Relying on a rate constraint to reduce Motion Estimation complexity

Gabriel B. Sant’Anna, Luiz Henrique Cancellier, Ismael Seidel, Mateus Grellert, José Luís Güntzel

Embedded Computing Laboratory (ECL)
Dept. of Computer Science and Statistics (INE)
Federal University of Santa Catarina (UFSC)
Florianópolis, Brazil
Outline

1. Video Coding
2. Motion Estimation
3. Rate-based Candidate Elimination
4. Results
5. Conclusions
Outline

1. Video Coding
2. Motion Estimation
3. Rate-based Candidate Elimination
4. Results
5. Conclusions
Video

- Video data: **75% of global internet traffic** back in 2017.
  [Cisco; *Cisco Visual Networking Index: Forecast and Trends; 2019*]
Video data: 75% of global internet traffic back in 2017.
[Cisco; Cisco Visual Networking Index: Forecast and Trends; 2019]

COVID-19: worldwide increase in digital media consumption.
[A. Watson; Consuming media at home due to the coronavirus worldwide; 2020]
Compression

Example: **Full HD**

- 1920x1080 pixels/frame
- 30 frames per second
- 24 bits per pixel
Compression

Example: **Full HD**
- 1920x1080 pixels/frame
- 30 frames per second
- 24 bits per pixel

→ $1920 \times 1080 \times 30 \times 24 \approx 1,5 \text{ Gb/s}$
→ 1 hour of content $\approx 672 \text{ GB}$
Compression

Example: Full HD

- 1920x1080 pixels/frame
- 30 frames per second
- 24 bits per pixel

→ 1920 x 1080 x 30 x 24 ≈ 1,5 Gb/s
→ 1 hour of content ≈ 672 GB
Codecs

2003: H.264
2013: HEVC
2020: VVC

- x 0.61 bitrate
- x 1.5 time

Average values over tested sequences and QPs *

* [I. Siqueira, G. Correa and M. Grellert; Rate-Distortion and Complexity Comparison of HEVC and VVC Video Encoders; 2019]
Goal: Reduce encoder complexity.

→ Motion Estimation algorithm.

Average values over tested sequences and QPs *

* [I. Siqueira, G. Correa and M. Grellert; Rate-Distortion and Complexity Comparison of HEVC and VVC Video Encoders; 2019]
Outline

1. Video Coding
2. Motion Estimation
3. Rate-based Candidate Elimination
4. Results
5. Conclusions
Integer Motion Estimation

Original frame
Integer Motion Estimation

Candidate frame

Original frame
Integer Motion Estimation

\[ j(\vec{m}v) = d(C^{\vec{m}v}) + \lambda \cdot r(\vec{m}v - \vec{m}v') \]
Integer Motion Estimation

\[ j(\vec{m}v) = d(C^{\vec{m}v}) + \lambda \cdot r(\vec{m}v - \vec{m}v) \]

\[ d(C) = \sum_{i=1}^{m} \sum_{j=1}^{n} |C_{i,j} - O_{i,j}| \]
Block-Matching Algorithms

- Various search patterns developed throughout the years.

* Figures: [Amirpour et al.; 2019]
[Koga et al.; 1981]*
[Puri, Hang, Schilling; 1987]*
[Ghanbari; 1990]*

[Po and Ma; 1996]*
[Zhu and Ma, 2000]*
[Zhu, Lin, Chau; 2002]*

* Figures: [Amirpour et al.; 2019]
[Gonçalves et al.; 2018]
Block-Matching Algorithms: OARP

Octagonal-Axis Raster Pattern

[ Gonçalves et al.; Octagonal-Axis Raster Pattern for Improved Test Zone Search Motion Estimation; 2018 ]
Block-Matching Algorithms: OARP

[ Gonçalves et al.; Octagonal-Axis Raster Pattern for Improved Test Zone Search Motion Estimation; 2018 ]
Outline

1. Video Coding
2. Motion Estimation
3. Rate-based Candidate Elimination
4. Results
5. Conclusions
MV bitrate vs. decision distribution

Average block matching distribution
(TZS in HM-16.14)
MV bitrate vs. decision distribution

Average block matching distribution (TZS in VTM-6.2)
MV bitrate vs. decision distribution

\[ j(\vec{mv}) = d(C^{\vec{mv}}) + \lambda \cdot r(\vec{mv} - \vec{mv}_p) \]

Average block matching distribution
(TZS in VTM-6.2)
$j(\vec{m}v) = d(C^{\vec{m}v}) + \lambda \cdot r(\vec{m}v - \vec{m}v_p)$

$\rho = -0.89$
Candidate Elimination criterion

\[ j(\tilde{m}, \tilde{v}) = d(C^{\tilde{m}, \tilde{v}}) + \lambda \cdot r(\tilde{m}, \tilde{v} - m, v) \]

\[ r(\tilde{m}, \tilde{v} - m, v) > t \]

Average block matching distribution
(TZS in VTM-6.2)

Bitrate surface

Average block matching distribution

Bitrate surface

(TZS in VTM-6.2)
Candidate Elimination criterion

\[ j(\vec{mv}) = d(C_{r,v}) + \lambda \cdot r(\vec{mv} - \vec{mvp}) \]

![Average block matching distribution (TZS in VTM-6.2)](image1)

![Bitrate surface](image2)

\[ r(\vec{mv} - \vec{mvp}) > t \]
Outline

1 Video Coding
2 Motion Estimation
3 Rate-based Candidate Elimination
4 Results
5 Conclusions
Setup

**Common Test Conditions**  
[Bossen et al., 2019]

- VVC reference implementation: VTM 6.2
- 17 test sequences
- 4 QPs: {22, 27, 32, 37}
- 2 configurations (RA and LDP)
- Octagonal pattern replicated in VTM

→ 408 experiments
Encoding Efficiency vs. Complexity Reduction

- Results for all tested sequences in both RA and LDP configurations. $t = 4$
Results - RA

- BD-Rate over 1% with $t=4$
Results - RA

- **BD-Rate over 1% with t=4**
- **Threshold variation**

### Results - RA

- Search region similar to that of the Octagonal-axis pattern
- Comparable quantitative results
Results - LDP

- **86%** average complexity reduction
- **0.74%** average BD-Rate
  - Under 0.5% for most sequences
  - Exceptions being slide content videos

<table>
<thead>
<tr>
<th>Class</th>
<th>$t = 4$</th>
<th>Octagonal-axis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BDBR</td>
<td>$\Delta C$</td>
</tr>
<tr>
<td>B</td>
<td>0.18</td>
<td>87.8</td>
</tr>
<tr>
<td>C</td>
<td>0.22</td>
<td>88.8</td>
</tr>
<tr>
<td>D</td>
<td>0.20</td>
<td>86.5</td>
</tr>
<tr>
<td>E</td>
<td>0.04</td>
<td>82.3</td>
</tr>
<tr>
<td>F</td>
<td>3.44</td>
<td>87.3</td>
</tr>
</tbody>
</table>

LDP: per-classe average results
Outline

1. Video Coding
2. Motion Estimation
3. Rate-based Candidate Elimination
4. Results
5. Conclusions
Conclusions

- **Flexible** candidate elimination technique: can be applied on top of existing block-matching algorithms.

- Rate threshold can be parameterized to suit specific applications and constraints.

- With an elimination criterion that can be very efficiently computed.

- Relates the precision of IME search patterns to the estimated MV bitrate cost surface.
References


Relying on a rate constraint to reduce Motion Estimation complexity

Gabriel B. Sant’Anna, Luiz Henrique Cancellier, Ismael Seidel, Mateus Grellert, José Luís Güntzel

Thank you!