Block Merging for Quadtree-Based Video Coding

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Overview

- Development of video coding
- New standardization project
- The hybrid coding concept
- Motion model
- Quadtree picture partitioning
- Block merging
- Simulation results
Development of Video Coding

PSNR [dB]

Bit-rate Reduction: 75%

Foreman
10 Hz, QCIF
100 frames

(H.264/AVC, 2003)
(MPEG-2 1994)
(H.261, 1991)

Rate [kbit/s]

(JPEG, 1990)

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Advances in video coding technology

- H.264/AVC standard created in 2003
- Significant advances in technology since 2003
- A new standard is in development

High Efficiency Video Coding (HEVC)

- New project of MPEG and VCEG
- Joint Collaborative Team on Video Coding (JCT-VC)
- Goal: 50% bit rate reduction vs. H.264/AVC High Profile (HP) at the same picture quality
High-Efficiency Video Coding (HEVC)

Project timeline

- **Jan 2010**: Call for proposals issued
- **Apr 2010**: 27 Proposals subjectively evaluated
- **Oct 2010**: Creation of first Test Model (HM1.0)
- **Early 2013**: Intended finalization of standard

Fraunhofer HHI proposal

- One of the 5 best proposals for HEVC
- 30% bit rate reduction vs. H.264/AVC HP
High-Efficiency Video Coding (HEVC)

HEVC Target

- (H.261, 1991)
- (H.264/AVC, 2003)
- (MPEG-2 1994)

Foreman
10 Hz, QCIF
100 frames

Rate [kbit/s]

PSNR [dB]

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The hybrid coding concept

Video Signal input

Split into blocks

Coder Control

Transform/Scal./Quant.

Entropy Coding

Control Data

Quant. Transf. coeffs

Intra/Inter Coder Control

Decoder

Scaling & Inv. Transform

De-blocking Filter

Intra-frame Prediction

Motion Compensation

Motion Estimation

Output Video Signal

Motion parameters

Video Signal input

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Translational motion model

- Motion parameters: \([\Delta t \ \Delta x \ \Delta y]\)
  - \(\Delta t\): Reference picture index
  - \(\Delta x, \Delta y\): Spatial displacement

Parameters signaled for each block:
- 1 vector for uni-predictive coding (P-pictures)
- 2 vectors for bi-predictive coding (B-pictures)
The hybrid coding concept

Video Signal input

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Intra/Inter Coder Control

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Quant. Transf. coeffs

Entropy Coding

Input Video Signal

Output Video Signal

Motion parameters
Quadtree based partitioning

- Simple scheme to allow for multiple block sizes
- Few bits for representation
- Fast quadtree pruning algorithms exist for selecting the optimal tree structure in terms of rate-distortion cost
Drawbacks of simple quadtree partitioning:

- Predefined borders
- Unnecessary divisions
- Unable to jointly code arbitrary partitions

Prediction blocks

Different signal properties call for different models or model parameters.
Some observations

- Differently moving objects, complex motion:
  - Different block parameters
- Quadtree drawbacks, maximum block size:
  - Similar/equal block parameters

Detail of „Cactus“ sequence

Original  Quadtree partitioning  Regions of equal parameters
Partitioning scheme and motion model are simple

- Redundancies among blocks
- Extreme case: equal parameters

Entropy code the parameters

- For each motion vector in current block
  - Derive predictor $p$ from adjacent blocks
  - Only transmit the difference $d$

*Idea:* In case of equal parameters

- Merge current block by copying parameters
Block merging for prediction blocks

- Compensates for drawbacks of quadtree partitioning
- Joins blocks of an initial quadtree decomposition
- Creates regions of equal motion parameters

Similar ideas in literature:
- [Shukla, Dragotti, Do & Vetterli, 2005],
- [De Forni & Taubman, 2005], [Mathew & Taubman, 2010]
Block merging algorithm

- Block X: current block to encode
- Merge candidates: causal neighboring blocks

Merge algorithm

1. Compose set of merge candidates
2. Choose one candidate by using rate-distorsion decision
3. Copy the motion parameters of the corresponding candidate to block X

Detail of "Parkscene" sequence
Region composition
- Seed blocks (S) contain parameters
- Merged blocks (M) copy parameters from S

Signaling
- *Merge flag*: signals if/when merge is used
- *Merge index*: identifies the merge candidate

```plaintext
merge_flag
if ( merge_flag ) {
    merge_index
} else {
    new motion parameters
}
```

Detail of "Parkscene" sequence
Block merging is conceptually similar to direct mode

- Spatial direct mode in H.264/AVC

<table>
<thead>
<tr>
<th>Differences</th>
<th>Set of motion parameters used</th>
<th>Operations</th>
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<tr>
<td>Direct mode</td>
<td>Up to 4 motion vectors for each reference picture</td>
<td>Mean and median calculation</td>
</tr>
<tr>
<td>Block merging</td>
<td>Only one neighboring parameter set</td>
<td>Compare and copy</td>
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- Fraunhofer HHI proposal initially employed a direct mode
- Block merging replaces this direct mode
Common coding conditions as in the HEVC Call for proposals

4 classes of video sequences
- Variety of different content
- Different resolutions (416x240 to 1920x1080 samples)

2 constraint sets (CS)
- Random access: hierarchical B pictures coding
- Low delay: hierarchical P pictures, no picture reordering
Simulation results

Average block merging gain
- Around 3% overall bit rate reduction relative to direct mode
- Independent of resolution, sequence type or bitrate

Overall gain of HHI proposal
- Around 30% compared to H.264/AVC High Profile
Simulation results

Natural video content

- Complex motion
- Distinct, translationally moving objects
- Still or translating background

Block Merging

- Reveals differently moving moving objects
- Efficiently deals with sharp motion object boundaries

„BQMall“ sequence (832x480 pixels)
Conclusion

Block merging with quadtree partitioning

- Simple and efficient way to code motion parameters
- January 2011: Adoption of Block merging in HEVC Test Model (HM2.0)
- March 2011: Adoption of Block merging with SKIP in HEVC Test Model (HM3.0)
- Further studied in ongoing standardization core experiments

Detail of „BQTerrace“ sequence
Are there any questions?

Detail of „Parkscene“ sequence