Image De-blurring when Kernel is Known

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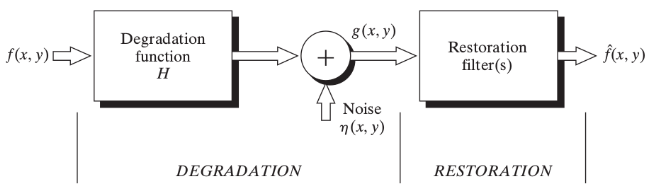
Abstract – *This paper is focused on the reconstruction of images when the blurring kernel is known.*

I. INTRODUCTION

The images captured in real world are not suitable for computer algorithms such as opencv programs or machine learnig algorithms because these are degraded by camera's motion (motion blur) and noise. Since all kind of computer algorithms require high quality images, deblurring is a really important task. The deblurring problem can be modeled by the degradation model as shown below



II. HERE F(X,Y) IS THE ORIGINAL UNDEGRADED IMAGE G(X,Y) IS THE DEGRADED IMAGE, H(X,Y) IS THE BLURRING KERNEL, AND F^(X,Y) THE RECOVERED IMAGE. THIS PROBLEM IS EASY IF WE KNOW THE BLUR KERNEL BECAUSE WE CAN JUST APPLY TRUNCATED INVERSE FILTER OR WIENER FILTER TO OBTAIN OUR UNDEGRADED IMAGE. BUT IF BLUR KERNEL IS UNKNOWN THEN IT HAS TO BE ESTIMATED WHICH IS A BIG TASK. IN THIS PROJECT BLURRING KERNEL IS KNOWN AND WE HAVE TRIED TO RECOVER THE IMAGE USING FULL INVERSE, TRUNCATED INVERSE, WIENER FILTER AND CONSTRAINED LEAST SQUARE FILTER.BACKGROUND AND RELATED WORK

A. *Full inverse filter*

In the degradation model we see that the degraded image is given by

G(u,v) = H(u,v)*F(u,v) + N*(u,v)

in full inverse filtering we neglect noise component so that G(u,v) = H(u,v)*F(u,v), hence to recover the original F(u,v) we divide the given blurred image by H(u,v).

B. *Truncated inverse using butterworth filter*

The result of full inverse filtering is not useful at all. Dividing G(u,v) by H(u,v) actually gives us F(u,v) + N(u,v)/H(u,v) which can have very high values at points where N(u,v)/H(u,v) has high values. To avoid this issue we apply full inverse filter and then we pass it through a low pass filter and try to find the optimal radius for filtering. Low pass filtering work because in most cases noise is high frequency so we filter-out high frequency components and get a better result.

C. *Wiener filter*

this approach incorporates both the degradation function and statistical characteristics of noise into the restoration process by considering them as uncorrelated random variables. objective is to find an estimate f^ of the uncorrupted image f such that the mean square error between them is minimized.

e^2 = E[(f-f^2)^2]

Since the noise is unknown we approximate the standard wiener by this expression

$$\hat{F}(u, v) = \left[\frac{1}{H(u, v)} \frac{|H(u, v)|^2}{|H(u, v)|^2 + K} \right] G(u, v)$$

where K is a constant which can be tuned to obtained better result.

D. *Constrained Least Square*

This method requires knowledge of only the mean and variance of the noise. These values can be calculated from a given degraded image. Wiener filter is based on minimizing a statistical criterion and, as such, it is optimal in an average sense. This algorithm has the notable feature that it yields an optimal result for each image to which it is applied. It is important to keep in mind that these optimality criteria, while satisfying from a theoretical point of view, are not related to the dynamics of visual perception. As a result, the choice of one algorithm over the other will almost always be determined (at least partially) by the perceived visual quality of the resulting images. The formula used is

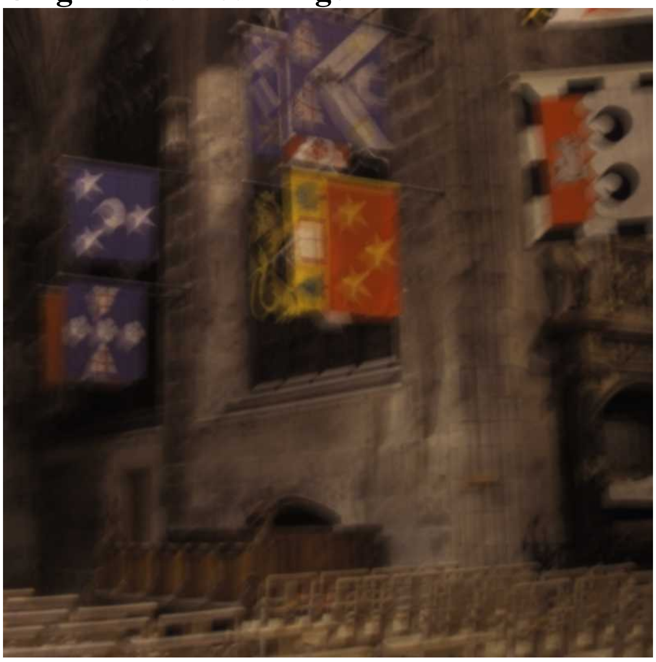
$$\hat{F}(u,v) = \left[\frac{H^*(u,v)}{|H(u,v)|^2 + \gamma |P(u,v)|^2}\right] G(u,v)$$

here P is $p(x,y) = \begin{bmatrix} 0 & -1 & 0 \\ -1 & 4 & -1 \\ 0 & -1 & 0 \end{bmatrix}$

III. Experiments and Results

Image blurred by kernel_1

Original blurred image



results of deblurring with kernel_1

A. Result of full inverse filter

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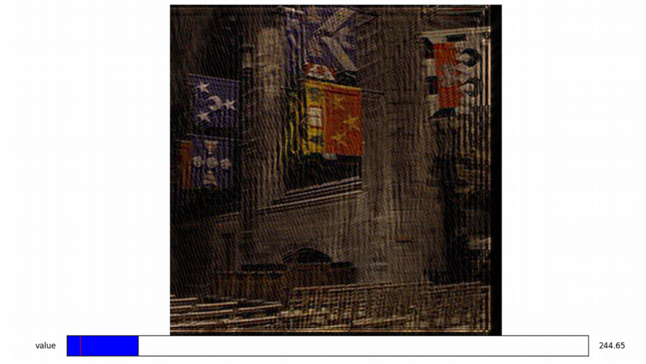


B.

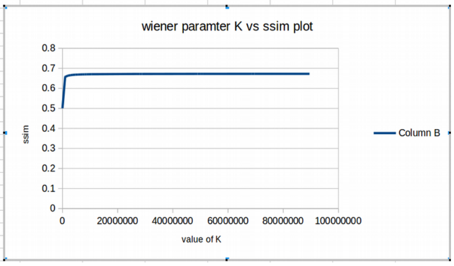
Result of truncated inverse filteringThe best result at 244.64

C. Result of Wiener filtering

D. Results of constrained least square

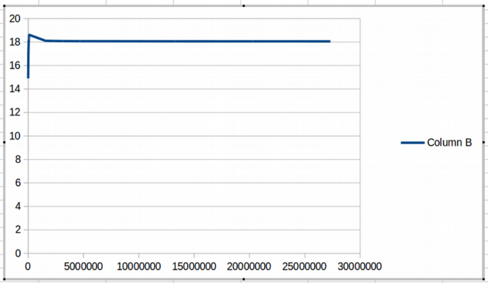
for image_1 plot of K vs ssim where k is value of approximation parameter in wiener filter.

values of K	values of ssim
1500	0.5007008712
980057.5	0.6571686268
1955115	0.6633401314
2930172.5	0.6659582456
3710218.5	0.6671830813
4685276	0.6682019234
5660333.5	0.6689040661
6440379.5	0.6693274975
7220425.5	0.669668595
8000471.5	0.6699534257
8780517.5	0.6701961358
9560563.5	0.6704037984
10535621	0.6706235409
26916587	0.6719920635
27891644.5	0.6720239321
28866702	0.6720538934
48952886.5	0.6724081039
50122955.5	0.6724201838
50903001.5	0.6724277337
68454036.5	0.6725551287
69624105.5	0.6725613276
69624105.5	0.6725613276
89515278.5	0.6726425489



for image_1 plot of K vs psnr where k is value of approximation parameter in wiener filter.

values of k	psnr
700	14.90956068
1965.419922	15.14248133
2930.839844	15.29672742
4089.34375	15.46759963
5440.931641	15.65348983
15095.13086	16.67806864
23590.82617	17.25017548
33631.19336	17.61613488
47726.32422	17.98244238
61435.28711	18.2341373
64910.79883	18.28599334
69351.73047	18.34642649
71861.82227	18.37790728
80164.43359	18.46976876
93294.14453	18.58228564
97541.99219	18.61141324
1565092	18.10732841
2345138	18.09075356
3125184	18.0809319
4685276	18.07271957
13265782	18.05968881
20286196	18.05885077
24576449	18.05720568
27306610	18.05657029



Last part where we had to take an image and estimate a kernel

blurred image

estimated kernel (PSF)

result

IV. Discussion and Conclusion

In this project we learn about deblurring techniques when blue kernel is known. This includes full inverse filter, truncated inverse filtering, wiener filtering and constrained least square. All these filters are generated by using the kernel and out of all these wiener and constrained least square gives best results.

Few points :-

a.) We learned that full inverse filter will work only when there is no noise or very little noise. As soon as noise levels increase it will fail.

b.) Truncated inverse filter works fine when noise is high frequency, or low frequency because we can create a lowpass or highpass filter accoding to the situation. But if the noise is spreaded over the entire frequency domain then this method will not work correctly.

c.) wiener filter work better than above two because it tries to minimize expectation of estimated and original image, by considering image and noise as random variables.this approximated method works fine if noise is white so that its power spetcral density is constant. But if it is not true we can’t use this appoximation and situations in which noise distribution or undegraded image are not known this filter won’t be a good choice.

d.) constrained least square requires knowledge of only the mean and variance of the noise and these parameters usually can be calculated from a given degraded image.

. Links

https://github.com/AwanishKr/Image_Restoration_when_kernel_is_known

VI. References

Rafael C.Gonzalez, Richard_E._Woods book digital image processing