Assignment 4 Question 2: CS 663, Digital Image Processing

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Suppose you are standing in a well-illuminated room with a large window, and you take a picture of the scene outside. The window undesirably acts as a semi-reflecting surface, and hence the picture will contain a reflection of the scene inside the room, besides the scene outside. While solutions exist for separating the two components from a single picture, here you will look at a simpler-to-solve version of this problem where you would take two pictures. The first picture g_1 is taken by adjusting your camera lens so that the scene outside (f_1) is in focus (we will assume that the scene outside has negligible depth variation when compared to the distance from the camera, and so it makes sense to say that the entire scene outside is in focus), and the reflection off the window surface (f_2) will now be defocussed or blurred. This can be written as $g_1 = f_1 + h_2 * f_2$ where h_2 stands for the blur kernel that acted on f_2. The second picture g_2 is taken by focusing the camera onto the surface of the window, with the scene outside being defocussed. This can be written as $g_2 = h_1 * f_1 + f_2$. Given g_1 and g_2, and assuming h_1 and h_2 are known, your task is to derive a formula to determine f_1 and f_2. Note that we are making the simplifying assumption that there was no relative motion between the camera and the scene outside while the two pictures were being acquired, and that there were no changes whatsoever to the scene outside or inside. Even with all these assumptions, you will notice something inherently problematic about the formula you will derive. What is it? What do you think the effect of noise (in g_1 and g_2) will be on the accuracy of your solution (be careful)?

Given,

$$\begin{aligned} g_1 &= f_1 + h_2 * f_2 \quad h_2\, stands\, for\, the\, blur\, kernel\, and, \\ g_2 &= h_1 * f_1 + f_2 \quad h_1\, stands\, for\, the\, blur\, kernel \end{aligned}$$

Applying Fourier Transforms to above equations

$$
\begin{aligned}
G_1 &= F_1 + H_2F_2 \\
G_2 &= H_1F_1 + F_2
\end{aligned}
$$

Solving the above two equations

$$
\begin{aligned}
F_1 &= \frac{G_1 - G_2H_2}{1 - H_1H_2} \\
F_2 &= \frac{G_2 - G_1H_1}{1 - H_1H_2}
\end{aligned}
$$

The problem with above method is that there is possibility of denominator $1 - H_1H_2$ tending to zero this leads to F_1 being in $\frac{0}{0}$ form.
Now adding noise to the images

$$
\begin{aligned}
g_1 &= f_1 + h_2 * f_2 + n_1 \quad h_2\, stands\, for\, the\, blur\, kernel\, and, \\
g_2 &= h_1 * f_1 + f_2 + n_2 \quad h_1\, stands\, for\, the\, blur\, kernel
\end{aligned}
$$

Applying Fourier Transforms to above equations

$$
\begin{aligned}
G_1 &= F_1 + H_2F_2 + N_1 \\
G_2 &= H_1F_1 + F_2 + N_1
\end{aligned}
$$

Solving the above two equations

$$
\begin{aligned}
F_1 &= \frac{G_1 - G_2H_2}{1 - H_1H_2} + \frac{N_2H_2 - N_1}{1 - H_1H_2} \\
F_2 &= \frac{G_2 - G_1H_1}{1 - H_1H_2} + \frac{N_1H_1 - N_2}{1 - H_1H_2}
\end{aligned}
$$

Adding noise to the equations leads to the scenario where at High frequencies the fourier transforms for the noise will be significant. And at high frequencies the product H_1H_2 is ~ 0 . The term N_2H_2 will be quite low H_2 acting as a low pass filter. So noise N_1 will directly get added without amplications to F_1. Similarly applies for F_2