EVALUATION METHODS OF PQoS FOR MULTIMEDIA APPLICATIONS

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Acronyms & Terminology for this presentation

- **PQoS**: Perceived Quality of Service
  - Similar to video quality level
- **Video**: Digitally encoded video sequence
  - i.e. MPEG-4 visual (part 2), H.264 AVC (part 10)
- **MPEG-4@SP**: MPEG-4 Simple Profile
  - Each Profile determines specific encoding techniques and parameters

Video Services

Multimedia applications and especially audiovisual services will dominate over communication networks

- such as video on demand (VOD) & real time entertainment streaming services.

Digital encoding lossy techniques will be used

- (e.g. MPEG-4, H.264),

because uncompressed video requires a lot of network and system resources.

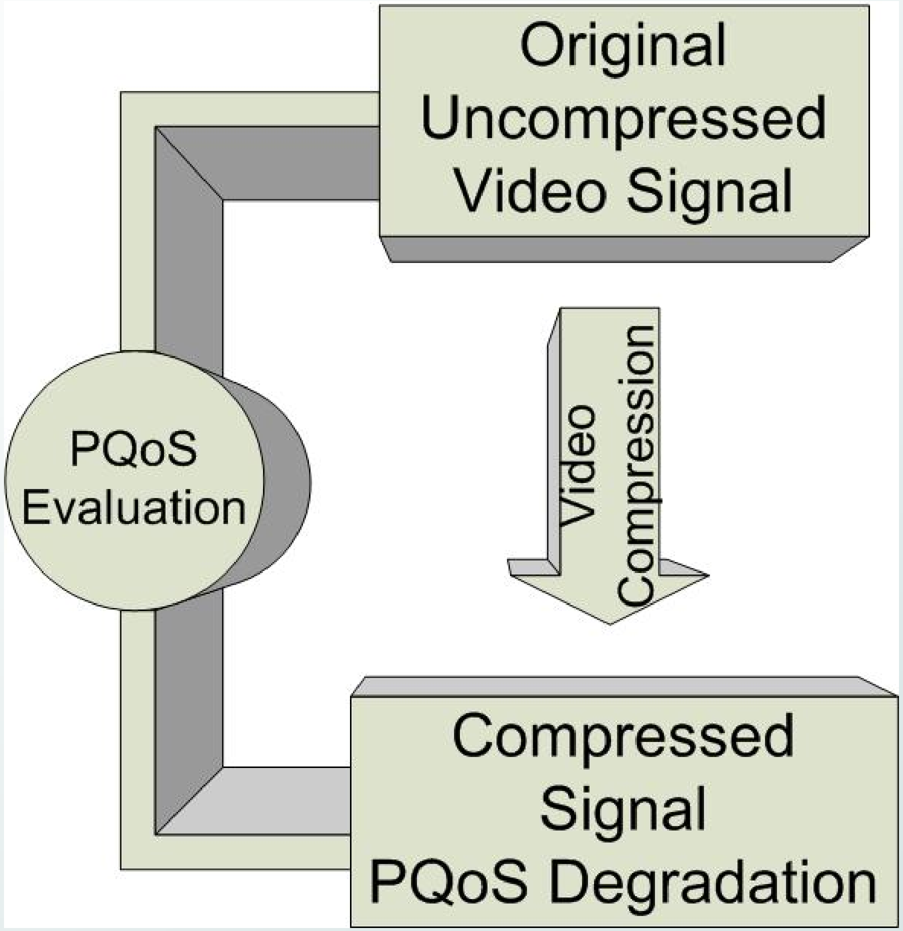
The encoding lossy techniques

- Achieve high compression ratios, by exploiting the spatial and temporal redundancy in video sequences.

Video Quality Degradation

- Lossy compression methods introduce distortions whose visibility depends highly on the content.
- These artifacts result in perceived quality degradation.
- The parameters with strong influence on the video quality are the encoding-related
  - (the bit rate, the frame rate and the resolution)
- Thus, the issue of the **user satisfaction in correlation with the encoding parameters** has been raised.

PQoS Evaluation



PQoS Evaluation

Evaluating and optimizing the quality of digital imaging systems with respect to the

- Capture
- Display
- Storage
- Transmission of visual information

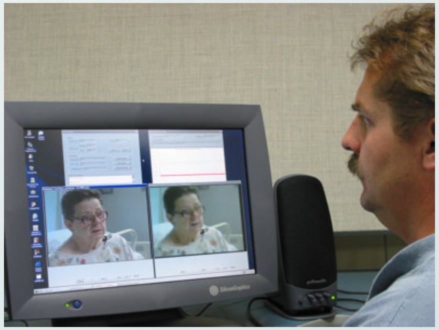
is one of the biggest challenges in the field of image and video processing.

PQoS Evaluation
Subjective Methods

- The subjective test methods
  - proposed by ITU and VQEG
  - ITU-R Rec. T.500-11 (2002) and ITU-T Rec. P.910 (1999)
  - involve an audience of people, who watch a video sequence and score its quality as perceived by them, under specific and controlled watching conditions.
  - Afterwards, the statistical analysis of the collected data is used for the evaluation of the perceived quality.
    - The Mean Opinion Score (MOS) is regarded as the most reliable method of quality measurement and has been applied on the most known subjective techniques

PQoS Evaluation Subjective Methods

- Double Stimulus Impairment Scale (DSIS)
  - Scene pairs (reference scene is always first)
  - Overall impression scale of impairment
- Single Stimulus (SS) Methods
  - Multiple separate scenes are shown
  - Three different scoring methods are used:
    - Adjectival: the aforementioned 5-grade impairment scale, however half-grades may be allowed.
    - Numerical: an 11-grade numerical scale, useful if a reference is not available.
    - Non-categorical: a continuous scale with no numbers or a large range, e.g. 0-100



PQoS Evaluation
Subjective Methods

- Single Stimulus Continuous Quality Evaluation (SSCQE)
  - The viewers watch a program of typically 20–30 minutes without the original reference to be shown
  - The subjects/viewers using a slider continuously rate the instantaneously PQoS on scale from ‘bad’ to ‘excellent’ (0 to 100).

- Double Stimulus Continuous Quality Scale (DSCQS)
  - Scene pairs (reference scene is always first)
  - The subjects/viewers using a slider continuously rate the instantaneously PQoS on scale from ‘bad’ to ‘excellent’ (0 to 100)

PQoS Evaluation Subjective Methods

- Subjective experiments
  - An audience is questioned for the perceived quality evaluation of a encoded signal
  - Subjective experiments to date are the only widely recognized method of determining the actual perceived quality
  - They are **complex** and **time-consuming**, both in their preparation and execution.

PQoS Evaluation
Objective Methods

Subjective Methods

Time consuming, Expensive, Require Sophisticated Equipment

Objective Methods

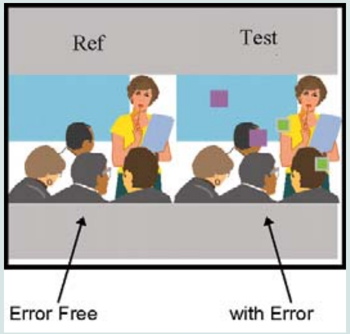
Exploiting Mathematical Models
for Emulating the Results of Subjective Procedures

PQoS Evaluation Objective Methods

Objective Methods

"**Psychophysical approach**", where metric design is based on models of the human visual system. (e.g. VQ metric by Stefan Winkler, VDP by Daly, VDM by Lubin…)

"**Engineering approach**", where metrics make assumptions about the artifacts that are introduced by the compression process or transmission link. (e.g. SSIM metric Z. Wang, DVQ metric by Watson…)



- **Full-reference metrics** (frame-by-frame comparison between a reference video and the video under test)
- **No-reference metrics** (no need of reference information)
- **Reduced-reference metrics** (extract a number of features from the reference and degraded video (e.g. amount of motion, spatial detail))

Objective Methods - Advantages

- Faster
- Cheaper
- Economically Affordable
- No audience is required
- No statistical analysis is needed
- …

Objective Methods - Cons

- Full Reference Methods
  - Initial undistorted clips are not always available.
  - Synchronization predicaments between the undistorted and the distorted signal (which may have experienced frame loss)
- Reduced Reference
  - Very few implementations
  - Similar problems to Full Reference
- No Reference
  - Usually Codec Specific

PQoS Evaluation
Practical Limitations

The 3G/4G vision is the provision of audiovisual content at various quality and price levels

(P. Seeling, 2004)

All the aforementioned subjective/objective post-encoding methods require repeating tests in order to determine the encoding parameters that satisfy a specific level of user satisfaction.

Need for predicting PQoS

There is need for developing methods for predicting quickly and easily the PQoS level of a media clip.

These methods will enable the determination of the specific encoding parameters that will satisfy a certain quality level.

Assuming that available network resources can be efficiently confronted by traffic control techniques

PQoS is mostly depended on initial encoding parameters

Our innovation

Evaluation of PQoS today:

- Subjective procedures
  (time-consuming, expensive)
- Objective procedures
  (many repeated tests required)

Post-encoding evaluation

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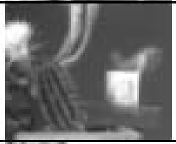
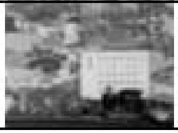
We propose:

- Objective pre-encoding PQoS evaluation method
  - For ISO MPEG-4 Clips
  - Based on a single metric

Test Video Signals

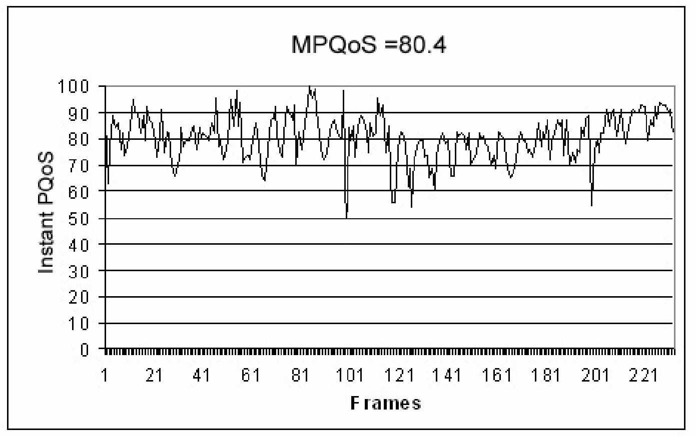
- Four reference clips were used
  - Short in duration
  - Representative of specific Spatial and Temporal activity
  - The clips were encoded with MPEG-4@ASP CBR

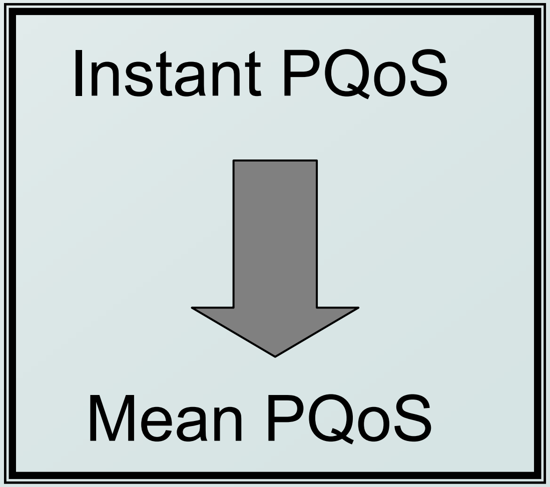
Clip 1	Low Temporal & Spatial Activity	Suzie	
Clip 2	Medium Temporal & Spatial Activity	Cactus	
Clip 3		Flower Garden	
Clip 4	High Temporal & Spatial Activity	Mobile & Calendar	

Quality Meter Tool

A non-reference objective evaluation software

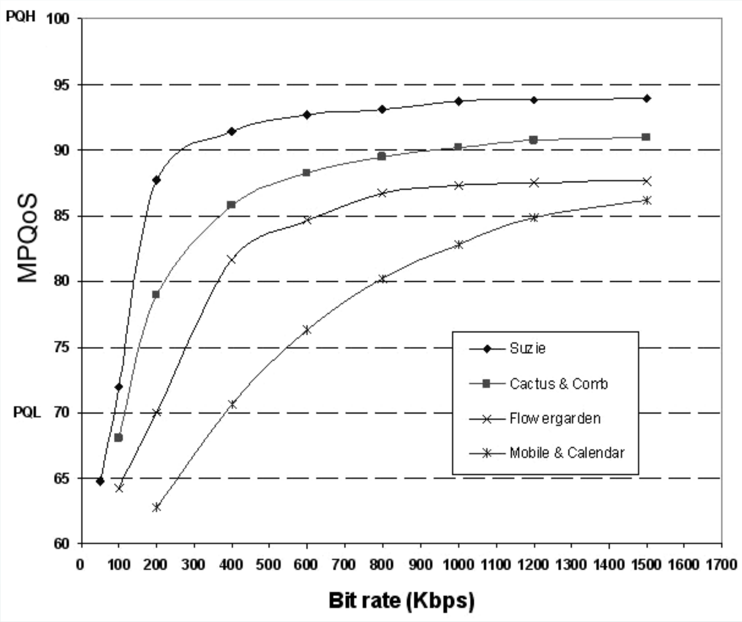
- The instant PQoS (iPQoS) level of each frame
- The evaluation is based on one-channel DCT filtering
- We examined the CBR case, which is more complicated in respect to PQoS, because the VBR mode (approx.) retains the same PQoS level for the whole duration of the video.



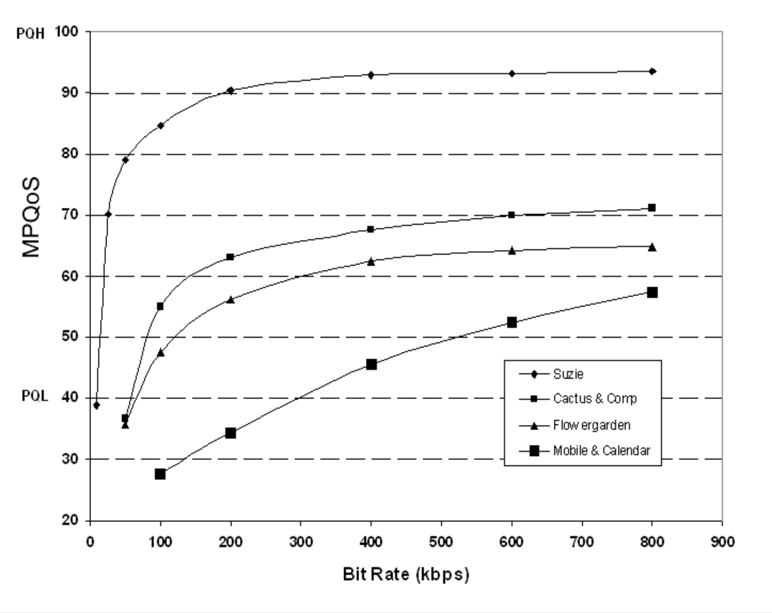


Mean PQoS Curves

- Repeating the extraction of MPQoS from the Instant PQoS for each of the four test signals for different encoding parameters
- MPQoS curves vs. encoding parameters (bit rate, resolution)



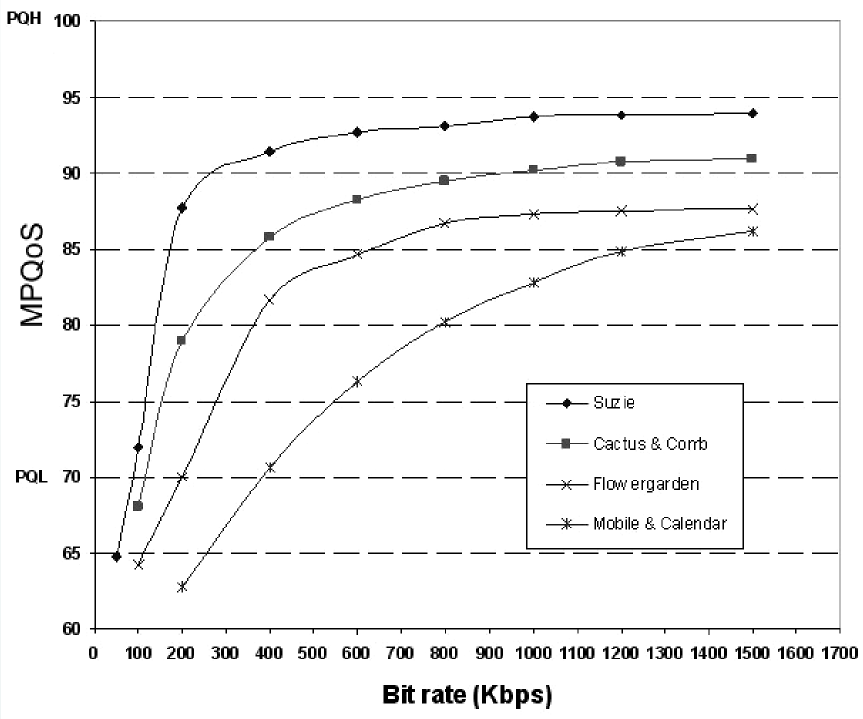
CIF Resolution



QCIF Resolution

Mean PQoS Curves

1. The minimum bit rate, which corresponds to the lowest acceptable MPQoS level (PQL) depends on the S-T activity level of the video clip.
2. The variation of the MPQoS vs. bit rate is an increasing function, but non linear.
3. The quality improvement is not significant for bit rates higher than a specific threshold. This threshold depends on the S-T activity of the video content.



Similarity to Benefit Functions

- The MPQoS curves are qualitatively similar to the theoretically expected benefit functions (user satisfaction vs. allocated resources),

- The algebraic model of Benefit Functions can be used :

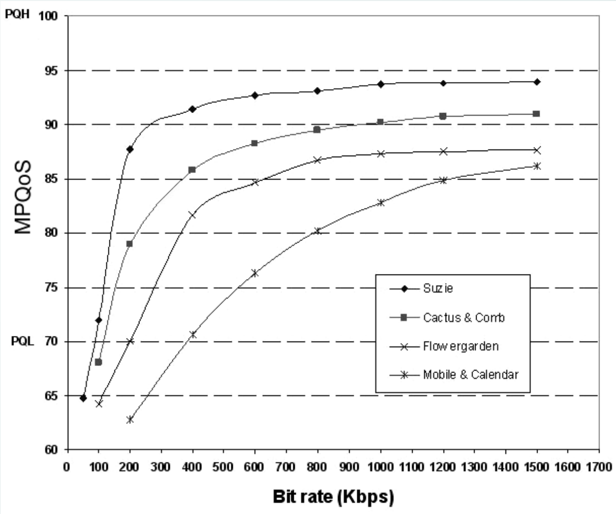
  - Every multimedia service can be described by a QoS Vector
  - QoS Vector's elements defines uniquely the benefit function of the specific multimedia service.

QoS Vector

Each MPQoS curve can be described by a Quality of Service Vector

$$QV = (\alpha, BR_L, PQ_H)$$

- BR_L corresponds to the lowest acceptable PQoS value (e.g. 70 for CIF resolution)
- PQ_H corresponds to the highest reached PQoS level
- Parameter α defines the shape and subsequently the slope of the curve.



Exponential Approximation

- The experimental MPQoS curves can be approximated by a group of exponential functions (deviation error < 4%):

$$MPQoS = [PQ_{\mathbf{H}} - PQ_{\mathbf{L}}]\,(1 - e^{-\alpha\,[BR - BR_{\mathbf{L}}]}) + PQ_{\mathbf{L}},\ \alpha>0 \text{ and } BR>BR_L$$

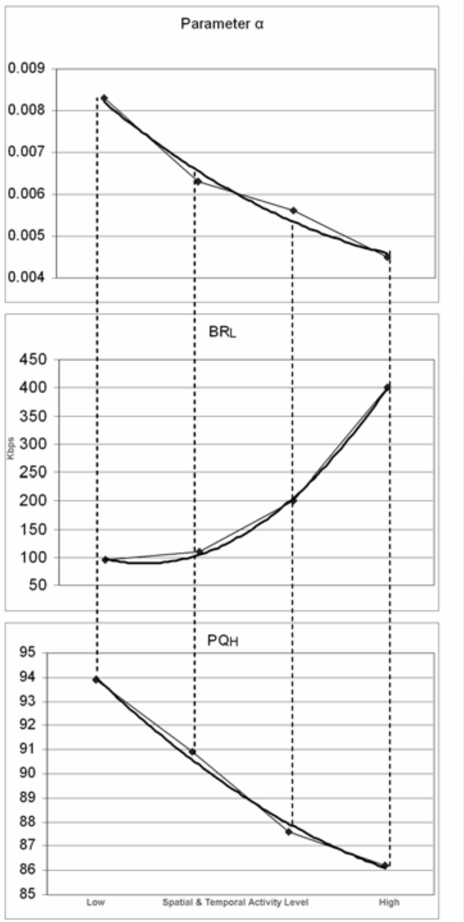
$$QV = (\alpha,\ BR_{\mathbf{L}},\ PQ_{\mathbf{H}})$$

- QV contains the necessary QoS parameters for describing analytically the dependence of the MPQoS level on the encoding bit rate and subsequently the resolution.

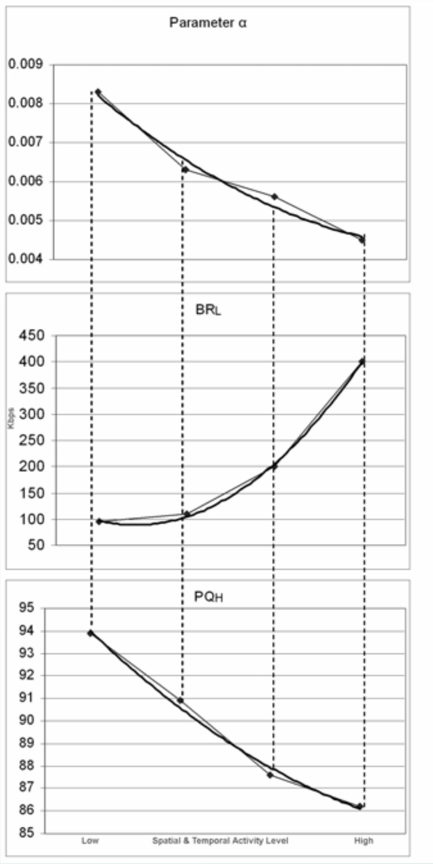
Correlation of QV Elements

Based on the exponential approximation, the variation of the QV elements was derived for the four test signals

Test Sequence	α	BR_L (Kbps)	PQ_H (Quality Units)
Suzie (MPEG-4 CIF)	0.0083	95	93.91
Cactus (MPEG-4 CIF)	0.0063	110	90.89
Flower (MPEG-4 CIF)	0.0056	200	87.62
Mobile (MPEG-4 CIF)	0.0045	400	86.20



Correlation of QV Elements



$$\text{Parameter\_}\alpha(x) = \sum_{k=0}^{\infty} b_k x^k = b_0 + b_1x + b_2x^2 + b_3x^3 + \ldots \approx 0.0103 - 0.0023x + 0.0002x^2$$

$$BRL(x) = \sum_{k=0}^{\infty} c_k x^k = c_0 + c_1x + c_2x^2 + c_3x^3 + \ldots \approx 181.25 - 130.75x + 46.25x^2$$

$$PQH(x) = \sum_{k=0}^{\infty} d_k x^k = d_0 + d_1x + d_2x^2 + d_3x^3 + \ldots \approx 98.255 - 4.64x + 0.4x^2$$

where x is related to the S-T activity level of the media clip

The proposed method

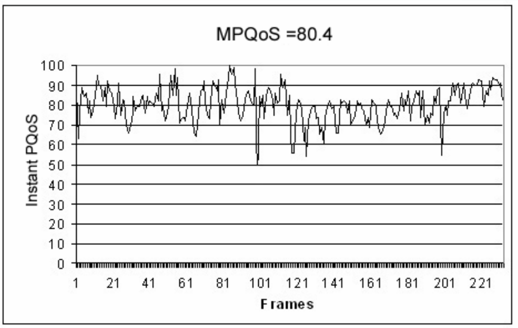
- Using the QMS tool, the PQH value for a given video clip can be measured.

- The other two QV elements can be extrapolated using the equation of PQH

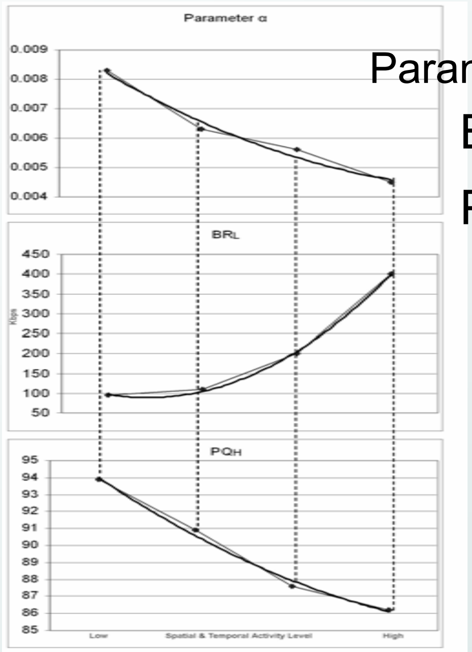
- Having estimated the QV = (α, BRL, PQH) the analytical exponential expression of the MPQoS vs. Bit rate can be derived.

- The bit rate that corresponds to any PQoS level can be estimated pre-encodingly.

The proposed method



PQH



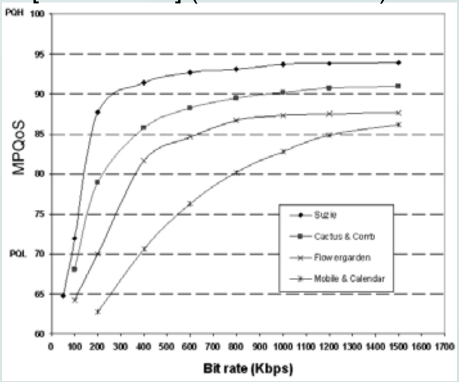
Parameter_α(x) $= 0.0103 - 0.0023x + 0.0002x^2$

BRL(x) $= 181.25 - 130.75x + 46.25x^2$

PQH(x) $= 98.255 - 4.64x + 0.4x^2$

QV = (α, BRL, PQH)

MPQoS = [PQ**H** - PQ**L**] (1 – e $^{-\alpha\,[BR-BRL]}$) + PQ**L**



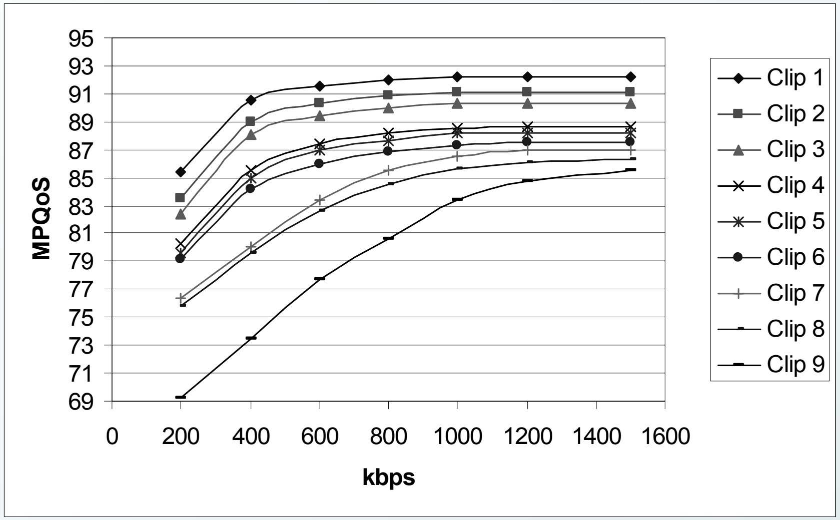
PQoS prediction for the various bit rate values

At a Pre-encoding Stage!

Efficiency of the proposed method

Clips	Total Talk Show Duration (sec)	Total Football Duration (sec)	Ratio Talk/Football
Clip 1	120	0	∞
Clip 2	105	15	7.00
Clip 3	90	30	3.00
Clip 4	75	45	1.67
Clip 5	60	60	1.00
Clip 6	45	75	0.60
Clip 7	30	90	0.33
Clip 8	15	105	0.14
Clip 9	0	120	0.00

MPQoS vs. Bit rate curves & Mean Error of the proposed method



Clip Name	Mean Error %
Clip 1	0.434
Clip 2	0.708
Clip 3	0.942
Clip 4	1.884
Clip 5	0.836
Clip 6	1.062
Clip 7	1.934
Clip 8	4.364
Clip 9	0.718

Limitations of the proposed method

- It adopts all the limitation of the used objective metric
- It can’t be applied on **CBR** clips with very long durations (i.e. >5 minutes)
- It is required one encoding of the test signal in order to produce results

Future Work

- We are working on H.264 and an extension of the proposed method
  - No encoding is necessary for the determination of the Quality Vector
- How network QoS-sensitive parameters (e.g. jitter, delay…) degrade the PQoS level

Other research areas

- Analysis and Traffic Modeling of H.264 traffic
- Shot Boundary Detection in DCT-based encoded sequences
- Perceived mapping between VBR and CBR mode

Thank you…

Contact

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