Relying on a rate constraint to reduce Motion Estimation complexity

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Canada
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Outline

Outline

Video

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

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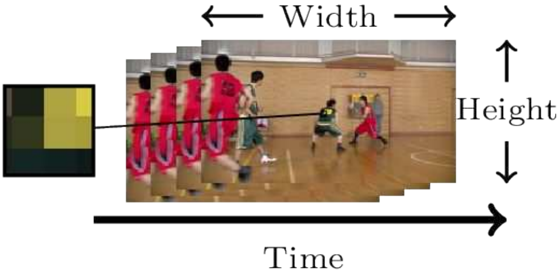
COVID-19: worldwide increase in digital media consumption.
[A. Watson; *Consuming media at home due to the coronavirus worldwide*; 2020]

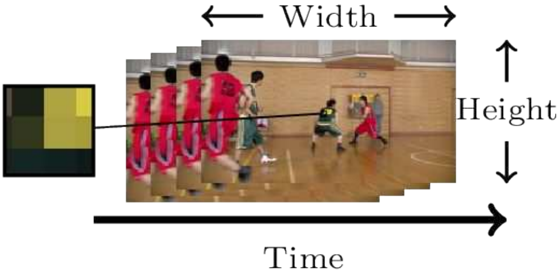
Compression

Example: **Full HD**

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



Compression



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➔ 1920 x 1080 x 30 x 24 ≅ **1,5 Gb/s**
➔ 1 hour of content ≅ **672 GB**

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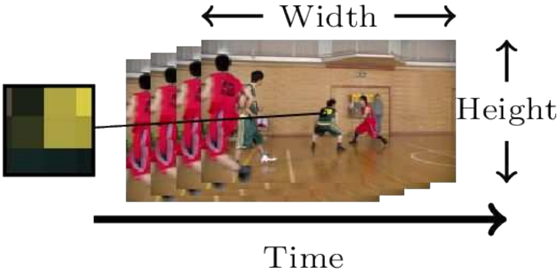

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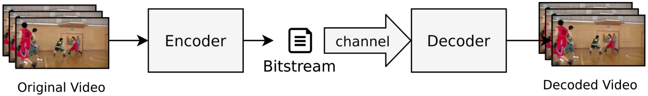

Codecs

2003 — H.264 MPEG-4/AVC → 2013 — HEVC → 2020 — VVC

ISO, ITU

H.264 → HEVC:
x 0,61 bitrate
x 1,5 time

HEVC → VVC:
x 0,56 bitrate
x 10 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]

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Average values over tested sequences and QPs *

- ➔ Goal: **Reduce encoder complexity.**
  - ➔ **Motion Estimation** algorithm.

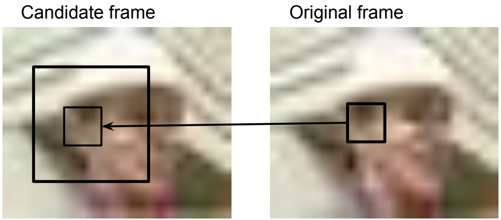
* [I. Siqueira, G. Correa and M. Grellert; *Rate-Distortion and Complexity Comparison of HEVC and VVC Video Encoders*; 2019]

Outline

Integer Motion Estimation

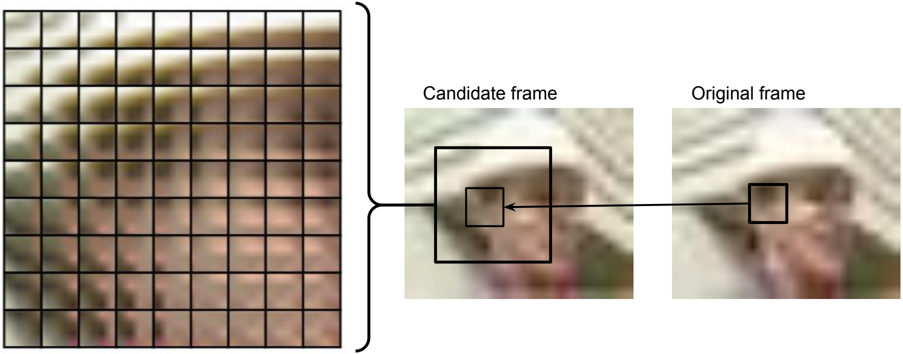
Original frame

Integer Motion Estimation



Integer Motion Estimation

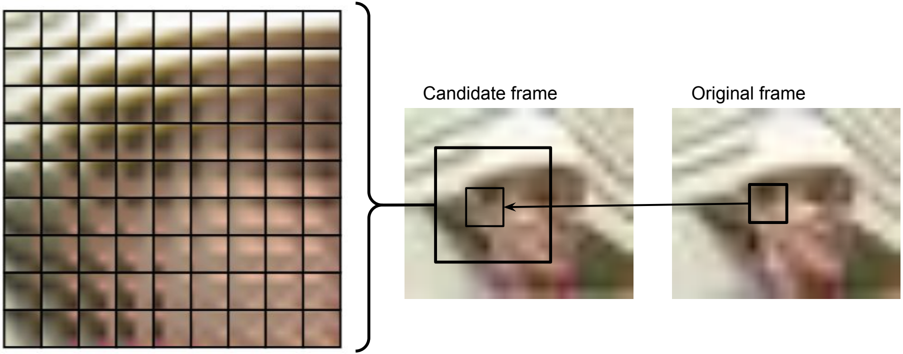
$$j(\vec{mv}) = d(\mathbf{C}^{\vec{mv}}) + \lambda \cdot r(\vec{mv} - \vec{mvp})$$



Integer Motion Estimation

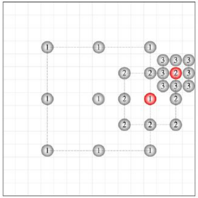
$$j(\vec{mv}) = \boxed{d(\mathbf{C}^{\vec{mv}})} + \lambda \cdot r(\vec{mv} - \vec{mvp})$$

$$d(\mathbf{C}) = \sum_{i=1}^{m}\sum_{j=1}^{n} |\mathbf{C}_{i,j} - \mathbf{O}_{i,j}|$$

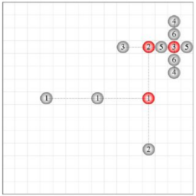


Block-Matching Algorithms

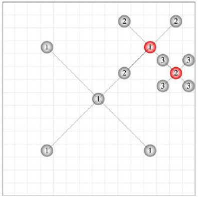
- Various search patterns developed throughout the years.



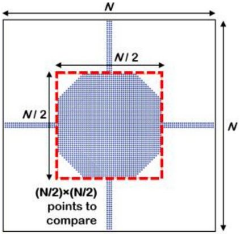
[Koga et al.; 1981]*



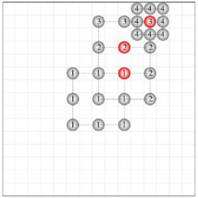
[Puri, Hang, Schilling; 1987]*



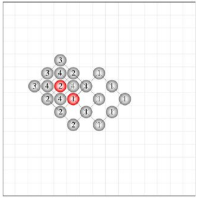
[Ghanbari; 1990]*



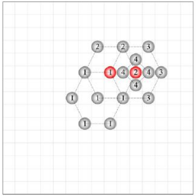
[Gonçalves et al.; 2018]



[Po and Ma; 1996]*



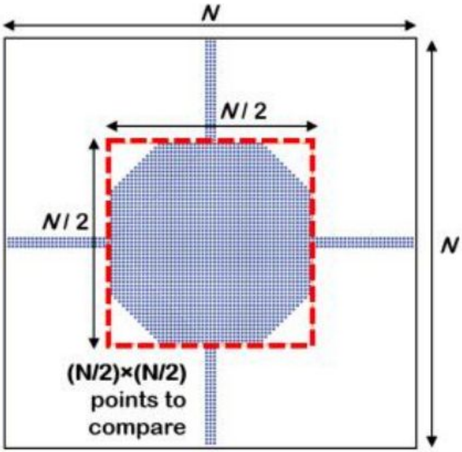
[Zhu and Ma, 2000]*



[Zhu, Lin, Chau; 2002]*

* Figures: [Amirpour et al.; 2019]

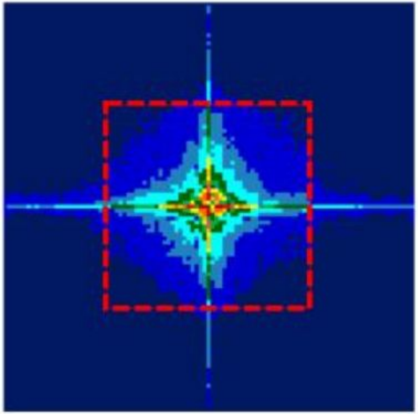
Block-Matching Algorithms: OARP



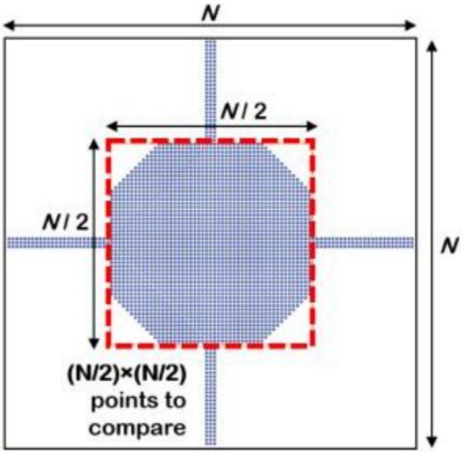
Octagonal-Axis Raster Pattern

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

Block-Matching Algorithms: OARP



Average block matching distribution



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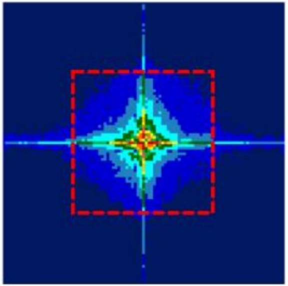
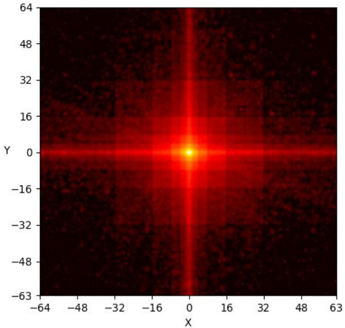
Outline

MV bitrate vs. decision distribution



Average block matching distribution
(TZS in HM-16.14)

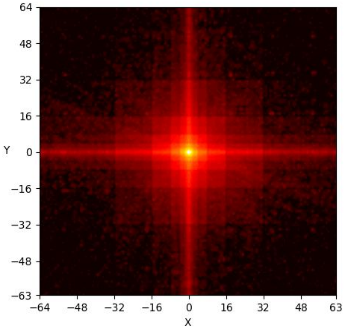
MV bitrate vs. decision distribution



Average block matching distribution
(TZS in VTM-6.2)

MV bitrate vs. decision distribution

$$j(\vec{mv}) = d(\mathbf{C}^{\vec{mv}}) + \lambda \cdot \boxed{r(\vec{mv} - \vec{mvp})}$$



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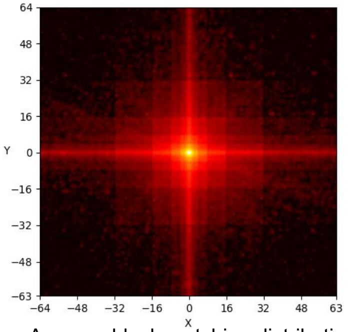
ρ = −0.89



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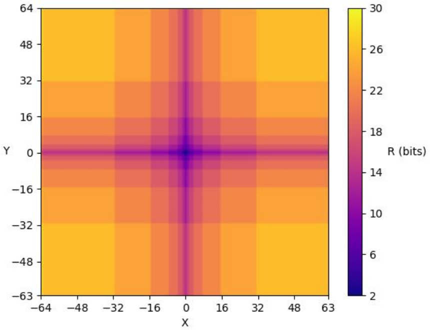
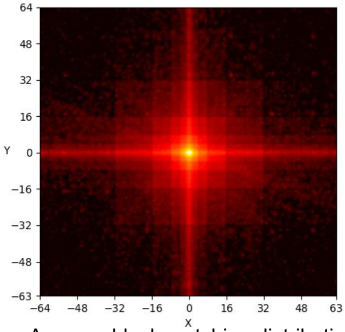


Bitrate surface

Candidate Elimination criterion

$$j(\vec{mv}) = d(\mathbf{C}^{\vec{mv}}) + \lambda \cdot \boxed{r(\vec{mv} - \vec{mvp})}$$

$$\boxed{r(\vec{mv} - \vec{mvp}) > t}$$



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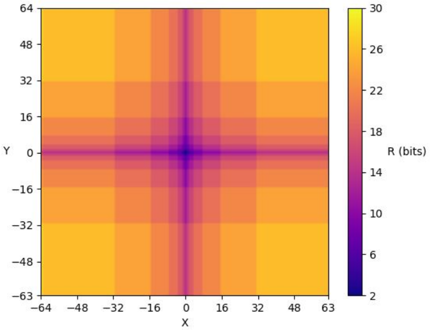

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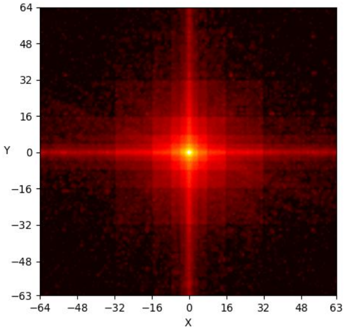

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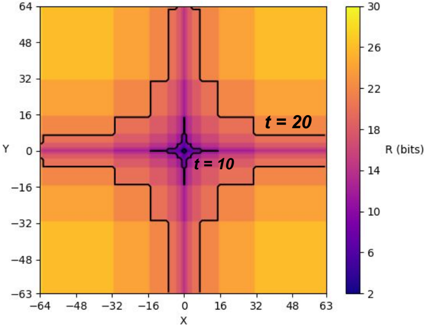


Bitrate surface

Outline

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

Setup

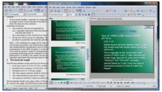
Common Test Conditions

[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











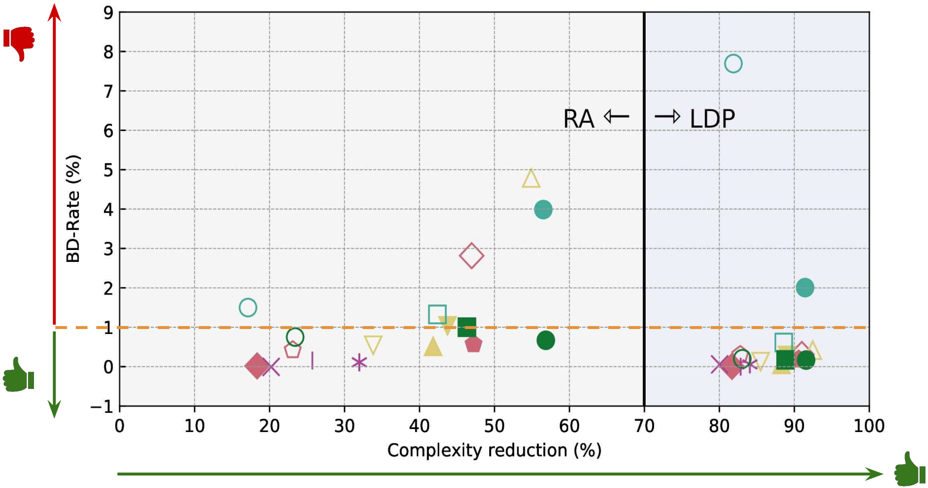






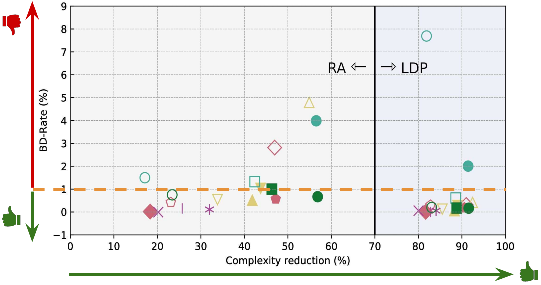

Encoding Efficiency vs. Complexity Reduction

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



Results - RA

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

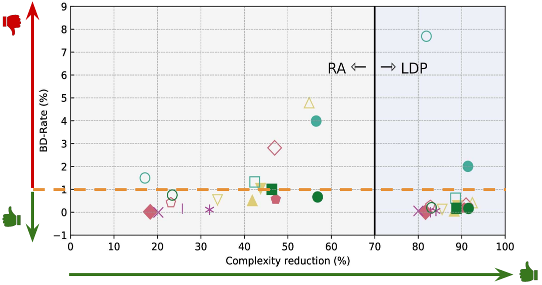


Results - RA

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

Sequence	$t = 20$		Octagonal-axis	
	BDBR	ΔC	BDBR	ΔC
Cactus	0.12	28.8	0.02	26.2
BballDrill	0.14	23.4	0.01	22.2
BballDrillTxt	0.09	22.9	-0.04	21.2
SlideEdit	0.63	6.8	0.03	6.1
RHorses	0.35	25.1	0.02	22.5
SShow	0.88	42.5	-0.05	36.4
RHorsesC	0.70	33.9	0.10	30.2

RA: threshold variation to limit BD-Rate increase



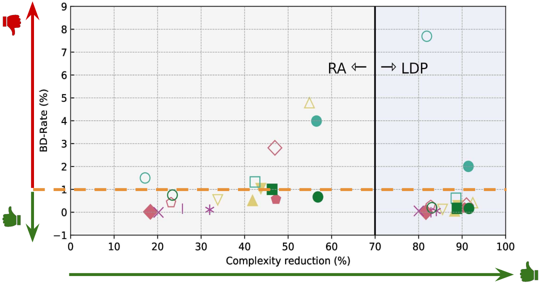
- Search region similar to that of the Octagonal-axis pattern
- Comparable quantitative results

Results - LDP

- **86%** average complexity reduction
- 0,74% average BD-Rate
  - Under 0,5% for most sequences
  - Exceptions being **slide content videos**

Class	$t = 4$		Octagonal-axis	
	BDBR	ΔC	BDBR	ΔC
B	0.18	87.8	0.02	13.9
C	0.22	88.8	0.00	15.2
D	0.20	86.5	0.04	10.7
E	0.04	82.3	-0.04	6.5
F	3.44	87.3	0.37	16.4

LDP: per-classe average results



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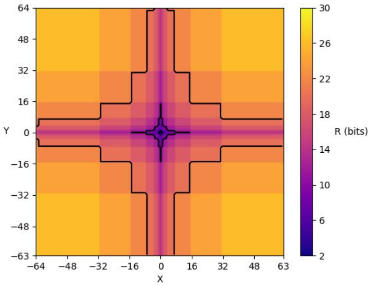
Conclusions

- **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

[1] Hadi Amirpour et al. "Motion estimation with chessboard pattern prediction strategy". In: *Multimedia Tools and Applications* 78.15 (2019), pp. 21785–21804.

[2] F. Bossen et al. *JVET common test conditions and software reference configurations for SDR video.* Document JVET-N1010. Geneva: JVET of ITU-T, 2019. URL: http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=6643.

[3] Cisco. *Cisco Visual Networking Index: Forecast and Trends, 2017–2022 White Paper.* https://web.archive.org/web/20190820234616/https://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/white-paper-c11-741490.html. Accessed: 20 Aug. 2019. 2019.

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[5] I. Siqueira, G. Correa, and M. Grellert. "Rate-Distortion and Complexity Comparison of HEVC and VVC Video Encoders". In: *2020 IEEE 11th Latin American Symposium on Circuits Systems (LASCAS)*. 2020, pp. 1–4.

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