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Minds in Motion

An Adaptive RDO with Constant Bitrate in Real Time H.264 Encoder

Efficient Rate Control Implementation on DM642 DSP

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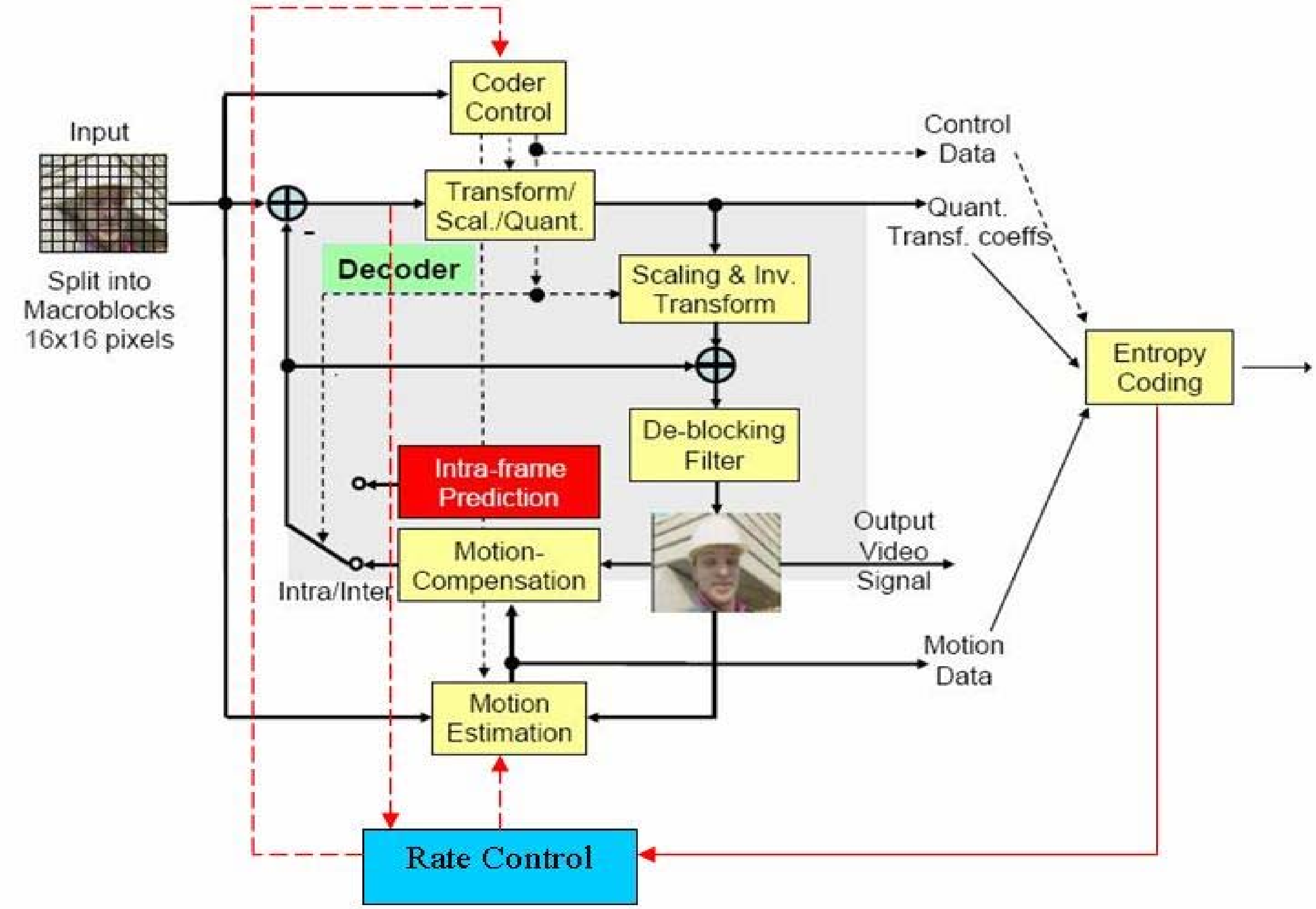
VESTEK
Connectivity and Processing

Agenda

- Introduction to Rate Model
- Rate Control Parts
  - Pre Encoding
  - Encoding
  - Post Encoding
- MAD Estimation
  - MAD Layers
- Vestek Real-Time H.264 Encoder
  - Encoder Configuration
  - Optimization
  - Rate Control Results
    - Comparison with X264
    - Results with Test Sequences
- Demo
- References

H.264 with Rate Control



Application Areas

- Low Bitrate & Low Delay Applications
- Real-time Applications
  - Video Conferencing, Video Phone
  - Consumer Electronics
  - Streaming & Multimedia

Rate Model

- The Bit Rate in H.264 is considered to have Laplacian Distribution [1]

$$P(x) = \frac{\alpha}{2} \cdot e^{-\alpha |x|}$$

- Rate Distortion Optimization is performed using the lagrangian formula.

$$J = D + \lambda R$$

Rate Model

- The distortion is measured as:

$$D(x, x') = |x - x'|$$

- The R-D function can be expressed as:

$$R(D) = \ln(\frac{1}{\alpha D})$$

- We can expand this function into Taylor Series:

$$R(D) = (\frac{1}{\alpha D} - 1) - 1/2(\frac{1}{\alpha D} - 1)^2 + R_3(D)$$

$$R(D) = -3/2 + \frac{2}{\alpha} D^{-1} - \frac{2}{\alpha^2} D^{-2} + R_3(D)$$

Rate Model

- Using the first two coefficients we can estimate the bit rate as follows:

$$R_i = \alpha_1 \cdot Q_i^{-1} + \alpha_2 \cdot Q_i^{-2}$$

- This function can be evaluated a little further

Rate Model

- Using the header infortmation and the MAD the Rate Model becomes:

$$\frac{R_i - H_i}{M_i} = \alpha_1 \cdot Q_i^{-1} + \alpha_2 \cdot Q_i^{-2}$$

- Where:
  - Ri: total number of bits used for encoding the current frame
  - Hi: Header bits
  - Mi: MAD computed using the motion compansated residual Y Component
  - Qi quantization level
  - a1, a2 first and second order coefficients

Rate Model

- This quadratic R-D model enables us to calculate a Qp before encoding the GOP, frame, MB
- With this model it is easy to update the Qp value according to bit rates of previous frames

Rate Control Parts

- Rate control can be made in three parts:
  - Pre-Encoding
  - Encoding
  - Post-Encoding
- These parts are used in three layers in encoder which are:
  - GOP Layer
  - Frame Layer
  - MB Layer

Pre-Encoding

- Pre-encoding consists of the following steps:
  - Target bit rate estimation
  - Qp calculation according to Rate-Model
- These steps are performed on two layers:
  - Frame Layer
  - MB Layer

Encoding

- Encoding the frame
- Using the MB-Layer control according to the results
  - – The MB-Layer control can have considerable overhead when changed frequently

Post-Encoding

- The quaratic R-D model needs to be updated.
- The model given calculates the coefficients with n-sample data points
  - The number of samples can be disscused further

$$X_2 = \frac{n\sum^{n} R_i - (\sum^{n} Q_i^{-1})(\sum^{n} Q_i R_i)}{n\sum^{n} Q_i^{-2} - (\sum^{n} Q_i^{-1})^2}$$

$$X_1 = \frac{(\sum^{n} Q_i R_i) - X_2 Q_i^{-1}}{n}$$

MAD Estimation

- When updating the Qp value the MAD of the previous frame is used

$$MADP_j = \alpha_1 \cdot MADA_{j-1} + \alpha_2$$

  - Initially a1=1 and a2=0
  - MADP is the estimated MAD of the current frame
  - MADA is the actual MAD of the previous frames

Macroblock MAD

- While estimating frame layer MAD
  - Linear regression
    - Mad estimation
  - Quadratic R-D Model
    - QP_{step} calculation

- This approach can give better results in frame layer but not in MB layer or scene change.

MB Layer Rate Control

$$ave\_t\_Bits = \frac{T(j)}{N_{mb}}$$

Average bits for MB in a picture

$$f_{rb} = T(j) - \sum_{i=1}^{fps-N_{rb}} (m_{hdr,i} + m_{tex,i})$$

Remaining bits (f_{rb}) for remaining block in picture (N_{rb})

$$t\_B_i = (\alpha \times \frac{f_{rb}}{N_{rb}} + \beta \times ave\_t\_Bits) \times \frac{MB\_MAD\_P_{i,j}}{Ave\_MB\_MADA(j-1)}$$

$Ave\_MB\_MADA(j-1)$ is average actual MADs of all MBs in previous picture (frame j-1).

MB Layer Rate Control

$$\tilde{m}_{hdr,l} = \tilde{m}_{hdr,l-1} \times (1 - \frac{1}{l}) + \frac{\hat{m}_{hdr,l}}{l}$$

$$m_{hdr,l} = \tilde{m}_{hdr,l} \times \frac{l}{N_{mb}} + m_{hdr,1} \times (1 - \frac{l}{N_{mb}}); 1 \le l \le N_{mb}$$

- where $\hat{m}_{hdr,l}$ is the actual number of header bits generated by the *l*th macroblock in the current picture.
- $m_{hdr,1}$ is the estimation from all macroblock in the previous stored picture.

MB Layer Rate Control (MAD correction)

$$m\_B_i = t\_B_i - m_{hdr,i}$$

$$m\_B_i = X_1 \times \frac{MB\_MAD\_P_{i,j}}{Q_{step,i}(j)} + X_2 \times \frac{MB\_MAD\_P_{i,j}}{Q^2_{step,i}(j)}$$

MB_MAD_Pi,j (the MAD of the ith macroblock in the jth frame) has to be calculated.

Linear regression ($MB\_MAD\_EST_{i,j}$) can give misleading estimation results in MB layer estimation. For better results; b_1= 0,7 b_2=0,3 for simulation

$$MB\_MAD\_P_{i,j} = b_1 \times MB\_MAD\_EST_{i,j} + b_2 \times \min(MB\_MAD_{curr,i,j}, MB\_MAD_{pred,i,j})$$

Different Qp Different Lagrange Multiplier

- Updating the Qp also has an effect on Lagrange Multiplier and also on Mode selection
- This means:
  - Larger LM higher Distortion but less Bit-Rate
- This show us that the LM should also be changed with Qp to be able to have more control on Bit-Rate [3]

QP and Coefficents' Cost

- Changing the Qp value changes the Bit Rates but also changes the overall quality of the frame (PSNR).
- This can be reduced a little with first changing the Luma and Chroma Coefficient Cost of the current frame and eliminating the High frequency components
  - The similiar way as in JPEG still image coding

Encoder Configuration

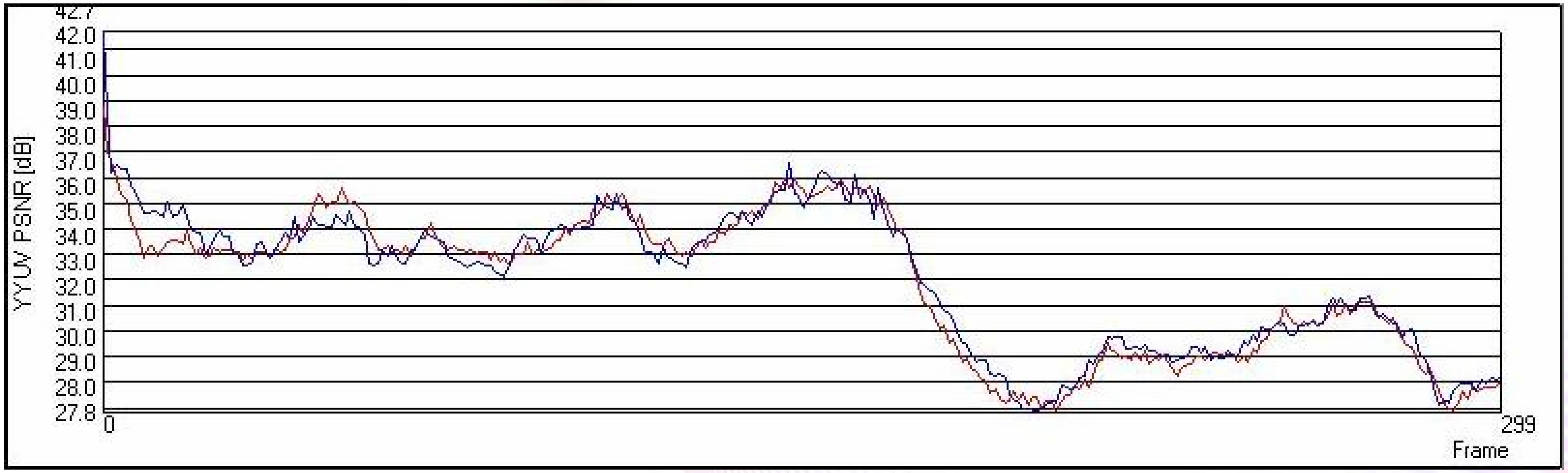
- ME Algorithm
  - N-TSS & Hexagon search
  - Flexible search range
  - Full-pel, half-pel Accuracy
  - MV partitions (16x16, 16x8, 8x16, 8x8)
  - Number of reference frame = 1
- Resolution
  - QCIF[176x144], CIF [352x288]
- CAVLC, CABAC
- Deblocking filter
  - Selective on/off
- CBR (Frame & MB level Rate Control)
  - Selective CBR or CQP

Optimization Hints

- Algorithmic Optimizations
  - Fast Motion Estimation & Mode Decision
- Architectural Optimizations
  - SIMD inst., Lineer ASM, etc.
- Memory & Structural Optimizations
  - On-chip Memory Usage
  - Cache Tuning
  - EDMA (Quick DMA)

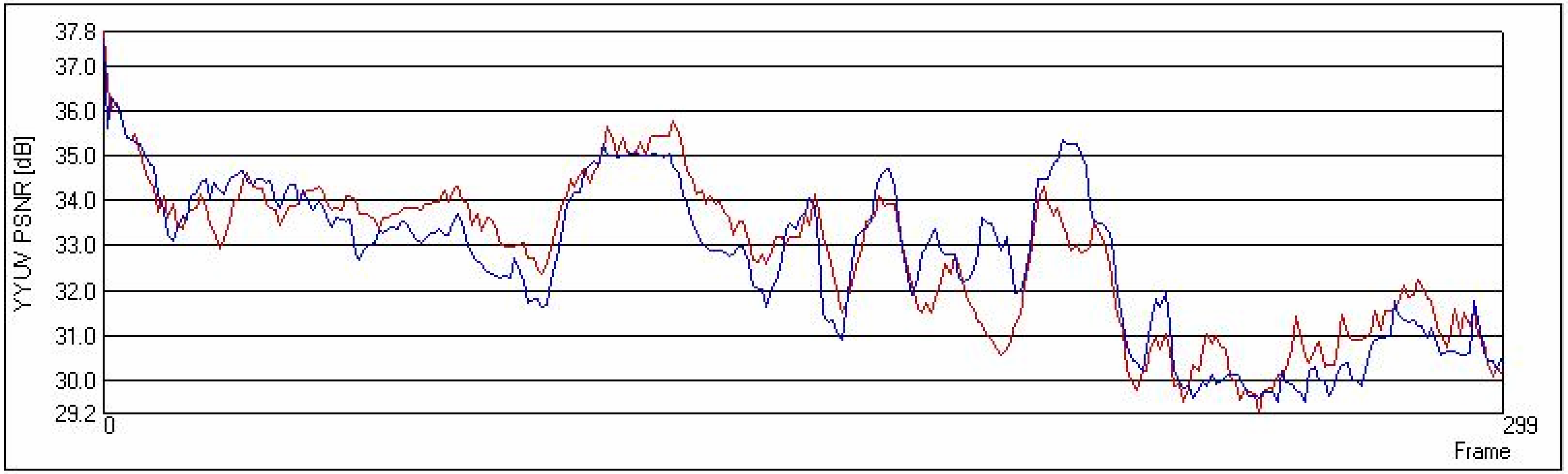
Comparison with X264

- Carphone, QCIF 300 frame [128 kb/s]



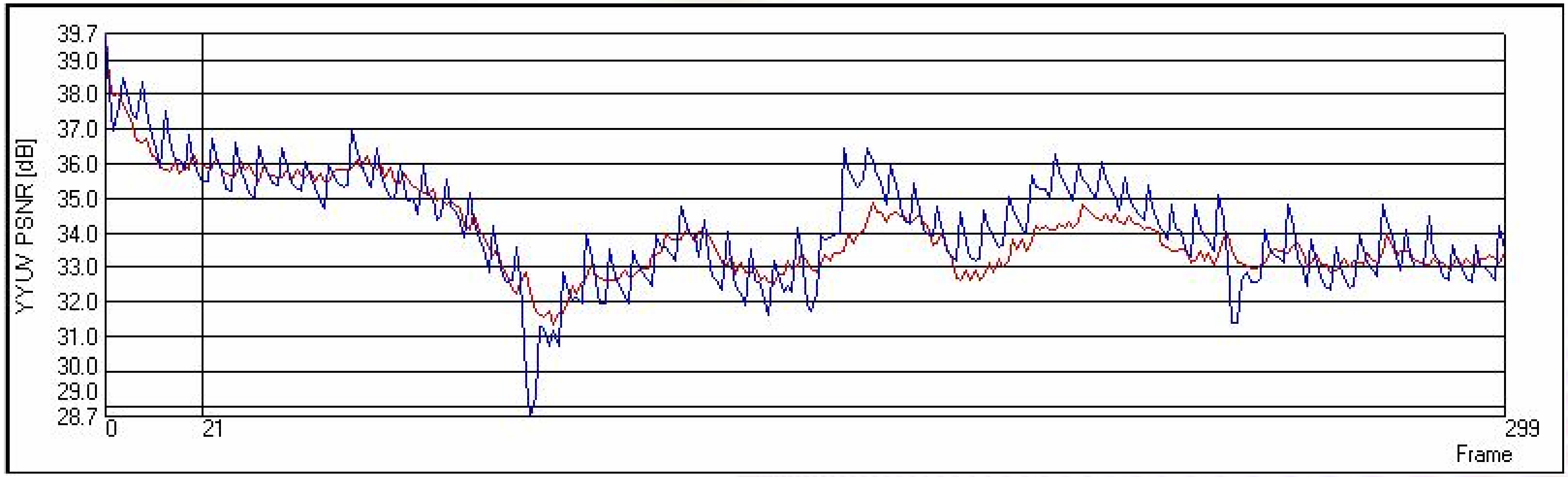
Comparison with X264

- Foreman, CIF 300 frame [384 kb/s]



Comparison with X264

- News, QCIF 300 frame [64 kb/s]



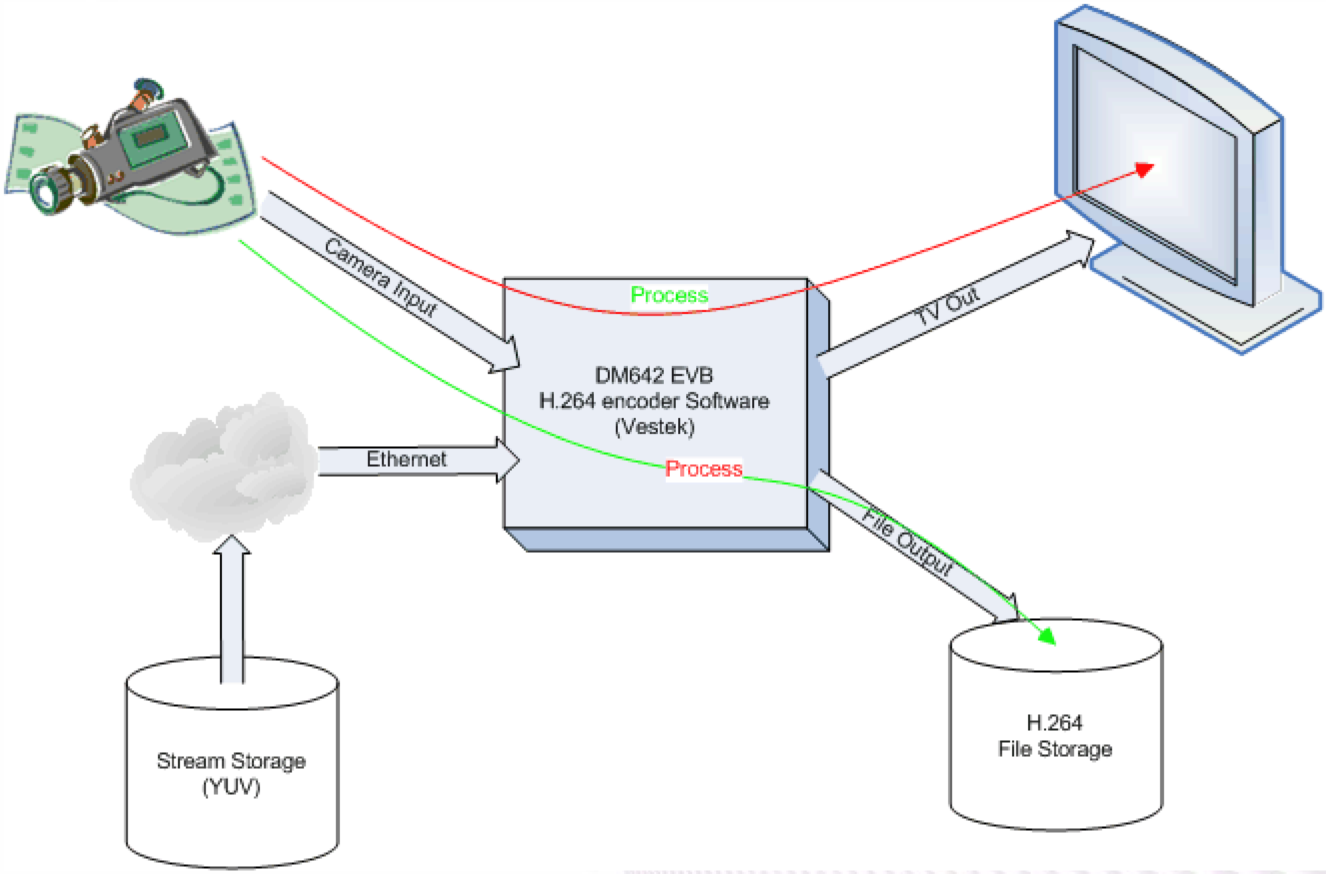
Rate Control Outputs

Sequence (120 frames)	Resolution	Y-SNR (dB)	Rate with CBR*
News	176x144	33.54	64 Kbps
Carphone	176x144	31.17	128 Kbps
Foreman	352x288	32.68	384 Kbps
Stephan**	352x288	29.28	768 Kbps
Mobile	352x288	30.05	1 Mbps

* 30 fps outputs

** 90 frames sequence

DEMO


Camera Input
Process
TV Out
DM642 EVB
H.264 encoder Software
(Vestek)
Ethernet
Process
File Output
Stream Storage
(YUV)
H.264
File Storage

References

- [1] Scalable Rate control for MPEG-4 Video, Hung-Ju Lee, Tihao Chiang, Ya-Qin Zhang IEEE Transaction on Circuits and systems for video Technology 2000
- [2] Low Delay Rate Control for Real-Time h.264/AVC Video Coding Minqiang Jiang, Nam Ling IEEE 2006
- [3] Frame Layer H.264 Rate Control Improvement Using Lagrange Multiplier and Quantizer Minqiang Jiang, Nam Ling IEEE 2005
- [4] JVT-N046, Joint Video Team (JVT) of ISO/IEC MPEG and ITU-T VCEG Hong Kong, Jan, 2005
- [5] Video Encoder Optimization on TMS320DM64x/c64x, Texas Instruments Application Note, spraa63