Rate-control algorithms testing by using video source model

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Real-time video compression and transmission system

\[ b^e(t) = \max\{0, b^e(t - 1) - c\} + r_t. \] (1)
Real-time video compression and transmission system

Disadvantages of the traditional testing of rate-control algorithms:

- Long time for testing
- Short length of video sequence
- Small set of test video sequences
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Rate-control algorithms testing by using video source model

- Input video sequence
- Video encoder
- Transmitter buffer
- Rate-Distortion controller
- Channel
- Video source model
- Rate-Distortion function model

\( \alpha_1, \alpha_2 \)

\( r_t \)

\( d_t \)

\( b^c(t) \)

\( c \)
Video source model description

Model assumptions:

- **Encoder memory restriction**
  - the whole memory of the encoder is much smaller than the number of bits for one frame of video sequence
  - only intra-encoder is valid (without motion-compensation)
  - input video frame is divided into a lot of tiles

- **Three probable tile types** (three source states \( s \in \{1, 2, 3\} \))
  - tile with computer graphic \((s = 1)\)
  - tile of mixed type \((s = 2)\)
  - natural (photographic) tile \((s = 3)\)

- **Two-parametric \((\alpha_1, \alpha_2)\) rate-distortion function model**
- **Encoder is the function** of the distortion \(d\), rate \(r\) and \((\alpha_1, \alpha_2)\)
  - \(r = f(d, \alpha_1, \alpha_2)\)
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Video source model construction
Source state detection and transition probability matrix calculation

Transition probability matrix $P_s$:

$$P_s = \begin{pmatrix} p_{11} & p_{12} & p_{13} \\ p_{21} & p_{22} & p_{23} \\ p_{31} & p_{32} & p_{33} \end{pmatrix}$$

For classification of image tile types it is proposed to use lossless tile compression with different number of wavelet decomposition levels\(^1\).

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Video source model construction
Calculation of parameters \((\alpha_1, \alpha_2)\) of rate-distortion function model

It is proposed to use the follow rate-distortion function model\(^2\)

\[
\text{PSNR}(D) = \alpha_1 \cdot \log R + \alpha_2.
\]

To define parameters \(\alpha_1\) and \(\alpha_2\) for each image tile:

- experimentally rate-distortion function is calculated
- technique of least squares is used to define the model parameters \((\alpha_1, \alpha_2)\).

Video source model scheme

\[ \text{PSNR}(D) = \alpha_1 \log R + \alpha_2 \]

\( D \rightarrow \text{PSNR}(D) \) \( R \)
Video source model checking by using rate-distortion control algorithm

Video source model checking

Figure shows PSNR dependence for frame from channel rate for real and modulated data with the fixed transmitter buffer size.
Figure shows PSNR dependence for frame from transmitter buffer size for real and modulated data for the fixed channel rate.
Conclusions

Advantages of the proposed rate-control testing scheme:

- Suitable video source model is proposed
- Testing time is significantly less than in traditional scheme
- Testing could be done over the big video sequence data
- It is possible to construct wide set of test data
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