Blind Quality Assessment System for Multimedia Communications Using Tracing Watermarking

P. Campisi, M. Carli, G. Giunta and A. Neri
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Outline

- Introduction
- Tracing watermarking procedure
- QoS system embedding
- QoS evaluation
- Experimental results
Motivation

• 3G mobile communication systems are expected to offer multimedia services with negotiation of end-to-end quality of service (QoS)
  – Effective and simple billing systems related to the QoS provided
  – The quality assessment systems that will not increase the bit rate of transmission
Digital Watermarking

- Conventional usages
  - Copyright protection
  - Fingerprinting
  - Broadcast monitoring
  - Multimedia indexing
  - Content-based retrieval
  - Authentication
    - Altered or not
    - Localization information

- Requirements
  - Perceptual invisibility
  - Robustness
  - Capacity
  - Fragility
MPEG-2/4 Video Standards

• MPEG-2
  – Layered syntax
    • Video sequences -> GOPs -> Frames -> Slices -> Macroblocks -> Luma/chroma blocks
  – DCT + Quantization + VLC
  – Motion compensation

• MPEG-4
  – Object-based representation
    – Scenes are composed of video objects, each described by motion, texture and shape

• Frame types in the MPEG-2/4 standards
  – I frame, P frame and B frame
Watermarking for Evaluating QoS?

• Fragile watermarking is used to evaluate the QoS in multimedia mobile communication
  – Why?
    • The mark undergoes the same alterations suffered by the data over a communication Channel
  – How?
    • The watermark is estimated and compared with the original at the receiving side
    • The watermark degradation is used to trace the overall alterations endured by the data
For each frame, the watermark is the same, while the PN matrices are different for each frame to improve the perceptual fidelity.

Embedding is performed in the DCT domain – the middle-band frequencies of the whole image.
QoS System Embedding (1)

- Video sequence:
  - \{f_i[n_1, n_2], i=1,2,...,M\}

- DCT transformed video frame:
  - \{F_i[k_1, k_2], i=1,2,...,M\}

- Middle-high frequency:
  - S of \(F_i[k_1, k_2]\)

- Watermark:
  - \{w[k_1, k_2]\}

- PN matrices:
  - \{p_i[k_1, k_2], i=1,2,...,M\}

- Spread version of watermark:
  - \(w_i^{(s)}[k_1, k_2] = w[k_1, k_2] * p_i[k_1, k_2], i=1,2,...,M\)
QoS System Embedding (2)

• Embedding:
  – if \((k_1, k_2)\) belongs to \(S\),
    • \(F_i^{(w)}[k_1, k_2] = F_i[k_1, k_2] + a w_i^{(s)}[k_1, k_2]\),
  – else
    • \(F_i^{(w)}[k_1, k_2] = F_i[k_1, k_2]\)
  – where
    • \(a\) is a scaling factor and is chosen as 0.04

• Obtaining watermarked frame:
  – \(f_i^{(w)}[n_1, n_2] = \text{IDCT}\{F_i^{(w)}[k_1, k_2]\}\)
QoS Evaluation

- Received video sequence:
  - $f_i^{(w)}[n_1,n_2]$, $i=1,2,...,M$

- DCT transformed receiving frame
  - $F_i^{(w)}[k_1,k_2]=\text{DCT}\{f_i^{(w)}[n_1,n_2]\}$

- Watermark Estimation
  - $w_i^{(s)}[k_1,k_2]=F_i^{(w)}[k_1,k_2]*w[k_1,k_2]$

- Disperading
  - $w_i^{(s)}[k_1,k_2]=w_i^{(s)}[k_1,k_2]*p_i[k_1,k_2]$

- Averaging
  - $w'[k_1,k_2]=\text{Sum}(w_i'[k_1,k_2])/M$

- MSE calculation
Experiments

- QCIF video sequences are used to match the limited dimensions of mobile terminal’s display
- Marked video is transmitted over a noisy channel simulated by a Poission error generator
- MPEG-2/4 videos are tested at different bit-rates
  - The MSE of the extracted watermark increases when the BER increases and the bit rate decreases
Experimental Results (1/6)

Akiyo
Experimental Results (2/6)
Experimental Results (3/6)

Akiyo at 600 kb/s
Experimental Results (4/6)

![Graph showing MSE vs BER for Watermark and Sequence, with Akiyo at 200 kb/s]
“Mother and Daughter” object in the “Mother and Daughter” sequence
“Background” object in the “Mother and Daughter” sequence
Discussion (1/2)

- The estimated quality of the received video can be used by the service provider as a feedback information for billing purposes
  - False declaration about the QoS
    - If the mobile station declares a received quality lower than the provided one, it implies that the channel is not suitable for current bit rate and the base station will lower the emitted bit rate in a few seconds.
    - If the mobile station declares a null quality, the operator interrupt the call.
    - Frequent declaration of poor or null quality is a valid reason to stop further access from the user.
Discussion (2/2)

- The mobile station must perform real-time processing to evaluate the QoS.
  - As compared to the complexity of the MPEG-2/4 codec, the overheads of the QoS evaluation scheme is negligible.
Conclusions

• An unconventional method of tracing watermarking as a hidden technique suited for estimating the QoS in multimedia mobile communications has been presented.

• The error affecting the watermark is very sensitive to the channel bit error rate and to the compression rate.

• One can blindly estimate the QoS of the video communication
Application Scenarios

- Control feedback to the sending user of the effective quality of the link
- Detailed information to the operator for billing purposes
- Diagnostic information to the operator on the effective status of the link