Technion - IIT
Dept. of Electrical Engineering
Signal and Image Processing lab

Overview of SIPL Activity in

Transrating and Transcoding of Coded Video Signals

STRIMM

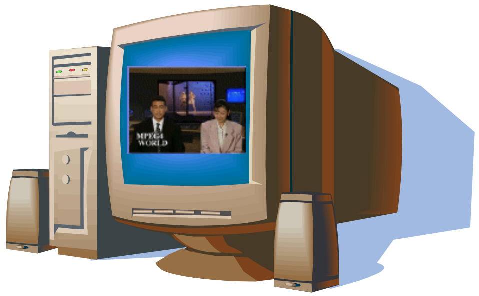
Naama Hait, Michael Lavrentiev, Zeev Maor, Michael Tolchinsky
Supervisors: Ran Bar-Sella and Prof. David Malah

Lab support: Nimrod Peleg, Yair Moshe

SIPL Annual Project Presentation Day - June 22th, 2005

Video Transcoding

Coded Bit Stream → **Compressed-domain Transcoder** → Transcoded Bit Stream



Compressed-domain transcoding

Advantages over trivial "decoder + encoder":

- Efficient, suitable for real time applications
- Uses first encoder's coding decisions

Transcoding Goals

- Convert input stream to match end-user requirements. Examples:
  - Format conversion (between standards)
  - Spatial resolution reduction
  - Temporal resolution reduction
  - Bit rate reduction
- Achieve the highest quality at the target bit rate
- Minimal complexity – Use as much information from the coded bit stream

Transcoding Activities at SIPL

- Focus on the following Advanced Video Coding Standards: MPEG-2, H.264

1. Transrating (Bit rate reduction):
   MPEG-2 → MPEG-2
2. Transcoding (Format conversion):
   MPEG-2 → H.264
3. Transrating (Bit rate reduction):
   H.264 → H.264
4. Transcoding and transrating:
   MPEG-2 → H.264

MPEG-2 Transrating

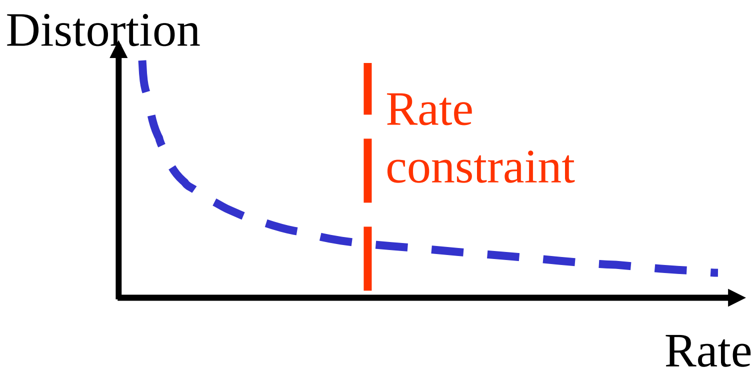
- Transrating of Coded Video Signals via Optimized Re-quantization – Michael Lavrentiev (M.Sc., July 2004); Supervisor: Prof. David Malah

  - Re-quantization by Lagrangian Optimization

$$\min_{Q_1, Q_2, \ldots, Q_N} \sum_{i=1}^{N} d_i(Q_i)$$

$$s.t.$$

$$\sum_{i=1}^{N} r_i(Q_i) \le R_T$$



d_i – Distortion for block #i, r_i – rate for block #i, R_T – Target rate
N – Number of blocks in the frame, Q_i – Quantization step for block #i

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

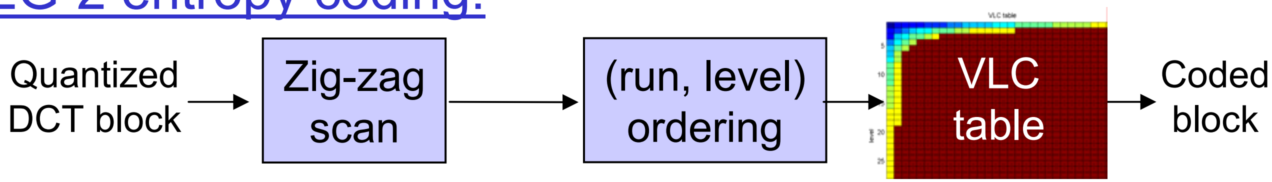
$$J = D + \lambda R$$ (Assunção and Ghanbari, 1997)

Decompose cost into sum of independent costs for each block

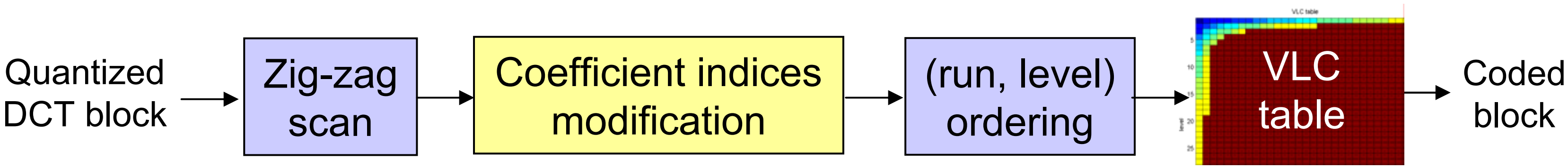
MPEG-2 Transrating (cont.)

- Extended Lagrangian Optimization (trellis-based)

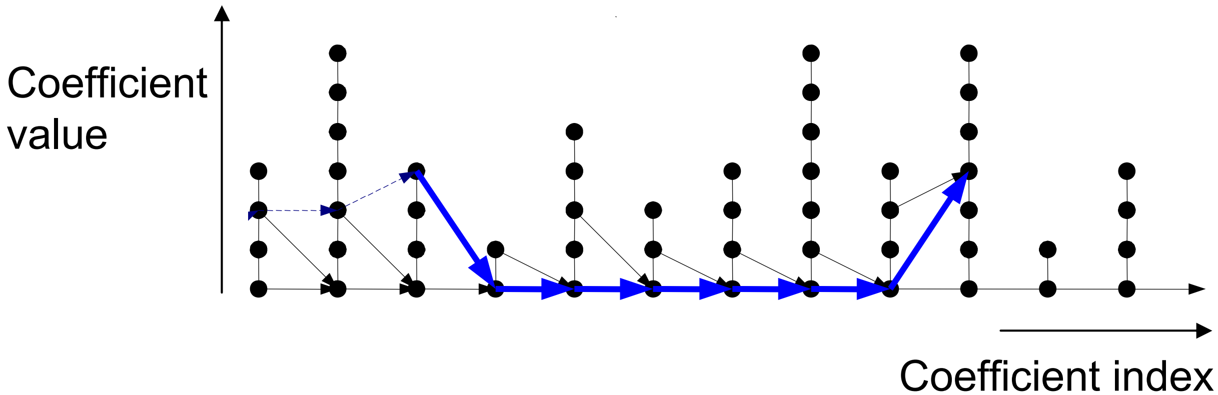
MPEG-2 entropy coding:



Extension: Allow modification of the quantized coefficient indices



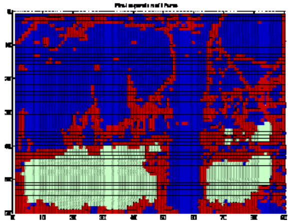
Solution:
block-level trellis



MPEG-2 Transrating (cont.)

- HVS-based bit allocation

Segmentation into regions: Texture, Edge, Smooth →



→ Block distortion weights → w_i

Modify the distortion metric accordingly:

$$\min_{Q_1,Q_2,\ldots,Q_N} \sum_{i=1}^{N} w_i \cdot d_i\left(Q_i\right)$$

$$s.t.$$

$$\sum_{i=1}^{N} r_i\left(Q_i\right) \le R_T$$

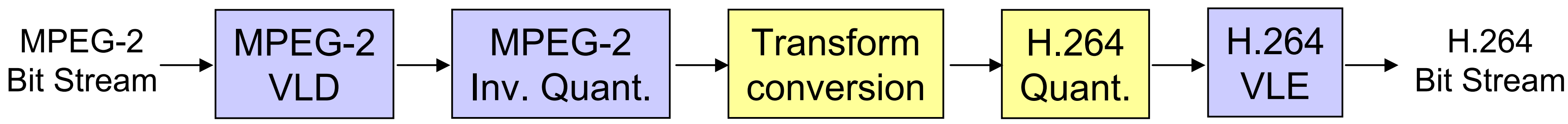
di – Distortion for block #i, ri – rate for block #i, R_T – Target rate, w_i – Weight for block #i
N – Number of blocks in the frame, Q_i – Quantization step for block #i

MPEG-2 → H.264 Transcoding Project

Naama Hait, Zeev Maor, Michael Tolchinsky; Supervisor: Ran Bar-Sella

- Major standards' differences:
  - Transform (DCT→ICT)
  - Quantization
  - Intra prediction
  - Motion Compensation
  - De-blocking filter
  - Advanced entropy coding

- Design guidelines:
  - MPEG-2 tools are a sub-set of the tools used in H.264
  - "Translate" MPEG-2 coding tools to their H.264 counterparts:

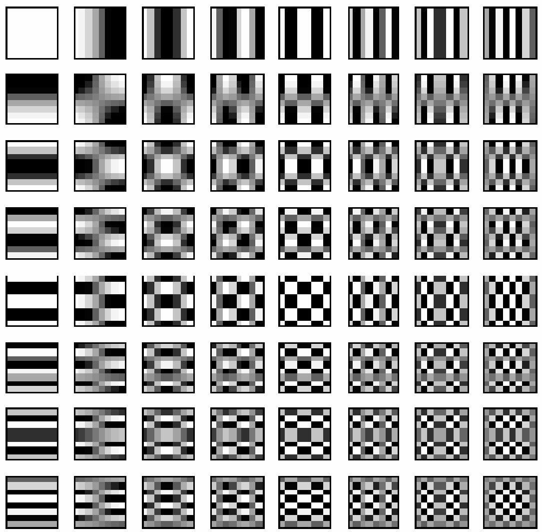


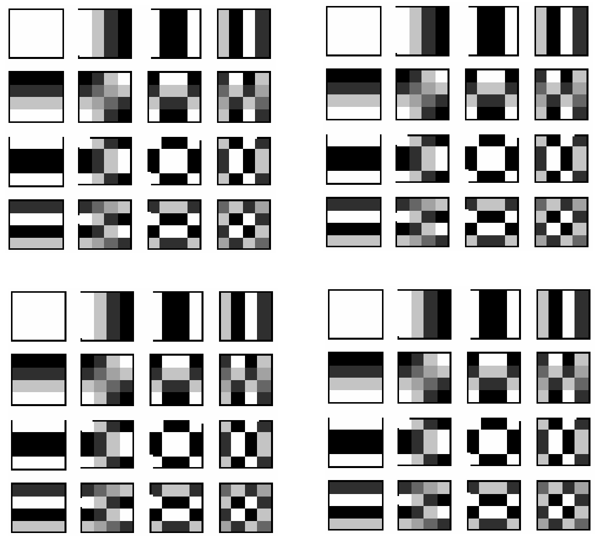
  - Try to get similar quality and measure bit rate

Transform Conversion

MPEG-2
DCT 8x8

H.264
4 ICT 4x4





Break down to:

1. **DCT 8x8 → 4 DCT 4x4**
2. **DCT 4x4 → ICT 4x4**

Transform Conversion (cont.)

1. DCT 8x8 → 4 DCT 4x4

- Pixel domain quadrant extraction:

$$A_1 \cdot \begin{bmatrix} X_1 & X_2 \\ X_3 & X_4 \end{bmatrix} \cdot B_1 = X_1$$

⇩

- DCT domain split:

$$DCT_{4x4}(X_1) =$$

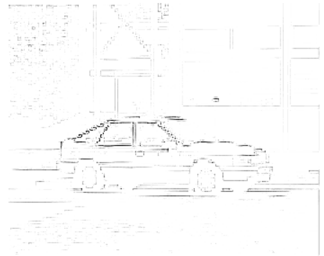
$$DCT_{4x8}(A_1) \cdot DCT_{8x8}\left(\begin{bmatrix} X_1 & X_2 \\ X_3 & X_4 \end{bmatrix}\right) \cdot DCT_{8x4}(B_1)$$

2. DCT 4x4 → ICT 4x4

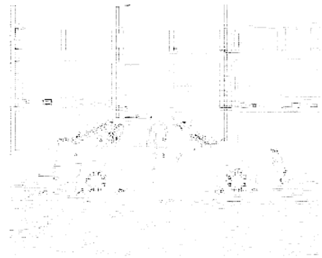
The transformed blocks share 4 coefficients, and the difference in the other terms is small

DCT^{-1} picture | Scaled difference (X 50)

Intra frame:



Inter frame:



→ We can use the DCT 4x4 coefficients as is with little introduced error

Re-quantization

Goal: Minimize re-quantization distortion (no target rate)

Overcome standards' differences by breaking down to:

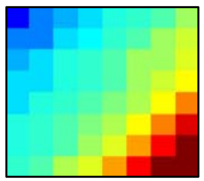
- Block-level data "preservation" (steps' matching, MPEG-2 intra Q. matrix)
- Frame level (H.264 ΔQP limiter)

Algorithm:

- Block level

1. Inter blocks: single MPEG-2 step → closest H.264 step
2. Intra blocks:

MPEG-2 Quant. [Q. matrix



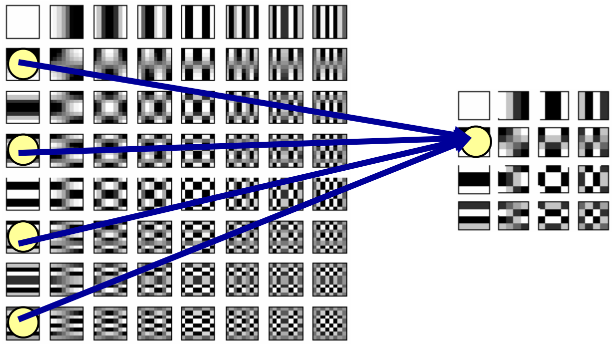
· Intra DCT block] ⇨ Multiple MPEG-2 steps ? ⇨ Ranked list of H.264 steps

Rank H.264 steps according to re-quantization distortion definition:

Coefficient re-quantization distortion ~ Coefficient magnitude X Step-size mismatch

Re-quantization (cont.)

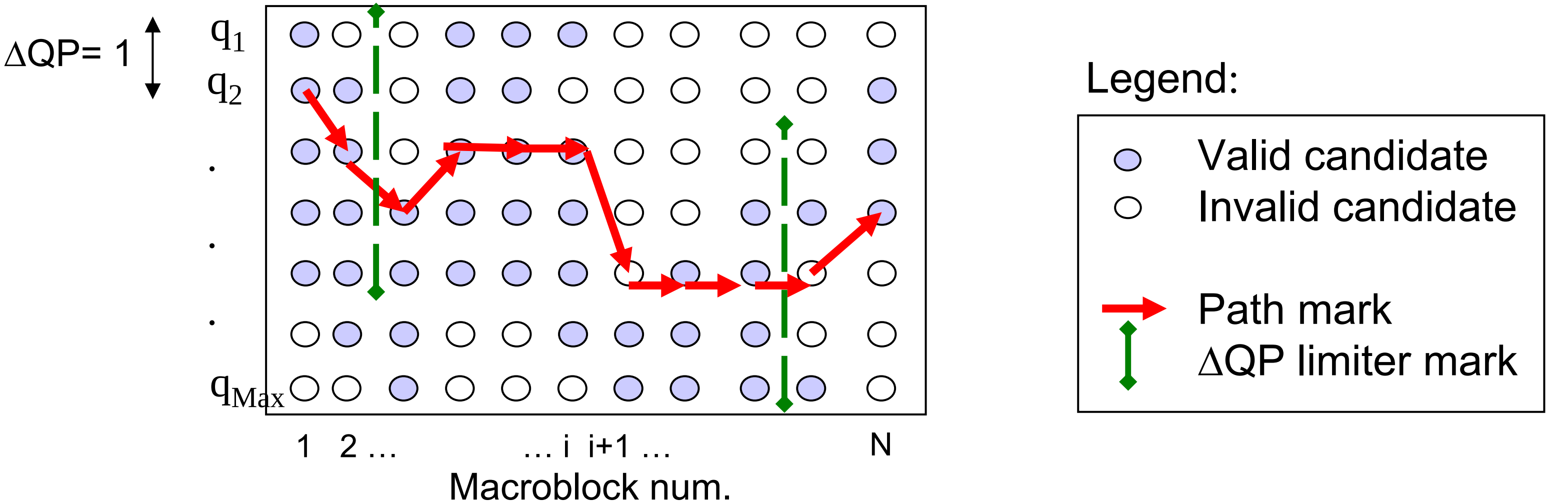
Since few DCT 8x8 coefficients → one ICT 4x4 coefficient, there is more than one original step that created each ICT coefficient:



⇨ Choose the most dominant DCT 8x8 "parent" coefficient as the step size representaive & sum over all ICT coefficients

- Frame level

Minimize the total distortion, subject to the ΔQP limiter using dynamic programming

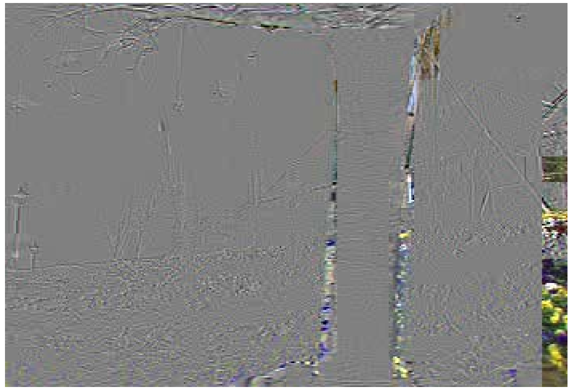


Transcoding – Partial Results

'Flower garden' sequence example

Intra frame:

Inter frame:



Preliminary results:

Intra frame:

- PSNR:
  MPEG-2 input: 34.4 [dB]
  H.264 output: 30.7 [dB]
- Bit rate reduction factor: 1.2

Inter frame:

- PSNR:
  MPEG-2 input: 30.7 [dB]
  H.264 output: 29.2 [dB]
- Bit rate reduction factor: 1.77

Planned additions:

- **Closed-loop architecture to compensate for the drift error**
- **Bit rate control**

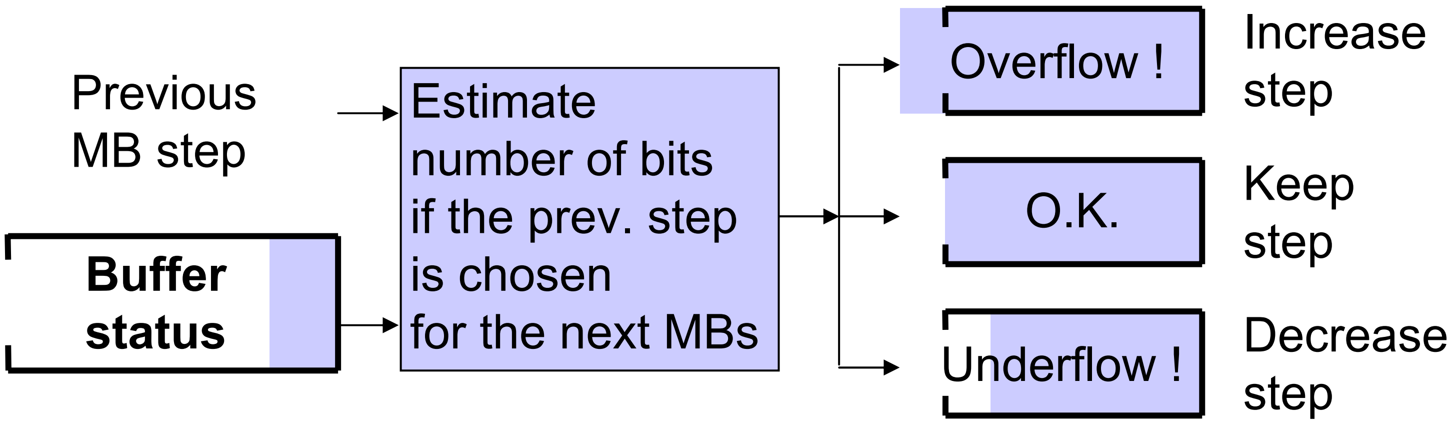
H.264 Transrating

Bit rate reduction via Re-quantization

1. Student project: Bit rate control for H.264 Transrater

   Mikael Cohen, Yohann Sabbah; Supervisor: Naama Hait

- One pass rate control algorithm (non optimal) subject to the ΔQP limiter

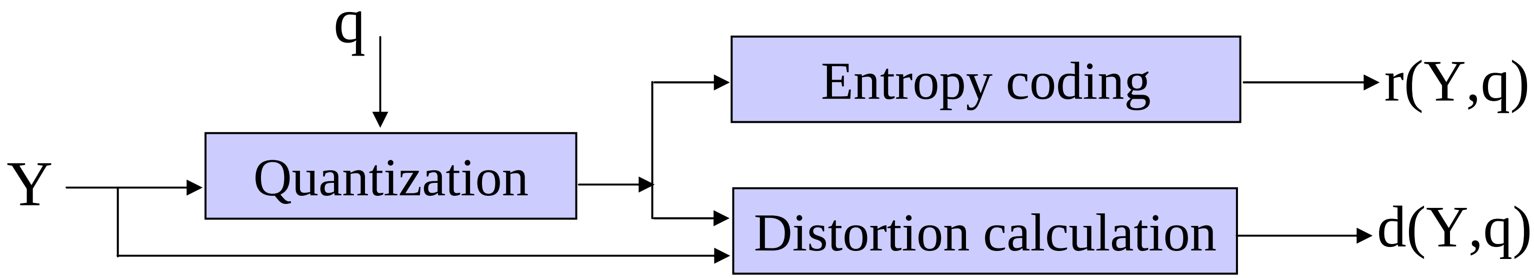


- Compensate for the drift error (closed loop)

Model-based Transrating in H.264

2. Model-based Transrating of Video Signals –
Naama Hait (M.Sc.); Supervisor: Prof. David Malah

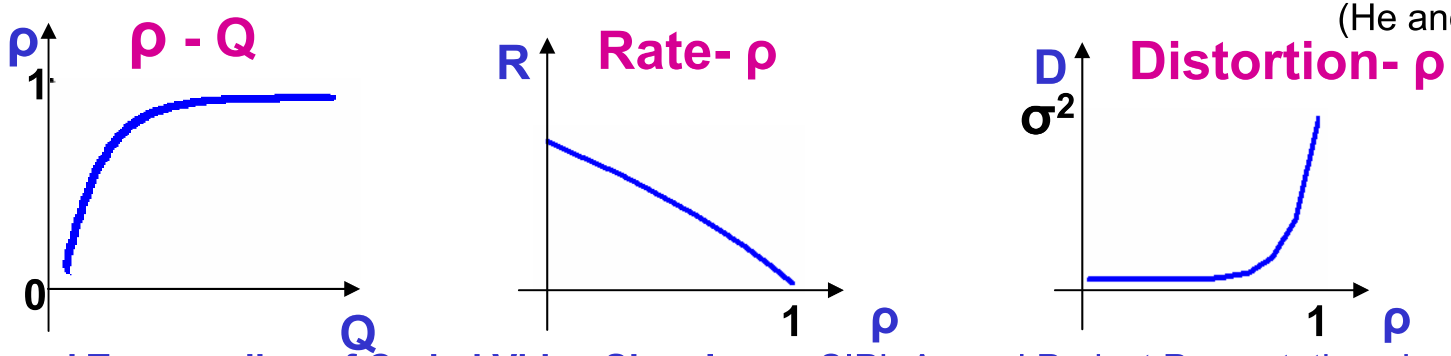
- Non-model based evaluation of rate and distortion:



- Multiple repetition for every (block, step size) combination
  ⇨ High computational complexity

- Use R-D models in the ρ domain (fraction of zeroed coefficients):

(He and Mitra, 2002)

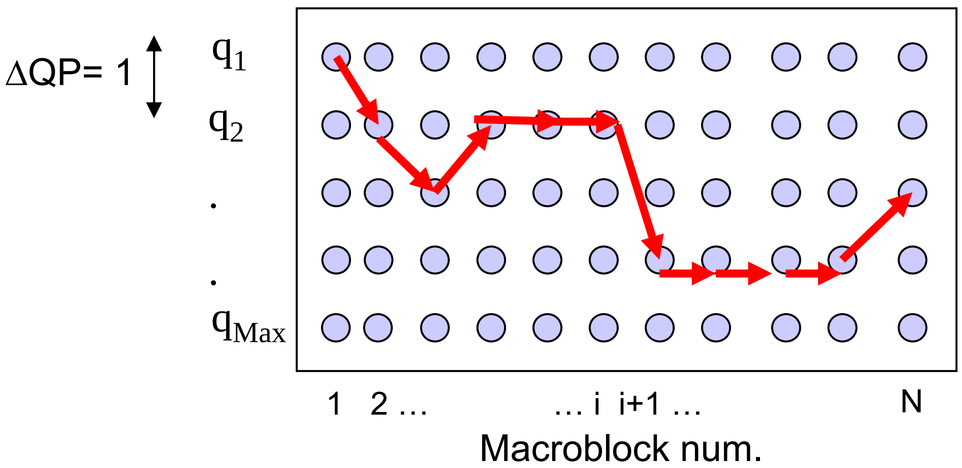


Model-based Transrating in H.264 (cont.)

Frame Level Optimization

- Estimate rate and distortion for all (block, step size) combinations
- Solve R-D optimization subject to the **ΔQP limiter**:

- Define Lagrangian cost: **$J = D + \lambda \cdot R$**
- Solve constrained dynamic programming problem:



- Change Lagrangian parameter λ to improve rate guess

Planned Activity

- Incorporate the model-based transrating algorithms into the H.264 transrating system
- Add the closed-loop architecture and bit rate control to the MPEG2 → H.264 transcoding system
- Transcoding and transrating of MPEG-2 → H.264
  Examine different integrations of previous developments: