Computational Photography Assignment 3

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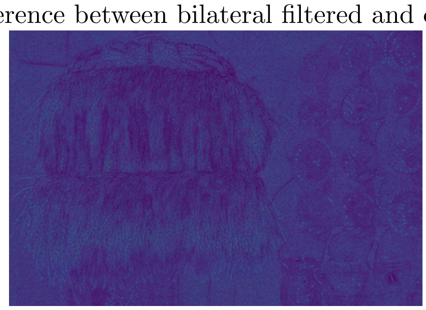
1 Bilateral Filtering

1.1 Implement bilateral filtering

The final parameters I chose for this are $\sigma_s = 10$ and $\sigma_r = 0.05$. This achieves the perfect balance between denoising and not blurring the edges much. The results are below. From the difference image, it is clear that it is high in the regions of noise and high-texture but there are no strong edges discernible. This is more or less the behavior we expect.

Figure 1: Ambient image bilateral filtered

Figure 2: Difference between bilateral filtered and original images



If I choose a higher value of σ_r, say 0.2, the edges get overly blurred. Choosing a higher value of σ_s does not have a noticeable improvement in terms of denoising while being more computationally expensive. Choosing a lower value of σ_s does not denoise adequately.

Figure 3: Ambient image bilateral filtered $\sigma_r = 0.2$

Figure 4: Ambient image bilateral filtered $\sigma_s = 3$

Figure 5: Ambient image bilateral filtered $\sigma_s = 20$

1.2 Implement joint-bilateral filtering

The final parameters I chose are $\sigma_r = 0.25$ and $\sigma_s = 2$. The result of this method appears slightly better than simple bilateral filtering of the ambient image. If you look closely at the wall in the background, the subtle texture is blurred out in the bilateral filtered ambient image whereas it is preserved in the join-bilateral filtered image. Notice that the value of σ_r is much higher than the simple bilateral case. This is because the contrast of the flash image is much higher, leading to higher intensity differences across edges.

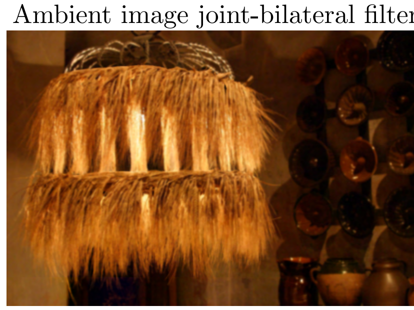
Figure 6: Ambient image joint-bilateral filtered

Figure 7: Difference between bilateral filtered and joint-bilateral filtered images

Choosing a lower value of σ_r, say 0.05, does not produce a noticeable improvement while improving the computational cost. Choosing a higher value of σ_s seems to overly blur the image. This could be because there's a slight feature mismatch between the ambient and the flash images. As observed before, as we can use a higher value of σ_r, joint-bilateral filtering performs better despite the mismatch.

Figure 8: Ambient image joint-bilateral filtered $\sigma_r = 0.05$

Figure 9: Ambient image joint-bilateral filtered $\sigma_s = 5$



1.3 Implement detail transfer

The parameters I used to filter the flash image are $\sigma_r = 0.15$ and $\sigma_s = 5$. The texture in the high-texture regions clearly look more pronounce. The same conclusion can be drawn from the difference image, where the regions with high texture seem to be modified the most.

Figure 10: Detail transfer

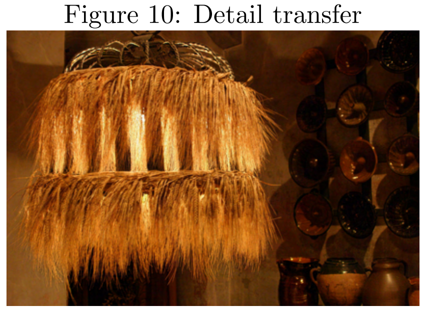
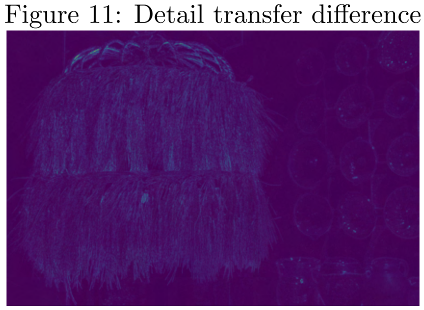


Figure 11: Detail transfer difference



An observation I made after varying the parameters used to filter the flash image is that more aggressively blurring the flash image (i.e., increasing σ_r and σ_s) leads to transferring more details from the flash image to the ambient image and vice-versa. Shown below are results obtained by decreasing σ_s to 2, which leads to a decrease in details transferred, and by increasing σ_r to 0.25, which leads to an increase in the details transferred. It is quite evident from the difference images.

Figure 12: Detail transfer $\sigma_s = 2$

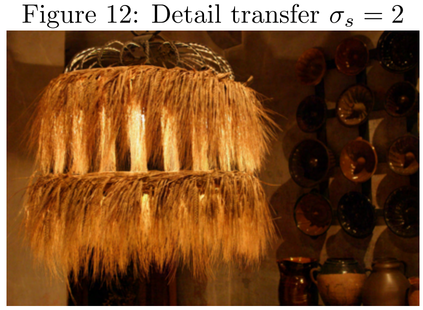


Figure 13: Detail transfer difference $\sigma_s = 2$

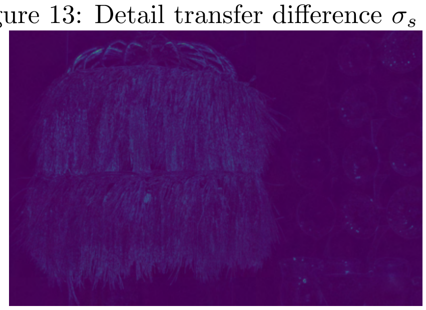


Figure 14: Detail transfer $\sigma_r = 0.25$

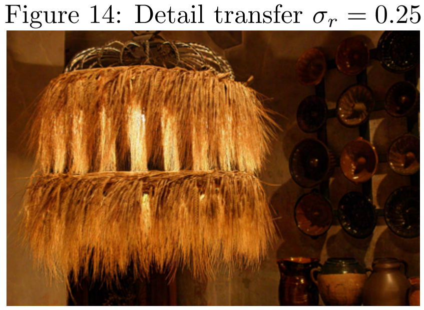
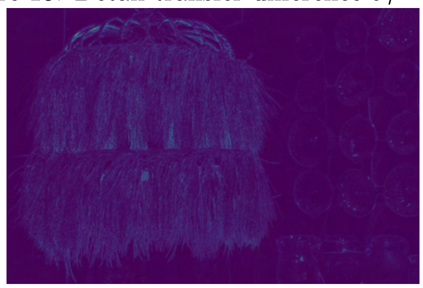


Figure 15: Detail transfer difference $\sigma_r = 0.25$

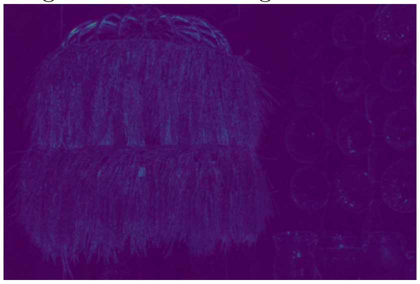


1.4 Implement shadow and specularity masking

The value of τ_{shad} I used was 0.001. While I used opening, closing, and dilation morphological operations on the shadow masks, I used only dilation on the specularity mask because the regions of specularity were already small, and opening and closing operations just removed them completely. Here's the result:

Figure 16: Final result

Figure 17: Final image difference



2 Gradient-domain processing

2.1 Differentiate and then re-integrate an image

The number of iterations and tolerance I used are 1000 and 0.001 respectively for my poisson solver. Shown below are the original ambient and the reintegrated images. There is no perceptible difference between the two.

Figure 18: Original image

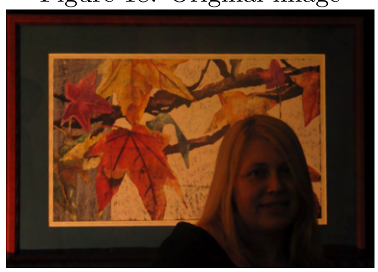


Figure 19: Reintegrated image

2.2 Create the fused gradient field

Changing the values of σ and τ_s do not seem to make an appreciable difference in the fused gradient. I stuck with the values recommended in the paper, $\sigma = 40$ and $\tau_s = 0.1$. From the images below, it is clear that the fused gradient is non-zero in the regions affected by flash, which is what we want.

Figure 20: Gradient of a along x

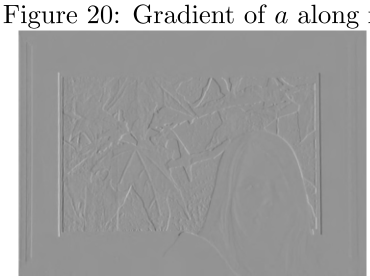


Figure 21: Gradient of Φ' along x

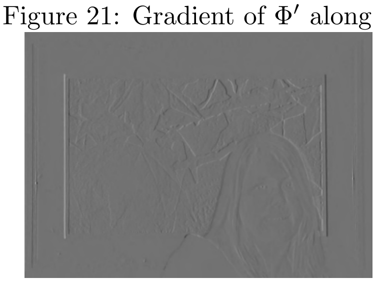


Figure 22: Gradient of $\Phi*$ along x

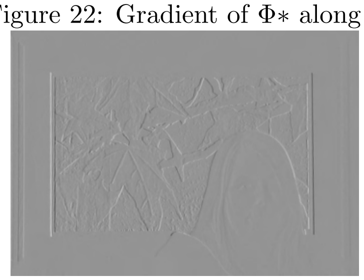


Figure 23: Gradient of a along y

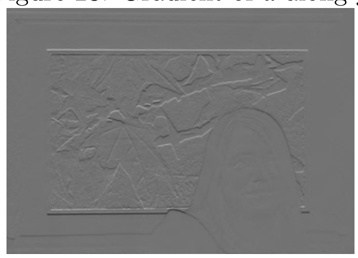


Figure 24: Gradient of Φ' along y

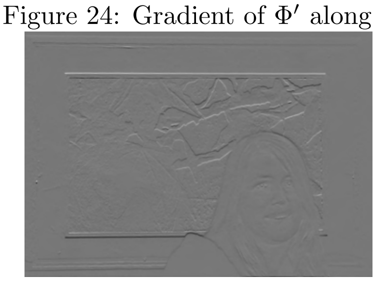
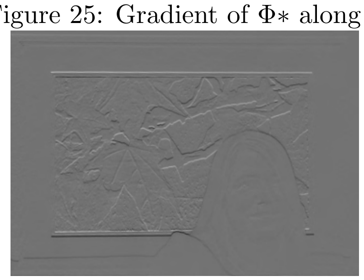


Figure 25: Gradient of $\Phi*$ along y



Changing the initialization does not seem to have a noticeable impact on the final fused image. Changing the boundary values does significantly change the final fused image. Using the ambient image for the boundary values leads to an image that is very similar to the ambient image in which the person's face is underexposed. Using an average of the ambient and flash images for the boundary values leads to a better image in which the person's face is better exposed. Using the flash image for the boundary values leads to an image in which the person's face is well exposed and while preserving the texture that was affected by the flash.

Figure 26: Fused image with averaged boundary values

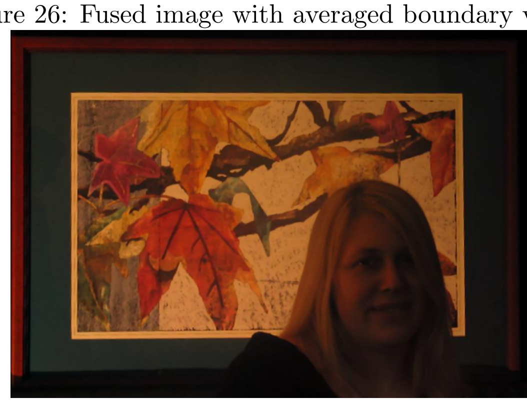
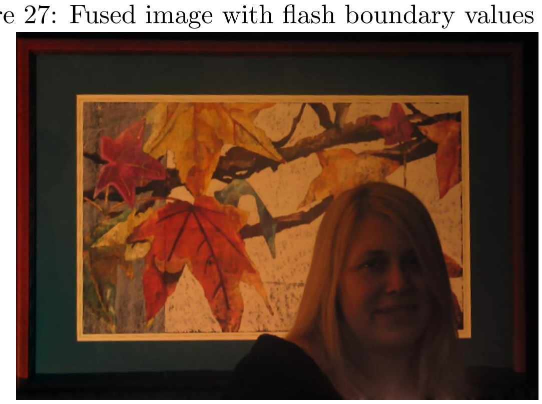


Figure 27: Fused image with flash boundary values (final)



3 Capture your own flash/no-flash pairs

For bilateral filtering, I captured images of my room illuminated by a table lamp outside the field of view. I used the same exposure but different ISOs (1600 and 200) for the ambient and flash images. The final image clearly has less noise than the ambient image (evident from the guitar) while having higher texture (the bag and the painting).

Figure 28: Ambient

Figure 29: Flash

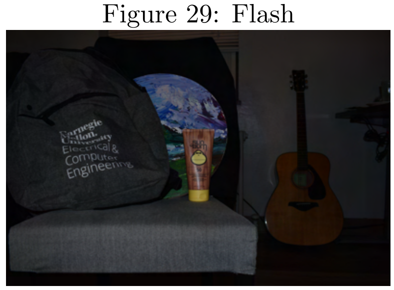
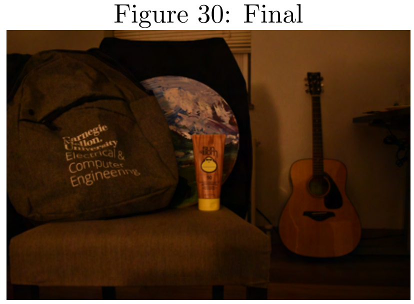


Figure 30: Final



For gradient-domain processing, I captured images of objects in my room which were a mix of specular and diffuse objects. It can be seen from the final image that the foreground which was not well exposed in the ambient image is well exposed while not having any of the saturation artifacts because of the flash (on the markers and the protein bag). While the algorithm does what we expect it to, the final image does look kind of unnatural and that could be because the flash affects the overall brightness of the foreground a lot more than the background, relatively darkening the background. This might not have been much of a problem if I had chosen a scene which was farther away from the flash (gone outdoors).

Figure 31: Ambient

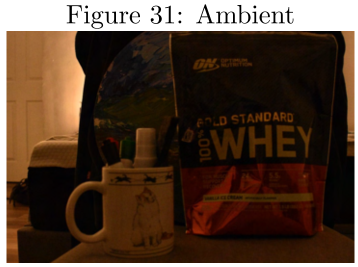


Figure 32: Flash

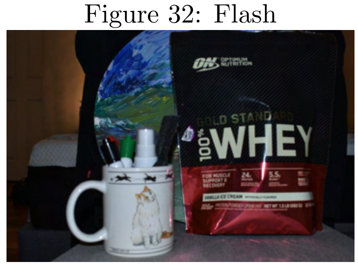
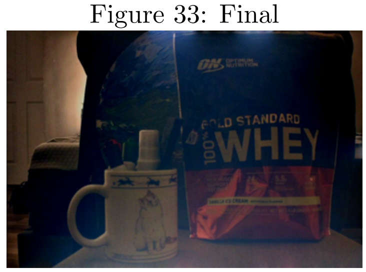


Figure 33: Final



4 Description of submitted images

- Problem 1 - All the submitted images follow the naming convention in the assignment and the papers.
- Problem 2 - All the submitted images follow the naming convention in the assignment and the papers.
- Problem 3 - The images captured for bilateral filtering are named bilateral_ambient and bilateral_flash. The final image is name A_final_cptr. The images captured for gradient-domain processing are named gradient_ambient and gradient_flash. The final image is named fused_cptr.