DWT-Based Multi-Adaptive Image Coding for Frame Memory Reduction in LCD Overdrive

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Abstract— **In this paper, DWT-Based Multi-Adaptive Image Coding (DBMAIC) is proposed to increase compression performance for Frame Memory Reduction in LCD Overdrive. The DBMAIC development is based on DWT-Based Adaptive Mode Selection (DAMS)[9] integrated with Adaptive-Threshold Technique (ATT). ATT is proposed to reduce blocking effect and increase adaptability of DAMS. Experimental results show that the performance of the proposed method is significantly better than DAMS and that of conventional schemes.**

Keywords-Embedded Frame Delay Memory; LCD; Overdrive Technique; Image Adaptive Coding; Discrete Wavelet Transform (DWT); Adaptive Mode Selection; Adaptive-Threshold Technique.

I. INTRODUCTION

The industry of liquid crystal displays (LCD) has quickly developed in recent years, with great gains in picture quality, in addition to a continuously rising image resolution. In turn, many devices, such as HDTVs, tablets and mobile phones are now all predominantly making use of LCD. However, liquid crystals are, in general, slow in response speed to display motion pictures. The overdrive technique has been proposed and developed to reduce the response time of liquid crystal displays [1][2][4][5]. The overdrive technique, which was developed by Oura and Nakanishi et al [1], needs a full frame memory to store and output the previous frames. With the increasing resolutions of LCD panel, the amount of data to be stored in the frame memory is escalating; therefore, ideal overdrive suffers from the challenge of increasing frame memory size and data transfer rate [7]. A solution to this problem is to apply high-quality image compression methods. Several of these are proposed to improve the performance of image compression in LCD overdrive. We consider some compression techniques applied for introduced LCD overdrive, such as: Using scalable DCT-based compression as shown in [2]; A fast discrete wavelet transform as in [4]; Vector quantizer based block truncation coding for color image compression as in [6]; compression using color space conversion [3]; or Advanced Hybrid Image Codec (AHIC) [5][7]. However, the most recent remarkable method is DWT-Based Adaptive Mode Selection (DAMS) which is mentioned in [9]. Although DAMS has a rather high complexity compared with the methods in [3][4][5], it does give a high rate of compression and outstanding image quality.

By inheriting and developing DAMS, we propose in this paper a new compression scheme for overdriving technique, named the DWT-Based Multi-Adaptive Image Coding (DBMAIC). Its development is based on DAMS integrated with Adaptive-Threshold Technique (ATT) to reduce blocking effect and enhance image quality. Furthermore, we propose to integrate no. 7 encoding mode, *which uses 32 level-AQC (Adaptive Quantization Coding)* to decrease the error when quantizing high-detail block. This helps to increase reconstructed image quality. We evaluate the proposed DBMAIC method on reference images from the LIVE Image Quality Assessment Database Release 2 [13]. The experimental results show that DBMAIC has much better quality from 0.95dB to 5.82dB and from 1.88dB to 8.66dB when compared with DAMS and AHIC respectively.

II. BACKGROUND OF LCD OVERDRIVER AND IMAGE CODING

The overdrive technique may be described in Fig. 1. It reduces the response time of liquid crystal, however, requires the values of pixels in previous frame to collate with the values of pixels in current frame. A LCD overdrive system may be described in Fig. 2: where the 'overdriving data' to be used is generated through look-up tables and previous frame data. An overdrive system using image compression technique may be described in Fig. 3.

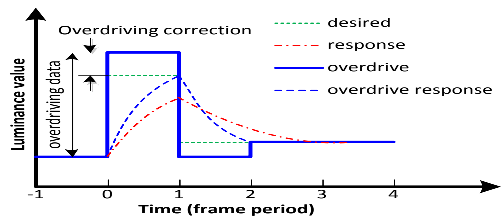


Figure 1. Illustration of Overdrive

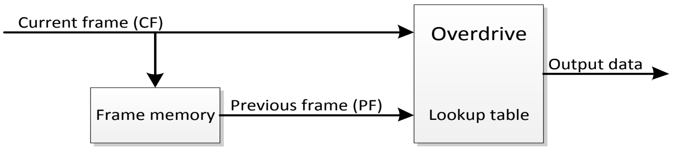


Figure 2. Block diagram of system overdrive

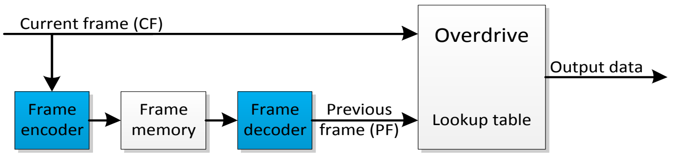


Figure 3. Block diagram of system overdrive using image compression technique

DWT-based adaptive mode selection (DAMS) algorithm was suggested by Haksub Kim and Sanghoon Lee [9]. To improve coding efficiency even in images with high complexity, the authors proposed to use many encoding modes and adaptively selected an optimal mode according to the spatial and frequency features of each image in the DWT domain. Fig. 4 showed DAMS encoder model without fixed rate control.

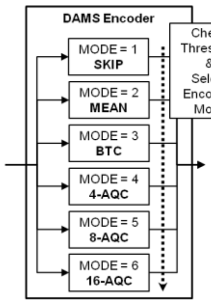


Figure 4. DWT-based adaptive mode selection encoder model [9] (without fixed rate control).

The authors proposed mode selection algorithm for fixed rate processing. Based on these proposals, we build block diagram of DAMS encoder with fixed rate control in Fig. 5.

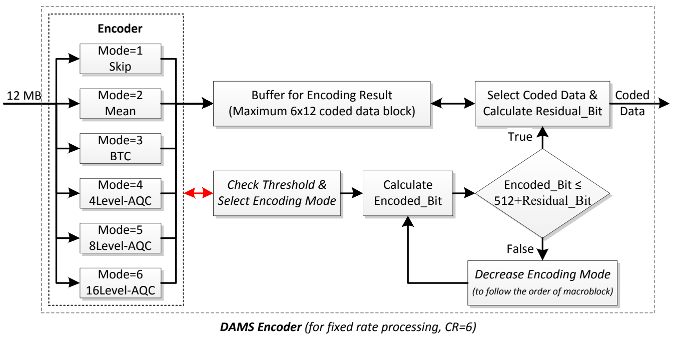


Figure 5. Block diagram of DAMS Encoder has been fixed rate control.

In DAMS encoder, let the target PSNR be 35 dB for reconstructed images. The authors' proposed fixed value for RMSE (Root Mean Square Error) threshold is:

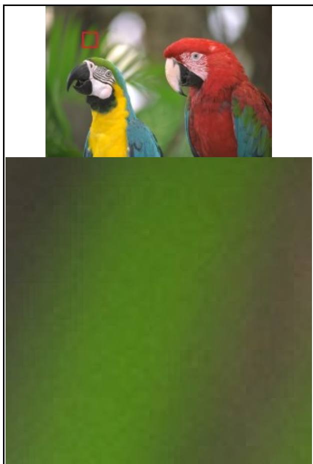
$$R_{th} = RMSE \approx 4.5 \tag{1}$$

When considering DAMS, some drawbacks are specified as follows:

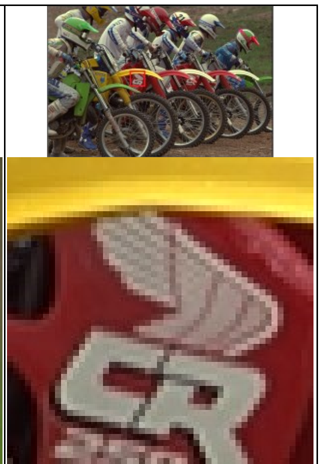
1. Color gradient zones are susceptible to blocking artifacts.
2. Detailed areas of an image shows more noise.
3. It is not effective for bit use in the case of images with low-detail areas, or have many low-details areas at the bottom of the image. It is expressed through the big value of residual bit when the compression of frame image is completed.

We can see blocking effect in the reconstructed image in Fig. 6 (c). Fig. 6 (d) shows noise typical of a decoded high-detail part of the image. Fig. 7 shows the residual bit can be up to 60% in some images.

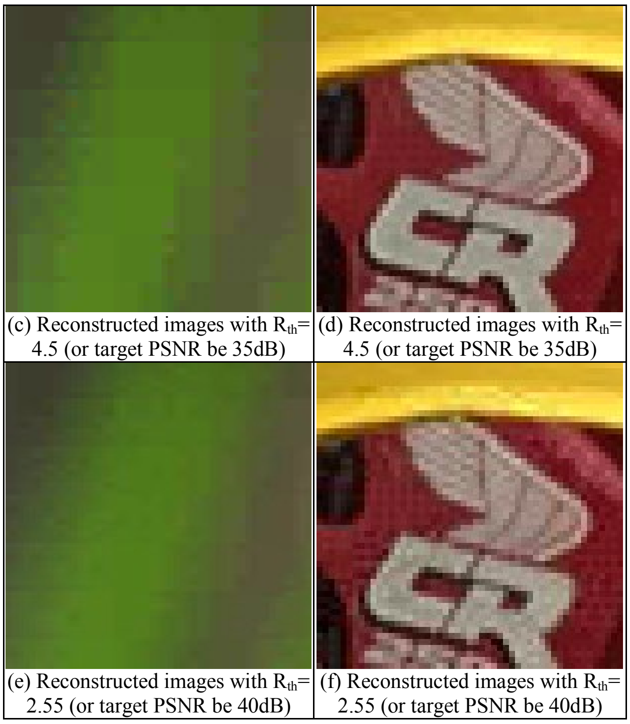
To reduce blocking effect, it is required to enhance the target PSNR for reconstructed images which, in turn, corresponds to decreasing the threshold value. However, this implementation also has the tendency of decreasing the image quality in high-details regions. The reason for this is, when compressed quality for each macroblock (MB) increases, it also leads to total number of bits for coding 12 MB increase. In which, 12MB is input data of DAMS encoder, is the gained result after the stages of wavelet transform & grouping and priority assignment, as shown in Fig. 8). If residual bit is not enough to compensate for coding 12 MB, (*in common situation, when target PSNR increases, residual bit declines)*, Encoding Model decreases in order to satisfy condition Encoded_bit ≤ (512 + Residual_bit). The decrease leads to the quality of many reconstructed MB to also decrease. It creates noise in reconstructed image at the invert DWT stage. The problem is shown in Fig. 6 (e) & (f) when target PSNR for reconstructed images is increased to 40dB. We can easily recognize that in Fig.6 (e), blocking artifacts on image are visibly less and noise on image Fig. 6 (f) is more present.



(a) Original Parrots image and zoom region



(b) Original Bikes image and zoom region



(c) Reconstructed images with R_{th}= 4.5 (or target PSNR be 35dB)
(d) Reconstructed images with R_{th}= 4.5 (or target PSNR be 35dB)
(e) Reconstructed images with R_{th}= 2.55 (or target PSNR be 40dB)
(f) Reconstructed images with R_{th}= 2.55 (or target PSNR be 40dB)

Figure 6. Blocking effect and noise on reconstructed image of DAMS.

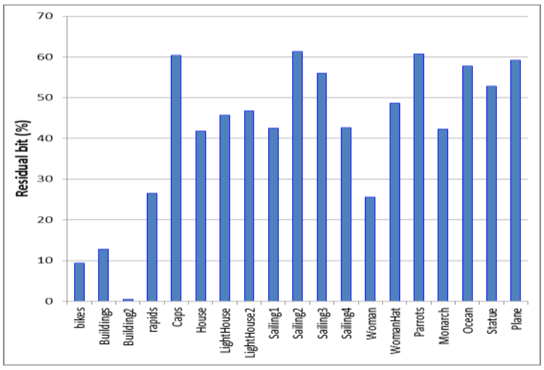


Figure 7. Residual bit of DAMS.

We propose to integrate Adaptive-Threshold Technique (ATT) into DAMS to enhance the adaptability of this compression method in order to address the drawbacks mentioned above. This, in turn, helps to increase image quality.

III. PROPOSED DBMAIC

In this section, we present the proposed DWT-Based Multi-Adaptive Image Coding (DBMAIC), based on DAMS integrated with ATT. Block diagrams of DBMAIC Encoder are shown in Fig. 8 & 9, in which Adaptive-Threshold Controller works at mid-phase after coding 12 MB and before fixed rate processing.

A. Adaptive-Threshold Technique

To perform Adaptive-Threshold Technique, we define some terms as follows:

- **Encoded_bit:** number of bits for coding 12 MB which satisfy the condition *RMSE of MB < Rth*.

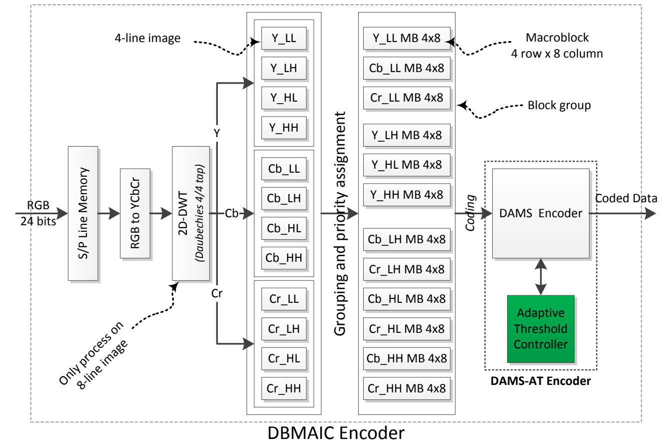


Figure 8. Block diagrams of DBMAIC Encoder

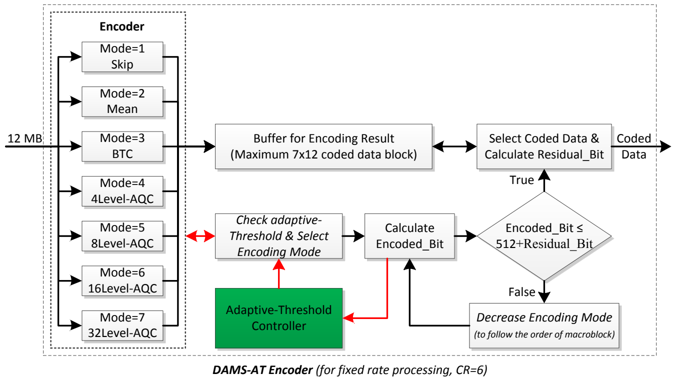


Figure 9. Block diagrams of DAMS-AT Encoder

- **Quota_bit**: total number of bits for coding 12 MB. If Quota_bit = 512, compression ratio CR=6, or if Quota_bit = 1024, compression ratio CR=3, etc…
- **Residual_bit**: the remaining bits after coding process. After coding 12 MB step, residual bit is updated following the formula: *Residual_bit = (Quota_bit+Residual_bit)-Encoded_bit*. Fixed rate processing always insures that *Residual bit ≥0*.
- **Rest_block_group**: the rest of block group in frame image which is waiting to be processed by DAMS-AT Encoder.

We propose a technique to change the threshold value adaptively. The major factors determining the change of Threshold value are:

1. The level of complexity of the image region to be encoded. It is indirectly evaluated by Encoded_bit. If Encoded_bit is less than Quota_bit, it means that Quota_bit is not used up completely. In this situation, we need to lower the threshold value in order to enhance the compressed quality of the image region that will be processed in the next iteration. Conversely, we need to increase the threshold value to limit the impact of the lower Encoding Modes. This helps in reducing noise in the next image region.

2. Residual_bit. If the rate of *Residual_bit/Rest_block_group* is high enough to enhance 12MB compressed quality, it is necessary to lower the threshold value. Its purpose is to increase effective for bit use, avoid Residual_bit has a very big value situation when the compression of frame image has finished

Moreover, the change of threshold value has been limited by Min_threshold and Max_threshold. This avoids the case of threshold value being too high or too low, which would make for poor image quality or would require too high Encoded_bit value respectively .Hence, the accumulation function of residual bit cannot function effectively. From these problems, we suggest the formula of adaptive change of threshold as the following:

$$Step1 = \frac{\Delta}{C_1} \cdot \frac{Encoded\_bit - Quota\_bit}{Quota\_bit} \quad (2)$$

$$Step2 = -\frac{\Delta}{C_2} \cdot \frac{Residual\_bit}{Rest\_block\_group \times Quota\_bit} \quad (3)$$

In which: $\Delta = \left(Max\_threshold - Min\_threshold\right)$, C_1 and C_2 are constant values need to be determined by the experiment.

Threshold is adjusted according to the following algorithm:

Adaptive-Threshold controller function

if (Encoded_bit ≠ Quota_bit)
Adaptive_Threshold= Adaptive_Threshold+Step1;
if ((Residual_bit/Qouta_bit)>C₃)
Adaptive_Threshold= Adaptive_Threshold+Step2;
if (Adaptive_Threshold<Min_Threshold)
Adaptive_Threshold= Min_Threshold;
else
if (Adaptive_Threshold>Max_Threshold)
Adaptive_Threshold= Max_Threshold;

In the above algorithm, C_3 is a constant value that needs to be determined empirically.

We suggest the use of MSE (Mean Square Error) threshold instead of RMSE (Root Mean Square Error) threshold. It helps in reducing computational cost. In the next section, threshold value will be changed into PSNR threshold, with the only purpose of understandable presentation, as the same PSNR measure is used to quantify reconstructed image quality.

B. Adaptive Quantization Coding Algorithm

Considering Encoding Mode Function [9] presented AQC algorithm with high complexity computation, we suggest applying new AQC algorithm to DBMAIC, which has lower computational complexity.

AQC function

Input: *MB: macroblock; N: element number of MB; Level: level-quantization number*

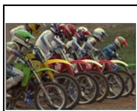
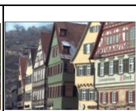
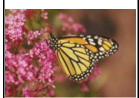
Output: *Code: Coded data; MB_re: reconstructed MB; MSE: mean square error.*

```
Min=MIN(MB);
Max=MAX(MB);
Diff=Max-Min; // value of Diff can be up to 511
Qstep = Diff/ Level;
Qstep_Half=Qstep/2.0 + 0.5;
for (i=1; i<=N; i++) {
    Code (i)=Integer((MB(i)-Min)/Qstep);
    if (Code (i)==Level)
      {Code (i)= Level;}
         MB_re(i)=Integer(Code(i)*Qstep+Qstep_Half+Min);
      E(i)=(MB(i)-MB_re(i));
      E(i)= E(i)* E(i);
}
  MSE=mean(E(:));
//Integer(x): return integer part of x.
```

IV. EXPERIMENTAL RESULTS

To evaluate the proposed DBMAIC method, we used reference images from the LIVE Image Quality Assessment Database Release 2 [13]. Table I shows 19 images which will be used in this experiment.

TABLE I. THE REFERENCE IMAGES FROM THE DATABASE IN [13]

 Bikes	 Buildings	 Building2	 Rapids	 Caps
 House	 Lighhouse2	 Sailing1	 Sailing4	 Parrots
 Monarch	 Ocean	 Plane	 Woman	 Womanhat
 Lighhouse2	 Sailing2	 Sailing3	 Statue	

The result indicates that the constants C_1, C_2 and C_3 can be chosen from a very large range of values but the reconstructed image quality does not change significantly. Fig. 10 shows the relationship between image quality and C_2 & C_3 constants in Bikes image, in which the remaining constants have fixed values as follows: Min_threshold = 30 dB, Max_threshold = 45 dB, C_1 = 80. Fig. 10 displays the reasonable value for C_3 is greater than or equal to 7, and the reasonable value for C_2 is greater than or equal to 40 (therefore, $C_3 \geq 8$ if $C_2 < 40$).

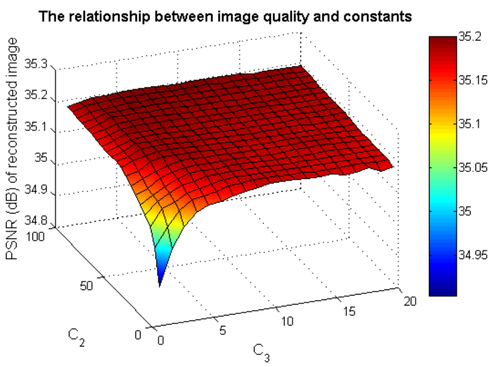


Figure 10. The relationship between image quality and C_2 & C_3 constants of DBMAIC method – Tested in Bikes image and Min_threshold=30 dB, Max_threshold=45 dB, C_1 = 80, Compression ratio = 6.

Fig. 11 shows the relationship between image quality and C_1 & C_2 constants in Bikes image, in which the remaining constants have fixed values as follows: Min_threshold = 30 dB, Max_threshold = 45 dB, C_3 = 9. This indicates the reasonable value for C_1 is greater than or equal to 30, C_2 can be any value from 5 to 150, but the reconstructed image quality does not change significantly.

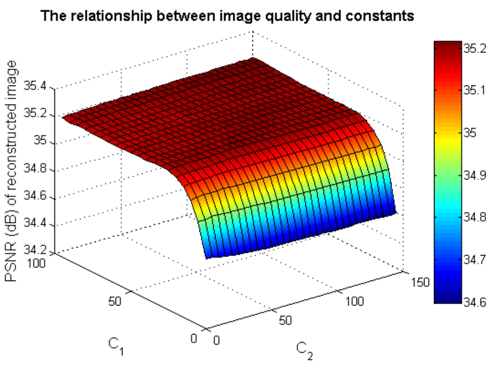


Figure 11. The relationship between image quality and C_1 & C_2 constants of DBMAIC method – Tested in Bikes image and Min_threshold=30 dB, Max_threshold=45 dB, C_3 = 9, Compression ratio = 6.

Fig. 12 displays the experimental results on 19 images that have been introduced in Table I. It finds that the reasonable value for C_1 is in the scope of [15; 150] and the reasonable value for C_2 is in the scope of [5; 150].

Fig. 13 shows the reasonable range of values for Min-threshold & Max-threshold constants, *in the cases of compression ratio =6*, are [23; 33] and [44; 47] respectively. And Fig. 14 indicates the change of threshold to adapt to the change of image region.

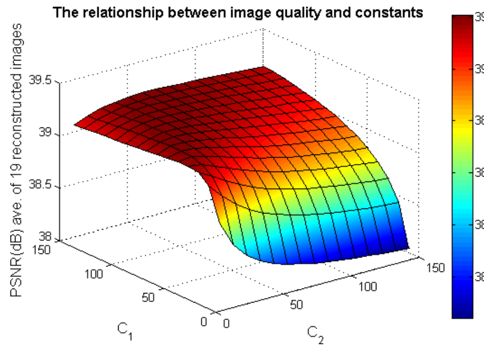


Figure 12. The relationship between image quality and C_1 & C_2 constants of DBMAIC method – Tested in 19 images in Table I and Min_threshold=30 dB, Max_threshold=45 dB, C_3 = 9, Compression ratio = 6.

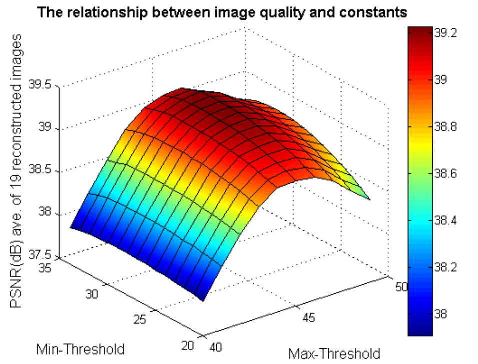


Figure 13. The relationship between image quality and Min-Threshold & Max-Threshold constants of DBMAIC method – Tested in 19 images and C_1 = 100, C_2 = 40 , C_3 = 9, Compression ratio = 6.

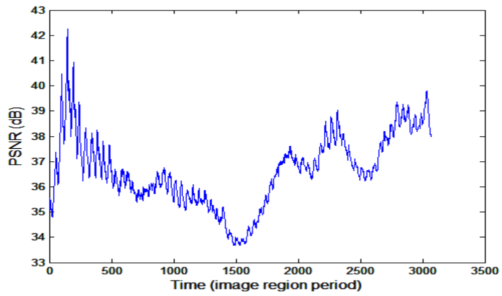


Figure 14. Change of threshold - Tested in Bikes image and Min_threshold=30 dB, Max_threshold=45 dB, C1 = 80, Compression ratio=6.

To evaluate the performance of DBMAIC method, we compare DBMAIC method with the original DAMS method, and two recent methods deemed very competitive: AHIC in [7] and AM-BTC in [8] with the same compression ratio = 6. The result in Fig. 15 indicates that DBMAIC method gives better PSNR metrics than that of the others. Fig. 16 indicates the residual bit of DBMAIC method is much lower than that of DAMS.

Fig. 17 shows a region of reconstructed image of DBMAIC method. When referring to Fig. 6, it can be seen that blocking effect and noise on reconstructed image of DBMAIC have been greatly improved.

These above results demonstrate the multi- adaptive ability of DBMAIC method and the effectiveness of Adaptive-Threshold Technique.

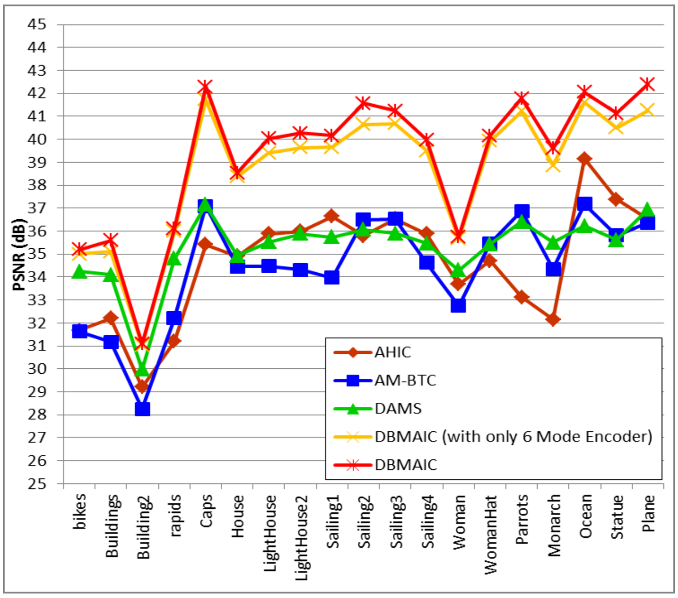


Figure 15. Comparison of performances in PSNR – Tested in 19 images in Table I and Min_threshold=30 dB, Max_threshold=45 dB, C_1 = 100, C_2 = 40 C_3 = 9, Compression ratio = 6.

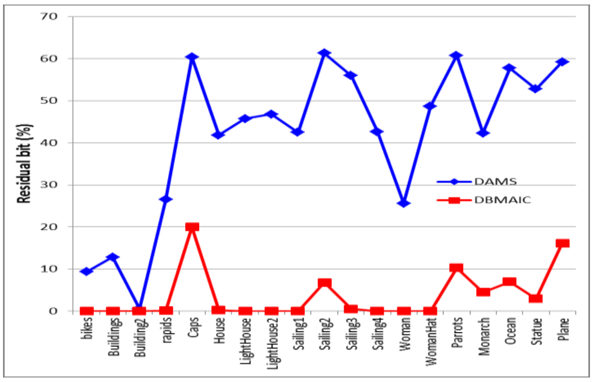
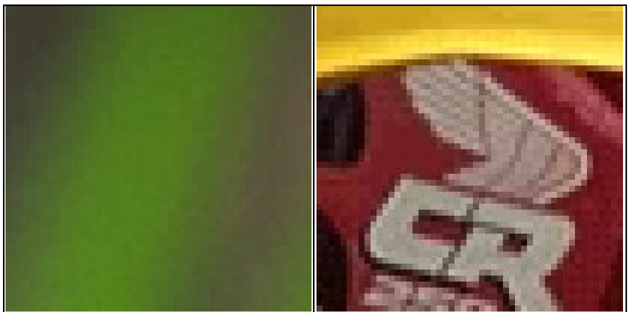


Figure 16. Comparison of residual bit value – Testing with 19 images in Table I and Min_threshold=30 dB, Max_threshold=45 dB, C_1 = 100, C_2 = 40 C_3 = 9, Compression ratio = 6.



(a) Reconstructed images of DBMAIC

(b) Reconstructed images of DBMAIC

Figure 17. Reduce blocking effect and noise on reconstructed image of DBMAIC – Testing with Min_threshold=30 dB, Max_threshold=45 dB, C_1 = 100, C_2 = 40, C_3 = 9, Compression ratio = 6.

V. CONCLUSION

In this paper, we propose a DWT-Based Multi-Adaptive Image Coding (DBMAIC) to improve image quality for overdriving technique. Its development is based on DWT-Based Adaptive Mode Selection (DAMS) [9] integrated with Adaptive-Threshold Technique (ATT). In which, ATT is a new technique allowing to change threshold adaptively to the change of image region. It reduces blocking effect and noise. Moreover, it also gives DBMAIC a multi-adaptive ability to increase the quality of reconstructed image. The carried out results show that DBMAIC reduces bandwidth requirements (and memory etc) for applications that need a frame buffer, such as certain LCD overdrive methods, while maintaining an outstanding picture quality.

VI. REFERENCES

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