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# Power Efficient Edge Sharpening

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***Abstract***

*This paper studies power efficient image processing method for power consuming display device. Power is consumed by display device and its portion is large. We developed unsharp masking under power-constrained condition. For this system, we assume an image is dark with low contrast. The presented unsharp masking adopts high pass filter, Butterworth filter, and histogram equalization. Simulation results compare visual performance in several power-constrained conditions with factors of n. Results show that the proposed method achieved good visual quality and significant power saving performance.*

***Keywords****: power efficient, edge sharpening, unsharp masking*

## 1. Introduction

There are several flat panel display (FPD) devices which have been developed for decades. Organic light-emitting diode (OLED), plasma display panel (PDP), liquid crystal display (LCD) technologies are widely used in consumer electronics [1-3]. FPDs give better linearity and higher resolution. They are much thinner and lighter than conventional heavy TV such as CRTs (cathode ray tubes) [4]. In general, FPDs are less than ten centimeters thick. It is known that most LCD displays are back-lit to have them easier to read in bright condition.

All devices give satisfactory color quality under bright condition. However, power issue in OLED and PDP (even LCD) displays is huge task to solve [5-7]. Power is consumed by display device and its portion is large [8,9]. Therefore, power efficient system is important especially for power limited system such as mobile [10-15]. In this paper, we study power efficient image processing method for power constrained condition display device. The purpose of this paper is to reconstruct visually good images with low power consumption method. We study unsharp masking under power-constrained condition. In this condition, image is assumed to be darkened and its contrast is low. The presented unsharp masking uses high pass filter, Butterworth filter, and histogram equalization.

This paper is organized as follows. Section 2 explains details of proposed method. Section 3 provides the experimental results and comparison. The results of simulation conducted by proposed method achieved good visual quality and significant power saving performance. Conclusion remarks are shown in Section 4.

## 2. Proposed Method

There have been various unsharp masking methods to improve contrast enhancement. However, unsharp masking under power constrained condition has not been studied yet. In this paper, a new unsharp masking method under power-constrained condition is studied.

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Let us assume an image is $x$. It is known that high pass filter (HPF) results zero out DC term, and reducing the average value of an image to zero. The main idea of the proposed method is to add HPF information on original image $x$. This effect is high frequency emphasis (HFE) effect or unsharp making, because the constant multiplier highlights the high frequency information. Filtering image with $h$ coefficient is obtained as

$$y = imfilter(x, h), \tag{1}$$

Where $h$ is filter coefficient and $y$ is output image. The image with HEF effect, $z$, can be obtained as

$$z = \alpha + \beta y. \tag{2}$$

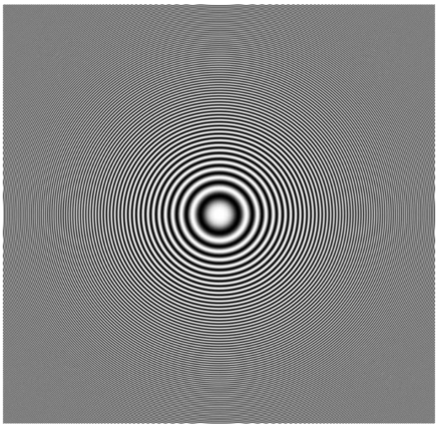
Here, $\alpha$ and $\beta$ are tuning parameters, which represent offset and multiplier, respectively.

There are several filters to design HPF. In this paper, we used Butterworth filter which is defined as,

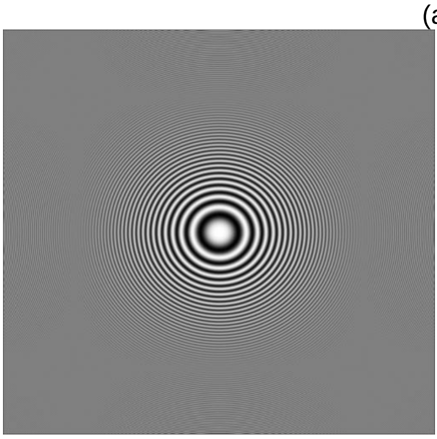
$$H(u,v) = \frac{1}{1 + \left[\frac{D_0}{D(u,v)}\right]^{2n}}, \tag{3}$$

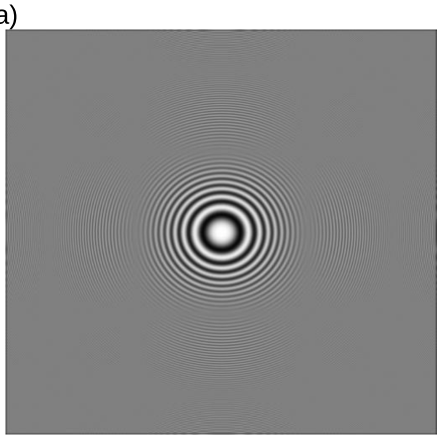
Where $D_0$ is a positive number and $D(u,v)$ is the distance from the point $(u,v)$ to the filter's center. Parameter $n$ is cutoff frequency at a distance $D_0$. In this paper we assume $n$=1. Equation (3) shows Butterworth high pass filter of order $n$ with cutoff $D_0$. Few other options to determine $H(u,v)$ are,

$$H(u,v) = \begin{cases} 0 & if \ D(u,v) \le D_0 \\ 1 & if \ D(u,v) > D_0 \end{cases}, \tag{4}$$



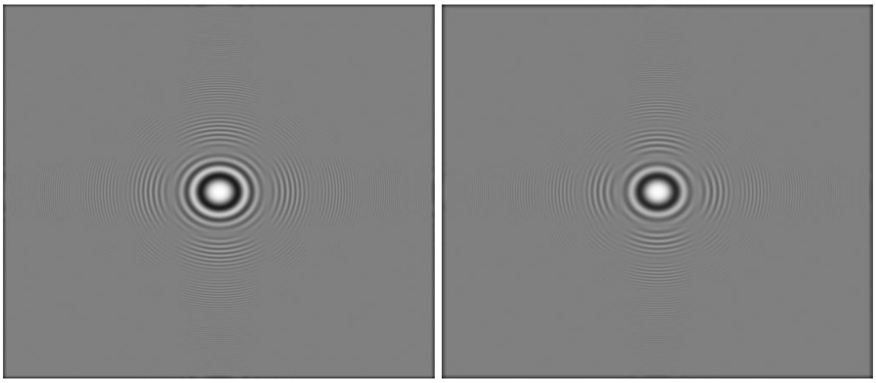
(a)





(b) (c)



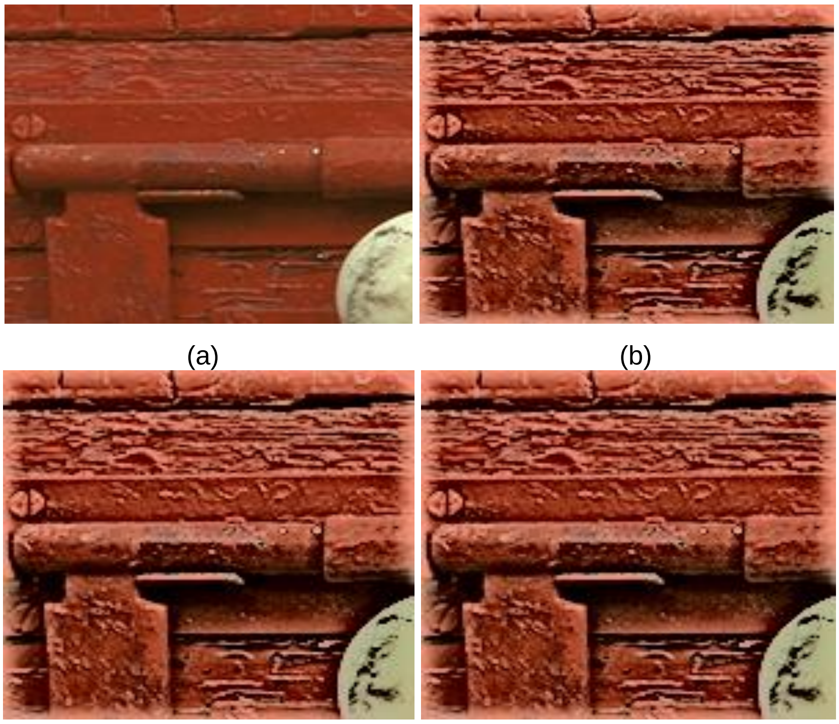
(d) (e)

**Figure 1. Test Images on Zero-Pole Generated Image: (a) Original Image, (b) Parameter Set (20,100,2), (c) Parameter Set (20,100,4), (d) Parameter Set (30,150,2), and (e) Parameter Set (30,150,4)**

$$H(u,v) = 1 - \exp\left(-\frac{D^2_{(u,v)}}{2D_0^2}\right). \tag{5}$$

Equation (4) shows ideal filter case, where cutoff frequency is $D_0$ (positive value) and $n$ information is not needed for this equation. Equation (5) is Gaussian high pass filter with cutoff frequency $D_0$. In the same manner, $n$ information is not needed and $D_0$ is positive.

Figure 1 shows an example of Butterworth bandpass filter on zero pole generated image with (lower cutoff frequency higher cutoff frequency)=(20,100) or (30,150), respectively. The order, $n$, of the filter is considered as 2 or 4.



(a) (b)

(c) (d)

**Figure 2. Processed Images with Several Parameter Sets: (a) ($\alpha,\beta$)=(0.5,2.0), (b) ($\alpha,\beta$)=(0.8,1.9), and (c) ($\alpha,\beta$)=(1.0,3.0)**

As can be seen in Eq. (2), proposed method is controlled by two parameters $\alpha$ and $\beta$. To determine both parameters are another issue, and in this paper both parameters are assumed to be $\alpha$=0.8 and $\beta$=1.9. Figure 2 shows comparison of several parameter sets.

The block diagram of the proposed method is shown in Figure 3.

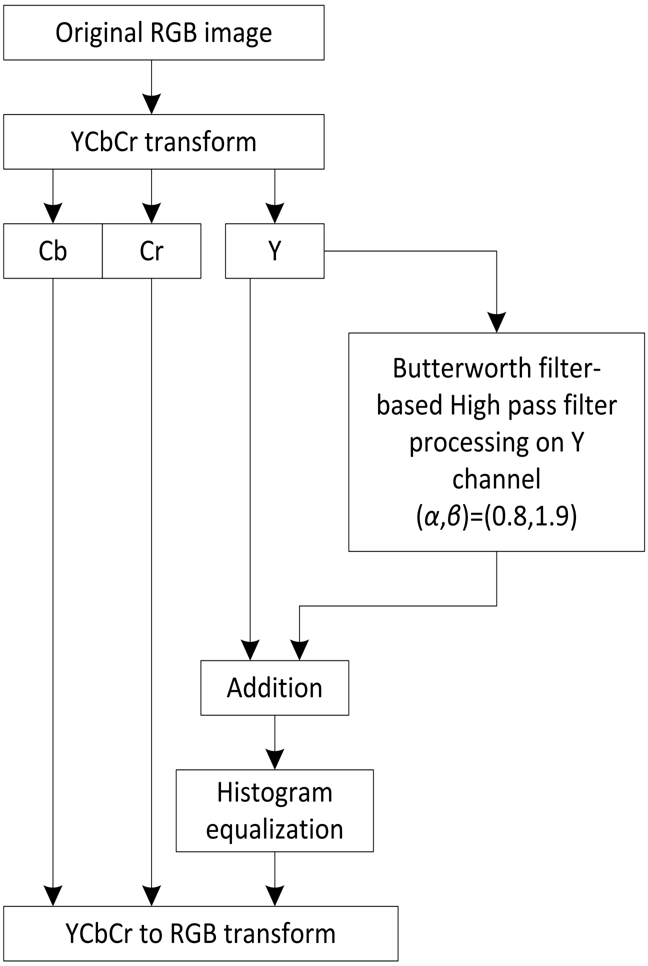



**Figure 3. Flowchart of the Proposed Method**

## 3. Experimental Results

We use standard test images from Kodak dataset to assess performance of the proposed method. To evaluate subjective performance, we used four images, #1, #8, #19, and #24. It is hard to evaluate contrast enhancement as it is hard to quantify an improved perception of an image. Generally speaking, PSNR, MSE, SSIM metrics are widely used in black and white images, while CPSNR, S-CIELAB, FSIM metrics are used for color images. However, as our method is for improving visual quality, we do not use objective performance metrics.

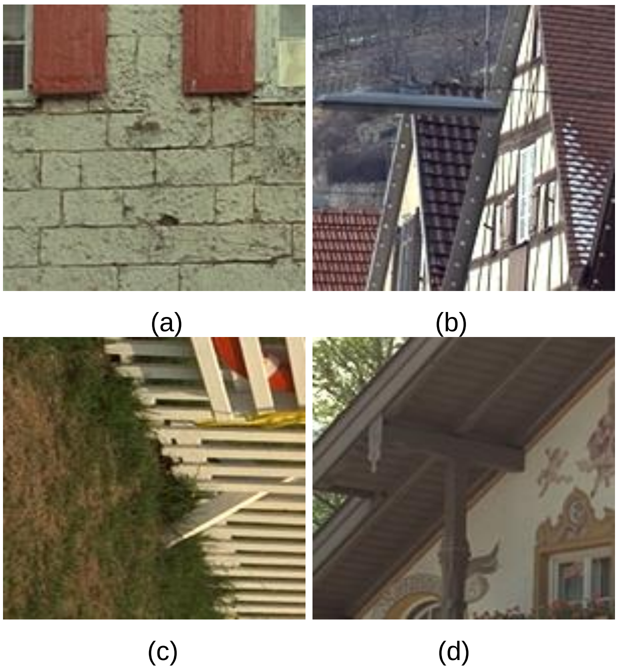



**Figure 4. Test Images: Kodak Dataset #1, #8, #19, and #24.**

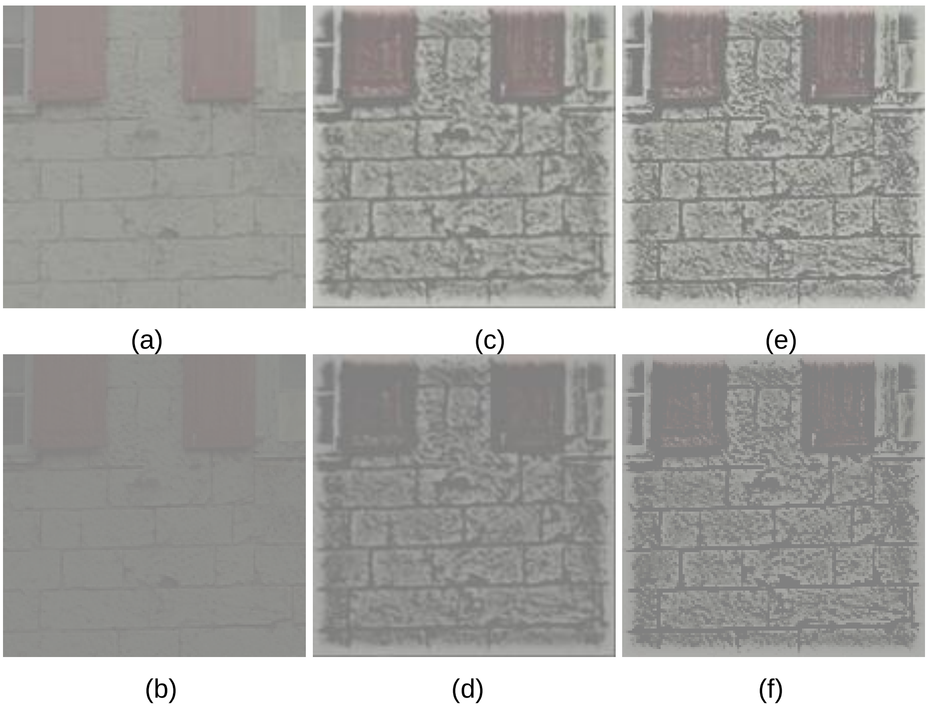



**Figure 5. Simulation Results Under Power Saving Mode on Kodak Image #1: (a) Factor of 5, (b) Factor of 10, (c) LPF Method on (a), (d) LPF Method on (b), (e) Proposed Method on (a), and (f) Proposed Method on (b).**

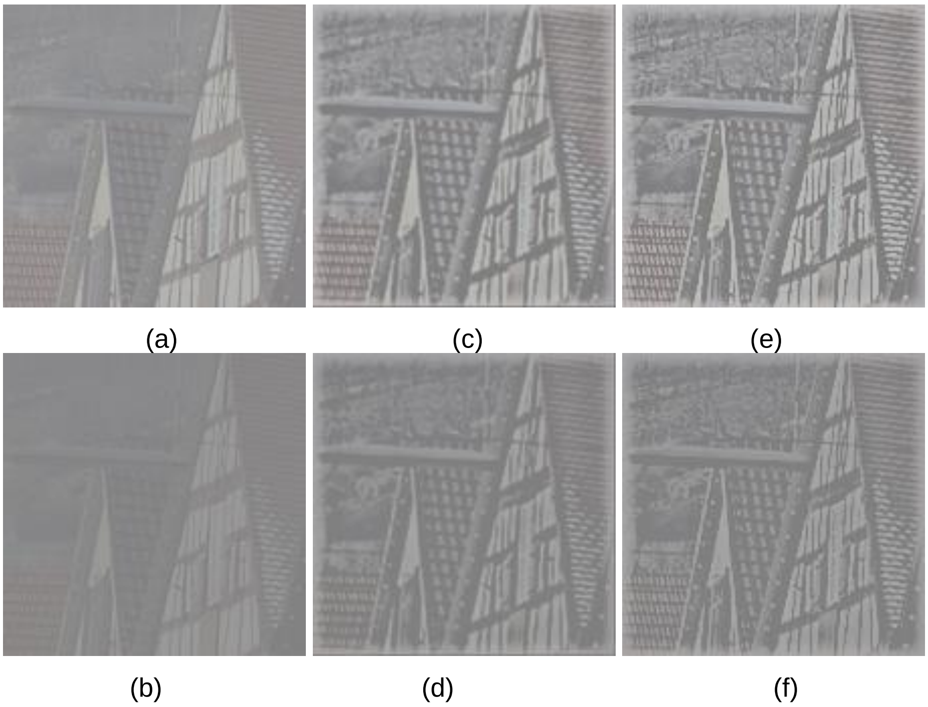



**Figure 6. Simulation Results Under Power Saving Mode on Kodak Image #8: (a) Factor of 5, (b) Factor of 10, (c) LPF Method on (a), (d) LPF Method on (b), (e) Proposed Method on (a), and (f) Proposed Method on (b)**

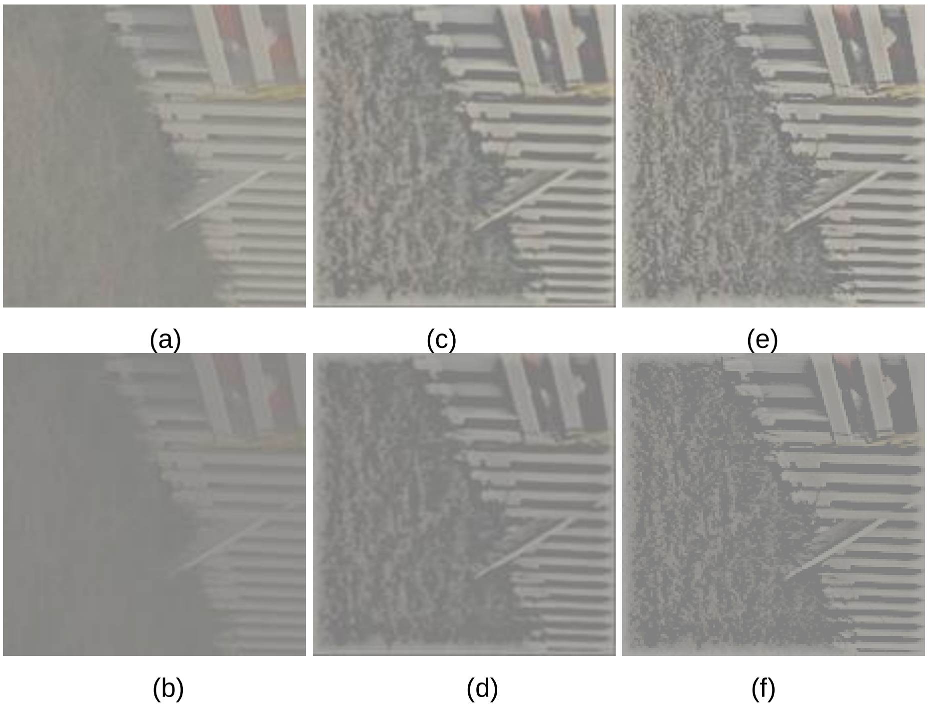
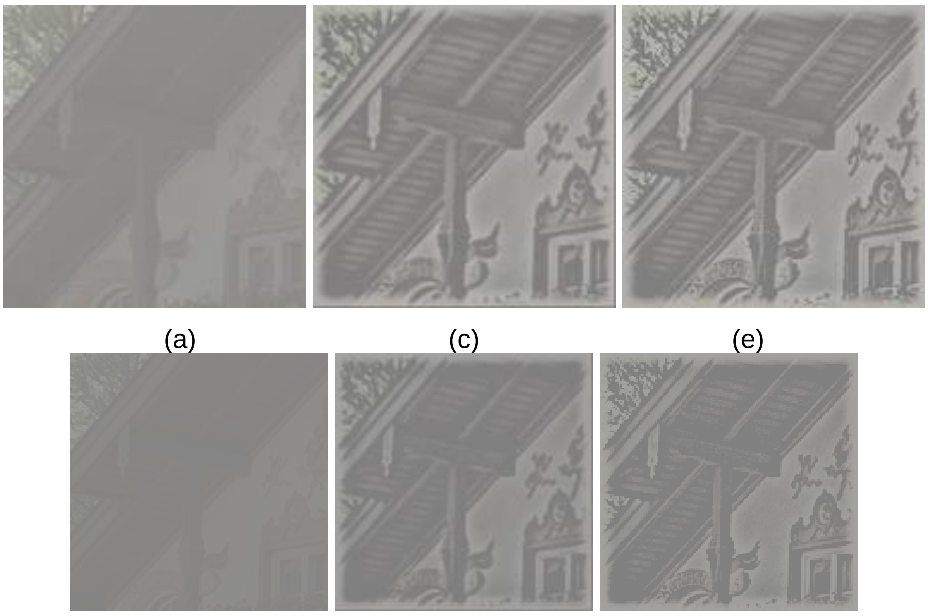



**Figure 7. Simulation Results Under Power Saving Mode on Kodak Image #19: (a) Factor of 5, (b) Factor of 10, (c) LPF Method on (a), (d) LPF Method on (b), (e) Proposed Method on (a), and (f) Proposed Method on (b)**



(a) (c) (e)

(b) (d) (f)

**Figure 8. Simulation Results Under Power Saving Mode on Kodak Image #24: (a) Factor of 5, (b) Factor of 10, (c) LPF Method on (a), (d) LPF Method on (b), (e) Proposed Method on (a), and (f) Proposed Method on (b)**

Figure 4 shows original four images of Kodak dataset, particularly four images #1, #8, #19, and #24. Figure 4(b) has many details in roof, while Figure (c) has high frequency information in vertical direction.

Figures 5-8 show results images. All (a) and (b) images are with power saving mode with factor of 5 and 10, respectively. Images (c) and (d) are conventional LPF results on each factor. Images (e) and (f) are results with proposed method.

Figures 9 and 10 show difference images between LPF and the proposed method for four test images #1, #8, #19, and #24. As one can see, the difference at the case of factor of 5 is more evident than the case of factor of 10.

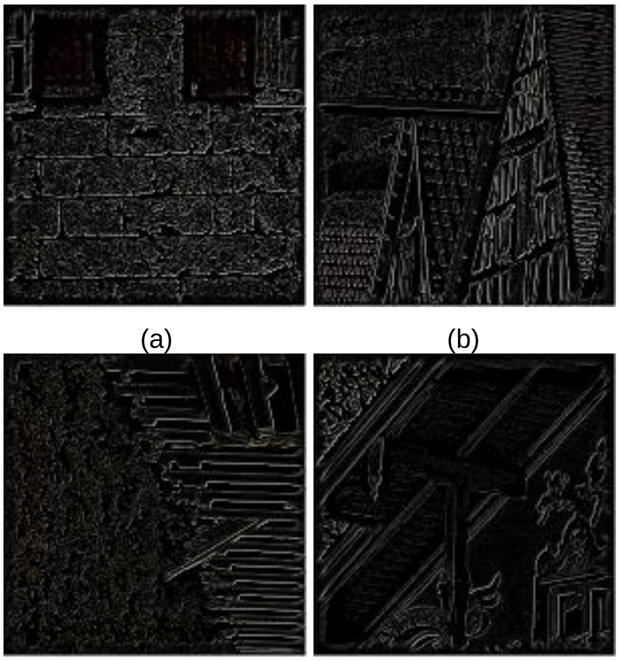
## 4. Conclusions

In this paper, we studied power effective image processing approach for power constrained condition. This paper is especially effect for mobile environment. We studied unsharp masking on darkened images with low contrast. The high pass filter, Butterworth filter, and histogram equalization were used to design the proposed method. Experimental results indicate that the proposed method is effect for power-constrained conditions with factors of *n*.

(a) (b)

(c) (d)

**Figure 9. Difference Images Between LPF and Proposed Method for Four Test Images with Factor of 5 Condition: (a) #1, (b) #8, (c) #19, and (d) #24**



(a) (b)

(c) (d)

**Figure 10. Difference Images Between LPF and Proposed Method for Four Test Images with Factor of 5 Condition: (a) #1, (b) #8, (c) #19, and (d) #24**

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## References

[1] R. C. Gonzalez and R. E. Woods, “Digital Image Processing”, 3rd ed. Upper Saddle River, NJ: Prentice-Hall, **(2006)**.

[2] P. S. Tsai, C.-K. Liang, T.-H. Huang and H. H. Chen, “Image enhancement for backlight-scaled TFT-LCD displays”, IEEE Trans. Circuits Syst. Video Technol., vol. 19, **(2009)**, pp. 574-584.

[3] T. Arici, S. Dikbas and Y. Altunbasak, “A histogram modification framework and its application for image contrast enhancement”, IEEE Trans. Image Process., vol. 18, **(2009)**, pp. 1921-1935.

[4] C. Lee, C. Lee and C.-S. Kim, “Power-constrained contrast enhancement for OLED displays based on histogram equalization”. in Proceeding IEEE ICIP, **(2010)**.

[5] R. D. Jones and T. Tjahjadi, “A study and modification of the local histogram equalization algorithm”, Pattern Recognition, vol. 26, no. 9, **(1993)**, pp. 1373–1381.

 

[6] T. K. Kim, J. K. Paik and B. S. Kang, "Contrast enhancement system using spatially adaptive histogram equalization with temporal filtering", IEEE Trans. Consum. Electron., vol. 44, no. 1, **(1998)**, pp. 82-87.
[7] M. A. A. Wadud, M. Kabir, M. Dewan and O. Chae, "A dynamic histogram equalization for image contrast enhancement", IEEE Trans. Consum. Electron., vol. 53, no. 2, **(2007)**, pp. 593-600.
[8] Q. Wang and R. K. Ward, "Fast image/video contrast enhancement based on weighted thresholded histogram equalization", IEEE Trans. Consum. Electron., vol. 53, no. 2, **(2007)**, pp. 757-764.
[9] C. C. Sun, S. J. Ruan, M. C. Shie and T. W. Pai, "Dynamic contrast enhancement based on histogram specification", IEEE Trans. Consum. Electron., vol. 51, no. 4, **(2005)**, pp. 1300-1305.
[10] T. Celik and T. Tjahjadi, "Contextual and variational contrast enhancement", IEEE Trans. Image Process., vol. 20, no. 12, **(2011)**, pp. 3431-3441.
[11] S. D. Chen and A. Ramli, "Minimum dkd mean brightness error bi-histogram equalization in contrast enhancement", IEEE Trans. Consum. Electron., vol. 49, no. 4, **(2003)**, pp. 1310-1319.
[12] C. E. Shannon, "A mathematical theory of communication," Bell System Technology Journal, vol. 27, **(1948)**, pp. 379–423, 623–656.
[13] S. Agaian, B. Silver and K. Panetta, "Transform coefficient histogram-based image enhancement algorithms using contrast entropy", IEEE Trans. Image Process., vol. 16, no. 3, **(2007)**, pp. 741-758.
[14] G. Jeon, "Contrast Intensification in NTSC YIQ", IJCA, vol. 6, no. 4, **(2013)**, pp. 157-166.
[15] G. Jeon, "Measuring and Comparison of Edge Detectors in Color Spaces", IJCA, vol. 6, no. 5, **(2013)**, pp. 21-30.

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