Review and evaluation of VVC fast partitioning search methods using a common baseline

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VVC Partitioning Complexity

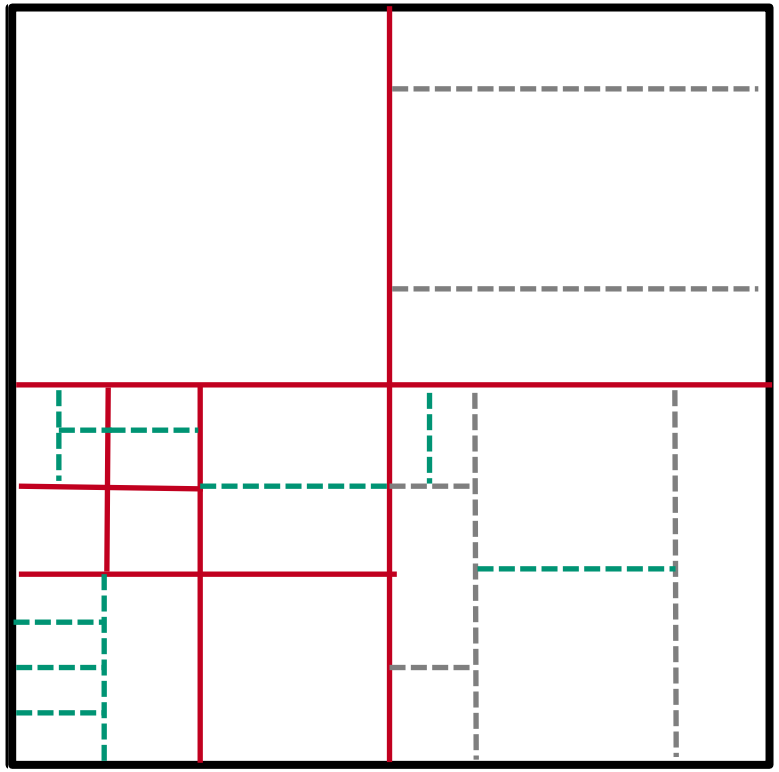
Quadtree (QT) plus Multi-Type Tree (MTT)

Flexible block partitioning major part of the new

Versatile Video Coding Standard (H.266 / VVC)

- Picture divided into **Coding Tree Units (CTU)**
  - square, fixed size e.g. 128x128
- CTU partitioned using a **Quadtree (QT)**
  - same as in H.265 / HEVC
- QT leaf is root of the nested **Multi-Type Tree (MTT)** with

binary split or ternary split

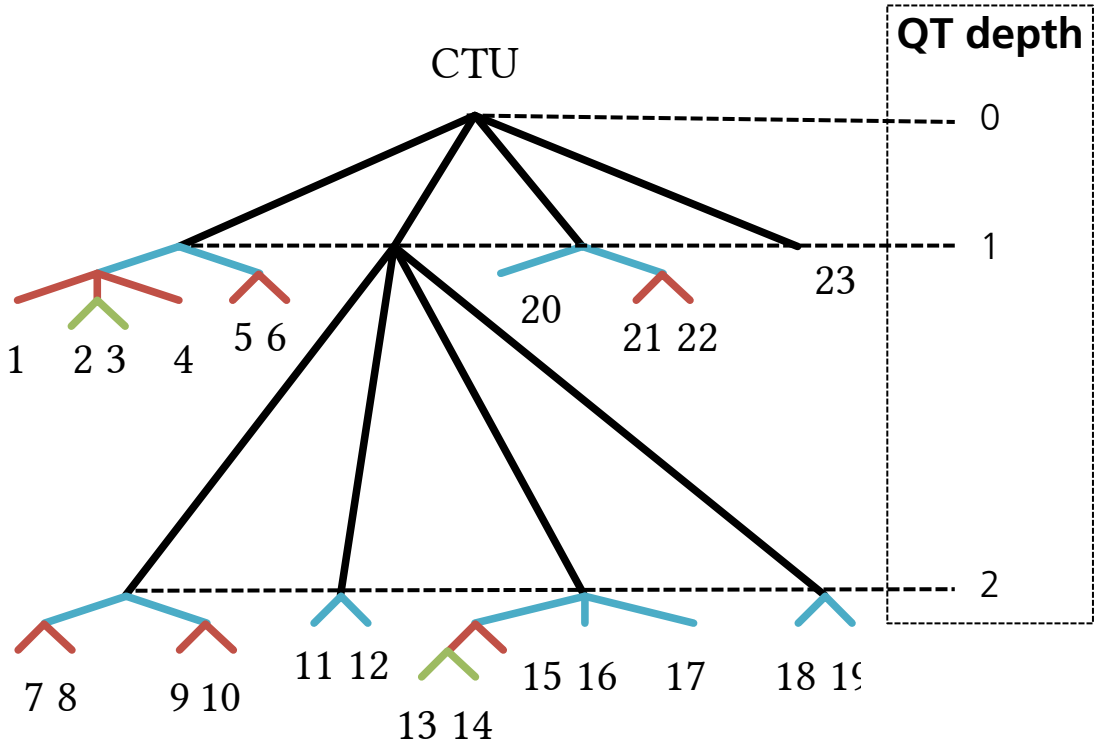


VVC Partitioning Complexity

QT and MTT depths

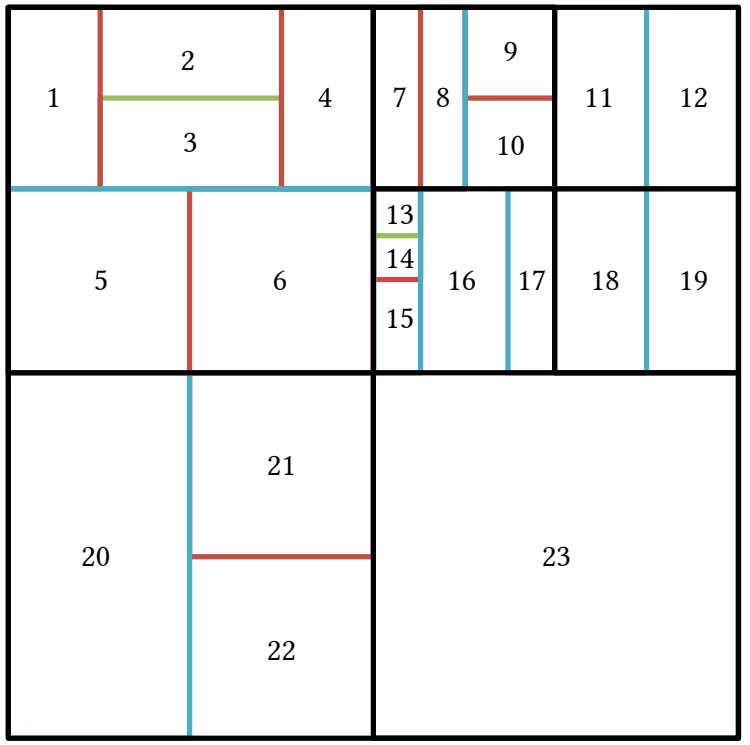
Partitioning depth has major impact on

Complexity



MTT depth

1 - 2 - 3



VVC Partitioning Complexity

Analysis by Wieckowski et al., TCE, 2023

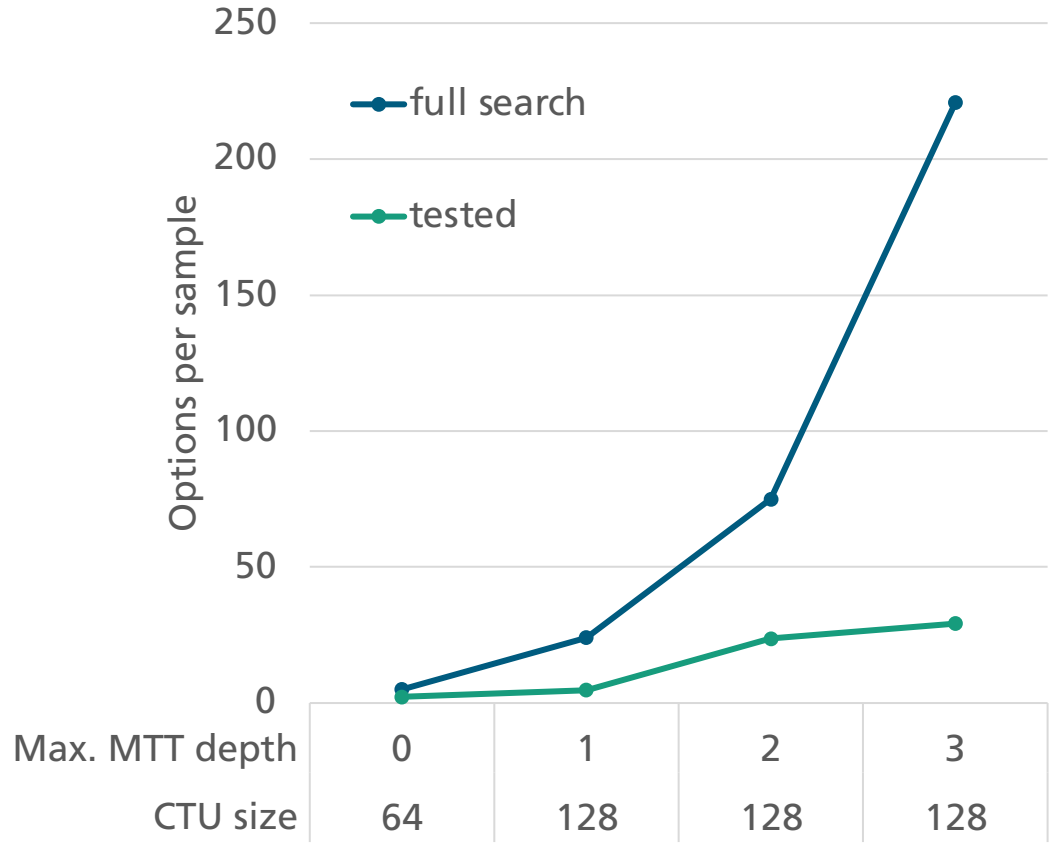
Full search complexity (forward-only, recursive)

- **Increases exponentially with max. MTT depth**
- HEVC partitioning corresponds to MTT depth 0 and CTU size 64x64

Tested options:

- Close to full search in HEVC reference encoder (HM)
- Significantly lower for higher MTT depth in the VVC reference encoder (VTM)
- Partitioning search in VTM already quite optimized

Max. MTT depth is the most important control parameter for VVC partitioning complexity control



Proposal: Common baseline for fast partitioning algorithm

To improve comparability and general performance assesment

Proposal

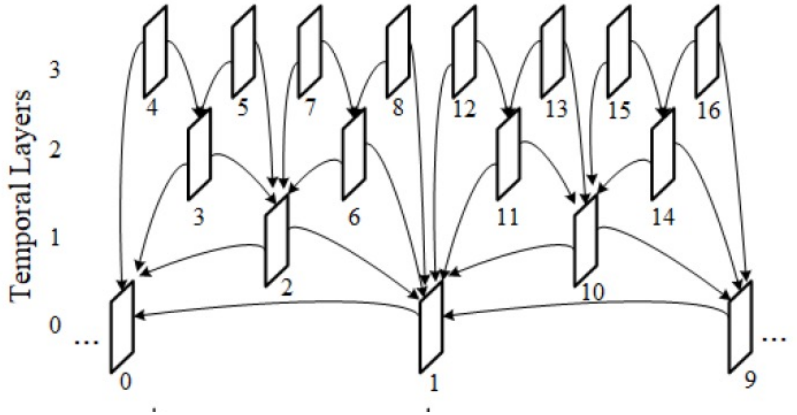
- Reduce max. MTT depth for different operation points

Problem

- **Coarse spacing of working points (only reduction to 0, 1 and 2 allowed)**

Solution

- Finer granular reduction, i.e. per temporal layer in hierarchical inter-picture referencing structures.



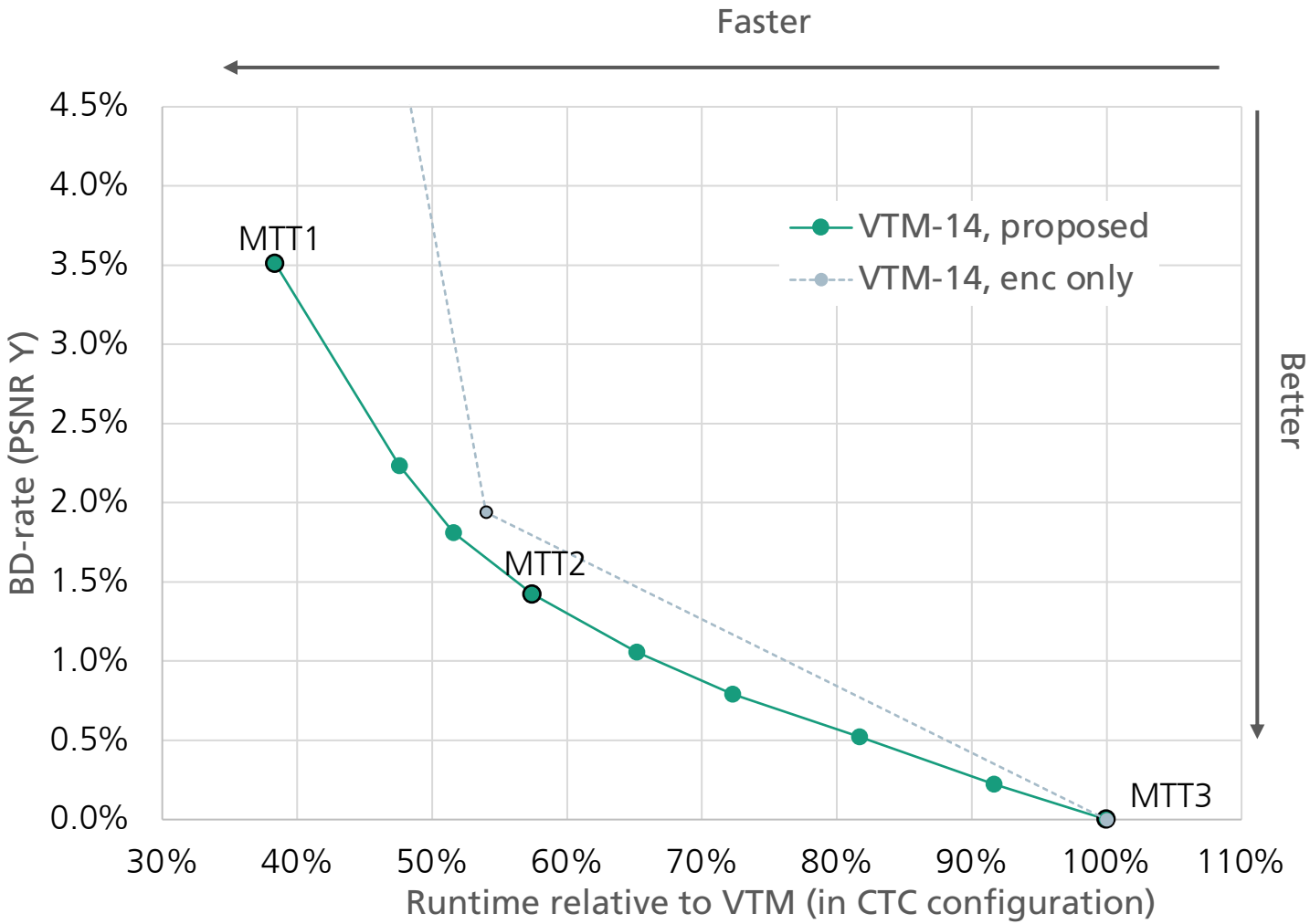
Max. MTT depth	TL0	TL1	TL2	TL3	TL4+
MTT 3 (VTM)	**3**	**3**	**3**	**3**	**3**
MTT 33332	3	3	3	3	2
MTT 33322	3	3	3	2	2
MTT 33222	3	3	2	2	2
MTT 32222	3	2	2	2	2
MTT 2	**2**	**2**	**2**	**2**	**2**
MTT 22221	2	2	2	2	1
MTT 22211	2	2	2	1	1
MTT 1	**1**	**1**	**1**	**1**	**1**

Proposal: Common baseline for fast partitioning algorithm

Gradual max. MTT depth reduction

Additional working points for fine granular complexity scaling

- VTM-14 results with JVET random-access configuration
- Encoder only working points:
  - Only search is restricted, not the signaling
  - Reduced efficiency due to obsolete „don’t split” flags sent



Review of fast VVC partitioning decision algorithms

General overview of the eight reviewed methods

A) Statistical analysis based (3/8)

- Based on
  - Decision history
  - Simple cost prediction
  - Pixel information

B) ML – Trained classifiers (2/8)

- Based on
  - Cost prediction
  - Decision history
  - Pixel information

C) ML – Convolutional Neural Network (CNN) (3/8)

- Based on
  - Residual
  - Motion field
  - Colocated frames' partitioning
  - Pixel information

All 8 methods…

- …decide per split (yes/no) and split-type (binary/ternary, hor/ver)
- …apply to P/B inter-coding frames

Challenges in comparing the methods due to different…

- …test sequences –> aligned in this work
- …versions of VTM –> aligned in this work

Review of fast VVC partitioning decision algorithms

How to interpret sequences being omitted in tests

Common Test Conditions (CTC)

- All methods use the same JVET CTC random-access config
- But not all use the same set of sequences or VTM version

Why not use CTC sequences?

- A1 / B1 –> No real explanation given in the paper
- B2 / C1 –> Omitted sequences used in training

Sequences and VTM versions have been aligned for testing the proposed method!

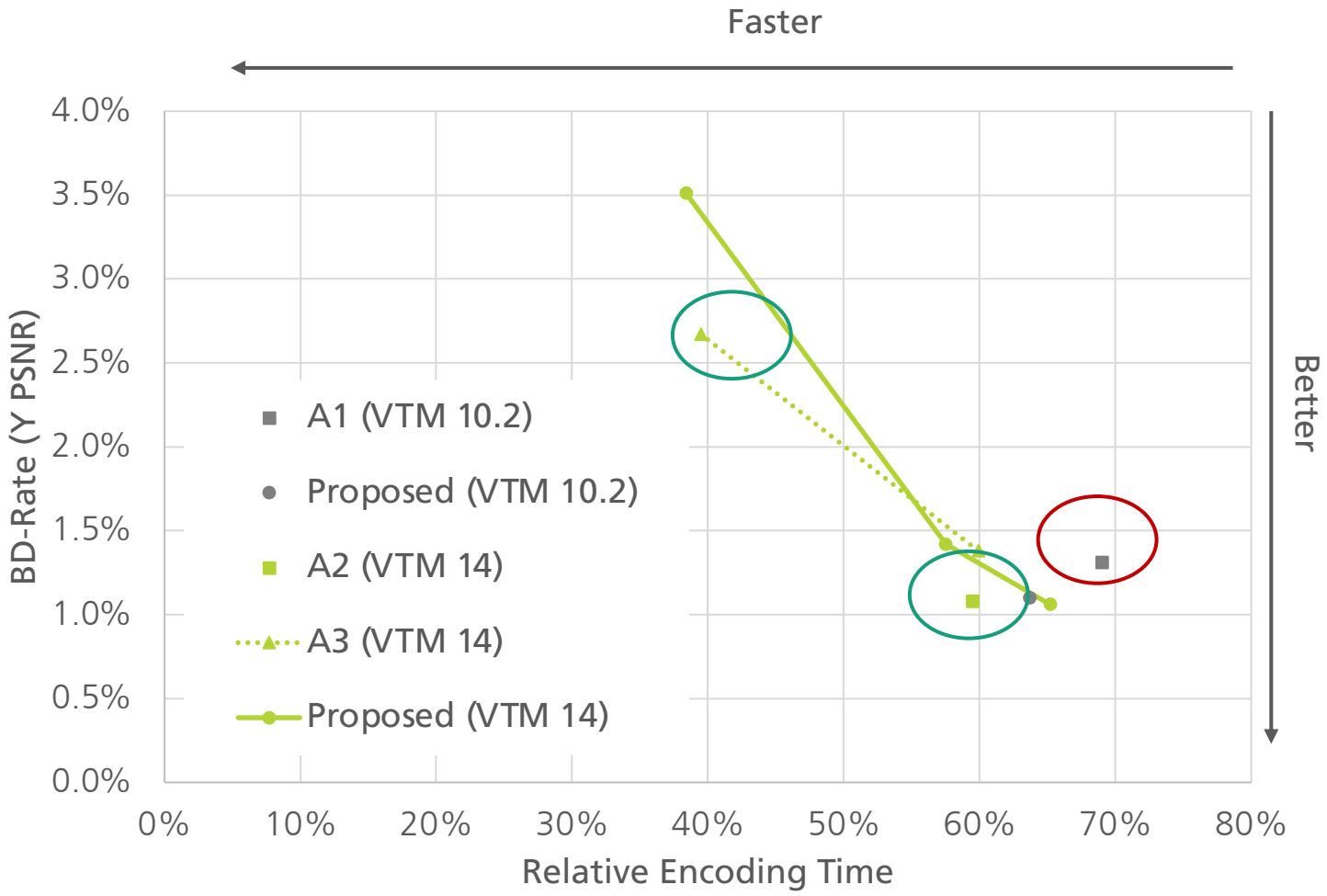
JVET Sequences		Stat. Analysis			Train. Clas.		ML CNN		
Class	Name	A1	A2	A3	B1	B2	C1	C2	C3
UHD1	Tango2	x	✓	✓	✓	✓	x	✓	✓
	FoodMarket4	x	✓	✓	✓	✓	x	✓	✓
	Campfire	x	✓	✓	✓	✓	✓	✓	✓
UHD2	CatRobot1	x	✓	✓	✓	x	x	✓	✓
	DaylightRoad2	x	✓	✓	✓	x	x	✓	✓
	ParkRunning3	x	✓	✓	✓	✓	✓	✓	✓
HD	MarketPlace	✓	✓	✓	x	✓	x	✓	✓
	RitualDance	✓	✓	✓	✓	✓	✓	✓	✓
	Cactus	✓	✓	✓	✓	✓	✓	✓	✓
	BasketballDrive	✓	✓	✓	✓	x	x	✓	✓
	BQTerrace	✓	✓	✓	✓	x	x	✓	✓
C	BasketballDrill	✓	✓	✓	✓	✓	✓	✓	✓
	BQMall	✓	✓	✓	✓	x	x	✓	✓
	PartyScene	✓	✓	✓	✓	✓	✓	✓	✓
	RaceHorses	✓	✓	✓	✓	✓	✓	✓	✓
D	BasketballPass	✓	✓	✓	✓	x	x	✓	✓
	BQSquare	✓	✓	✓	✓	x	✓	✓	✓
	BlowingBubbles	✓	✓	✓	✓	x	✓	✓	✓
	RaceHorses	✓	✓	✓	✓	x	✓	✓	✓
VTM Version		10.2	14.0	14.0	7.0	8.0	5.0	10.2	10.2

Review of fast VVC partitioning decision algorithms

Comparison with similar working points of proposed method (1/3)

A) Statistical analysis-based methods:

- A1 shows both higher runtime and more loss than proposed similar working point
- **A2 shows better trade-off**
- **A3 with reduced max MTT depth shows similar runtime but smaller loss**

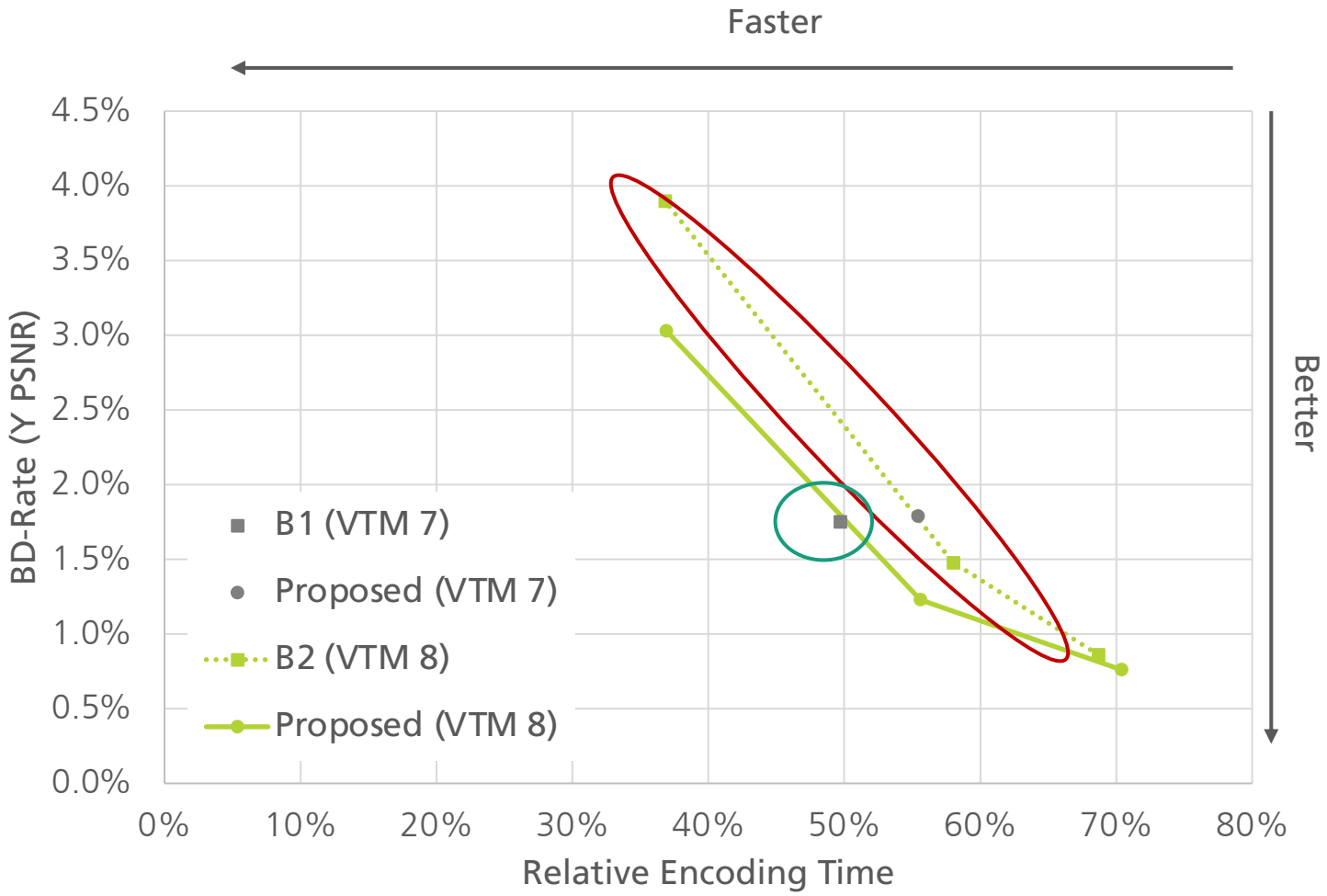


Review of fast VVC partitioning decision algorithms

Comparison with similar working points of proposed method (2/3)

B) ML trained classifier methods:

- **B1 shows better trade-off**
- B2 shows both higher runtime and more loss than proposed similar working points

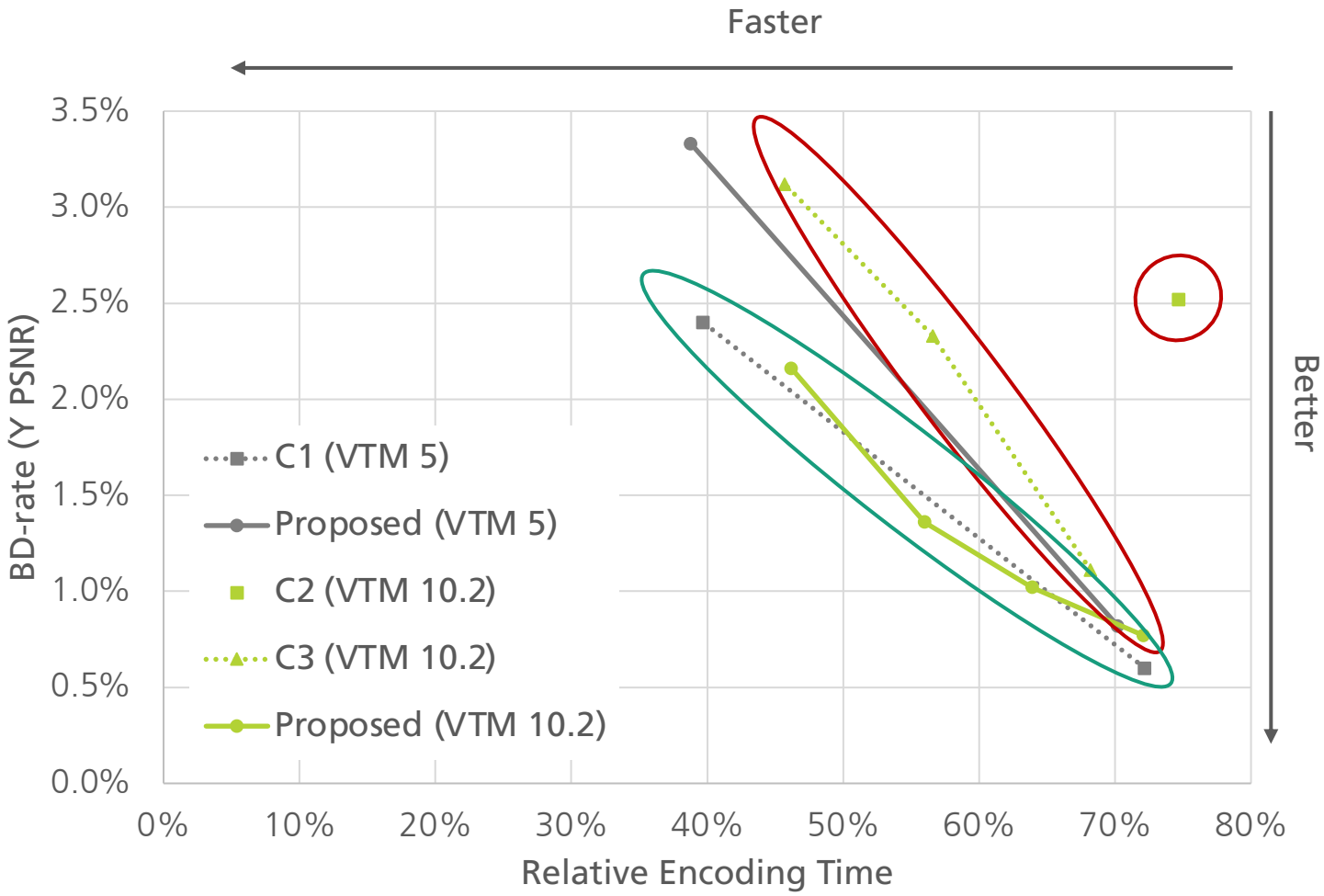


Review of fast VVC partitioning decision algorithms

Comparison with similar working points of proposed method (3/3)

C) ML CNN-based methods:

- **C1 shows better trade-off**
- C2 shows more loss than proposed similar working point
- C3 shows more loss than proposed similar working points



Conclusion

Only 4 out of 14 working points outperformed proposed common baseline

- Two of those four considered max. MTT depth
- One of those four uses a CNN

Lessons learned

- Fancy neural networks alone do not solve this problem
- Max. MTT depth is key for VVC partitioning complexity control
- **Per-CTU max. MTT depth adaptation instead of per-split decisions seems more promising for VVC partitioning**
- Further research should compare to the proposed baseline

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Thank you for your attention