AN ADAPTIVE SPATIAL ERROR CONCEALMENT FOR H.264/AVC VIDEO STREAM

Jun Wang, Lei Wang, Takeshi Ikenaga and Satoshi Goto
Graduate School of Information, Production and Systems, Waseda University, Japan

Keywords: Spatial Error Concealment, Adaptive, H.264/AVC.

Abstract: Transmission of compressed video over error prone channels may result in packet losses or errors, which can significantly degrade the image quality. Therefore an error concealment scheme is applied at the video receiver side to mask the damaged video. Considering there are 3 types of MBs (Macro Blocks) in natural video frame, i.e., Textural MB, Edged MB, and Smooth MB, this paper proposes an adaptive spatial error concealment which can choose 3 different methods for these 3 different MBs. For criteria of choosing appropriate method, 2 factors are taken into consideration. Firstly, standard deviation of our proposed edge statistical model is exploited. Secondly, some new features of latest video compression standard H.264/AVC, i.e., intra prediction mode is also considered for criterion formulation. Compared with previous works, which are only based on deterministic measurement, proposed method achieves the best image recovery. Subjective and objective image quality evaluations in experiments confirmed this.

1 INTRODUCTION

Transmission of compressed video over error prone channels such as wireless network may result in packet losses or errors in a received video stream. Such errors or losses do not only corrupt the current frame, but also propagate to the subsequent frames (Jao-Won, 2002). Several error control technologies, such as forward error correction (FEC), automatic retransmission request (ARQ) and error concealment (EC), have been proposed to solve this problem. Compared with FEC and ARQ, EC wins the favour since it doesn't need an extra bandwidth and can avoid transmission delays (Yao.Wang, 1998).

The EC scheme attempts to recover the lost MBs (LMBs) by utilizing information from spatially or temporally adjacent blocks, i.e., spatial error concealment (SEC) and temporal error concealment (TEC). For SEC which this paper focuses on, several related works have been published. The algorithms proposed in (Y.K.Wang, 2002), (Jae-Won Suh, 1997), (Yan Zhao, 2005), (Dimitris, 2006) and (Zhou Wang, 1998) interpolate pixel values in LMB by using pixels in its correctly reconstructed neighbouring MB (NMB). In (Y.K.Wang, 2002), the pixels in LMB are recovered by bilinear interpolation (BI) from its NMB, either vertically or horizontally. In (Jae-Won Suh, 1997), the pixels in LMB are recovered by directional interpolation (DI). In this method, in order to get the suitable direction for interpolation, some edge detection mask is applied in NMB before interpolation. Obviously, BI is suitable for smooth MB (SMB) concealment, while DI is suitable for some edge existed area, i.e., edged MB (EMB), see Figure 1. Under this fact, in (Yan Zhao, 2005) and (Dimitris, 2006), the authors used an adaptive method which combines BI and DI together. However, there exits another kind of content area in natural image, i.e. the high-detailed or textural content, which we called textural MB (TMB), see Figure 1. For TMB neither BI nor DI can achieve a satisfied recovery performance. In order to recover this kind of content area, in (Zhou Wang, 1998), a method called best neighbourhood matching (BNM) was proposed by making use of a special kind of *a priori* information, blockwise similarity within the textural area. This is because there is a characteristic existing in textural area that usually MBs seem very similar each other in textural area.

As a summary, we have 3 methods for 3 different MB types, i.e., BI for SMB, DI for EMB, and BNM for TMB. In section 2.5, more detailed description for each method will be shown.

Considering all the 3 contents, the authors in (Z Rongfu, 2004) proposed a content-adaptive SEC scheme, where BI, DI, and BNM are adaptively switched by edge features, which are the maximal edge strength ES_{max}, and number of strong edge directions N_d (see detail in section 2.4). Obviously, the edge feature extraction is deterministic, in other

Wang J., Wang L., Ikenaga T. and Goto S. (2008).
AN ADAPTIVE SPATIAL ERROR CONCEALMENT FOR H.264/AVC VIDEO STREAM.
In *Proceedings of the International Conference on Signal Processing and Multimedia Applications*, pages 23-28
DOI: 10.5220/0001937400230028

words, the decision for switching is deterministic. A significant problem in (Z Rongfu, 2004) is the threshold decision for ES_{max} and N_d, since the edge feature is modeled without considering any statistical factor. Therefore, this method can't achieve accurate MB type decision in all cases, which leads to an unsatisfied image quality.

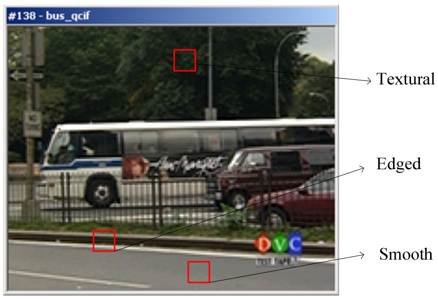


Figure 1: Three contents in a natural video frame.

In order to improve concealed image quality, we propose a statistical measure based adaptive SEC. In addition, the new features of latest video compression standard H.264/AVC (Thomas Wiegand, 2003), i.e., 16x16 and 8x8 intra prediction modes are also utilized for switching decision.

The rest of this paper is organized as follows. In the next section, the proposed EC algorithm is described in detail. Then the implementation of the proposal and its comparison results are presented in section 3. Finally the conclusions are drawn in section 4.

2 PROPOSED ALGORITHM

In this section, an adaptive SEC is proposed. The procedure of the proposed algorithm is illustrated in Fig 2. Firstly, some edge information extracted from the NMBs of a LMB is used to build a statistical model, which can classify LMBs into three types: SMB, EMB and TMB. Numerical measures obtained from this edge statistical model are selected as the criterion of classification. Afterwards, different error concealment methods are applied to each type of MB: BI is used for SMB, DI is used for EMB, and BNM is for TMB.

2.1 Three Types of MBs

Roughly the MBs of natural images could be characterized into three types:

- SMB: smooth MB, in which pixel values are basically constant or near so. In this MB, it is very hard to find some strong edges, and all the edge directions (although their edge strengths are weak) are spread widely
- EMB: edge existed MB, in which pixel values are significantly varied. In this MB, some dominant edges should be found while they are basically centralized within a small scope of directions
- TMB: textual MB in which pixel values are significantly varied basically in a periodical way. In this MB, some dominant edges also should be found but their directions are spread widely

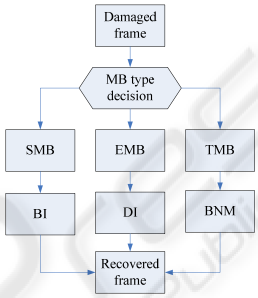


Figure 2: Whole procedure.

2.2 Edge Statistical Model based MB Type Decision

In this sub section, we will develop a statistical model to describe 3 kinds of MBs in section 2.1. The model is based on the edge information detected from boundary 3 layers of pixels, denoted with small squares in Fig. 3. All these pixels build an available boundary pixel set *M*.

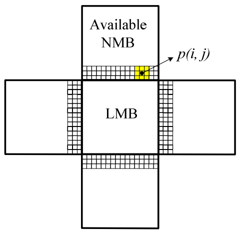


Figure 3: Edge detection.

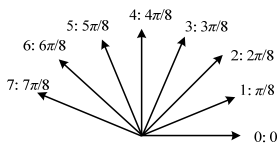


Figure 4: Eight directions.

For pixel $p(i,j)$ in M, its edge angle $\theta(i, j)$ and edge strength $ES(i, j)$ are calculated by Sobel operator, as shown in Eq. (1, 2, 3).

$$G_x(i,j) = p(i+1,j-1) - p(i-1,j-1) + 2p(i+1,j) - 2p(i-1,j) + p(i+1,j+1) - p(i-1,j+1) \quad (1)$$
$$G_y(i,j) = p(i-1,j-1) - p(i-1,j+1) + 2p(i,j-1) - 2p(i,j+1) + p(i+1,j-1) - p(i+1,j+1)$$

$$\theta(i,j) = \frac{\pi}{2} - \arctan\frac{G_y(i,j)}{G_x(i,j)} \quad (2)$$

$$ES(i,j) = \sqrt{G_x(i,j) + G_y(i,j)} \quad (3)$$

In practice, each $\theta(i, j)$ should be rounded to direction $d(i, j)$, which is one of 8 directions, see Fig. 4 and Eq.4.

$$d(i,j) = k = Round(\theta(i,j)/\frac{\pi}{8}), \quad (4)$$
$$k \in \{0,1,2,...,7\}$$

After all pixel calculations in M are finished, pixel set M is then divided into 8 sub pixel set (if all 8 directions are detected), i.e., N_0, N_1, N_k, …, N_7, while N_k corresponds to direction k. That is:

$$M = \{N_0, N_1, ...N_k, ...N_7\} \quad (5)$$

$$p(i,j) \in N_k \Leftrightarrow d(i,j) = k \quad (6)$$

Then the likelihood of each estimated direction k can be obtained as follows:

$$p(k) = \frac{\sum_{(i,j)\in N_k} ES(i,j)}{\sum_{(i,j)\in M} ES(i,j)} \quad (7)$$

Finally, the edge statistical distribution model is formulated. An example is shown Fig. 5. Note that, the distribution is discrete, only 8 directions are sampled.

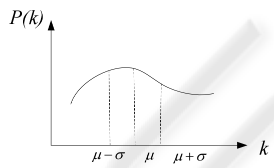


Figure 5: Edge statistical distribution.

Numerical measures shown below, mean and standard deviation, can be adopted to describe 3 different kinds of MBs. Note that, mean is finally round to k as the estimated direction for EMB.

Mean: $$\mu = \sum_{k=0}^{7} k * p(k) \quad (8)$$

Standard deviation: $$\sigma = \sqrt{\sum_{k=0}^{7} p * (k-\mu)^2} \quad (9)$$

According to σ value, LMB can be classified into 2 cases:

Case 1, $\sigma \leq 0.5$: This case means that the estimated edges are mostly centralized within a small region (μ-0.5, μ+0.5), whose size is 1. In other words, 1 predominant direction was found in this LMB. Therefore the LMB is regarded as EMB.

Case 2, $\sigma > 0.5$: This case means that the estimated edges are spread widely. From the description of 3 content MBs in section 2.1, both SMB and TMB belong to this case. Although we can define a threshold to decide whether the edge direction is spreaded widely or not, but it is very hard to find a fixed threshold for all videos. Therefore a different way for SMB/TMB type decision is need.

2.3 Intra Prediction Mode based MB Type Decision

In this sub section, the intra prediction modes in H.264/AVC (baseline/main/extended profile), i.e. 4x4 and 16x16 are utilized for SMB and TMB decision.

The latest standard H.264 introduced lots of new technologies which help to achieve very high compression efficiency. For intra prediction, the following prediction modes are supported which are 4x4 and 16x16 for luma component and chroma prediction for chroma component. For 4x4 mode, the entire MB is divided into 16 4x4 sub-blocks to perform the intra prediction respectively, 8 prediction directions are supported. For 16x16 mode, the entire MB is predicted in the same direction, either vertical or horizontal.

Generally speaking (Thomas Wiegand, 2003), 16x16 mode is more suited for coding very smooth area, i.e., SMB, while 4x4 is well suited for area with significant detail, i.e., TMB.

Due to high correlation of LMB and its NMB, the modes of NMB can be used for type decision of LMB, either SMB or TMB. If the number of 16x16 modes n_{16x16} of all available NMBs is more than the number of 4x4 modes n_{4x4} of all available NMBs, the destination LMB is regarded as SMB, otherwise is regarded as TMB.

2.4 The Final MB Type Decision

After considering the edge statistics and intra prediction mode, we can finally decide the type of a LMB belongs to. Fig. 6 shows the decision procedure.

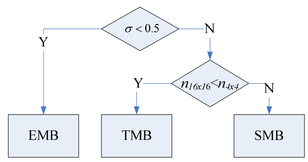


Figure 6: Proposed MB type decision.

For comparison, we give Fig. 8 to show the MB type decision in (Z Rongfu, 2004), which is deterministic based.

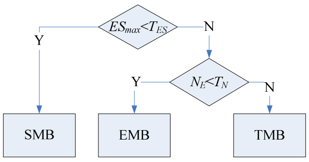


Figure 7: MB type decision in (Z Rongfu, 2004).

In Fig. 7, the ES_{max} shown in Eq. 10 is the maximal value among all 8 edge strengths, and N_E is the count of strong directions, whose ES values are more than $0.55*ES_{max}$. The threshold T_{ES} and T_N are found by trial and error, which are 3000 and 3 respectively, 2 fixed values for all cases. Since no statistics model based measurement is considered, it is very hard to achieve best image recovery in all cases.

$$ES_{\max} = \max\left(\sum_{(i,j)\in N_0} ES(i,j),\ldots,\sum_{(i,j)\in N_k} ES(i,j),\ldots,\sum_{(i,j)\in N_7} ES(i,j)\right) \quad (10)$$

2.5 EC for Different MB Types

This section will briefly describe 3 different methods for 3 different MBs respectively.

2.5.1 BI for SMB

Since pixels in SMB are basically constant or near so, each pixel in LMB can be concealed by bilinear interpolation using the nearest pixels from its 4 neighbourhood boundaries. As the Fig. 8 shows, the interpolated value of pixel Y is interpolated by Eq.11:

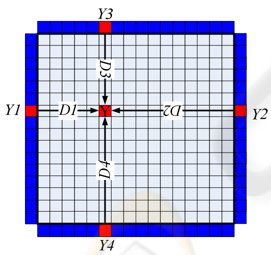


Figure 8: BI.

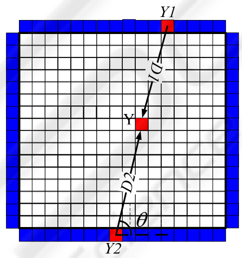


Figure 9: DI

$$Y = \frac{Y1*D2+Y2*D1+Y3*D4+Y4*D3}{D1+D2+D3+D4} \quad (11)$$

2.5.2 DI for EMB

In order to preserve edge consistency, the LMB classified as EMB is interpolated along the edge direction described in section 2.2. Therefore, if the edge of a certain direction k (corresponding to θ) is estimated via Eq. 8 as a strong edge, then a series of one-dimensional linear interpolation are carried out along direction k to recover pixel values within the LMB. This can be shown in Fig. 9 and Eq. 12.

$$Y = \frac{Y1*D2+Y2*D1}{D1+D2} \quad (12)$$

2.5.3 BNM for TMB

Under the characteristics that TMB has some spatial similarity compared with its NMB, a searching for best neighbourhood matching (BNM) is performed in this method. The best matching neighbour is the one that minimizes the matching cost (MC), which is a difference between the pixels of available part (1 layer of boundary pixels) in local window and the pixels of corresponding part in remote window, shown in Fig. 10.

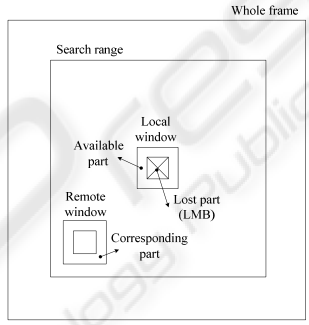


Figure 10: BNM.

The mean square error (MSE) is used for measurement of difference, which is shown in Eq.13.

$$MC = \frac{1}{N}\sum_{(i,j)\in available\_part} w(i,j)*[p(i,j)-p(i+s,j+t)]^2 \quad (13)$$

where,

$$w(i,j) = \begin{cases} 1, & if\ both\ p(i,j)\ and\ p(i+s,j+t)\ are\ available \\ 0, & otherwise \end{cases} \quad (14)$$

and N is the number of calculated available pixels. The region of s and t are both (-16x2, 16x2), which denote that the search range is (16x5x16x5) square area. After the best neighbourhood was found, the lost part in local window is concealed by copy from remote window.

3 EXPERIMENTS

The proposed error concealment algorithm is implemented based on the H.264/AVC reference software JM9.1. In order to evaluate our proposal, other 5 methods, BI in (Y.K.Wang, 2002), DI in (Jae-Won Suh, 1997), BNM in (Zhou Wang, 1998), BI+DI in (Dimitris, 2006) and BI+DI+BNM in (Z Rongfu, 2004) are also implemented. All 6 methods are tested by 6 CIF sequences “foreman”, “bus”, “flower, “waterfall”, “tempete”, and “stefan”. All tests are using the same simulation setup. For each sequence, all frames are encoded with intra encoding under H.264 baseline profile, and QP=28. For the MB loss, we use FMO (flexible macroblock ordering) tool with 2 slices per frame in encoding (Stephan Wenger, 2003), while 1 slice is lost for channel simulation. In Fig. 14(b), green MBs compose a lost slice while all 4 NMBs are available for each LMB. To evaluate image recovery, both subjective and objective image qualities are observed.

Fig. 11 shows the comparison of objective image quality measurement, luminance PSNR for concealed frames using different methods. A larger PSNR value leads to a better image recovery. By observing Fig. 13, some conclusions can be obtained:

I. For different sequence, within DI, BI, and BNM, different method wins the best recovery, e.g., DI wins for foreman, BI wins for bus, while BNM wins for flower. In other words, in order to find a best image recovery, an adaptive scheme is necessary.
II. For adaptive method in (Dimitris, 2006), compared with BI and DI, it dos not always win the best recovery, such as bus, although the difference with the winner is very small. Same case was found in (Z Rongfu, 2004). Compared with BI, DI, and BNM, method in (Z Rongfu, 2004) does not always win the best, such as foreman. However, for proposed one, it always wins the best recovery.

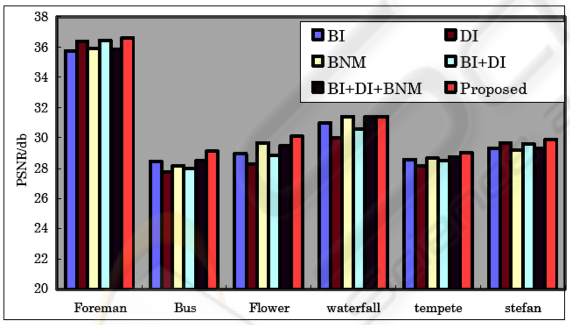


Figure 11: Objective image recovery comparison.

Fig. 12 shows the subjective image quality comparison for flower sequence. Proposed method achieves the best image recovery. It is easy to see that, the optimal MB type for the flowers area should be texture. However in algorithm of (Z Rongfu, 2004) whose result is shown in Fig. 12(g), some LMBs in flower area are regarded as SMB and recovered by BI, which is a false MB type decision. In contrast, our proposal avoided such false decision wel.

4 CONCLUSIONS

Considering there are 3 types of MBs in natural video frame, i.e., TMB, EMB, and SMB, this paper proposed an adaptive spatial error concealment, which can choose 3 different methods for these 3 different MBs. For criterion of choosing, both edge statistics measurement and intra prediction mode for H.264 are taken into consideration. In terms of subjective and objective image quality evaluation, experiments show that the proposed method achieves the best image recovery compared with previous work.

ACKNOWLEDGEMENTS

This work was supported by CREST, JST and Global-COE program of Japan.

REFERENCES

Jao-Won Suh, et al., 2002: Error concealment techniques for digital TV. IEEE Trans. Broadcasting, Vol. 48

Yao.Wang, et al., 1998: Error control and concealment for video communication: a review. Proceedings of IEEE, pp947~997

Y.K.Wang, et al, 2002: The error concealment feature in the H.26L test model. Proc. ICIP, vol.2, pp729~732

Jae-Won Suh, et al., 1997: Error concealment based on directional interpolation. IEEE Trans. on consumer electronics

Yan Zhao, et al, 2005: Spatial error concealment based on directional decision and intra prediction. ISCAS

Dimitris, et al.: Enhanced error concealment with mode selection. IEEE Trans. on circuits & sys for video tech (2006)

Zhou Wang, et al., 1998: Best Neighborhood Matching: An information loss based image coding systems. IEEE Trans. on image processing

Z Rongfu, et al. 2004: Content-adaptive spatial error concealment for video communication. IEEE Trans. on consumer electronics, vol. 50, No.1

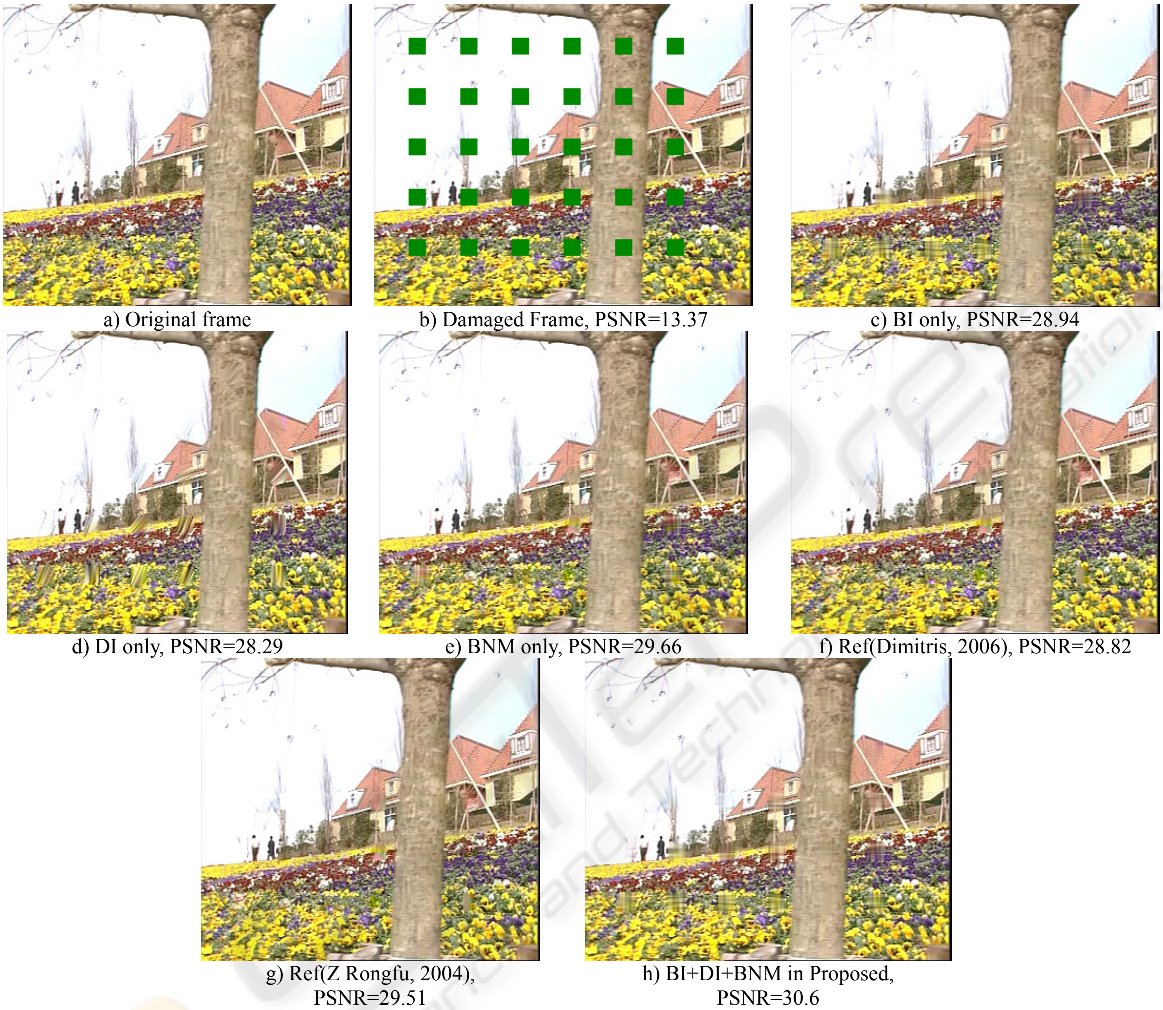
Thomas Wiegand, et al., 2003: Overview of the H.264/AVC video coding standard. IEEE Trans. on circuits and system for video technology

Stephan Wenger, 2003: H.264/AVC over IP. IEEE Trans. on circuits and system for video technology

APPENDIX

In order to show the fact that 16x16 mode is more suited for coding very smooth area, i.e., SMB, while 4x4 is well suited for area with significant detail, i.e., TMB, we did experiments to observe this.

In our experiments, 2 CIF sequences, flower and foreman, are observed. Fig 13 shows the result of flower and foreman.
As the observation in Fig. 13 shows, MBs which have lower ES_{max}, usually are the MBs whose n_{16x16} is more than n_{4x4}. In the other hand, SMB always has lower ES_{max}, while TMB has higher of that. Therefore, the observation successfully can match the fact that generally 16x16 mode is suited for SMB while 4x4 mode is suited for TMB.



a) Original frame
b) Damaged Frame, PSNR=13.37
c) BI only, PSNR=28.94
d) DI only, PSNR=28.29
e) BNM only, PSNR=29.66
f) Ref(Dimitris, 2006), PSNR=28.82
g) Ref(Z Rongfu, 2004), PSNR=29.51
h) BI+DI+BNM in Proposed, PSNR=30.6

Figure 12: Subjective image recovery comparison.

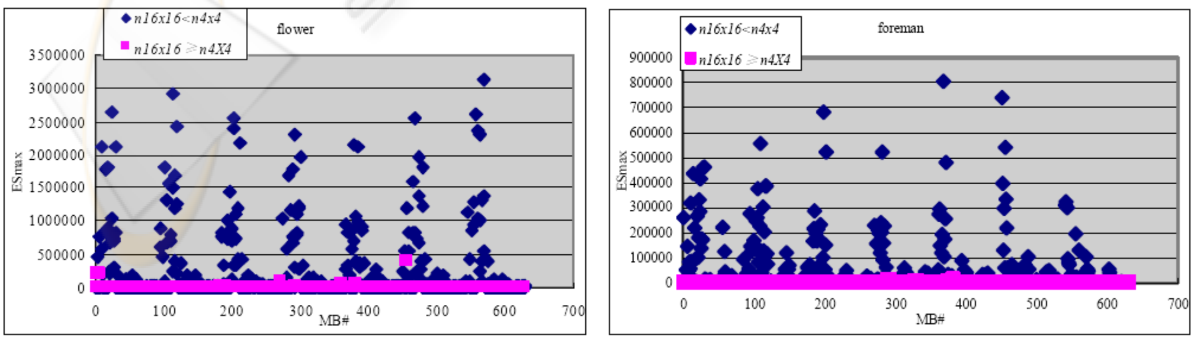


Figure 13: Intra mode observation.