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Digital Photography with Flash and No-Flash Image pairs

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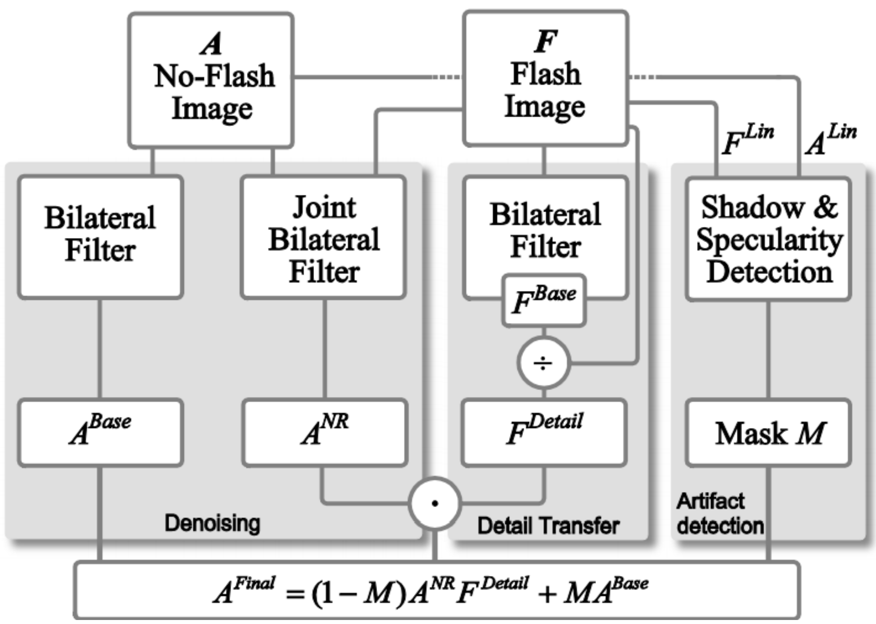
1.Introduction

Digital photography today be it using a smartphone or a digital camera has made it possible for the user to take multiple photographs in a very less time interval. This particular feature of the modern photography equipment made us realize the importance of image pairs. In this research we talk about the use of pairs of Flash and Ambient(No Flash) images to create a much superior quality noise free detailed image.
We have taken qualities from both the images, the Noise-free nature and high amount of details from Flash images and the unique colour richness of the Non flash images and combined them using the below mentioned combining algorithm. There are many applications for which this method can be used like finding and removing Red Eyes from images.



2.Method

2.1. Denoising:

To denoise the image we need apply an edge-preserving smoothing filter such as bilateral filtering or anisotropic diffusion. Bilateral filter solves the problems beyond denoising, including tone-mapping,separating illumination from texture and mesh smoothing.

Bilateral filter:

$$A_p^{Base} = \frac{1}{k(p)} \sum_{p' \in \Omega} g_d(p' - p)\, g_r(A_p - A_{p'})\, A_{p'}$$

where

$$k(p) = \sum_{p' \in \Omega} g_d(p' - p)\, g_r(A_p - A_{p'})$$

$$\begin{aligned} G_\sigma(x,y) &= \frac{1}{2\pi\sigma^2} \exp^{-\frac{x^2+y^2}{2\sigma^2}} \\ &= \left(\frac{1}{\sqrt{2\pi}\sigma} \exp^{-\frac{x^2}{2\sigma^2}}\right) \left(\frac{1}{\sqrt{2\pi}\sigma} \exp^{-\frac{y^2}{2\sigma^2}}\right) \end{aligned}$$

g_d and g_r are the Gaussian functions with standard deviations Sd and Sr, which sets the spatial weight and the weight on the range based on intensity differences respectively.

Joint Bilateral Filter:

Even after adjusting the standard deviations, the result tends to over-blur or under-blur in some regions. Based on observations bilateral filter is modified by replacing flash image instead of ambient image with Sr set to 0.1% of total image range. This is called **Joint Bilateral Filter** given by:

$$A_p^{NR} = \frac{1}{k(p)} \sum_{p' \in \Omega} g_d(p' - p)\, g_r\left(F_p - F_{p'}\right) A_{p'}$$

But it fails in the shadow and specular regions. This is solved by the following improved denoising algorithm where M is the mask generated by detection algorithm. This is explained properly in the

$$A^{NR'} = (1 - M)A^{NR} + MA^{Base}$$

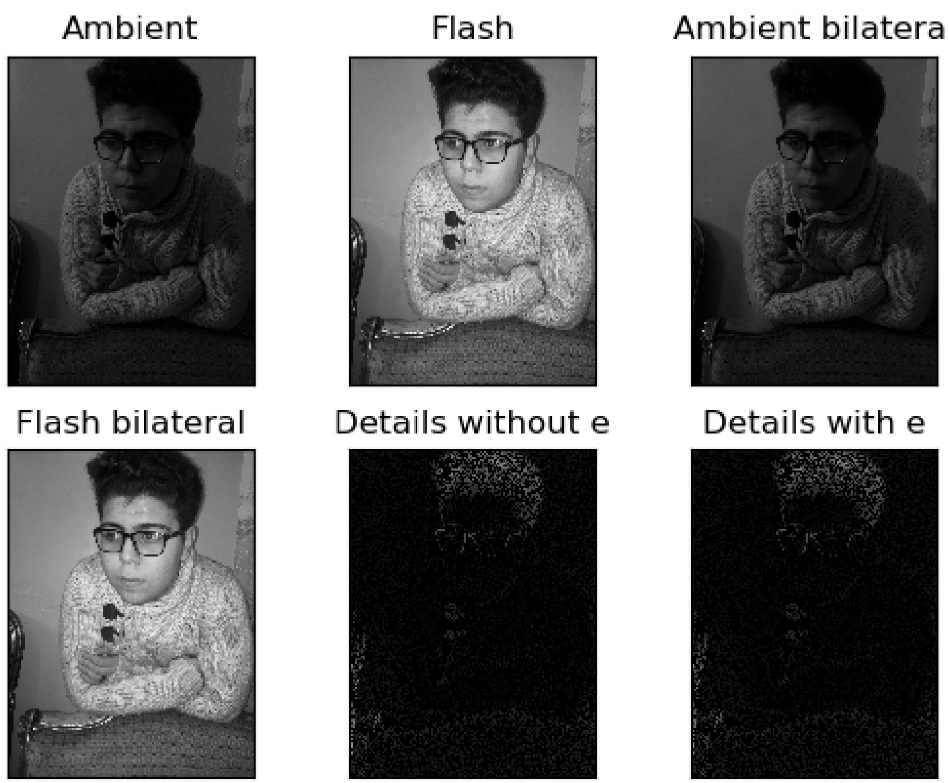

2.2. Flash to ambient detail transfer:

The following algorithm is used to compute the detail layer from flash image with an $\varepsilon = 0.02$ so as to remove artifacts unnoticeable by human eye and transfer 3.1details to ambient image by multiplying A^{NR} by F^{Detail}. However, to overcome the problems caused by shadow and specular regions, we should use the following algorithm as we did in the Joint bilateral filter.

$$F^{Detail} = \frac{F + \varepsilon}{F^{Base} + \varepsilon}$$

where A^{Base} and F^{Base} are computed using basic bilateral filter.

$$A^{Final} = (1 - M) A^{NR} F^{Detail} + M A^{Base}$$



2.3. Detecting flash shadows and specularities:

2.3.1. Flash Shadows:

A point in a flash shadow is not illuminated by the flash, it should appear exactly as it appears in the ambient image. Therefore we take a difference of the array values of the two images, that is the flash and the no flash image. Theoretically the places where this value is zero must be the Flash Shadow locations but practically we provide a threshold value so as to avoid certain problems.The below shown values are used while finding Flash Shadows-

$$M^{Shad} = \begin{cases} 1 \text{ when } F^{Lin} - A^{Lin} \leq \tau_{Shad} \\ 0 \text{ otherwise.} \end{cases}$$

2.3.2. Flash Specularities:

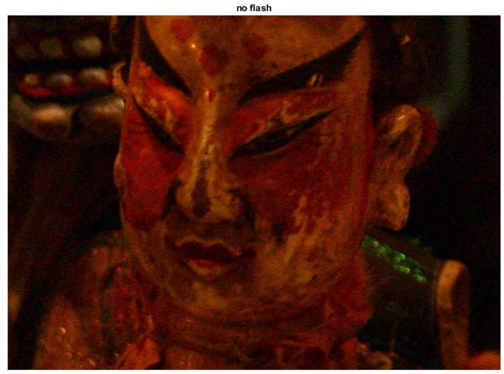
Specular regions should be bright in $FLin$. Hence, we first convert the image to LAB colour space from which we look for luminance values in the flash image that are greater than 95% of the range of sensor output values. We clean, fill holes, and dilate the specular mask using morphological erosion and dilation.

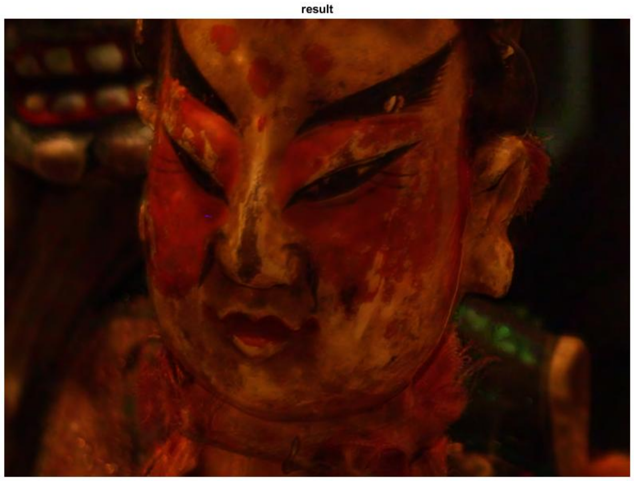
2.3.3. Final merging for mask creation:

We use the results we obtained from the above two processes of Flash Shadow and Flash Specularity detection, first apply erosion and dilation on them and then take union of both to create a mask on which we apply blur which provides us the final mask **'M'** that we use in our main algorithm to gain the better quality image.

3.Results:

The images given below show the Flash image and the ambient image used by us to implement the whole procedure of extracting a better quality image. The image shown at the end is the one which is noise-less, detailed, one that preserves natural colours, has no flash shadows and is an overall better picture than the two mentioned first.





The flash image has flash shadow in the right side,due to which we see a dark patch rather than the original image, the ambient image has no proper surface details and is filled with noise, while the resultant image produced using our code is devoid of all such problems and hence is in better overall condition.

4.Conclusion

We have used the above given techniques to obtain a better quality image with more details and higher signal to noise ratio.The naturale-ness and visual richness of the provided ambient image has been preserved in the resultant image while reducing the noise to a bare minimum. The applications of ‘Red Eye Removal’ and ‘White Balancing’ have been further explored by us using this technique.

Future Work: Now that we have prepared a program to generate superior quality images using the pairs of Flash and Non Flash images we have thought to use this program to create a dataset of numerous images which would be further used to train a Deep Learning model that would be able to prepare such a better quality image using Deep Learning techniques.

5.Acknowledgements

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6.References

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