

SELECTIVE MOTION VECTOR REDUNDANCIES FOR IMPROVED ERROR RESILIENCE IN HEVC

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ABSTRACT

This paper addresses the problem caused by motion vector coding dependencies on the error resilience performance of the emergent High Efficiency Video Coding (HEVC) standard. We propose a method based on the prediction dependency of motion vectors (MV) to select the most relevant ones for redundant coding with reduced overhead. The spatial dependencies are analysed in the encoder to prioritise the MVs that should be selected for redundancy, based on the number of subsequent dependent coding units. Then, a subset of prioritised MVs is transmitted as redundancy (referred to as side information in the paper), to reduce the use and propagation of mismatched MV predictions in case of transmission errors or data loss. The simulation results show that the proposed MV selection method can effectively identify the most relevant motion field, achieving improved error robustness with a reduced redundancy overhead. Exploiting only 30% of the generated MVs for redundancy, average quality gains of up to 1 dB are achieved compared to a uniform MV selection scheme, and up to 2 dB compared to the original HEVC standard with no redundant encoded information.

Index Terms— HEVC, error resilience, motion vectors redundancy.

1. INTRODUCTION

The High Efficiency Video Coding (HEVC) standard is the most recent project of the ITU-T Video Coding Experts Group (VCEG) and the ISO/IEC Moving Picture Experts Group (MPEG) standardisation organisations, working together in a partnership known as the Joint Collaborative Team on Video Coding (JCT-VC) [1]. This standard aims to fulfil the requirements not only of HD video but also the emergent Ultra-HD formats (e.g., $4k \times 2k$ or $8k \times 4k$ resolution). The demands for these services is increasing, creating stronger needs for coding efficiency superior to H.264/AVC capabilities. The HEVC aims to address essentially all existing applications of H.264/AVC, extending it in two key aspects: increased video resolution and increased use of parallel processing architectures. To address these aspects, the HEVC standard adopts a new block partition structure, enabling block sizes up to 64×64 [2]. The standard also improves the intra and inter coding, and includes new high-level features [3].

This work was supported by the Fundação para a Ciência e a Tecnologia, Portugal (under the PhD grant SFRH/BD/86368/2012), and the ROMEO project (grant number: 287896), which was funded by the EC FP7 ICT collaborative research programme.

Although new coding tools bring further compression efficiency, some disadvantages come along, such as complexity increasing and error robustness decreasing [4]. Error resilience mechanisms should be employed in video transmission to mitigate the artefacts caused by packet losses. Depending on the functional characteristics, there are four types of error resilience tools: localisation, data partitioning, redundant coding and concealment techniques [5]. Localisation techniques reduce the spatial and temporal dependencies in bitstreams, data partitioning groups the coded data into different categories depending on their importance. Redundant coding makes use of redundant blocks of data to correct transmission errors and achieve robust decoding in error prone conditions. Finally, error concealment methods can be performed to reduce the effect of errors by exploiting the existing redundancies between neighbouring information. Although these techniques significantly improve the overall video transmission quality in case of errors, they may compromise the coding performance if they require side information. Therefore, it is essential to achieve an efficient trade-off between the coding efficiency and error robustness while applying such tools.

There are quite a few related works in the recent past. A system integration of HEVC with existing technologies, such as RTP and MPEG-2, was presented in [6]. An end-to-end framework for HEVC streaming was proposed in [7], where the perceived video quality was analysed at different bitrates. The error robustness of HEVC was also analysed in [8], and compared against the H.264/AVC. The results had shown that HEVC has reduced error robustness despite its increased coding efficiency. In [9], the vulnerability of the motion vector prediction was evaluated under different packet loss conditions, showing the lack of error robustness in the HEVC standard. To overcome such vulnerability in HEVC, error resilience techniques may be applied to increase the video quality. Regarding error resilience, redundant pictures were widely used in H.264/AVC [5] to increase the error resilience in combination with different approaches, such as multiple description coding [10]. Although redundant pictures achieve good performance under error prone conditions, such approach generates a large amount of redundant data and overhead. In [11] a new approach was proposed to reduce the amount of information in the redundant pictures of H.264/AVC, by introducing only redundant motion vectors (MVs). This approach increases the overall performance of the system by presenting an efficient trade off between the resultant bitrate and the error robustness.

In this paper a novel method to improve the error resilience of HEVC coded video is proposed. In order to reduce the error propa-

gation due to incorrect MV prediction when frame losses occur, redundant motion information is proposed to be used. As in [11] only the motion information is used to increase the error robustness. However, only the relevant motion vectors are selected, based on the HEVC standard characteristics, *i.e.*, dependencies between differential coded MVs. The selected redundant MVs are able to recover from erroneous MV prediction when temporal dependencies are used. A selection algorithm is proposed that identifies the relevant MVs based on their spatial dependencies, in order to limit the increase in total bit-rate due to added redundancies.

The remainder of the paper is organised as follows: Section 2 describes the proposed method to select the redundant motion vectors in the HEVC standard; Section 3 covers the experiments performed to assess the effectiveness of the proposed method and illustrates the obtained results; finally, Section 4 concludes this paper.

2. IMPROVED RESILIENCE USING REDUNDANT MOTION INFORMATION

As mentioned before, the emergent HEVC coding standard introduces new features that enable high coding gains. However, these features increase the coding complexity, while at the same time compromising the error resilience by giving rise to more error propagation as a result of the complex prediction structure. In HEVC, error propagation does not only appear due to mismatch of pixel predictions, but also due to mismatch of motion predictions, caused by the use of temporal motion vector predictors [12]. This leads to severe quality degradations as well as difficulty in error recovery mechanisms.

The HEVC standard uses differential MV coding in order to increase the compression rates. This means that each motion vector is related to one of its neighbours, in spatial or temporal domains. Therefore, whenever a MV is lost the subsequent ones will also be affected by errors, until a refresh point that breaks the dependencies is decoded. The current HEVC standard does not have refresh points since MVs are always differential encoded. Thus, a complete error-free decoding of the MVs can only be achieved after a intra frame is decoded. Therefore, the usage of redundant motion information is likely to improve the error recovery by introducing refreshing points into the bitstream without changing the encoding process.

This is the aim of this work, where a method to select the relevant MVs is proposed, based on their spatial dependencies. The selected MVs are transmitted as side information in the bitstream and then used to recover wrong motion predictions. Thus, the error recovery capability of HEVC is improved, increasing the quality of the frames affected by errors. The next two subsections describe the redundant MV selection procedure, and the procedure for transmitting the generated side information, respectively.

2.1. MV selection method for redundancy

The selection method is based on an analysis of the MV coding dependencies in both temporal and spatial domains. Figure 1 illustrates an example with different MV dependencies. The arrows point to the block corresponding to the MV predictor used to encode a given MV. As shown in the Figure, both spatial and temporal predictions are possible in HEVC. The proposed method is described as follows:

- An initial analysis of the encoded motion field detects the MVs using temporal predictions, since these are the ones affected by frame loss and consequently will propagate the error to the subsequent coding units' MVs.

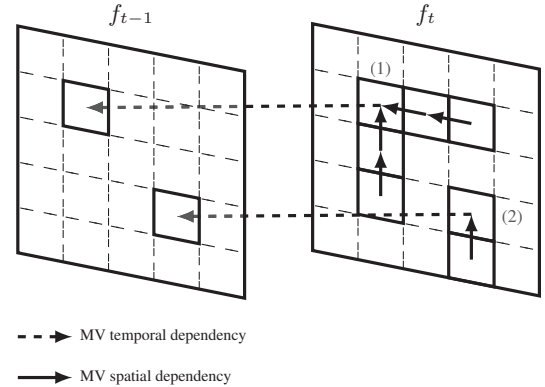


Fig. 1. Motion vector dependencies example in HEVC.

- The motion field is then subject to a further spatial analysis, which identifies the MVs that are dependent on the ones previously selected, *i.e.*, those predicted using the temporal MV candidate.
- Since under error prone conditions, the increase of spatial dependencies results in a higher number of affected MVs, a prioritisation scheme is applied based on the number of spatial dependencies related with a given MV, *i.e.*, the MV importance is quantified using the number of subsequent dependent MVs.
- Finally, using this prioritisation scheme, a sub-set of most relevant MVs is selected from the initial motion field, in order to achieve increased error resilience with a reduced redundancy overhead.

In the example shown in Figure 1 two MVs are temporally dependent. On one side, the MV of block (1) is used to predict a total of four other MVs. On the other side, the MV of block (2) is only used to predict one single MV. As a result, in case of error the MV of block (1) has more impact on quality degradation than the MV of block (2). Therefore, the MV analysis performed using the proposed method described above, will give higher priority to the MV of block (1) ensuring that this motion vector is selected even when the redundant overhead is reduced. Further analysis to the next temporal dependencies in the subsequent frames is not performed, in order to avoid encoding delay.

2.2. Redundant MVs as side information

The previous sub-section described how MVs are characterised based on their impact on the error propagation. This information is then used to select the most relevant MVs to be transmitted as side information in HEVC bitstreams. In order to maintain compatibility with the HEVC standard, the redundant motion information is transmitted using the supplemental enhancement information (SEI) NAL units [3].

The subset of selected MVs are independently encoded, ensuring that no reference information is needed in the receiver to properly decode the redundant information. In order to reduce the bitrate required to convey the redundant information, arithmetic coding [13] is used. Since the side information uses significantly less bitrate than the video signal, it is less likely to be hit during transmission. Moreover, the side information is transmitted using different packets in the transport layer, in order to reduce the probability of both video and redundant MVs being hit by the same errors/loss.

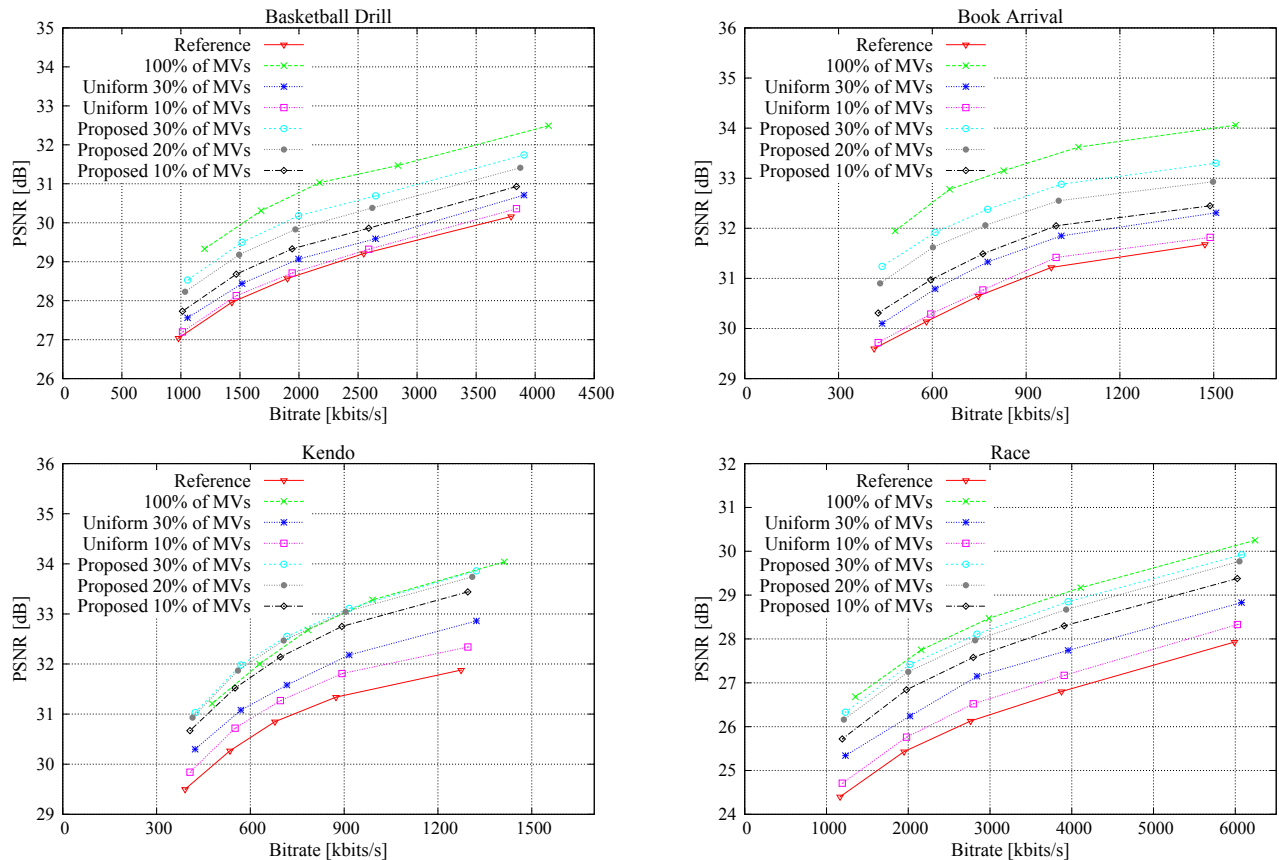


Fig. 3. Average quality of the decoded video sequences under 5% of packet loss rates (bitrate includes the redundant information).

3.1. Performance under packet loss

Further tests were performed to evaluate the effectiveness of the proposed error resiliency method under realistic packet loss patterns. In this experiment, each coded frame is transmitted in one packet whilst the redundant information is transmitted in a different packet. As previously mentioned, motion-copy concealment is used to cope with lost frames. For each test condition 50 trials were performed and the average of all trials are reported for increased accuracy. Figure 3 shows the average PSNR of the decoded video sequences under 5% packet loss rate condition. It can be observed from Figure 3 that the proposed algorithm is able to select the most relevant MVs in terms of error propagation and still maintain an acceptable quality when compared with the reference case without redundancies. Moreover, it is seen that there is a clear performance difference between the proposed MV selection method and the other that selects the MV uniformly. When lesser redundancies are introduced, for the Book Arrival and Basketball Drill sequences, the effectiveness of the proposed selection method decreases, revealing that more redundant MVs are required even with a low level of spatial dependency. For Kendo and Race sequences, the proposed method is able to select the most relevant MVs, achieving lesser quality degradation while reducing the bitrate increase by approximately 5 times. This indicates that the MVs used as reference for a high number of subsequent ones, increase the error propagation in case of errors. An average of 1 dB gain is achieved with the proposed method compared to the uniform selection method and up to 1.5 db is achieved compared to

the reference HEVC bitstream, using only 10% of redundant MVs.

In summary, the proposed method is able to select the most relevant motion information that should be introduced as redundant side information to increase the error resilience of HEVC. The results discussed above also indicate that the level of spatial dependency of the MVs is correlated with the quality of the decoded video in case of errors. Moreover, since in certain cases the redundant MV information may not lead to increased quality, these findings are useful to define a threshold for the required minimum redundancy in error prone conditions, possibly based on the packet loss rate. Thus, further analysis will be performed in regard to the spatial dependencies of MVs, incorporating the sequence characteristics and distortion measurement in order to achieve an efficient threshold for the MV redundancy ratio.

4. CONCLUSION

In this paper a MV selection method for redundant coding in HEVC was proposed to identify the most relevant MVs in terms of error propagation prevention. The results show that the relevance of MVs for error resilience is correlated with their spatial dependencies, which can be used to select those MVs that should be redundantly encoded. The proposed method can also be used in combination with other error resilience methods. The analysis of the results also indicates that further research should be carried out to define a dynamic threshold for choosing the amount of redundant MVs, such that only the most useful ones are encoded as side information.

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