ACTIVITY 6

Morphological Operations

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APPLIED PHYSICS 157

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Objective 1

Increase knowledge about string theory by performing erosion and dilation.

Objective 2

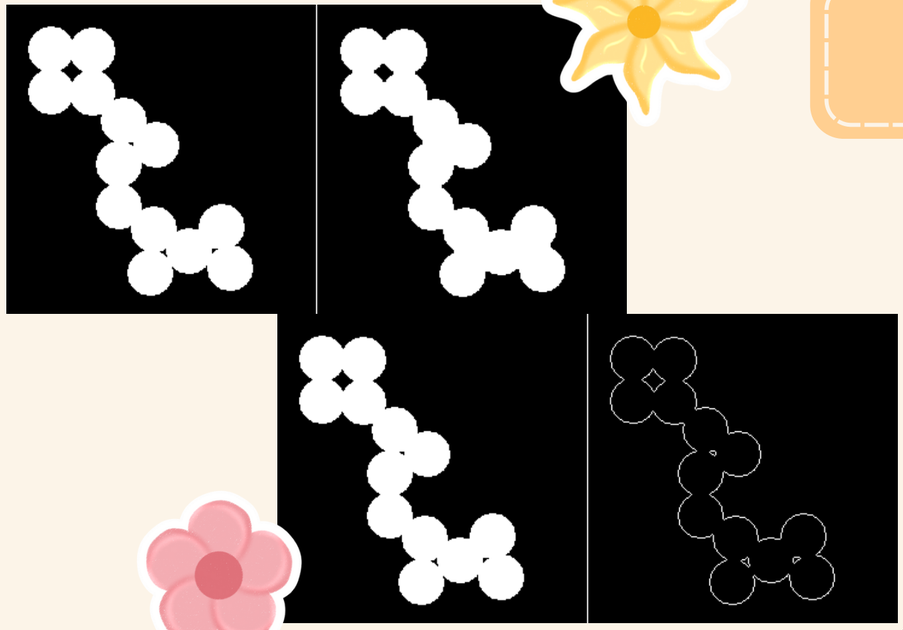
Use morphological operations to eliminate noise and improve the segmented image.

Objective 3

Discover different morphological operations and how they operate on images.

INTRODUCTION

Mathematical morphology is a valuable area of study within image processing, offering significant operations such as erosion, dilation, opening, and closing. Each of these morphological operators requires two sets of information. The first is the input image, which can be binary or grayscale for most operators. The second is the structuring element which plays a crucial role in defining how the operator affects the image with specific details [1]. In this activity, we will use morphological operations in image analysis.



Intro

01

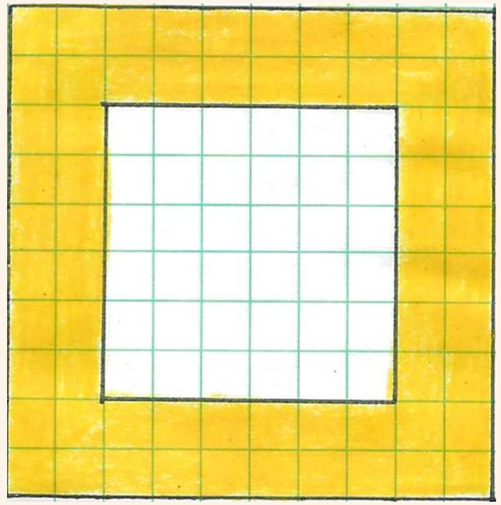
ACTIVITY 6.1

Morphological operations make use of set theory. In this activity we will increase our knowledge about set theory. Also, we will try to predict what happens when we perform erosion and dilation on certain images.

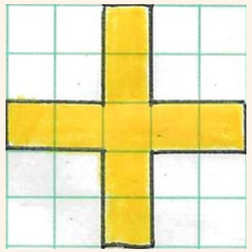
IMAGES

Below we have the shapes that we will be using for this activity. We have a 5x5 square, a hollow 10x10 square with thickness of 2, a plus sign with thickness of 1 and length of 5 on both axis, and a dumbbell with two 5x5 squares with a 3x1 connecting line. I hand-drawn these images to be used to predict what happens when we apply erosion and dilation to them. The next slide shows the elements that we will use to operate on them.

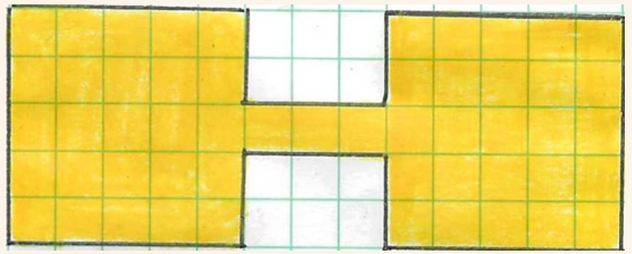
square



holllow square



plus sign



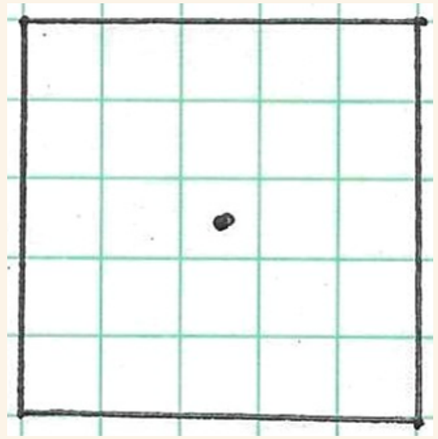
dumbbell

STRUCTURING ELEMENT

Structuring elements are sometimes called the kernel. The structuring element is composed of a pattern defined by the coordinates of several distinct points in relation to a reference point. Typically, Cartesian coordinates are employed, making it convenient to represent the element as a small image on a rectangular grid. Each structuring elements below has the origin marked by a dot. Note that the origin does not have to be in the center of the structuring element [1]. We will use these to dilate and erode the images from the previous slide.

SE 1

SE 2



SE 3

DILATION

First, we'll look at dilation. Dilation is one of the fundamental operators in mathematical morphology. While it is commonly used with binary images, there are also variants that can be applied to grayscale images. The primary function of dilation on a binary image is to gradually expand the boundaries of foreground pixels (typically represented as white pixels). As a result, regions consisting of foreground pixels increase in size, while the gaps or holes within those regions becomes smaller [2]. The next slide shows the resulting images after we use the structuring elements to dilate the original images that we have.

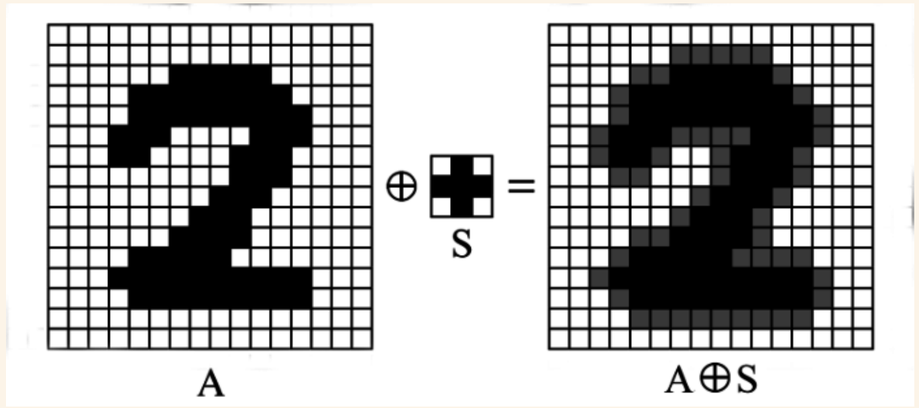


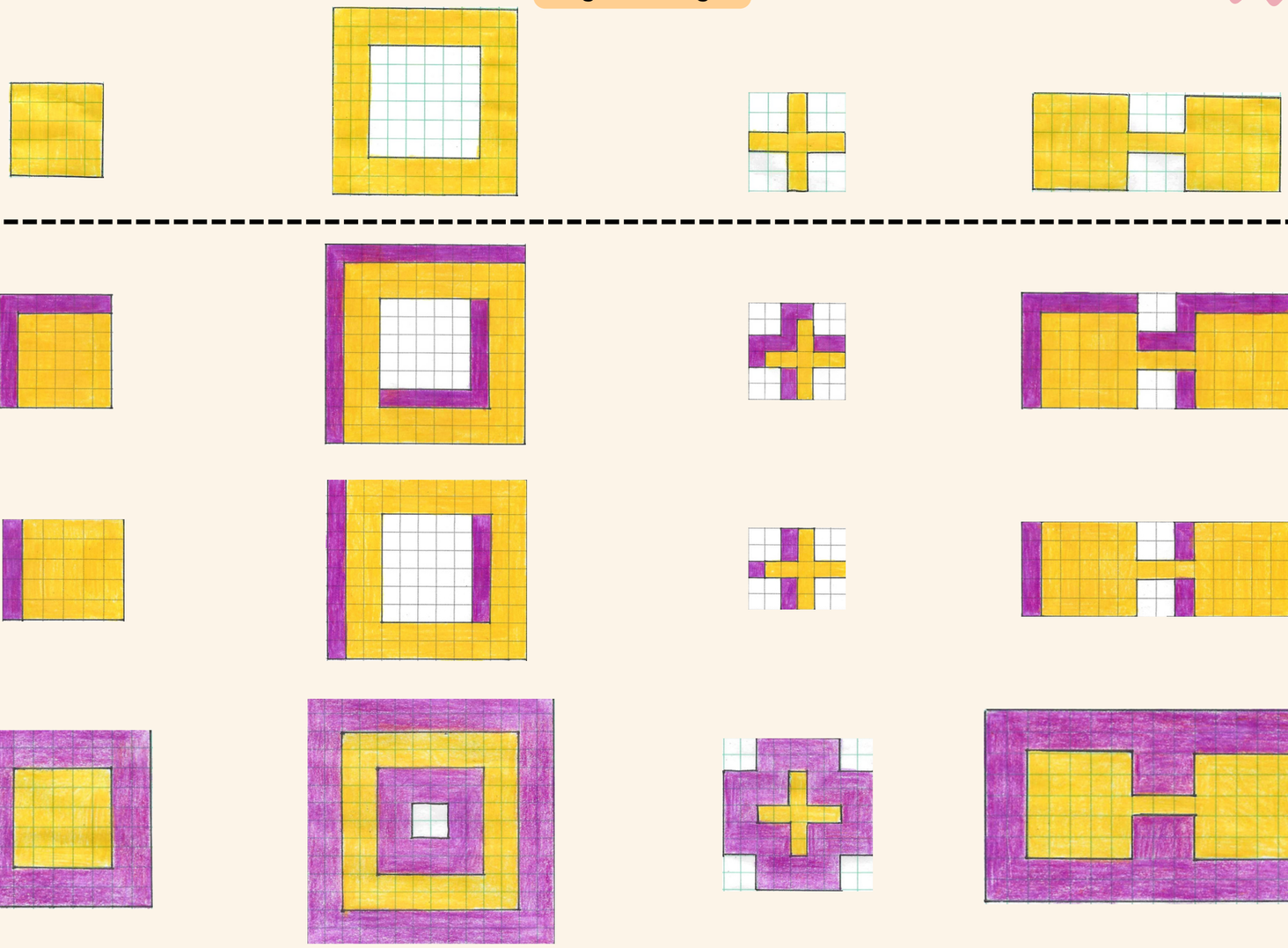
image referece: researchgate.net/figure/The-dilation-of-an-object-by-a-structuring-element_fig2_305375221

DILATION

–foreground pixels

–added pixels due to dilation

Original Images



Structuring Elemetns

DILATION : IMDILATE

From the previous slide, we see that the original images expanded when we dilated them using the structuring elements. Moreover, the hollow part of the the 10x10 box becomes smaller because it was filled in. Overall, we can see firsthand what dilation does to particular images. To verify our results, let's turn the original images to arrays and use a function in MATLAB: `imdilate.`

`imdilate` is a morphological operation in MATLAB that dilates a grayscale, binary, or packed binary image using the structuring element SE. Its simplest syntax is

```
J = imdilate( I , SE )
```

where I is the image and SE is the structuring element. This structuring element is created using the `strel` function [3,4]. How does strel function work?

STREL

A strel object represents a flat morphological structuring element that is crucial for performing morphological dilation and erosion operations. The center pixel of the structuring element, known as the origin, specifies the pixel within the image under processing [4]. The usual syntax of strel function assumes the center pixel as the structuring element. However, the structuring elements that we will be using, except the 5x5 square, do not have the origin at their center pixel. Therefore, we need to do some manipulations. Since the strel function only considers the true pixels (numbered 1), we can use this to our advantage. I created 3x3 arrays and placed the desired origin at index (2,2) which is the center of the arrays. Shown below is the code I created for the structuring elements.

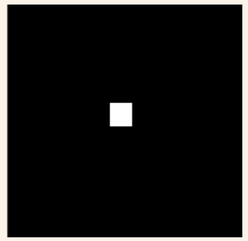
```
%structuring elements
SE1 = strel([0 0 0; 0 1 1; 0 1 1]); %2x2 square
SE2 = strel([0 0 0; 0 1 1; 0 0 0]); %2x1 line
SE3 = strel("square", 5);           %5x5 square
```

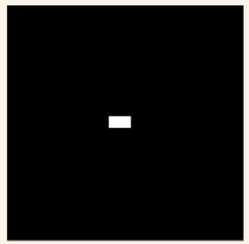
The next slide shows the resulting images after dilation.

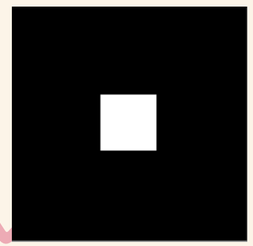
DILATION

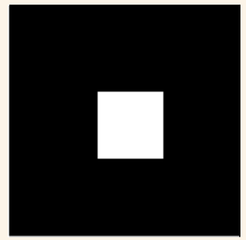
Original Images

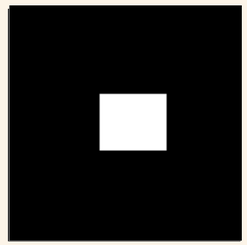
Structuring Elemetns

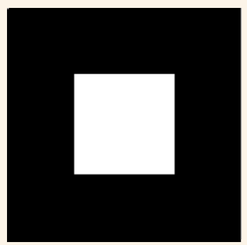


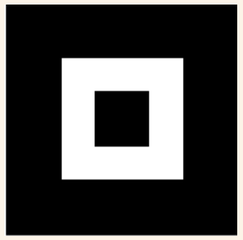


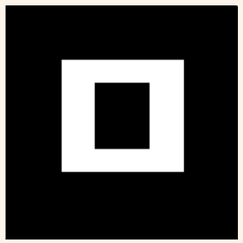


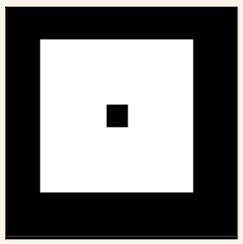


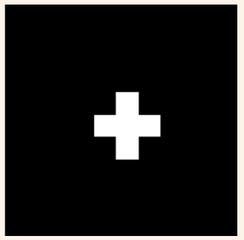


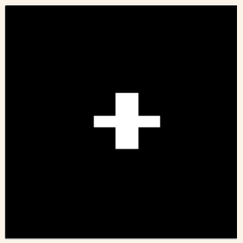


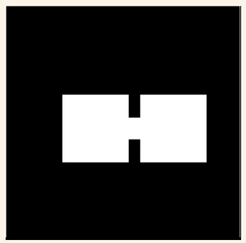


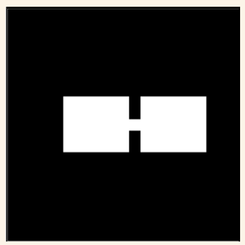


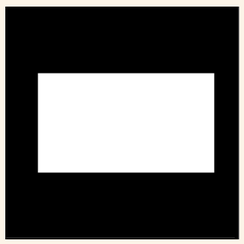












Our results are verified! Now, let's move on to erosion.

EROSION

Now, let's see what happens with erosion. **Erosion,** along with dilation, is a fundamental operator in mathematical morphology. While erosion is commonly used with binary images, there are also versions that can be applied to grayscale images. When applied to a binary image, the primary impact of the erosion operator is to **gradually remove the boundaries** surrounding regions of foreground pixels (typically represented as white pixels). Consequently, areas composed of foreground pixels reduce in size, and any existing holes within those areas expand [5]. Using the structuring elements that we have, the eroded images are shown in the next slide.

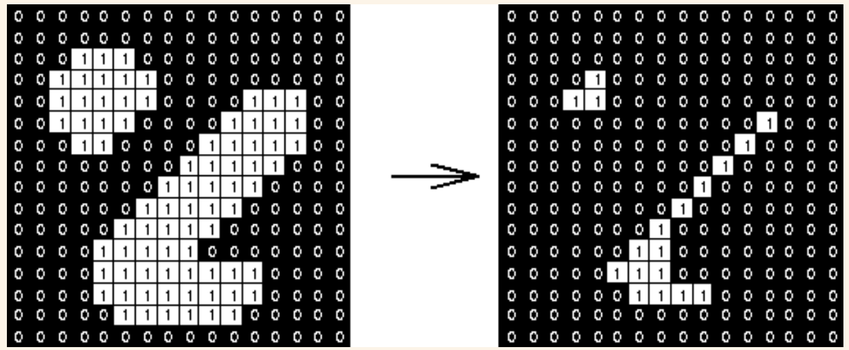


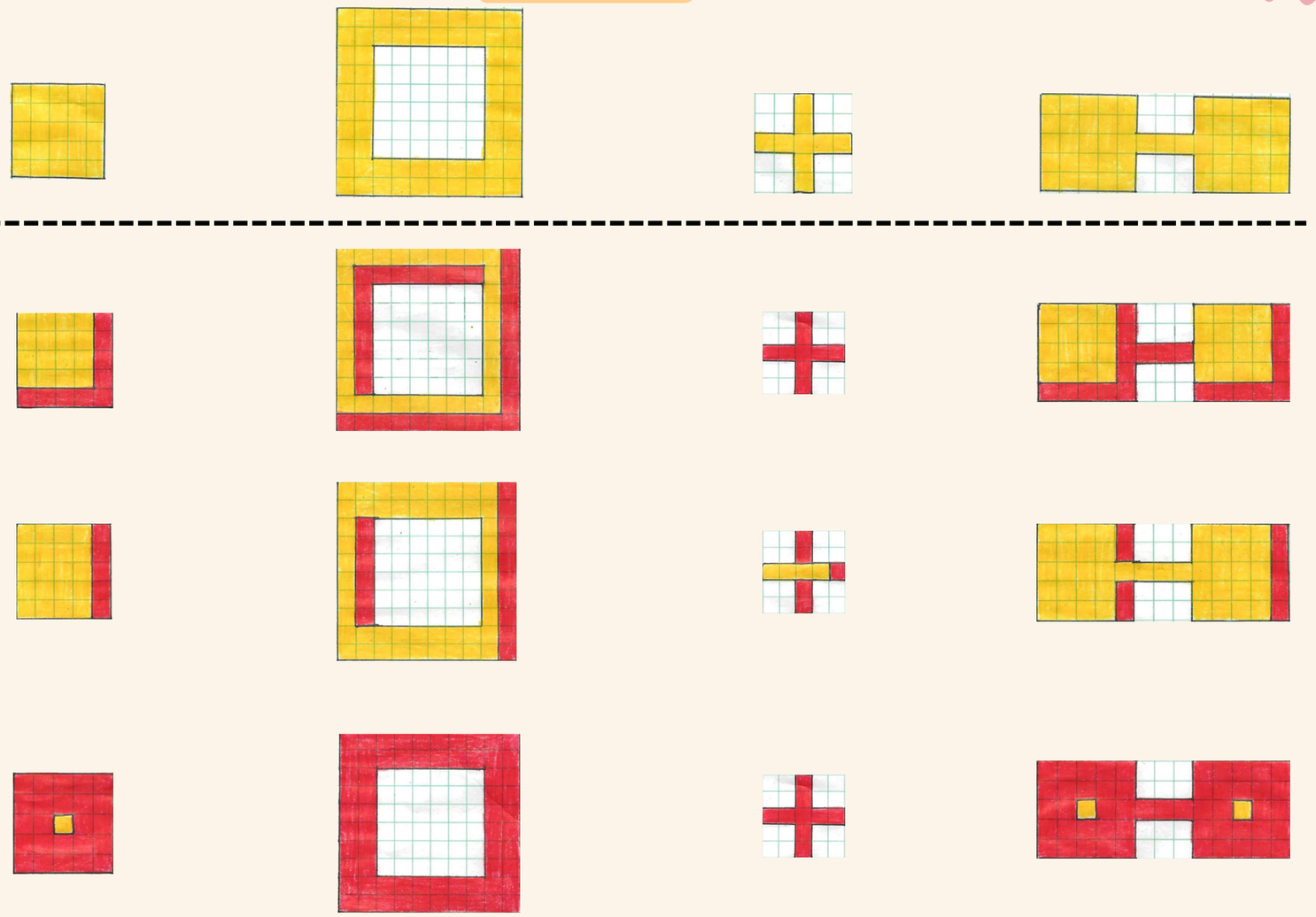
image referece:
https://homepages.inf.ed.ac.uk/rbf/HIPR2/erode.htm

EROSION

–foreground pixels

–eroded pixels

Original Images



Structuring Elemetns

EROSION: IMERODE

From the previous slide, it is shown that the original images decreased in size; some even disappeared completely. Moreover, the hollow part of the 10x10 square expanded. Now, to verify the results, we will perform erosion in MATLAB by using the function: imerode.

imerode is a morphological operation in MATLAB that erodes a grayscale, binary, or packed binary image using the structuring element SE. Its simplest syntax is

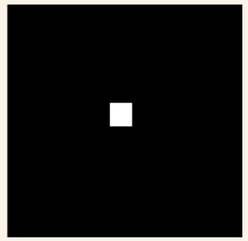
```
J = imerode( I , SE )
```

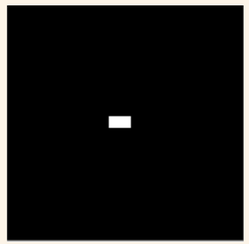
where I is the image and SE is the structuring element [6].
The next slide shows the resulting images after applying erosion to the original images.

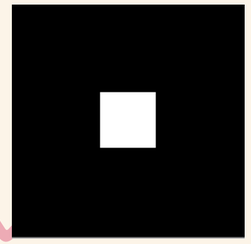
EROSION

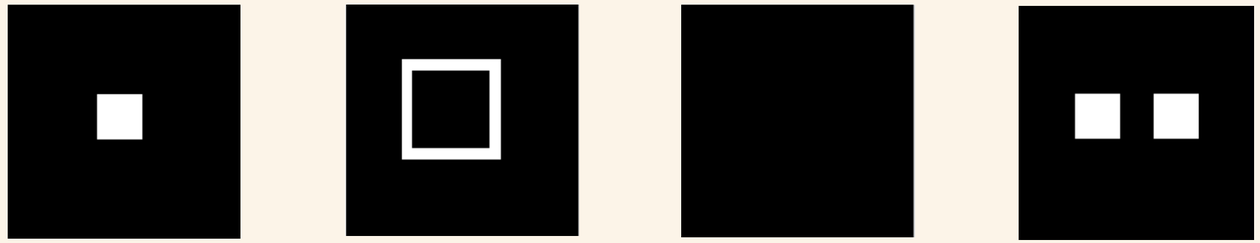
Original Images

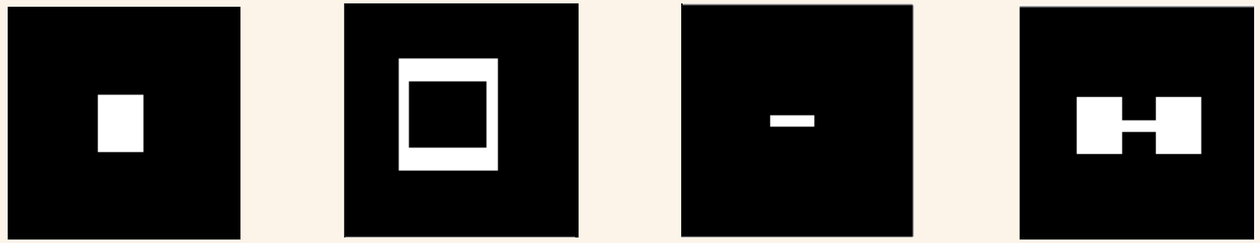
Structuring Elemetns











The results are verified!

02

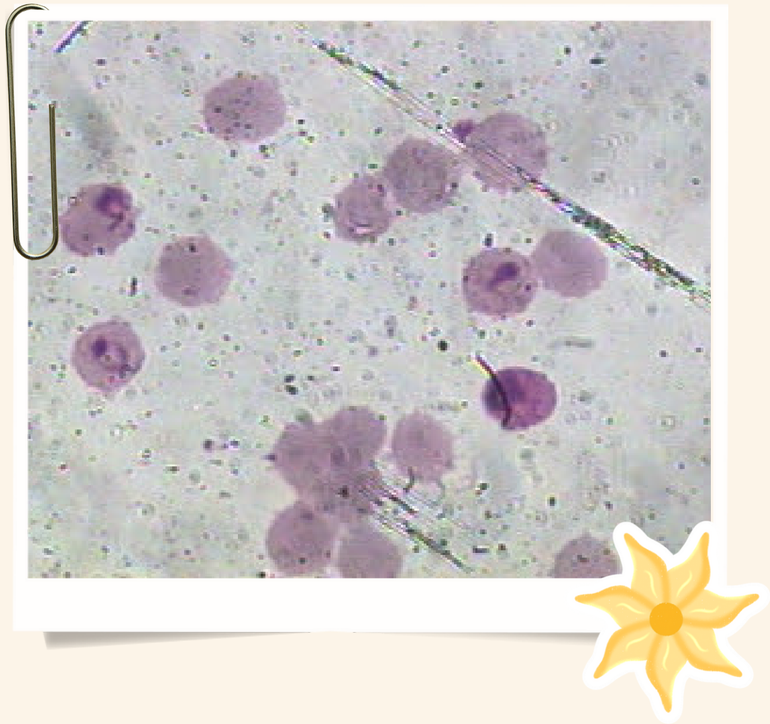
ACTIVITY 6.2

In this activity, we will use different morphological operations on segmented images to eliminate noise and isolate only the regions of interest.

ACTIVITY 6.2

MORPHOLOGICAL OPERATIONS

From Activity 5, we learned how to segment images. However, after segmentation, there are usually noise or small pixels that light up that are not part of the regions of interest. To clean up the image and eliminate these noise, we use different morphological operations. Here, we demonstrate the different morphological operations and choose which best to use for a particular image of malaria. Our goal is to segment the image, eliminate noise, and determine the best operation to use. For this demonstration we will use bwmorph majority, opening, and closing.



MORPHOLOGICAL OPERATIONS

BWMORPH MAJORITY

You can apply specific morphological operations to binary images using bwmorph function. A specific operation is majority which sets a pixel to 1 if five or more pixels in its 3x3 neighborhood are 1; otherwise, it sets the pixel to 0 [7].

IMOPEN

Morphological opening is an erosion followed by a dilation, using the same structuring element. The imopen function performs this operation on grayscale or binary images.

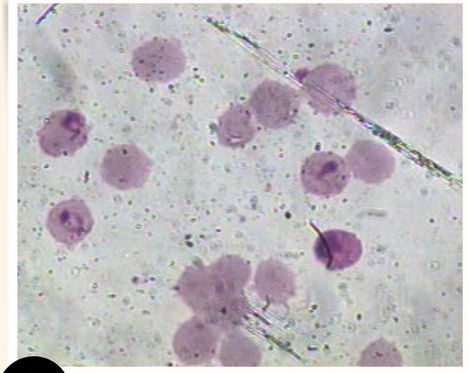
IMCLOSE

In contrast with opening, morphological closing is a dilation followed by an erosion, still using the same structuring element. The function in MATLAB that performs this operation is imclose.

There are several morphological operations included in MATLAB. For the purpose of this demonstration, we will only use these three above.

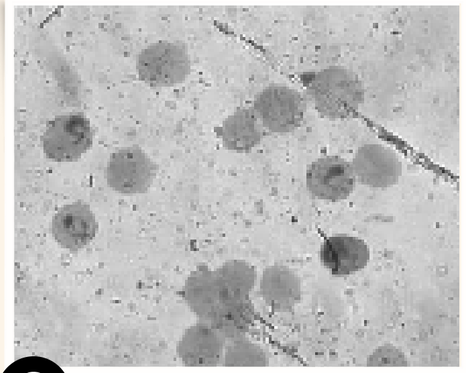
IMAGE SEGMENTATION

original image



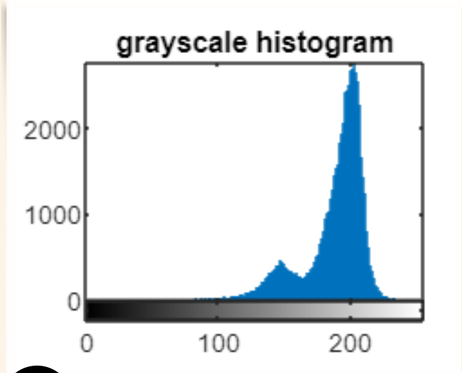
1

grayscale



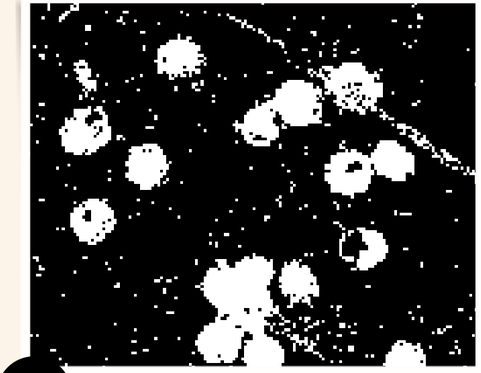
2

histogram



3

segmented

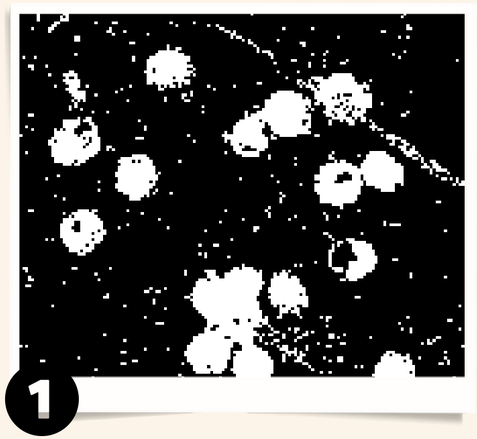


4

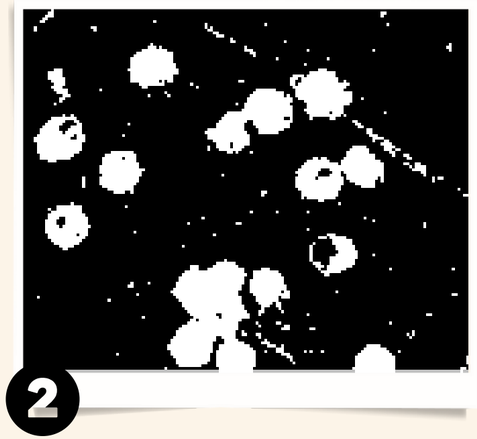
This is the process of segmenting the image of malaria cells by thresholding. We first get the grayscale image, construct its histogram, then choose the boundaries for the thresholding. For this I chose 100–164. Then, after thresholding the resulting segmented image still consists tiny spots that are clearly not our region of interest. This is where morphological operations come into play. Let's apply the three operations!

IMAGE SEGMENTATION

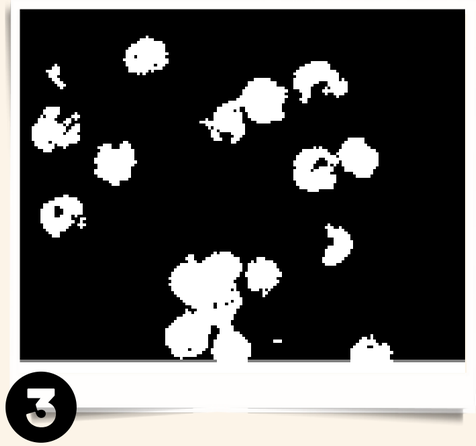
original image



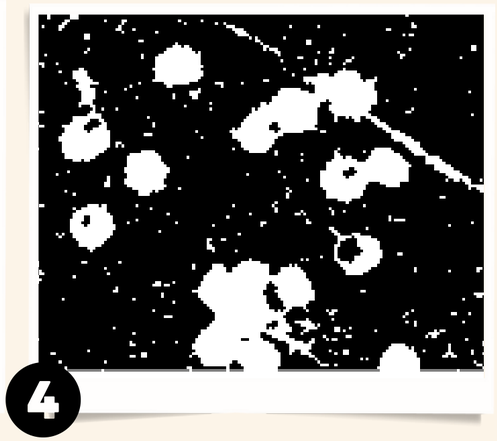
majority



open



close



As we can see, using the three operations yielded different results. Out of all the three, the opening operator seems to have the best result. It managed to eliminate all the noise almost without distorting the shape and size of the cells. For this round, opening operator wins!

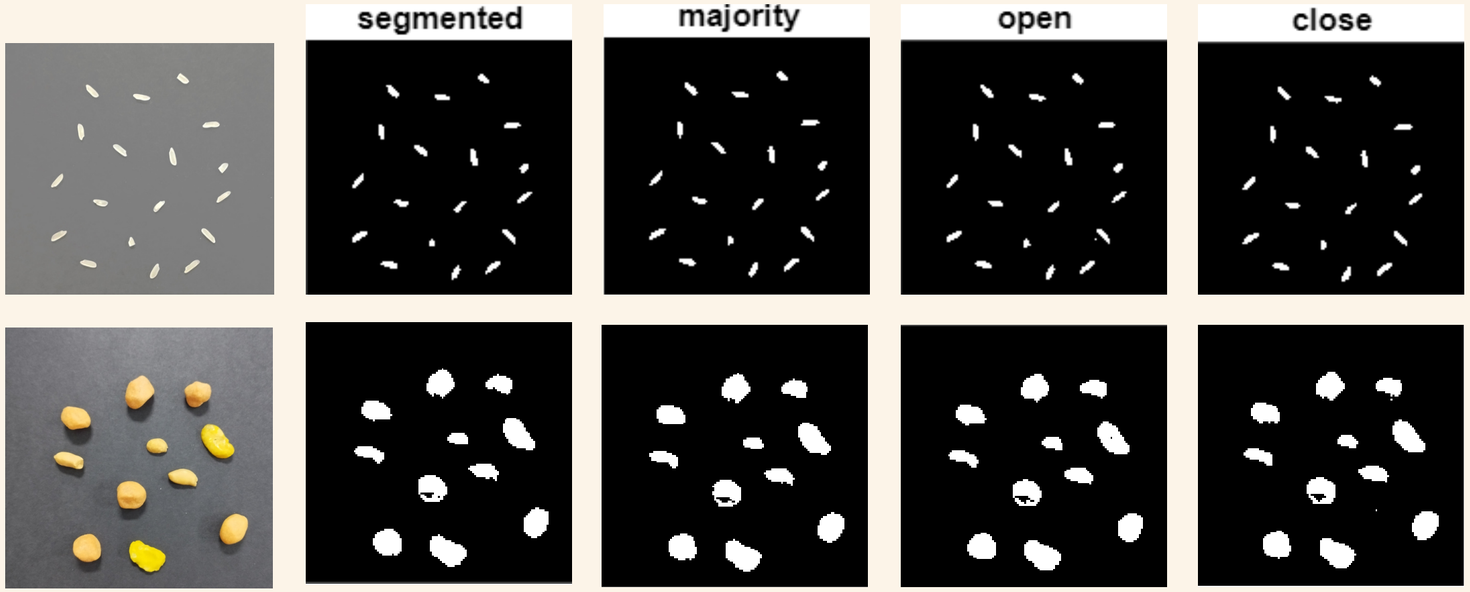
03

ADDITIONAL ACTIVITY

The results included here are all the additional stuff that I did because I had fun doing the activity.

RICE GRAINS AND NUTS

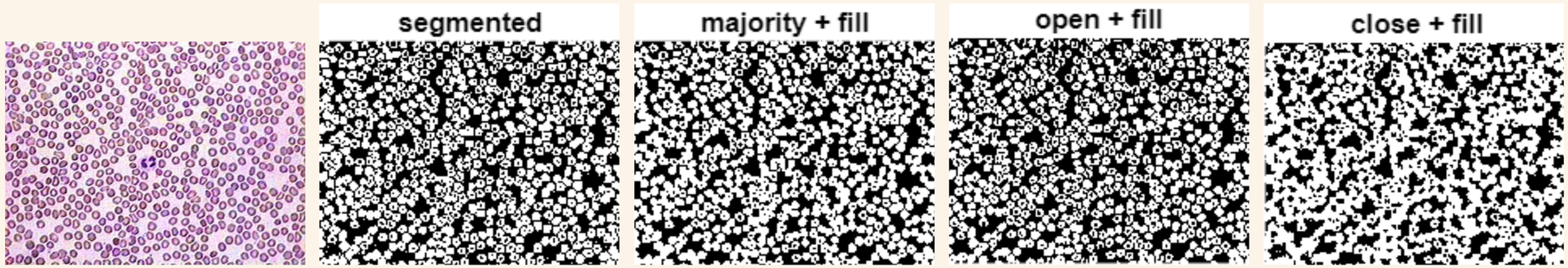
Here are images of rice grains and nuts that I used for the ImageJ activity. I tried to segment and apply morphological analysis to these images.



As we can see, there are not much noise in the picture because I chose a plain background. Only a few spots are left. Moreover, the morphological operations were able to make the edges smoother and eliminate some of these noise spots.

RED BLOOD CELLS

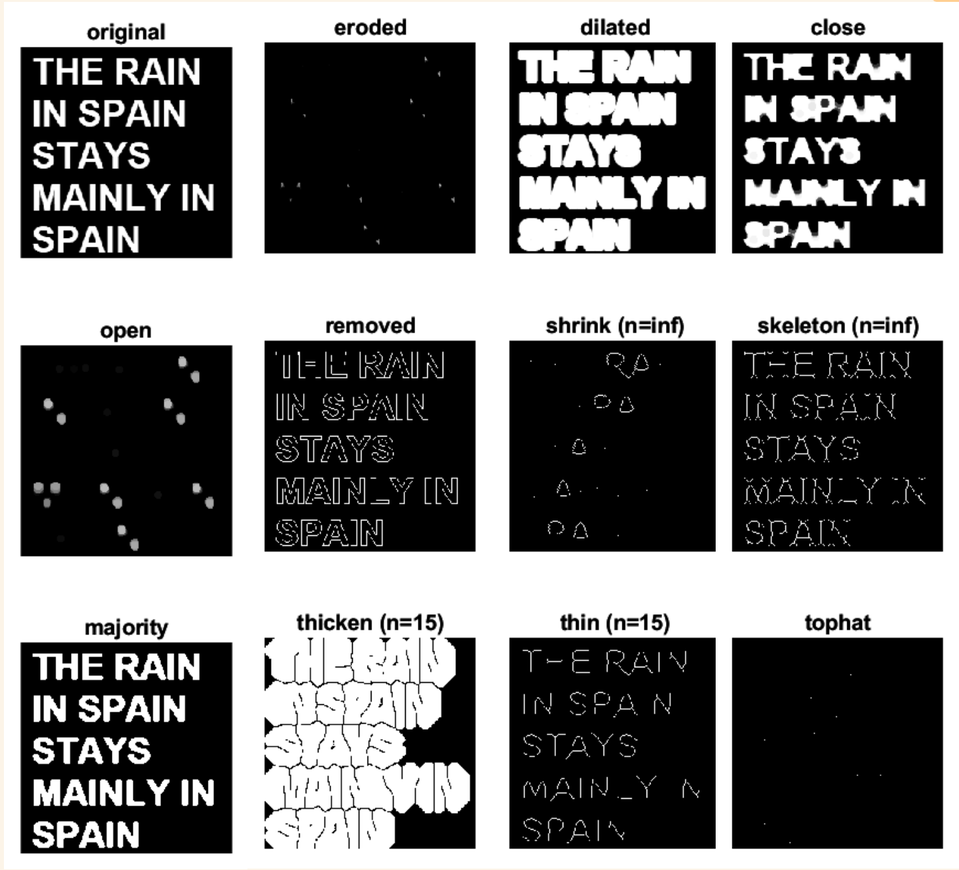
Here are images of rice grains and nuts that I used for the ImageJ activity. I tried to segment and apply morphological analysis to these images. I added another operator "fill" that will fill in the holes.



From the resulting images, we can see that "close+fill" yielded the worst result. "Majority+fill" and "open+fill" worked out fine.

OTHER MORPHOLOGICAL OPERATIONS

Here I used some of the morphological operations from MATLAB [8] for the original image of the text that we used from the previous activity. As we can see, the different operations yielded different results. This only shows that morphological operations has so many applications and we just have to identify what to use for specific images and for specific cases. The documentation of these operations can be seen in MATLAB website.



REFERENCES

1. https://homepages.inf.ed.ac.uk/rbf/HIPR2/strctel.htm
2. https://homepages.inf.ed.ac.uk/rbf/HIPR2/dilate.htm
3. https://www.mathworks.com/help/images/ref/imdilate.html?searchHighlight=IMDILATE&s_tid=srchtitle_IMDILATE_1
4. https://www.mathworks.com/help/images/ref/strel.html?searchHighlight=strel&s_tid=srchtitle_strel_1
5. https://homepages.inf.ed.ac.uk/rbf/HIPR2/erode.htm
6. https://www.mathworks.com/help/images/ref/imerode.html?searchHighlight=imerode&s_tid=srchtitle_imerode_1
7. https://www.mathworks.com/help/images/ref/bwmorph.html?searchHighlight=bwmorph&s_tid=srchtitle_bwmorph_1
8. https://www.mathworks.com/help/images/morphological-filtering.html?searchHighlight=morphological%20operation&s_tid=srchtitle_morphological%20operation_1

KEY TAKEAWAYS

- Understanding set theory further deepens our knowledge about morphological operations.
- Morphological operations are essential for improving the segmented image to make it easier for the next step which is feature extraction.
- Different morphological operations can be used and they can also be combined as needed.

REFLECTION

This activity for morphological operations is fun because you get to see the changes in the segmented images once you apply the different operations. Moreover, predicting the outcome of dilation and erosion is like a mystery game, and to see that you get your predictions right is a whole level of "kilig." Also, I get to be in-touch with my "artistic" (wao) self again from hand-drawing the images. I think that's the part that took most of my time, but it was worth it because I get to understand how dilation and erosion works.

Overall, I enjoyed doing this activity because it is not "code-heavy" but more on concepts. I get to understand the concept better.

REPORT GRADE

Criteria	Score
Technical Correctness	35
Quality of Presentation	35
Self Reflection	30
Initiative	10
TOTAL	100 (+10)

EVALUATION

Overall, I know that I have accomplished all the tasks included in this activity. Moreover, I did some extra experiments and made some comparisons in the resulting images. I also put a lot of effort in creating this presentation and cited a lot of sources for additional information in the report.