Fast H.264 to HEVC Transcoder Based on Post-Order Traversal of Quadtree Structure

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Outline

Introduction
Related works
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What is H.264, HEVC and video transcoding?

**H.264** (2003)
- A popular video coding format for various applications

**HEVC** (2013)
- Successor to H.264
- Halved the bit-rate for similar video quality compared to H.264

**Video transcoding**
- Converts a video stream from one format to another

**Why we need to transcode H.264 streams to HEVC?**
- Reduce the bit-rate
- Assure interoperability between systems
The Cascaded Pixel-Domain Transcoding (CPDT) Architecture

The full transcoding architecture **decodes** the H.264 input in pixel domain and **re-encodes** the data in the HEVC format.

**Advantages**
- Easy implementation
- Flexible
- High coding efficiency

**Drawback**
- Very complex computationally

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Franche, Coulombe
Fast H.264 to HEVC Transcoder Based on Post-Order Traversal of Quadtree Structure
Transcoding Architecture Based on Reuse of Extracted Information from H.264

To reduces the transcoding complexity many works reuse extracted information from H.264 to simplify complex encoding tasks.
Transcoding Architecture Based on Reuse of Extracted Information from H.264

Transcoder must adapt the extracted information from H.264 to HEVC coding tools

Table 1: Relevant differences between H.264 and HEVC coding tools

<table>
<thead>
<tr>
<th>Tool</th>
<th>H.264</th>
<th>HEVC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic Unit Size</td>
<td>16 × 16 (MB)</td>
<td>64 × 64* (CTU)</td>
</tr>
<tr>
<td>Inter Partitioning</td>
<td>From 16 × 16 to 4 × 4</td>
<td>From 64 × 64 to 8 × 4 (4 × 8)</td>
</tr>
<tr>
<td>Motion Prediction</td>
<td>Median predictor</td>
<td>AMVP (2 candidates)</td>
</tr>
<tr>
<td>Motion Copy</td>
<td>Skip (1 candidate)</td>
<td>Skip/merge (5 candidates)</td>
</tr>
<tr>
<td>Intra Partitioning</td>
<td>16 × 16, 4 × 4</td>
<td>From 32 × 32 to 4 × 4</td>
</tr>
<tr>
<td>Intra Prediction</td>
<td>Up to 9 predictors</td>
<td>Up to 35 predictors</td>
</tr>
</tbody>
</table>

*CTU size is configurable from 8 × 8 to 64 × 64. In literature, 64 × 64 is a common size.

In practice, the transcoder must achieve a trade-off between the computational complexity reduction and the coding efficiency.
Motion Vector Refinement

Motion search in video encoding

- Motion is unknown
- Requires a large search window

Motion search in video transcoding

- Refines motion from H.264
- Requires a smaller search window

+ Less integer positions evaluated
- Unchanged sub-pixel refinement
- Redundancy in prediction errors computation
Mode Reduction Based on H.264 Information

▶ Several approaches create a mapping between H.264 information and HEVC modes [1–10].
   ▶ Fang et al. use H.264 modes, residuals and variances of motion vectors to disable some prediction unit (PU) modes [1]

+ Reduce a reasonable number of modes.
  – Used alone, the speed-up is limited to 2-3x
Mode Reduction Based on HEVC Information

- In addition to H.264 information, some works consider HEVC information to reduce more modes.
  - Peixoto et al. propose an early termination method based on rate-distortion (RD) cost [3]
- Reduce more modes and achieves greater speed-ups
  - The most promising modes are not firstly processed
    - The CTU quadtree is still processed with a pre-order traversal
Architecture of the proposed transcoder

Our approach is composed of two main contributions:

1. A two stages motion estimation based on motion propagation
2. A fast mode decision framework based on post-order traversal of the CTU quadtree structure
Two Stages Motion Estimation Algorithm

Stage 1 - Operate at the CTU level

- Create a motion vector (MV) candidates list
  - Composed of H.264 MVs, HEVC MVs and MV (0,0)
- Compute the prediction errors for each candidate
  - Interpolate the predicted CTU region
  - Divide the CTU region in $4 \times 4$ blocks
  - Compute and store the sum of absolute transformed differences (SATD) for each $4 \times 4$ block
Two Stages Motion Estimation Algorithm

Stage 2 - Operate at the PU level

- Compute the prediction errors for each candidate
  - Sum the SATD (computed in stage 1) of the $4 \times 4$ blocks covering the PU region
- Select the best combination of MV and AMVP predictors
  - Combination that minimize:
    \[
    J_{PM} = SATD(R) + \lambda_{pred} \times \text{bits}(M)
    \] (1)

$R$ is the difference between the predicted and original blocks, $\lambda_{pred}$ depends on QP and $M$ is the motion information.

Advantages

+ Eliminates computational redundancy
  - Prediction errors are computed only once
+ Very low complexity at PU level
  - No SATD, no interpolation, no motion refinement
Early Termination of the RD Cost Computation

Problem

- Determining motion parameters for a PU is a low-complexity task
- However, determining the RD cost $J_{RD}$ is still a very complex task:

$$J_{RD} = (SSE_Y(\tilde{R}) + 0.57 \cdot SSE_{CbCr}(\tilde{R})) + \lambda_{mode} \times \text{bits (mode)}, \quad (2)$$

$\tilde{R}$ is the difference between the original and reconstructed blocks, $\lambda_{mode} = \lambda_{pred}^2$ and bits (mode) is the number of bits to encode the mode.

Solution

- The RD cost $J_{RD}$ is highly correlated with the SATD cost $J_{PM}$
- We developed an early termination criterion that ends the RD cost computation when:

$$J_{PM}^{current} > (J_{PM}^{best} + T), \text{ where } T \geq 0 \quad (3)$$

* In our simulations, the threshold $T$ was set to : $3\lambda_{pred}$. This value offers a excellent trade-off between speed-ups and coding efficiency
Post-Order Traversal of the CTU quadtree structure

Problem with the pre-order traversal

- The early termination criterion can only be applied when the compared modes have the same size.
- In the pre-order traversal, it impossible to apply this criterion on a CU and a sub-CU

Solution: post-order traversal

- The post-order traversal allows to apply the early termination criterion on the combination of 4 sub-CUs and the CU parent
Mode Reduction based on H.264 information

- HEVC partitions finer than H.264 partitions are disabled
- Intra modes are disabled when the H.264 region contains no intra.
- Inter modes (excepts split/merge modes) are disabled when H.264 region contains no inter.
- AMP modes are disabled since they are time-consuming and have low impact on coding efficiency
Mode Reduction based on HEVC information

- The idea
  - If the current best HEVC mode have a complex partitioning structure, a really more simple partitioning structure is unpromising

- The heuristic
  - When all descendants of the current CU of depth $d$ are processed, the CU is early-terminated if the best mode contains a CU deeper than $d + 1$
## Validation Methodology

<table>
<thead>
<tr>
<th>H.264 Encoder</th>
<th>JM 18.2, baseline, fast full search</th>
</tr>
</thead>
<tbody>
<tr>
<td>HEVC Encoder</td>
<td>HM 12.1, low-delay, fast search</td>
</tr>
<tr>
<td>Configuration</td>
<td>H.264/HEVC common configuration</td>
</tr>
<tr>
<td></td>
<td>▶ Coding structure : IPPP</td>
</tr>
<tr>
<td></td>
<td>▶ QPs : 22, 27, 32, 37</td>
</tr>
<tr>
<td></td>
<td>▶ Reference frames : 1</td>
</tr>
<tr>
<td></td>
<td>▶ Search range : [-64,64]</td>
</tr>
<tr>
<td>Anchor</td>
<td>Full transcoding (CPDT)</td>
</tr>
<tr>
<td>Measures</td>
<td>Transcoding performance measures</td>
</tr>
<tr>
<td></td>
<td>▶ Bjontegaard Delta-Rate (BD-Rate)</td>
</tr>
<tr>
<td></td>
<td>▶ Speed-up based on HEVC encoding time</td>
</tr>
</tbody>
</table>
Performances for $416 \times 240$ sequences

<table>
<thead>
<tr>
<th>Sequence</th>
<th>BD-RATE 2.31%</th>
<th>BD-RATE 2.88%</th>
<th>BD-RATE 1.16%</th>
<th>BD-RATE 2.61%</th>
</tr>
</thead>
<tbody>
<tr>
<td>RaceHorses</td>
<td>10.0</td>
<td>8.6</td>
<td>7.7</td>
<td>6.9</td>
</tr>
<tr>
<td>BasketballPass</td>
<td>11.7</td>
<td>10.0</td>
<td>7.0</td>
<td>5.3</td>
</tr>
<tr>
<td>BQSquare</td>
<td>10.0</td>
<td>9.0</td>
<td>7.2</td>
<td>6.4</td>
</tr>
<tr>
<td>Keiba</td>
<td>11.7</td>
<td>10.0</td>
<td>7.0</td>
<td>6.1</td>
</tr>
</tbody>
</table>

- Blue bar: QP=22
- Red bar: QP=27
- Beige bar: QP=32
- Gray bar: QP=37
Performances for $832 \times 480$ sequences

![Graph showing speed-up and BD-RATE for different sequences and quantization parameters.]

- **RaceHorses**: BD-RATE 4.73%
- **PARTYSCENE**: BD-RATE 2.57%
- **Keiba**: BD-RATE 5.22%
- **FLOWERVASE**: BD-RATE 2.61%

**Legend:**
- Blue柱状图: QP=22
- Red柱状图: QP=27
- Brown柱状图: QP=32
- Gray柱状图: QP=37
Comparison with related works

- Compared to the state of the art approaches:
  - Greater speed-up
  - Better trade-off between speed-up and BD-Rate
- Experimental set-ups are different
  - Different configurations, parameters, sequences, HM version, etc.

<table>
<thead>
<tr>
<th>Speed-up</th>
<th>BD-Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>PROPOSED</td>
<td>7.9x</td>
</tr>
<tr>
<td>CHEN[9]</td>
<td>1.8x</td>
</tr>
<tr>
<td>JIANG[2]</td>
<td>2.0x</td>
</tr>
<tr>
<td>PEIXITO[3]</td>
<td>3.8x</td>
</tr>
</tbody>
</table>
Conclusion

Contributions

- Two stages motion estimation approach
  - No motion refinement, low complexity at PU level
- Fast mode decision framework based on post-order traversal of the CTU
  - Criterion to early terminate the RD cost computation
  - Mode reduction techniques
  - Exploits information from H.264 and HEVC

Future works

- Improve mode reduction techniques
Thanks for your attention! Any questions?

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Reference


