CSE 691: Image and Video Processing

Spring 2020 Assignment 3

Corner Detection

Lichen Liang

02/24/2020

Objectives

- Understand the Corner Detection Algorithm
- Understand each step of the algorithm and what does it do.
- Know how the sigma, tau, lambda values affect the output
- Apply corner detection to an image

Method

To run the code, run ***main.m*** and make sure all function files are in same folder.

The output image is labeled as :

Out [Original Image Number]S[sigma value]N[neighborhood size]T[tau value (in thousands)]

For example, out1S2N3T50 represents it used image1, sigma = 2, neighborhood = 3x3, tau = 50,000

If you prefer to run your own image, but cannot decide on the tau value to choose, you can set a very large tau value, say 1,000,000 and the code will return a fault because there are no lambda values larger than 1 million(and the list will be empty). In the command section you can see the largest lambda value, then you can re-run the code to set your desired tau value(must be less than max-lambda).

1. First, the image is loaded and filtered with gaussian filter. I used the built in function *imgaussfilt()* for the same reason I mentioned in my assignment two. The scaling between 0 and 1 or 0 and 255, and the filter size depending on the sigma value.
2. Using the filtered image, I created a horizontal filter $[-1 \quad 0 \quad 1]$ and a vertical filter $\begin{bmatrix} -1 \\ 0 \\ 1 \end{bmatrix}$. Next, convolve the horizontal filter with image to get Jx and vertical filter with image to get Jy. Using Jx and Jy we can get matrix C, defined as $\mathrm{C} = \begin{bmatrix} \sum J_x^2 & \sum J_x J_y \\ \sum J_x J_y & \sum J_y^2 \end{bmatrix}$. Then diagonalize C to get two eigenvalues λ1 and λ2. If both lambda values are zero, there is no edge nor corner. If one of the lambda is zero, then there is an edge. If both lambdas are non-zero, then there is a corner. Assume $\lambda 1 \geq \lambda 2 > 0$, then we can identify this point is a corner as long as lambda2 is greater than a threshold tau τ.
3. In the code, there is a part where it calculates the maximum lambda2 value. τ can be any value between 1 and maximum lambda2 obtained. If τ is larger than maximum lambda2, then we would not have any corners detected and displayed. In this case, I chose τ to be half of maximum lambda2 value.
4. For all coordinates (x,y) who has a lambda2 value greater than τ, I added them to a list L that has the form of Nx3 matrix where N is the number of coordinates stored and varies depending on value of τ. The first column of L contains all x values, the second column

contains all y values, and the third column contains their corresponding lambda2 values. With the list L completed, sort it by lamdba2 value in descending order.

5. Next, for each entry on top of L, delete other entries who share the same neighborhood as the top entry. I created a new list FinalList that has the form Mx3 similar to list L, but M will be less than N after the process has been done. First, copy the first entry in L to FinalList. In list L, starting from second entry until the last entry in L, compare it to the first entry and determine if it is part of the first entries' neighborhood. If it is, then delete this current entry. After looping through, delete the first entry from L as well. The next in line becomes the first entry, copy to FinalList, and repeat the process. If the first entry in L is also the last, move it to FinalList and delete itself in L. The loop ends when L is empty. That leaves us FinalList with all coordinates that do not have another coordinate in each other's neighborhood.
6. Finally, plot FinalList into the image, demonstrating the locations of the corners.

Results and Discussion

I am going to first use my own image to discuss about the effects of different values of sigma and tau. Then use the professor's image to check if my observations are correct.

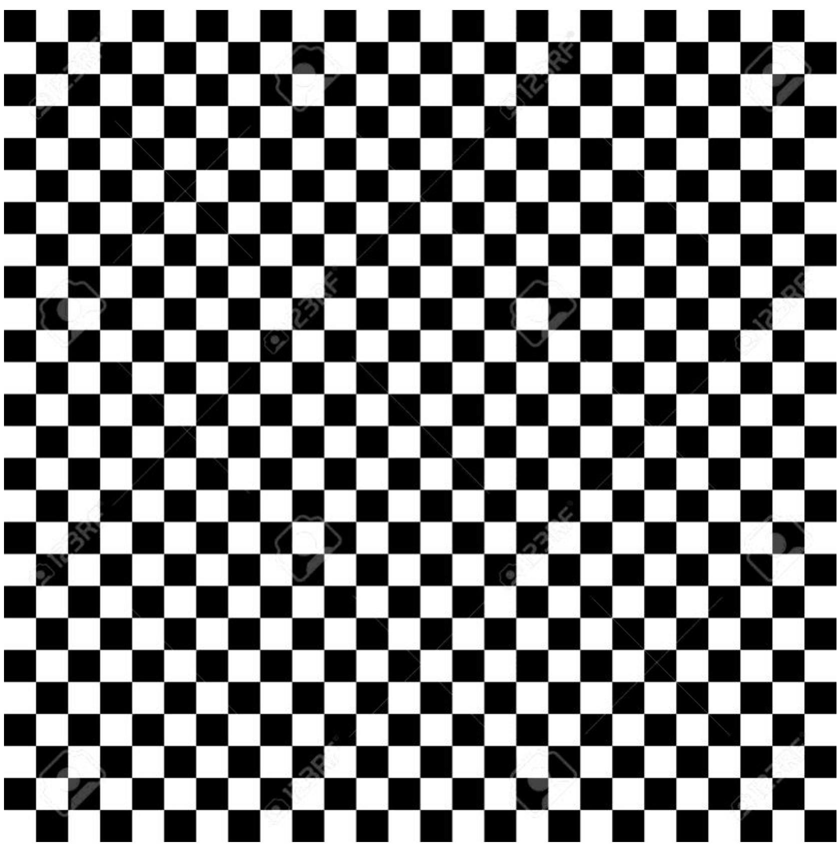

Figure 1. Original image of check3.jpg

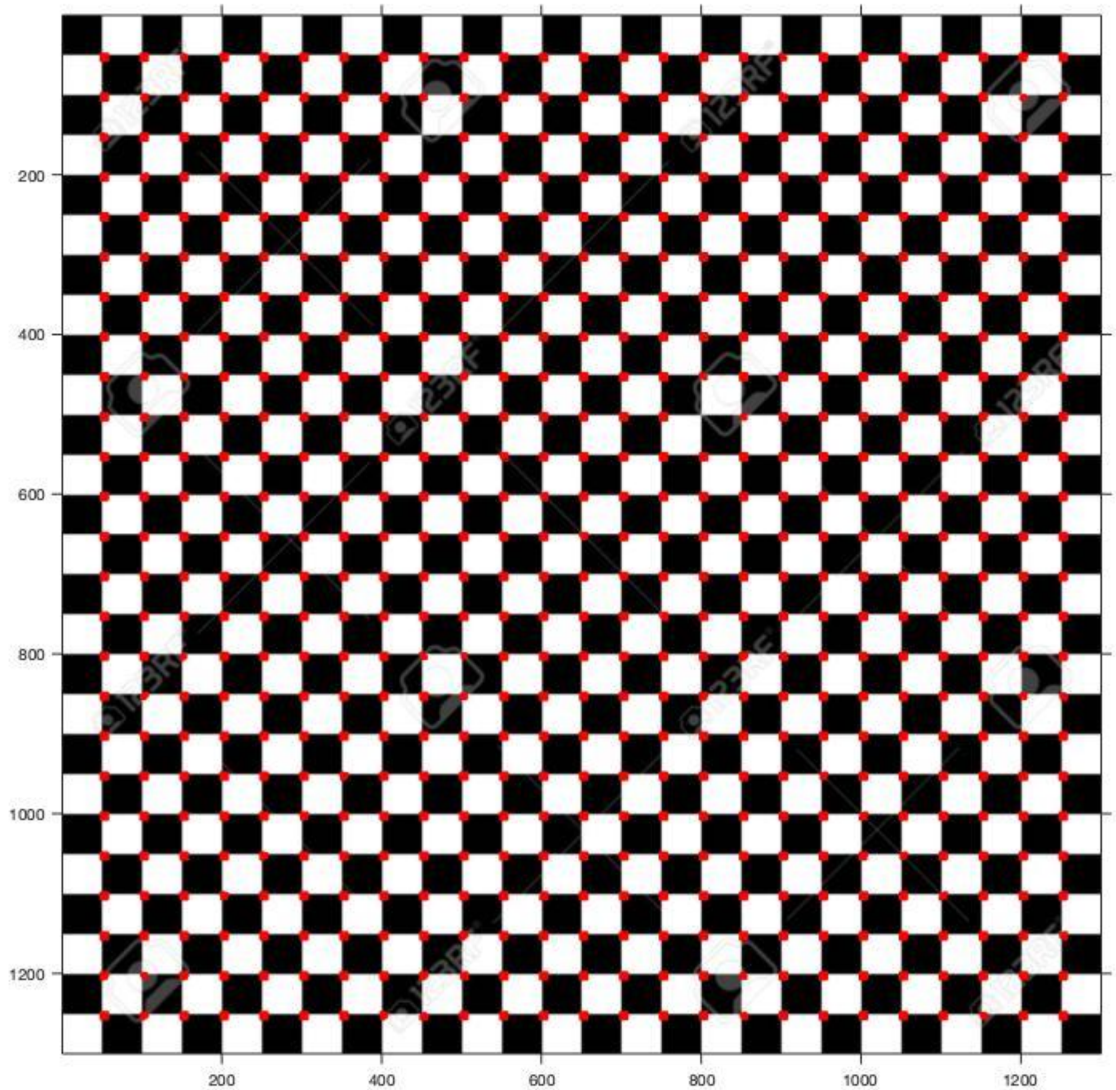

Figure 2. out check3.jpg with sigma = 1, N = 5, tau = 93,000, max-lambda = 186,211

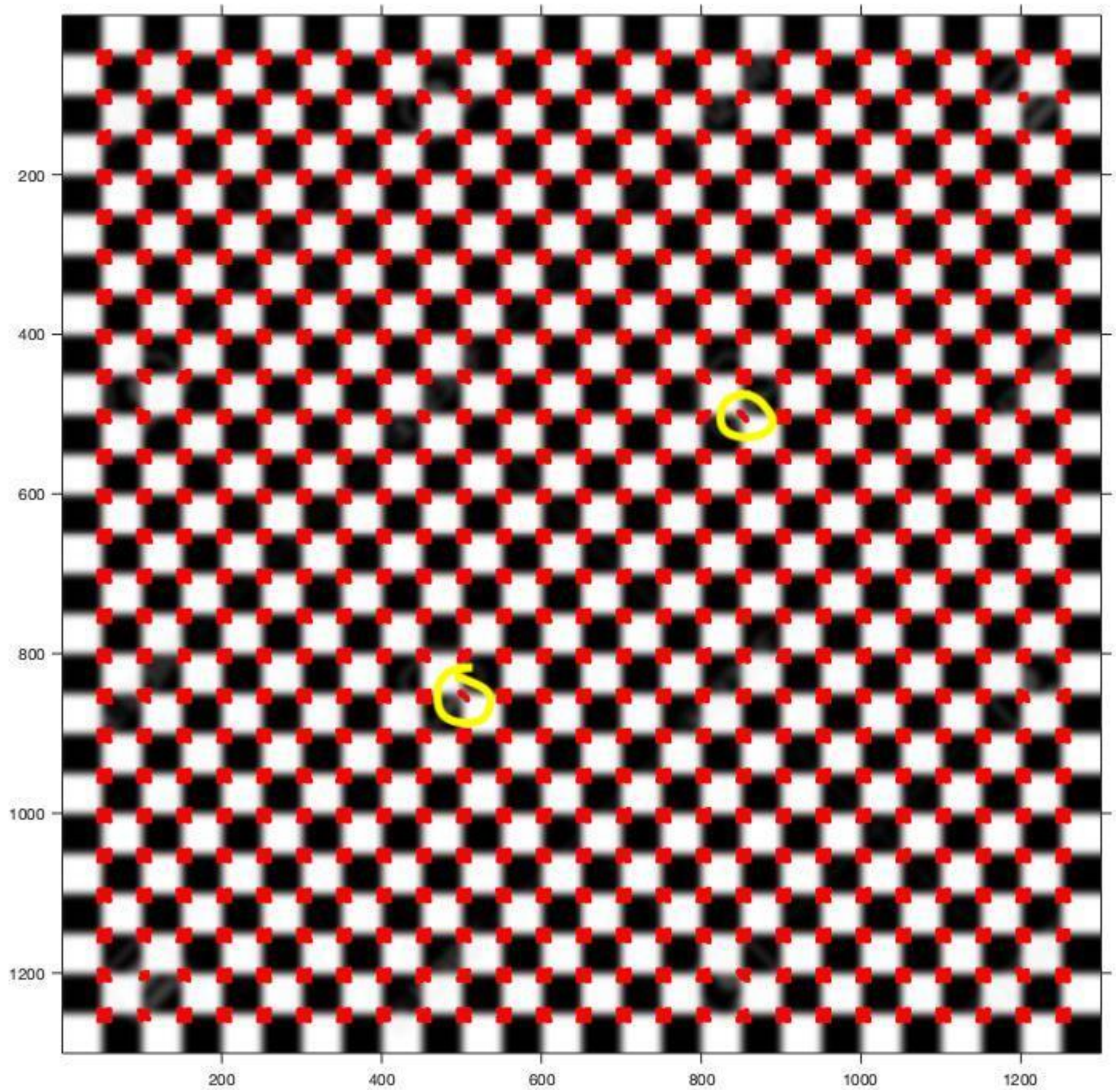

Figure 3. out check3.jpg with sigma = 5, N = 5, tau = 1100, max-lambda = 2218

The first thing to notice is that for figures 2 and 3, I used different tau values. Both values are roughly half of the maximum lambda2 value. In other words, figure 2 with the gaussian sigma of 1 gave a maximum lambda2 value of 186,211 whereas figure 3 with gaussian sigma of 5 gave a maximum lambda2 value of 2,218. Therefore, I cannot use the same tau value for both. Otherwise, figure 2 with smaller lambda value will be flooded with red markings. I tried to keep tau constant by making it half of the maximum lambda value.

Now compare the effect of gaussian filter on corner detection. With the smaller sigma value, it does not seem to have a big impact on the detection. However, in figure 3 with a larger sigma value, the area where I circled in yellow has a poor detection compared to some other points.

Compare it with figure 2 we can conclude that a larger sigma value affects the detection negatively. If we try an even bigger sigma value, we can expect that some corners will not be detected because of the blur.

For the next analysis, I will use a sigma of 1 for all images.

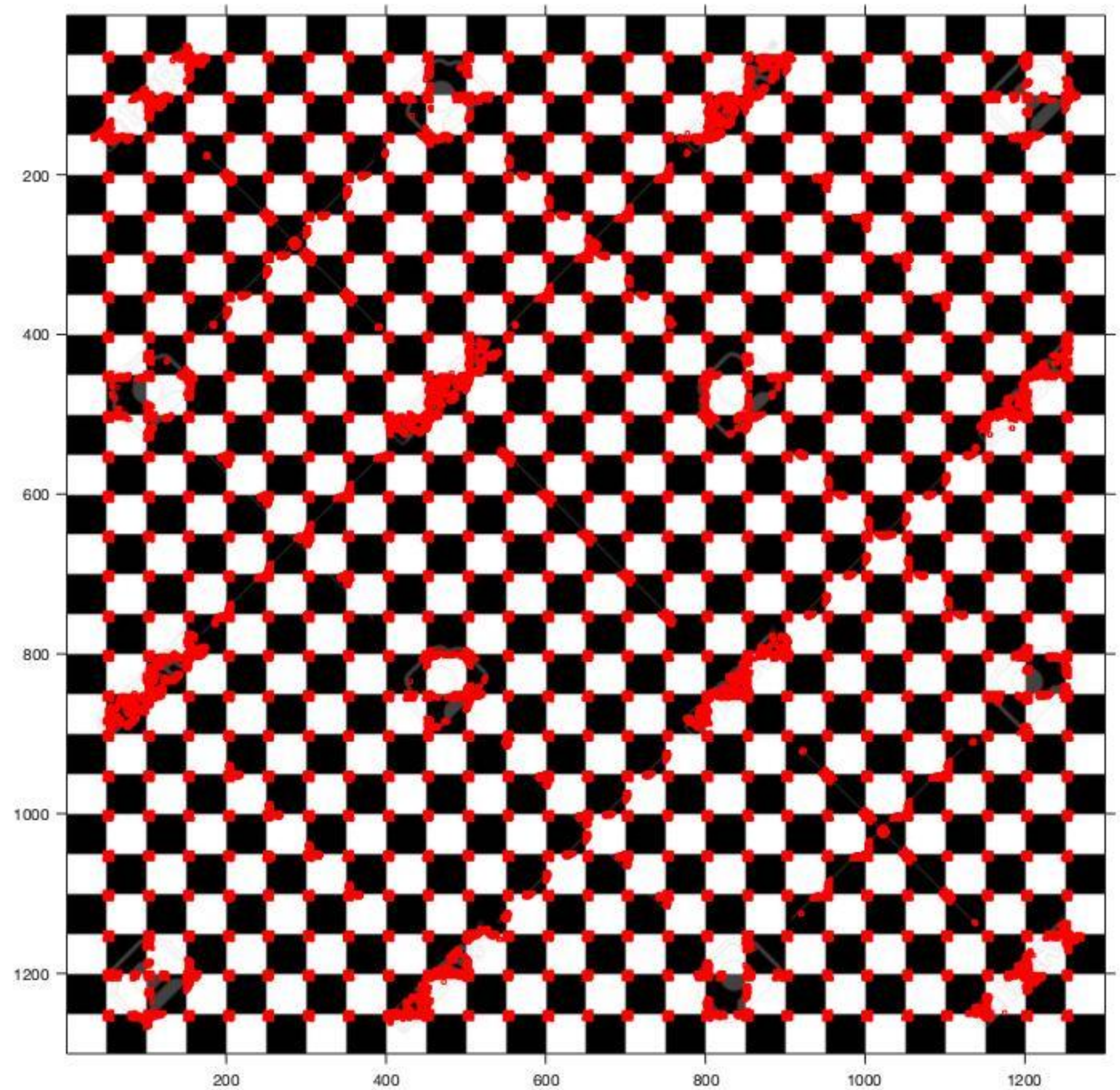

Figure 4. out check3.jpg with sigma = 1, N = 5, tau = 1,000, max-lambda = 186,211

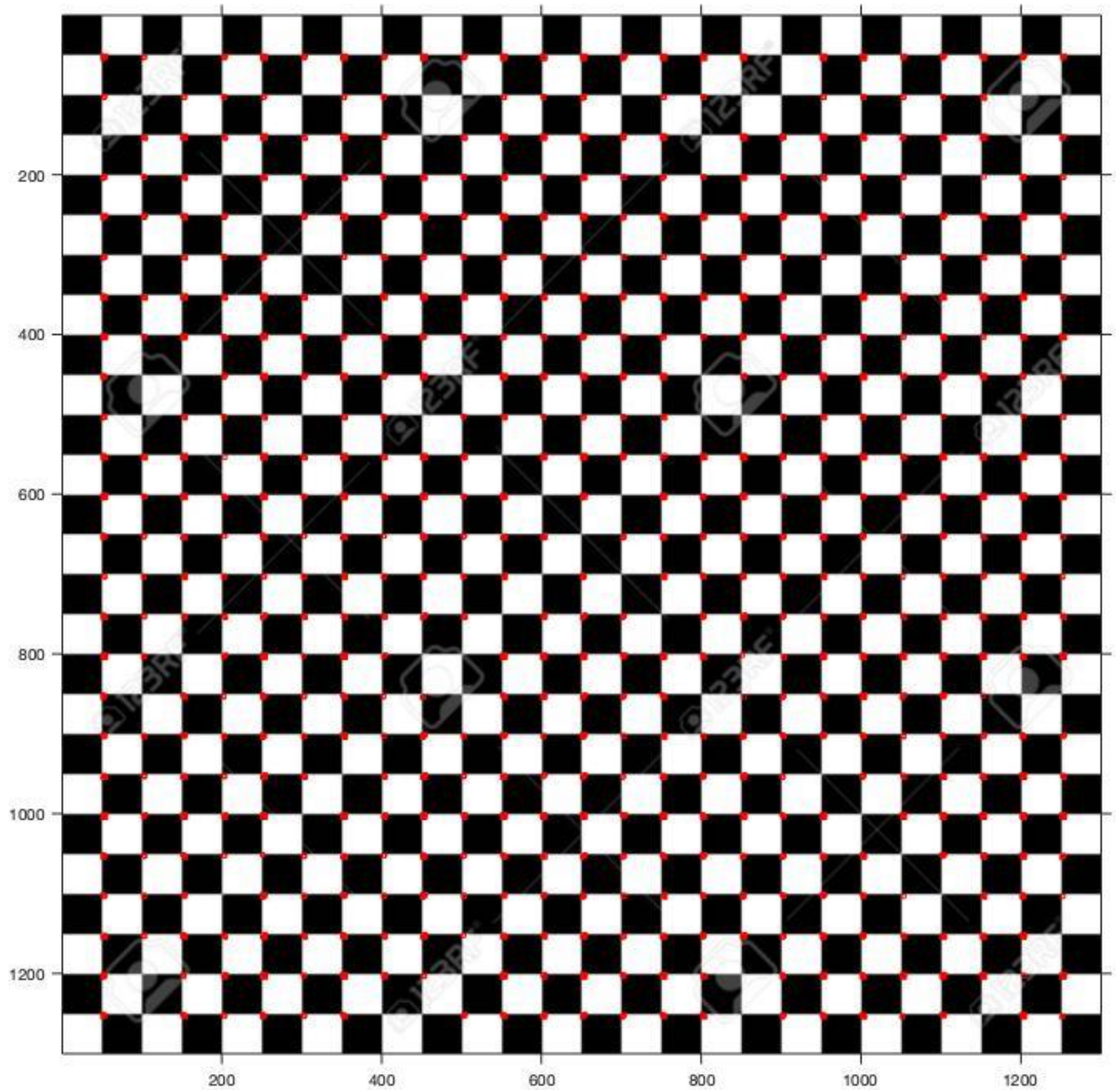

Figure 5. out check3.jpg with sigma = 1, N = 5, tau = 170,000, max-lambda = 186,211

Compare figure 4 and 5, I changed the tau value. The maximum sigma value is 186,211, so I tried two extremes of tau: 1,000 and 170,000. The effects are quite obvious. When tau is 1000, the FinalList has a size of 46,243x3 meaning that there are 46,243 lambda values larger than 1000. Then there are 46,243 boxes plotted onto the output image. This will create a lot of points where a non-corner will be considered as a corner.

On the other hand, in figure 5 where tau is 170,000. The FinalList only has 2,646 entries (corners detected). In this case, many true corners are not being plotted because the tau value is too high. Both figures are expected since tau acts as a threshold value for a point to be considered as a corner.

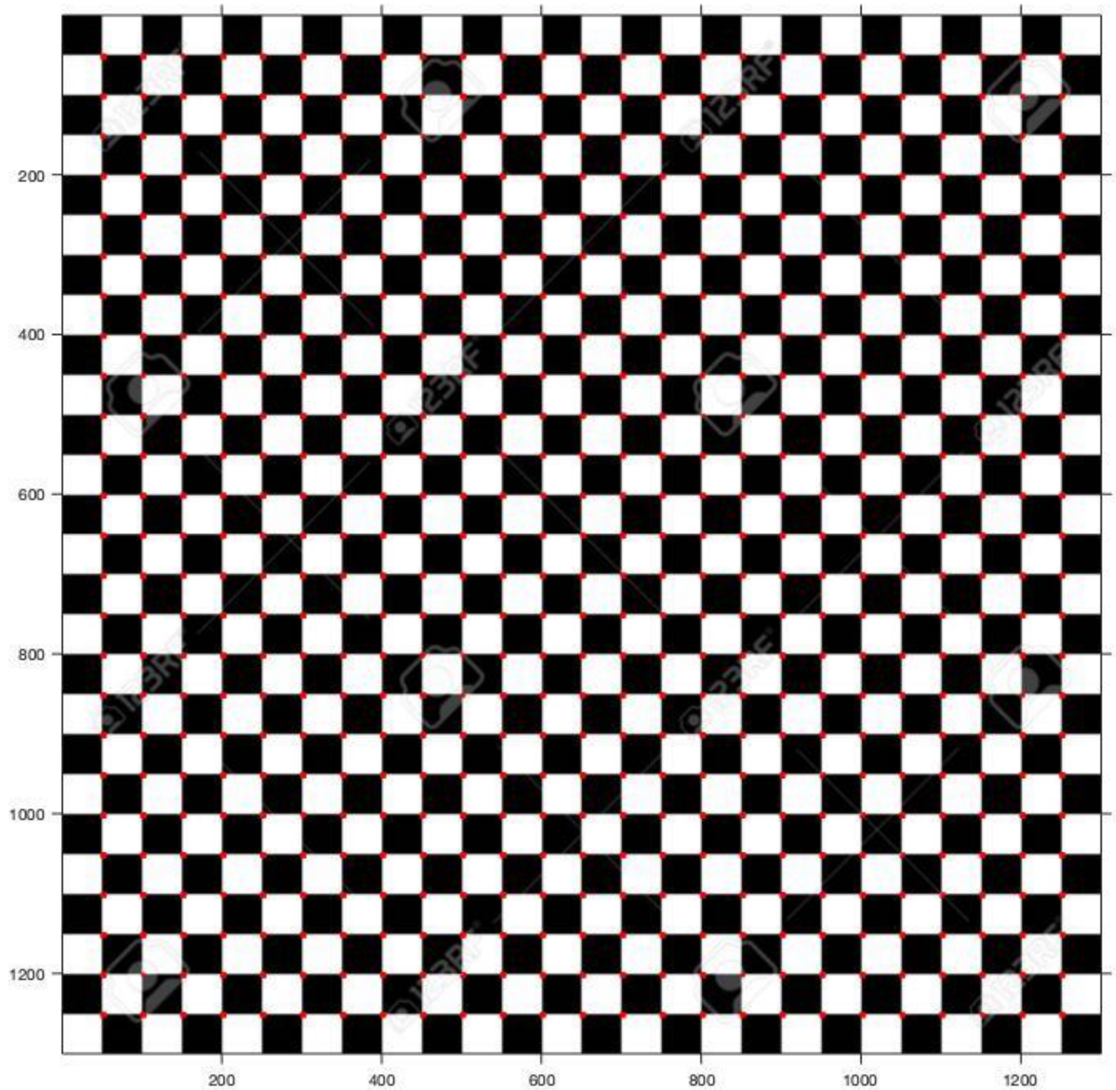

Figure 6. out check3.jpg with sigma = 1, N = 3, tau = 30,000, max-lambda = 60,981

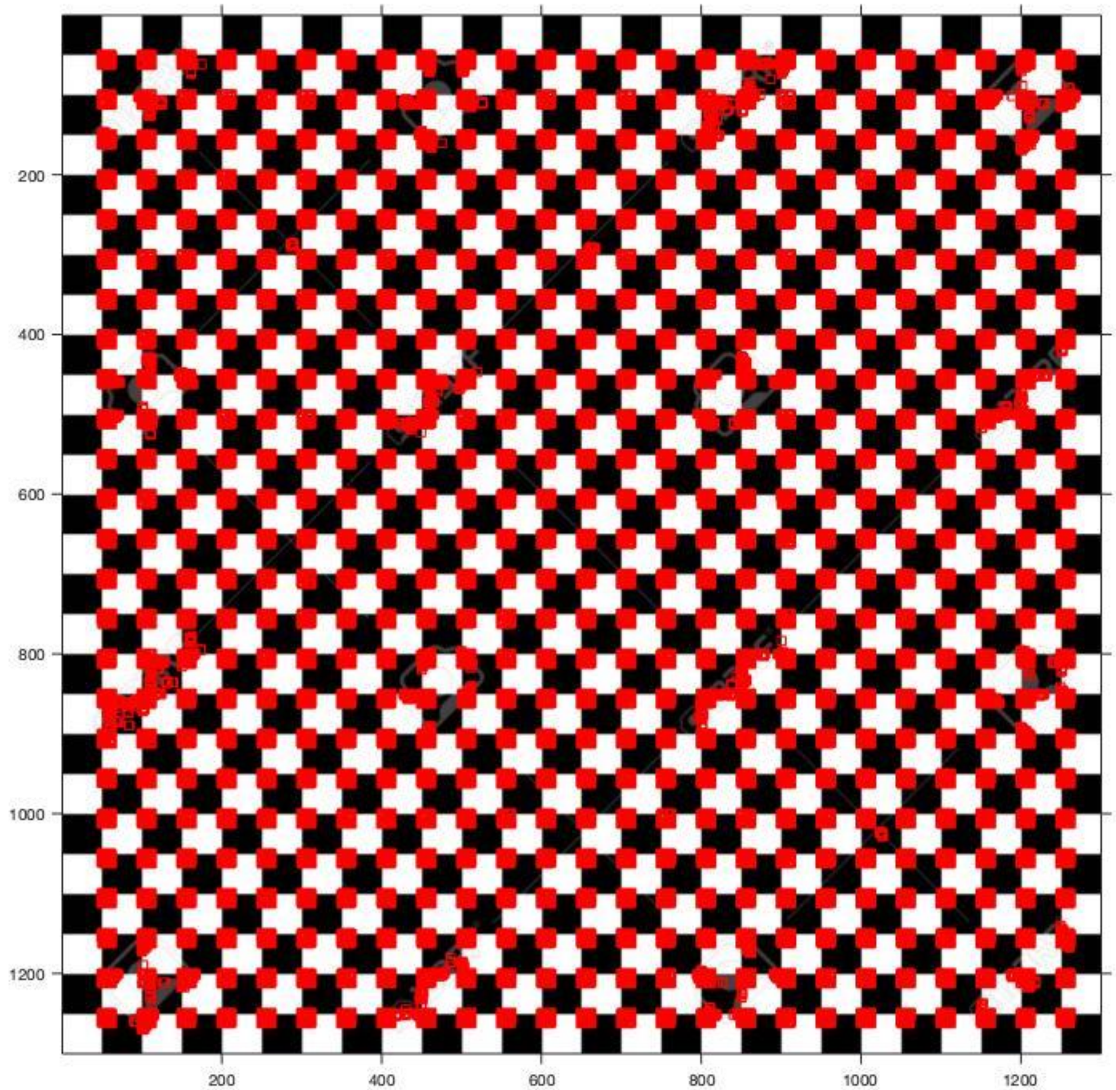

Figure 7. out check3.jpg with sigma = 1, N = 11, tau = 290,000, max-lambda = 576,844

Again, I used different tau values. Different neighborhood sizes will affect the number of lambdas in the FinalList. In order to see the effect of neighborhood sizes. I had to use tau to be half of max-lambda. In figure 6, the neighborhood size is 3x3(N=1) with max-lambda of 60,981. In figure 7, the neighborhood size is 11x11(N=5) with max-lambda of 576,844. When I set the tau to be 30,000 and 290,000, their number of lambda values in the FinalList are respectively 8,413 and 9,874. Therefore, it is quite fair to compare the two.

In figure 6, the red boxes are exactly on top of the corners and the red box size is decided by the neighborhood size. On the other hand, in figure 7, the red boxes are not exactly on top of the corner. Comparing the two, we can see that the larger the neighborhood, the further the red box is away from the actual corner. To confirm this point, I tried 17x17 neighborhood in figure 8 and it proves my observation.

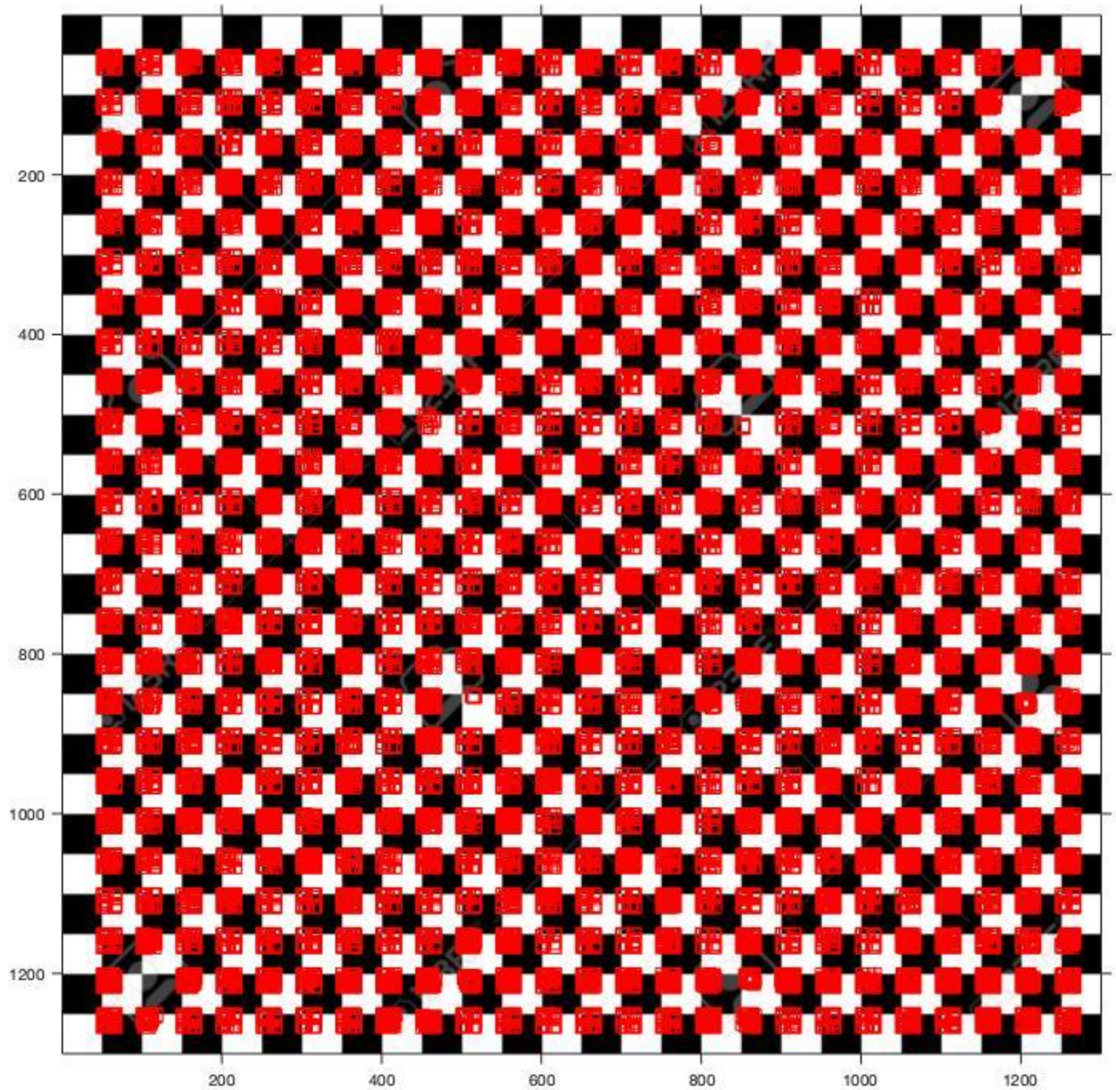

Figure 8. out check3.jpg with sigma = 1, N = 17x17, tau = 550,000

Now with required images, I am going to test the effect of sigma value first.

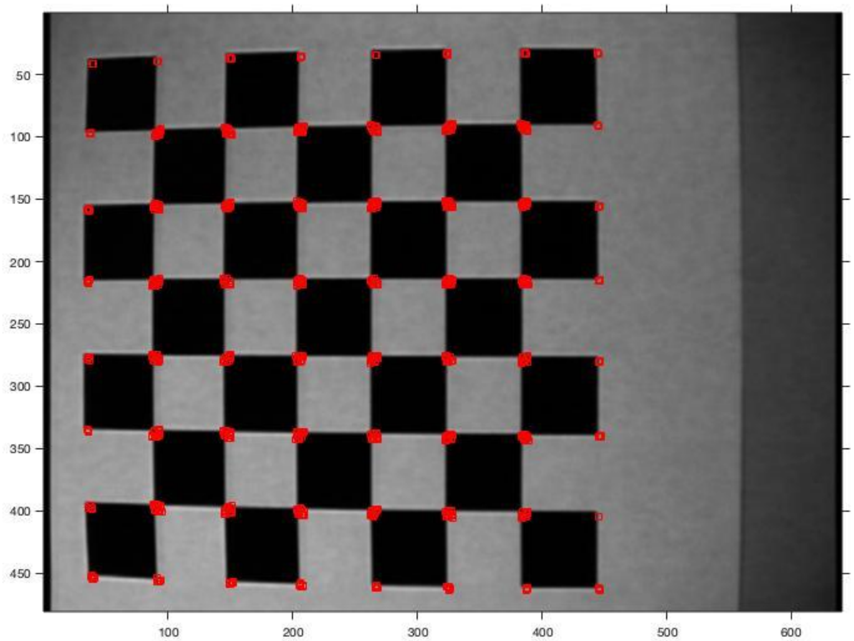

Figure 9. out CheckerBoard.jpg with sigma = 1, N = 5, tau = 20,000, max-lambda = 69,707

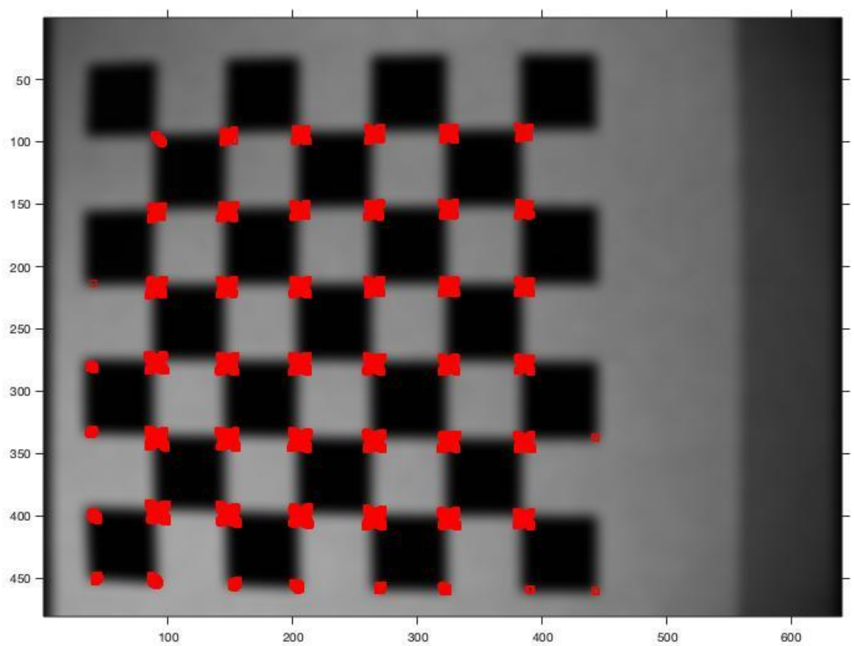

Figure 10. out CheckerBoard.jpg with sigma = 5, N = 5, tau = 400, max-lambda = 914

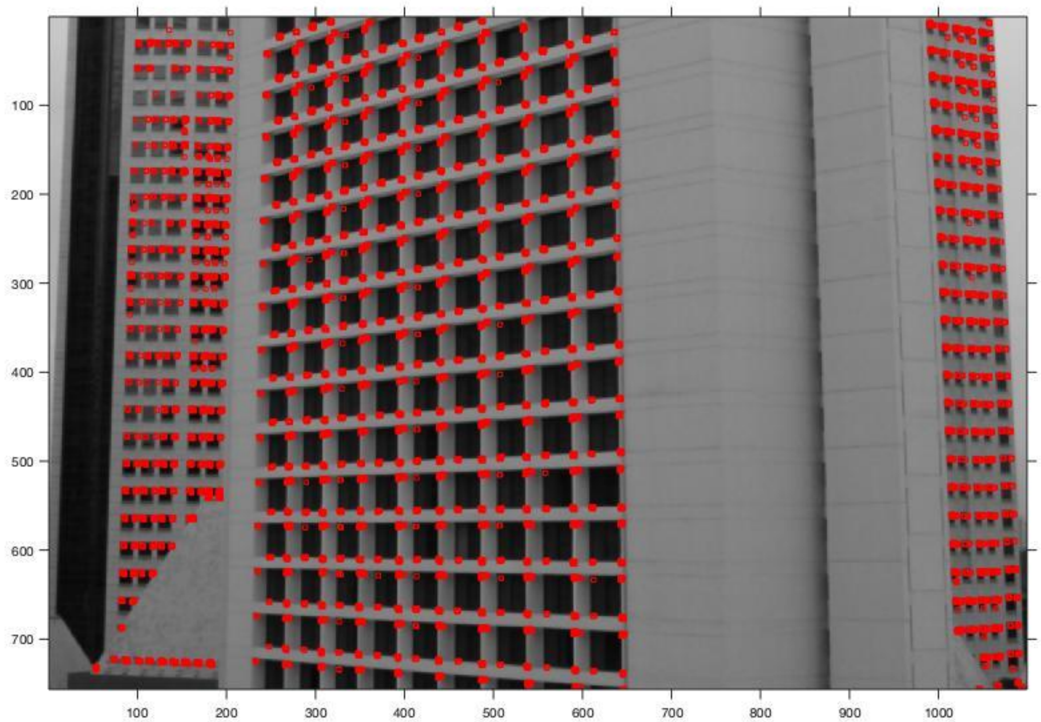

Figure 11. out building1.jpg with sigma = 1, N = 1, tau = 7000, max-lambda = 25752

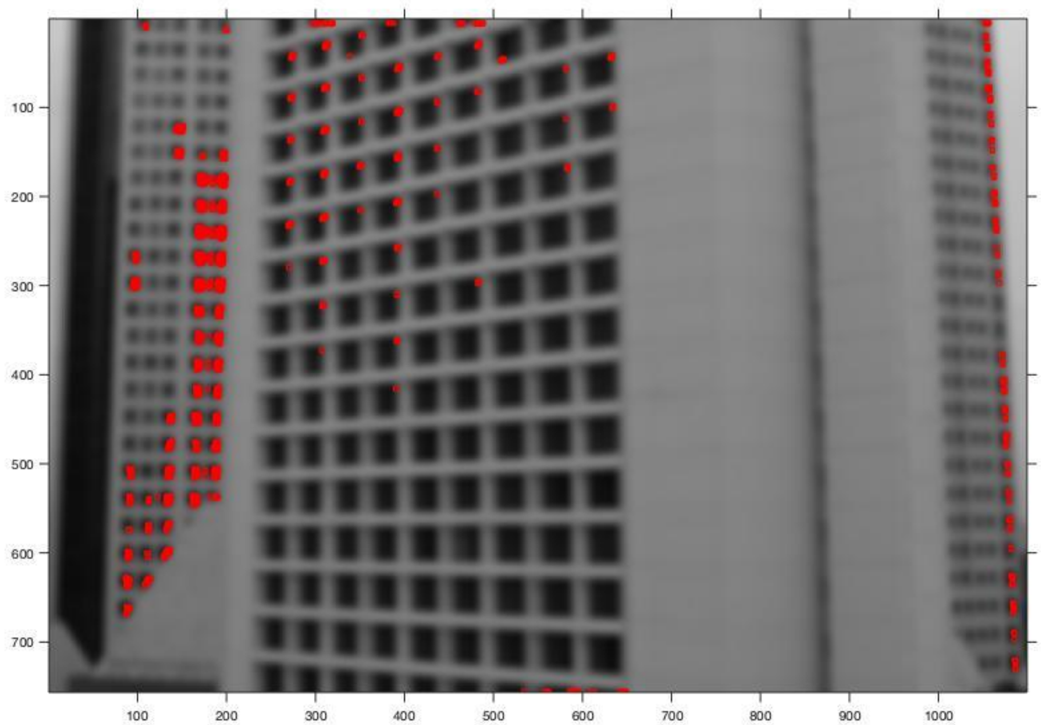

Figure 12. out building1.jpg with sigma = 5, N = 5, tau = 300, max-lambda = 859

Figure 9 has 623 entries in the FinalList and all corners are marked out. However, figure 10 has 3133 entries in the FinalList and some corners are left undetected. This means that many points in figure 10 are plotted to a non-corner location. Figures 11 and 12 are similar to figures 9 and 10 respectively.

This proves my previous observation that a higher sigma value results in corners being undetectable.

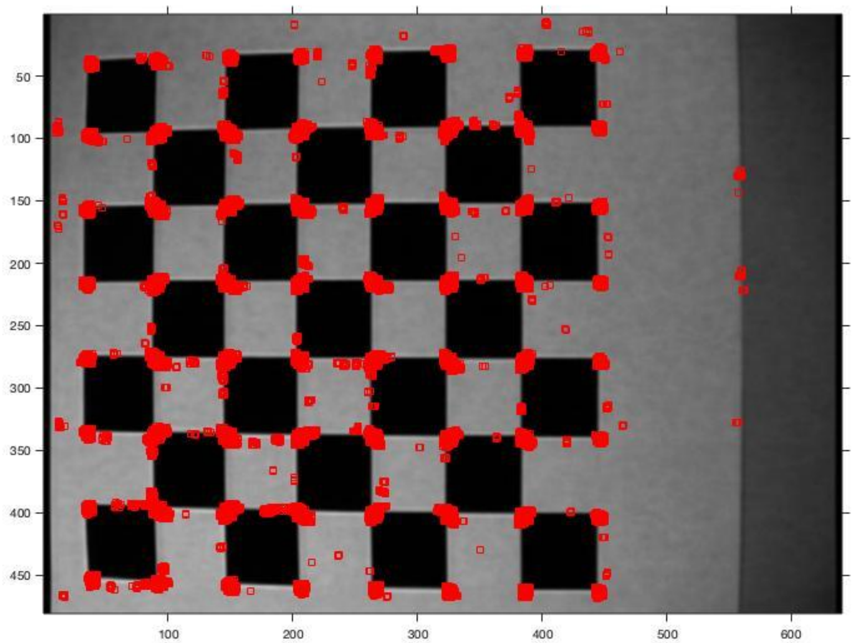

Figure 13. out CheckerBoard.jpg with sigma = 1, N = 5, tau = 200, max-lambda = 69,707

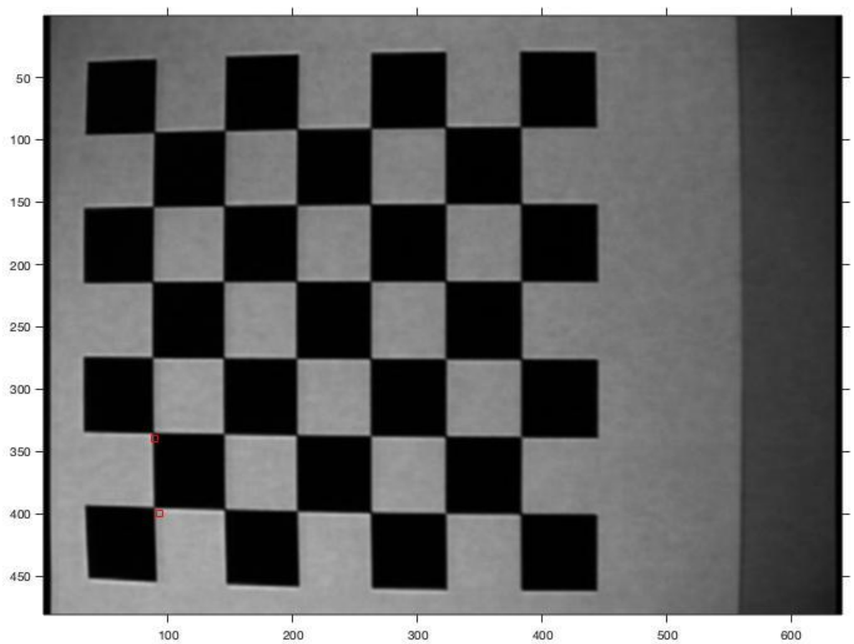

Figure 14. out CheckerBoard.jpg with sigma = 1, N = 5, tau = 67000, max-lambda = 69,707

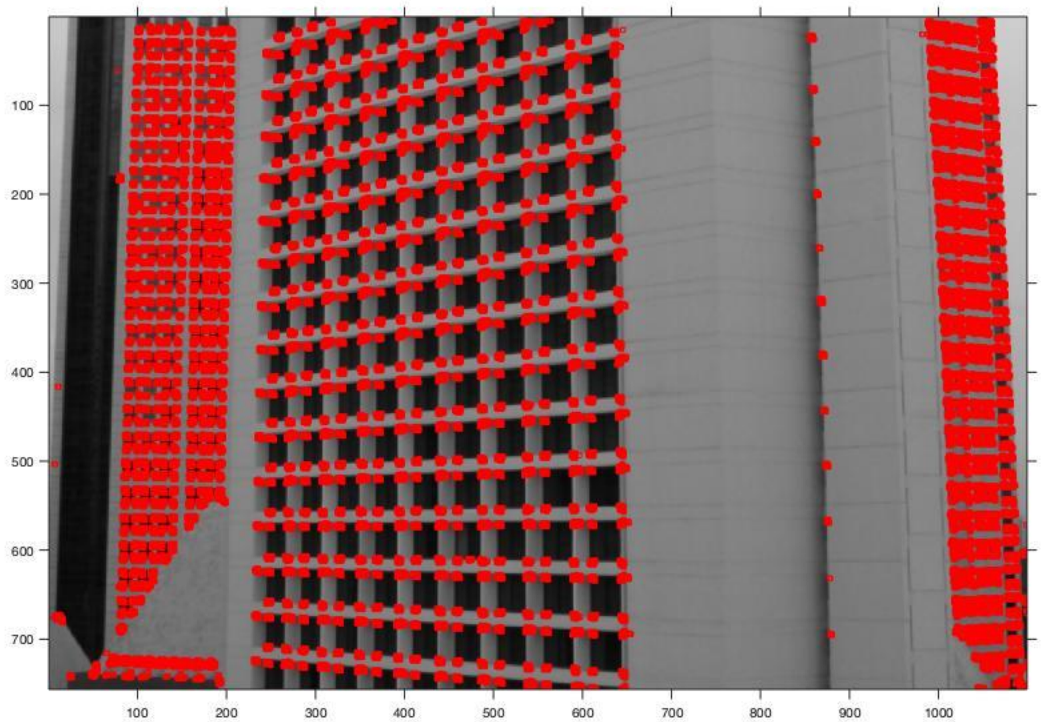

Figure 15. out building1.jpg with sigma = 1, N = 5, tau = 1000, max-lambda = 25,752

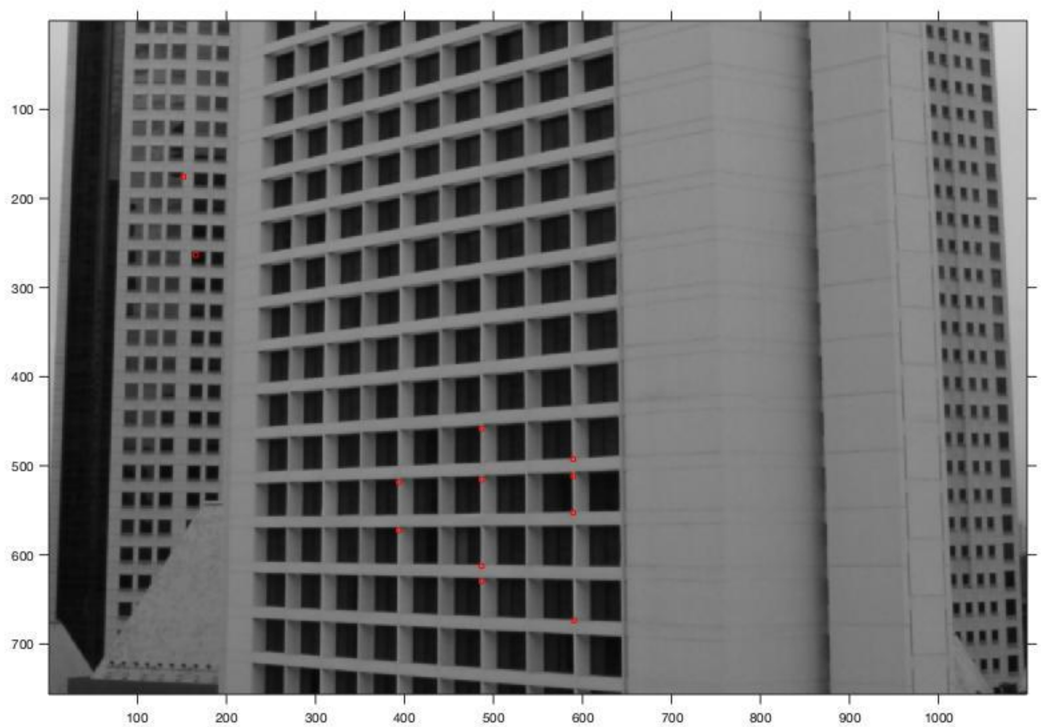

Figure 16. out building1.jpg with sigma = 1, N = 5, tau = 23,000, max-lambda = 25,752

Compare figures 13 with 14, 15 with 16, I set the tau value to be two extremes. When tau is very small compared to max-lambda, it will have lots of points where it is not a corner. Similarly, when tau is very large, many true corners are excluded because the lambda value did not pass the threshold.

In figure 13 there are 5,341 plots whereas in figure 14 there are only 3.

In figure 15 there are 43,423 plots compared to only 13 in figure 16.

This again proves my observation that if the threshold is too small, it will give too many non-corners, and if the threshold is too large, it will not give out enough true corners.

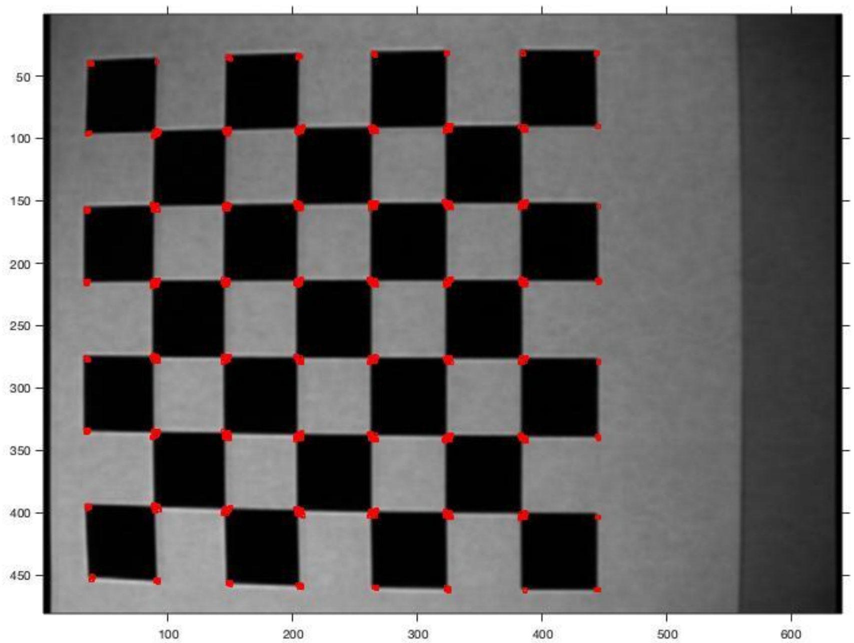

Figure 17. out CheckerBoard.jpg with sigma = 1, N = 3, tau = 4000, max-lambda = 20,410

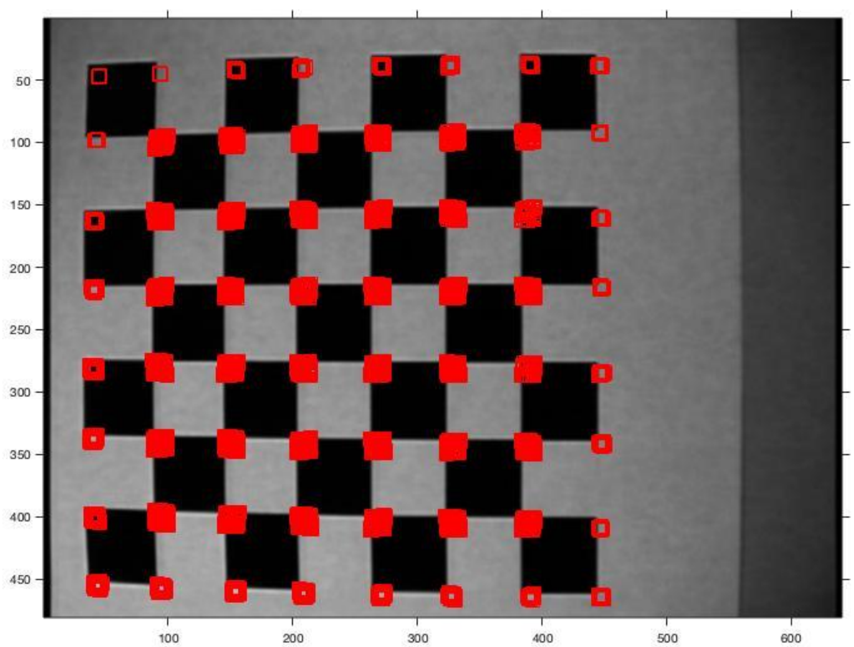

Figure 18. out CheckerBoard.jpg with sigma = 1, N = 11, tau = 80000, max-lambda = 227,909

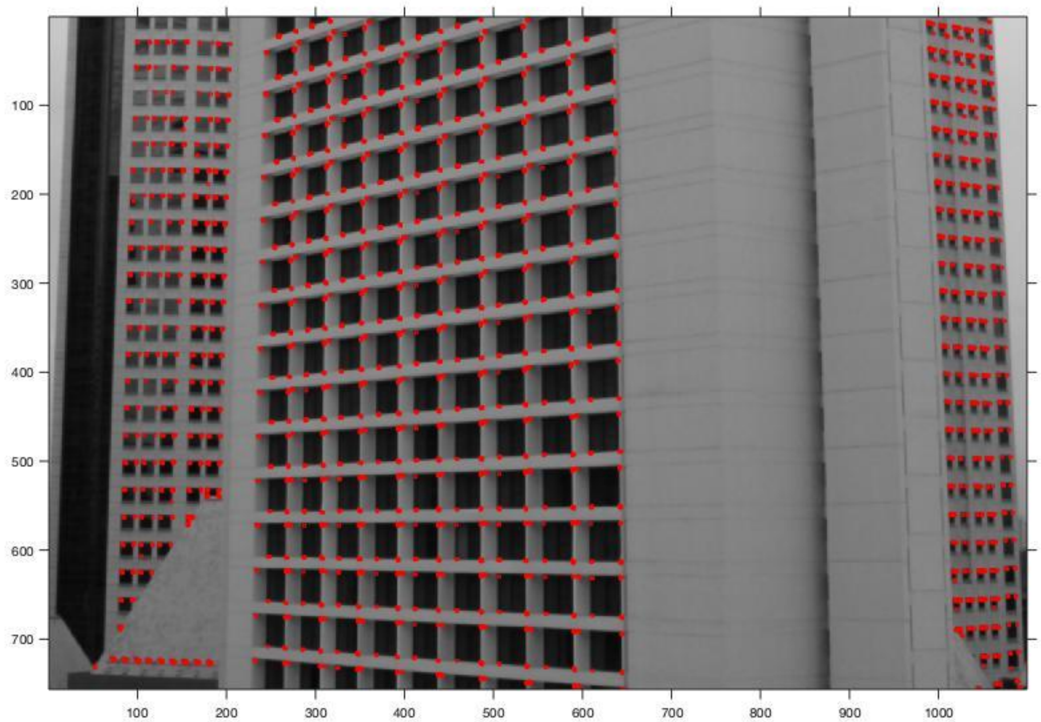

Figure 19. out building1.jpg with sigma = 1, N = 3, tau = 2000, max-lambda = 7767

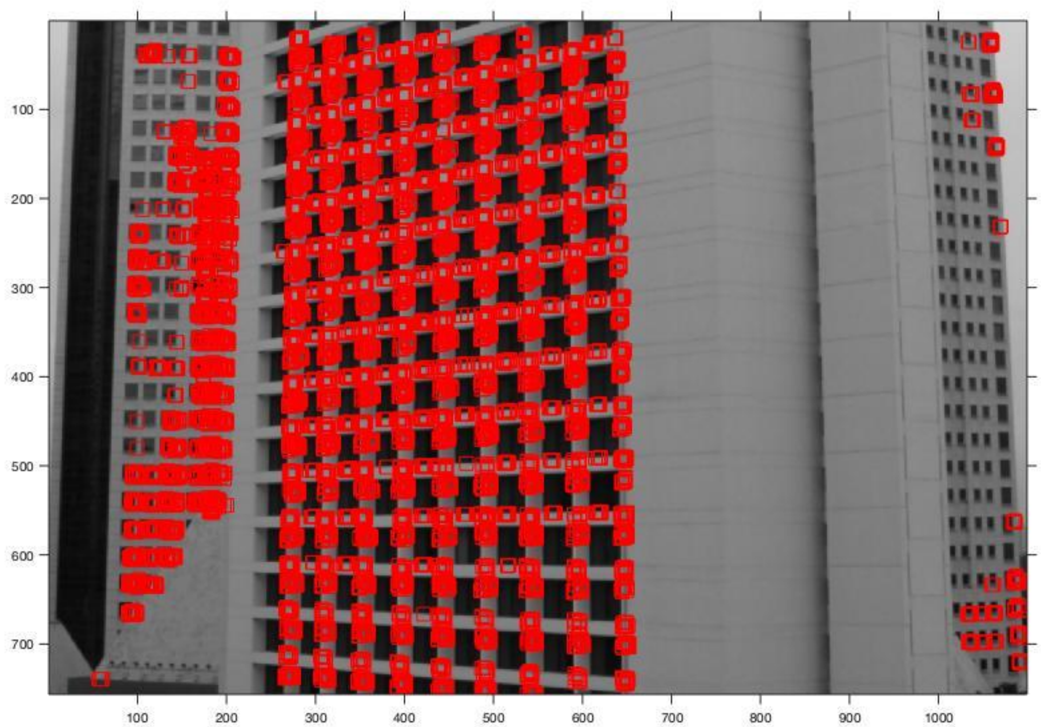

Figure 20. out building1.jpg with sigma = 1, N = 13, tau = 60,000, max-lambda = 144,035

Compare figures 17 with 18, 19 with 20, I tried different neighborhood sizes. With a small neighborhood size, the plots are quite accurate on top of the corners and with a larger neighborhood size, the plots are off the mark. This means that the larger the neighborhood, the less accuracy of the plotting, which also supports my observation from previous.

Future Improvement

With this algorithm, there is no best output. The only thing we can do is to keep on adjusting the variables to get a better result. With nothing much to improve in the algorithm, we can try to improve the code. For example, improving its speed of execution or decrease its memory requirement.

Conclusion

- Larger sigma value affects the accuracy of corner detection due to blur.
- Small tau value with result in lots of non-corner plotting and large tau value will result in true corner being missed.
- Large neighborhood size diverges the plot from the actual corner.