Tic-tac-toe game analysis

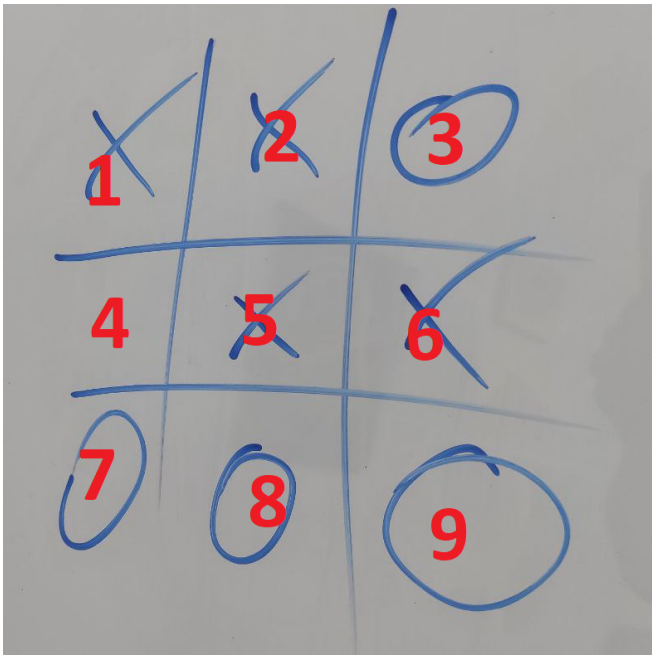
Author: kriuchkvskyi.vlad@gmail.com

Introduction | Splitting the task

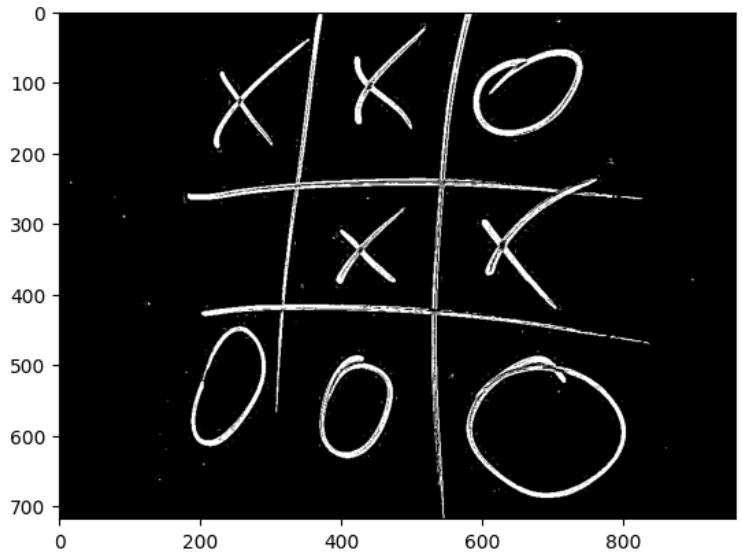
The task can be split into three parts: segment detection, segment classification, and drawing a winner. The tic tac toe game has 9 segments overall, and each of them can be marked as one of three classes depending on what is the image inside a segment: zero, cross, or nothing. That is what my approach was built upon.

Segment detection

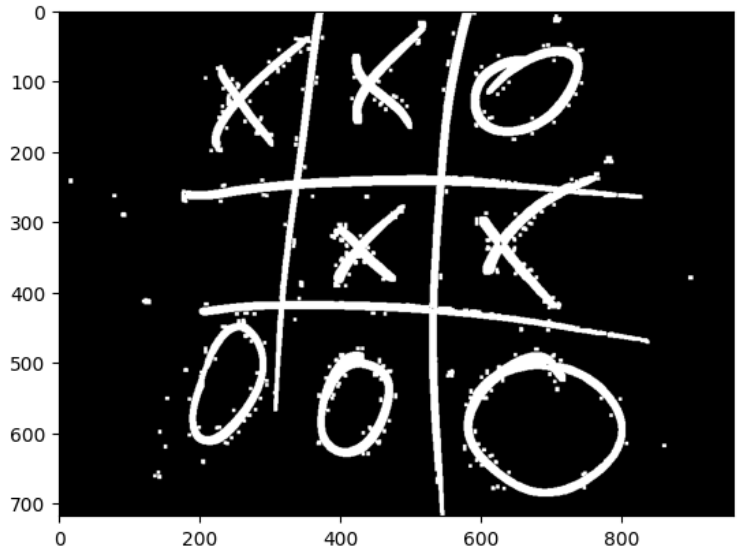
As mentioned earlier, tic tac toe game has basically 9 segments. Let's numerate them on the image.



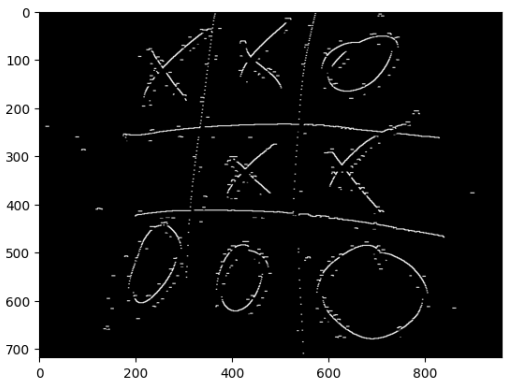
Each segment is split by vertical and horizontal lines. So the segment detection task will consist of two parts, find 2 horizontal and 2 vertical lines on the image and obtain game segments by knowing intersection points of the lines.
Images are imported in a grayscale mode. Since all of the images contain the tic tac toe game near the center, the crop will be used, which will obtain 75% of an image across the center. Then the ADAPTIVE_THRESH_MEAN_C due to a variety of lighting conditions on images.
Image after applying preprocessing:

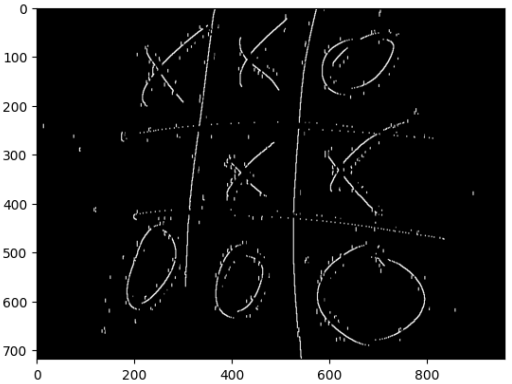


The next thing comes to detecting vertical and horizontal lines. Since lines are inconsistent on images, and there are some gaps inside of them, the dilation with a 5 x 5 kernel was used to expand the lines and fill in the gaps.

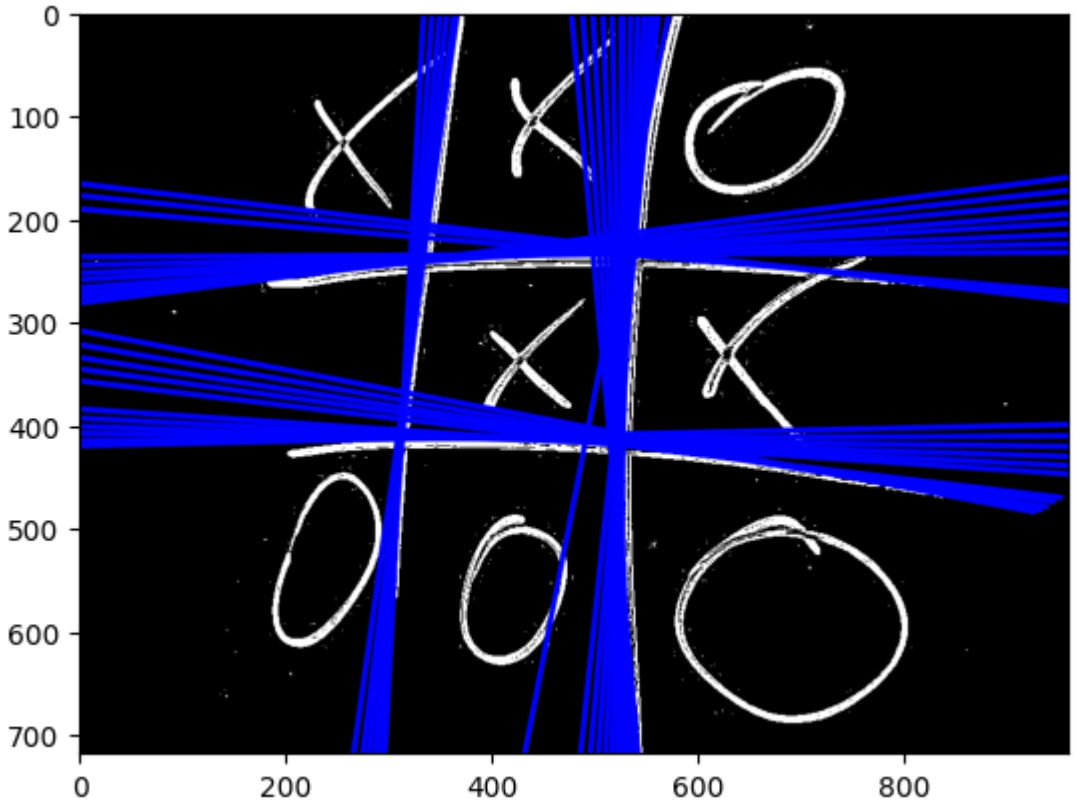


Then, the Sobel derivatives were obtained since they will perfectly fit our task of detecting vertical and horizontal lines (since those are just like Y and X derivatives).

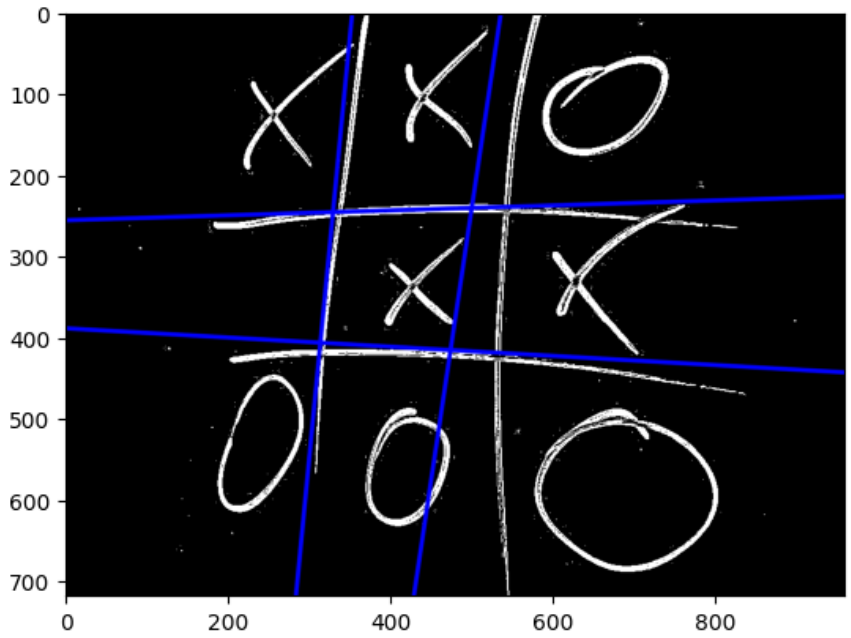




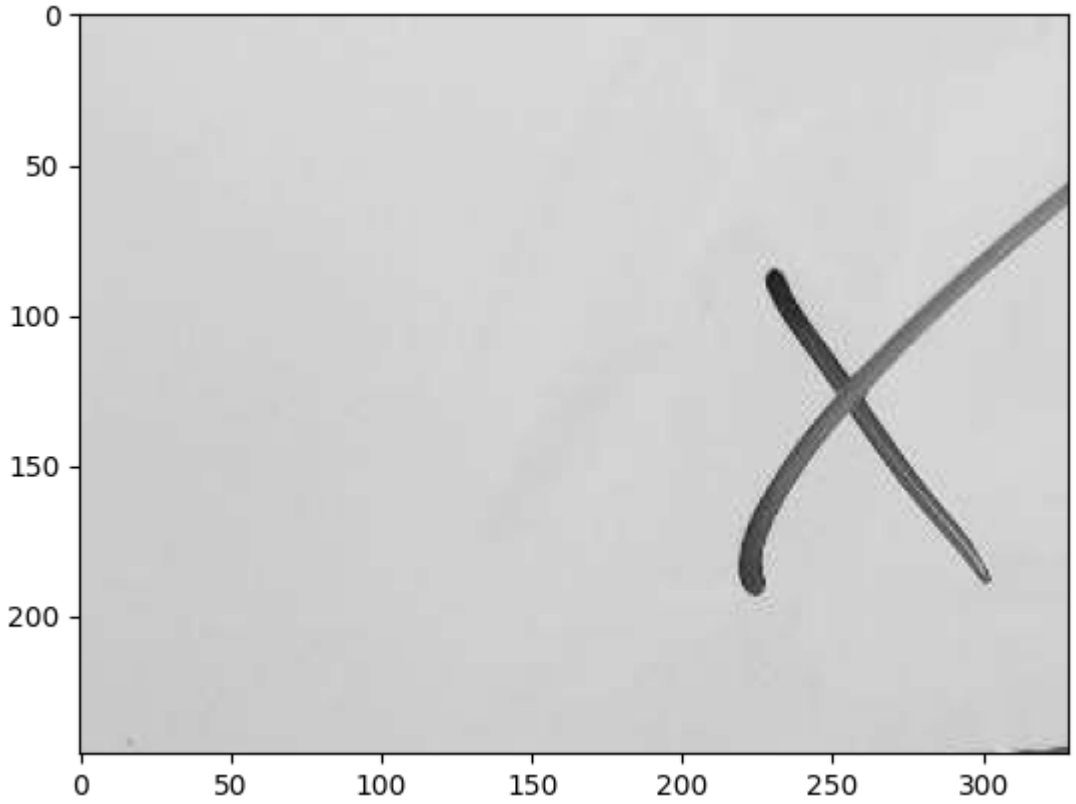
After that, the horizontal and vertical lines were found using the HoughLines transform on dX and dY images respectively. Since Sobel derivatives also give us outlines of symbols inside the segments, the min_theta and max_theta parameters were used to limit found lines. For horizontal lines, the parameter was set as 1.2 for min_theta and 1.8 for max theta. For vertical lines two hough line transform were applied, the first one with parameter max theta = 0.2 and, the second one with min theta = 3.
Results of applying lines detection:



For main lines extraction, the K-means algorithm was applied, and the median of the result was taken for both vertical and horizontal lines.
Result after K-means:

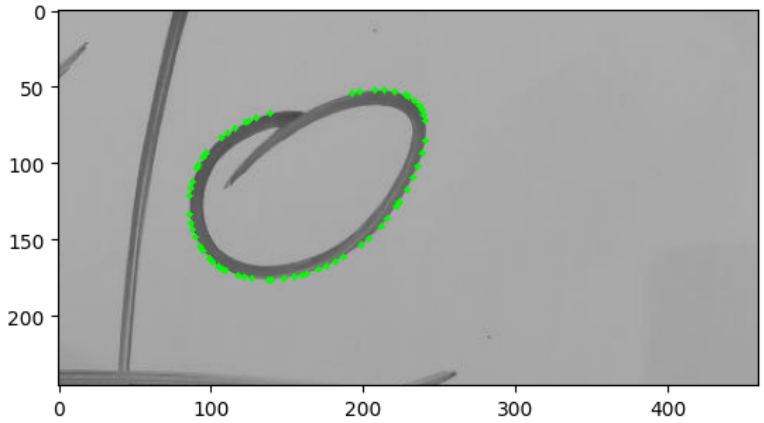


As we can see, the K-means algorithm along with the hough lines transform has not perfectly described the lines on the images, but it was enough for solving the task. For obtaining crops of segments, the intersection points were found between the lines. Here is a crop of the first segment:

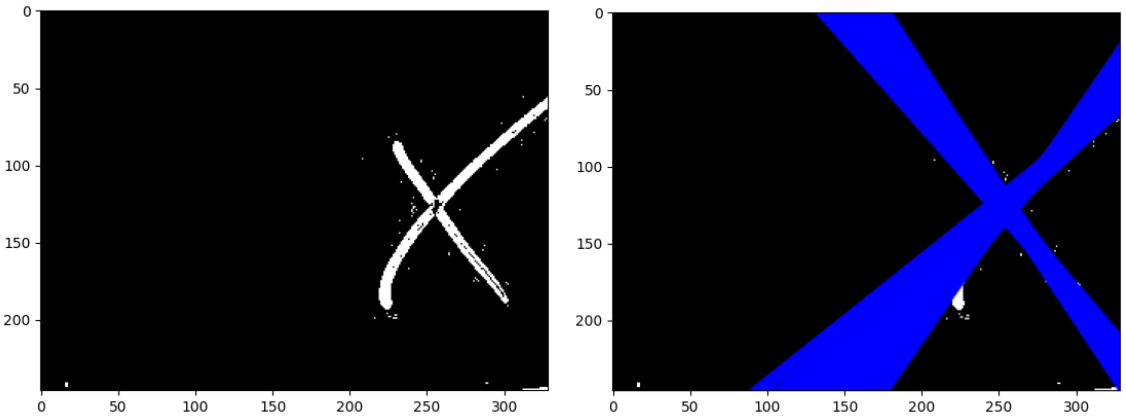


Segment classification

Since zero is the easiest to classify as I assumed, I'll start from it. The two criteria I've chosen to find zeros on an image are a big amount of points on the convexHull algorithm since contour for Zero is quite hard to be closed or the hard hough circles transform. The second one is needed for edge cases where zero is not quite completed, so the contour highlights only part of a zero and not the whole circle.
Convex hull on zero segment:



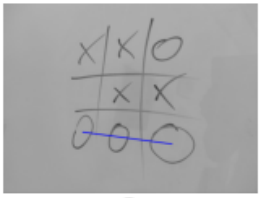
After zero is classified, classification between X and Nothing is left. Generally, X is two lines, so that's how it can be found, and to not be affected by segments with lines from the grid only, the theta parameter can be tuned again to obtain nice results. I've used two HoughLines transform with parameters theta between 0.6 - 1 and 2 - 2.6.
Lines detection on a segment with cross:



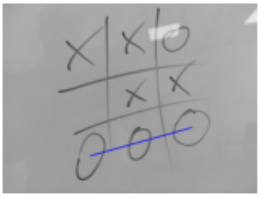
Drawing a winner

For detecting a winner, a simple algorithm that analyzes the tic tac toe array was used. For drawing a winner on an image, contours with the largest areas were obtained in needed segments and a combination of intersection points with contours center was used in order to draw a line that crosses the needed segments.
Results:

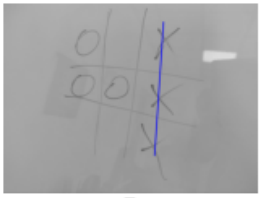
0



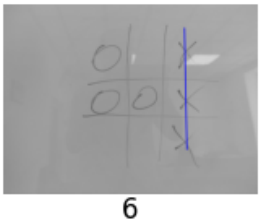
1



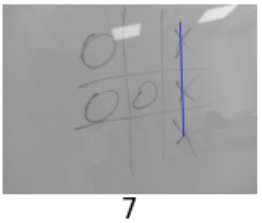
2



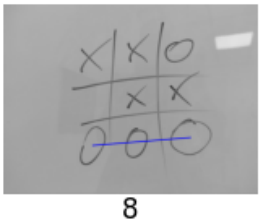
3



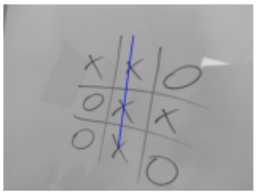
4



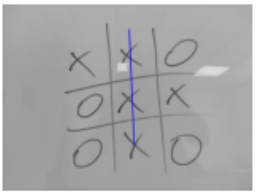
5



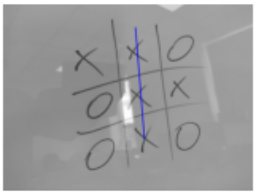
6



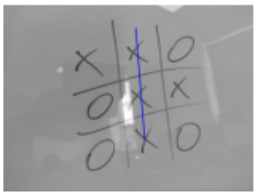
7



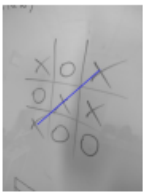
8



9



10



11