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Brightness Compensation Investigation for Power-Efficient System

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Abstract

This paper presents brightness compensation and enhancement method for power-constrained condition. The proposed method is useful for low-power device. We assumed two conditions: half and quarter power-consumption. We compare two brightness enhancement methods in both scenarios, histogram equalization and contextual and variational contrast enhancement methods. Both methods are contrast adjustment approaches using the given images histogram. Simulation results thoroughly report objective and subjective performance.

Keywords: *brightness compensation, power-efficient system, histogram equalization*

1. Introduction

Nowadays, various displays are adopted in various devices, such as mobile TV or phones, portable media players, personal digital assistants, and notebooks [1]. The purpose of all devices is delivering information, however the main challenge and limitation of their usage is battery capacity [2]. Especially, watching multimedia such as pictures or videos consumes more battery than other activity. Although many researchers have been studying display techniques, the low power consumption is still important and unsolved issue yet.

Contrast enhancement often generates impractical effects in pictures [3]. However, contrast enhancement is somehow effective for scientific scene such as thermal or satellite images. Meanwhile, contrast enhancement can generate undesirable effects when it is applied to low color depth images [4]. In this paper we assume two scenarios, half- and quarter power power-consumption.

To show high color fidelity image with less energy consumption, some researchers propose various ideas [5]. For example, sender sends half contrast image and receiver can reproduce full contrast image. However, half contrast image looks very dark especially in daylight and may harm human visual system [6]. Therefore contrast enhancement method is important to be studied.

After grayscale contrast enhancement is performed, this can be applied to color image case. One can apply the same approach in each color components, red, green, and blue. However, implementing the identical approach on the red, green, and blue channels of color image can produce drastic change of image. To alleviate this issue, YUV transform can be firstly applied. This can prevent white balance error. To reduce energy consumption by the backlight, two enhancement methods were assumed in this paper. One is histogram equalization and the other one is contextual and variational contrast (CVC) enhancement.

This paper is organized as follows. Section 2 explains details of both contrast enhancement methods. Section 3 shows the simulation results with four metrics. Conclusion remarks are shown in Section 4.

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2. Histogram Equalization and Contextual and Variational Contrast Enhancement

There have been various contrast enhancement histogram equalization methods which were presented by various authors with different purpose and complexity. The contrast enhancement is widely used for low contract image. Especially, histogram equalization method is one of broadly used techniques to enlarge intensities of low-contrast image. By applying contrast enhancement, the number of pixels of each intensity becomes similar to each other. The CVC enhancement method is another method which is recently introduced. In this paper, we use two methods to design and investigate a power efficient contrast enhancement system. Here are reviews of both methods. Details of histogram equalization and CVC can be found [7].

Figure 1 shows the flowchart of the proposed method.

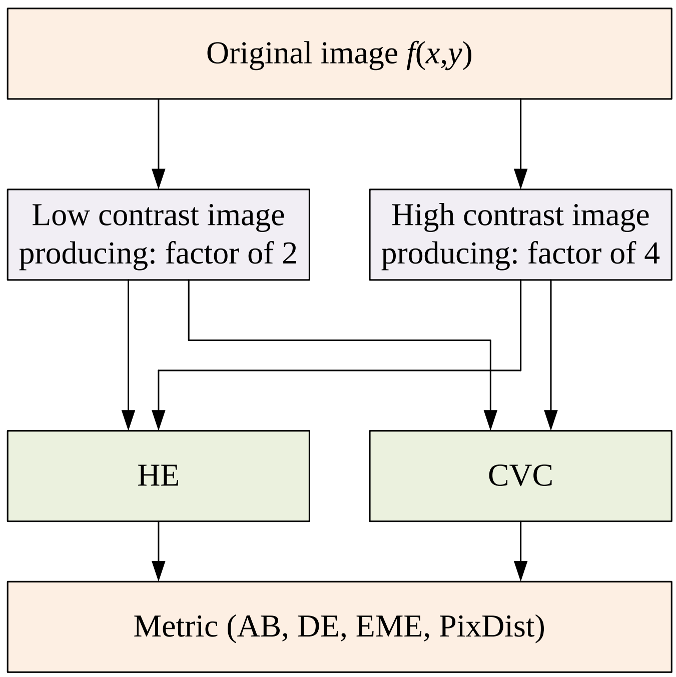


Figure 1. Flowchart of the Proposed Method

For grayscale image, the probability of level i image is,

$$p(i) = \frac{n_i}{n}, \tag{1}$$

where i is less than L and bigger than 0. L is normally determined as 256 as we assume gray scale image. The cumulative distribution function, CDF, is

$$CDF(i) = \sum_{j=0}^{i} p(j). \tag{2}$$

When i is L-1, CDF is

$$CDF(L-1) = 1. \tag{3}$$

The output histogram h_{HE} is defined as Eq. (4).

$$h_{HE} = \frac{L-1}{1^T h_{ori}} h_{ori}. \tag{4}$$

where h_{ori} are original histogram. The details of h_{CVC} are modified version of histogram equalization which can be found [7].

Figure 2 shows the code of histogram equalization.

```
PDF=inhist/sum(inhist);
CDF=zeros(length(inhist),1);
CDF(1,1)=PDF(1,1);
for t = 2:length(hist_in)
    CDF(t,1)=CDF(t-1,1)+PDF(t,1);
end
OUT=(2^BD-1)*CDF;
```

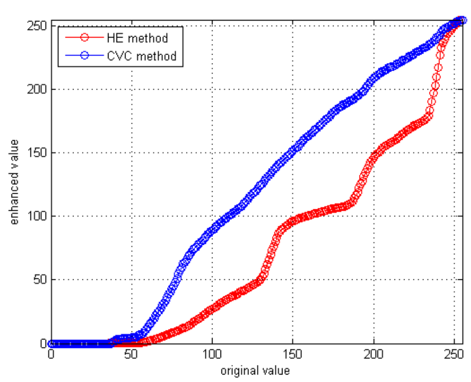
Figure 2. Histogram Equalization Software

Here, parameter BD stands for bit depth, which is 8 for gray scale image. Figure 3 shows the step of contextual and variational contrast.

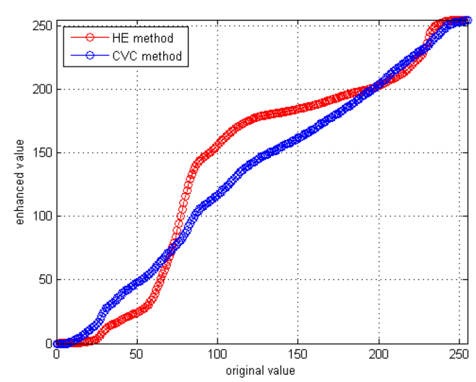
```
Step 1: obtain Hx in Eq. (1)
Step 2: obtain hx and hp in Eqs. (2) and (3)
Step 3: calculate weighted hx using hp
Step 4: compute Hu in Eq. (6)
Step 5: compute Ht in Eq. (8)
```

Figure 3. Contextual and Variational Contrast Steps

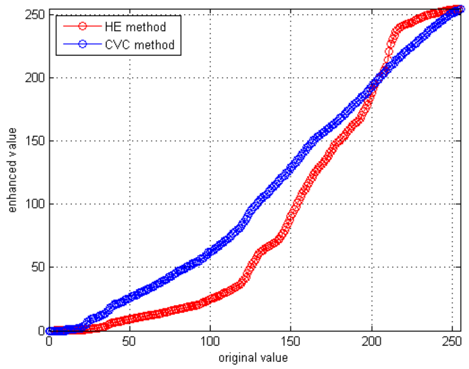
The contrast enhancement method is originally generated for gray scale image. However, as most images are color, we can apply contrast enhancement methods to color image. We assume the obtained results can be applied to color images. To do so, one can convert RGB image into YUV and apply the method in Y channel only, and preserve chrominance channels, U and V. Figure 4 shows the illustration of HE and CVC on #22 to #25 Zahra imageset. Line in red shows HE method results, and blue line shows CVC method result.



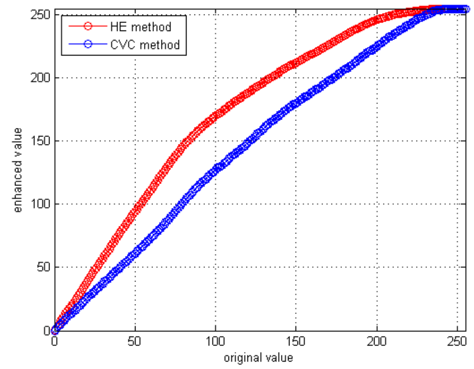
(a)



(b)



(c)



(d)

Figure 4. Illustration of HE and CVC for (a) #22, (b) #23, (c) #24, and (d) #25 Zahra imageset; Line in Red Shows HE Method Result and Line in Blue Shows CVC Method Result

3. Experimental Results

We use standard test images from Zahra dataset to evaluate an compare HE and CVC under two conditions, half power-consumption and quarter power-consumption. The parameters for CVC is $w \times w = 7 \times 7$ adjacent block and α, β, and γ are 0.33, respectively.

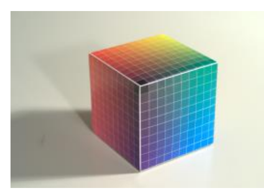
To evaluate subjective performance, we used four images, #2, #3, #13, and #22. It is hard to evaluate contrast enhancement as it is hard to quantify an improved perception of an image. In general, PSNR or MSE metrics are widely used, however they have original images which are known as ground truth. However, in our case, there is no ground truth to catch up with. Therefore, we used four metrics, absolute mean brightness error (AB) [8], discrete entropy (DE) [9], measure of enhancement [10], and pixel distance.

Figure 5 shows original four images and Figures 6 and 7 show half and quarter powered original images, respectively.

(a)

(b)

(c)

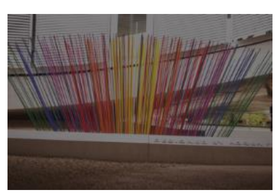


(d)

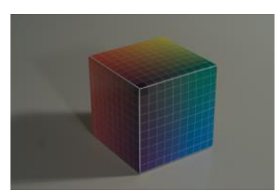
Figure 5. Original Zahra Image: (a) #2, (b) #3, (c) #13, and (d) #22

(a)

(b)



(c)



(d)

Figure 6. Original Zahra Images with Half Power-consumption: (a) #2, (b) #3, (c) #13, and (d) #22

(a) (b) (c) (d)

Figure 7. Original Zahra Images with Quarter Power-consumption: (a) #2, (b) #3, (c) #13, and (d) #22

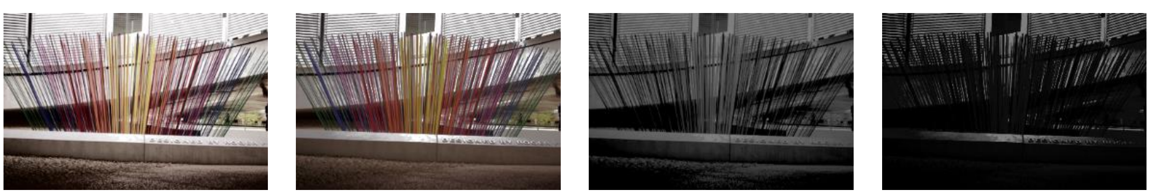
Figures 8-11 show subjective performance comparison for half power-consumed on four Zahra image. And Figures 12-15 show subjective performance comparison for quarter power-consumed on four Zahra image.

(a) (b) (c) (d)

Figure 8. Subjective Performance Comparison for Half Power-consumed #2 Zahra image: (a) HE result, (b) CVC result, (c) difference between HE and original, and (d) Difference between CVC and Original

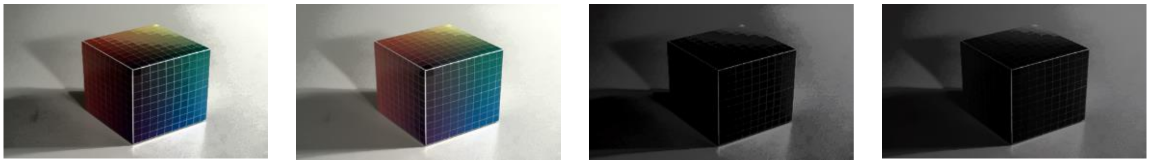
(a) (b) (c) (d)

Figure 9. Subjective Performance Comparison for Half Power-consumed #3 Zahra Image: (a) HE result, (b) CVC result, (c) difference between HE and Original, and (d) Difference between CVC and Original



(a) (b) (c) (d)

Figure 10. Subjective Performance Comparison for Half Power-consumed #13 Zahra Image: (a) HE result, (b) CVC result, (c) difference between HE and original, and (d) difference between CVC and original



(a) (b) (c) (d)

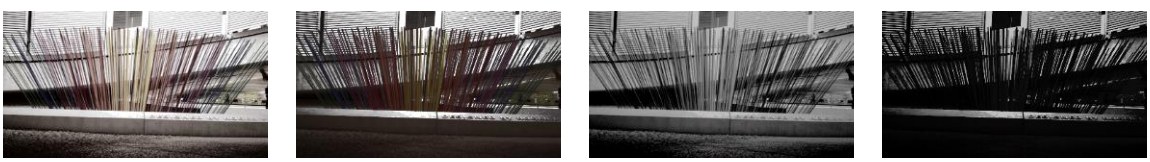
Figure 11. Subjective Performance Comparison for Half Power-consumed #22 Zahra Image: (a) HE Result, (b) CVC Result, (c) Difference between HE and Original, and (d) Difference between CVC and Original

(a) (b) (c) (d)

Figure 12. Subjective Performance Comparison for Quarter Power-consumed #2 Zahra Image: (a) HE Result, (b) CVC Result, (c) Difference between HE and Original, and (d) Difference between CVC and Original

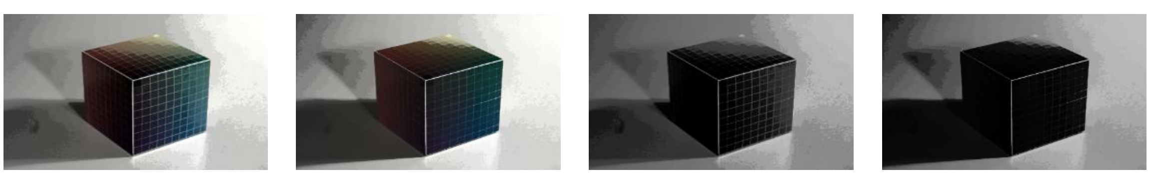
(a) (b) (c) (d)

Figure 13. Subjective Performance Comparison for Quarter Power-consumed #3 Zahra Image: (a) HE Result, (b) CVC Result, (c) Difference between HE and Original, and (d) Difference between CVC and Original



(a) (b) (c) (d)

Figure 14. Subjective Performance Comparison for Quarter Power-consumed #13 Zahra Image: (a) HE Result, (b) CVC Result, (c) Difference between HE and Original, and (d) Difference between CVC and Original



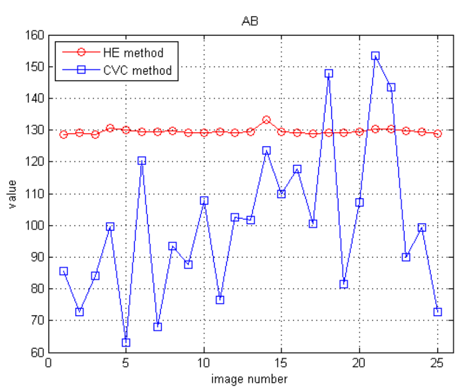
(a) (b) (c) (d)

Figure 15. Subjective Performance Comparison for Quarter Power-consumed #22 Zahra Image: (a) HE Result, (b) CVC Result, (c) Difference between HE and Original, and (d) Difference between CVC and original

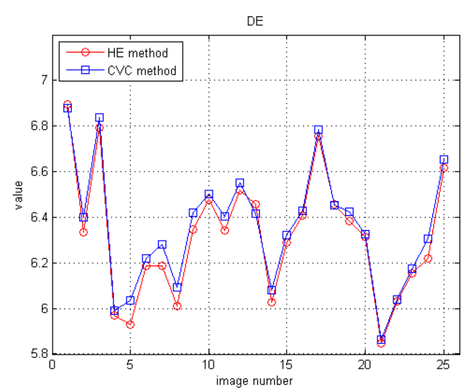
To assess objective performance, we used 25 images of Zahra imageset. Four metrics were used, and they are absolute mean brightness error (AB), discrete entropy (DE), measure of enhancement, and pixel distance. Table 1 and Figure 16 show four metrics' performance results on HE and CVC methods for half power consumption case.

Table 1. Objective Performance Results between Two Methods on Four Metrics (Half Power-consumption)

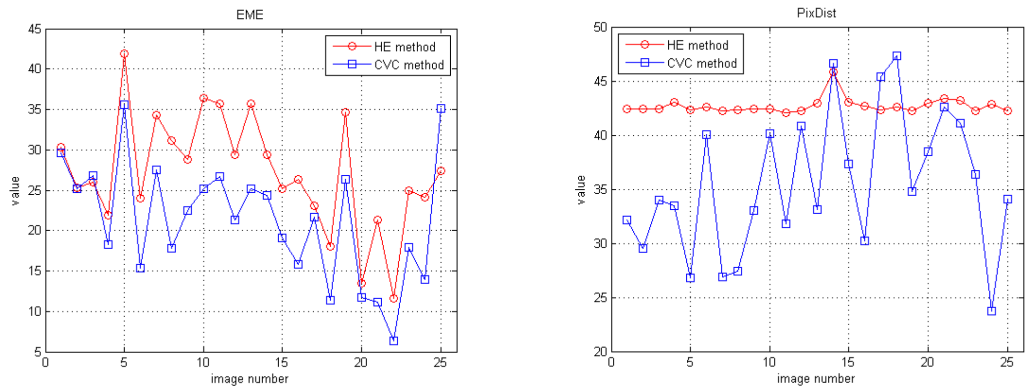
Metric	AB		DE		EME		PixDist	
Method	HE	CVC	HE	CVC	HE	CVC	HE	CVC
1	128.67	85.57	6.89	6.88	30.35	29.65	42.42	32.15
2	129.19	72.85	6.33	6.40	25.27	25.14	42.43	29.51
3	128.64	84.07	6.79	6.84	26.03	26.86	42.41	33.96
4	130.55	99.56	5.97	5.99	21.96	18.28	43.06	33.42
5	130.01	62.94	5.93	6.03	41.90	35.53	42.29	26.78
6	129.58	120.46	6.19	6.22	24.02	15.35	42.62	40.04
7	129.59	68.18	6.19	6.28	34.27	27.52	42.20	26.93
8	129.73	93.35	6.01	6.09	31.13	17.80	42.33	27.38
9	129.14	87.51	6.35	6.42	28.77	22.49	42.44	32.99
10	129.11	107.73	6.48	6.50	36.40	25.19	42.40	40.13
11	129.40	76.44	6.34	6.40	35.67	26.73	42.09	31.84
12	129.04	102.61	6.52	6.55	29.34	21.32	42.20	40.79
13	129.39	101.57	6.46	6.41	35.71	25.13	42.97	33.15
14	133.16	123.53	6.03	6.08	29.39	24.32	45.85	46.60
15	129.57	109.94	6.29	6.32	25.22	19.07	43.00	37.34
16	129.21	117.85	6.41	6.43	26.29	15.77	42.70	30.23
17	128.77	100.61	6.76	6.79	23.12	21.69	42.37	45.42
18	129.11	147.90	6.46	6.45	18.08	11.43	42.59	47.34
19	129.25	81.50	6.38	6.42	34.70	26.40	42.21	34.81
20	129.45	107.15	6.31	6.32	13.51	11.76	42.95	38.45
21	130.42	153.28	5.85	5.86	21.35	11.13	43.40	42.61
22	130.25	143.42	6.03	6.04	11.58	6.29	43.20	41.14
23	129.87	90.02	6.16	6.18	24.90	17.87	42.24	36.37
24	129.58	99.30	6.22	6.30	24.16	13.95	42.86	23.71
25	128.88	72.86	6.62	6.65	27.45	35.09	42.22	34.12
Avg.	129.58	100.41	6.32	6.36	27.22	21.27	42.70	35.49



(a)



(b)



(c) (d)

Figure 16. Objective Performance Results between Two Methods (Half Power-Consumption): (a) AB, (b) DE, (c) EME, and (d) PixDist

Table 2 and Figure 17 show four metrics' performance results on HE and CVC methods for quarter power consumption case.

Table 2. Objective Performance Results between Two Methods on Four Metrics (Quarter Power-consumption)

Metric	AB		DE		EME		PixDist	
Method	HE	CVC	HE	CVC	HE	CVC	HE	CVC
1	129.69	64.62	5.90	5.90	29.83	30.86	42.32	31.89
2	130.96	57.57	5.40	5.43	24.69	32.08	42.30	30.63
3	129.81	66.76	5.83	5.83	25.68	33.78	42.31	34.85
4	133.63	89.04	5.00	4.99	18.24	23.77	43.56	39.13
5	132.37	50.11	5.01	5.04	39.05	44.61	42.02	27.79
6	131.80	108.87	5.23	5.26	20.58	17.03	42.79	45.09
7	131.54	51.54	5.26	5.30	33.50	31.60	41.91	26.97
8	131.85	73.59	5.07	5.11	30.72	22.99	42.13	32.38
9	130.85	74.16	5.39	5.42	26.11	27.03	42.38	36.43
10	130.65	90.72	5.51	5.52	36.39	27.07	42.27	43.84
11	131.51	61.09	5.40	5.41	35.75	30.68	41.61	32.89
12	130.49	91.56	5.55	5.56	27.81	23.65	41.92	44.53
13	130.76	77.72	5.53	5.49	33.88	28.54	42.91	34.79
14	134.39	106.65	5.24	5.26	28.48	29.16	45.88	50.91
15	131.69	94.47	5.36	5.32	24.84	24.79	43.43	42.33
16	130.91	98.32	5.43	5.43	23.65	16.03	42.87	37.80
17	130.01	87.79	5.80	5.80	18.89	25.94	42.17	47.10
18	130.82	135.04	5.50	5.51	16.55	12.11	42.66	50.96
19	130.88	67.35	5.44	5.45	35.19	30.87	41.93	36.78
20	131.46	94.61	5.33	5.32	12.88	15.75	43.35	43.62
21	133.13	139.55	4.89	4.90	19.20	12.50	44.09	48.30
22	132.80	126.27	5.06	5.04	11.24	7.36	43.75	47.50
23	132.16	73.27	5.24	5.16	23.90	21.43	41.90	38.17
24	131.69	75.23	5.33	5.31	24.14	16.97	43.10	28.77
25	130.27	59.62	5.64	5.66	25.99	44.39	41.90	34.30
Avg.	131.44	84.62	5.37	5.38	25.89	25.24	42.70	38.71

4. Conclusions

In this paper, we investigated contrast enhancement methods' performance. Subjective and objective performance results are shown in simulation results section. The proposed brightness compensation method works well for half and quarter power-consumed devices.

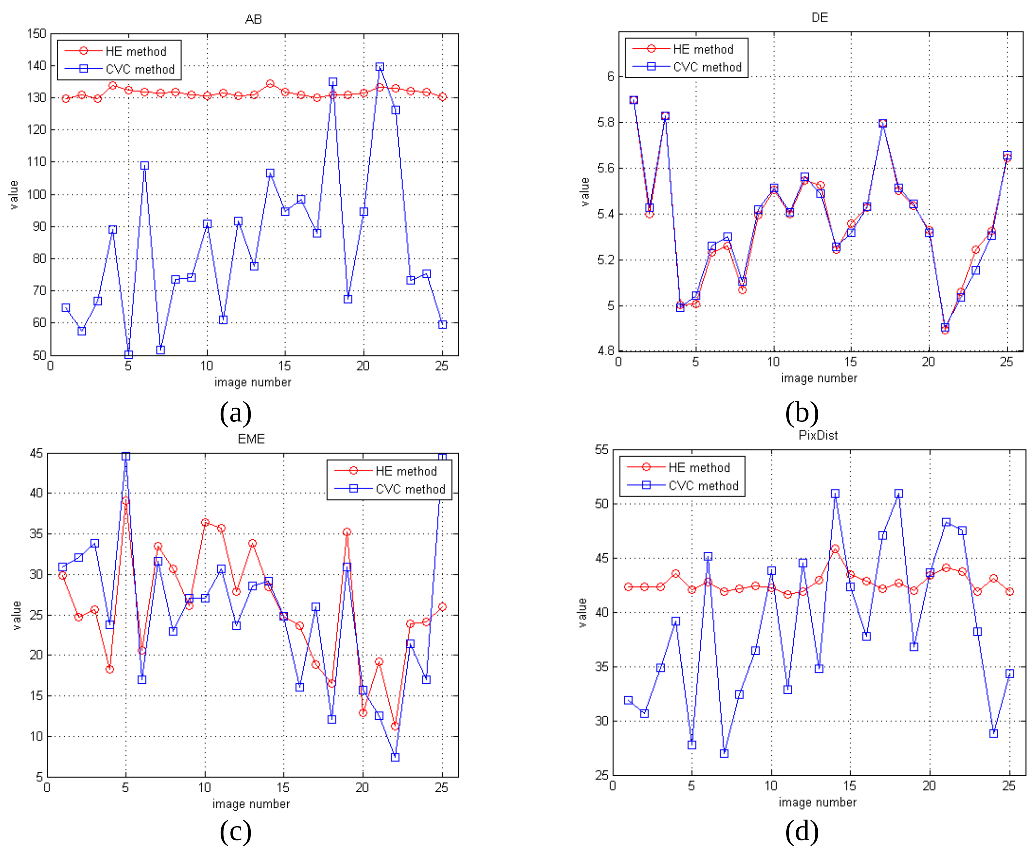


Figure 17. Objective Performance Results between Two Methods (Quarter Power-consumption): (a) AB, (b) DE, (c) EME, and (d) PixDist

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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] R. Dale-Jones and T. Tjahjadi, "A study and modification of the local histogram equalization algorithm," Pattern Recognit., vol. 26, no. 9, (**1993**) September, pp. 1373–1381.

[3] 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**) February , pp. 82–87.

[4] M. Abdullah-Al-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**) May, pp. 593–600.

[5] 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**) May, pp. 757–764.
[6] 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**) November, pp. 1300–1305.
[7] T. Celik and T. Tjahjadi, "Contextual and variational contrast enhancement," IEEE Trans. Image Process., vol. 20, no. 12, (**2011**) December, pp. 3431–3441.
[8] S.-D. Chen and A. Ramli, "Minimum mean brightness error bi-histogram equalization in contrast enhancement," IEEE Trans. Consum. Electron., vol. 49, no. 4, (**2003**) November, pp. 1310–1319.
[9] C. E. Shannon, "A mathematical theory of communication," Bell Syst.. Tech. J., vol. 27, (**1948),** pp. 379–423, 623–656**.**
[10] 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)** March**,** pp. 741–758.

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