Motion Compensated Error Concealment for HEVC Based on Block-Merging and Residual Energy

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Talk outline

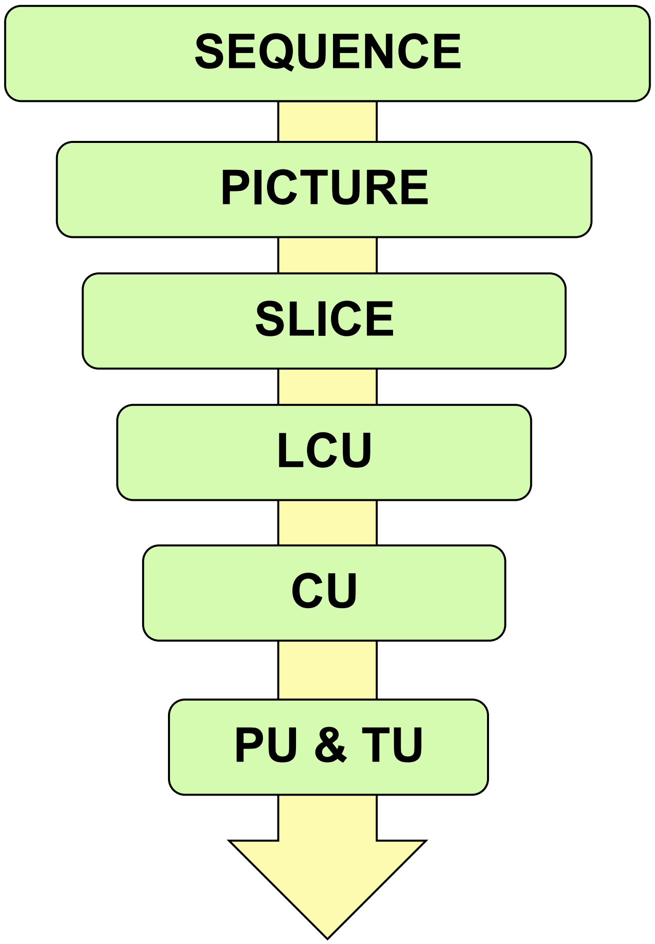
- Overview of HEVC
- Problem formulation
- Proposed method
- Simulation

Overview of HEVC

- HEVC is still under the block-based motion-compensation and transform coding structure, but there is no Macroblock (MB) in the codec.
- The MB concept has been extended by defining three types of variable size unit: Coding Unit (CU), Prediction Unit (PU) and Transform Unit (TU).
- Two encoding modes: intra- and interpicture prediction.

Overview of HEVC

- Largest CU (LCU): size LxL selected by encoder, L= 64, 32, or 16.
- CUs: allow recursive quadtree splitting into multiple sub-CUs, for sizes from 64x64 (CU depth=0) to 8x8 (CU depth=3). Each sub-CU will be specified an encoding mode and can be further split into multiple PUs.
- PUs: basic unit for motion prediction. After PU segmentation, a proper size of TU is determined for residual coding.
- Slice: a series of LCUs, can be delivered and decoded independently.



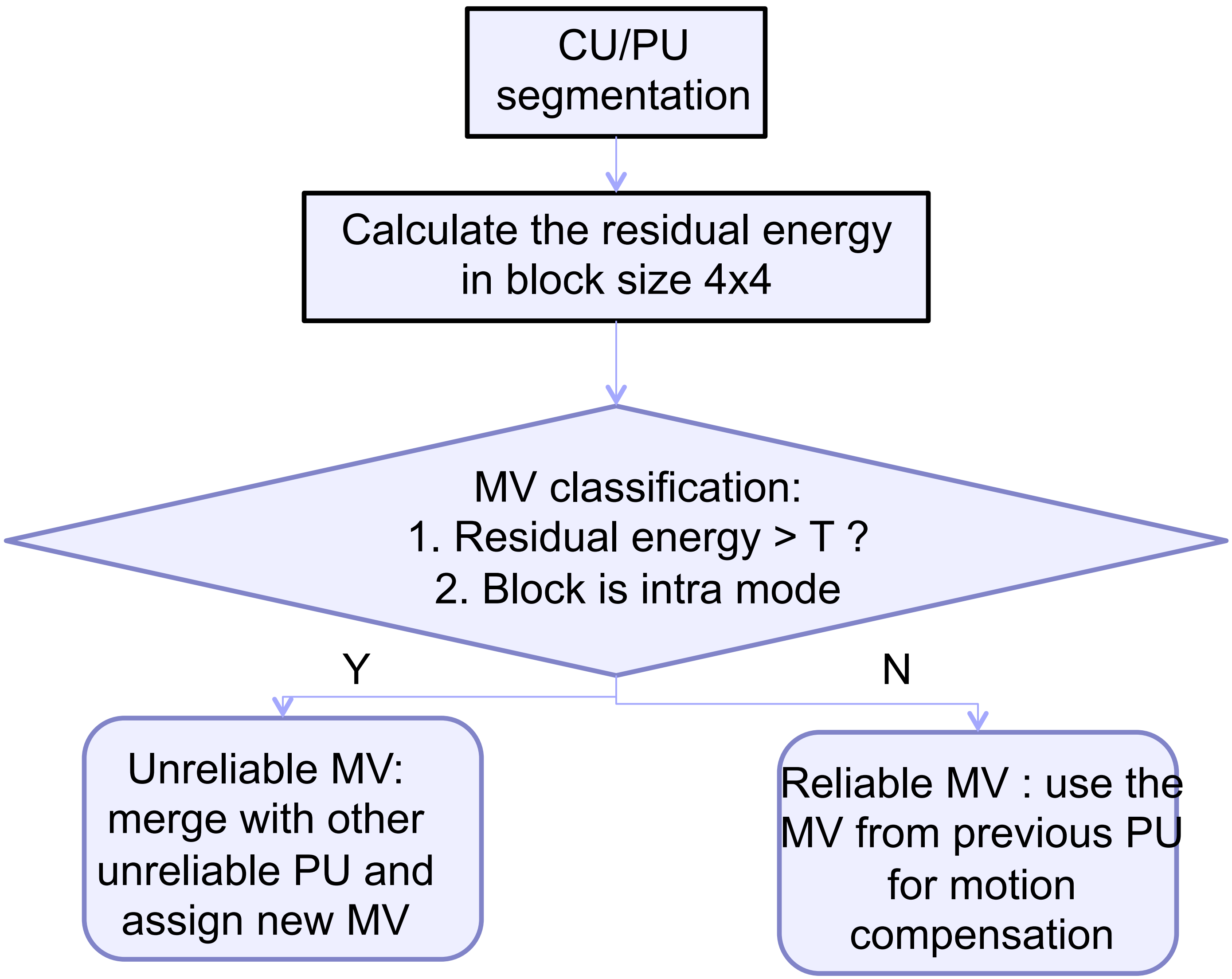
Problem formulation

- Prior error concealments were usually designed for smaller lost blocks and often took the nearby correctly received pixels as reference.
- A loss in HEVC contains at least one LCU, the large lost block makes most of the lost pixels distant from the correctly received pixels, thus the distortion measure between the block edge no longer serves as a good criterion for recovery.

Loss detection

- Frame loss: reference picture buffer will be checked. If loss, frame copy for concealment, implement in HM.
- Slice loss: tracking a slice level syntax slice_segment_address, if there’s discontinuity, slice loss is detected
- Concealment will be based on each LCUs, the info from the co-located area will be reused.

Proposed method



CU/PU segmentation

- For a lost slice, each LCU will be concealed sequentially by the previous diagram.
- Much of the time, the CU depth is highly correlated with its co-located one, and so is PU segmentation.
- We assumes the lost LCU has the same CU partition and PU segmentation as the co-located one in the reference frame.

Motion vector classification based on residual energy

- HEVC uses block-based motion estimation

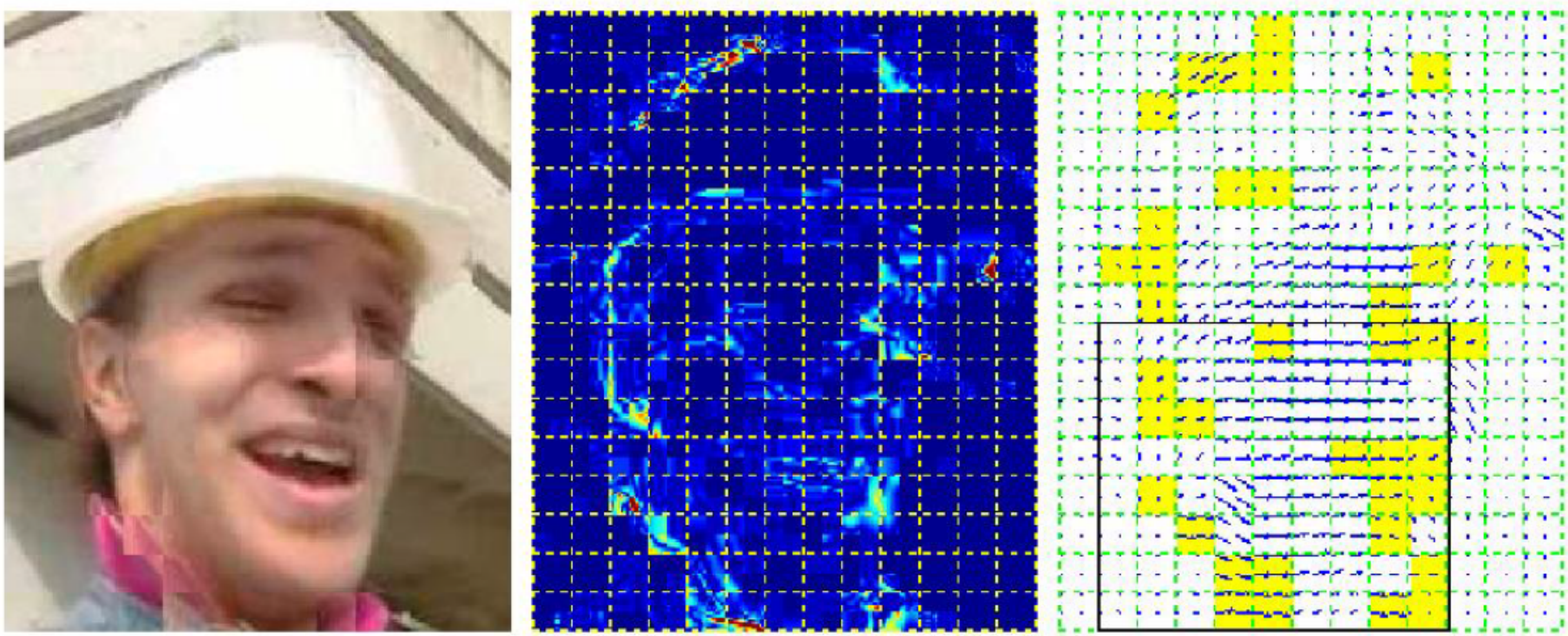
  -> possible that MV doesn't represent true motion.
- PU has high residual energy -> MV may be unreliable
- Residual energy E of co-located CU calculated for each 4x4 block, *bm,n* : used to classify MVs as reliable or not

$$E = \sum_{(i,j)\in b_{m,n}} | r_Y(i,j) |$$

- $r_{Y\ (i;\ j)}$: reconstructed residual signals of the Y component

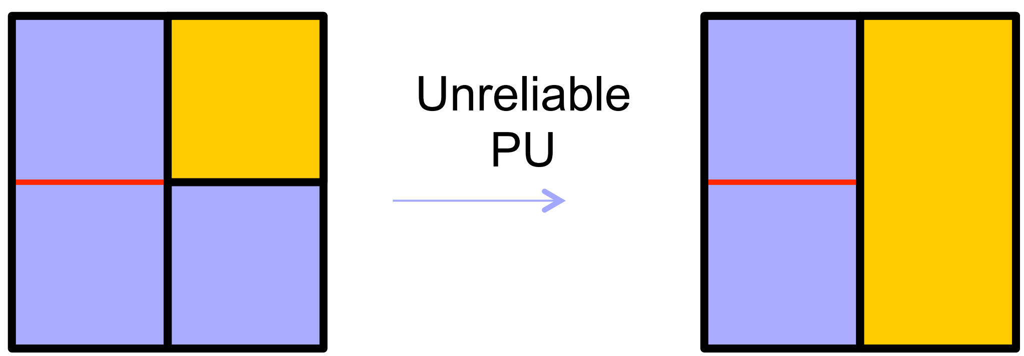
Motion vector classification based on residual energy

- E > threshold : unreliable region
- An intra CU will also be categorized as unreliable.
- Example:



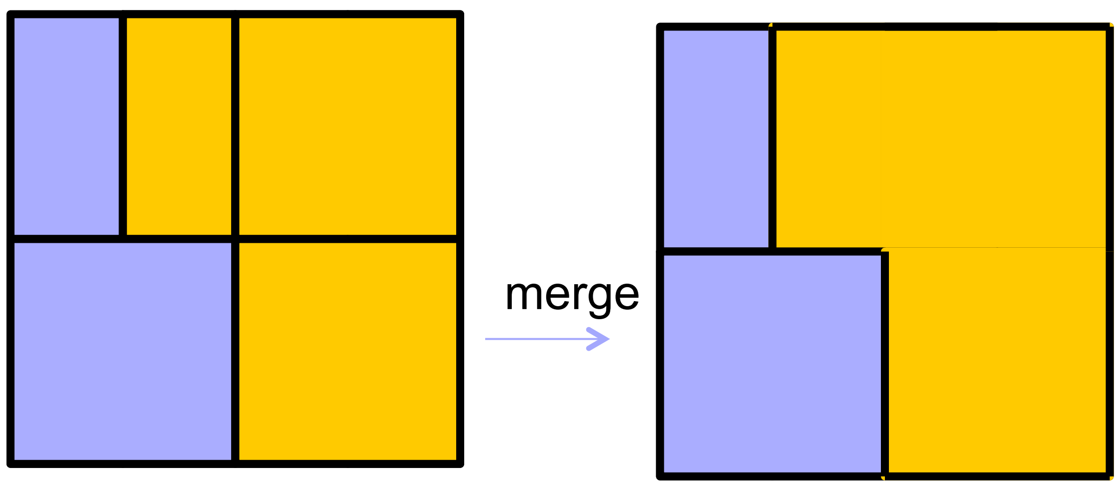
Define unreliable PU

- Residual energy is calculated in the unit of 4x4 block, however, if any block in a PU is unreliable, the whole PU is signaled as an unreliable PU.
- EX: an 8x8 CU contains two 4x8 PUs, the yellow denotes an unreliable block while blue stands for reliable ones



PU Merging and MV reassignment

- Group of adjacent unreliable PUs: misalignment happens easily, and the structure is deformed.
- Unreliable PUs: merged and reassigned with one refined MV, which is the average of its adjacent reliable MVs.
- Example: four 16x16 CUs contains five PUs. The yellow denotes three unreliable PUs, so they are merged into one piece



- Reliable PUs: the MV from the co-located area will be used directly.

Simulation setup

- The proposed method is compared with two other schemes: 1) pixel copy, and 2) basic motion compensation error concealment (MCEC), where the MV from the co-located CU is applied directly with no refinement.
- Two sequences, Soccer (720x480) and Drill (832x480), are encoded by reference software HM 10.0 and simulated under various packet loss rates (PLRs) of 1%, 3%, 5% and 10% for 100 random realizations.

Simulation result

- The table presents the PSNR performance average over all frames for different sequences with different PLRs. The proposed method outperforms others by up to 0.26 dB.

Sequence	Method	Packet Loss Rate			
		1%	3%	5%	10%
Soccer	Copy	28.63	24.58	22.07	19.84
	MCEC	28.56	24.51	21.99	19.77
	Proposed	28.84	24.74	22.28	20.02
Drill	Copy	30.93	27.05	25.32	23.13
	MCEC	30.86	26.97	25.25	23.06
	Proposed	31.17	27.31	25.58	23.34

Simulation result

- The table presents the PSNR performance average over ONLY the first erroneous frame in a GOP for all PLRs. The proposed method outperforms others by up to 1.3 dB.

Sequence	Total number of the first erroneous frame in a GOP from all realizations	**Method**	**PSNR(dB)**
Soccer	2114	Copy	28.84
		MCEC	28.71
		Proposed	29.82
Drill	2184	Copy	30.98
		MCEC	30.81
		Proposed	32.11

Simulation result

- MCEC performs the worst: blocky due to the improper reuse of the co-located MVs.
- The copy method roughly maintains the shape of the object but fails at the boundary of the corrupted area.
- The proposed method successfully preserves the shape of the moving object with smooth edges, and it is effective yet simple without doing edge or object detection explicitly.

Visual Comparison

Copy(22.58dB)

MCEC(22.58dB)

Proposed(27.16dB)