Methods to improve error resilience in inter-frame High Efficiency Video Coding

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Summary

1. Context and motivation
2. Motion vector redundancies
3. Proposed reference picture selection method
4. Conclusions

Context and motivation

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- The most recent video coding standard (HEVC):
  - high compression efficiency;
  - introduces complex prediction structures.
- Highly predictive coding is more prone to error propagation.

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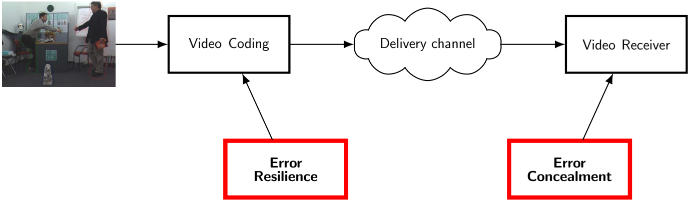
Decreased error robustness and inherent decreasing on video quality.

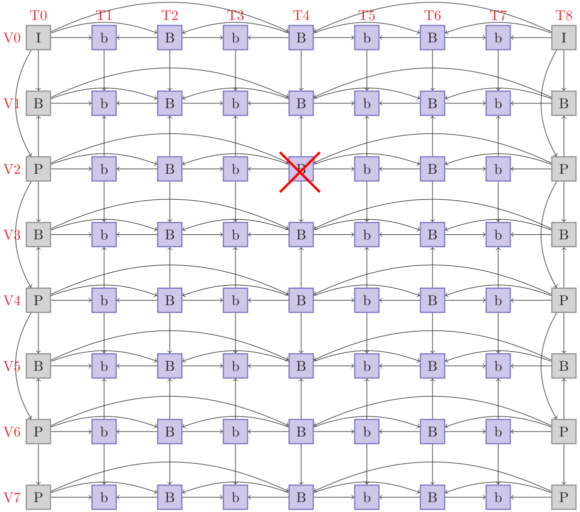
Objectives

- To increase error resilience combined with error concealment in high efficiency video coders.

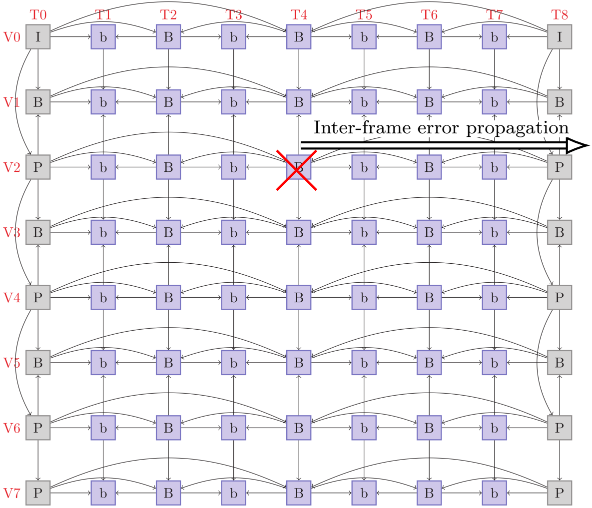
- To investigate the following topics:
    - **source coding level:** enhance the error robustness in the latest coding standard.
    - **error concealment:** cope with the concealment paradigm at the encoder side.



Error propagation



Error propagation



Error propagation

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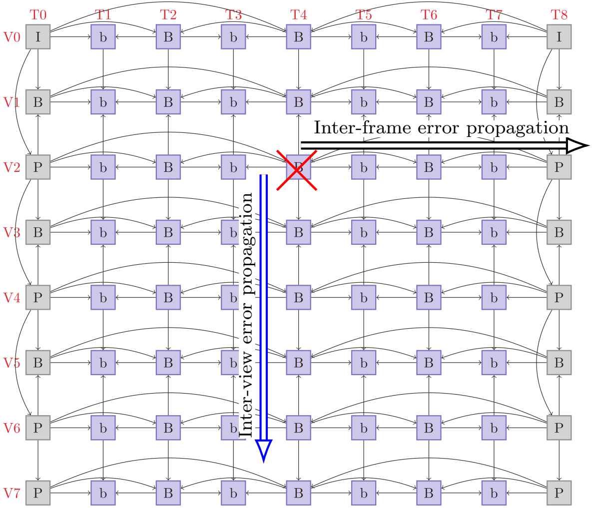
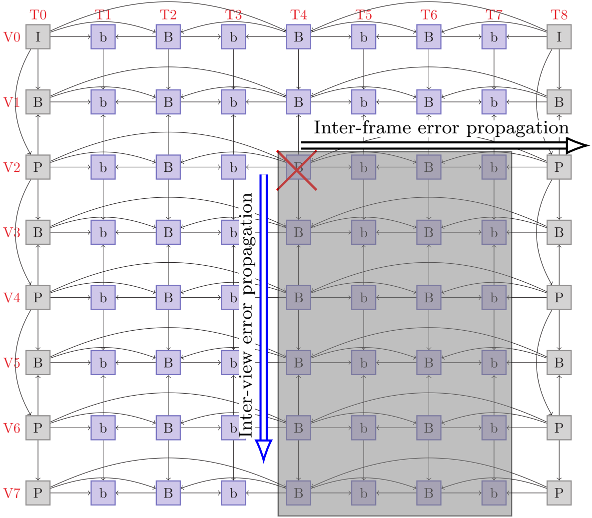


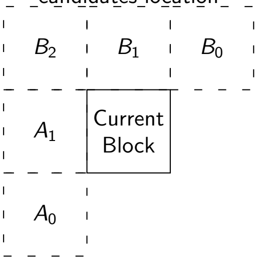
Error propagation

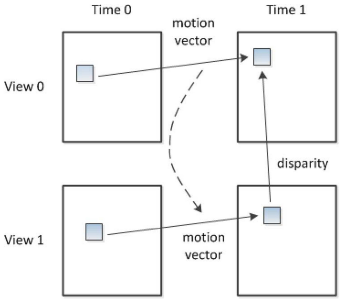


Motion Vector (MV) prediction

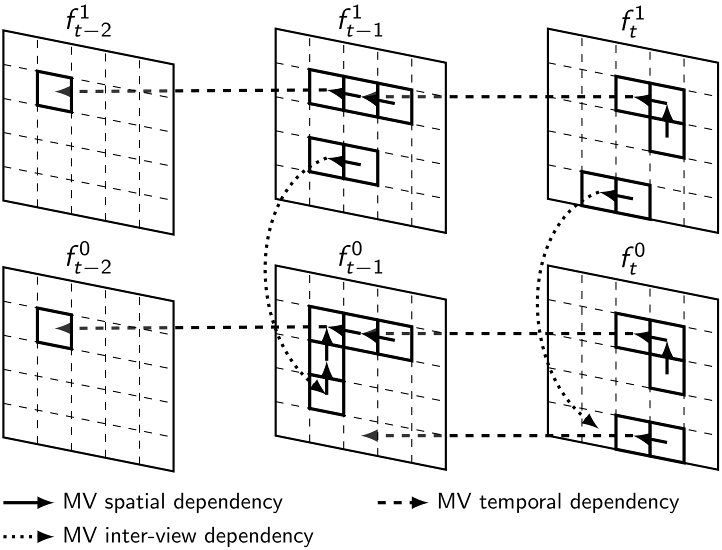
- HEVC introduces the merge mode similar to H.264/AVC SKIP mode.
- More spatial candidates are allowed in HEVC.
- Temporal MV predictor (TMVP).
- In a multiview system inter-view candidates are also supported.

MV spatial candidates location

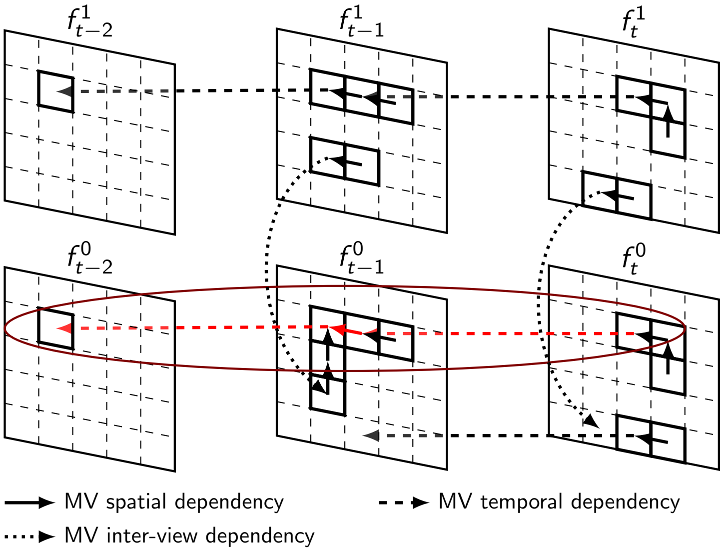




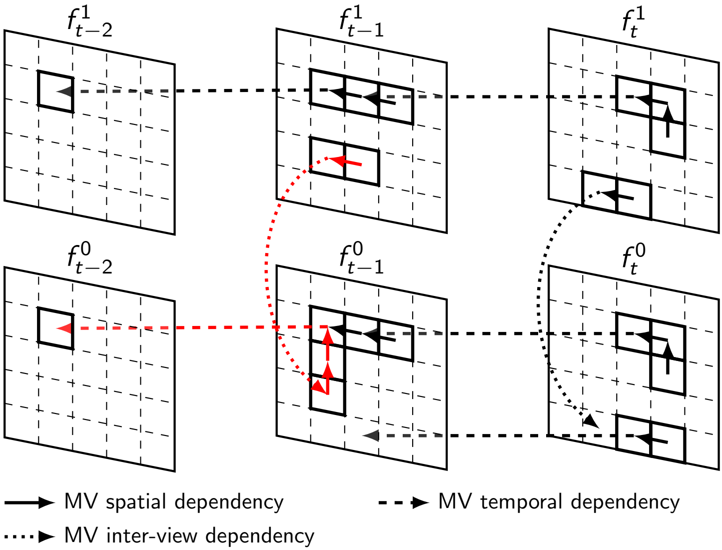
Motion vector dependencies example



Motion vector dependencies example



Motion vector dependencies example

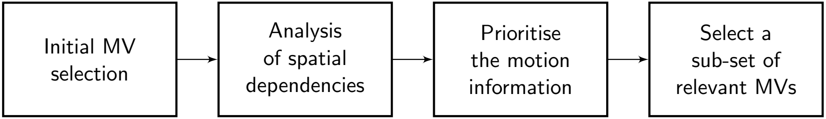


Motion vector redundancies

- **Problem:**
  - Severe error propagation due to a large amount of MV dependencies.
- **Solution:**
  - Break the MV dependencies, by transmitting redundant MVs that can be independently decoded.
  - The selected MVs are transmitted through the SEI messages.

Motion vector prioritization method

- Motion vector redundancies highly increase the overall bitrate.
- Reduce the redundancies with the following method:
  - Spatial dependencies are taken into consideration to prioritise the MVs in terms of error propagation;
  - Select a small sub-set of MVs.



Test conditions

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- Seven test sequences with different kinds of motion and complexity:

Sequence	Resolution	Description
Basketball Drill	832 × 480 50 fps	High motion with several basket ball 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
Kimono	1920 × 1080 24 fps	Person moving next to a moving camera
Race Horses	832 × 480 30 fps	Moderate motion with several horse riders
Park Scene	1920 × 1080 24 fps	Moderate motion with cyclists passing across the scene

- IDR period of 32 frames.
- HEVC common test conditions.
- Random error patterns generated using a two-state Markov model.

Test conditions - methods used

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- The following method were tested:
  - Reference HEVC without redundancy:
  - Using all MVs as redundancy (**100% MVs**)
  - Selecting 30% and 10% of MVs using the **proposed** method.
  - Selecting 30% of MVs uniformly spaced MVs (**Uniform**).

Performance under single loss event

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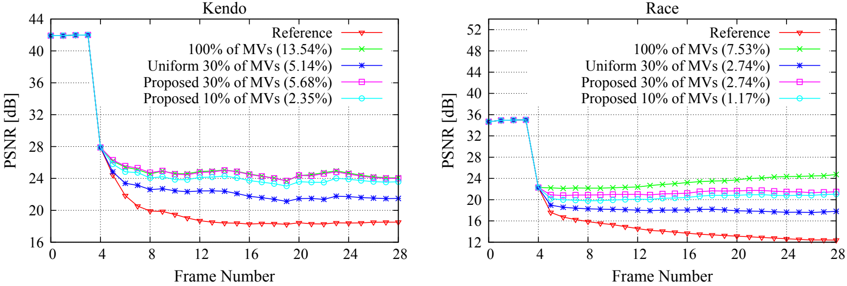

- The proposed method clearly outperforms the uniform selection;
- The proposed selection method with 30% of MV redundancy is able to provide similar robustness to the 100% case.

Motion vector redundancies - Optimization

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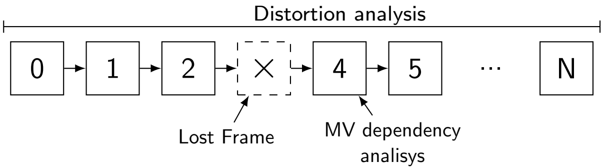


- The quality is evaluated for a group of pictures.
- Lagrangian optimization is performed to select the optimal trade-off between robustness and redundancy ratio:

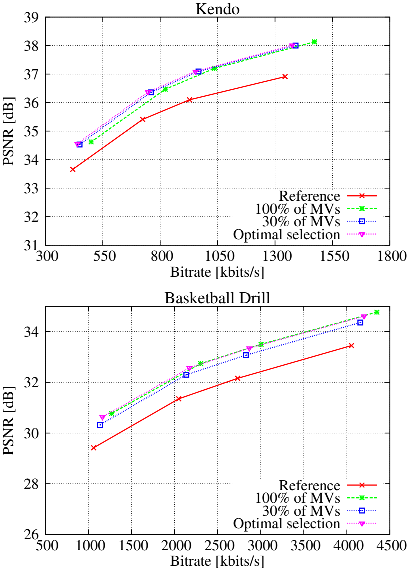
$$J = D + \lambda \times Redundancy$$

Optimal selection - redundancy ratio

- Bjontegaard's Δbitrate is used to measure the amount of redundancy introduced using different methods:

Sequence	**Amount of redundant MVs**		
	100% of MVs	30% of MVs	Optimal selection
Basketball Drill	12.53	4.38	7.17
Book Arrival	9.51	3.53	4.52
BQSquare	11.77	4.49	7.09
Kendo	14.12	5.16	4.95
Race Horses	7.71	2.67	3.18

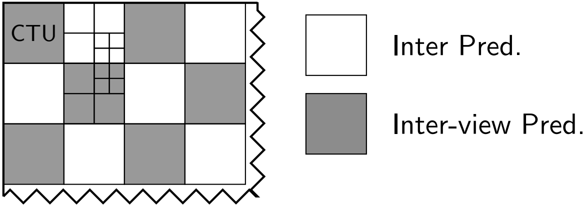
Performance under random loss events



Reference Picture Selection (RPS)

- Error propagation decreases by distributing the inter predictions to several reference frames.

- **Objective:**:
  - Minimize the prediction mismatch.
  - Minimization of $\sigma(\mathbf{X})$, with $\mathbf{X} = [n_1 \ n_2 \ \dots \ n_N]$ and n_i the amount of times the reference frame i was used.



Reference picture selection - Optimization

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- **Problem:**
  - Severe impact on the coding efficiency with a fixed approach.
- **Solution:**
  - Dynamic selection of reference frames.
  - The lagrangian optimization takes into consideration the usage of the reference frame.
  - The following is applied:

$$J = (D + \lambda R) \times K_{global} \times K_{local},$$

  - With K factor:

$$K = \frac{1}{2^{T_{ID}}} \times e^{\gamma . x . 10^{-}3}, \text{ with } x = E\left[\mathbf{X}\right] - n_i,$$

Example of the proposed method

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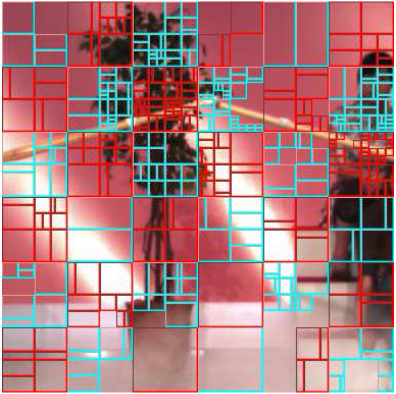
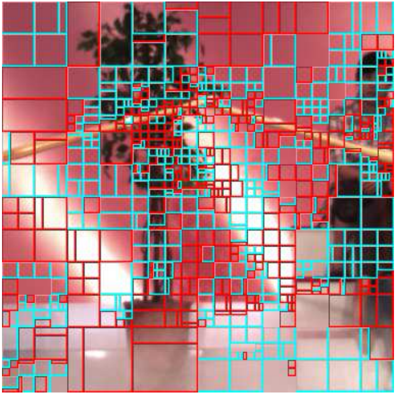
Checkerboard pattern (CHKB)



Proposed method (EXP)



- The red squares indicate that the MV is using the reference f_{t-1} and light blue squares indicate the reference f_{t-2}.

Concealment method

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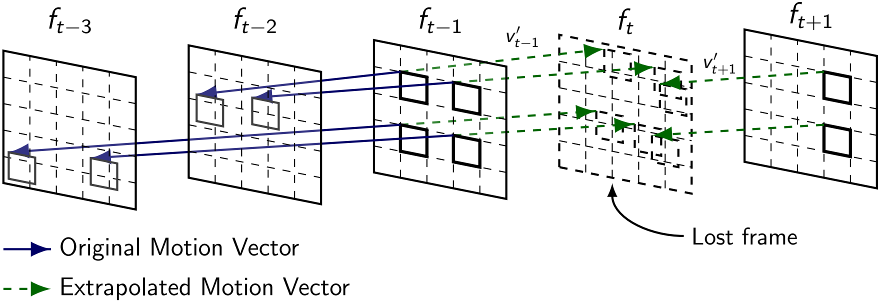

- Motion vector extrapolation from past and future neighbours.
- Motion compensation is applied using the extrapolated MVs.
- The regions on the subsequent frame not affected by errors are used to reconstruct the missing frame using bi-directional prediction.

Reference selection - Coding performance

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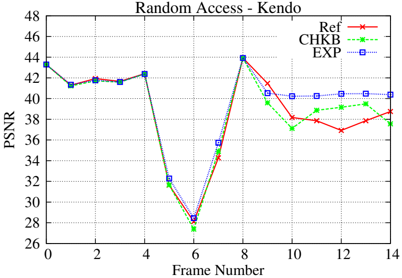
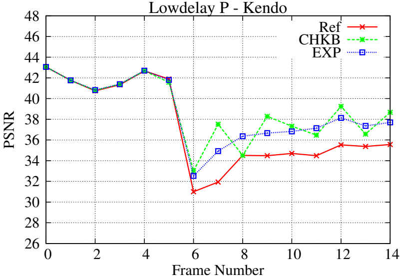
- Bjontegaard's ΔPSNR for different selection algorithms:

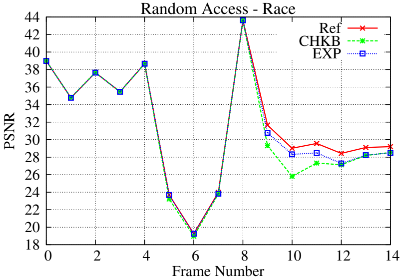
Sequence	Selection method	ΔPSNR Lowdelay	ΔPSNR Lowdelay P	ΔPSNR Random Access
Basketball Drill	CHKB	-0.70	-1.20	-0.29
	EXP	-0.37	-0.56	-0.20
Book Arrival	CHKB	-0.56	-1.12	-0.25
	EXP	-0.35	-0.49	-0.16
BQSquare	CHKB	-0.21	-0.81	-0.35
	EXP	-0.09	-0.08	-0.08
Kendo	CHKB	-0.75	**-1.48**	**-0.48**
	EXP	-0.54	**-0.97**	**-0.28**
Park Scene	CHKB	-0.57	-1.51	-0.35
	EXP	-0.29	-0.81	-0.25
Race Horses	CHKB	-0.85	**-1.37**	**-0.32**
	EXP	-0.44	**-0.89**	**-0.20**

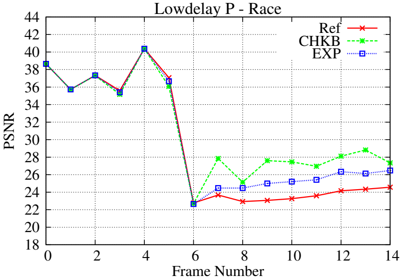
- Using the exponential optimization to select the reference clearly increases the coding performance compared with the fixed approach.

Reference selection - Single loss

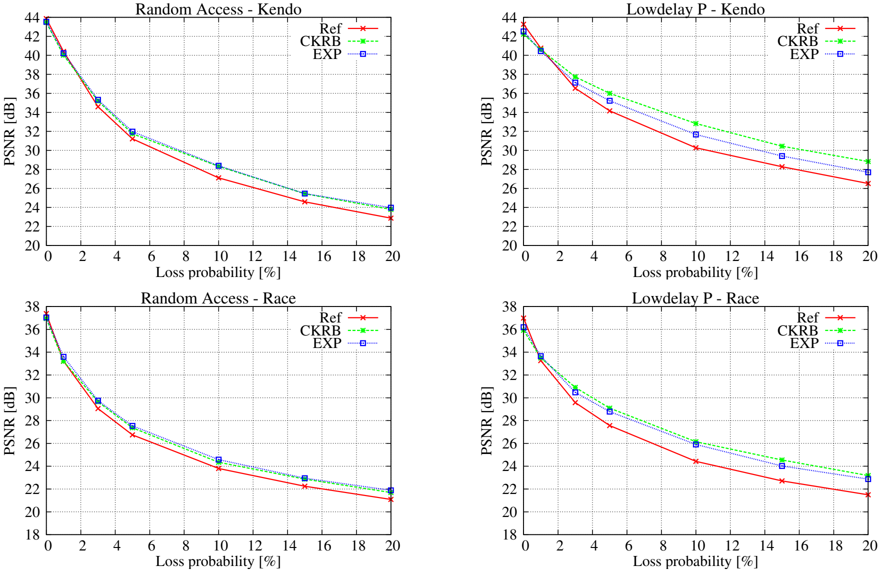








Reference selection - Random packet loss



Conclusions and future directions

- **Conclusions:**
  - High predictive coding standards have low error resilience.
  - The spatial dependencies of MVs are related with the error propagation.
  - The proposed reference picture selection scheme achieves increased error resilience.
- **Future work:**
  - Evaluate the performance of the proposed MV selection algorithm for multi-view.
  - Extend the reference picture selection algorithm to decide between inter and inter-view predictions.

Thanks for your attention!

João Carreira

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