An Adaptive Search Ordering For Rate-Constrained Successive Elimination Algorithms

Luc Trudeau, Stéphane Coulombe, Christian Desrosiers

Department of Software and IT Engineering, École de technologie supérieure, Université du Québec, Montréal, Canada

Vantrix Industrial Research Chair in Video Optimization

NSERC CRSNG

ÉTS Department of Software and IT Engineering

Introduction

- Block-matching algorithms (BMAs) must select the best candidate block (C) from a search area in one or many anchor frames to serve as a predictor for the content of the current block (B) (see Fig. 1).
- Beyond HD video formats (e.g., 4K or 8K), multiview video content and feature-rich video compression standards are all factors that require video encoders to consider more block sizes, more anchor frames, and use bigger search areas.
- The solution space for BMAs is so big, that state of the art approaches only consider a subset of that space and won't always find the optimal solution.
- We propose an adaptive ordering of block matching candidates that eliminates unnecessary block matching operations and allows for early termination.

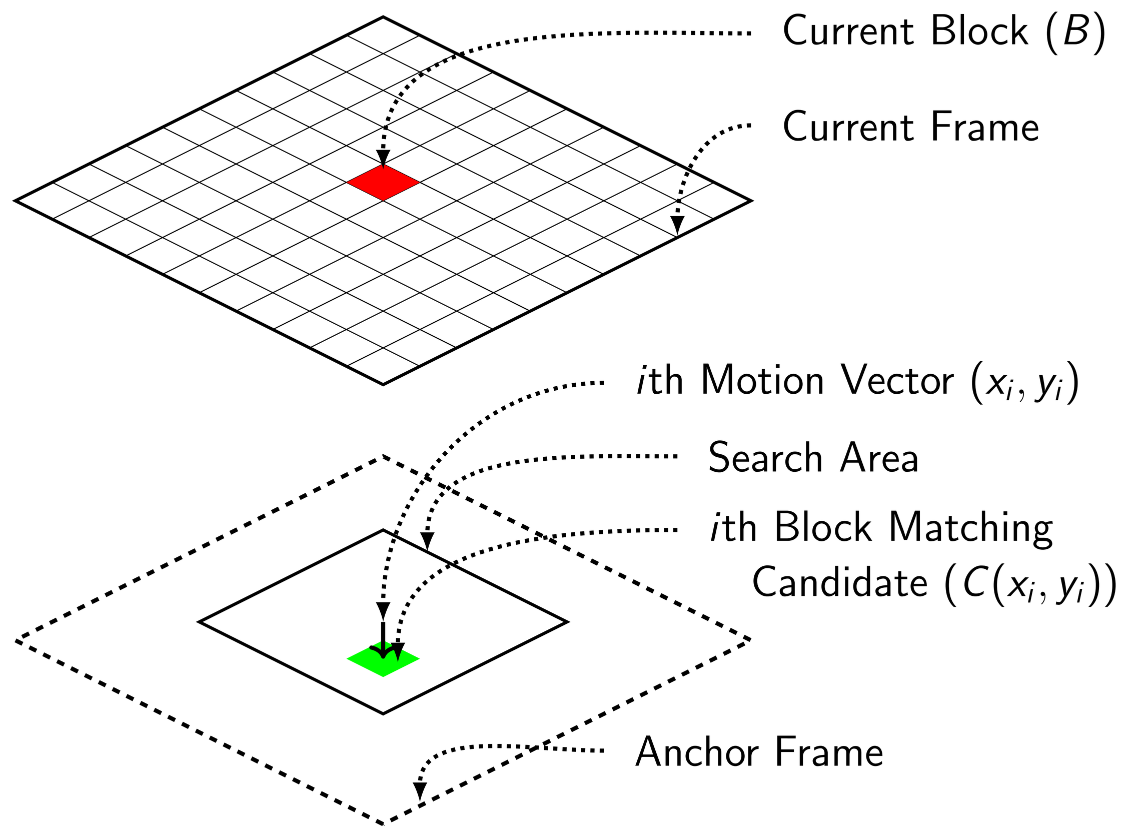

Figure 1: Block-matching consists of comparing candidate blocks ($C(x_i, y_i)$) in a search area against the current block B using a cost function.

Rate-Constrained Successive Elimination Algorithms

- The BMA evaluates candidates by computing the rate-constrained sum of absolute differences (RCSAD)

$$\text{RCSAD}(x, y) = \sum |B - C(x, y)| + \lambda R(x, y) . \tag{1}$$

- The rate-constrained successive elimination algorithm (RCSEA) uses a 1D projection of the RCSAD, the rate-constrained absolute difference of sums (RCADS), as a lower bound for the RCSAD

$$\text{RCADS}(x, y) = \left|\sum B - \sum C(x, y)\right| + \lambda R(x, y) \leqslant \text{RCSAD}(x, y) . \tag{2}$$

- The RCSEA can use this lower bound to filters out unnecessary block matching operations. For example, let (x^*_{i-1}, y^*_{i-1}) be the best candidate found so far, if

$$\text{RCSAD}(x^*_{i-1}, y^*_{i-1}) \leqslant \text{RCADS}(x_i, y_i) , \tag{3}$$

then computing $\text{RCSAD}(x_i, y_i)$ is unnecessary.

Adaptive Search Ordering

- The efficiency of RCSEA depends on the ordering of block matching candidates.
  - For example, the best filtering is achieved when (x_1, y_1) is the best candidate (see eq. 3).
- The proposed solution is outlined in Fig. 2. The main ideas are:
  - Prune the candidates with eq. 3, but instead of (x^*_{i-1}, y^*_{i-1}), we use $\text{RCSAD}(x_p, y_p)$ for each candidate, where (x_p, y_p) is the predicted motion vector (MVP).
  - Sort in ascending order the retained candidates by RCADS.
  - Perform BMA on the ordered candidates using *RCSEA*.
    - Stop the BMA when eq. 3 is met for a candidate (early termination).

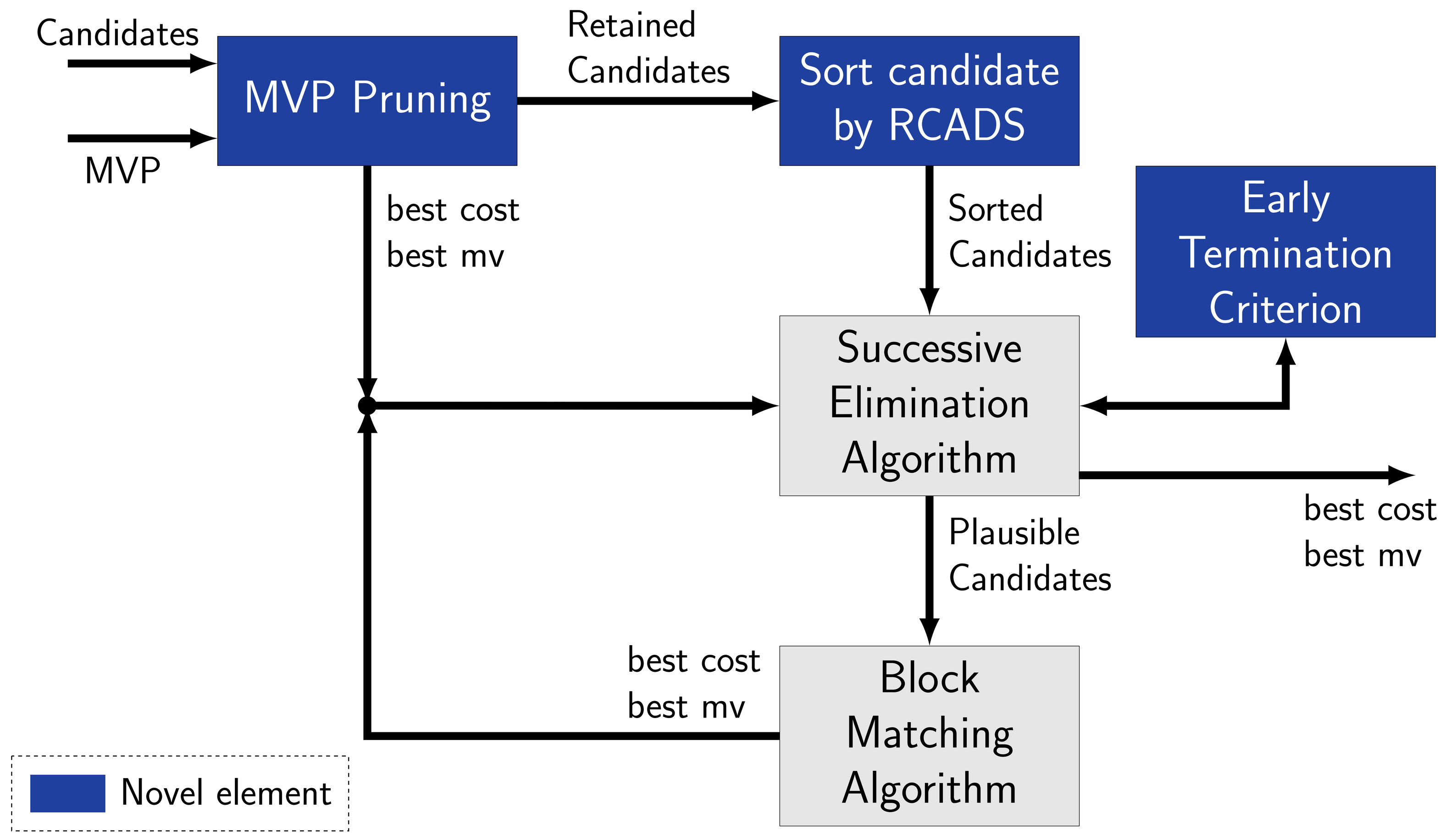

Figure 2: Outline of the proposed solution. See the paper for a complete algorithm.

Early Termination

- Let (x_1, y_1) be the best candidate. The BMA will compute the RCSAD for $\{(x_i, y_i) \mid \text{RCADS}(x_i, y_i) \leqslant \text{RCSAD}(x_1, y_1)\}$.
- Now, let the best candidate be unknown and let the candidates be sorted by RCADS. The BMA will compute the RCSAD for $\{(x_i, y_i) \mid \text{RCADS}(x_i, y_i) \leqslant \text{RCSAD}(x^*_{i-1}, y^*_{i-1})\}$.
- Both sets contain the same candidates.

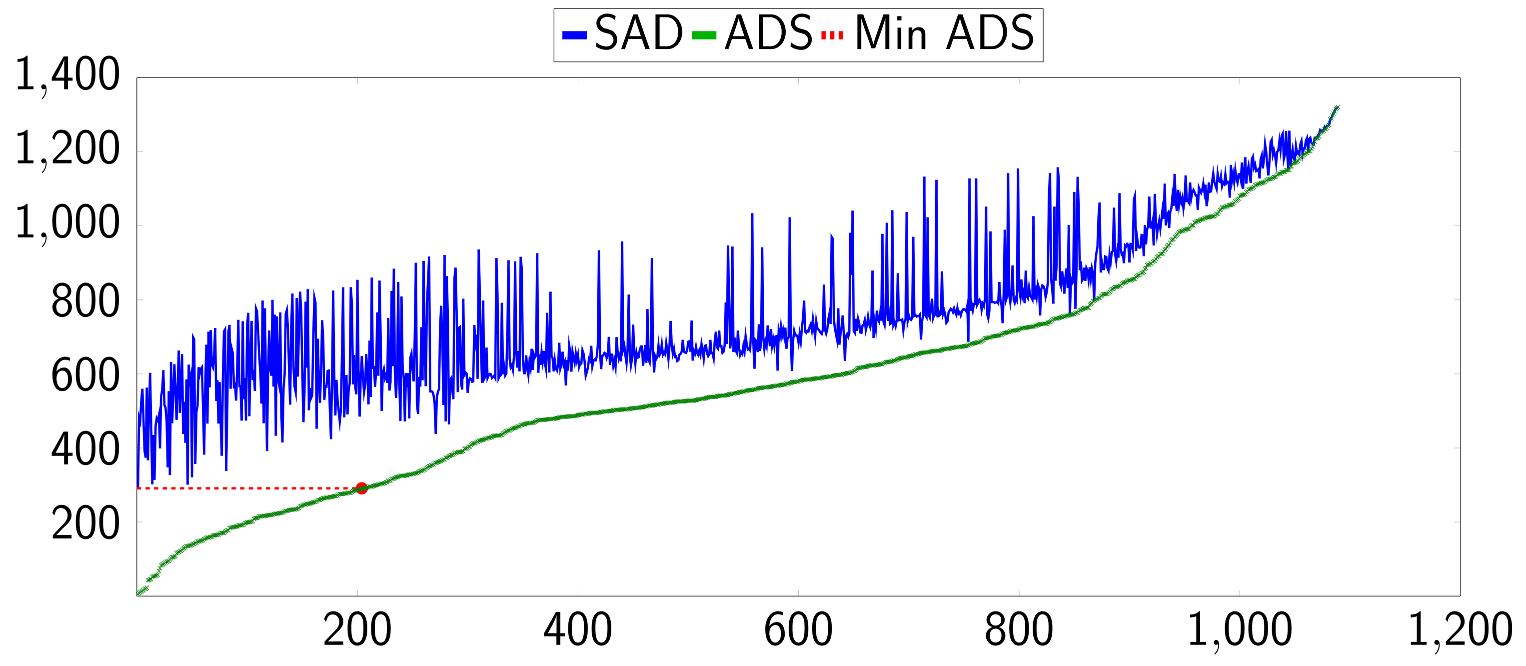

Figure 3: Block matching candidates sorted by RCADS. The early termination criterion is shown in red.

Experimental Results

- Our experiments where performed on the first 100 frames of Class C (832×480) video sequences ("*Basketball Drill*", "*Party Scene*", "*BQ Mall*" and "*Race Horses*") using the main profile.
- The results are presented by block sizes and by QP values in Fig. 4.
- The proposed algorithm is more effective for smaller block sizes.
  - Smaller blocks comprise fewer pixels leading to more precise ADS values. This filters out more unnecessary cost function evaluations.
- As the QP increases, the effectiveness of the proposed algorithm also increases.

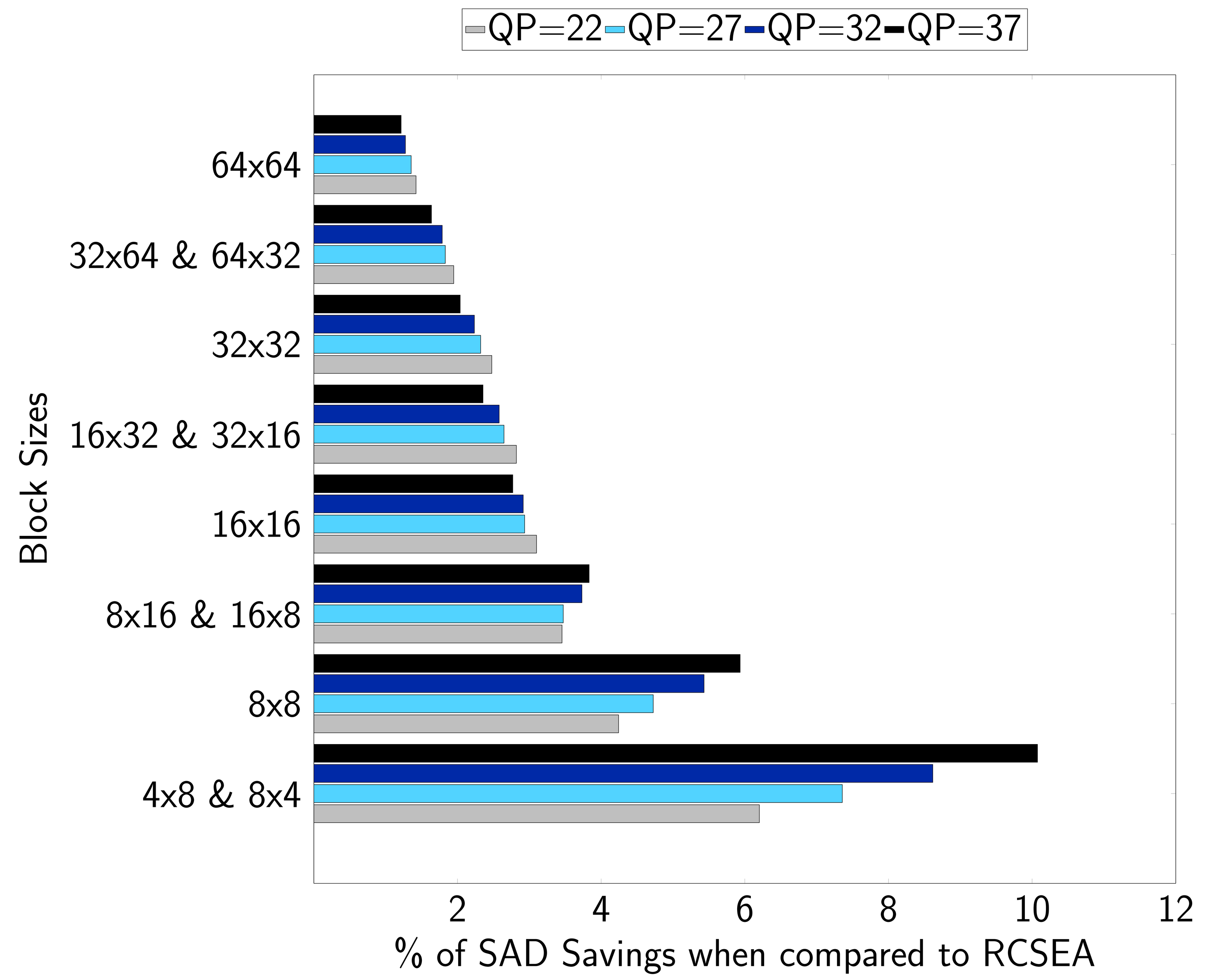

Figure 4: Percentage of SAD operations saved by the proposed solution.

Conclusion

We proposed:

- An adaptive search ordering for the motion estimation module that evaluates only necessary cost functions.
- An early termination criterion for the BMA.

Our experiments showed:

- Without our algorithm, an RCSEA using a spiral scan search ordering in the H.265/HEVC HM reference software would evaluate, on average, 3.5% of unnecessary cost functions.
- In some instances, the percentage of cost function evaluations can be reduced up to 15%.