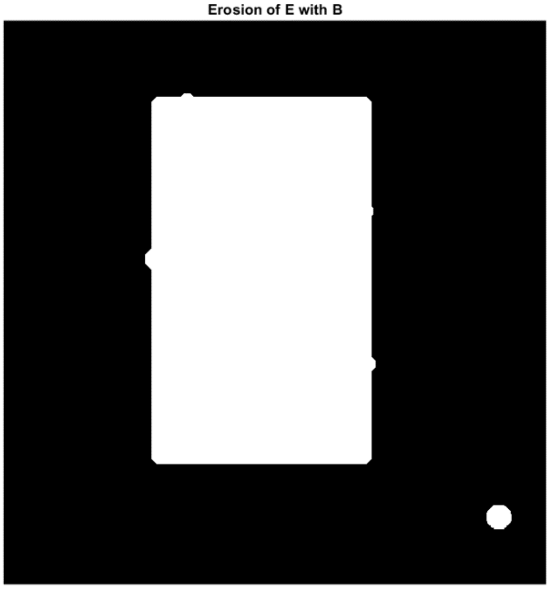
After the second dilation operation overall image shapes experience a growth in their areas. That is due to the extra pixels that are determined by the intersection of the structural element with the corresponding neighborhood. Therefore, the debris (black) on the foreground is now gone.

The corners are now more alike to the boundaries of the structural element. If a smoother disc could be generated more smooth curves could be introduced to the corners.

It can be said that the overall size of the foreground is increased, and the edges became more alike to the structural element boundaries. The sides remain unaffected (as a line) because they were determined by the pixels that are tangent to the structural element.

Erosion of E with B resulting in F:

Erosion of E with B



Since the enlarging effect of the dilation and the shrinking effect of the erosion, after 2 dilation and 2 erosion operations now the size of the foreground is much close to the original image.

The white debris that were touching to the foreground rectangular could not be removed from the rectangular. After the erosion, the boundaries and the corners became sharper since they are not determined by the neighborhood of the SE but by the center pixels.

Prob. 9.34: Some grayscale morphology

Original Image

Grayscale Dilated A

Grayscale Eroded B

Morphological Gradient of C

After the dilation, the background debris became smaller. Then the erosion operation is applied to neutralize the enlarging effect of the dilation. In the meantime, the noise presented the image became erased after these two operations. Then the difference between the dilated and erosion version of C is obtained which is the morphological gradient of the C. At the end, the morphological features of the original image are obtained. It can be said that this gradient gives us information about the edges and boundaries that are present on the skull.