UNIVERSIDADE FEDERAL DO RIO GRANDE DO SUL
INSTITUTO DE INFORMÁTICA
PROGRAMA DE PÓS-GRADUAÇÃO EM COMPUTAÇÃO

Energy-Efficient Memory Hierarchy for Motion and Disparity Estimation in Multiview Video Coding

South Symposium on Microelectronics - 2013

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Support:
CNPq
Conselho Nacional de Desenvolvimento Científico e Tecnológico

Introduction

- Multiview Video Coding (MVC)
  - H.264/AVC extension
  - **20%-50%** better compression rates
  - **Impressive energy consumption!**
    (focus of this work)
- Challenge:
  - **Memory issues** is the main optimization target for energy-efficient MVC encoding
  - Motion and Disparity Estimation (ME/DE)

Motion/Disparity Estimation

- **Motion/Disparity Estimation**
  - **Goal:** find most similar block into reference frames
  - **Reference frame:** already coded and reconstructed frames (stored in the external memory)
  - **Search window:** squared search delimitation (96x96 size)
  - **Output:** motion/disparity vector
- **Search Algorithm for Block Matching**
  - TZ Search (JVT, 2012): used in the MVC and HEVC reference software
- **Similarity Criterion for Best Matching**
  - SAD (Sum of Absolute Differences)

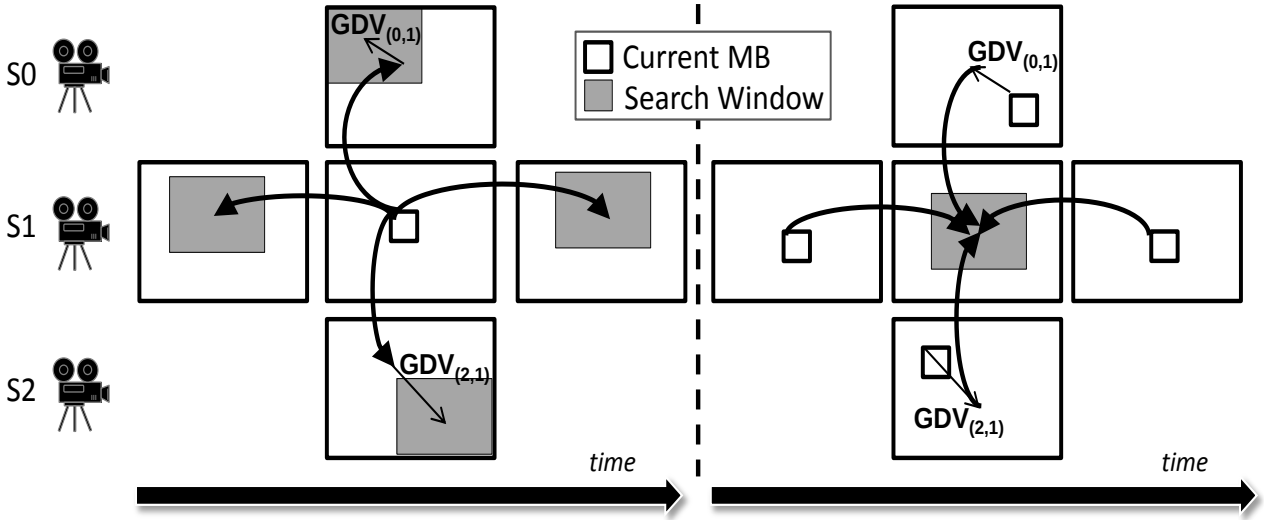
$$SAD(x,y) = \sum_{i=0}^{m-1} \sum_{j=0}^{n-1} \left| R_{i,j} - O_{i,j} \right| \qquad \text{Eq. (1)}$$

Goals

- **Main Goal:** Reduce the energy consumption related to the off-chip and on-chip memory issues in the ME/DE on MVC
  - Reduce the number of memory accesses to reduce the off-chip memory energy consumption
  - Allow regular memory accesses to exploit the DDR burst read operations (more energy-efficient)
  - Minimize the on-chip energy consumption to keep locally stored the ME/DE reference data
  - Compress the data to save off-chip memory accesses while minimizing the error propagation along the MVC prediction structure

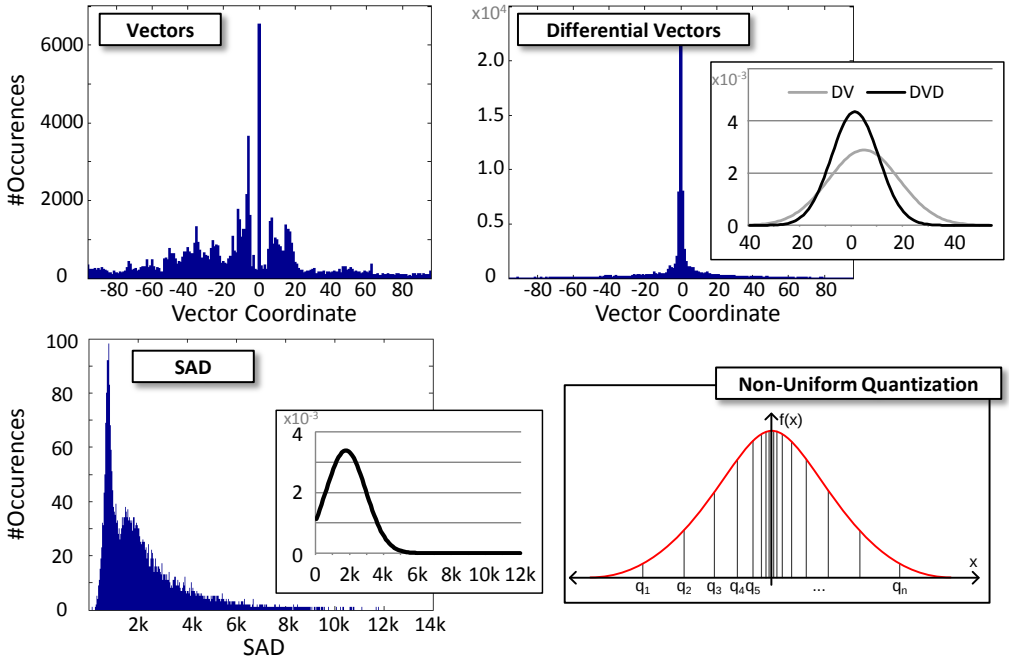
Reference-Centered Memory Hierarchy

- **Reference-Centered Data Reuse (RCDR)**
  - Traditional: MB-Centered Data Reuse (MBDR)
  - Search Window is the centric of the scheduling
  - Once one search window is stored on-chip, all dependent MBs are immediately processed
  - Penalties: partial results are generated



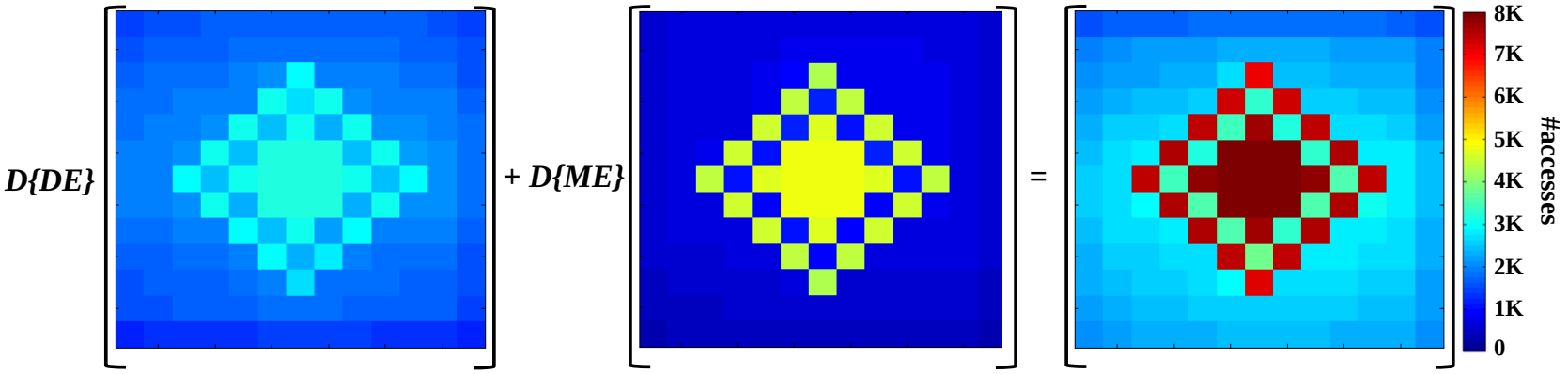
Reference-Centered Memory Hierarchy

- **Partial Results Compression**
  - Data types: motion/disparity vectors and SAD
  - Vectors: median spatial prediction and Huffman encoding
  - SAD costs: non-linear quantization and Huffman encoding



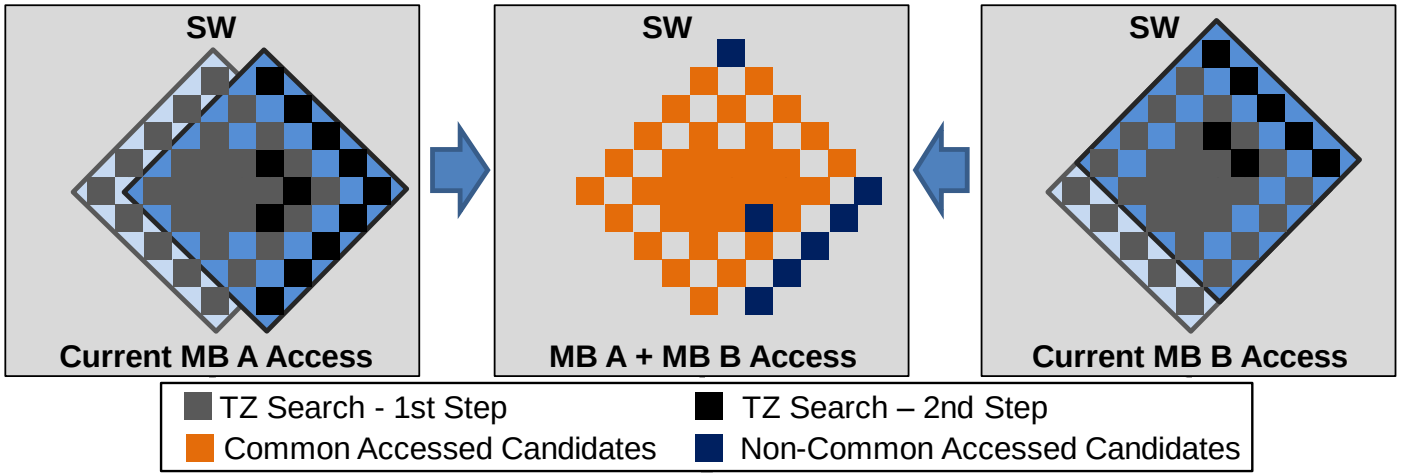
Reference-Centered Memory Hierarchy

- **On-Chip Power Gating Control**
  - Statistics from ME/DE of past frames
  - **Multiple power states:** *S3 (ON), S2-S1 (Data Retentive) and S0 (OFF)*
  - Power states are assigned according to the usage statistics



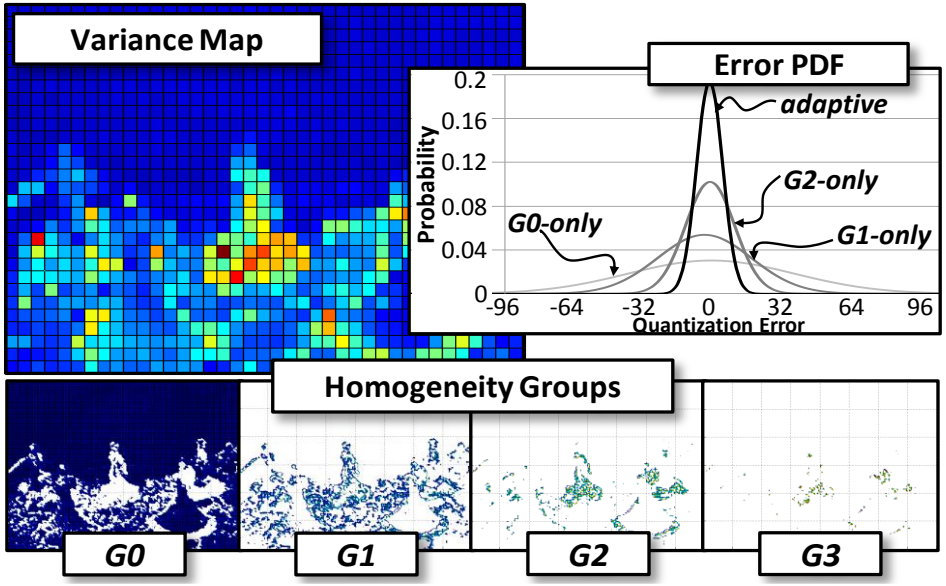
Reference-Centered Memory Hierarchy

- **Candidate Blocks Merging**
  - **Scenario:** multiple MBs searching in the same search window (stored on-chip)
  - **Technique:** reorder the candidate blocks evaluation to avoid redundant memory accesses



Reference-Centered Memory Hierarchy

- **Content-Adaptive Reference Frame Compression**
  - Simplified intra-prediction
  - Residue compression path: non-linear quantization and Huffman encoding
  - Content adaptation scheme



Results

- **External Memory Energy Savings**
  - Compared to MBDR: 68% of reduction, in the best case
  - Compared to (Zatt et al., 2011): 30% of energy savings, due to the regular access
  - Partial Results Compression: 52% of reduction in the partial results transmission
- **On-Chip Memory Energy Savings**
  - 74% smaller on-chip video memory (compared to MBDR)
  - Best results on static energy savings
  - First work to deal with on-chip dynamic energy reduction (65% on average)

Results

- **Reference Frame Compression Savings**
  - Negligible rate-distortion drops
  - External memory access savings: 69% on average
  - Best results compared to related works

Conclusions

- The memory hierarchy system accomplished the goal of jointly minimizing the energy consumption related to the off-chip and on-chip memories targeting ME/DE on MVC
- The regular memory access pattern allowed energy savings when compared to related works that perform irregular accesses
- Even storing one entire search window, the on-chip video memory was energy-efficient due to the proposed techniques to reduce both static and dynamic energies
- The error propagation along the MVC prediction structure was minimized due to the content-adaptive compression

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Thank You!

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