New Techniques for Improved Video Coding

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Outline

§ Inter-frame Encoder Optimization

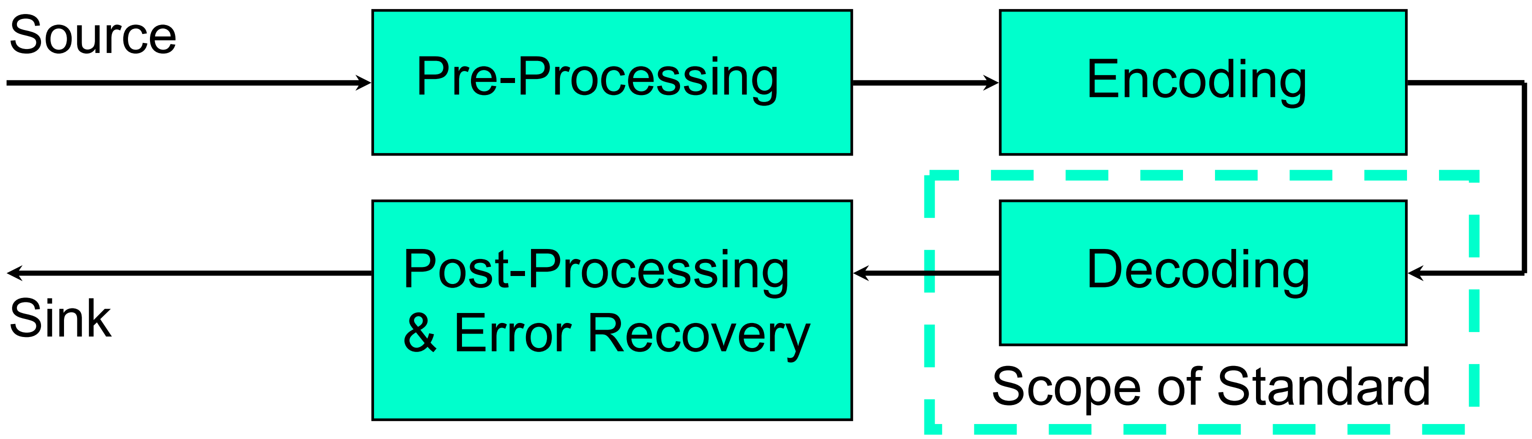
§ Texture Analysis and Synthesis

§ Model-Aided Coding

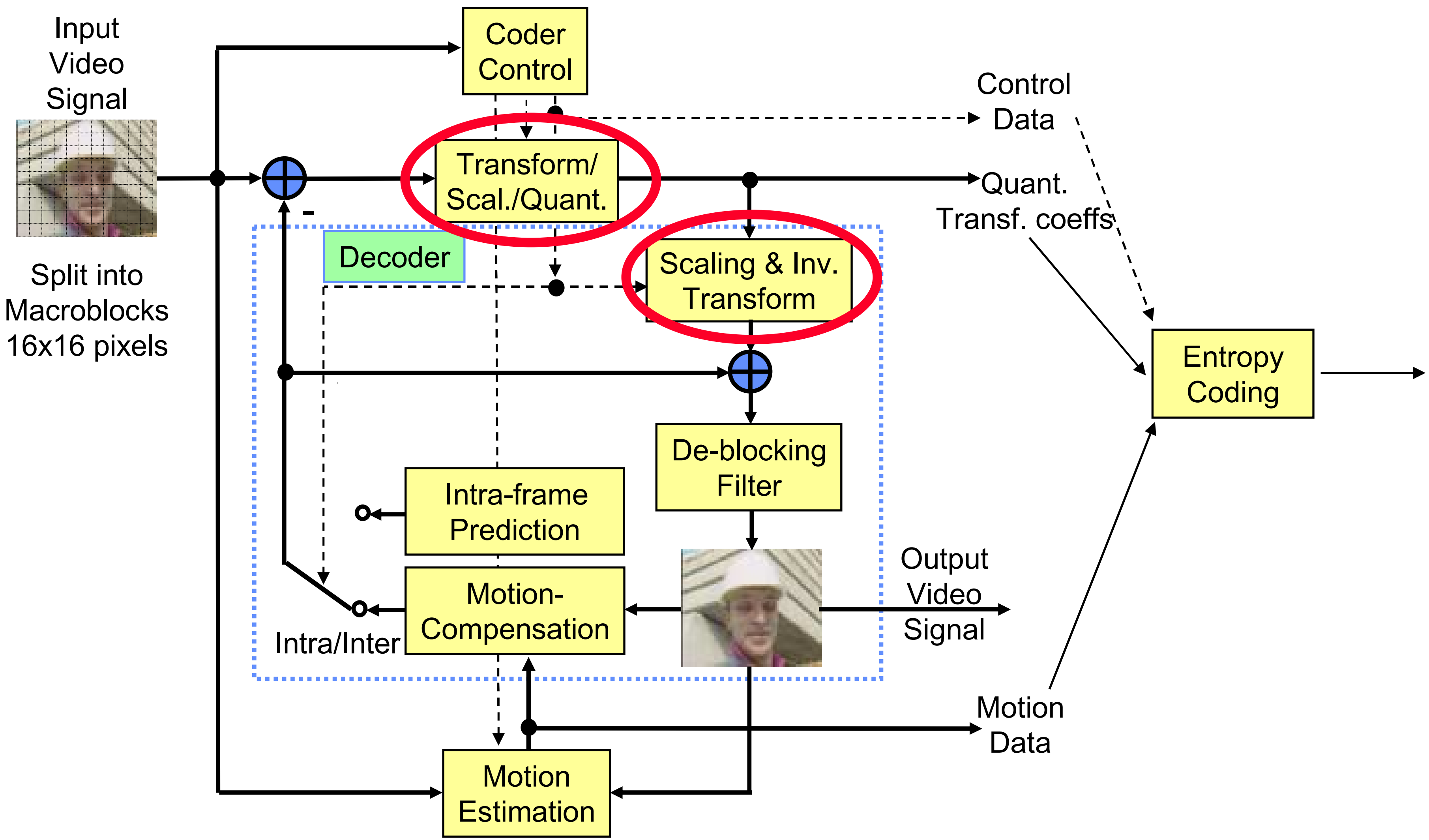
Scope of Video Coding Standardization

Only Restrictions on the *Bitstream*, *Syntax,* and *Decoder* are standardized:

- Permits optimization beyond the obvious
- Permits complexity reduction for implementability
- Provides *no* guarantees of quality

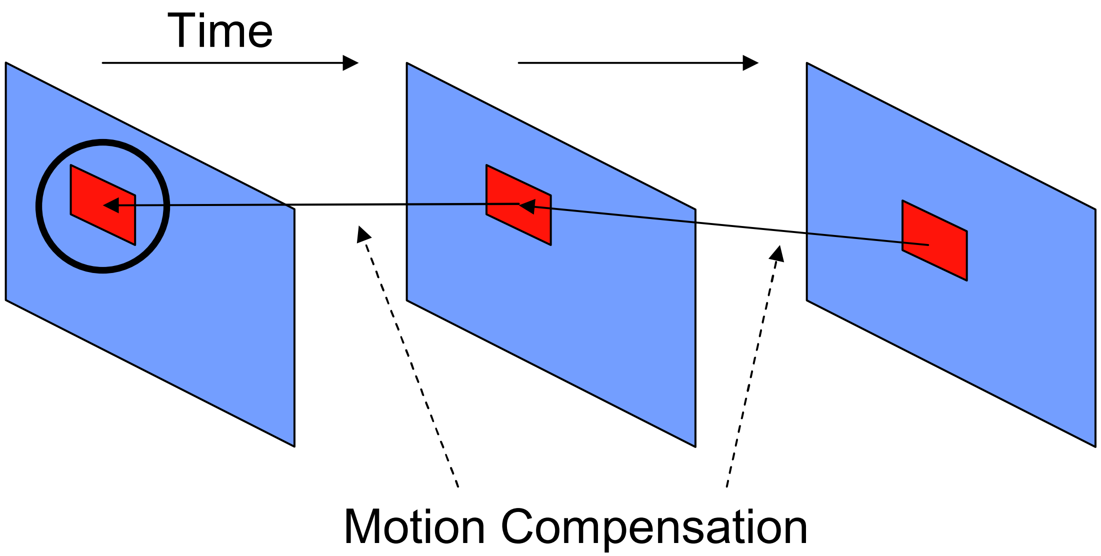


Hybrid Video Encoder



Inter-frame Optimization of Video Encoding

- Most video encoders select locally optimal transform coefficients as they ignore temporal dependencies



- New approach that takes inter-frame dependencies into account

Linear Signal Model for Decoder

motion data

transform coefficients

$$\mathbf{s} = \mathbf{M}\mathbf{s} + \mathbf{T}\mathbf{c} + \mathbf{p}$$

reconstructed sample values

static predictor

inverse transform & scaling

- Very large size of matrices
- Numbers when optimizing 4 QCIF pictures jointly: M, T: 100,000 x 100,000 entries

Quadratic Program

- Use Mean Squared Error distortion
- Select transform coefficient levels by solving:

original video signal

minimize $$(\mathbf{s}-\mathbf{v})^T(\mathbf{s}-\mathbf{v}) + \lambda \sum_i \text{abs}(\mathbf{c}_i)$$

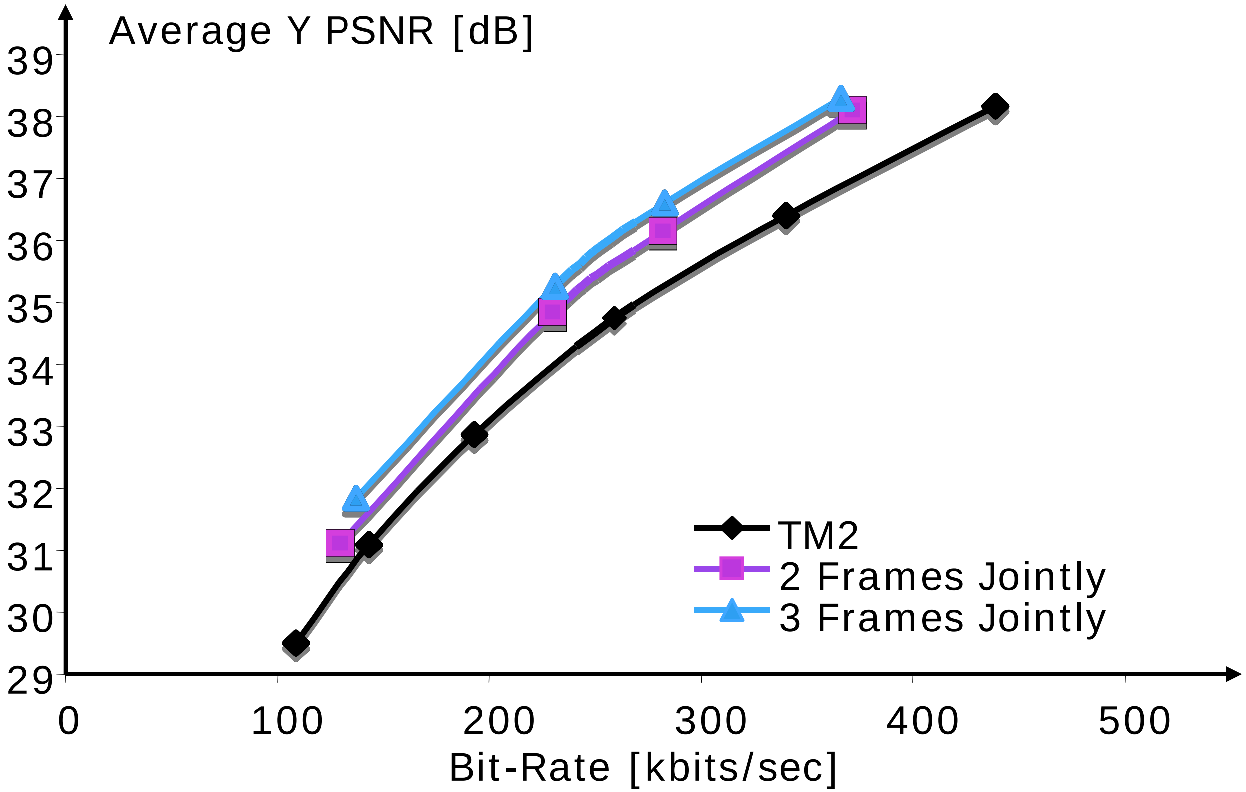
subject to: $$\mathbf{s} = \mathbf{M}\mathbf{s} + \mathbf{T}\mathbf{c} + \mathbf{p}$$

- Equivalent to a quadratic program
- Can be solved by standard solution methods!

Results

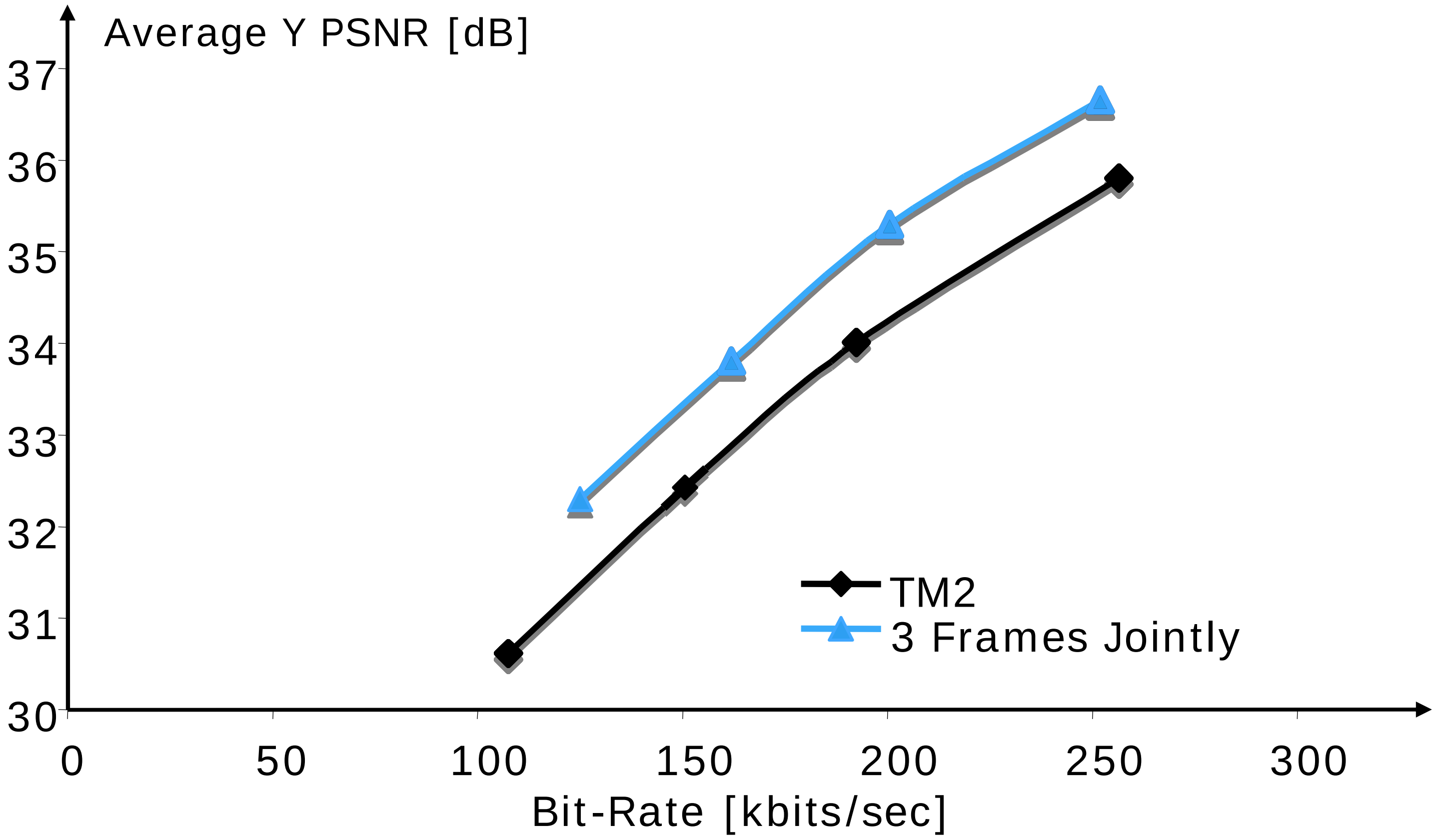
- Used H.264/MPEG4-AVC
- Compare looking at 2 or 3 frames at a time
- Compare to H.264/MPEG4-AVC Test Model
- Constant QP
- Motion estimation on original frames
- Only optimized inter-frames

FlowerGarden 30Hz IPPP.....



16% Bit-rate improvement

FlowerGarden 30Hz IbPbPbP.....



15% Bit-rate improvement

Summarizing Inter-frame Optimization

- Very complex: has only recently become possible
- Problems with H.264/MPEG4-AVC: rounding
- Adjust design to support efficient encoding methods
- Heavy incorporation of encoding methods has been used in H.264/MPEG4-AVC development with Lagrangian encoder optimization
- Do not standardize the encoder!

Texture Analysis and Synthesis

- Textures with large amount of visible details are difficult to code e.g., grass, sand, clouds, water ...
- Viewer often does not perceive large differences between different versions of grass, sand, clouds, water ...

Where is the original texture ?

Video Analysis and Synthesis

§ **Approach**: Exact reproduction of details is irrelevant if

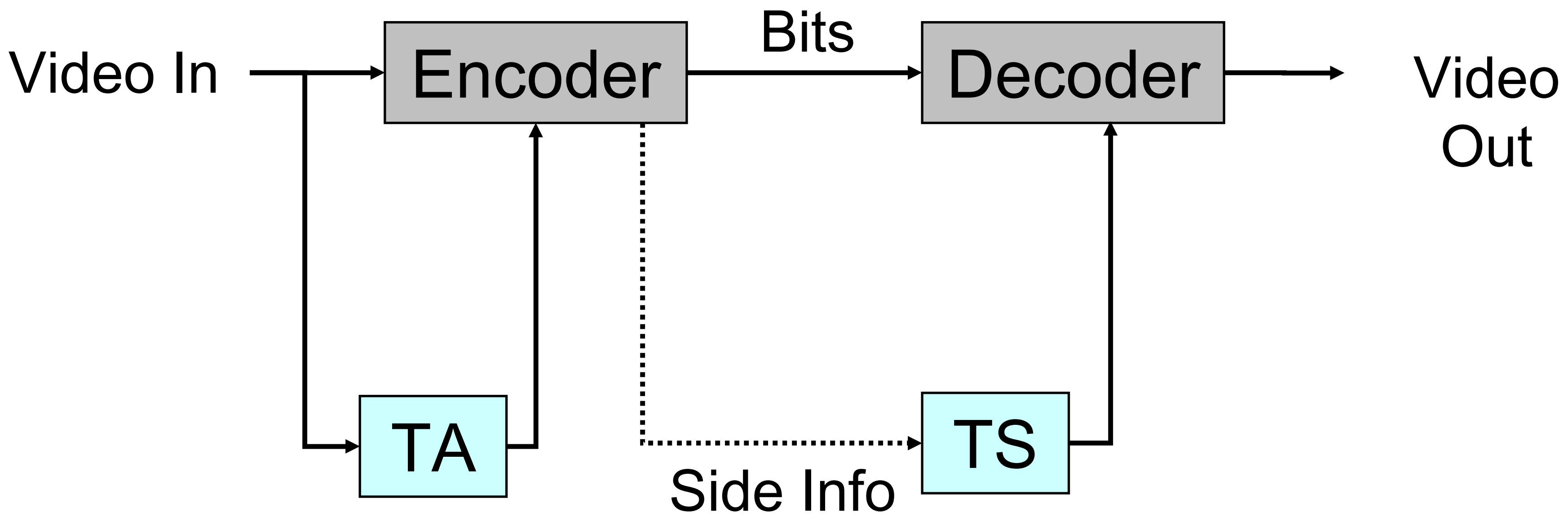
- Textures are shown with limited spatial accuracy
- Viewer does not know the original video

§ **Consequence**: Mean Squared Error (MSE) distortion criterion is not suitable for efficient coding of detail-irrelevant textures

§ **Issue**: Could we use similarity criteria (color histograms, etc) instead of MSE as coding distortion ?

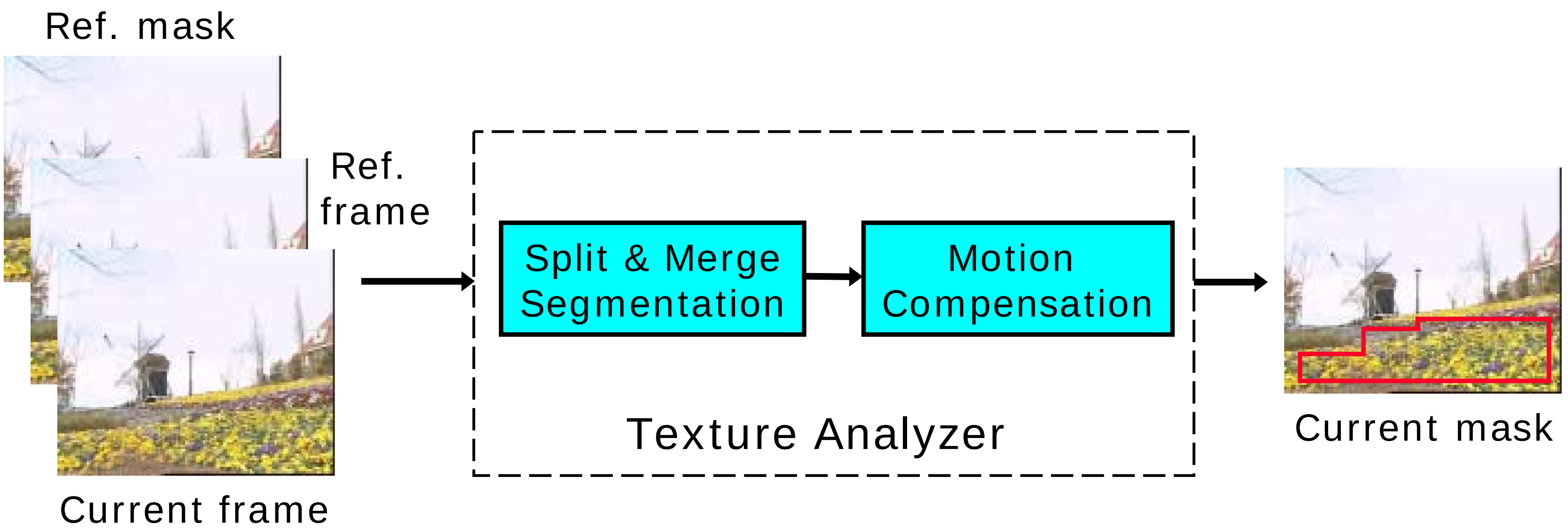
§ **Scheme**: If information needed for approximate reproduction of detail-irrelevant textures requires less bit-rate than using MSE
Ł ***bit-rate savings***

Video Codec Architecture

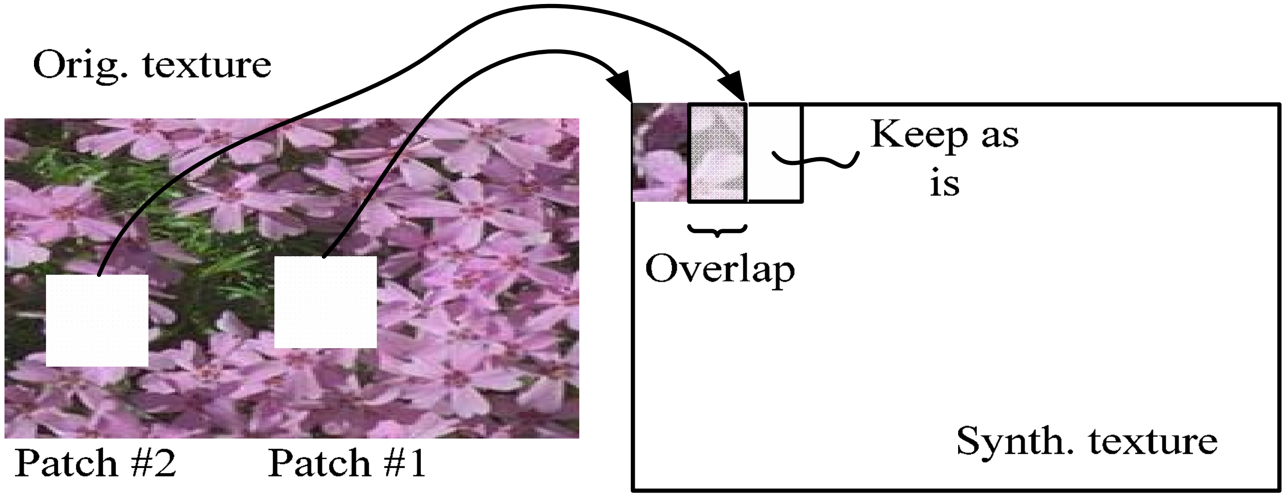


Video coding using a
texture analyzer (TA) and a texture synthesizer (TS)

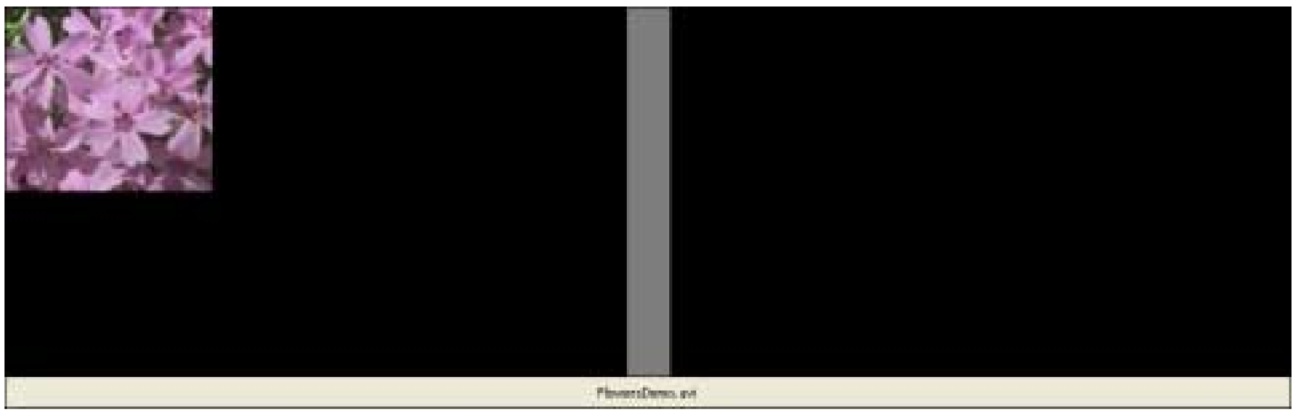
Texture Analyzer Principle



Texture Synthesizer

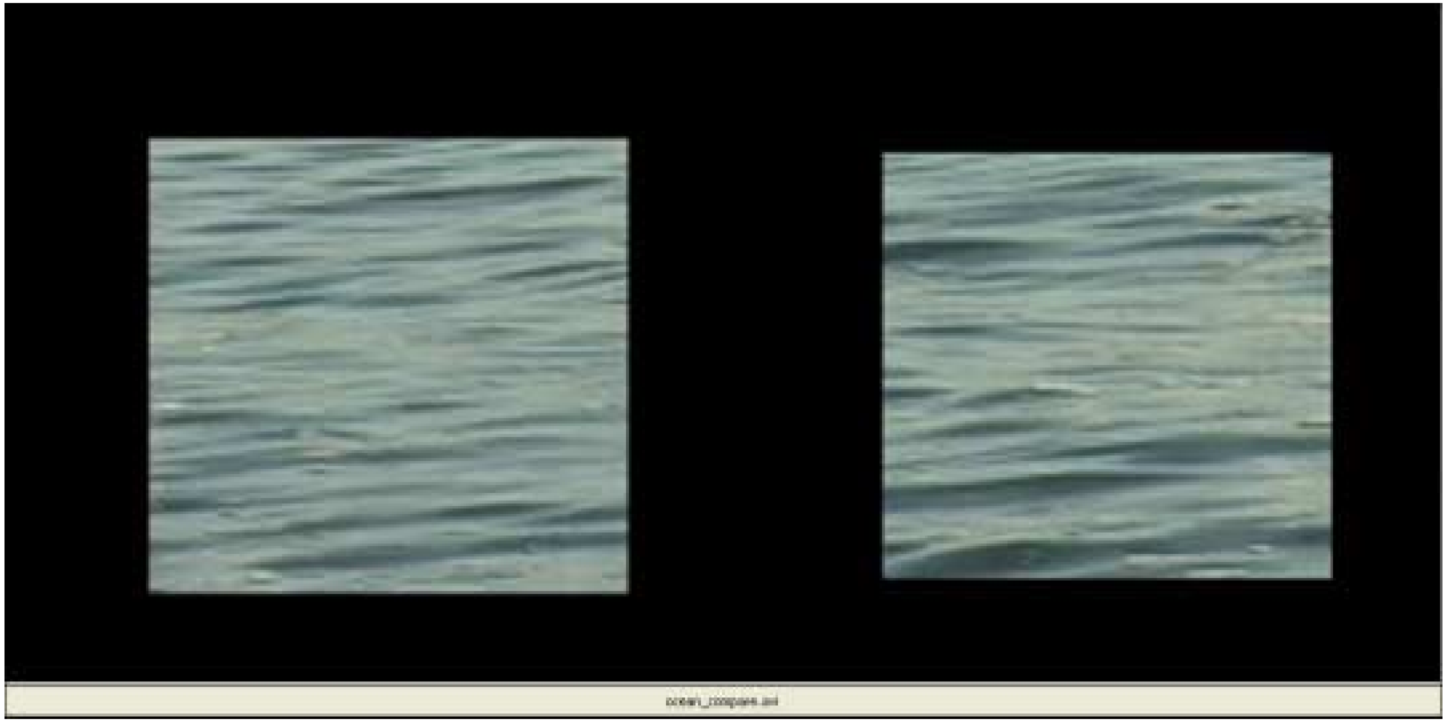


Stuffing procedure



Texture Synthesizer

- Match surrounding samples between current picture and warped pictures to find synthesis sample for the current sample
- Decoder processing required!
- Volume matching for water and temporal consistence



Flowergarden, CIF, 30 Hz, QP=16, 41 frames

Bit-rate savings: 19.4%

Canoe, CIF, 30 Hz, QP=16, 73 frames

Bit-rate savings: 8.8 %

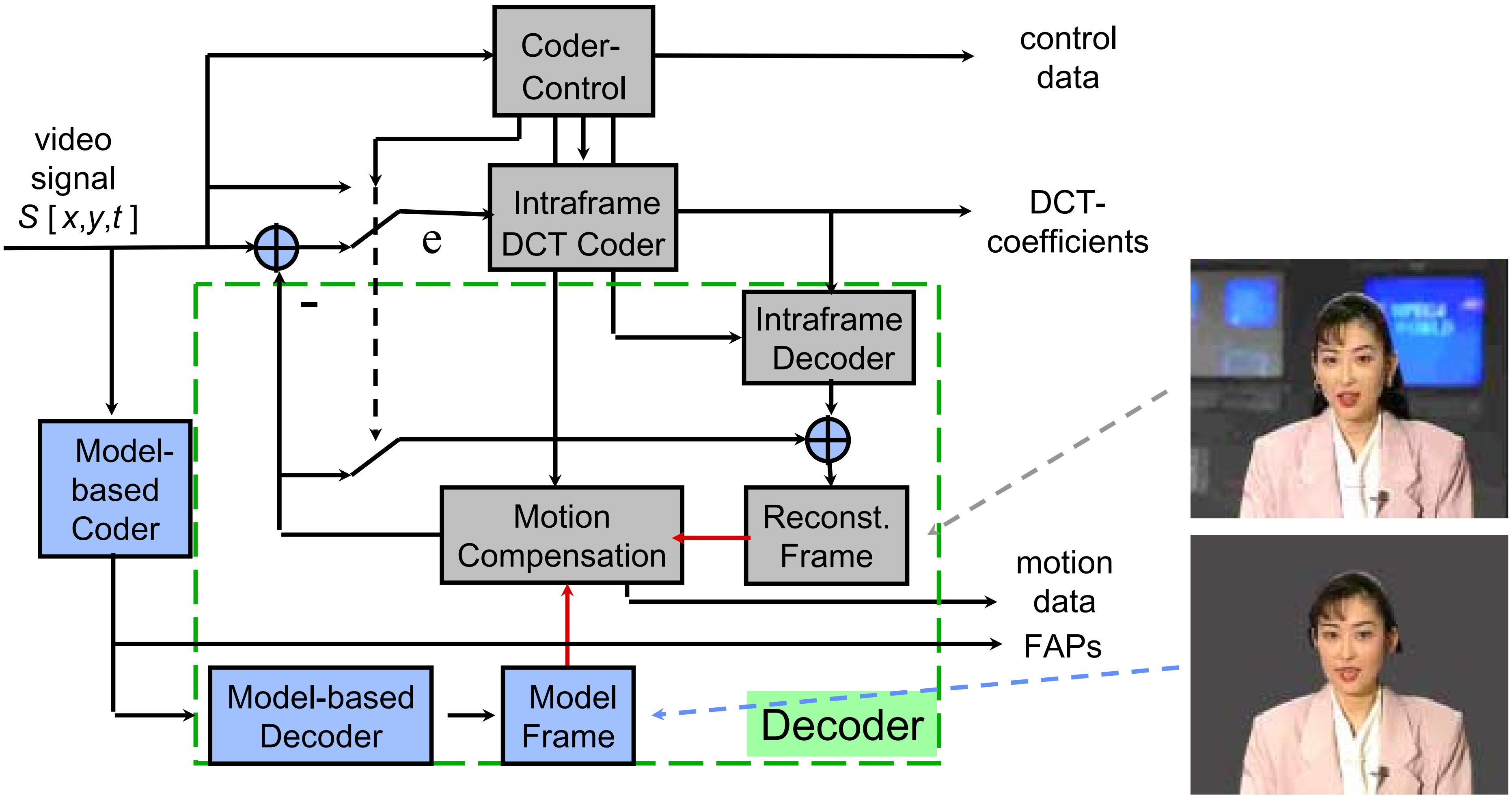
Summarizing Texture Analysis and Synthesis

- Textures with large amount of visible details are difficult to code e.g., grass, sand, clouds, water ...
- Errors in these textures are barely visible
- Texture analysis and synthesis can help to represent these textures efficiently
- Method requires processing at the decoder side
- Other methods require processing at the decoder side to achieve coding efficiency improvements through backward adaptation (CABAC)

Model-Aided Coding

- Model-based coding (MBC):
  - Extreme low bit-rates possible
  - Missing generality
- Hybrid video coding (H.263/4, MPEG-2/4,...)
  - Robust against scene changes
  - Higher bit-rates
- Combination of MBC with hybrid video coding
  $\Rightarrow$ Model-aided codec
  - High coding efficiency
  - No restriction to scene content

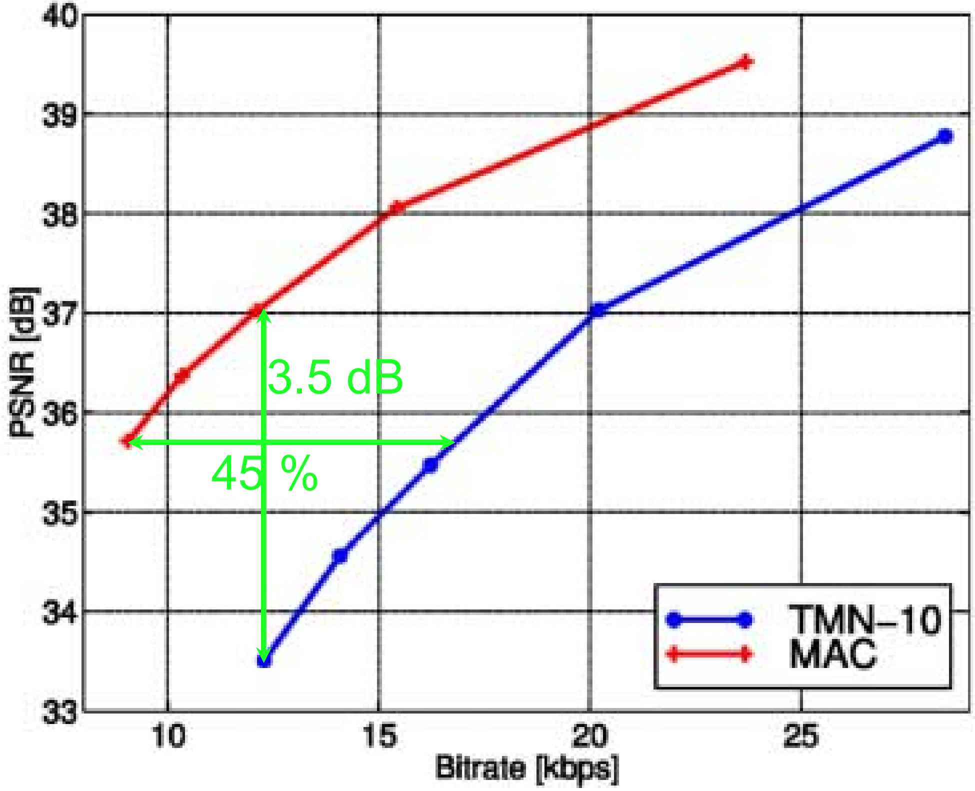
Architecture of the Model-Aided Codec



Coding Results

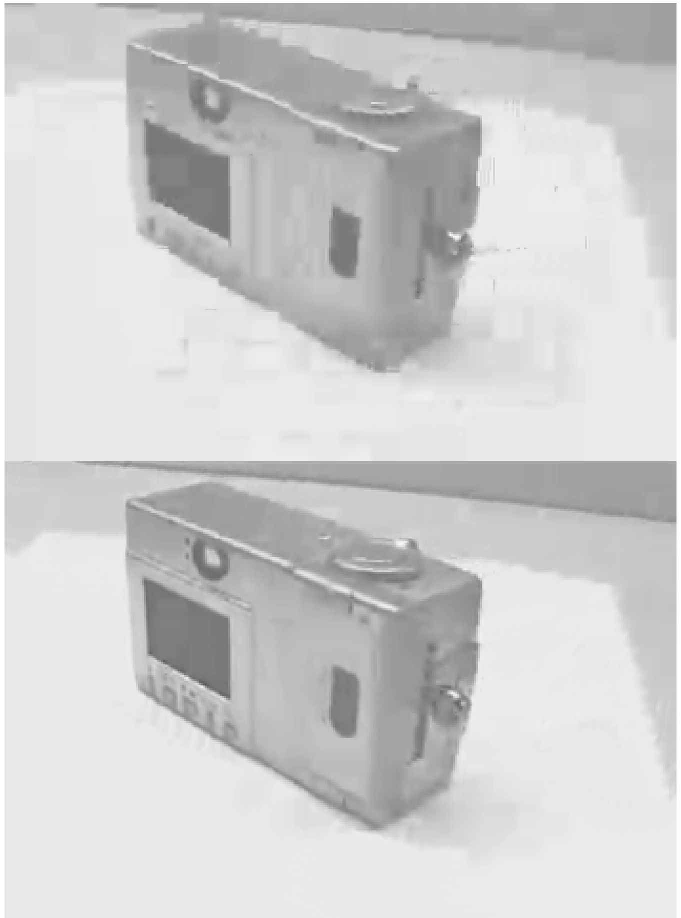
- Sequenz *Clapper Board*: 8.33 Hz, CIF resolution, 260 frames
- Same average bit-rate (≈12 kbit/s)
- H.263 annexes D, F, I, J, T

Reconstruction Quality vs. Bit-rate



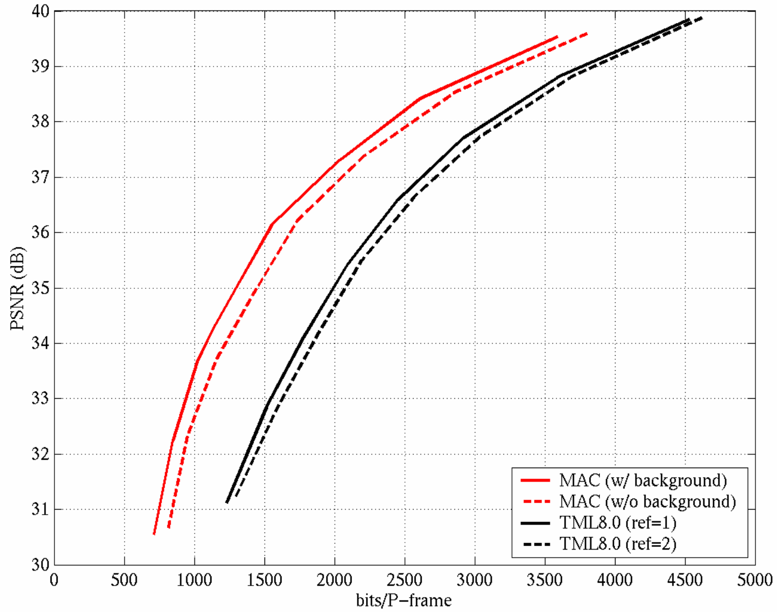
- Gain of 3.5 dB PSNR compared to H.263 Coder (TMN-10)
- Bit-rate reduction ≈ 45 %

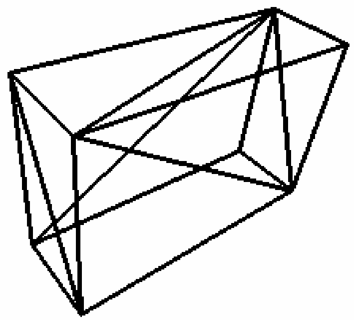
Model-Aided Coding with Approximate Geometry



H.264
(TML-8)

MAC





Summarizing Model-Aided Coding

- §Waveform-coding and 3-D model-based coding can be combined to efficiently exploit statistical dependencies in the video signal
- §The "trick" is to generate a model/representation of the video signal and to animate the central representation to predict the video signal:
  - §3D computer graphic models
  - §Mosaics
  - §MCTF

Concluding Remarks

Three Techniques are presented that improve against existing H.264/MPEG4-AVC coding

1. **Inter-frame encoder optimization**
   - Exploit dependencies over multiple pictures
   - Incorporate/anticipate efficient encoding into decoder standardization process (do not standardize encoder)
2. **Video analysis and synthesis (VAS)**
   - Consider subjective methods in video compression (investigate alternative distortion measures)
   - Allow more processing at the decoder side for backward adaptive coding
3. **Model-aided coding**
   - Further enhance exploitation of statistical depenedencies
   - Incorporate more semantic ideas – combination with VAS

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