MODEL-BASED TRANSRATING OF H.264 INTRA CODED FRAMES

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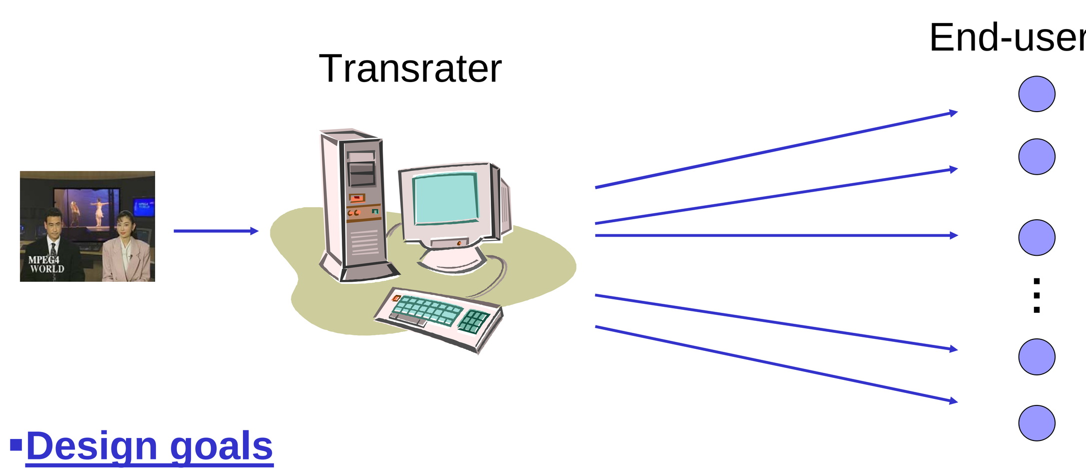
Transrating of coded video

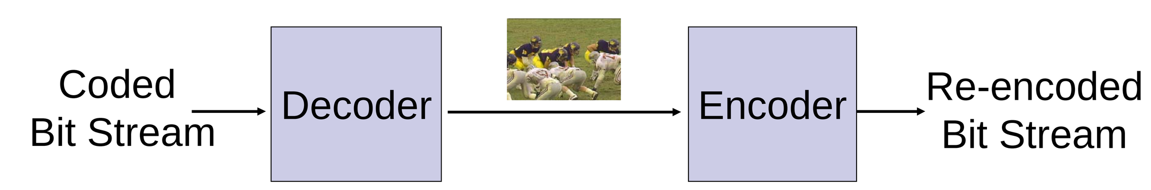
- **Transrating**: bit rate reduction of pre-encoded video.
- **Method**: transform coefficients requantization.
- **Applications**: television broadcast, internet streaming



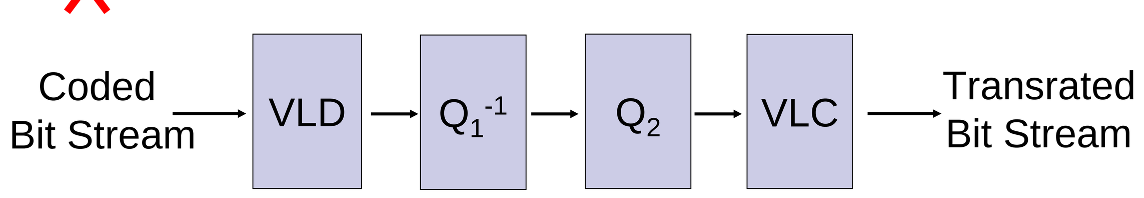
- **Design goals**
  - Achieve the highest quality at the target bit rate.
  - Minimal complexity – use as much information from the coded bit stream.

Transrating architectures

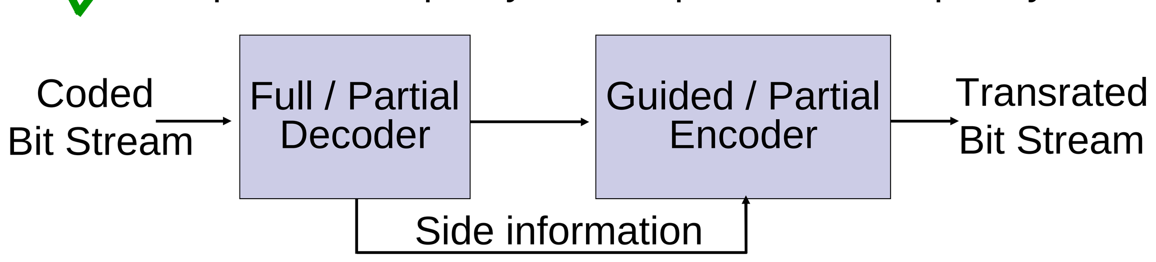
- **Trivial solution – re-encoding**
  - ✗ high computational complexity due to full encoding



- **Lowest complexity – open-loop**
  - ✗ drift error

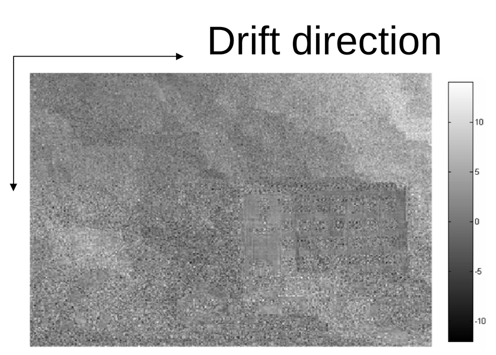


- **Reuse of input coding modes**
  - ✓ compromise of quality vs. computational complexity



- **Intra-frame transrating architectures**
  - **Partial Decoder – Partial Encoder**
    - ✗ Decode up to the residual transform coefficients

Non-linear operations cause a drift error that cannot be fully compensated



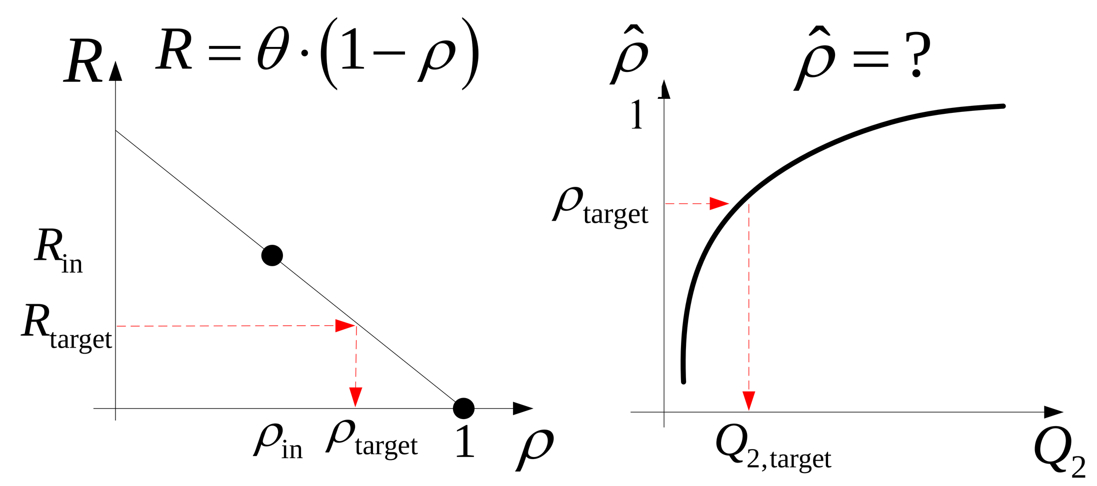
  - **Full Decoder – Guided Encoder**
    - ✓ No drift error

    Guided encoding, based on the input intra prediction modes with optional modes modification.

Model-based uniform requantization

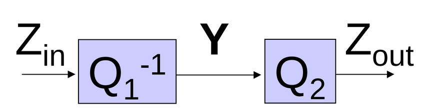
- **Uniform requantization**
  - A sufficiently high bit budget is typical (intra-frames).
  - Spatial prediction → block dependencies
- **Model-based**
  - Transform coefficients requantization → evaluation of rates at many step sizes → high complexity.
  - Reduce the complexity by model-based evaluation.
  - Use a robust rate model in the ρ domain (fraction of zeroed coefficients), (He and Mitra, 2002)
- **Procedure**:

1. Estimate $rate-\rho$ model
2. Find the target ρ.
3. Estimate $\rho-Q_2$ relation
4. Find the target Q_2.

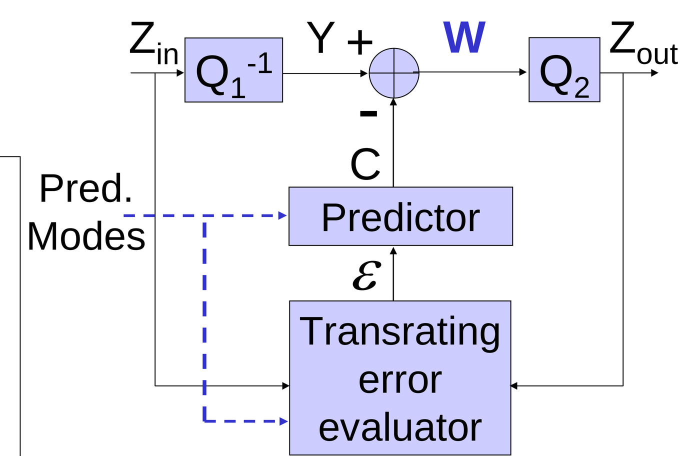


Open-loop vs. closed-loop $\rho(Q_2)$ estimator

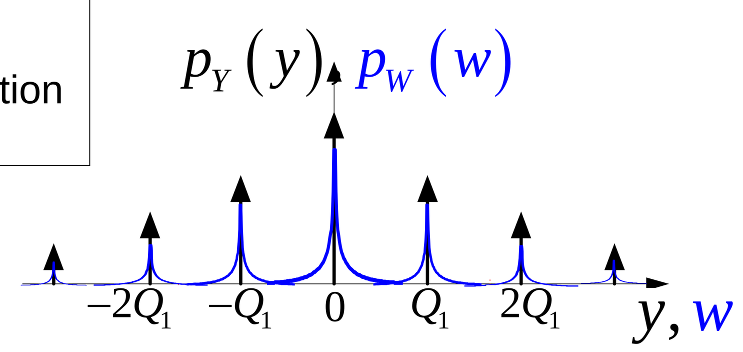
Open-loop estimator



Closed-loop estimator



- Z – residual quantized indices
- Y – input residual transform coeff.
- W – corrected signal to be requantized
- C – correction signal
- ε – transrating error
- $Th(Q_2)$ – requantization deadzone



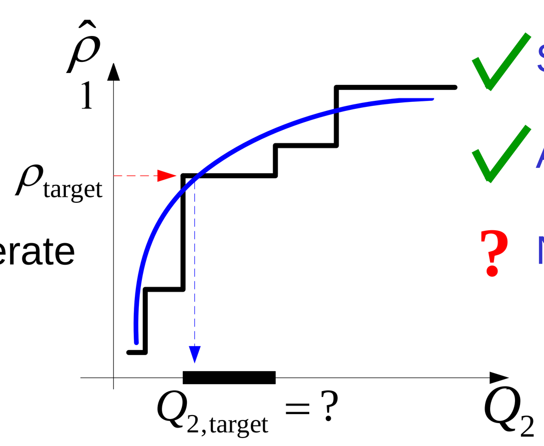
Open-loop:

$$\hat{\rho}(Q_2)=\Pr.\left(|Y|\le Th(Q_2)\right)$$

Closed-loop:

$$\hat{\rho}(Q_2)=\Pr.\left(|W|\le Th(Q_2)\right)$$

- ✗ Staircase → uncertainty
- ✗ Not accurate enough at moderate to coarse steps



- ✓ Smooth estimator
- ✓ Accurate
- ? No known model

Statistical $\rho(Q_2)$ estimator

Modeling stages (closed-loop scheme just for modeling)

1. Extract the distribution of Y from the input:

$$p_Y(y)=\sum_{m=-M}^{M}p_m\cdot\delta(y-mQ_1)$$

2. Model the distribution of the correction signal **C**
   - I. Characterization: segment into homogenous data parts
   - II. Γ probability distribution
   - III. Estimation of Γ distribution parameter
3. Use 1.+2. to model the distribution of **W**.

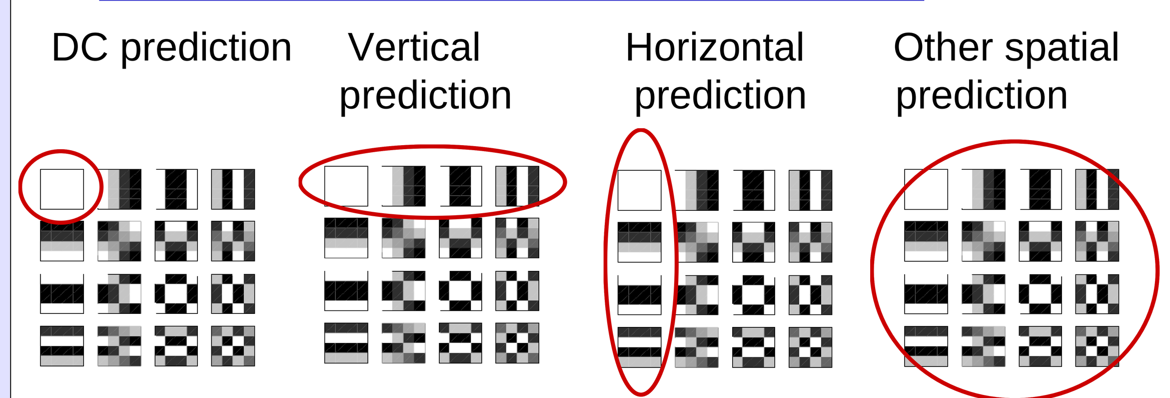
$$\Pr.(W\le w_0)=\sum_{m=-M}^{M}p_m\cdot\int_{-\infty}^{w_0-mQ_1}p_{-C|Y}(c|y=mQ_1)dc$$

4. Estimate $\hat{\rho}(Q_2)=\Pr.\left(|W|\le Th(Q_2)\right)$

Correction signal modeling (I) Characterization of C

Segment the correction signal into groups according to the following criteria

1. **Spatial prediction modes** (e.g. DC, vertical, horizontal, various diagonal)
2. **Affected / unaffected transform coefficients**:



3. **Input quantization step-size** (Q_1)

Benefits

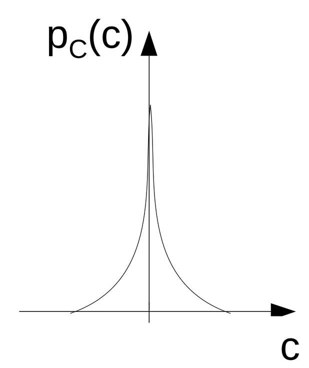
- ✓ Increased precision
- ✓ Complexity reduction – use open-loop estimator for unaffected coefficients.

Correction signal modeling (II) Γ probability distribution

- Definition:

$$p_C(c)=\frac{1}{2\sqrt{\pi}}\sqrt{\frac{\beta}{|c|}}\cdot\exp\left(-\beta|c|\right)$$

where smaller β → wider distribution



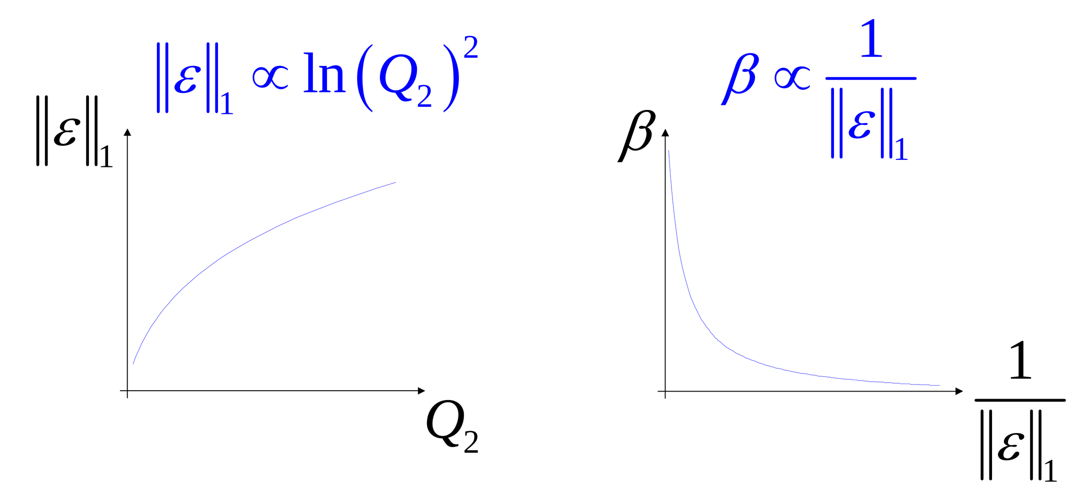
- ML estimator: $\hat{\beta}=\dfrac{0.5N}{\sum_{i=1}^{N}|c_i|}$

Correction signal modeling (III) Estimation of Γ distribution parameter

Problems:

1. C is not evaluated → online β estimation required
2. Great variability in the β-Q_2 relation over different data groups complicates its modeling.

Solution: **Decompose β-Q_2 model**



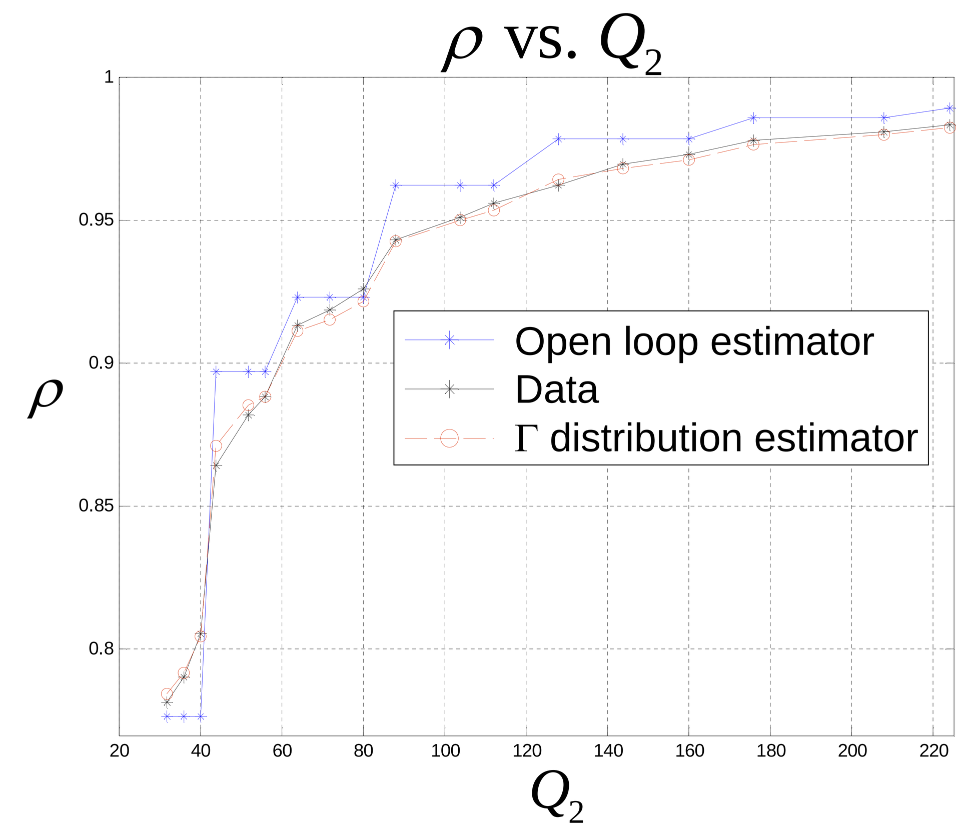
Parameters depend on input: $Q_1, \|Y\|_2$

Parameter changes with prediction mode

Results

- **ρ-Q_2 estimator performance**

The proposed Γ distribution estimator has an average relative error of less than 1.7%



- **Rate-Q_2 estimator performance**

ρ-Q_2 estimator	Mean relative rate deviation [%]
Open loop estimator	10.8
Data	2.5
Γ distribution parameter	3.0

Conclusion

- Novel **statistical-based ρ-Q_2 model** for transrating of H.264 intra-coded frames.
- The model provides **average rate deviation of 3%**, as compared to 10.8% average deviation, obtained using an open-loop estimator.