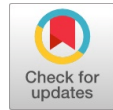


Modified Boundary Matching algorithm for Error detection and Error Concealment for Video Communication



Ketki C. Pathak, Jignesh N. Sarvaiya, Anand D. Darji

Abstract: As the demand of video transmission over communication network has grown rapidly, the data compression and error correction in video processing have shown significant improvement day by day. When the error occurs in a single frame, the visual quality of the subsequent frames gets degraded due to error propagation. Thus, the error control techniques are required for the recovery. Concealment of error at the receiver (decoder) side feats the spatial and temporal characteristics of the frame. Without the requirement of the extra bandwidth and retransmission delay, it enhances the quality of the reconstructed video. However, the output of the error concealment may get affected if the error located before is misleading. Thus error detection also plays an important role while reconstructing the video. However, the output of the error concealment may get affected if the error located before is misleading. This paper proposes error detection and concealment approach for the recovery of lost Macro Block (MB) in video. The spatio-temporal techniques has been used for the error detection followed by the MB type decision applied for classifying the damaged macro block .For the concealment method a new method i.e. Modified Spatio-Temporal Boundary Matching Algorithm (MSTBMA) has been proposed. The proposed work is compared with various existing method for spatial and temporal error concealment. The comparison has been done for various types of error such as block error (single, multiple), burst error and random error generated by the software. Performance is improves in terms of PSNR and visual quality by considering the type of lost MB.

Index Terms: Macro block, Error Detection, Spatio-temporal error, Temporal Error detection, Error concealment, Modified Boundary Matching algorithm

I. INTRODUCTION

The information transmitted can be affected or lost due to channel noise which proves to be the inherent problem of the communication system. The loss to the compressed bit stream may result into overall distortion in the video. Due to the bandwidth limitation data is compressed, thus loss of a bit may result into the loss of a whole frame. Considering the

real-time application, retransmission has never been a solution due to the delay factor. Error resilience works on the encoder side, but after the transmission frames can get erroneous. To combat the above problem, error concealment is used for the recovery of damaged area at the decoder. The spatial and temporal characteristics of the neighborhood and previous /future frames are exploited for the concealment of errors. In order to provide the good visual quality to the end user, robust and effective error concealment technique should be applied. Due to bandwidth and Power limitation in real time scenario, computational complexity should be taken in consideration. Presently there are no defined standards for the comparison of complexity in different error concealment algorithms. The purpose of applying error detection algorithm before error concealment is that , if we received any information without any correction, then based on error detection algorithm, we can able to identify the nature of corrupted or lost macroblock . This way we can reconstruct the lost or erroneous block correctly without retransmission and extra bandwidth requirement. Error detection is the means where errors can be detected based upon received information without correction. In 2007, Guan-Lin Wu and Shao-Yi Chienhad analyzed various spatio-temporal error detection algorithm to transmit the video frames over erroneous channel [11]. According to the characteristic of spatio-temporal behavior, they have detected various corrupted macro-block or errors within frame. For spatial characteristic, the parameter called Average Inter pixel Difference Boundary (AIDB)is calculated and for temporal characteristic, Average Difference Across the Frame (ADF) (Average Difference across the Frames) is calculated. To detect spatial type of error or temporal type of error equations (1), (2) and (3) were implemented. This method ruled out the possibility of complexity in the calculations as it was simple in implementation with both spatial and temporal error detections applied on a frame giving better results.

$$A(C:L) = \begin{cases} 0 & \text{if LeftMacroblock does not exist} \\ \frac{1}{M} \sum_{i=0}^{M-1} |P_i^{in} - P_i^{out}| & \end{cases} \quad (1)$$

$$AIDB = \frac{1}{K_2} (AIDB(C:L) + AIDB(C:R) + AIDB(C:T) + AIDB(C:B)) \quad (2)$$

$$ADF = \frac{1}{M \times M} \sum_{i=0}^{M-1} \sum_{j=0}^{M-1} |x(i,j) - \hat{x}(i,j)| \quad (3)$$

Manuscript published on 30 August 2019.

*Correspondence Author(s)

Ketki C. Pathak, Electronics & Communication Engineering Department ,Sarvajani College of Engineering & Technology, Gujarat Technological University, Surat, India.

Jignesh N Sarvaiya, Electronics Engineering Department, Sardar Vallabhbhai National Institute of Technology(S.V.N.I.T.) , Surat, India.

Anand D. Darji, Electronics Engineering Department, Sardar Vallabhbhai National Institute of Technology(S.V.N.I.T.) , Surat, India.

© The Authors. Published by Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP). This is an [open access](https://creativecommons.org/licenses/by-nc-nd/4.0/) article under the CC-BY-NC-ND license <http://creativecommons.org/licenses/by-nc-nd/4.0/>.

Modified Boundary Matching algorithm for Error detection and Error Concealment for Video Communication

Yan Chen,[21] derived a cost function based on smoothness property of video macroblock. He has suggested two stage error concealment procedure. He has designed two stage algorithm. The cost function is minimized in first stage so that Motion Vector (MV) of each lost Macro Block (MB) in the reference frame is retrieved again. Copy paste algorithm is applied on lost MB in second stage of algorithm. In Partial Differential Equation (PDE) based algorithm, weighting factor is used to remove blocking artifacts of reconstructed frame. This algorithm achieves higher degree of removal of blocking artifacts while preserving lost macroblock. Youjun Xiang et.al suggested an efficient spatiotemporal boundary matching algorithm (ESTBMA) by introducing the concept of smoothness measurement. They suggested medical motion vector which improves the subjective visual quality of concealed video.

After reviewing various literatures, we have analyzed that the various algorithm suggested the smoothness property of Macroblock in video frames as a spatial and temporal prime characteristic. None of the authors consider the texture or edge based property of lost MB. So, in our proposed modified Spatio-Temporal Boundary matching algorithm, we first analyzed the lost MB type like whether it is texture, edge or smooth, based on that decision we have applied of proposed BMA algorithm. So our proposed algorithm divides in three major tasks, a). Error detection b). Type of lost MB decision and c). BMA based novel algorithm to conceal lost MB.

Rest of the paper arranged in this manner. Section II describes conventional BMA algorithm and its classification. Section III describes proposed modified spatio-temporal boundary matching algorithm (MSTBMA). Section IV gives results analysis and final section summarizes the proposed work flow and future improvement.

II. BOUNDARY MATCHING ALGORITHM (BMA)

For any kind for visual improvement, there is a tradeoff criteria between computational complexity of algorithm and vision enhancement of reconstructed video sequences. The boundary matching algorithm provides better performance for low complexity error concealment to recover lost MB. BMA is considered as a not adhering to a standard H.264 for temporal error concealment [13]. However, in the case of continuous loss of slices, the frames are not concealed properly leading to poor visual quality. There are many algorithms are designed to minimize side match distortion factor between inner and outer boundaries of video frames.

The minimization of boundary Side Match Distortion (D_{sm}) between inner and outer boundaries of Macro block can be applied so that lost or erroneous Motion vector can be recovered using standard BMA algorithm. D_{sm} is the measure of Sum of Absolute Difference (SAD) between the inner boundaries of the candidate block of interest in the reference frame and the outer boundaries of the lost block in current frame. Internal boundaries are the boundary of the lost MB and external boundaries are the pixels of spatially neighboring MBs. For spatio temporal BMA side match distortion is summation of Spatial Distortion and Temporal Distortion.

$$D_{sm} = a * D_{sm}^{temporal} + b * D_{sm}^{spatial} \quad (4)$$

Where, a and b are the coefficients. The values are between 0 and 1.

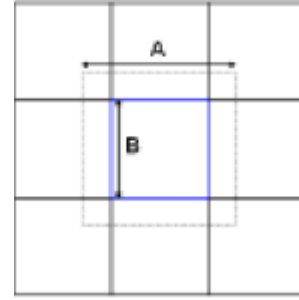


Fig. 1. Frame F_n with the missing area B and its boundary pixel area A [12]

In Fig.1, B is boundary of missing block in nth frame and it is one pixel wide. According to the availability of boundary pixel, we can able to find Motion vectors in missing block. The coordinates $|\hat{x}, \hat{y}|$ are found in the reference frame as the best matching criteria to B region within the searching area A:

$$|\hat{x}, \hat{y}| = \arg \min_{x,y \in A} \sum |x(i,j) - \hat{x}(MV_x + i, MV_y + j)| \quad (5)$$

The Mean Absolute Differences (MAD) is the measuring parameter which is used to find similarity. Motion requirement sets the parameter A for the search of best match MB. In this research work search area of 20 x 20 pixel area is used.

A. Classification of BMA

Conventional BMA aimed to recover the edges of lost blocks, which are applied to erroneous MB in a sequence starting from top left. Thus in the case of VLC encoded data, when the sequence is affected by bit errors, the error gets propagated to the subsequent video frame till the next resynchronization code word is received. In slice layer, it may cause a problem of dependent recovery issue because recovery of one MB is accomplished based on the previously recovered MB or the correctly received MB. thus failure in the recovery of one MB does harm the succeeding blocks, which is termed as a dependent recovery problem in slice layer [1]. The BMA algorithms are broadly classified into its derived algorithms as under as shown in Fig. 2. Among prescribed BMA algorithm, STBMA i.e Spatio-temporal Boundary Matching Algorithm is the best algorithm as it analyzed the smoothness property of MB. It can select appropriate MV among available candidate MV. Though it is computationally complex but is advantageous in many applications like real-time applications-medical services, video surveillance etc.

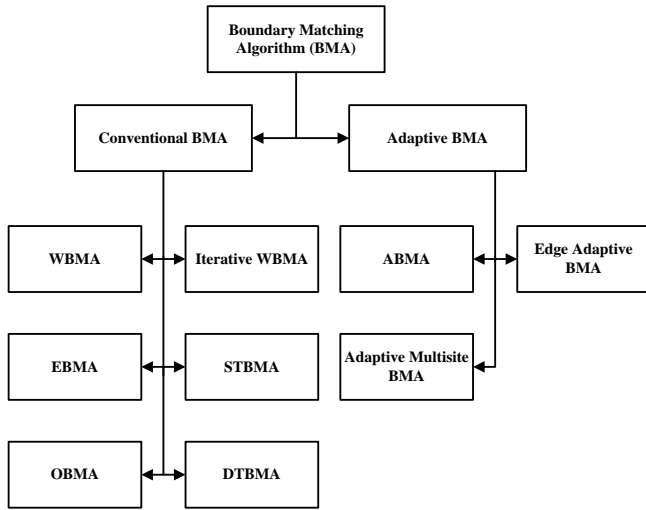


Fig. 2. Classification of BMA algorithm [2]-[9]

B. Adaptive temporal error concealment

As explained in section 1, the edge statistical model is used to decide the class of MB (i.e. smooth or edge) [10]. In research work [10], adaptive spatial error concealment is used with the MB type Decision for the recovery of damaged MB. But in the case where neighborhood of the damaged MB is lost in the same frame, the spatial concealment doesn't prove to be efficient then. Therefore information from the reference frame is vital for concealment.

With the help of spatio temporal error detection approach which are then categorized into different classes of MB (i.e. edge or smooth) by edge statistical model. If the damaged MB is smooth then it is concealed with simple copy paste algorithm and if it is edge, then STBMA is used for concealment. The following Fig.3 shows the error detection algorithm according to the nature of MBs type.

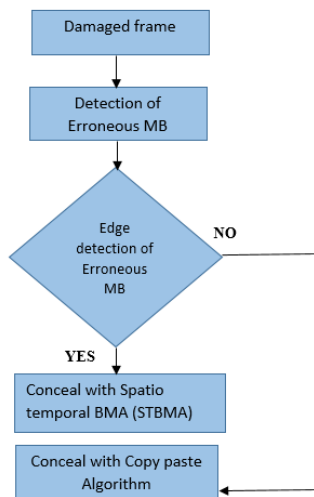


Fig. 3. Flowchart for the decision of Macroblock type and suitability of BMA algorithm

In our adaptive approach, the errors are detected with the Compares the adaptive method for different spatial and temporal error concealment methods with graphical representation in Fig.4. Five test sequences were used for the comparison which is given in terms of SSIM and PSNR

Modified Boundary Matching algorithm for Error detection and Error Concealment for Video Communication

Table 1.PSNR(dB) and SSIM Comparison for different algorithms on different sequences

Video Sequence	BI		DI		BI+DI		Copy Paste		STBMA		Modified STBMA (proposed)	
	PSNR	SSIM	PSNR	SSIM	PSNR	SSIM	PSNR	SSIM	PSNR	SSIM	PSNR	SSIM
Foreman	33.27	0.978	34.17	0.981	34.82	0.981	34.90	0.985	35.00	0.989	36.02	0.99
Akiyo	28.43	0.95	25.96	0.929	26.09	0.933	42.69	0.952	44.28	0.97	49.80	0.99
Baboon	23.15	0.95	23.52	0.96	24.15	0.965	24.52	0.975	25.17	0.98	26.17	0.99
Bunny	25.47	0.94	26.45	0.951	27.01	0.96	28.73	0.972	28.95	0.981	30.63	0.98
Salesman	26.28	0.879	25.47	0.870	25.58	0.875	28.58	0.91	29.52	0.92	29.86	0.93

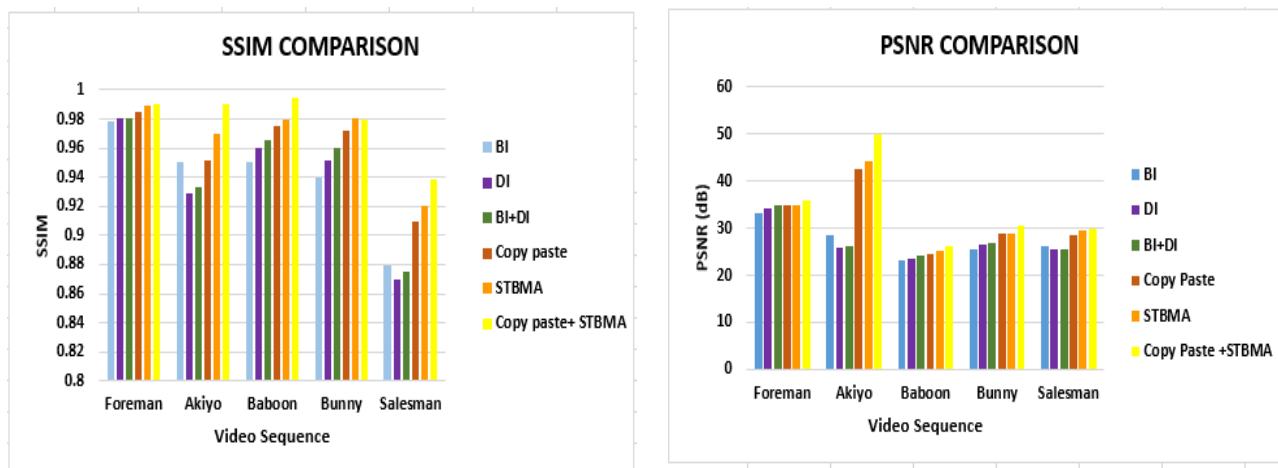


Fig. 4. Comparison of PSNR and SSIM for different methods

III. ROPOSED METHOD MODIFIED SPATIO-TEMPORAL BOUNDARY MATCHING ALGORITHM(MSTBMA)

The proposed method is the modification in Spatio-Temporal Boundary Matching Algorithm (MSTBMA) in which two factors are considered for minimization of side distortion match. The proposed method include the third factor which undertakes the concealment of boundary when neighborhood of lost MacroBlock(MB) are also lost, which is not considered in previous algorithm of Boundary matching algorithms for error concealment purpose.

The Fig.4 shows the block diagram used for the implementation of the system. It shows the decoder side where the error is detected and concealed. The spatio-temporal error detection method is carried out for the determination of the error.

The factors like Average Inter-pixel Difference across Boundary (AIDB) and Average Difference across Frame (ADF) detects the presence of error in MB. The MB type decision for the damaged MB is done by the edge statistical model. For concealment the proposed method i.e. modified STBMA is used for concealment of the lost MB.

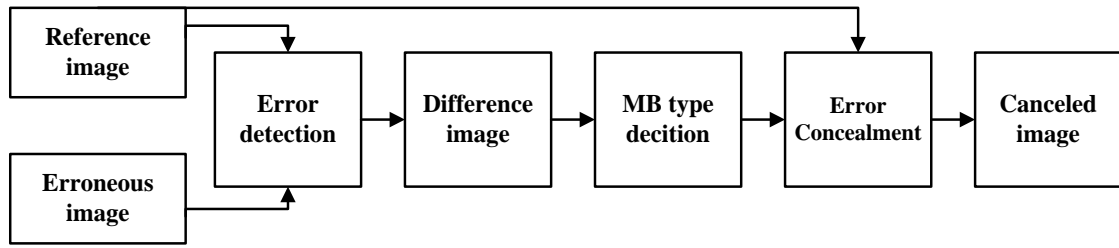


Fig. 5. Block Diagram for Implementation

The erroneous image received at the decoder is first compared with the reference image for the determination of error.

1. The spatio temporal error detection method is carried out for the determination of the error. The factors like Average Interpixel Difference across Boundary (AIDB) and Average Difference across Frame (ADF) detects the presence of error in MB.
2. The difference image received is the image highlighting the error in the frame.
3. The MB type decision for the damaged MB is done by the edge statistical model. The mean and the variance is determined and compared with the threshold value. If the variance value is greater than threshold then the block is considered to be smooth else it is edged.
4. After the type of the MB decided, the error concealment is implemented on the damaged area. In the adaptive approach presented in thesis, the copy paste algorithm is used to conceal the smooth MB and STBMA is used for the edged MB. The combination of both algorithm yields the better results than other.
5. Moreover, the thesis propose the modified STBMA algorithm for the concealment of the frame which include the third factor in order to minimize the side distortion factor.
6. Thus, the concealed image is received at the end.

A. Technical Description of Proposed MSTBMA

In STBMA D1 and D2 factors are used for minimizes the side match distortion which is defined as under:

$$\begin{aligned}
 & [w_w \sum_{m=0}^{M-1} |x(i+m, j-1, n) - \hat{x}(i+MV_x+m, j+MV_y, n-1)| \\
 & + w_E \sum_{m=0}^{M-1} |x(i+m, j+M, n) - \hat{x}(i+MV_x+m, j+MV_y+M-1, n-1)| \\
 & + w_N \sum_{m=0}^{M-1} |x(i-1, j+m, n) - \hat{x}(i+MV_x+M-1, j+MV_y+m, n-1)| \\
 & + w_S \sum_{m=0}^{M-1} |x(i+M, j+m, n) - \hat{x}(i+MV_x+M-1, j+MV_y+m, n-1)|] \quad (6)
 \end{aligned}$$

In above equation $x(i, j, n)$ indicates the pixel present in current frame and $\hat{x}(i, j, n-1)$ is the pixel which corresponds to reference frame. For any boundary matching algorithm we are considering four main directions of Macro block MB (i,j). w_N, w_S, w_W, w_E are the weighting coefficient corresponding to Four direction like North, South, West and East respectively. Here M indicated the size of Current Macro block. The location of candidate Motion vector of the current lost block is denoted as (MVx, MVy). Conventional BMA algorithm is most suitable to recover the lost MV by

exploiting smoothing property of adjacent pixels. But it increases complexity for abrupt change in edges and textures based Motion vector which are present at the border or if there is an abrupt scene change. This increases side distortion. Which is demonstrated in Fig.6. SR indicated search region and LMB indicates Lost Macro Block. D1 measure is used to find strong structure similarity of adjacent block of lost block and reference block

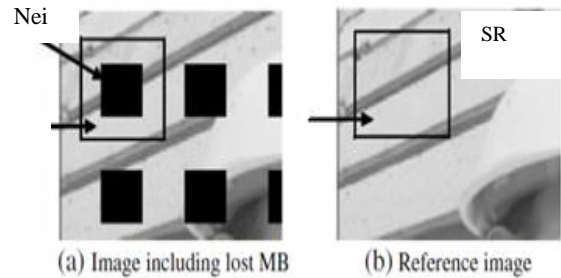


Fig. 6. Structural similarity^[15]

D^2 , which uses to find the average difference between the external boundaries of the candidate reference block in the reference frame and those of the lost block in current frame.

$$\begin{aligned}
 D^2(MV_x, MV_y) &= \frac{1}{(w_N + w_S + w_E + w_W)M} * \\
 & [w_w \sum_{m=0}^{M-1} |x(i+m, j-1, n) - \hat{x}(i+MV_x+m, j+MV_y-1, n-1)| \\
 & + w_E \sum_{m=0}^{M-1} |x(i+m, j+M, n) - \hat{x}(i+MV_x+m, j+MV_y+M, n-1)| \\
 & + w_N \sum_{m=0}^{M-1} |x(i-1, j+m, n) - \hat{x}(i+MV_x+M-1, j+MV_y+m, n-1)| \\
 & + w_S \sum_{m=0}^{M-1} |x(i+M, j+m, n) - \hat{x}(i+MV_x+M, j+MV_y+m, n-1)|] \quad (7)
 \end{aligned}$$

The third factor is considered for the case when neighboring MBs are also erroneous. Thus considering the smoothness at the boundaries, the MSE of the boundary of the candidate MB in the reference MB and the boundary of the neighboring MB of candidate MB in reference MB is considered as it will help to provide the smoothness at the boundary of the concealed image and will improve the overall PSNR and SSIM of the image. The conceptual representation of MVs for the proposed work is shown in Fig.7.



Modified Boundary Matching algorithm for Error detection and Error Concealment for Video Communication

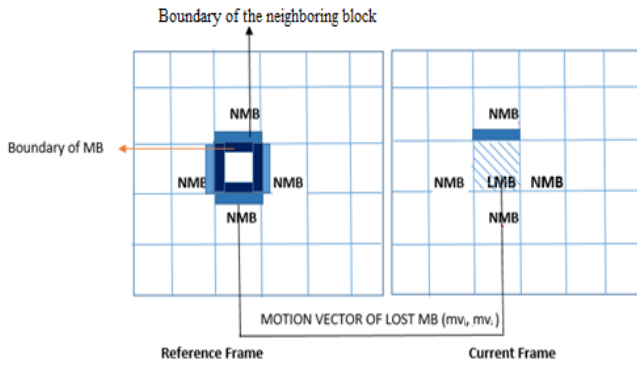


Fig. 7. Smoothness measurement at the boundary

Thus, the proposed factor for the minimization of overall distortion is given as:

MSE = (Boundary of candidate MB in reference frame) - (boundary of neighboring MB of candidate MB in reference frame)

$$D^3(MV_x, MV_y) = \frac{1}{(w_N + w_S + w_E + w_W)M} * [w_W \sum_{m=0}^{M-1} |\hat{x}(i + MV_x + m, j + MV_y - 1, n - 1) - \hat{x}(i + MV_x, j + MV_y, n - 1)| + w_E \sum_{m=0}^{M-1} |\hat{x}(i + MV_x + m, j + MV_y + M - 1, n - 1) - \hat{x}(i + MV_x + m, j + MV_y + M, n - 1)| + w_N \sum_{m=0}^{M-1} |\hat{x}(i + MV_x + M - 1, j + MV_y + m, n - 1) - \hat{x}(i + MV_x + M - 1, j + MV_y + m, n - 1)| + w_S \sum_{m=0}^{M-1} |\hat{x}(i + MV_x + M - 1, j + MV_y + m, n - 1) - \hat{x}(i + MV_x + M, j + MV_y + m, n - 1)|] \quad (8)$$

In this algorithm we consider Match distortion as a const function D_{ST} which utilize spatio-temporal smoothness characteristic, structural similarity factor of nearby frames as well as smoothing properties of left boundary and right boundary.

D_{ST} is average value of spatial boundary-match distortion D^1 , temporal boundary-match distortion D^2 and side smoothness distortion D^3 . Overall distortion is given as D_{ST} :

The winning Motion Vector (MV) is the candidate MV which minimizes D_{ST} where a, b, c are weighting coefficients, where, $a+b+c=1$. The estimated MV is used to find out the corresponding MBs in the reference frame, and the MBs are used to substitute the missing MBs. For the analysis of the proposed work, Block errors- Single block error, multiple block error, Burst errors – Checkerboard error, Random error are considered. The JM Software is used for the generation of random error. The MB size considered for the concealment is $16*16$.

IV. EXPERIMENTAL SETUP AND SIMULATION RESULTS

There are various temporal methods for error concealment which recovers lost MVs for the damaged MB like copy paste, Block Matching Algorithm, Boundary Matching Algorithm and its variations such as STBMA. According to the analysis, the STBMA proved to be best for the recovery of edge type MBs. The STBMA exploits both spatial and temporal characteristic and find the minimum distortion factor. The performance is evaluated on the basis of PSNR and visual quality. The modified STBMA considers all the 4 neighborhood of the candidate MB. Moreover, it doesn't calculate the MV for the neighborhood (of candidate MB)

In this paper, there is an assumption for gradual change in the scene, thus considering the neighborhood of candidate MB as the best fit for estimation of the third factor. The result

comparison has been done for five QCIF sequences i.e. foreman, akiyo, salesman, city and bunny. The two cases are considered namely the concealment for the burst error and the concealment for the random error (considering the real case scenario).

A. Specification for Implementation

The Table.2 gives the detail of all the specifications and the parameters used in the research work.

Table 2. Parameters and their specifications

Sr.No	Parameters	Specifications
1	Type of error	Block errors - Single block error, multiple block error Burst errors – Checkerboard error, Random error. The JM Software used for the generation of random error.
2.	Methods Used	Error Detection – Spatio-temporal error detection method Mb type decision – Edge statistical Model Error Concealment – Adaptive methods combining copy paste and STBMA and Modified STBMA as the proposed method.
3.	Macroblock size	16*16
4.	GOP	The GOP of 10 frames considered GOP ₁ : frame 1 to 10 GOP ₆ : Frame 50 to 60 GOP ₁₀ : Frame 100 to 110
5.	Formulae Used	$ADF = \frac{1}{M * M} \sum_{i=0}^{M-1} \sum_{j=0}^{M-1} x(i,j) - \hat{x}(i,j) $ $Mean : \mu = \sum_{k=0}^7 k * p(k)$ $Standard\ Deviation : \sigma = \sqrt{\sum_{k=0}^7 p * (k - \mu)^2}$ <p>Side distortion factor:</p> $D^{ST}(MV_x, MV_y) = a * D_1(MV_x, MV_y) + b * D_2(MV_x, MV_y) + c * D_3(MV_x, MV_y)$ $D^{ST}(MV_x, MV_y) = a * D_1(MV_x, MV_y) + b * D_2(MV_x, MV_y) + c * D_3(MV_x, MV_y)$ <p>a+b+c=1, a=0.2, b=0.7, c=0.1</p>
6.	Threshold value	Threshold value=2.2 $\sigma < 2.2$, the MB is smooth else it is edged
7.	Weighting coefficient (m)	10
8.	Search Limit	20

Table 3. Comparison between Proposed Work and BMA for GOP₁₀

Frame	BMA		Proposed Method	
	PSNR(dB)	SSIM	PSNR(dB)	SSIM
Frame 101	26.1016	0.9447	27.035	0.9607
Frame 102	29.1382	0.9587	33.2488	0.9802
Frame 103	27.4349	0.9529	29.5272	0.9716

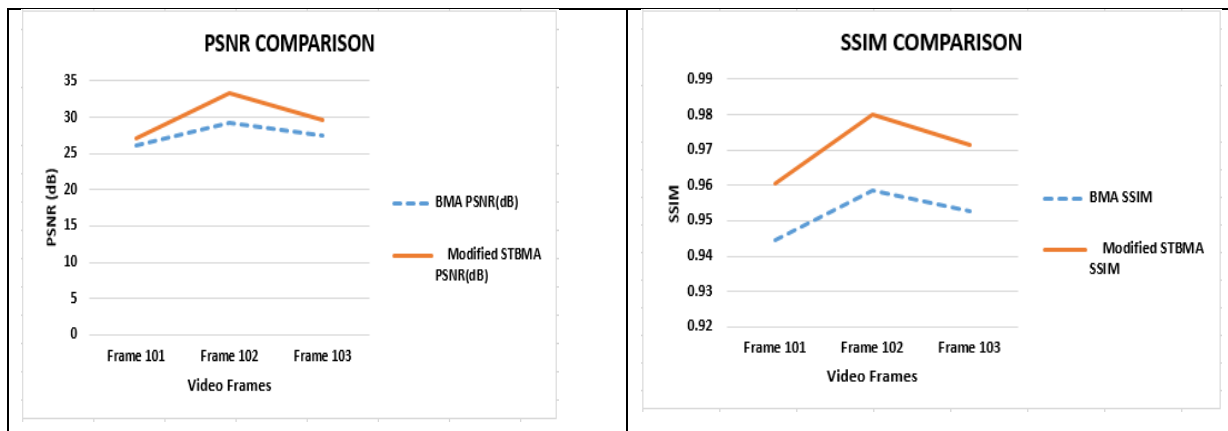


Fig. 8. Graphical analysis of PSNR and SSIM comparison between BMA and STBMA for GOP₁₀

Modified Boundary Matching algorithm for Error detection and Error Concealment for Video Communication



Fig. 9. Graphical analysis of PSNR and SSIM comparison between BMA and STBMA for GOP₁₀

Table 3 shows the comparison between BMA and Proposed Method for random error considering the GOP of 10 frames. Assuming 100th frame to be received correctly, the concealment of 101th, 102nd and 103rd frame is done. The previous frame is considered as the reference frame. Fig.8 gives the graphical representation with visual quality comparison for video sequence using conventional BMA and our proposed algorithm. Fig. 9 represents visual content using our proposed algorithm in comparison with conventional in Fig.8. The Table 4 analyzes the comparison between the proposed algorithm with the classic temporal error concealment methods such as copy paste, Block matching algorithm, BMA and STBMA (proposed in [2]). The approaches are tested on 5 QCIF sequences namely foreman, akiyo, city, salesman and bunny. PSNR is used as a performance parameter for the analysis shown in Fig.9.

Table 4.PSNR (dB)comparison of proposed method with different temporal error Concealment methods

Video Sequence	Copy Paste	Block Matching	Boundary[2] Matching	STBMA[2]	Proposed Modified STBMA
	PSNR	PSNR	PSNR	PSNR	PSNR
Bunny	34.6801	33.781	35.4064	36.281	36.989
Foreman	26.7702	27.2521	28.0785	30.041	31.242
Akiyo	45.4721	45.4722	46.8498	48.283	49.102
City	21.2645	20.5094	21.2900	23.761	24.267
Salesman	31.8138	31.9708	33.3065	34.636	35.240

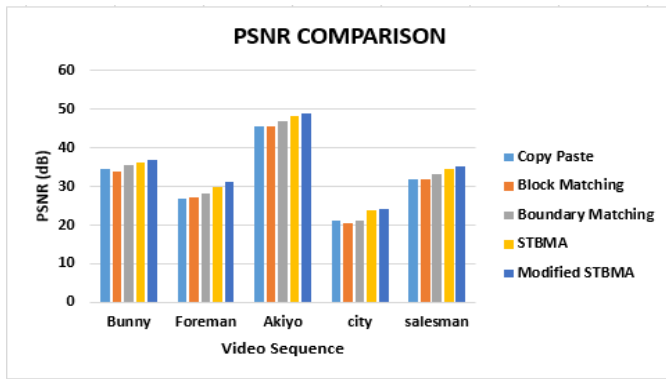


Fig. 10. Graph for the comparison of temporal EC methods

V.CONCLUSION

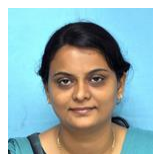
In this research work, one of the error concealment method i.e. modified STBMA has been proposed. This method is a temporal error concealment technique which has its root in the Boundary Matching Algorithm (BMA). The proposed work showed the increment of 0.5 dB to 1 dB improvement in PSNR and approximately 0.05 in SSIM than the conventional method. The proposed method proves to be better than the conventional BMA. But it was observed in the case of random error concealment that some parts (specially the sharp edges) were not concealed. The factor added, helps to estimate the lost MV at the boundary which are difficult to recover. Various algorithm of error concealment have been tested for different video sequences. The video sequences with gradual motion were considered which were easier to conceal than abrupt change in scene as most of the motion vectors were correlated and minimal energy loss was observed. The sequences that proved harder to conceal were the ones where the area with sharp edges. Previously an adaptive approach for spatial error concealment was suggested which has been implemented with the temporal error concealment in this research work. The results shows that adaptive approach with copy paste algorithm for smooth MB and STBMA algorithm for STBMA gives better result than the existing adaptive spatial error concealment method over images/video sequences. In future, the hybrid error concealment technique can be applied on the real time video for error detection and concealment automatically. The future work includes the development of the application for medical image processing based of Region of Interest for Telemedicine based system which provides high end reliability at the source and receiver side for correct diagnostic purpose.

REFERENCES

- Jung, Y. H., Kim, Y. G., &Choe, Y : “Robust error concealment algorithm using iterative weighted boundary matching criterion”, IEEE, Vol. 3, pp. 384-387, (2000).
- Kim, Eung Tae, Seung-Jong Choi, and Hyung-MyungKim : “Weighted boundary matching algorithm for error concealment in the MPEG-2 video bit stream. Signal processing”, vol.: 3, pp: 291-295, (1999).
- Lam, Wai-Man, Amy R., and Bede Liu : “Recovery of lost or erroneously received motion vectors. IEEE”, Vol. 5, pp: 417-420, (1993).
- Thaipanich, T., Wu, P.H. and Kuo, C.J. : “Low-complexity video error concealment for mobile applications using OBMA”. IEEE Transactions on Consumer Electronics, vol.:54(2), pp: 753-761, (2008).
- Thaipanich, Tanaphol, Ping-Hao Wu, and CC Jay Kuo. : “Video error concealment with outer and inner boundary matching algorithm”.optical

- engineering application International society for optics and Photonics(2017) Chen, Yan, Oscar Au, Chiwang Ho, and Jiantao Zhou. : “Spatio-temporal boundary matching algorithm for temporal error concealment”, IEEE International Symposium, pp:4, (2006).
- Deng, X., Liu, Y., Hong, C., Bu, J., & Chen, C. : “A temporal error concealment algorithm for H. 264/AVC based on edge directions”, IEEE International Conference, pp: 941-944, (2009).
- Su, C.Y. and Huang, C.H.August, : “Temporal error concealment algorithm using multi-side boundary matching principle”, IEEE International Symposium, pp: 448-453, (2006).
- M. Zadeh, S.M., H. G. Yakhdan, and S. Kasaei. : “An Efficient Adaptive Boundary Matching Algorithm for Video Error Concealment”, Iranian Journal of Electrical & Electronic Engineering, Vol.: 10.3, (2014).
- Wang J, Wang L, Ikenaga T, Goto S. : “An adaptive spatial error concealment (SEC) with more accurate MB type decision in H. 264/AVC”, 5th International Conference on Visual Information Engineering, pp: 759-764, (2008).
- Wu, Guan-Lin, and Shao-Yi Chien. : “Spatial-temporal error detection scheme for video transmission over noisy channels”, ,Ninth IEEE International Symposium on, pp. 78-85, (2007).
- ZiguanCUI ,Zongliang GAN, Xuefeng ZHAN, XiuchangZHU :”Error Concealment Techniques for Video Transmission over Error- prone Channels: A Survey”, in Journal of Computational Information Systems, vol.:8, pp:8807-8818, (2012).
- Jung, Y. H., Kim, Y. G., &Choe, Y:Robust “error concealment algorithm using iterative weighted boundary matching criterion”, IEEE, Vol. 3, pp. 384-387, (2000)
- Usman, M., He, X., Xu, M., & Lam, K. M :“Survey of Error Concealment techniques”, Research directions and open issues, IEEE, pp: 233-238, (2015).
- Wang J, Wang L, Ikenaga T, Goto S.:“An adaptive spatial error concealment (SEC) with more accurate MB type decision in H. 264/AVC”, 5th International Conference on Visual Information Engineering, pp: 759-764,(2008).
- Marvasti-Zadeh, SeyedMojtaba, and HosseinGhanei-Yakhdan. “Video temporal error concealment using improved directional boundary matching algorithm.” Turkish Journal of Electrical Engineering & Computer Sciences 24, no. 6 :pp 5195-5209(2016).
- Hasan, MdMehedi, Tasneem Rahman, KiokAhn, and OksamChae.“Artifacts Detection and Error Block Analysis from Broadcasted Videos.” arXiv preprint arXiv:1808.10086 (2018).
- Shih, Huang-Chia, Chiung-Ting Wang, and Chung-Lin Huang. “Spiral-Like Pixel Reconstruction Algorithm for Spatiotemporal Video Error Concealment.” IEEE Access 6 pp: 6370-6381(2018).
- Choe, Gwangmin, Cholman Nam, and ChanggonChu,“An effective temporal error concealment in H. 264 video sequences based on scene change detection-PCA model.”, Multimedia Tools and Applications 77, no. 24 pp:31953-31967(2018).
- El-Shafai, Walid, S. El-Rabaie, M. M. El-Halawany, and Fathi E. Abd El-Samie. “Performance evaluation of enhanced error correction algorithms for efficient wireless 3D video communication systems.”,International Journal of Communication Systems 31, no. 1: e3396, (2018).
- Chen, Yan, Yang Hu, Oscar C. Au, Houqiang Li, and Chang Wen Chen. “Video error concealment using spatio-temporal boundary matching and partial differential equation.” in IEEE Transactions on Multimedia 10, no. 1 (2007): 2-15.

AUTHORS PROFILE



Ketki C. Pathak She is PhD scholar and doing her research work in the area of medical image processing using video compression standard from Electronics Engineering Department, SVNIT, Surat. Her are of interest are VLSI design technology, signal and image processing, image compression and using video compression standard like HEVC.



Prof.(Dr.) Jignesh N. SarvaiyaHe is currently performs his duty as an Associate Professor at Electronics Engineering Department, SVNIT, Surat. He has done his PhD from SVNIT, Surat. His area of interest are image processing, image registration, super resolution.



Modified Boundary Matching algorithm for Error detection and Error Concealment for Video Communication

He has published various journal paper in the domain of image super resolution and image registration. Personal profile which contains their education details, their publications, research work, membership, achievements, with photo that will be maximum 200-400 words.



Prof.(Dr.) Anand D. Darji He is currently Head of Department of Electronics Engineering Department, SVNIT, Surat. His area of interest are VLSI Design, Biomedical signal processing, FPGA design. He has completed his Phd in Microelectronics from IIT Bombay. He has published various journal article in domain of vlsi

design.