EE5175: Image Signal Processing - Lab 6 report

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Contents

1 Shape from focus

Aim: To obtain the depth map of a 3-D scene by analyzing the focus measures of multiple images of the same scene taken at different distances from the scene. The Sum-modified Laplacian (SML) operator is to be used as a focus measure.

2 Sum-modified Laplacian operator:

Sum-modified Laplacian (SML) operator is a mathematical operator that is used in image processing as a focus measure. Using this operation, we can quantify the amount of sharpness present locally around a pixel. Let the image signal be $f(x, y)$ where x, y denote the row and column indices respectively. The SML operation pixel-wise is given as:

$$SML(x, y) = \sum_{(i,j)\in W(x,y)} |f_{xx}(i, j)| + |f_{yy}(i, j)|$$

where f_{xx} and f_{yy} denote partial double derivative w.r.t x and y respectively. $W(x, y)$ denotes the window over which the SML value is computed. In the given assignment, the window lengths are assumed $q = 0$, 1 and 2.

SML operator acts as a good focus measure since it captures the variation of the pixel intensities in the neighbourhood. If an image is sharp at a particular location, the variation within pixels in the neighbourhood will be high. Whereas if an image is heavily blurred at a location, the variation will be low. SML precisely captures this variation and hence, acts as a good focus measure. Since images are discrete 2-D signals, we have the following formulae for the double derivatives:

$$f_{xx}(x, y) = f(x + 1, y) + f(x - 1, y) - 2f(x, y)$$
$$f_{yy}(x, y) = f(x, y + 1) + f(x, y - 1) - 2f(x, y)$$

3 Gaussian function based depth estimate:

After getting the SML focus measure, we need to estimate the depth. Each frame is $\triangle d$ (50.50 in this assignment) depth apart. The standard idea is to find the depth at which the focus measure is maximum and declare it as the depth estimate for each pixel. However, a better method is using Gaussian interpolation to find the depth estimate.

Let us assume that d_m is the depth where the focus measure is the maximum among all frames. Let the focus measure be F_m for that depth. Similarly, $d_{m-1}, F_{m-1}, d_{m+1}$ and F_{m+1} are defined. According to this method, we fit a Gaussian curve to these data points, find the mean of the Gaussian function and declare it as the depth estimate. The Gaussian function is given below:

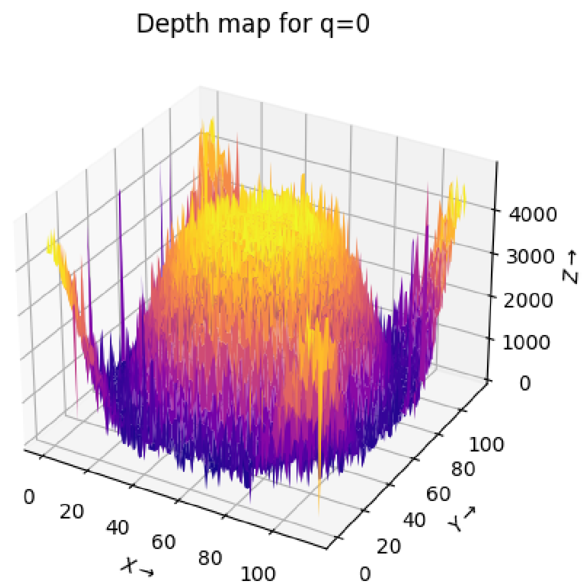
$$F(d) = F_p exp(\frac{-(d - d_{mean})^2}{2\sigma^2})$$

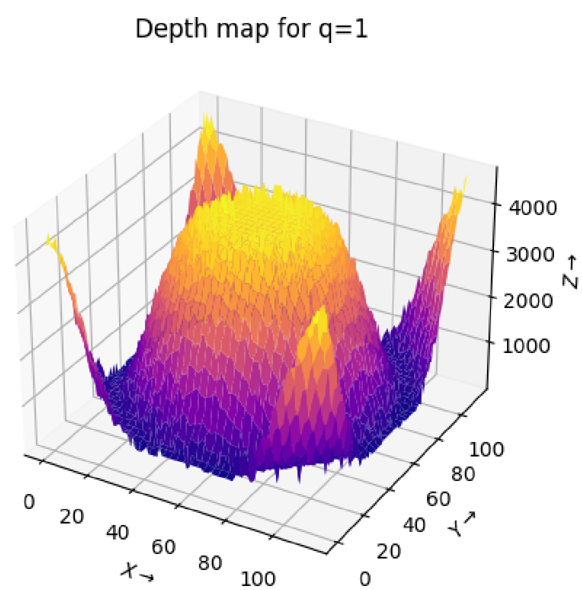
After substituting the focus measure values at relevant depths, we have the following equation for depth estimate:

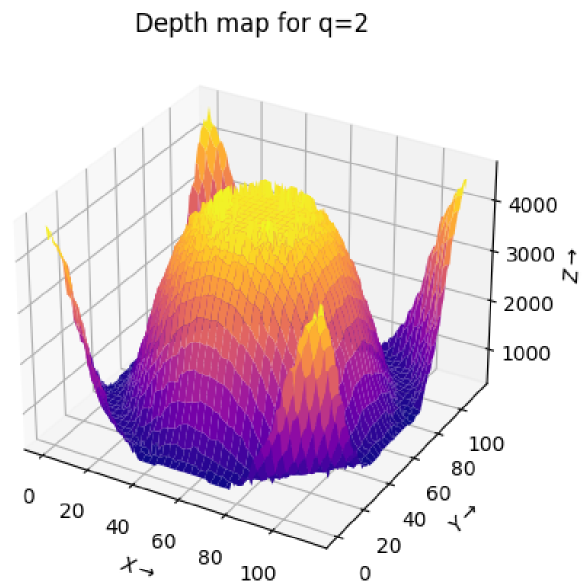
$$d_{mean} = \frac{d_m}{2} + \frac{(ln(F_m) - ln(F_{m-1}))d_{m+1} + (ln(F_m) - ln(F_{m+1}))d_{m-1}}{2(ln(F_m) - ln(F_{m-1}))(ln(F_m) - ln(F_{m+1}))}$$

4 Results:

For different frames, the SML values were computed. Different window sizes were used as given in the assignment. The depth maps are given below for different window sizes:







5 Observations and Conclusions

1. The scene seems to be a Gaussian bell curve with sharp flaps at the corners.

2. The depth map obtained is better and smoother for higher values of q than the one obtained for lower values of q. This implies that the focus measure computed is better when local averaging is done.