Image Signal Processing

Tutorial – 3: (Space-variant Blur, Shape from Focus)

Q 1. Suppose you have the following blurred (5×5) natural images

$$I_1 = \begin{bmatrix} 30 & 29 & 30 & 29 & 28 \\ 50 & 51 & 50 & 51 & 52 \\ 45 & 44 & 45 & 44 & 45 \\ 15 & 16 & 20 & 15 & 15 \\ 100 & 101 & 105 & 101 & 100 \end{bmatrix}, \quad I_2 = \begin{bmatrix} 99 & 98 & 101 & 100 & 101 \\ 99 & 98 & 99 & 101 & 100 \\ 99 & 98 & 100 & 98 & 99 \\ 99 & 100 & 98 & 99 & 98 \\ 100 & 101 & 100 & 100 & 100 \end{bmatrix}$$

Which one of them has motion blur and which one has defocus blur and for the one with motion blur, in which direction is the motion happening?

Sol: In case of defocus blur, the gradient would be the same in all the directions but for motion blur, the gradient along the direction of motion would be smooth whereas the one perpendicular to the motion would be sharper. Hence, I_2 has defocus blur and I_1 has motion blur. In I_1, the motion is horizontal.

Q 2. Considering the space-variant blur case of the globe you synthesized, answer the following:

1. Judging from the type of blur where do you think the globe is located: before the focal-plane or after the focal-plane?
2. From part (a), what blur can you expect if the globe is located otherwise.
3. Suppose that the globe is moved laterally. Comment whether the blur changes at each scene-point (with reason).

Sol:

1. After the focal plane.
2. If the globe is before the focal-plane ($D < w_d$), blur will be increasing from globe's side to its center (i.e., the globe's center will have more blur).
3. Blur can change as inplane translation need *not* warp every neighbouring coordinates equally (as Z varies in $\mathbf{KT}/Z$) and hence the summation of neighbouring pixels at a scene-point can be different (as compared to that of the initial globe-position).

Q 3. Consider a camera setting with aperture radius 8 mm, focal length 30 mm, and lens-sensor separation 40 mm. Out of three fronto-parallel scenes at 92 mm, 125 mm, and 180 mm, which one is most focused and which one is most blurry?

Sol: The working distance of camera is 120 mm. The blur corresponding to three planes is 120 mm. Using blur equation

$$r_b = r_0 u_0 \left(\frac{1}{w_d} - \frac{1}{D} \right)$$

corresponding blur radiuses are -0.8116, 0.1067, and 0.8889 mm. That is, the second case is the most focussed and the third case is the most blurry.

Q 4. Suppose that there is a fronto-parallel scene at depth D and you have to move that scene in one of the two axial direction by δd (i.e., along the optical axis). Comment on blur formed in either direction for the following cases and mention which direction you have to move for the least blur. (Use $\delta d = 20$mm and camera settings of Qn. 3)

1. D is the working distance (w_d). Particularly, note whether blur is symmetric about w_d.
2. D = 80 mm.
3. D = 170 mm.

Sol: If shifted towards the lens by δd, the blur is $-0.5333, -2.6667, 0.5333$ mm, whereas shifting away from the lens gives $0.3810, -0.5333, 0.9825$ mm. For least blur, for the first case we have to move away from the lens, and for second and third cases, away and towards the lens, respectively.

Q 5. Can you specify the position of a fronto-parallel planar scene (i.e., whether it is after or before the working distance) from corresponding blurred images.

Sol: From blurred images, it is not possible to tell the position. However, with blur radius, a positive radius implies the scene is positioned after the working distance and a negative radius implies the scene is positioned before the working distance.