Sub-Partition Reuse For Fast Optimal Motion Estimation In HEVC Successive Elimination Algorithms

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1. Introduction

- Motion Estimation (ME) is a crucial tool for video encoders.
- ME seeks the best candidate block (C) from a search area ($\mathcal{S}$) in a previously coded frame to predict the current block (B) (see Fig. 1).
- For HEVC, considering every candidate is prohibitively expensive, so modern search algorithms often find sub-optimal solutions.
- We want to reduce the number of candidates without sacrificing the optimal solution.
- We propose an early termination scheme for square prediction units (PUs) based on information reuse from rectangular ones.

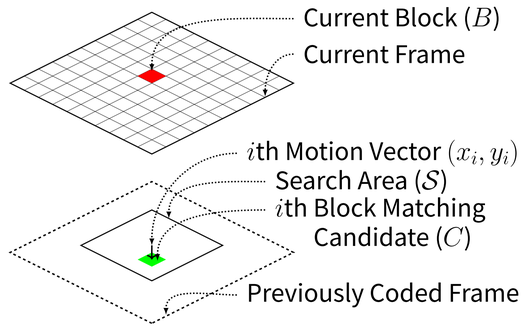


Figure 1: Motion estimation finds the best candidate to predict the current block.

2. Successive Elimination Algorithm

- Let $s \in \{\mathbb{S}, \mathbb{V}, \mathbb{H}\}$ be the partitioning shape of a PU and p be the partition index

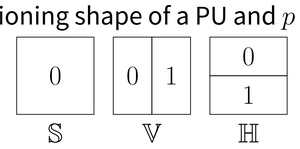


Figure 2: The first partition index is 0 and if a second partition exists, its index is 1.

- The candidate at position (x, y) is evaluated using

$$\text{RCSAD}(s,p,x,y) = \sum_{m=0}^{M_s-1}\sum_{n=0}^{N_s-1} |B_{s,p}(m,n) - C_{s,p,x,y}(m,n)| + \lambda R(x,y)\,.$$

- Successive elimination uses a lower bound approximation of the RCSAD

$$\text{RCADS}(s,p,x,y) = \left|\sum_{m=0}^{M_s-1}\sum_{n=0}^{N_s-1} B_{s,p}(m,n) - \sum_{m=0}^{M_s-1}\sum_{n=0}^{N_s-1} C_{s,p,x,y}(m,n)\right| + \lambda R(x,y)\,.$$

- Let $(\hat{x}, \hat{y})$ be the position of the current best candidate. By transitivity:

$$\text{RCADS}(s,p,x,y) \geqslant \text{RCSAD}(s,p,\hat{x},\hat{y})$$
$$\implies \text{RCSAD}(s,p,x,y) \geqslant \text{RCSAD}(s,p,\hat{x},\hat{y})\,.$$

3. Information Reuse Between PU Shapes

- Traditionally, PUs are evaluated in the order

$$\mathbb{S} \to \mathbb{V} \to \mathbb{H}\,.$$

- Consider the following orders

$$\mathbb{V} \to \mathbb{H} \to \mathbb{S} \text{ and } \mathbb{H} \to \mathbb{V} \to \mathbb{S}\,,$$

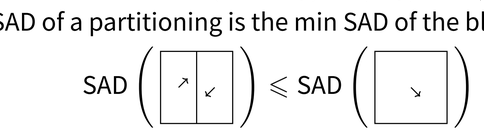
which allow for information reuse from $\mathbb{V}$ and/or $\mathbb{H}$ into $\mathbb{S}$. Such as

$$\text{SAD}^{\Omega} = \max\begin{pmatrix}\text{minSAD}(\mathbb{V},0) & +\text{minSAD}(\mathbb{V},1),\\ \text{minSAD}(\mathbb{H},0) & +\text{minSAD}(\mathbb{H},1)\end{pmatrix}.$$

- It follows that

$$\text{SAD}^{\Omega} \leqslant \text{SAD}(\mathbb{S},0,x,y),\ \forall\,(x,y) \in \mathcal{S}_{\mathbb{S},0}\,.$$

- At worst, the min SAD of a partitioning is the min SAD of the block



4. Improved Early Termination For $\mathbb{S}$

- We evaluate candidates in increasing order of rate. When the rate is large the search can terminate (without evaluating the remainder of $\mathcal{S}$).
- Early termination rate proposed at ICIP 2014

$$R(x,y) \geqslant \frac{\text{SAD}(s,p,\hat{x},\hat{y})}{\lambda} + R(\hat{x},\hat{y})\,.$$

- Improved early termination rate for $\mathbb{S}$

$$R(x,y) \geqslant \frac{\text{SAD}(\mathbb{S},0,\hat{x},\hat{y}) - \text{SAD}^{\Omega}}{\lambda} + R(\hat{x},\hat{y})\,.$$

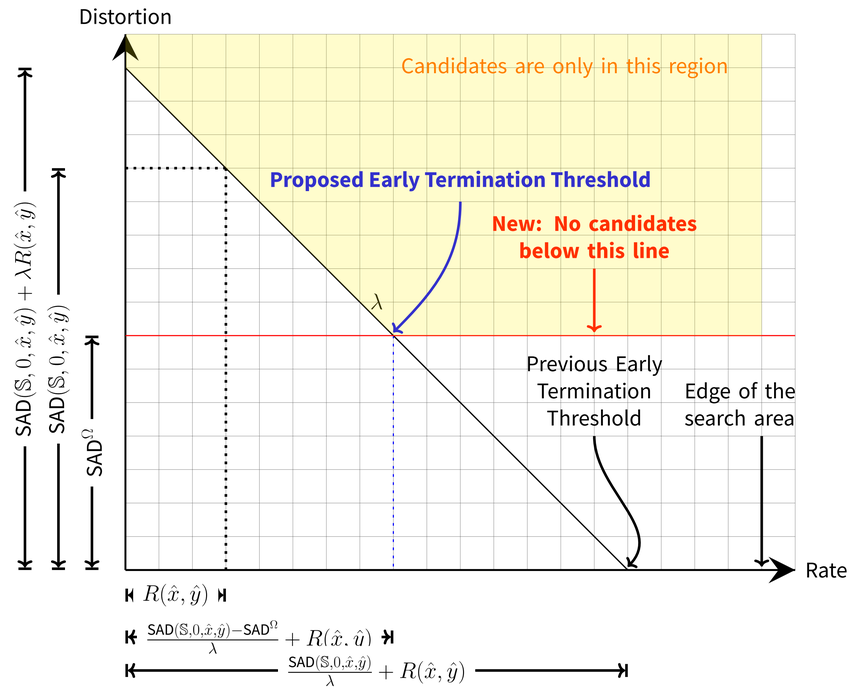


Figure 3: Geometric representation of the early termination thresholds.

5. Experimental Results

Class	Sequence name	Prop. vs HM Speedup	Prop. vs HM SAD Savings	Prop. vs HM BD-PSNR	Prop. vs Previous (ICIP2014) Speedup	Prop. vs Previous (ICIP2014) SAD Savings	Prop. vs Previous (ICIP2014) $\mathbb{S}$ SAD Savings
B (1920×1080)	Kimono	6.30	96.7%	0.0006	1.15	14.9%	45.6%
	ParkScene	6.42	95.8%	0.0014	1.35	25.7%	79.4%
	Cactus	7.07	96.3%	0.0018	1.27	21.8%	67.9%
	BQTerrace	5.92	94.6%	-0.0020	1.36	26.3%	81.9%
	BasketballDrive	6.05	95.4%	0.0016	1.23	20.2%	64.0%
C (832×480)	RaceHorses C	4.73	92.7%	0.0011	1.13	14.8%	50.2%
	BQMall	6.70	95.5%	-0.0008	1.18	16.0%	53.1%
	PartyScene	4.68	91.6%	-0.0003	1.27	19.9%	66.2%
	BasketballDrill	5.59	95.4%	-0.0026	1.24	19.3%	61.0%
D (416×240)	RaceHorses	4.56	93.0%	-0.0030	1.15	12.9%	43.1%
	BQSquare	8.75	96.1%	0.0032	1.34	27.6%	90.4%
	BlowingBubbles	6.78	95.2%	-0.0020	1.22	20.7%	68.1%
	BasketballPass	6.18	95.4%	-0.0011	1.20	17.8%	56.9%
	Overall	6.13	94.9%	0.0002	1.23	19.8%	63.7%

Table 1: Results for main profile with 8-bit coding and Low Delay P settings (No AMP)

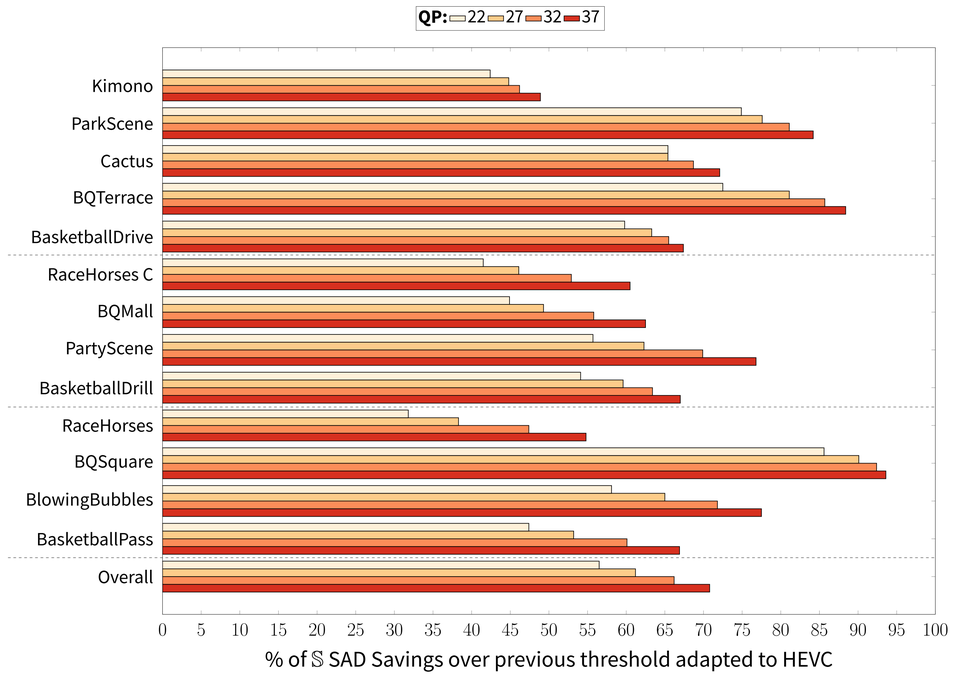


Figure 4: Results for main profile with 8-bit coding and Low Delay P settings (No AMP)

6. Conclusion

- The proposed early termination scheme for square PUs, based on information reuse from rectangular PUs, results in a **6.13x** speedup and **94.9%** SAD savings when compared to HM (Full Search).
- This work considerably decreases the number of candidates imposed by the HEVC standard in order to find the optimal solution.