Technion - IIT
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Transrating of MPEG-2 Coded Video via Requantization with Optimal Trellis-based DCT Coefficients Modification

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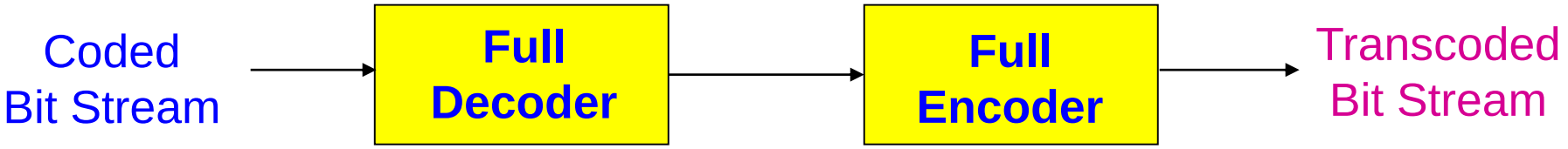
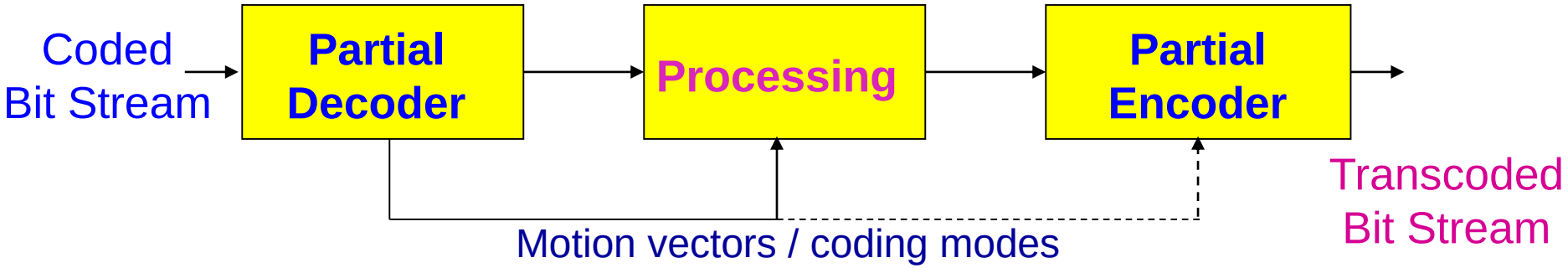
Outline

- Transrating approaches
- TM5-based requantization
- Lagrangian optimization
- Proposed Extended Lagrangian optimization
- Simulation results and summary

Transcoder Architectures



Cascading Decoder and Encoder (Re-encoding)



Complexity-Reduced Transcoding
(Compressed Domain)

Related Issues

- Open Loop
- Closed Loop
  - Pixel-Domain
  - DCT-Domain

Transrating Methods

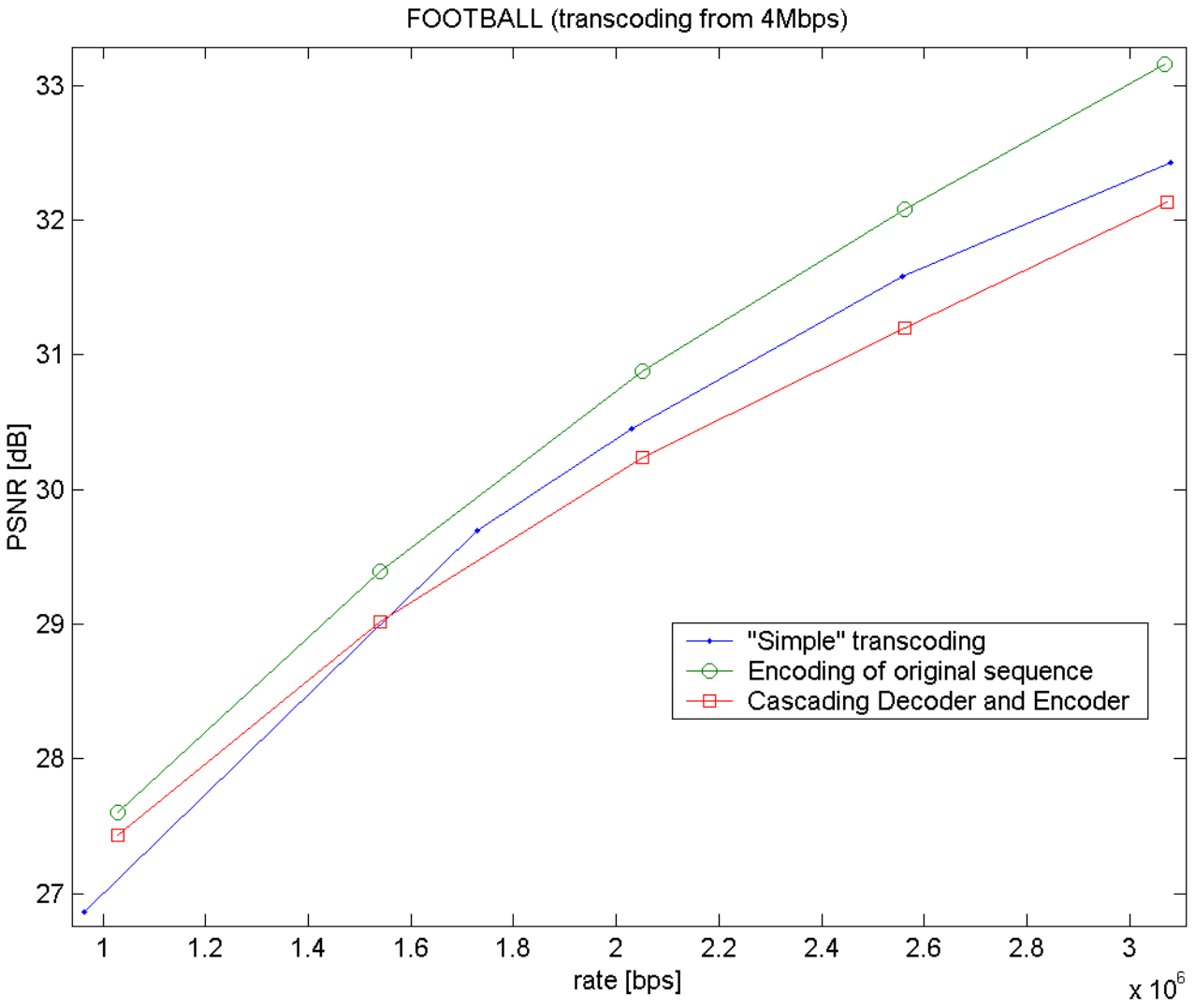
(Bit-Rate Reduction - BRR)

- Frame dropping (B, P)
- Color suppression
- Discarding high-frequency DCT coefficients
- Reducing spatial resolution (size reduction)
- DCT coefficients Requantization

TM5-based Transrating -1

- GOP-level BRC: the same reduction ratio for all frames
  - No buffer considerations
- MB complexity: MB bit-count multiplied by quantization step-size
- Frame-level BRC:
  - Bit-count for the remaining MBs is estimated as sum of complexities divided by current step-size
  - Rate-adaptive quantization:
    - Increase step-size if estimation is bigger than budget left
    - Decrease otherwise
- One-path algorithm
- Not optimal in any sense

TM5-based Transrating -2



Requantization by Lagrangian Optimization -1

(Assunção and Ghanbari, 1997)

Constrained Minimization problem:

$$\text{Min } D, \text{ under the constraint } R \le R_T \ ;$$

$$D = \sum_{k=1}^{N} d_k(q_k) \ ; \qquad R = \sum_{k=1}^{N} r_k(q_k)$$

N – number of MBs in picture; d_k – distortion introduced into k-th MB

q_k – quantization step for k-th MB; r_k – rate of k-th MB after transcoding

Rate and Distortion are merged using a Lagrangian parameter, $\lambda \ge 0$, :

$$J = D + \lambda R$$

Requantization by Lagrangian Optimization -2

(Assunção and Ghanbari, 1997)

Lagrangian cost function becomes sum of independent MB level calculated parts:

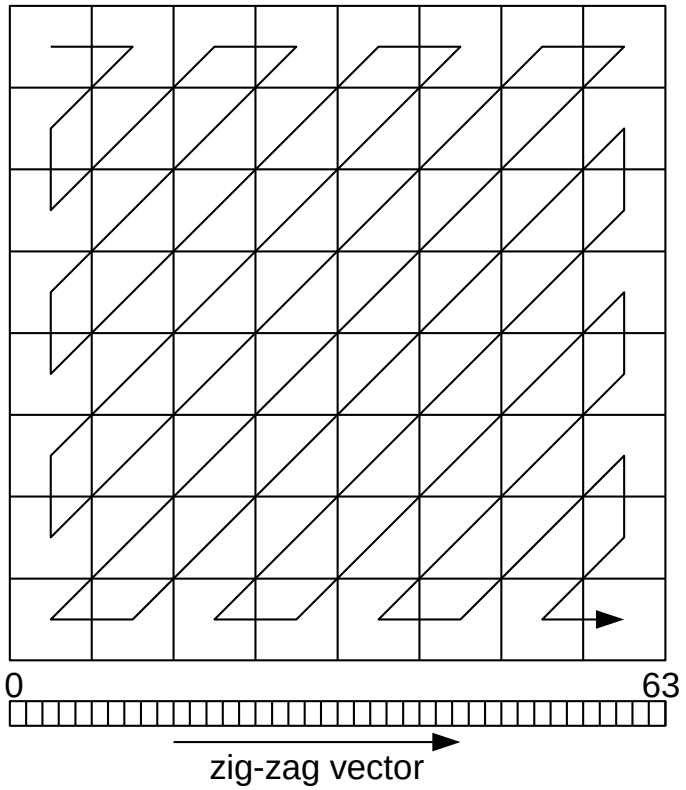
$$J_k(\lambda) = \min_{q_k}\{d_k(q_k) + \lambda r_k(q_k)\}$$

Lagrangian parameter, $\lambda \geq 0$, is iteratively updated to achieve desired bit-rate R_T:

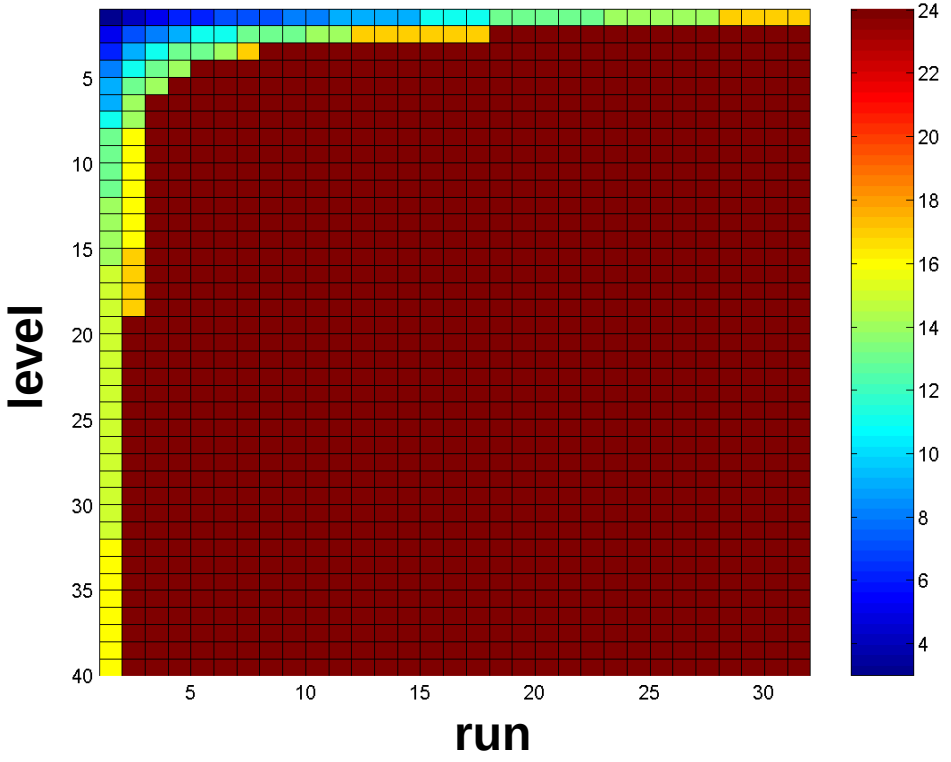
1. Calculate all $\mathbf{J_k(\lambda)}$ for all **k**
2. Compute total rate $R_{total}=\Sigma r_k(q_k)$ and check:
   - If $R_{total} = R_T$, transmit transrated frame and go to next frame
   - If $R_{total} < R_T$ => decrease λ ; If $R_{total} > R_T$ => increase λ
3. Goto 1 with new λ

Variable Length Coding

Zig-zag scan of DCT coeffs in block



VLC table



Extended Lagrangian Optimization

We propose to extend Lagrangian optimization by the modification of quantized coefficients index values :

Min D, under the constraint $R \le R_T$;

$$D = \sum_{k=1}^{N} d_k(q_k, \mathrm{v}) ; \qquad R = \sum_{k=1}^{N} r_k(\mathrm{v})$$

N – number of MBs in picture; d_k – distortion introduced into k-th MB

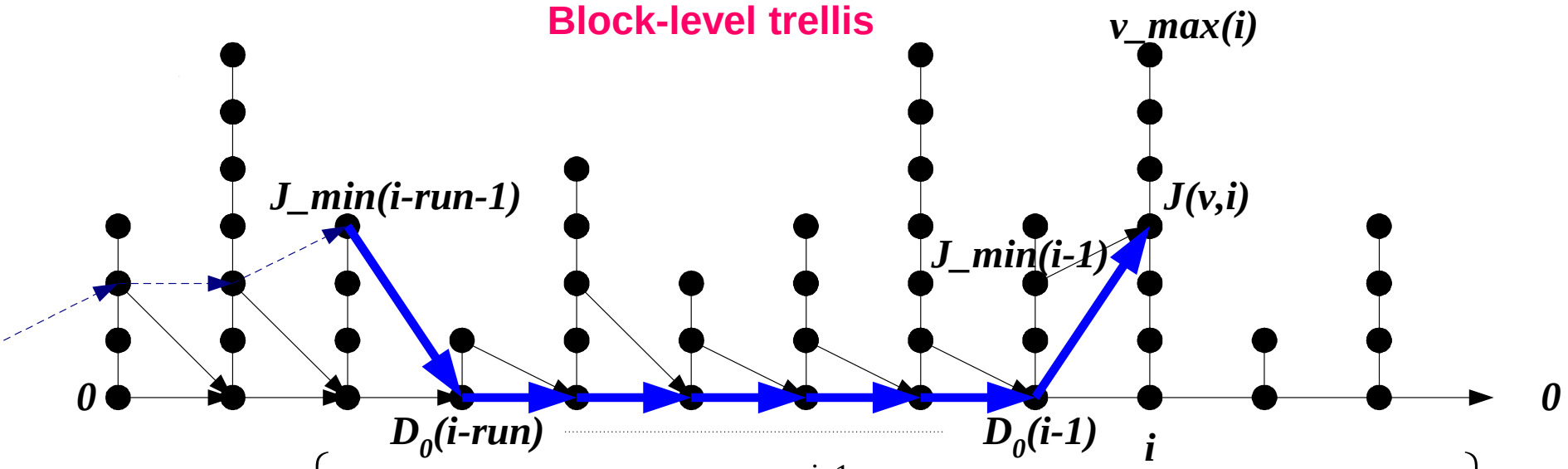
q_k – quantization step for k-th MB; r_k – rate of k-th MB after transcoding

v - vector of quantized DCT coefficients indices

Lagrangian cost function becomes sum of independent MB level calculated parts:

$$J_k(\lambda) = \min_{q_k, \mathrm{v}} \{ d_k(q_k, \mathrm{v}) + \lambda r_k(\mathrm{v}) \}$$

Trellis-based Re-quantization



$$J(v,i) = \min_{run} \left\{ J\_\min(i - run - 1) + \sum_{j=i-run}^{i-1} D_0(j) + \lambda R(run, v) + D(v,i) \right\}$$

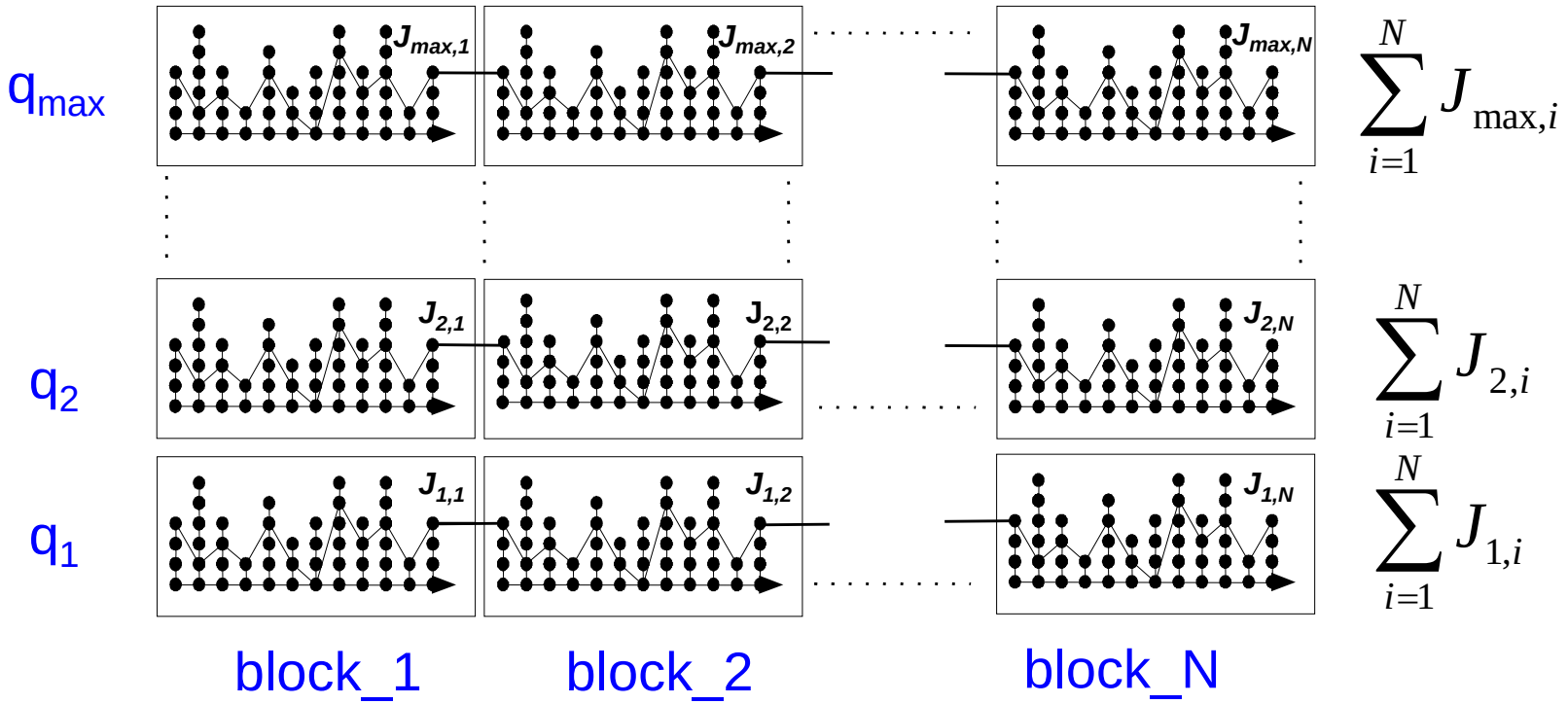
$$J\_\min(i) = \min_{v} J(v,i)$$

Complexity reduction:

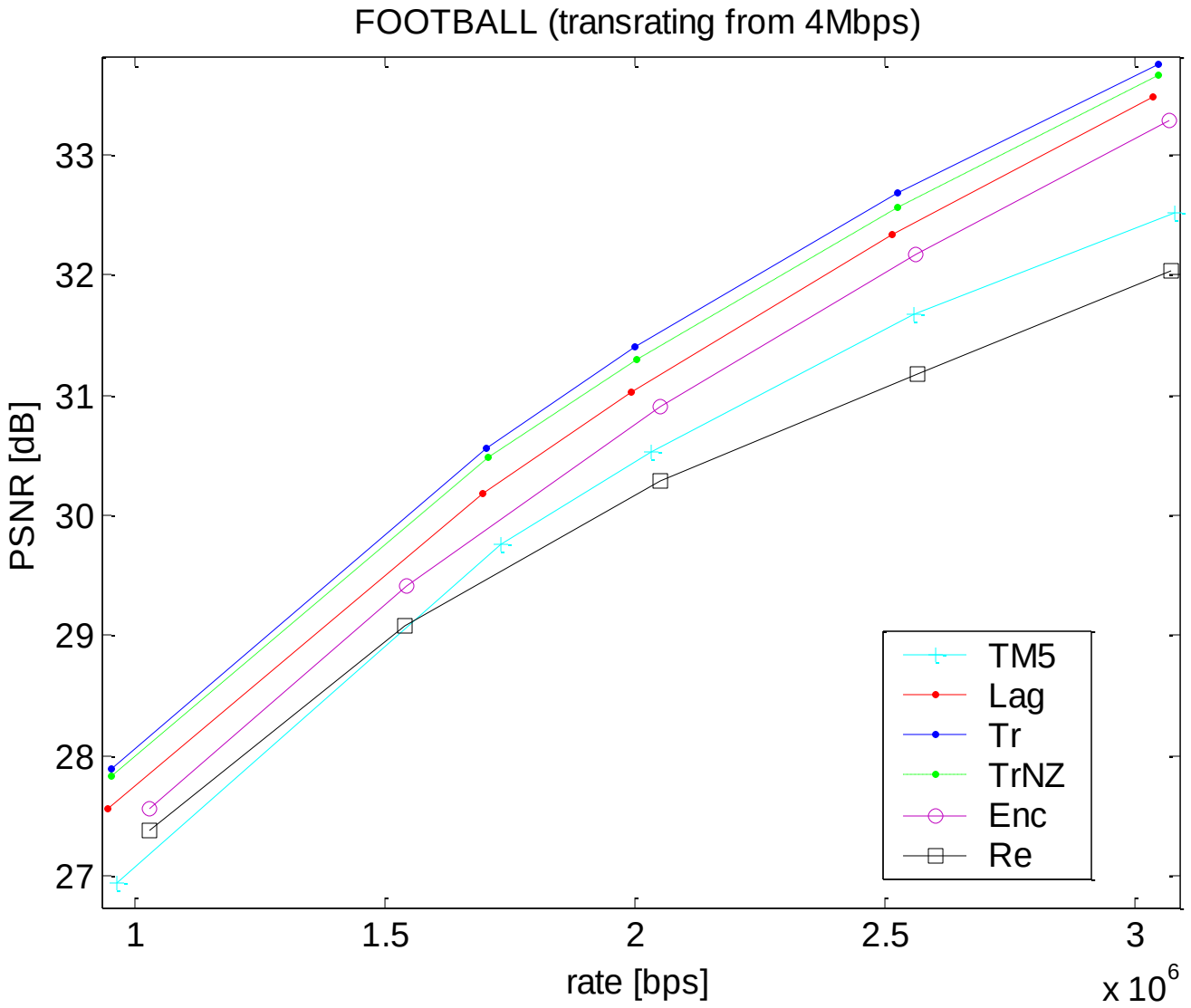
- When *R(run,v)* reaches the maximum, the result is known
- Sub-optimal: run-level pair splitting is forbidden

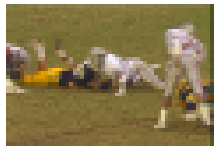
Trellis-based Re-quantization

Macro-Block

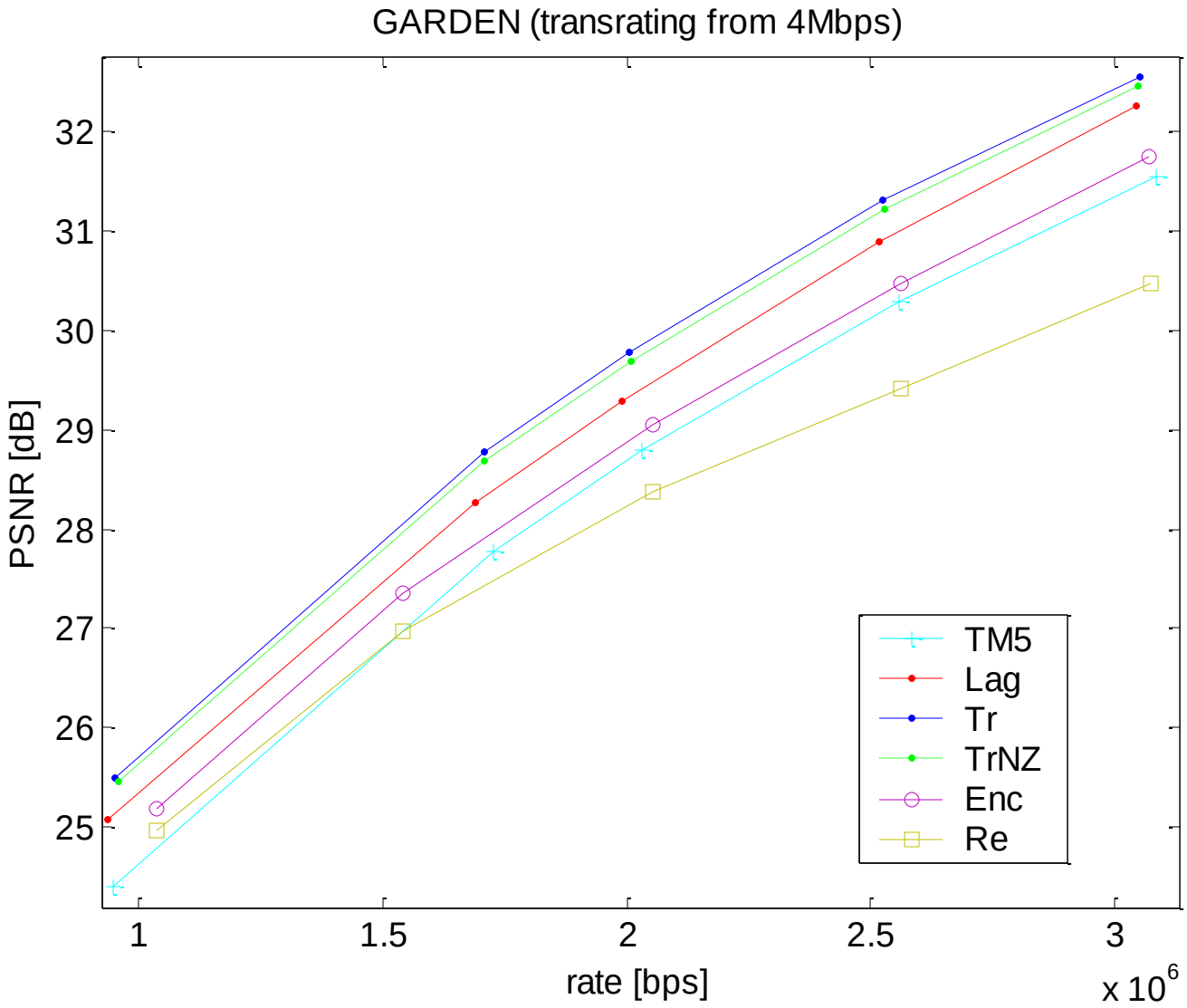


Experimental Results





Experimental Results



Experimental Results

FOOTBALL sequence from 4Mbps

Method	Run-time ratio	PSNR Improvement*
TM5-based	0.15	-0.4dB
Run-time optimized Lagrangian	1	0.3dB
Extended Lagrangian	7.9	0.7dB
Sub-optimal Extended Lagrangian	3.3	0.6dB

*** Relative to Source Encoding**

Summary and Future directions

- An Extended Lagrangian Optimization requantization is proposed and implemented using a trellis-based scheme.
- PSNR of the proposed scheme is always better than PSNR of original sequence encoding to the same rate using TM5 encoder.
- The proposed approach can be applied as is to other coders based on run-level VLC coding , like H.263.
- Smart GOP-level BRC can further improve the performance.
- Other methods like frame-rate reduction, resolution reduction and frame cropping can be combined with proposed requantization methods.

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