Ph21 Assignment 3
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1 Gaussian Filter

The original picture is shown in Figure 1.

Figure 1: The original picture used in this assignment.

We used a 7x7 stencil for the gaussian filter to blur the picture as in Figure 2. A sample of 3x3 gaussian array is: $\begin{bmatrix} e^{-((-1)^2+(-1)^2)} & e^{-(-1)^2} & e^{-(1^2+(-1)^2)} \\ e^{-(-1)^2} & e^0 & e^{-1^2} \\ e^{-((-1)^2+1^2)} & e^{-1^2} & e^{-(1^2+1^2)} \end{bmatrix}$. The gaussian array is normalized by dividing each entry by the sum of the array. The pixel array is then convolved with the gaussian array.

Figure 2: The picture after applying the gaussian filter.

2 Sobel method

We applied the Sobel method to find the intensity of the gradient. For the Sobel method $G_x = \begin{bmatrix} +1 & 0 & -1 \\ +2 & 0 & -2 \\ +1 & 0 & -1 \end{bmatrix} * pixels$ and $G_y = \begin{bmatrix} +1 & 2 & +1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix} * pixels$. The gradient matrix is $\sqrt{G_x^2 + G_y^2}$ and the direction matrix is $\theta = atan2(G_y, G_x)$. The picture obtained from the Sobel gradient matrix is in Figure 3.

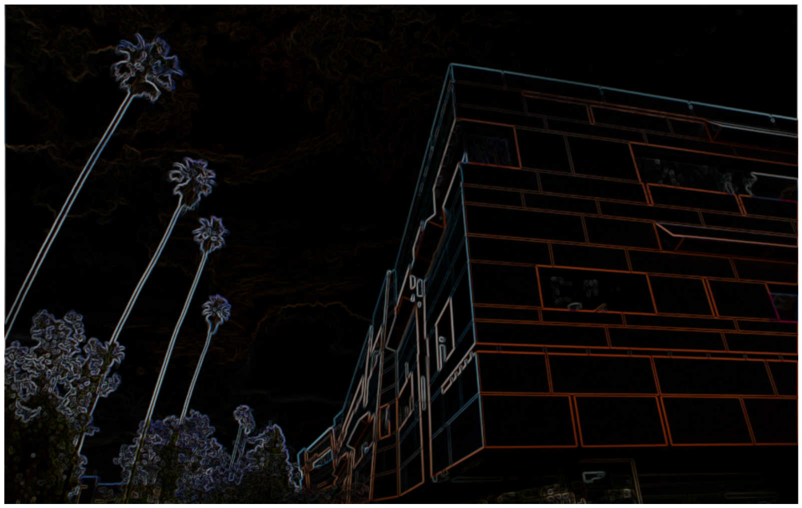

Figure 3: Picture obtained from Sobel method.

3 Non-maximum suppression

Notice that some of the edges in 3 are thicker. We use the non-maximum suppression method to make the edges thinner (reduce double detection rate). Each pixel is surrounded by 8 other pixels, except for the pixels at the ends of the picture. The direction matrix is used to determine which direction the gradient is pointing towards. The value of each pixel is compared with the other two pixels in the direction of the gradient. If the pixel is not a local maximum, we set its value to zero. This method indeed makes some edges thinner as in Figure 4.

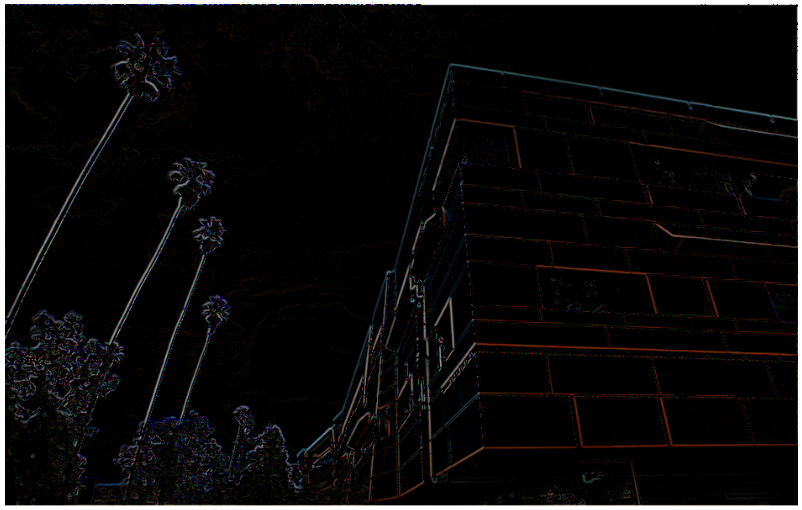

Figure 4: Non-maximum suppression applied to the gradient matrix from the Sobel method.

4 Gaussian derivative method

We also implemented the gaussian derivative method for the intensity of the gradient of the pixel array. Non-maximum suppression is applied to the gradient array from the gaussian derivative method. The size of the stencil convolved with the blurred pixel array and the width of the gaussian function are adjustable parameters. After several trials, we found that we can produce good results by using a 5x5 stencil with a width of 0.2. The edge detection graphs are shown in Figures 5, 6, 7, and 8. The edges detected become sharper and thinner as we decrease the width of the gaussian.

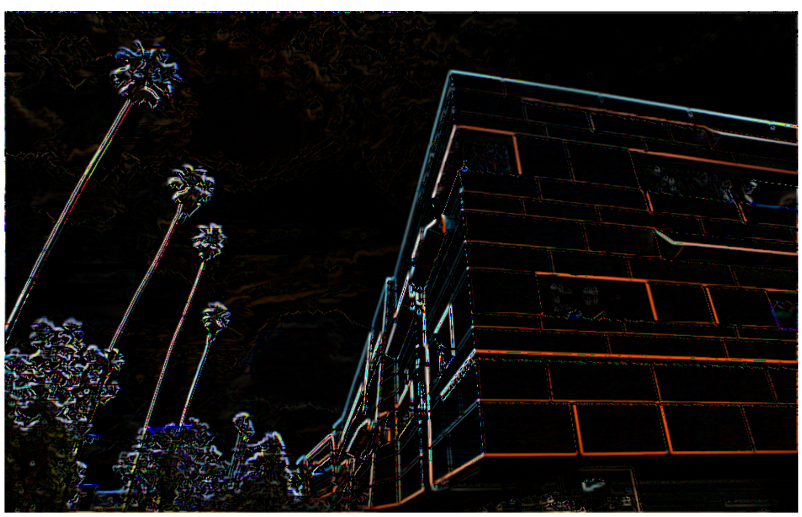

Figure 5: Gaussian derivative method with 5x5 stencil and gaussian width = 2.2.

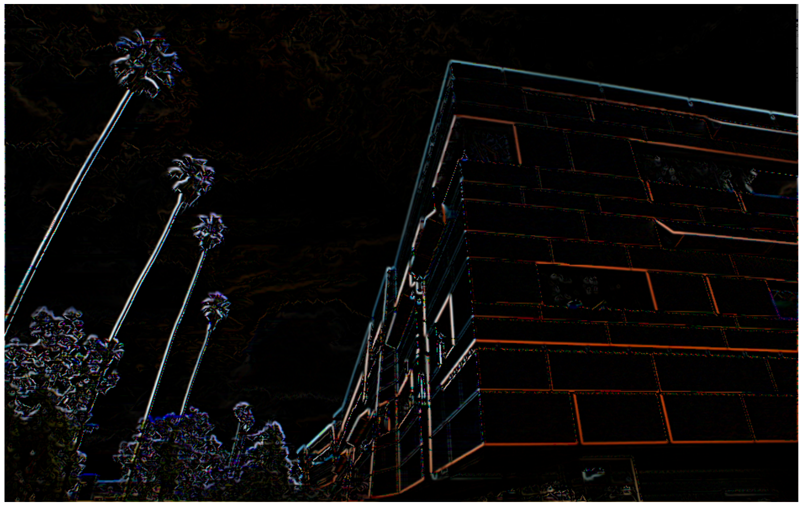

Figure 6: Gaussian derivative method with 5x5 stencil and gaussian width = 1.

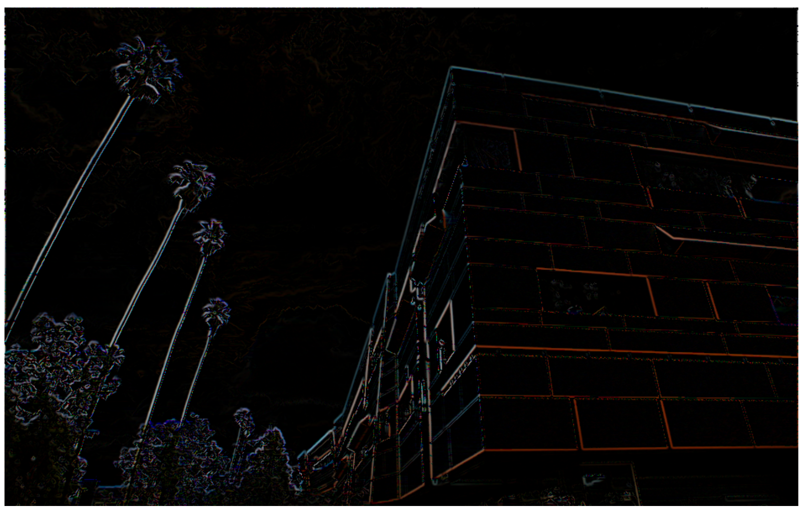

Figure 7: Gaussian derivative method with 5x5 stencil and gaussian width = 0.7.

Figure 8: Gaussian derivative method with 5x5 stencil and gaussian width = 0.2.

5 Conclusion

The gaussian derivative method is a little better than the Sobel method when the width of the gaussian is small enough. However, the Sobel method is much simpler and has almost the same effect as the gaussian derivative method.

It is possible to use edge detection to defeat CAPTCHAS if the algorithm is strong enough to detect the edges of objects and recognize the objects. Edge detection can be used in medical science to find tumors in brains. It can also be used in satellite images to create accurate edge maps.