Assignment 1 - 3D Computer Vision

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3rd September 2018

Question 1 (a and b)

Gaussian Kernel with standard deviation 1

$$\begin{bmatrix}
1.791e-08 & 5.931e-07 & 7.226e-06 & 3.238e-05 & 5.339e-05 & 3.238e-05 & 7.226e-06 & 5.931e-07 & 1.791e-08 \\
5.931e-07 & 1.964e-05 & 2.393e-04 & 1.072e-03 & 1.768e-03 & 1.072e-03 & 2.393e-04 & 1.964e-05 & 5.931e-07 \\
7.226e-06 & 2.393e-04 & 2.915e-03 & 1.306e-02 & 2.154e-02 & 1.306e-02 & 2.915e-03 & 2.393e-04 & 7.226e-06 \\
3.238e-05 & 1.072e-03 & 1.306e-02 & 5.855e-02 & 9.653e-02 & 5.855e-02 & 1.306e-02 & 1.072e-03 & 3.238e-05 \\
5.339e-05 & 1.768e-03 & 2.154e-02 & 9.653e-02 & 1.592e-01 & 9.653e-02 & 2.154e-02 & 1.768e-03 & 5.339e-05 \\
3.238e-05 & 1.072e-03 & 1.306e-02 & 5.855e-02 & 9.653e-02 & 5.855e-02 & 1.306e-02 & 1.072e-03 & 3.238e-05 \\
7.226e-06 & 2.393e-04 & 2.915e-03 & 1.306e-02 & 2.154e-02 & 1.306e-02 & 2.915e-03 & 2.393e-04 & 7.226e-06 \\
5.931e-07 & 1.964e-05 & 2.393e-04 & 1.072e-03 & 1.768e-03 & 1.072e-03 & 2.393e-04 & 1.964e-05 & 5.931e-07 \\
1.791e-08 & 5.931e-07 & 7.226e-06 & 3.238e-05 & 5.339e-05 & 3.238e-05 & 7.226e-06 & 5.931e-07 & 1.791e-08
\end{bmatrix}$$

Output on convolving with the above filter:

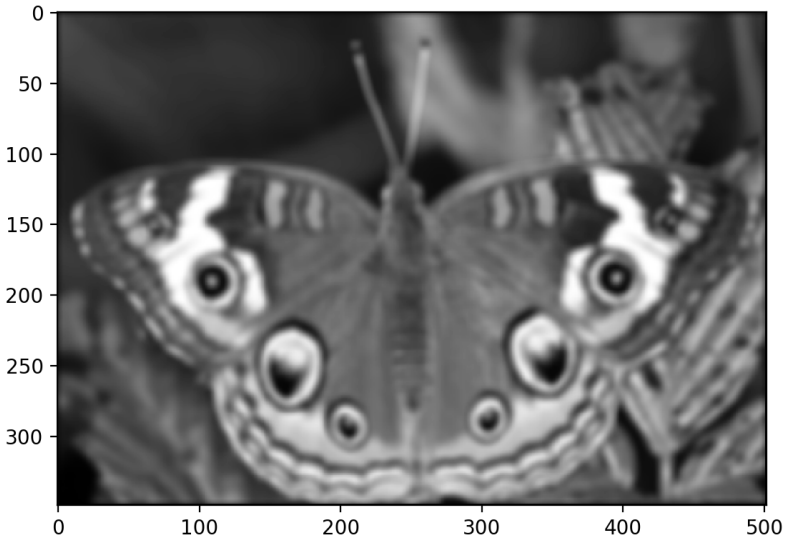
Figure 1: Convolution with Gaussian Kernel (Std. Deviation: 1)

Gaussian Kernel with standard deviation 3

$$\begin{bmatrix} 0.004 & 0.006 & 0.008 & 0.009 & 0.01 & 0.009 & 0.008 & 0.006 & 0.004 \\ 0.006 & 0.009 & 0.011 & 0.013 & 0.014 & 0.013 & 0.011 & 0.009 & 0.006 \\ 0.008 & 0.011 & 0.015 & 0.018 & 0.019 & 0.018 & 0.015 & 0.011 & 0.008 \\ 0.009 & 0.013 & 0.018 & 0.021 & 0.022 & 0.021 & 0.018 & 0.013 & 0.009 \\ 0.01 & 0.014 & 0.019 & 0.022 & 0.023 & 0.022 & 0.019 & 0.014 & 0.01 \\ 0.009 & 0.013 & 0.018 & 0.021 & 0.022 & 0.021 & 0.018 & 0.013 & 0.009 \\ 0.008 & 0.011 & 0.015 & 0.018 & 0.019 & 0.018 & 0.015 & 0.011 & 0.008 \\ 0.006 & 0.009 & 0.011 & 0.013 & 0.014 & 0.013 & 0.011 & 0.009 & 0.006 \\ 0.004 & 0.006 & 0.008 & 0.009 & 0.01 & 0.009 & 0.008 & 0.006 & 0.004 \end{bmatrix}$$

Output on convolving with the above filter:

Figure 2: Convolution with Gaussian Kernel (Std. Deviation: 3)

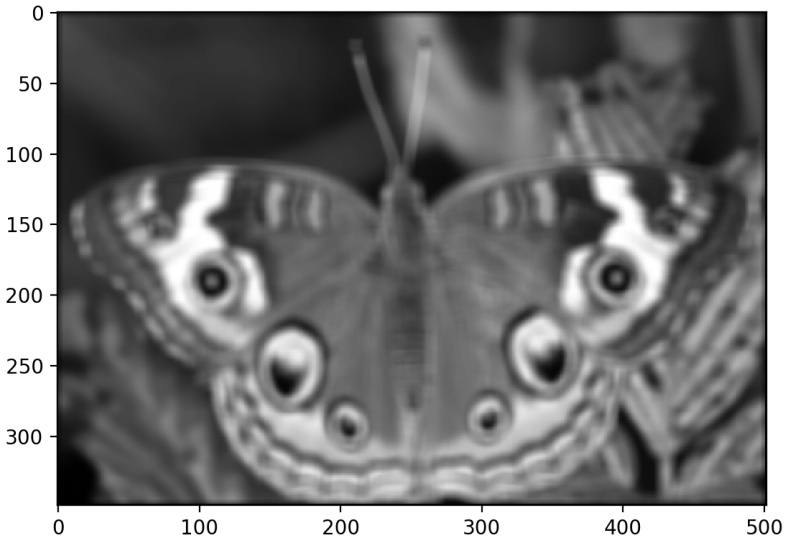


Gaussian Kernel with standard deviation 20

$$\begin{bmatrix} 0.012 & 0.012 & 0.012 & 0.012 & 0.012 & 0.012 & 0.012 & 0.012 & 0.012 \\ 0.012 & 0.012 & 0.012 & 0.012 & 0.012 & 0.012 & 0.012 & 0.012 & 0.012 \\ 0.012 & 0.012 & 0.012 & 0.012 & 0.012 & 0.012 & 0.012 & 0.012 & 0.012 \\ 0.012 & 0.012 & 0.012 & 0.013 & 0.013 & 0.013 & 0.012 & 0.012 & 0.012 \\ 0.012 & 0.012 & 0.012 & 0.013 & 0.013 & 0.013 & 0.012 & 0.012 & 0.012 \\ 0.012 & 0.012 & 0.012 & 0.013 & 0.013 & 0.013 & 0.012 & 0.012 & 0.012 \\ 0.012 & 0.012 & 0.012 & 0.012 & 0.012 & 0.012 & 0.012 & 0.012 & 0.012 \\ 0.012 & 0.012 & 0.012 & 0.012 & 0.012 & 0.012 & 0.012 & 0.012 & 0.012 \\ 0.012 & 0.012 & 0.012 & 0.012 & 0.012 & 0.012 & 0.012 & 0.012 & 0.012 \end{bmatrix}$$

Output on convolving with the above filter:

Figure 3: Convolution with Gaussian Kernel (Std. Deviation: 20)



It is evident that as the standard deviation is increased, the image is getting more blurred. This is because the Gaussian kernel begins to behave like an average filter as the standard deviation is increased.

Question 2 (a)

Difference of Gaussian Kernel (Standard Deviations 1.1 and 2.5)

$$\begin{bmatrix}
0.000 & 0.001 & 0.002 & 0.003 & 0.003 & 0.004 & 0.003 & 0.003 & 0.002 & 0.001 \\
0.000 & & & & & & & & & \\
0.001 & 0.002 & 0.004 & 0.005 & 0.007 & 0.007 & 0.007 & 0.005 & 0.004 & 0.002 \\
0.001 & & & & & & & & & \\
0.002 & 0.004 & 0.006 & 0.009 & 0.01 & 0.01 & 0.01 & 0.009 & 0.006 & 0.004 \\
0.002 & & & & & & & & & \\
0.003 & 0.005 & 0.009 & 0.009 & 0.001 & -0.006 & 0.001 & 0.009 & 0.009 & 0.005 \\
0.003 & & & & & & & & & \\
0.003 & 0.007 & 0.010 & 0.001 & -0.035 & -0.062 & -0.035 & 0.001 & 0.01 & 0.007 \\
0.003 & & & & & & & & & \\
0.004 & 0.007 & 0.010 & -0.006 & -0.062 & -0.105 & -0.062 & -0.006 & 0.01 & 0.007 \\
0.004 & & & & & & & & & \\
0.003 & 0.007 & 0.010 & 0.001 & -0.035 & -0.062 & -0.035 & 0.001 & 0.01 & 0.007 \\
0.003 & & & & & & & & & \\
0.003 & 0.005 & 0.009 & 0.009 & 0.001 & -0.006 & 0.001 & 0.009 & 0.009 & 0.005 \\
0.003 & & & & & & & & & \\
0.002 & 0.004 & 0.006 & 0.009 & 0.01 & 0.01 & 0.01 & 0.009 & 0.006 & 0.004 \\
0.002 & & & & & & & & & \\
0.001 & 0.002 & 0.004 & 0.005 & 0.007 & 0.007 & 0.007 & 0.005 & 0.004 & 0.002 \\
0.001 & & & & & & & & & \\
0.000 & 0.001 & 0.002 & 0.003 & 0.003 & 0.004 & 0.003 & 0.003 & 0.002 & 0.001 \\
0.000 & & & & & & & & &
\end{bmatrix}$$

Note that the last element in each row is getting truncated to the next line.

Question 2 (b)

The following is the output on convolution:

Figure 4: Image convolved with Difference of Gaussian filter

Question 2 (c)

The following is the result of detecting zero crossing:

Figure 5: Detecting zero crossing

The reason for extra edges could be noise in the image.

A slighltly better output is found when the image is convolved with a DoG filter that has been normalised:

Figure 6: Detecting zero crossing