Morphological Operations

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Process of Dilation

Fig. 1 demonstrates how dilation uses a structural element (SE) to expand an image. An SE has a set origin. This origin is intersected with each pixel on the image. For every pixel intersection, the area of the SE inside the image is kept, and the remaining area of the SE outside the image is added.

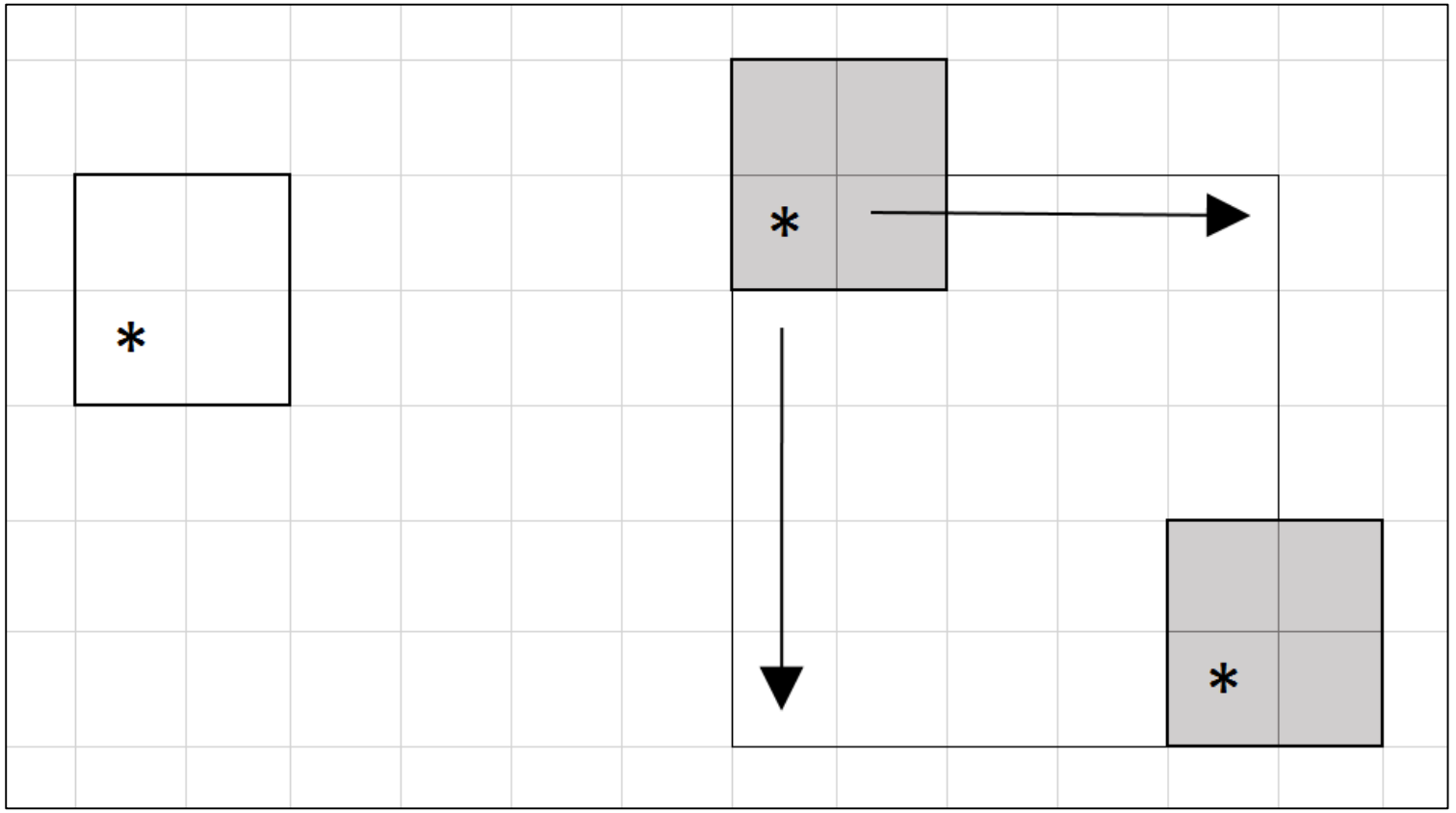


Figure 1. Structural element (left) is a 2x2 rectangle in bold borders, and image (right) is a 5x5 rectangle. The asterisk is the set origin, and the gray-filled area is the included area in the resulting image for the specific intersection of the SE origin and the image.

Process of Erosion

Fig. 2 demonstrates how erosion uses a structural element (SE) to deplete an image. Unlike dilation, the whole SE must be intersected with the image. For every possible pixel intersection of the SE and the image, the location of the origin is the only area to be kept.

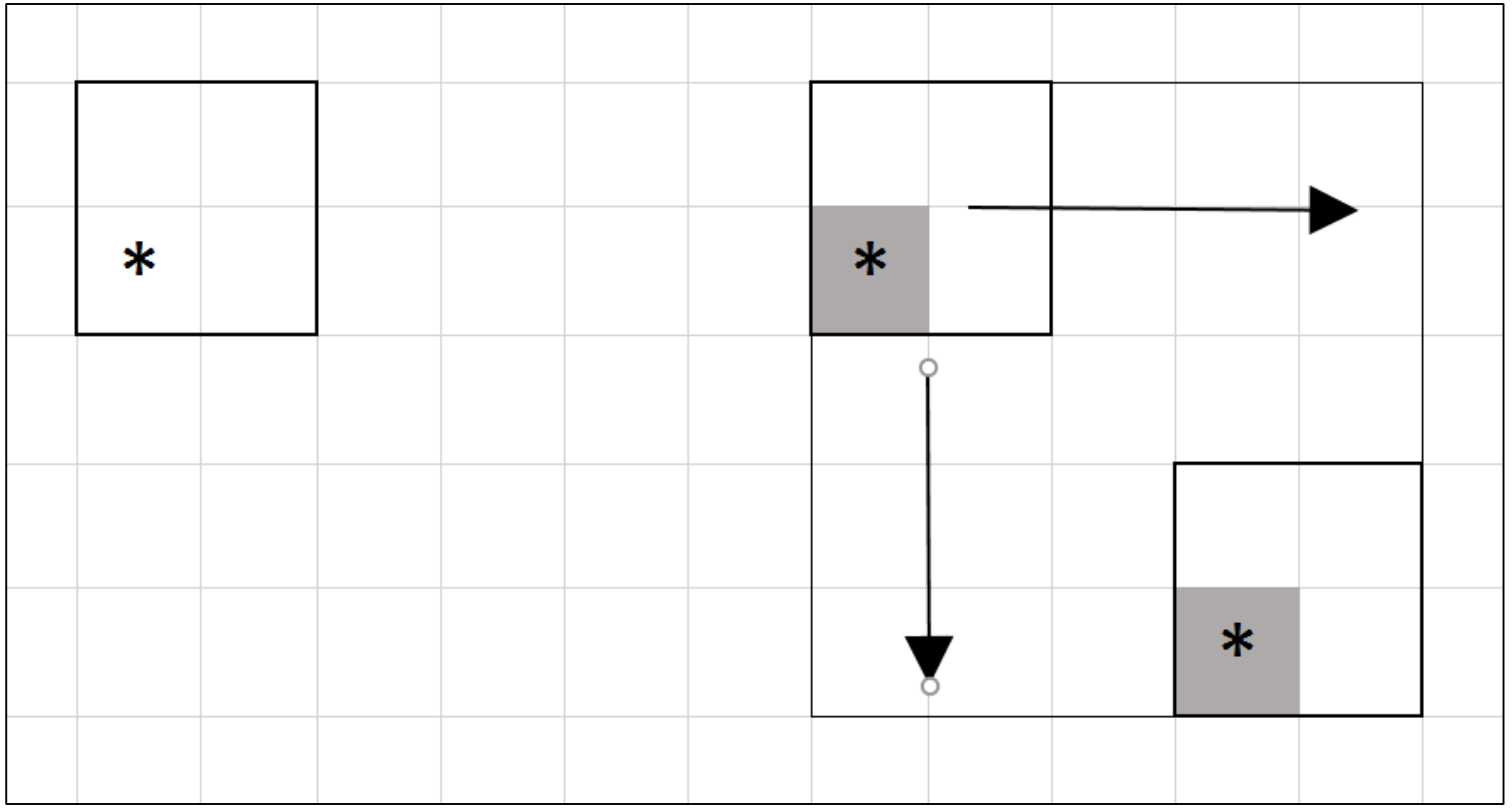
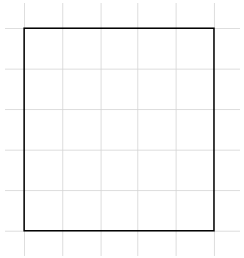
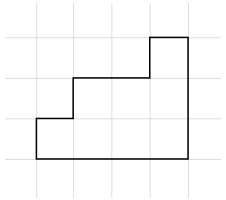


Figure 2. Structural element (left) is a 2x2 rectangle in bold borders, and image (right) is a 5x5 rectangle. The asterisk is the set origin, and the gray-filled area is the included area in the resulting image for the specific intersection of the SE origin and the image.

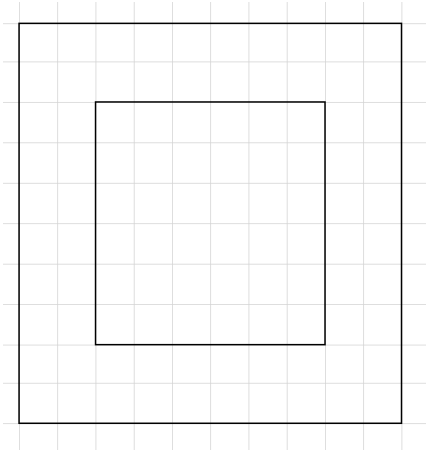
Knowing how to manually dilate and erode, we would now be able to predict the dilation and erosion of any image, given any SE. For the shapes:



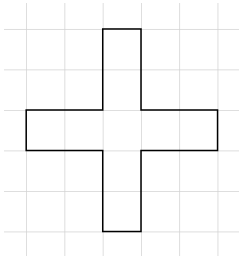
5x5 square



4x3 triangle

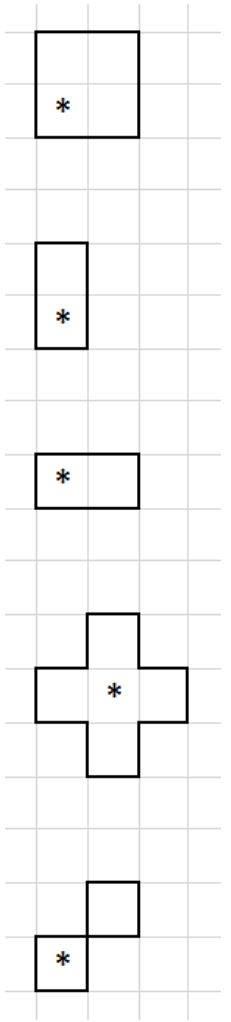


10x10 hollow square



plus sign: 5 units
down and across

eroded and dilated with the structural elements:



2x2 square

1x2 rectangle

2x1 rectangle

plus sign: 3 units

2 units diagonal

The predictions were done with pen and graphing paper and are shown in the following figures:

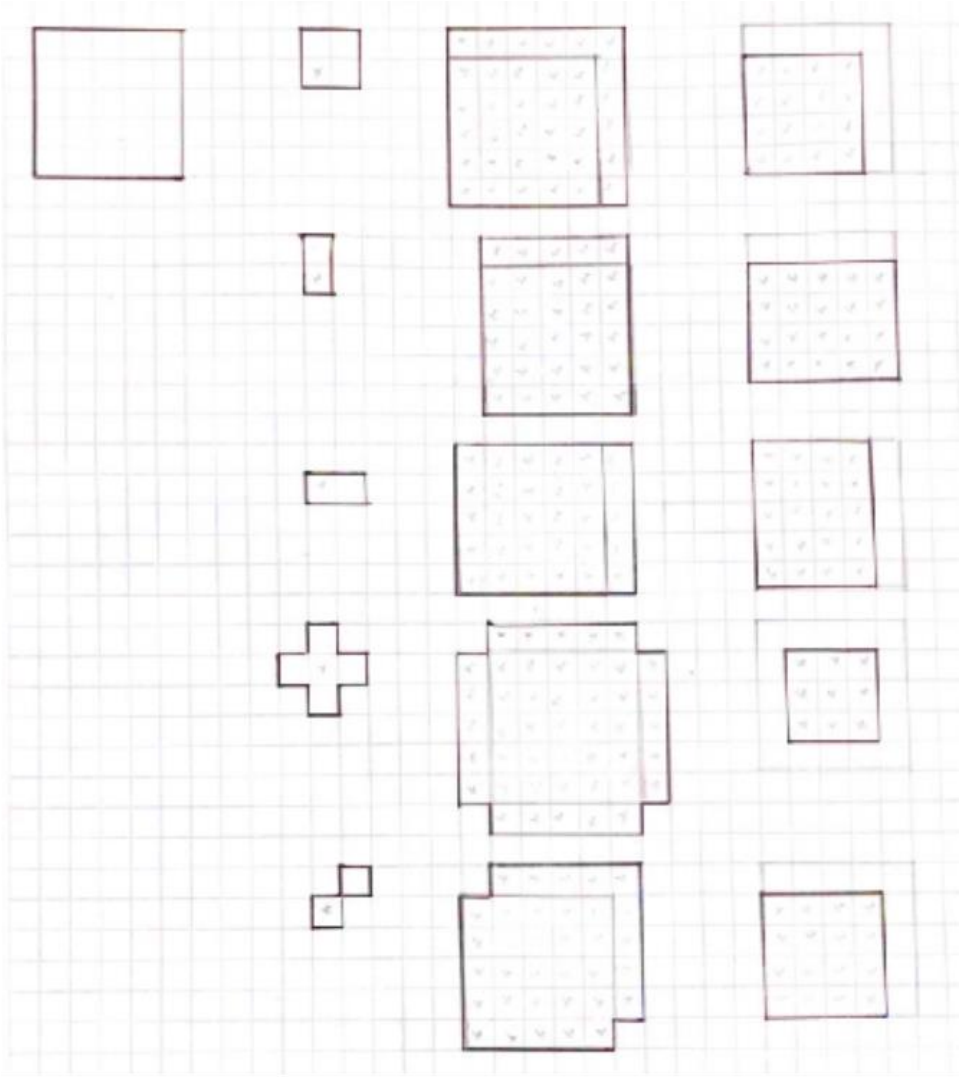


Figure 3. Square image morphed. Columns from left to right are image, SE, dilation result, and erosion result. The lighter lines on the result is the original image, and the darker lines are the results.

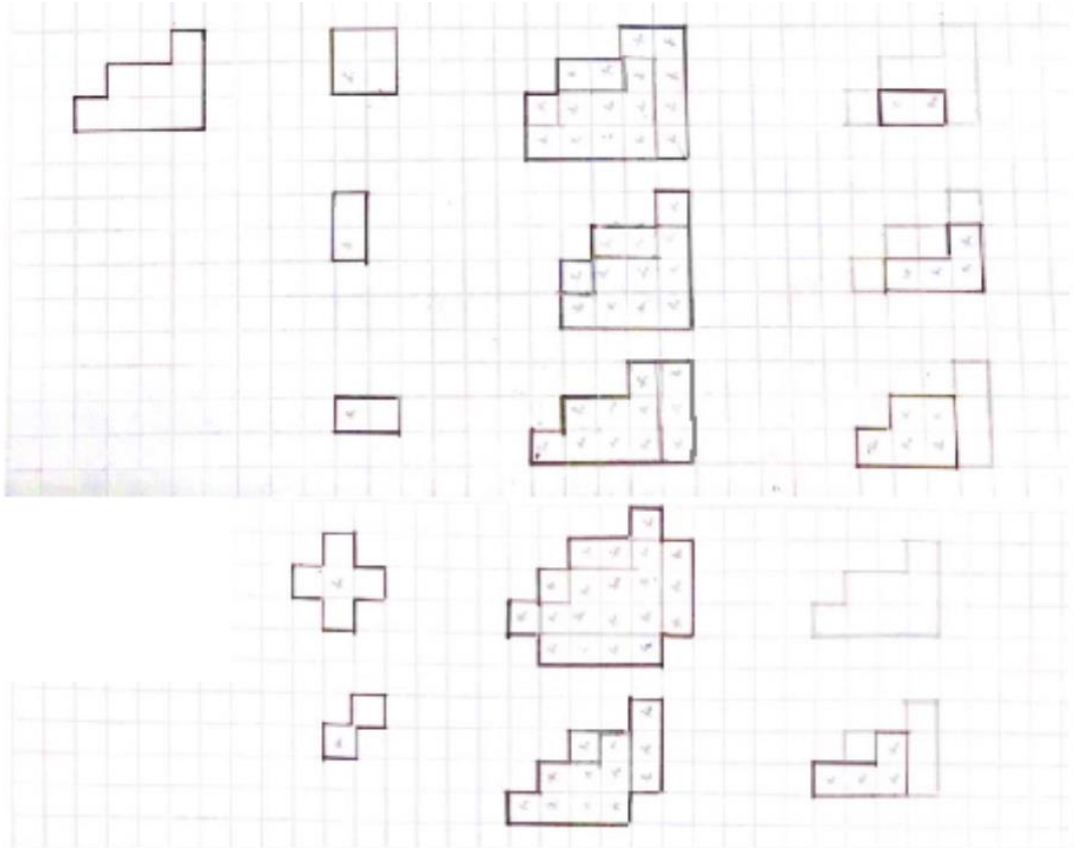


Figure 4. Triangle image morphed. Columns from left to right are image, SE, dilation result, and erosion result. The lighter lines on the result is the original image, and the darker lines are the results.

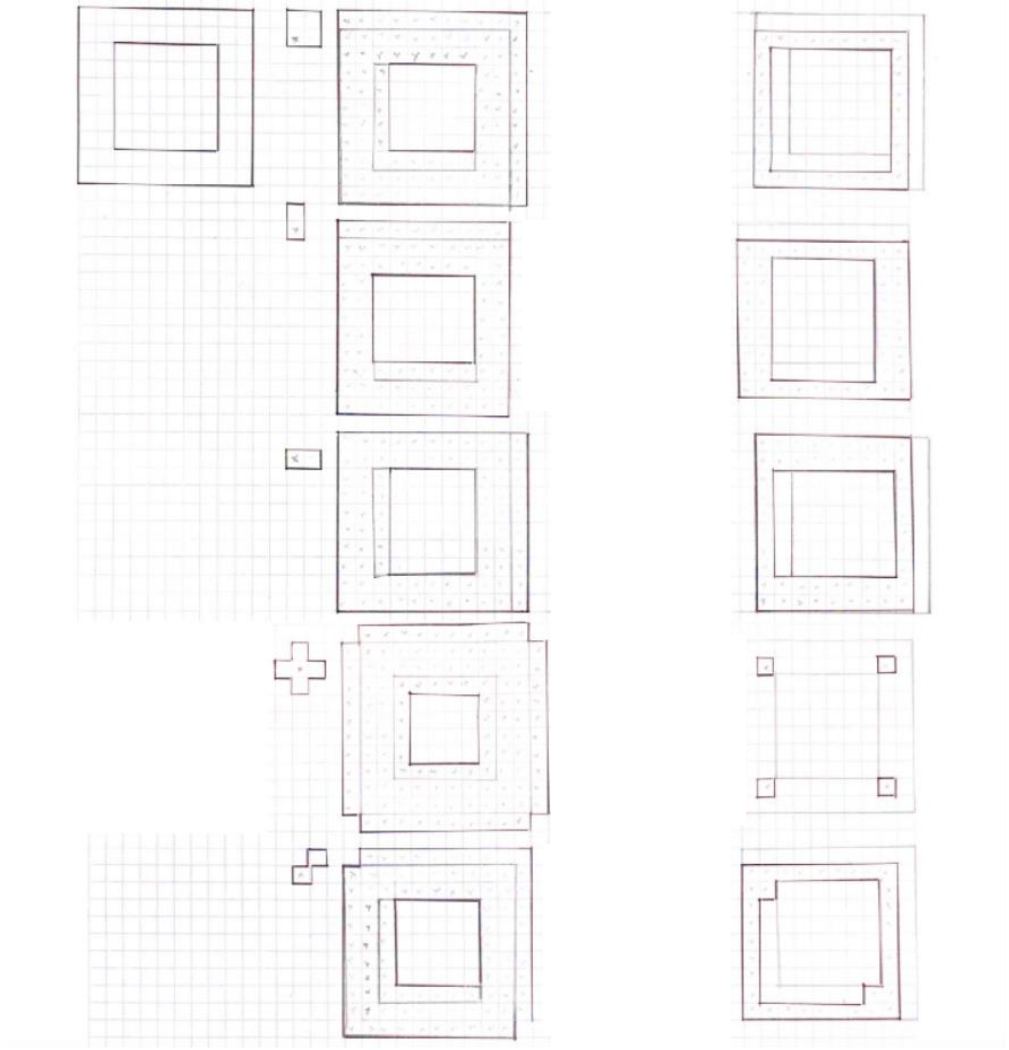


Figure 5. Hollow square image morphed. Columns from left to right are image, SE, dilation result, and erosion result. The lighter lines on the result is the original image, and the darker lines are the results.

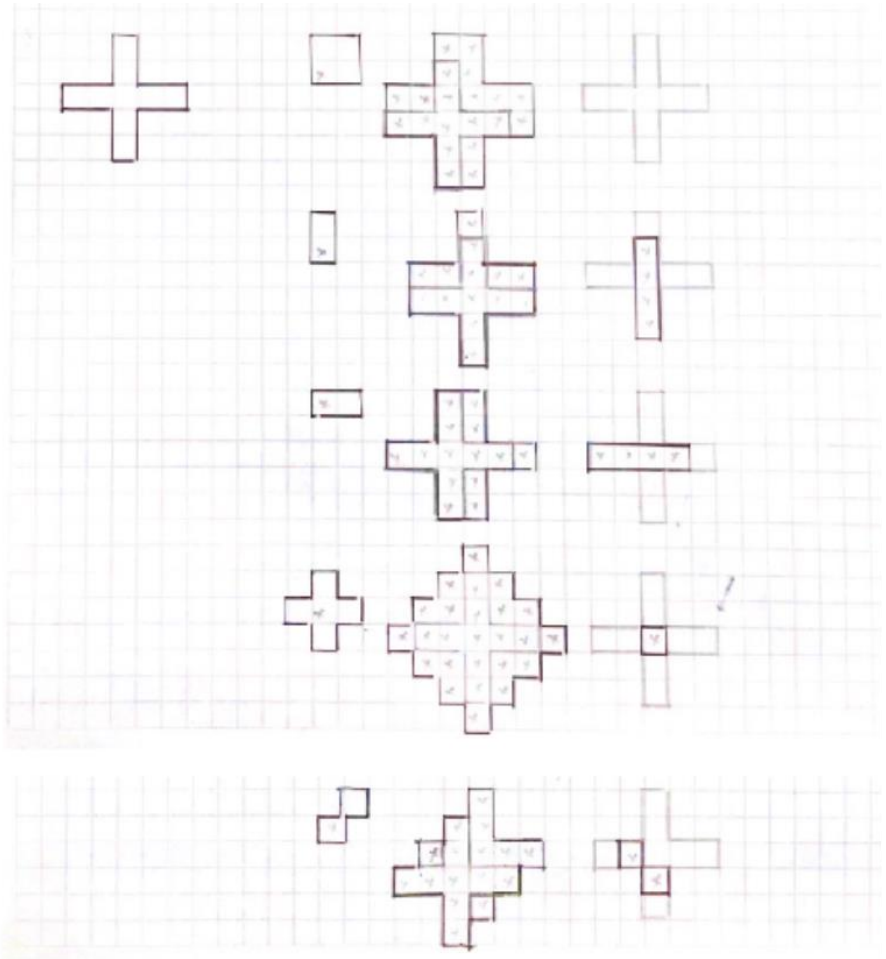


Figure 6. Plus sign image morphed. Columns from left to right are image, SE, dilation result, and erosion result. The lighter lines on the result is the original image, and the darker lines are the results.

To confirm the predictions, erosion and dilation for the same shapes and SEs were programmed in Matlab. Comparing the predictions from the Matlab results, it shows that the predictions were correct.

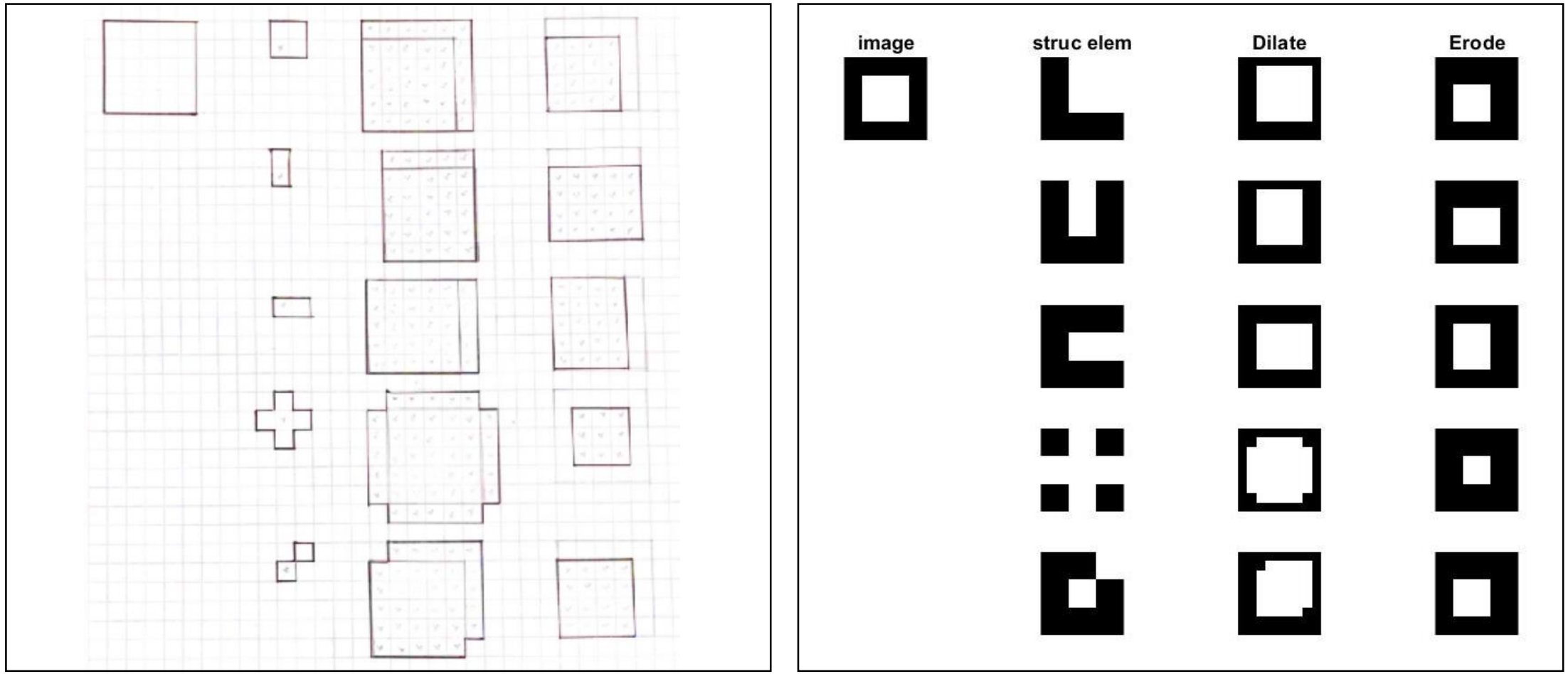


Figure 7. Matlab result of square image morphed. Prediction (left) Matlab result (right).

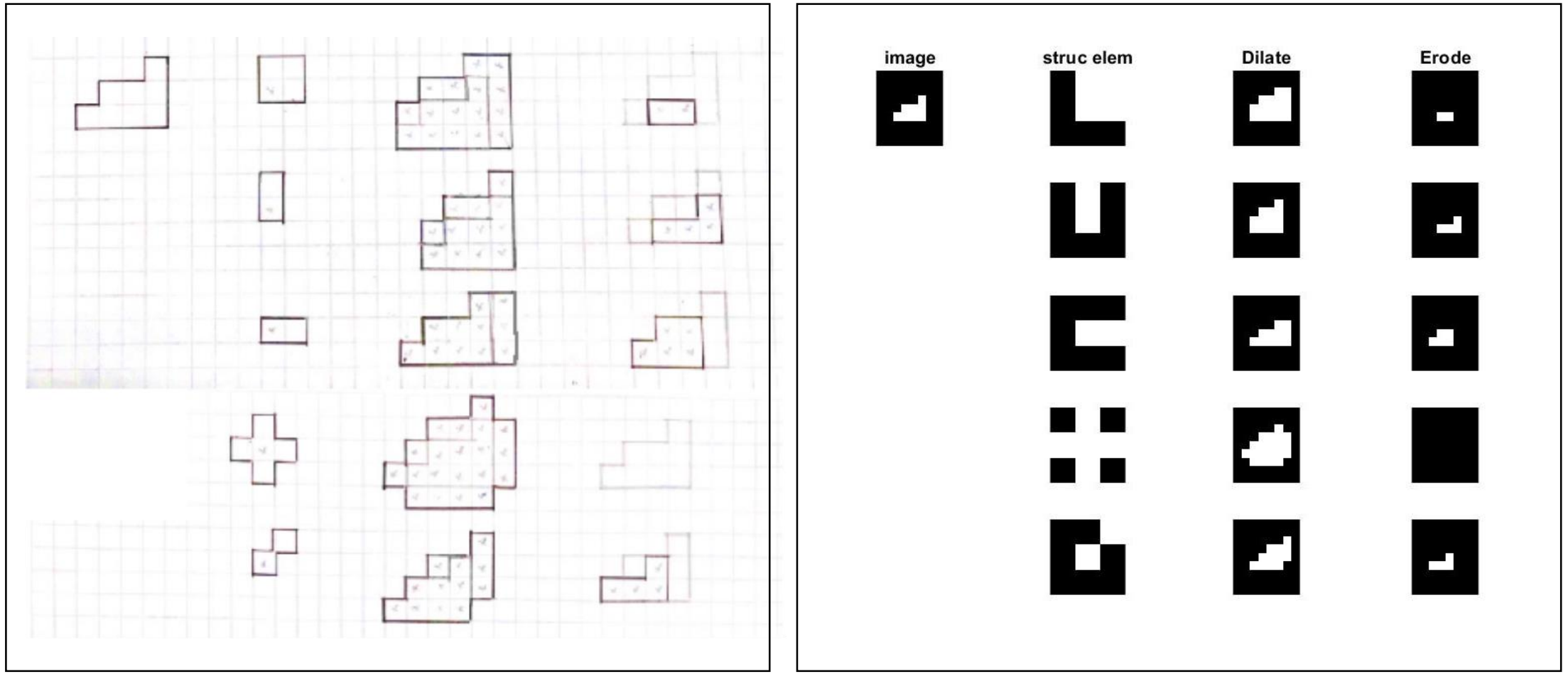


Figure 8. Matlab result of triangle image morphed. Prediction (left) Matlab result (right).

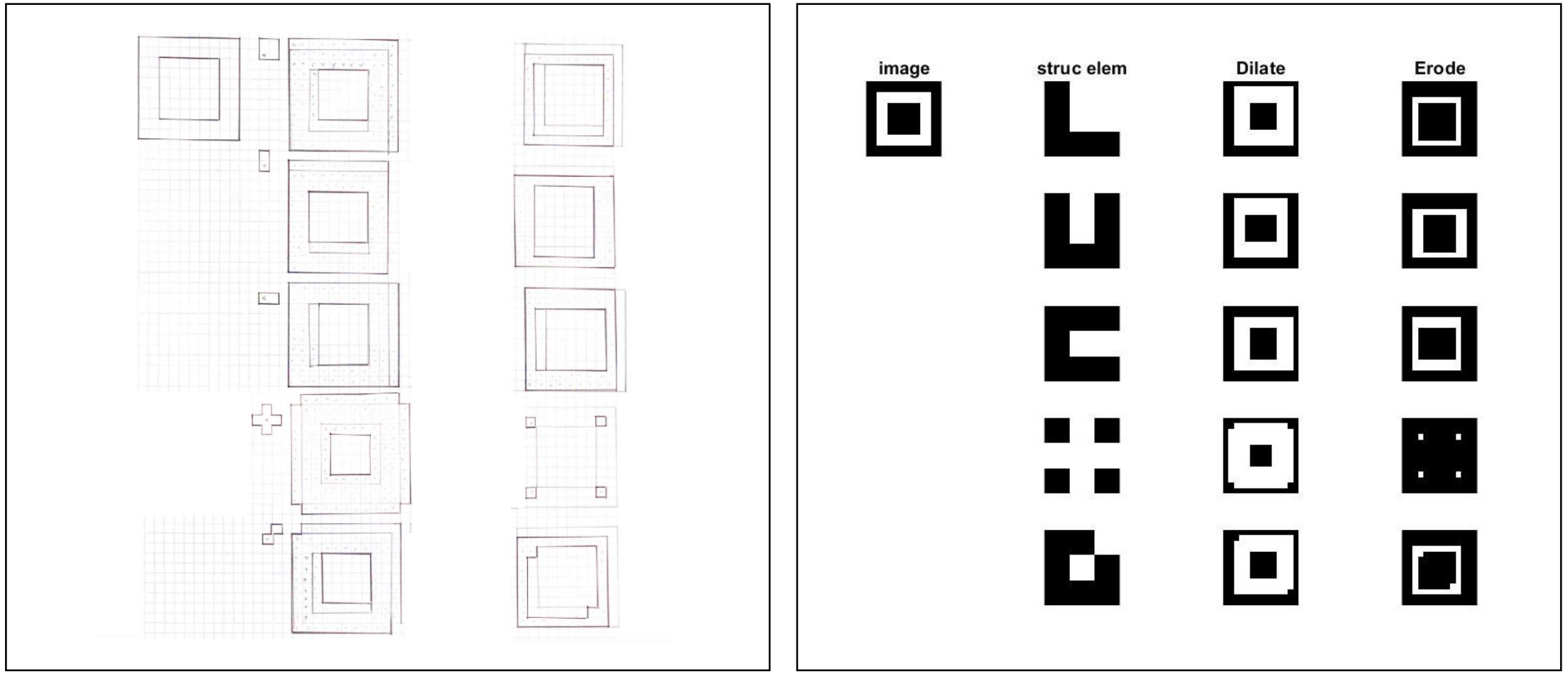


Figure 9. Matlab result of hollow square image morphed. Prediction (left) Matlab result (right).

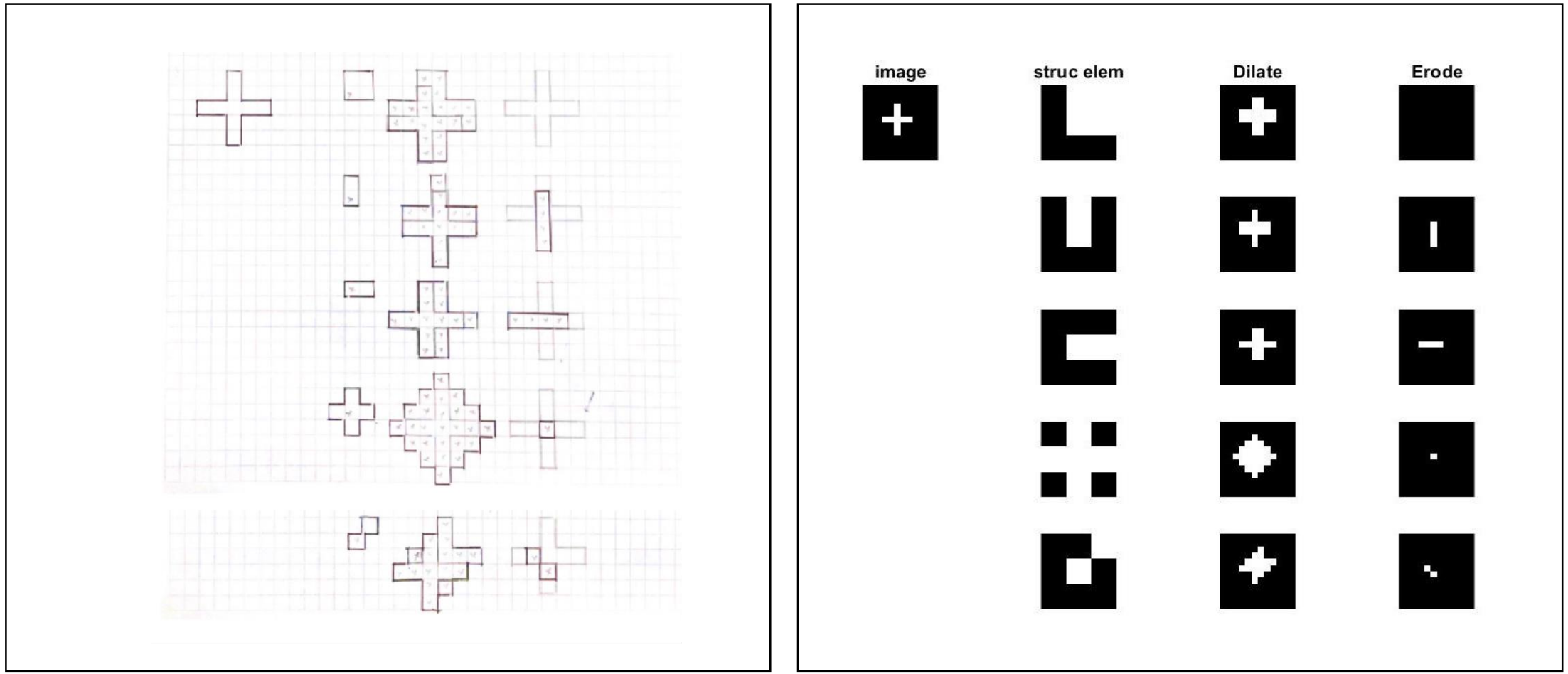


Figure 10. Matlab result of plus sign image morphed. Prediction (left) Matlab result (right).

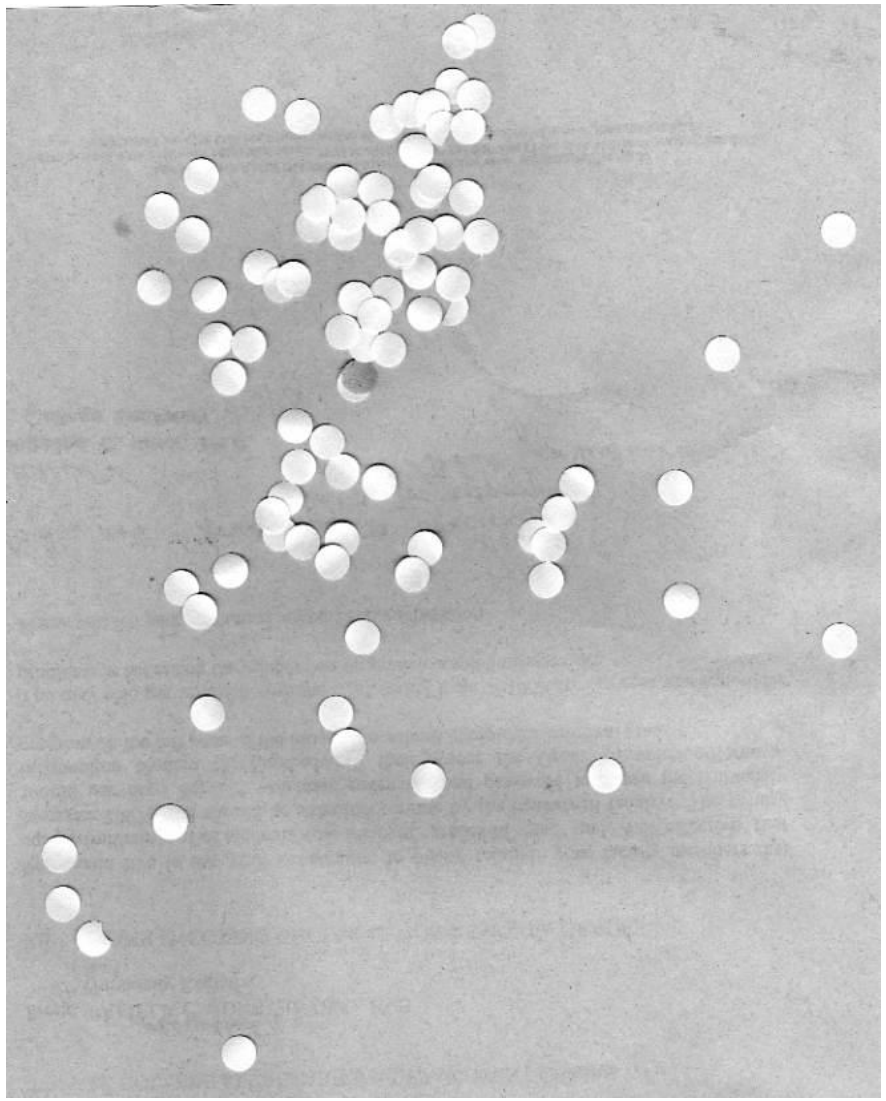


Figure 11. Image of circular cutouts of the same size scattered on a sheet of paper

The skills learned so far can be used to sort cells. Normal healthy cells are usually of the same size but cancer cells are larger. Sorting cells can be simulated with circular objects. Fig. 11 is an image of circular paper cut outs of the same size. To be able to sort objects into two group of sizes, I've outlined the steps I'd take:

I. Setting threshold area.

1. Segment the objects through thresholding,
2. Use morphological operations to remove any non-object segmentation,
3. Label each remaining blob with a marker using bwlabel(),
4. Measure the area of each blob, and
5. Find their mean and standard deviation.

II. Sorting

1. For input image, repeat steps I1-I4.
2. If the area of a blob is greater than the mean (standard dev. considered), mark blob as cancer.

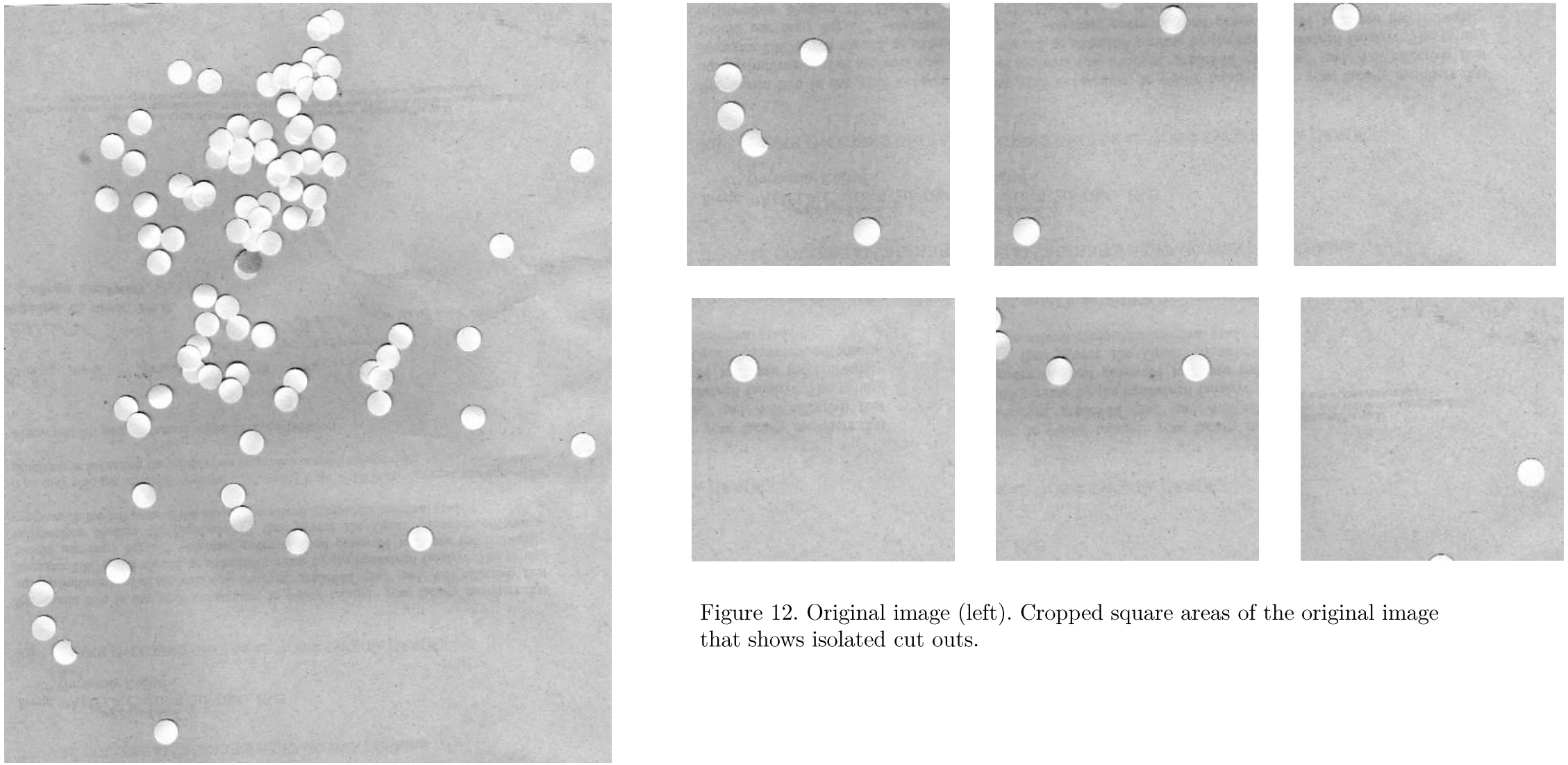


Figure 12. Original image (left). Cropped square areas of the original image that shows isolated cut outs.

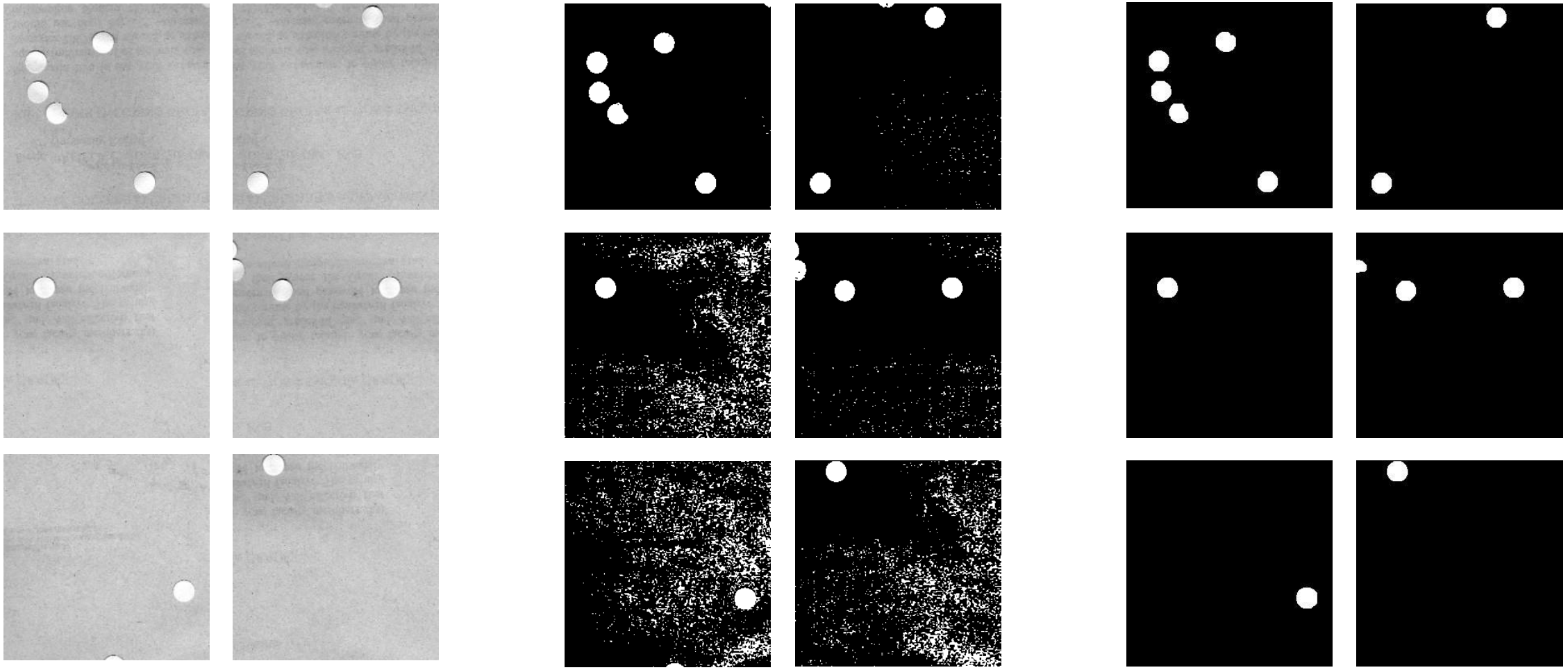


Figure 13. Chosen images from Fig. 11 (left). Segmented images by thresholding (center), morphed images to remove unwanted segmented objects (right).

Measured area is $464.87 \pm 24\%$.

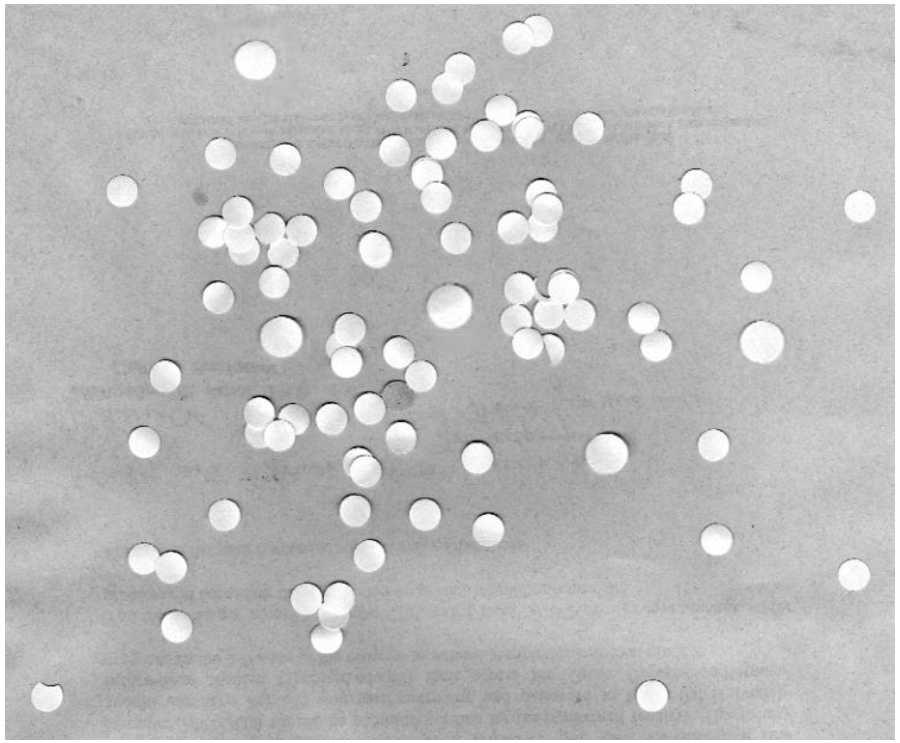
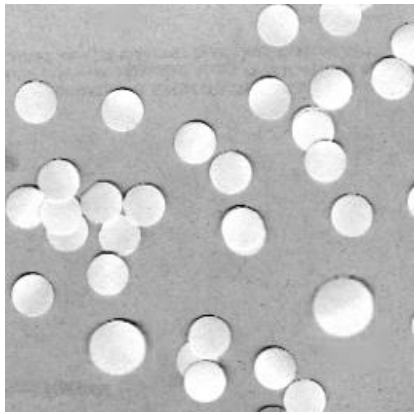
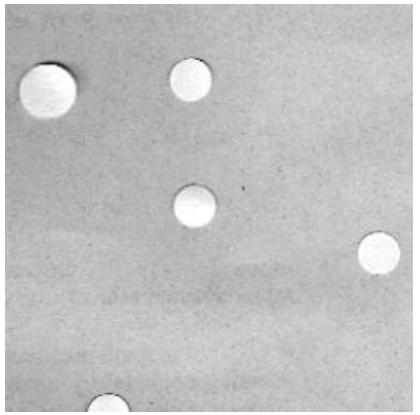
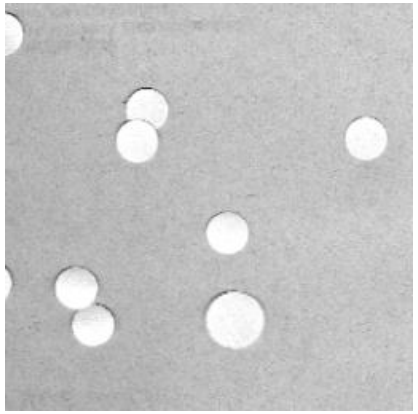
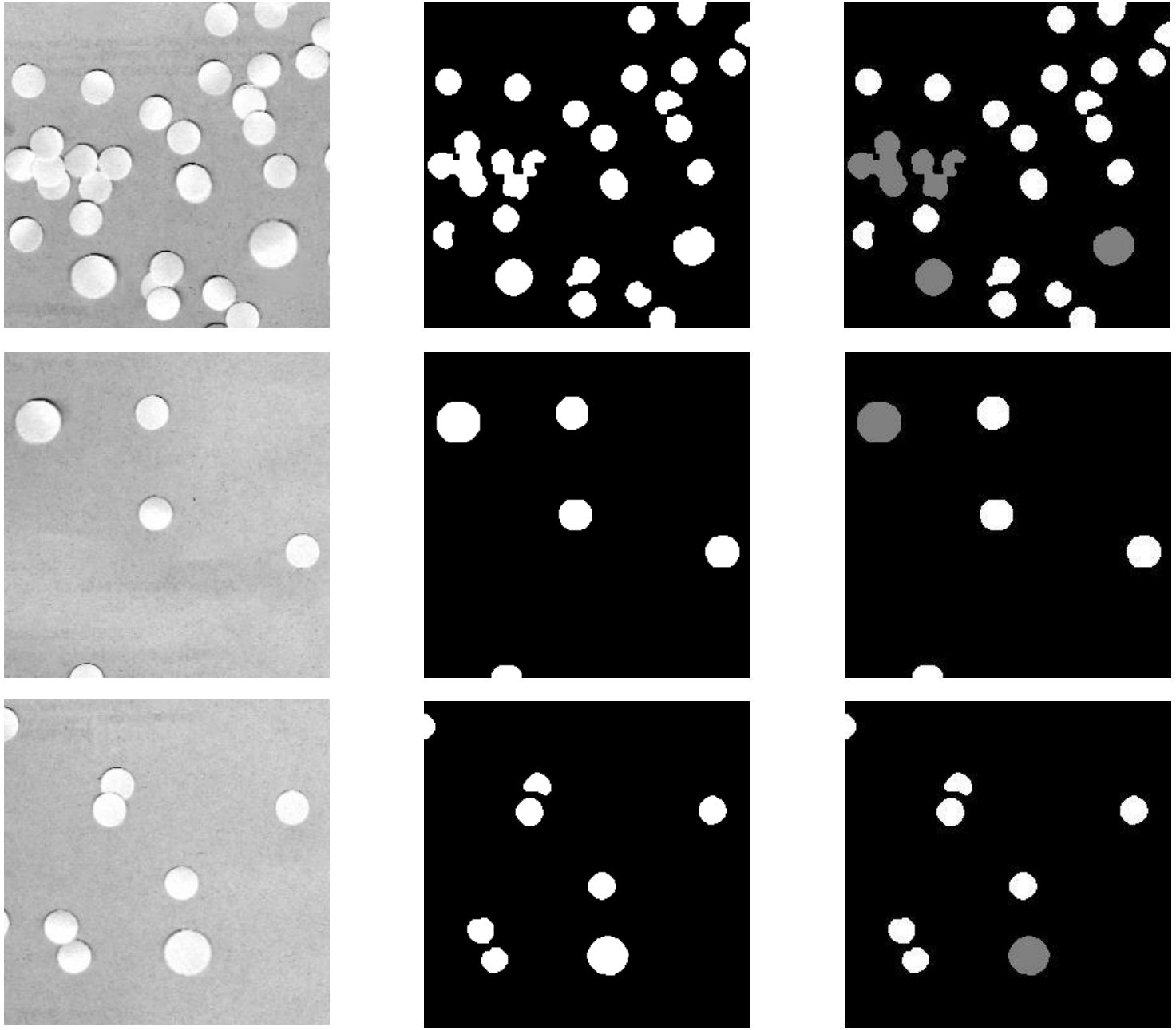


Figure 14. Image of cut out circles of different sizes (top). Cropped square areas from original image (bottom).









I was able to successfully sort most of the “cancer” cells from the regular cells. However, it was not able to differentiate a cancer cell from overlapping normal cells. This is the limitation of the method I used because it cannot separate some cells from each other and results to a very large area calculation which is then identified as cancer cell.

Figure 14. Original image (left). Segmented objects (center). Sorted objects by color, gray for cancer and white for normal cells (right).

I got the circle cut out images from previous AP 186 modules, and I used my previous codes in processing the image.

I would like to thank LJ Tan for teaching me how to predict erosion and dilation, however later we realize the Matlab syntax is different and we figured out how the dilation can be predicted through documentation.

I rate myself 12/10 for this activity.