Improving Compression Efficiency Using an Encoder-Aware Motion Compensated Temporal Filter

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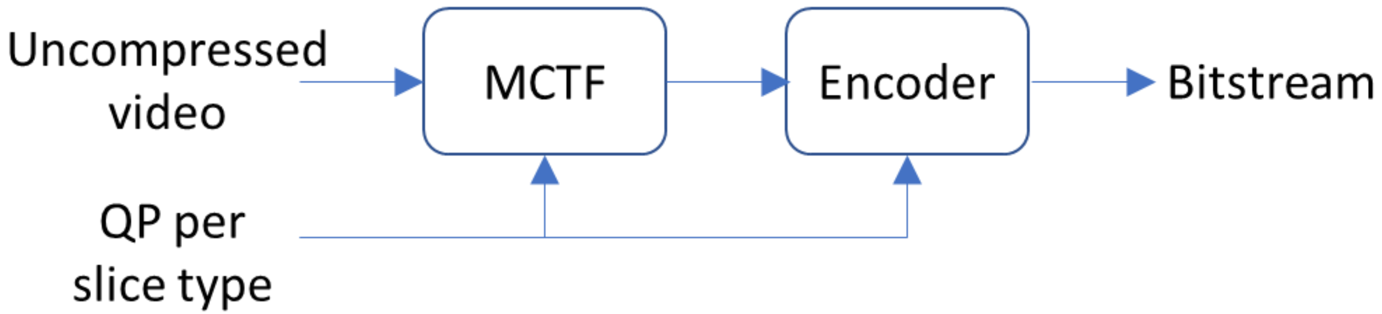
Introduction to Motion Compensated Temporal Filtering (MCTF)

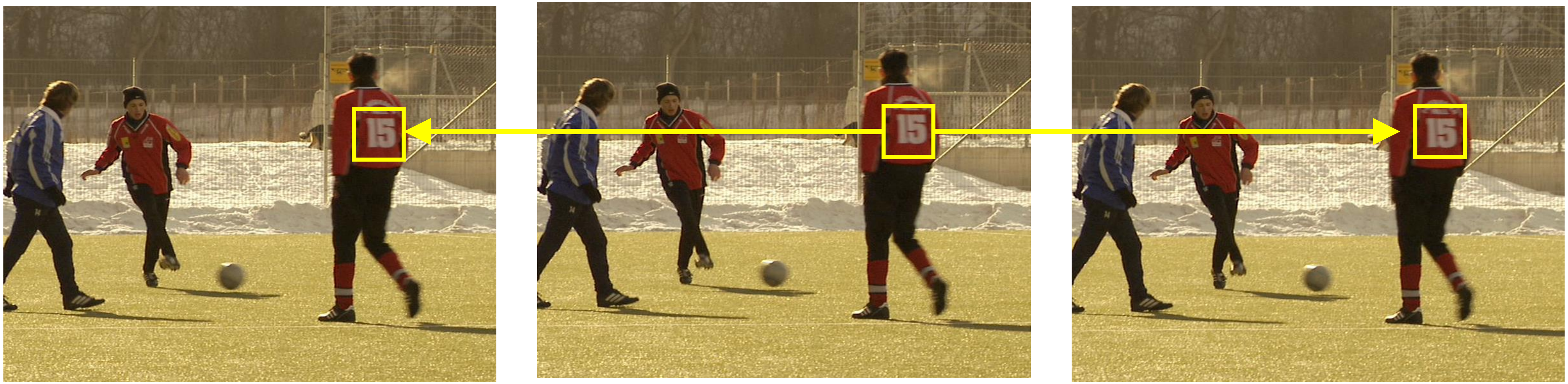
Classical MCTF framework



- MCTF is a pre-processing approach applied on uncompressed video prior to encoding, to improve compression efficiency
- No additionally signaling required for MCTF in the bitstream – players can play MCTF processed streams
- Prior work:
  - MCTF is a mature technology – earliest work in 1980s for pre-processing a DPCM-based video encoder [1]!
  - MCTF also used in more recent encoders: HEVC [2], VVC [3], and AV1 [5]

Introduction to Motion Compensated Temporal Filtering (MCTF)

- MCTF aligns blocks in a frame with matching blocks in neighboring frames
- These aligned reconstructed blocks can better predict neighboring blocks during inter-picture prediction coding
    - Reduces the inter-prediction residual energy
    - Fewer bits required to encode after quantization



Frame “t-1”

Frame “t”

Frame “t+1”

Proposed Encoder-Aware MCTF (EA-MCTF)

Fig 1. Encoder architecture with EA-MCTF

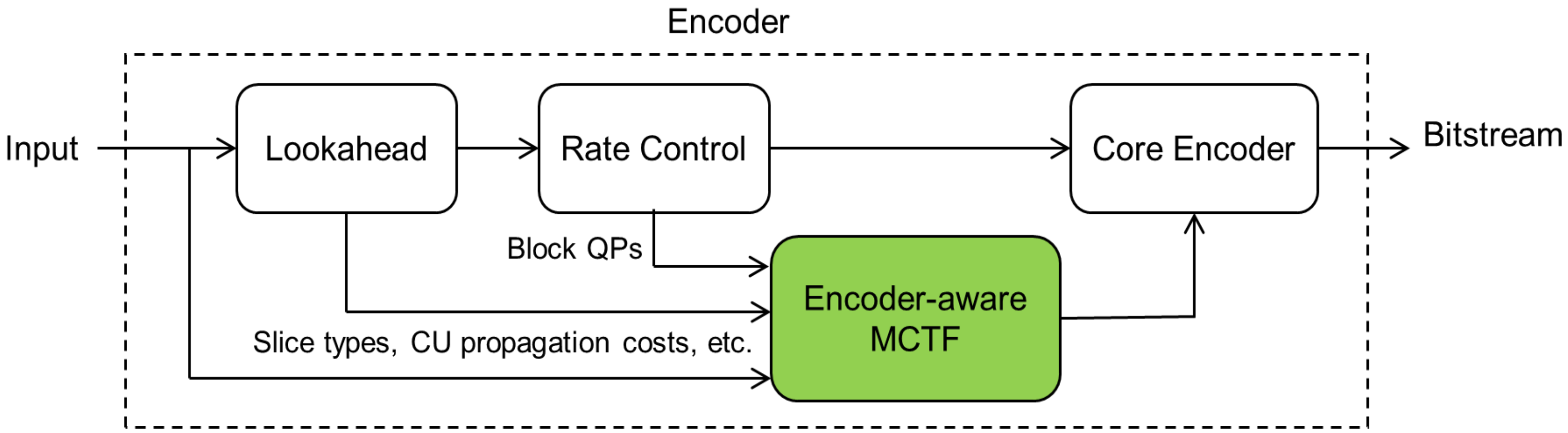
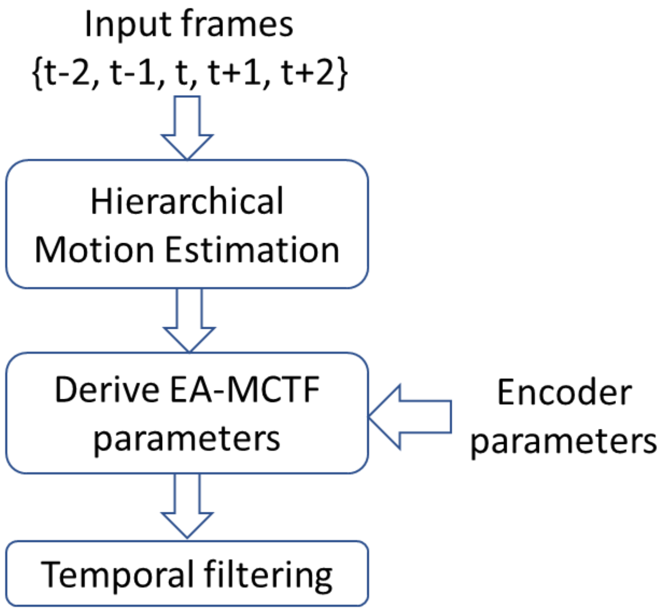


Fig 2. Stages of EA-MCTF



- EA-MCTF integrated into the x265 encoder [7] (open-source HEVC encoder)
  - Classical MCTF operates outside the encoder
- EA-MCTF can access internal encoder parameters for adapting filter on a block-basis
  - Internal encoder parameters include block-level QPs, slice types, CU propagation cost
- EA-MCTF consists of three stages
  - Hierarchical motion estimation on input frames, deriving filter parameters, and temporal filtering

Results

- x265 encoder settings: GOP length = 16, slow preset
- HM-MCTF: Integrated MCTF from HEVC reference software into x265, and modified to use block QPs
- Ten 1080p SDR 8bit test sequences from [8] and [9]
- Performance of EA-MCTF and HM-MCTF over no MCTF ("NO-MCTF") encodes
  - Average BD-rate gain: -12.4% for EA-MCTF vs. -1.9% gain for HM-MCTF. HM-MCTF yields loss on many of the clips
- Encoding with peak bitrate constraint of 9Mbps
  - Encoder bits usage saturates to peak bitrate for complex clips
  - EA-MCTF yields 0.26 average VMAF improvement over NO-MCTF, while HM-MCTF yields no VMAF improvement
- EA-MCTF includes features that trade-off well between speed and performance
  - Average encoding time overhead: 17% for EA-MCTF, 784% for HM-MCTF

Table 1. VMAF BD-rates using the NO-MCTF encodes as the anchor. (Negative value is gain)

1080p sequences	HM-MCTF	EA-MCTF
pedestrian_area	22.30%	-8.30%
rush_hour	10.70%	-8.90%
station2	-49.70%	-50.60%
sunflower	-3.30%	-11.30%
ducks_take_off	9.70%	-1.80%
crowd_run	-2.70%	-7.80%
BasketballDrive	7.80%	-5.70%
Cactus	-14.90%	-18.10%
ArenaOfValor	3.80%	-2.10%
MarketPlace	-2.60%	-9.40%
Average	-1.90%	-12.40%

$\mathrm{CRF}_{\mathrm{MCTF}}$ = {19, 19.5, 20, 20.5}

$\mathrm{CRF}_{\mathrm{NO\text{-}MCTF}}$ = {20, 20.5, 21, 21.5}

References

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9. JVET CTC test sequences, URL: ftp://ftp.ient.rwth-aachen.de.
10. VMAF, URL: https://github.com/Netflix/vmaf.