EFFICIENT ADAPTIVE INTRA REFRESH ERROR RESILIENCE FOR 3D VIDEO COMMUNICATION

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ABSTRACT:

3D video wireless communication is being repeatedly called upon to play a greater role in the quest for economic and political stability, peace and understanding in the world. However, excessive error propagation in compressed 3D video can dramatically decrease perceived quality of experience (QoE). Recent error control strategies suggested that using adaptive intra refresh (AIR) tool is a good candidate for fulfilling quality of service (QoS) requirements for 3D video transmission over wireless networks. We propose multi-view video AIR (MVV-AIR) based on H.264/advance video coding (AVC) to mitigate transmission error propagation in a two-way communication system. With the MVV-AIR, both high active macroblocks and channel bit error rate (BER)are computed to generate MVV-AIR refresh map. The generated map is used to periodically insert a cyclic intra-refresh line macroblock to suppress spatio-temporal error propagation. Experimental results show that MVV-AIR outperforms traditional refresh scheme in error prone transmission environment with improved objective and subjective visual quality.

KEYWORDS

3D video, Error Resilience, MVV, MVC, AIR, MVV-AIR map

1. INTRODUCTION

The multimedia communication renders very important services to any society in the world. Multimedia communication is a fast developing field and every day new technologies are coming up. Three dimensional (3D) video is one of the operational arms of multimedia communication which provides free 3Dvideo view point that allows arbitrarily change of viewing position. It also permits telepresence that expand the user's sensation far beyond the traditional 2D video. The 3D videos are now common sight at homes, sport channels, blue-ray disc and mobile Internet[1-7]. The deciding factors have been its extreme reliability and systematic dissemination of entertainment, information, educational programming and other features to scattered audience. The 3D video communication can now be found just about everywhere these days from 3D video movies, to 3D video television, 3D video conference, 3D animation etc. The modern 3D video information environment enables individuals, groups, and often nations to report and verify or refute information of varying authenticity and accuracy. For example, in winning the Global War on Terror (GWOT)the military around the world employ the potentials of 3D video communication for decision support system[8-10].The adaptation of 3D videos communication creates superior situational awareness that enable transmission of accurate critical information for identification of criminals.

As 3D video communication continue to grow rapidly, so do expectations on how to efficiently convey the 3D video data from the sender to the receiver. The 3D video communication chain is illustrated in Figure 1. Multiple cameras capture the same scene simultaneously from different angle. This generate huge data with spatial, temporal and inter views dependencies. Due to the limitation of bandwidth it is necessary to compress the 3D video data in order to reduce

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redundancies. H.264/AVC (Advanced Video Coding) is one of latest video coding standard that is frequently used for mobile communication system. The creditable performance of the H.264/AVC has improved users quality of experience (QoE) meeting by meeting viewers 'expectation, feelings, and thoughts of 3D video.

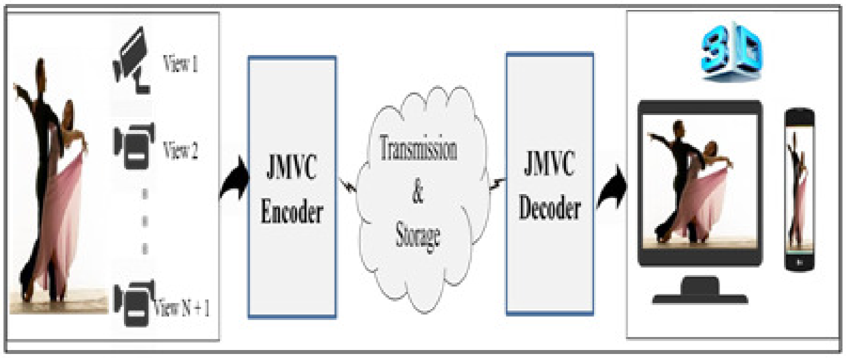


Figure 1: MVV communication system

However, the predictive nature of the multi-view video coding (MVC) makes the compressed bitstreams vulnerable lens to burst and random bit-errors often leave users in need of efficient QoE [11-15].In addition, father and child family chain of relationship that exists in the hierarchical B picture representation of the group of picture (GOP) in video compression causes distortion. The effect of this distortion in a variable length codes (VLC) may result to loss of synchronisation between the decoder and encoder. Owing to loss of synchronization the decoder cannot decode the bitstream correctly [16,17]. Furthermore, an error in the video stream can propagate in time, space and view example in Figure 2 when a frame is attack by error for instance in frame "N" in view 1, the error spread based on frames and view family interdependencies and motion compensation. These inevitable transmission errors propagate within frame and temporally across views pose a serious challenge to the coded bitstream. The effects of these error caused severe video quality degradation directly affecting end user QoE.

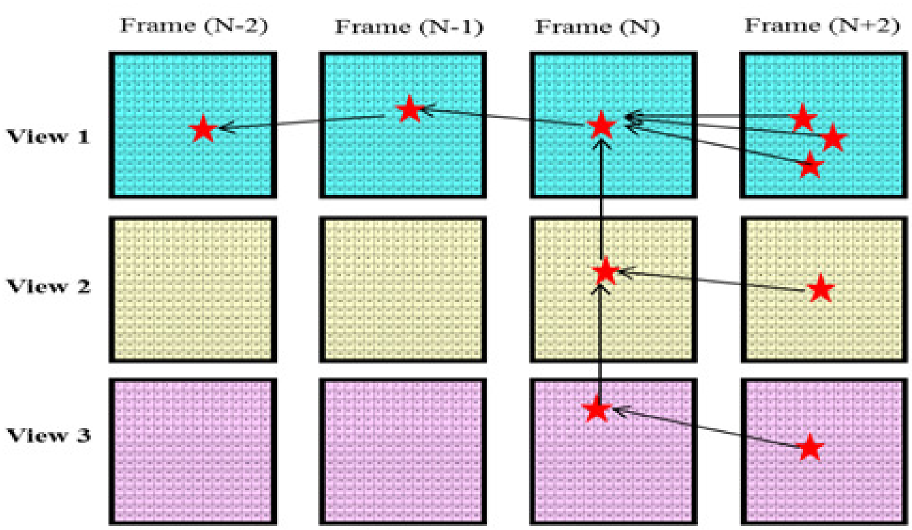


Figure 2: Error PropagationinSpace Time and Views

One way to suppress error propagation in a mobile 3D video communication is to transmits intra coded macroblocks, which are coded without referring to pervious encoded frame [ ]. To this effect, we proposed MVV-AIR scheme to mitigate transmission error propagation in a two-way communication for users that are geographically far from each other. The process involves encoding a complete frame in intra code mode in order to break all dependencies arising from pervious coded frames. Another approach is to intra code macroblock or a row of macroblock in a GOP level to limit any potential error propagation. The AIR scheme is a tool of MPEG-4 and H.264/AVC that combines the rate distortion of high motion sensitive frames and the information received from the decoder about the channel condition to suppress error propagation[18-20]. With the MVV-AIR, high motion macroblocks (MBs) and bit error (BER) variation in channel are modelled together to generate MVV-AIR refresh map. The generated map is used periodically insert intra coded frames in order to stop further error propagation.

As a contribution to using MVV-AIR map in solving the transmission error propagation problems, a subjective quality assessment survey was devised. The main objectives of the survey were to (i) evaluate viewers' attitudes towards 3D video communication, (ii) obtain accurate viewers or users' opinion on the quality of 3D video processed using Intra refresh error resilience scheme, and (iii) evaluate human perception and quality of experience (QoE) of 3D video. The survey was conducted at Brunel University, London and Nigerian Defence Academy, Kaduna.

The reminder of this paper is organized as follows. The adaptive intra refresh (AIR) and related data is presented in section 2. In section 3 outline the method of generating adaptive intra refresh map. In section 4 general characteristics of air-map in decoder is presented. Section 5 discussed experimental results. The paper is concluded in Section 6.

2. RELATED WORK

To fully understand generation of map used in error resilience at the source and destination of a two-way communication system, one would have to face the enormous task of reading through the various works of scholars who have put their thoughts on this subject. The idea of adaptive intra refresh called "AIR" is adopted as an error resilience tool in the MPEG and H.264/AVC video standards [21-23]. The AIR popularity in suppressing temporal error propagation attracted the interest of researchers who continue to make further improvement of the algorithm. According to [24-28], initial intra refresh method was established based on end-to-end rate distortion model. This model takes into account several aspects of human vision such as intensity, colour and orientation to perform intra/inter mode decision. However, this method has not taken the bit error rate (BER) or packet loss rate (PLR) challenges associated in wireless channels.

In [29], Flexible Macroblock Ordering (FMO) and adaptive macroblock grouping tools dynamically generate MacroBlock Allocation maps (MBAmaps) for every frame to intra code error infected frames. The work in [30]affirmed the MBAmaps scheme in which, once the decoder detects an error, it informs the encoder, which in its turn transmits intra-coded MBs to halt any further error propagation. However, this emphasizes the importance of a convenient feedback path for efficient management.

The method in [26, 31-34] recursively computes the total decoder distortion at pixel level precision. This results in an accurate spatio-temporal error propagation estimate. The pixel distortion is used with rate distortion optimization framework to optimally refresh macroblocks in intra mode. However, due to sub-pixel motion estimation in H.264, the pixel based error propagation estimate may not be accurate for the H.264 video codec.

An important aspect of cyclic intra-refresh was studied in [32, 35-38].An intra-refresh line was used as an error mitigation tool and unequal error sensitivity appears within slices from the same frame. The region-based and packet-based prioritization schemes were compared. However, the packet-based scheme incurs a one-frame delay in transmission due to the need to assemble packets prior to priority assignment.

To broaden the error resilience technique using intra refresh methods, isolated region based intra refresh has been proposed in[24] This method introduces a gradually growing region named isolated region, and the prediction area for those blocks, that are in the isolated region, is restricted. In [27], attention based adaptive intra refresh technique has been proposed. In this technique, an attention area is determined. The determination of the attention area is based on human perception for better subjective video quality. An attention based end-to-end rate distortion model is derived. The attention area is assigned higher priority for intra coding than non-attention area.

Presently, video encoders can support decoders to mitigate spatio-temporal propagation of transmission errors by coding macroblocks (MBs) in intra mode. The gap the research set out to fill in the role of error resilience in MVV communication involved encoding high motion MBs in intra mode. In the literature there are various types of algorithms that exist for encoding MB in intra mode. On one hand, we have the adaptive methods, which is further classified into cost-function-based and rate distortion optimized. On the other hand, there exit a family of non-adaptive algorithms, this feature elements of circular intra refresh algorithm that can scans the picture area in a pre-defined order and codes a certain number of intra MBs per picture in the pre-defined scan order. Another example of a non-adaptive algorithm is to intra code a certain number of MBs at randomly selected MB locations. The adaptive MB mode decision method has long been working on the selection of the intra-coded MB locations taken the content of the pictures into account. However, computational complexity is the key bottleneck in adaptive MB mode decision method.

3. PRINCIPLES OF OPERATION OF A MVV-AIR SCHEME

Figure 3 shows the configuration of the MVV-AIR. It consists of:

(a)**H.264/AVC encoder**: which often use baseline algorithm as a key tool in tackling the challenges of MVV-AIR map generation. The baseline algorithm has three stages: a discrete cosine transforms (DCT) stage, a quantization stage, and a binary entropy encoding stage[17, 39].

(b) **Transmission and Storage medium**: this is the medium over which compressed 3D video are convey from one geographical location to another. In the communication medium, transmission errors such as bits and random burst errors as well as packet loses are almost inevitable particularly over noisy channels. Despite continuing efforts to reduce the effect of transmission errors and error propagation related incidents, compressed 3D video bitstream is still been affected by channel error[40-46].

(c)**H.264/AVC decoder**: this is generally a cogent H.264/AVC MVV algorithm that reconstructed the 3D video transmitted for display. In the decoder motion estimation is employ to search the incoming bitstream for inconsistent H.264 syntax. The motion vector is compared with the set threshold to determine the presence of an error. If the magnitude of the error is beyond error concealment, than, an AIR map update is available with flags indicating which macroblocks are corrupted. The updated AIR map is sent to the encoder via the feedback channel[47-50].

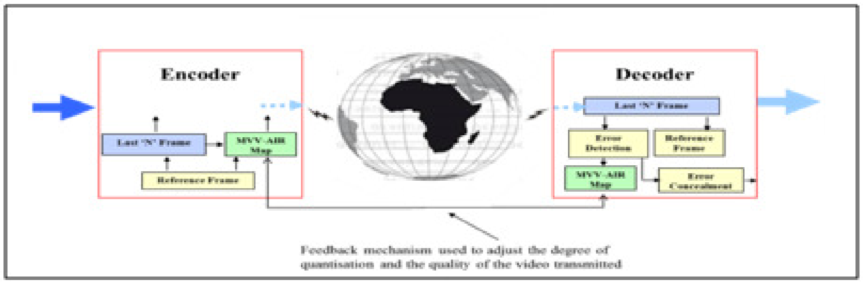


Figure 3: Configuration of the MVV-AIR Operation

3.1 TRACING HIGH MOTION REGION

The MVV-AIR map generation scheme begins in the encoder by tracing the high motion region of an incoming frame. This is because when the compressed bitstream is hit by error, most often the channel error hangs on the high motion region of the frame in the signal[27]. There are various methods proposed in literature of identifying high motion region in a frame. However, the mathematical rate control algorithm based on the network condition is one of the most widely used. This method takes note of the existence of temporal redundancy in consecutive 3D video frames and observed that not all the captured video contents in all the frames are in motion. Some content such as background in Figure 4remain static and are never changed during a long time video sequence. Therefore, the white static background areas need not be refreshed in intra mode as often as moving objects area that are circled in yellow colour. As objects move around in video, so also motion estimation is used to shift the pixels around in order to create the next image. Consequently, the information of high motion macroblocks in a frame is based on to the block rate distortion and channel condition information.

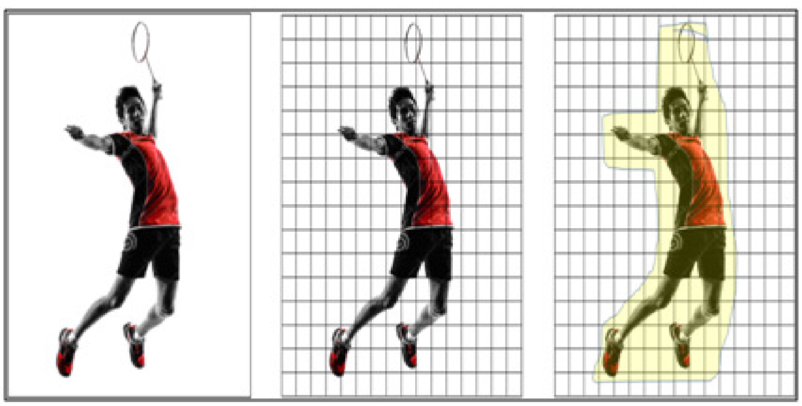


Figure 4: Area of high motion in a frame

The diagram in Figure 5 helps us to precisely determine locations and position of macroblocks. This is necessary because owing to temporal and spatial inter-frame prediction an object position keep on changing along the consecutive frames. For instance, the macroblock number104 in frame N is predicted by parts of macroblocks number 87, 88, 103 and 104 of the preceding N-1 frame [51]. It is clear that from the diagram that, when an error affects anyone of these macroblocks (87, 88, 103 and 104) in N-1 frame the error will definitely affairs in the macroblock 104 in frame N and even spread further to macroblocks 103, 105, 119, 120 and 121 of frame N+1. Hence, motion compensation mechanism makes error propagation accumulate in high motion macroblock and widens the damaged area between consecutive frames.

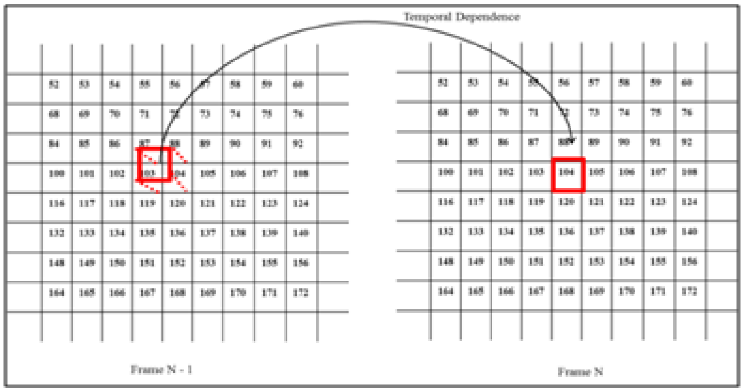


Figure 5: Motion Compensation Temporal Error Propagation

3.2 COMPUTING THE THRESHOLD

In this phase, decision is taken on the location of the macroblock to be refreshed by using a pre-determine threshold. The set threshold value compares the similarity metrics of the macroblocks to decide if there was high motion or not. Rate distortion control mechanism and the sum of absolute difference (SAD) facilitate motion energy detection of various difference MBs with minimum distortion (D) of a coded block within a coding rate (R) and complexity (C) constraints[52, 53]. The SAD exploits the relation between motion and texture within a scene. Figure 6 shows the flow chart of MVV-AIR map search. The threshold parameters used in the flow chart are expressed in the well-known Lagrangian cost function (J) equation $\mathbf{J = D + \lambda(R + C)}$ [54-56]**.** The λ symbol is the Lagrangian parameter for appropriate weighting, which is associated with both rate and complexity.

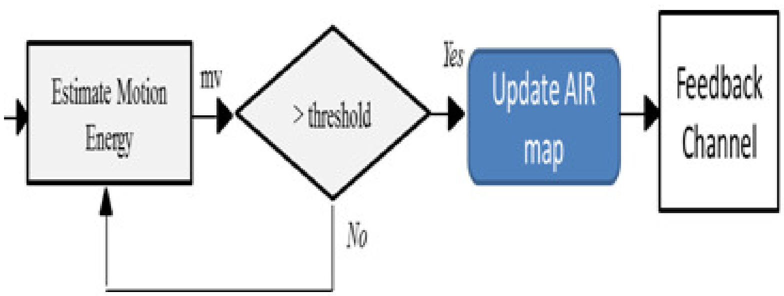


Figure 6: flow chart of MVV-AIR map

Evidently, an example of a variation in motion computed with set threshold over standard 'Vassar' sequence is shows in Figure 7. Referring to this figure it is clear that in the middle of the sequence is where the peak of the car's movements. Therefore, the range of MBs in the middle of the frame belongs to high motion.

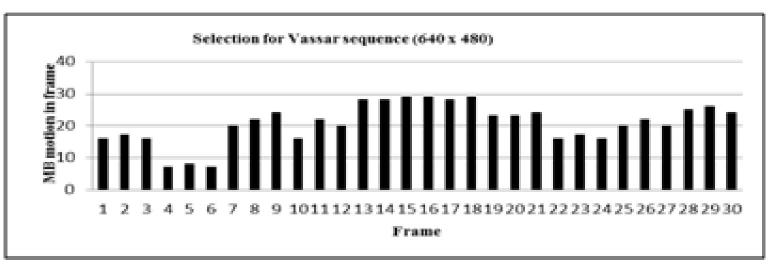


Figure 7: Variation in motion over 'Vassar' sequence

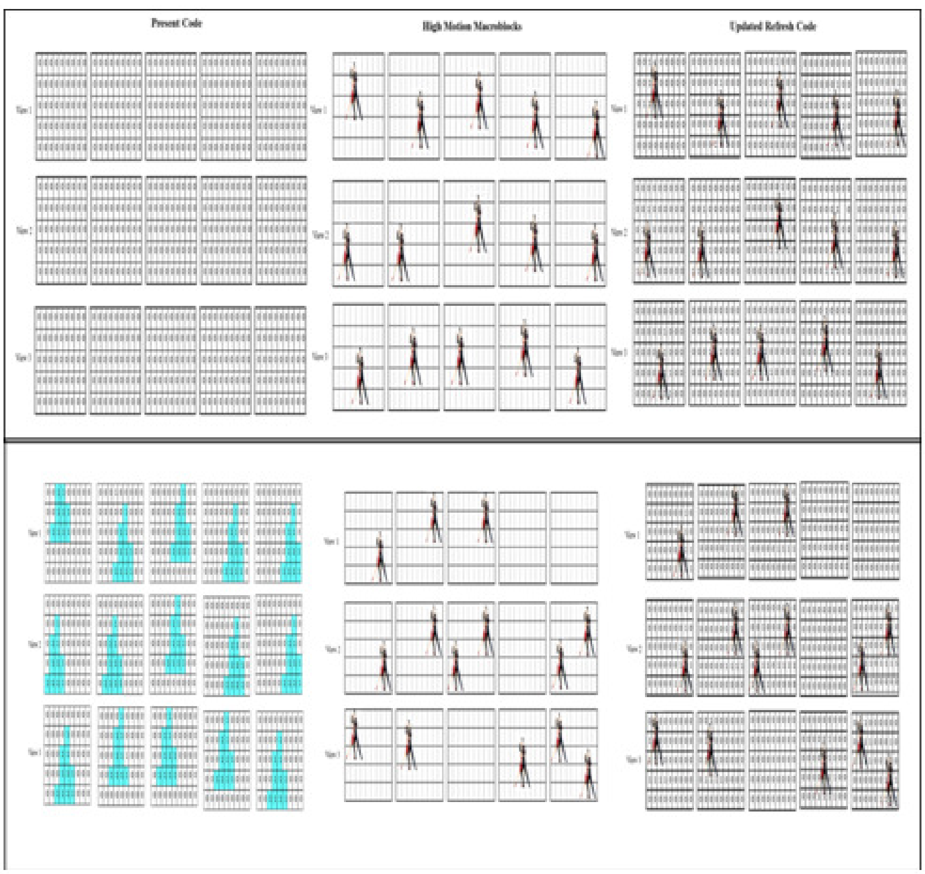
3.3 Generating Refresh Map

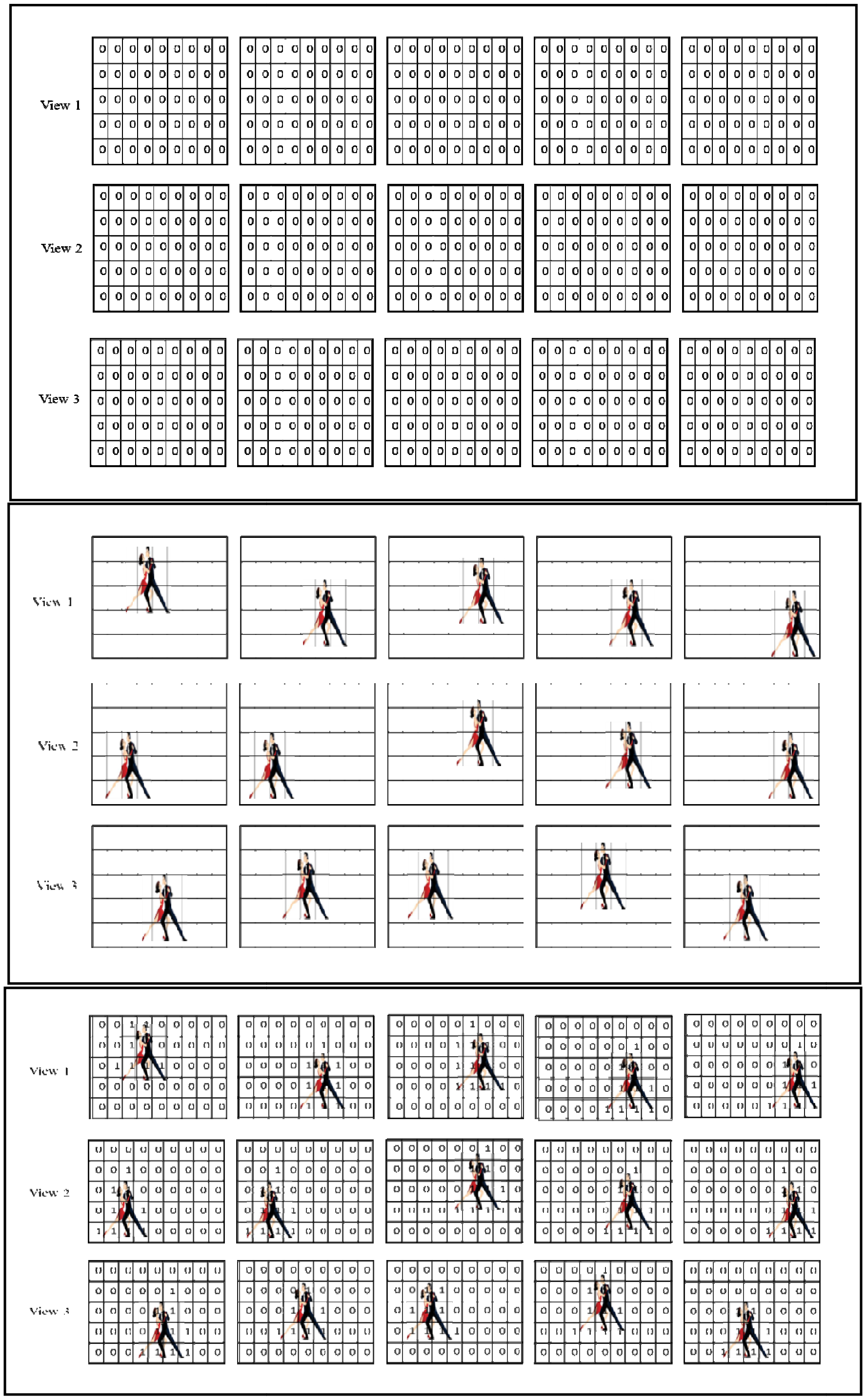
A core interest in MVV-AIR-map is toresolve the error propagation problem that exists in wireless transmission. The mapping entails constructing a table that keeps records of each macroblock activities as a data base. To mark the area of high motion on the mapping table, the motion vector is compare with the threshold set using the mathematical expression[57, 58]:

$$MV(x, y) > T$$

From the mathematical expression, when x or y or both is greater than the threshold, figure “1” is assigned to macroblock signifying high motion. Otherwise a figure “0” will be plotted. These processes continue until the table is completed. The table is updated since the activities in the scene are dynamic and randomly captured by the multiple cameras. An example of a complete generated MVV-AIRmap table of a ballroom dance with winding movement is illustrated in Table 1. At the beginning all the refresh map entry for the present macroblocks are zero coded. Then a new refresh map is constructed for the incoming GOP. As soon as activity developed within the GOP the old refresh map is updated by threshold value operation. This process of intra coding of macroblock continue until the GOP is coded as shown in Table 1.

Table 1: Example of MVV-AIR-map Table





3.4 MVV-AIR WITH PERIODIC CYCLIC LINE

The MVV-AIR scheme presented in this work exploit cyclic periodic insertion of intra coded macroblock lines within successive temporally predicted frames as shown in Figure 8. The main role of the cyclic MVV-AIR is to ensure effective erasure of error drift that arise from packet losses. However, what is not so clear is at what macroblocks in the GOP frames and views the error occupies. It is at this point that the main contribution of the MVV-AIR map generation presented in this study comes to play.

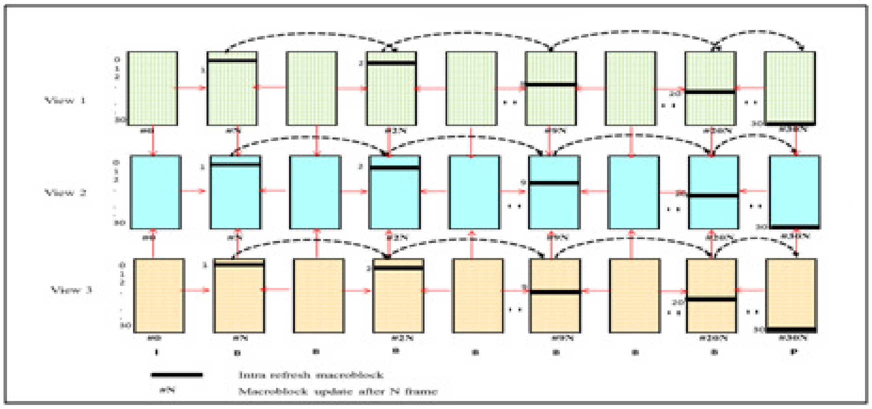


Figure 8: Cyclic Periodic Insertion of Intra Coded Macroblock Lines

To meet the need of unequal protection without introducing any additional bitrate and computation complexity, we adopted acyclic GOP intra refresh algorithm in H.264/AVC. The position of refreshed GOP follows an arrangement of block line of Intra coded macroblocks moving from top-to- bottom is employed. The cyclic intra refresh lines in a full GOP is updated with intra-coded macroblocks using a pre-defined scan order and selected number of macroblocks per picture. An example of complete round refresh of fixed number of frame refresh is shown in Figure xx. The row is numbered from row #1, #2 up to the last row, at the end of a GOP the numbering is reset to first row #0. Applying this to a sequence of (640 x 480) spatial resolution, one block equals 40 macroblocks and by refreshing 30 times, the entire frame of 1200 macroblocks is Intra refreshed. Thus, the effectiveness of this new MVV-AIR scheme is that the encoder would intra-code predicted frames in advance after it has cleaned the error reported to it by the decoder.

For real time application each GOP has different levels of sensitivity to channel errors. For instance, low motion macroblock in a GOP can easily concealed an error but high motion macroblock cannot promptly conceal error. Therefore, macroblock in a GOP with high motion need to be intra coded. Furthermore, the encoder is required to keep track of the decoder to know which part of the image area was recently refreshed. The encoder would then refresh those active macroblocks, which had an impact on error propagation. Receiver statistics is used to indicate the channel conditions by means of feedback messages. Therefore, a feedback channel is required to link H.264/AVC Intra-Decode Refresh (IDR) and Intra coded macroblock (I-picture) features that supported Intra refresh of the far end decoder with the encoder.

4. Experimental Results And Discussion

4.1 Experimental Conditions

In our simulation, we have used H.264/AVC software and common test sequence of Ballroom, Vassar and Exit with resolution 640×480 comprising 300 frames, at frame rate of 30 frames/seconds. Each primary picture is coded with two reference pictures at various quantization parameter (QP) sets. To evaluate the efficiency of the MVV-AIR performance, four other error resilience tools namely: random intra refresh (RIR), Flexible Macroblock ordering (FMO) and non-error resilience (NER) were implemented in H.264/AVC. In comparison, we use both objective and subjective measures. In the objective measure, the peak signal to noise ratio (PSNR) is used as the performance metric in quantifying the effectiveness of the techniques.

Simulations depicting wireless 3D video communication were run in Sirannon network simulator. One strongest feature of Sirannon is its capability to combine universal server (RTSP, HTTP, RTMP, RTMPT) and universal client. This combination gives Sirannnon the ability to transcode 3D video to 2D video users[59].

4.2 OBJECTIVE RESULTS

Figure 9 shows the PSNR performance and percentage of packet loss rate (PLR) using the Ballroom sequence. This figure reveals that the MVV-AIR has a competitive rate distortion (RD) advantage compared to the other error resilience methods. Even though, the NER starts with a higher PSNR at zero packet loss, it degrades significant at higher network PLR. This is because the NER methods require no additional coding overhead. However, similar results are observed with Exit and Vassar sequences.

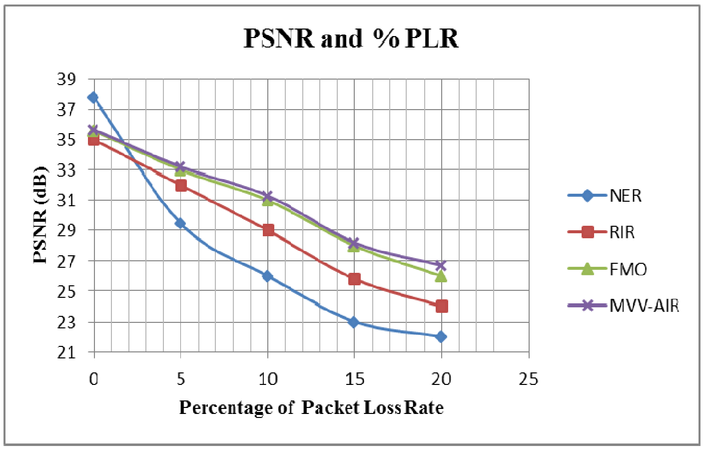


Figure 9: PSNR performance for the Ballroom

Figures 10 show the overall performance result for the experiments obtained in the case of no network packet loss. The proposed MVV-AIR method has a slight PSNR degradation compared with the FMO model-based coding method and even larger PSNR degradation compared with the NER scheme. This is because the number of lost important macroblocks is completed eliminated. The PSNR values attained in FMO curves are obtained from the decoded video sequence rather than the reconstructed video in the encoder side.

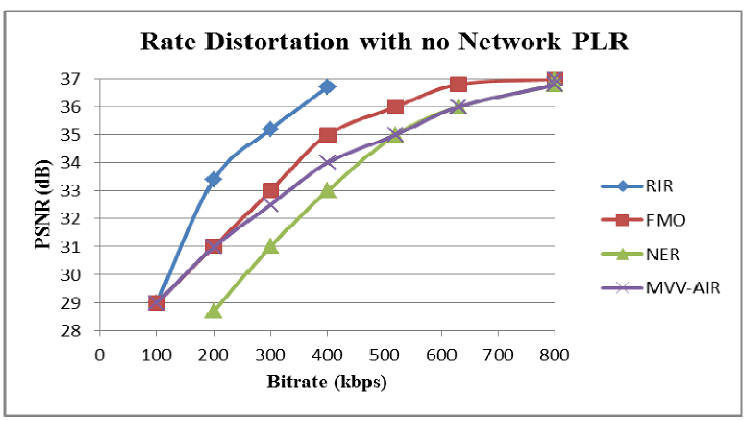


Figure 10: PSNR performance for the Ballroom

As shown in Figure 11, the end-to-end performance at 20 percent network packet loss indicates that the MVV-AIR and FMO outperform the RIR and NER approaches.

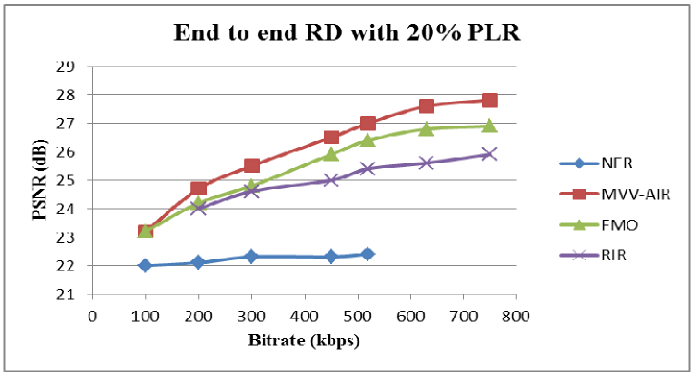


Figure 11: End to end RD with 20% PLR

Figure 12 illustrates the end-to-end rate distortion using the frames identified with high motion MBs, from the curves it can be observed that the MVV-AIR approach performed much better in the mitigation of error propagation than the other approaches. This achievement shows how the MVV-AIR refresh map gradually reduces the temporal error propagation in the GOP.

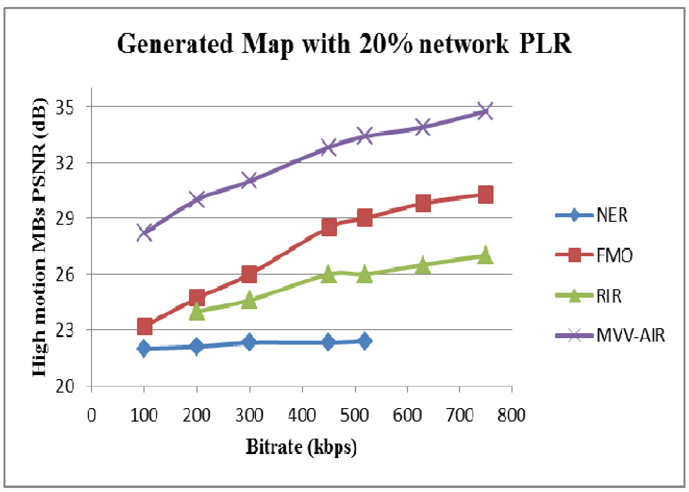


Figure 12: Shows the PSNR performance for the Ballroom

4.3 Subjective Test

As a contribution to solving the transmission error propagation problems using MVV-AIR error resilience tool, a subjective video quality assessment survey was devised. The main goal of the assessment survey is to make an impartial judgment about the 3D video quality and depth perception of a range of differently coded video sequences, with packet loss rates ranging from 0% to 20%. The survey also sought to identify any links between different groups within the society and their relative levels of interest regarding wireless 3D video information transmission. The subjective assessment was based on the ITU-R recommendation 500 [60, 61].

To do the subjective quality assessment experiment, a two-way 3D videos communication link was set up in UK and Nigeria as shown in Figure 13. In addition, MVV transcoder is used to deliver maximum quality 3D video data from the source to the 2D video destination. The assessors of the subjective test were volunteers drawn from Brunel University, London and Nigerian Defence Academy, Kaduna. The participants consist of literate and semi-literate and therefore they have the capacity to understand technical information. Some of the participants admit that this is the first time to watching 3D video clips.

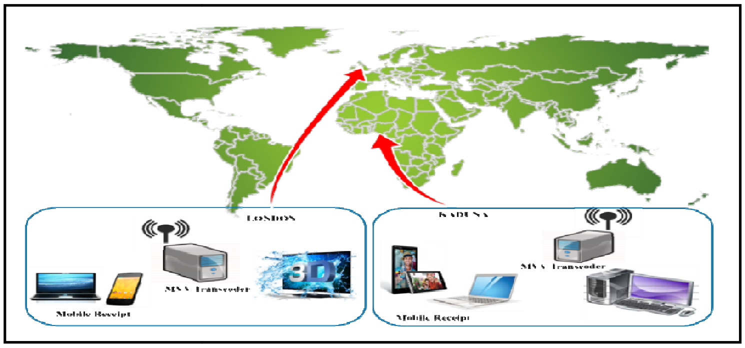


Figure 13: 3D videos communication link was set up in UK and Nigeria

Participants watched 3D videos in relaxed environment using stereoscopic shutter glasses. The 3D video effects were displayed on a laptop computer with screen resolution of 1152x 900pixels, frequency of 60 Hz x 60 Hz and a measured size of 360x 270mm. The optical path length is 320mm and the horizontal FOV is 0.8 rad. After watching the transmitted video clips, assessors rate the videos by completing a questionnaire. The mean opinion scores (MOS) for test was calculated and analysed.

Graphically, Figure 14 shows agedistribution of participant's. Thepie chart chart shows that about 12 percent or 15 assessors were of over 42 years old with older participants (ie those over *65* years) responded, while 18 percent representing 20assessors were between 18-25 years. Also, 37 of the assessors were aged between 34-41 years. The remaining 53 assessors were young people aged 26-33 years. It was observed that common and unique desires by age group to watch 3D video have been fairly covered.

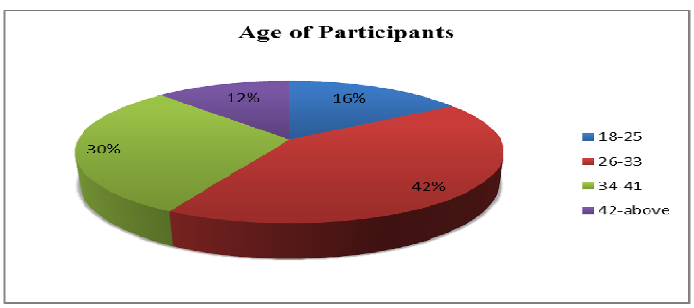


Figure 14: AgeDistribution of Participants

The impact of depth information on perceived compressed 3D video quality was one of the major questions in the questionnaire. The questions included whether the compressed 3D video clip watched is equitable.

Figure 15shows the response on the equitability of compressed 3D video. It was observed that 60 percent agreed that the 3D video was equitable while 15 percent disagreed. From the above statistics it can be deduced that the 3D video clip transmitted were well reconstructed. Majority of those who expressed dissatisfaction are non-experts in watching videos.

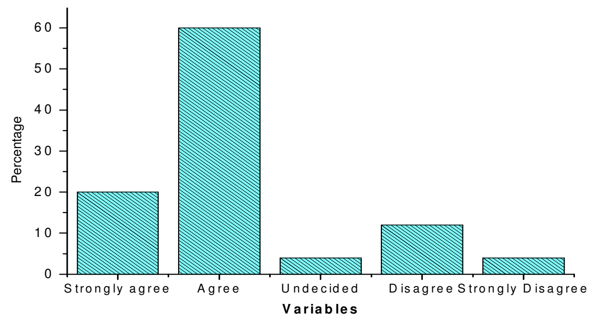


Figure 15: Rresponse on the Equitability of compressed 3D video

However, it could also be observed from Figure 16,that only 40 percent agreed that they were satisfied with the compressed 3D video quality, while 45 percent responded otherwise. When some of the respondents were interviewed, majority of them advocated for higher resolution especially those who were neither engineers nor expert on watching 3D video. Furthermore, the respondents dissatisfaction was because the discomfort in wearing the 3D video glass for long time.

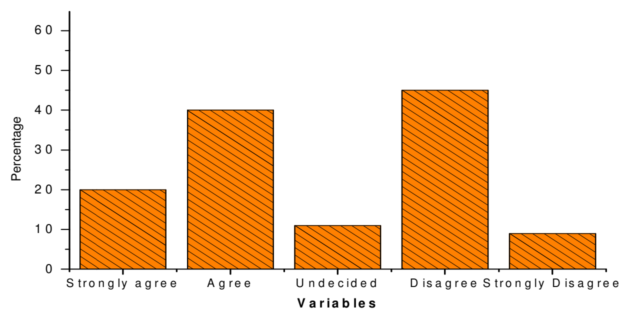
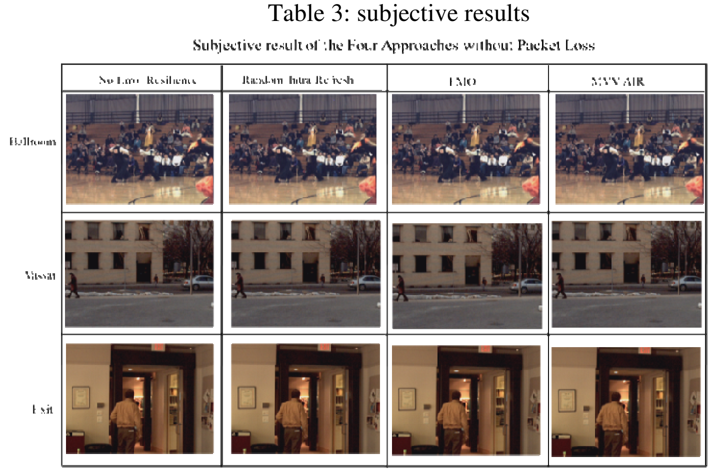


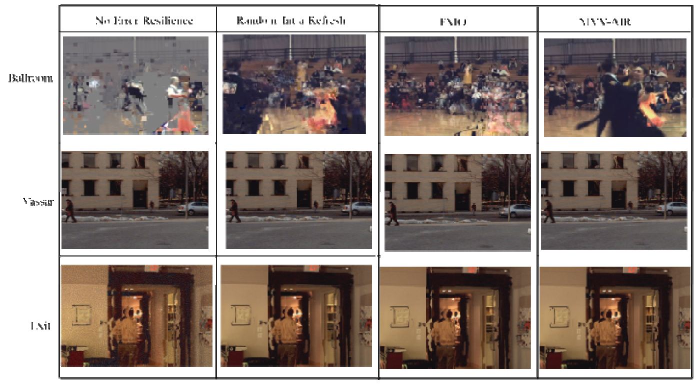
Figure 16:3D Video Quality

The subjective qualities under various PLRs (5 percent, 10 percent, 15 percent, and 20 percent) are tested according to [38] are illustrated in Table 2. In particular, a high PLR of 20 percent is focused, because it represents the happening of burst error, while a lower PLR (e.g., lower than 5 percent) usually does not deteriorate human perceptual feelings.

Table 3: subjective results



Subjective result of the Four Approaches with 20% Packet Loss



5. CONCLUSION

In this paper, we present MVV-AIR error resilience method for the wireless 3D video communication by using both the information of channel variation and high motion macroblock to generate MVV-AIR map. The generated map is used to periodically insert a cyclic intra-refresh line macroblock to suppress spatio-temporal error propagation. Experimental results indicate that the proposed MVV-AIR error resilience method achieved a better trade-off between the coding efficiency and the suppression of potential errors. Compared to intra refresh methods with RIR, FMO and NER error resilience, our proposed method has presented better video quality when video data are transported over wireless channel.

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