Dynamic Motion Vector Refreshing for Enhanced Error Resilience in HEVC

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Outline

- Context and motivation
- Related work
- Motion Vector coding in HEVC
- Evaluation of error resilience in HEVC
- Proposed Motion Vector Refreshing method
- Experimental results
- Conclusions

Context and motivation

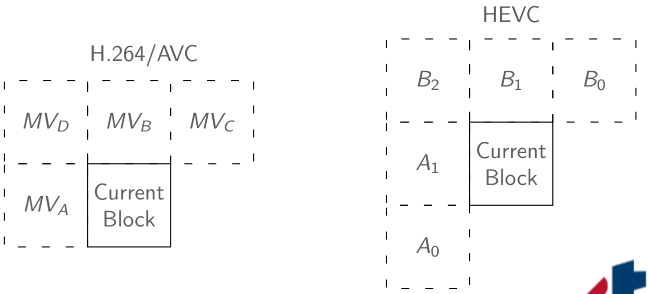
- Increasing diversity of services and demands for high quality multimedia contents;
- Recent development of the novel video coding standard - High Efficiency Video Coding (HEVC):
  - enables high compression rates;
  - leads to increased complexity and inherent reduction in error robustness.
- Motion Vector (MV) coding techniques in HEVC increase the temporal and spatial dependencies;
- Therefore, it is emergent to reduce the dependencies in order to increase the robustness in case of frame loss.

Related work

- Previous studies reveal that the new features introduced in the HEVC standard increase the complexity and lower error robustness due to high predictive coding:
  - it is clear by previous results that the HEVC is less robust than previous standards.
- The motion vector coding in HEVC increase the dependencies, leading to high error propagation in case of frame loss:
  - Previous work proposed to disable the temporal dependencies periodically in order to increase robustness.

Motion Vector coding in HEVC

- Similar to H.264/AVC SKIP mode: Motion Vectors (MV) are transmitted using previously encoded MVs as reference;
- HEVC uses more spatial candidates and allows a temporal MV predictor (TMVP) to be used as reference;
- The Merge Mode also allows encoding with zero residue (SKIP).



Test conditions

- Six test sequences with 240 frames were used:

Sequence	Resolution	Description
Basketball Drill	832 × 480 50 fps	High motion with several basketball players
Book Arrival	1024 × 768 30 fps	Low translational motion with two moving persons
BQSquare	416 × 240 60 fps	Moderate outside motion with moving camera capturing from high point
Kendo	1024 × 768 30 fps	Moderate motion with two moving persons, and moving camera
Race Horses	832 × 480 30 fps	Moderate motion with several horse riders
Tennis	1920 × 1080 24 fps	High motion with one moving person in the scene

- IDR period of 32 frames;
- GOP size of 1 (*i.e.*, I-P-P...) using one reference frame;
- Identical configurations for both H.264/AVC and HEVC encoders;
- Random error patterns generated using a two-state Markov Model.

Evaluation of error resilience in HEVC

- Bjontegaard Delta PSNR results with H.264/AVC as reference:

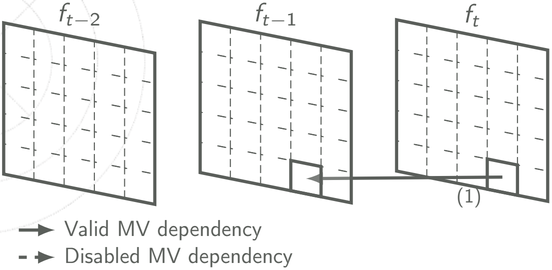
Sequence	HEVC configuration	Error free	1% loss	5% loss
Basketball Drill	Reference	**1.685**	0.149	-0.341
	Without TMVP	**1.572**	0.978	0.875
Book Arrival	Reference	0.876	-0.804	-1.252
	Without TMVP	0.846	0.309	0.357
BQSquare	Reference	1.168	**-2.312**	**-3.785**
	Without TMVP	1.130	0.709	0.616
Kendo	Reference	1.361	-0.927	-1.808
	Without TMVP	1.318	0.716	0.620

- Under error free conditions HEVC clearly outperforms the previous standard, the H.264/AVC;
- In the presence of errors the temporal MV candidate decreases the error robustness of the HEVC standard, achieving lower quality than H.264/AVC.

Dynamic motion vector refreshing in HEVC

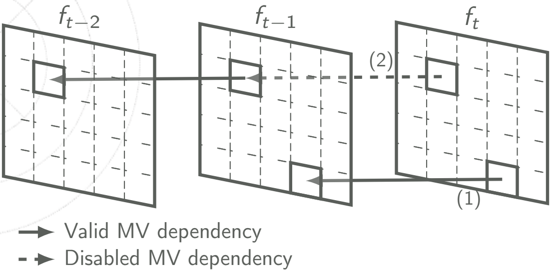
- The proposed method aims to reduce the temporal dependencies between MVs;
- Dependency reduction at the Coding Unit (CU) level for every frame;
- In the proposed method the temporal MV predictor is marked as unusable based on the following:
  - if it is encoded based on another temporal MV candidate from a previous encoded frame;
  - if it is predicted using a spatial neighbour that was previously encoded using a temporal MV candidate.

Dynamic motion vector refreshing in HEVC



- In this case, the MV corresponding to the block (1) may use the temporal MV candidate, since the co-located block in f_{t-1} is not temporally dependent;

Dynamic motion vector refreshing in HEVC



- In this case, the MV corresponding to the block (1) may use the temporal MV candidate, since the co-located block in f_{t-1} is not temporally dependent;
- However, the MV prediction (2) is not allowed in the proposed scheme in order to avoid the propagation of temporal dependencies;

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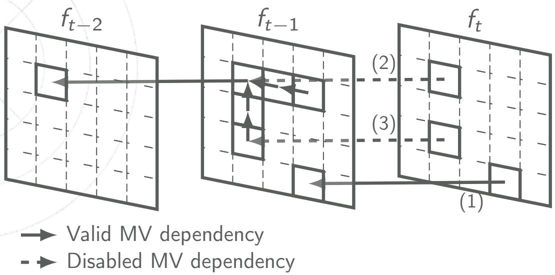
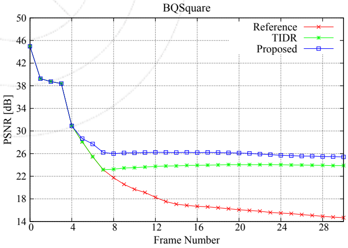
Dynamic motion vector refreshing in HEVC

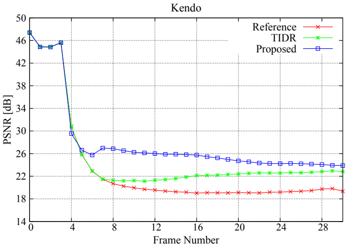


- In this case, the MV corresponding to the block (1) may use the temporal MV candidate, since the co-located block in f_{t-1} is not temporally dependent;
- However, the MV prediction (2) is not allowed in the proposed scheme in order to avoid the propagation of temporal dependencies;
- Moreover, the block (3) cannot use the temporal MV candidate since it already depends on a MV that was previously encoded using a temporal candidate.

Experimental evaluation

- Error propagation under a single frame loss event (lost frame #4) @ 2.5 Mbps:





- Higher quality is achieved when TMVP refresh is applied;
- The proposed method outperforms the TIDR, which only recovers after the refresh frame.

Experimental evaluation

- Decoded frames after a single frame loss event (lost frame #4) @ 2.0 Mbps:

Frame #6

TIDR method
PSNR = 30.37 dB

Proposed method
PSNR = 35.16 dB

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Experimental evaluation

- Decoded frames after a single frame loss event (lost frame #4) @ 2.0 Mbps:

Frame #10

TIDR method
PSNR = 29.35 dB

Proposed method
PSNR = 35.19 dB

Experimental evaluation

- Decoded frames after a single frame loss event (lost frame #4) @ 2.0 Mbps:

Frame #14

TIDR method
PSNR = 29.62 dB

Proposed method
PSNR = 36.25 dB

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Experimental evaluation

- Bjontegaard Delta PSNR results:

Sequence	Merge Mode configuration	Error free	1% loss	5% loss
Basketball Drill	TIDR	-0.0130	0.0924	0.3578
	Proposed	**-0.0639**	0.1973	0.7897
Book Arrival	TIDR	-0.0024	0.0963	0.4324
	Proposed	-0.0144	0.3518	1.4361
BQSquare	TIDR	-0.0064	0.3728	1.3393
	Proposed	-0.0333	**0.4764**	**1.6927**
Kendo	TIDR	-0.0078	0.1535	0.6051
	Proposed	-0.0361	0.3608	1.4510
Race Horses	TIDR	-0.0151	0.1377	0.5429
	Proposed	-0.0416	0.1691	0.6825
Tennis	TIDR	-0.0084	0.0991	0.4388
	Proposed	-0.0463	0.1623	0.7948

- The proposed method presents almost the same rate-distortion performance as TIDR in error free case;
- In case of errors, higher average quality is achieved when the proposed method is used.

Conclusions

- In this work, the HEVC standard was studied and its error resilience ability was evaluated;
- The influence of the motion vector coding in the error robustness was investigated;
- A new approach to address the drawback of the MV coding was proposed analysing the dependencies at the block level;
- The proposed method outperforms the existing techniques under different error conditions;
- The proposed technique may be applied with other error resilience techniques to enhance error robustness.

Thanks for your attention!

João Carreira

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