From Quality of Experience to Quality of Life

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Outline

1. Quality of Experience for Multimedia Systems and Services
2. Towards the Concept of Quality of Life
1. Quality of Experience for Multimedia Systems and Services

A. What is Quality
B. Quality of Service (QoS)
C. Quality of Experience (QoE)
D. Trends in QoE
Quality: a Simple yet Difficult Concept

- Like many human sensations, quality is easy to understand but difficult to define.

- According to Wikipedia:
  - A quality (from Latin - qualitas) is an attribute or a property.
  - Some philosophers assert that a quality cannot be defined.
  - In contemporary philosophy, the idea of qualities and especially how to distinguish certain kinds of qualities from one another remains controversial.
An old, largely under-investigated concept

Aristotle classified every object of human apprehension into 10 Categories
- Substance
- Quantity
- Quality
- Relation
- Place
- Time
- Position
- State
- Action
- Affection

Aristotle, 384 BC – 322 BC, Greece
Quality: Some Definitions from the Dictionary (1)

- **Definition 1**
  - **General**: Measure of *excellence* or *state* of being free from defects, deficiencies, and significant variations.
  - ISO 8402-1986 standard defines quality as “the totality of features and characteristics of a product or service that bears its ability to *satisfy* stated or implied *needs*”.

- **Definition 2**
  - **Manufacturing**: Strict and consistent adherence to measurable and verifiable standards to achieve uniformity of output that *satisfies* specific *customer* or *user* requirements.
Quality: Some Definitions from the Dictionary (2)

- **Definition 3**
  - **Objective**: Measurable and verifiable aspect of a thing or phenomenon, expressed in numbers or quantities, such as lightness or heaviness, thickness or thinness, softness or hardness.

- **Definition 4**
  - **Subjective**: Attribute, characteristic, or property of a thing or phenomenon that can be observed and interpreted, and may be approximated (quantified) but cannot be measured, such as beauty, feel, flavor, taste.
Quality According to ISO 9000

- ISO 9000: a family of standards for quality management systems.

- Quality of something can be determined by comparing a set of inherent characteristics with a set of requirements
  - High quality: if characteristics meet requirements
  - Low quality: if characteristics do not meet all requirements

- Quality is a relative concept
  - Degree of quality
The blind men and the elephant, poem by John Godfrey Saxe
Quality in QUALINET

- **Quality: Is the outcome of an individual’s comparison and judgment process.** It includes perception, reflection about the perception, and the description of the outcome.

- In contrast to definitions which see quality as “qualitas”, i.e. a set of inherent characteristics, QUALINET considers quality in terms of the evaluated excellence or goodness, of the degree of need fulfillment, and in terms of a “quality event” (see Martens & Martens, 2001, and Jekosch, 2005).

- **Event: An observable occurrence.** An event is determined in space (i.e. where it occurs), time (i.e. when it occurs), and character (i.e. what can be observed).

from “Qualinet White Paper on Definitions of Quality of Experience”, March 2013
What is QUALINET?

- Group of institutions and companies interested in multimedia quality assessment.
- Coordination of multidisciplinary QoE research in Europe and beyond.
- Strengthening dissemination efforts through already established, and new initiatives, e.g. QoMEX, special events, books, journals.
- Strengthening interaction between academia and industry (industrial forum, STSM, …).
- Strengthening educational efforts in QoE, e.g. summer schools, PhD events, exchange of young researchers.
- Coordinated contribution to international standardization bodies, e.g. ISO/IEC, ITU-T, VQEG, MPEG, JPEG.

In summary, group of researchers interested in (multimedia) QoE issues, both theoretical and practical ...

Open to new researchers ... http://www.qualinet.eu/
1. Quality of Experience for Multimedia Systems and Services

A. What is Quality
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“[The] Totality of characteristics of a telecommunications service that bear on its ability to satisfy stated and implied needs of the user of the service.”

ITU-T Rec. E.800, 2008

- QoS is focused on telecommunications services.
- The context of usage and the user characteristics are not comprehensibly addressed by QoS as defined by the ITU.

from “Qualinet White Paper on Definitions of Quality of Experience”, March 2013
Quality of Service (QoS): De-Facto

- The QoS de-facto definition deals mostly with **physical**, **measurable performance** factors of **networks and delivery platforms** in general.

- Sometimes, also **application-level factors**, such as encodings, and their effect on the underlying network's performance are addressed, e.g. by taking more of the available bandwidth.

Quality of Service (QoS) refers to a collection of networking technologies and measurement tools that allow for the network to **guarantee** delivering predictable results.

partly from “Qualinet White Paper on Definitions of Quality of Experience”, March 2013
The multimedia signal processing community is already often using concepts such as the Mean Opinion Score (MOS) which directly involves users…
QoS in Computer Networks and Communications

- Quality of Service (QoS)
  - Resource reservation control mechanisms
  - Ability to provide different priority to different applications, users, or data flows
  - Guarantee a certain level of performance (quality) to a data flow
- (Service) Provider-centric concept
QoS Boundaries

- **Scope**: QoS typically focuses on telecommunications services.

- **Focus**: QoS deals with performance aspects of physical systems.

- **Methods**: QoS has a very technology-oriented approach, and it relies on analytic approaches and empirical or simulative measurements.

  *from “Qualinet White Paper on Definitions of Quality of Experience”, March 2013*
User Quality: Mostly Signal Fidelity

- Subjective Evaluation

- Objective Evaluation

\[
\text{PSNR} = 10 \times \log \left( \frac{255^2}{\text{MSE}} \right)
\]

\[
\text{MSE} = \frac{1}{M \times N} \sum_{i=1}^{N} \sum_{j=1}^{M} \left[ I(i, j) - I'(i, j) \right]^2
\]
Subjective tests aim at producing User Opinion Scores as a delicate mixture of ingredients and choices:

- Test & lab environment
- Test material
- Test methodology
- Test subjects
- Analysis of the data
What is Mean Opinion Score (MOS)?

- Widely used in many fields:
  - Politics/Elections
  - Marketing/Advertisement
  - Food industry
  - Multimedia
  - ...

- The likely level of satisfaction of a specific service/product dimension, e.g. visual quality, as appreciated by an average user (from a provider point of view).

- Should be performed such that it generates reliable and reproducible results
  - Subjective evaluation methodology
  - More complex and difficult that it a priori seems
  - Much used for (and limited to) video and audio subjective qualities
Objective Evaluation

- Subjective tests are time consuming, expensive, difficult to design and not available in real time, …

- Objective algorithms, i.e. metrics, estimating subjective MOS with high level of correlation are desired
  - Full reference metrics
  - No-reference metrics
  - Reduced reference metrics
FR, RR and NR Scenarios

- **Full Reference** approach:

- **Reduced Reference** approach:

- **No-Reference** approach:
Full Reference scenario
- Most automatic MOS predictors are based on fidelity measures
- Metrics look at the fidelity of the signal when compared to an explicit 'perfect' reference:
  
  \[
  \text{processed signal} = \text{perfect quality reference signal} + \text{error signal}
  \]

- Examples:
  - Mean Square Error (MSE)
  - Peak Signal to Noise Ratio (PSNR)
  - Weighted PSNR
  - Masked PSNR
  - Structural SIMilarity (SSIM)
  - Multiscale Structural SIMilarity (MSSIM)
  - Visual Information Fidelity (VIF)
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Changing Landscape

- YouTube
- Facebook
- Twitter
- Blu-ray Disc
- Flickr
- Video conferencing

IEEE Distinguished Lecture
San Diego, 26 August 2016
UHD, 4K
HDR
HFR
3D
Light fields
Point clouds
...

Multimedia Signal Processing Group
Ecole Polytechnique Fédérale de Lausanne

IEEE Distinguished Lecture
San Diego, 26 August 2016
The user is King (and Queen)
Many Events ... Building Experiences ...

1. **Event**: An *observable occurrence*. An event is determined in *space* (i.e. *where* it occurs), *time* (i.e. *when* it occurs), and *character* (i.e. *what can be observed*).
   - **Sensation** refers to the responses of sensory receptors and sense organs to environmental stimuli.
   - **Perception** is a process which involves the recognition and interpretation of stimuli which register our senses.
   - **Emotion** is any relatively brief conscious experience characterized by intense mental activity and a high degree of pleasure or displeasure.

2. **Experience**: An experience is an individual’s stream of *perception and interpretation* of one or *multiple events*.

   *partly from “Qualinet White Paper on Definitions of Quality of Experience”, March 2013*
So, Users are More than Perception Engines …
Many Services Sell Emotions ...
Multimedia Nowadays …

- Multimedia is about **sharing experiences** (real or imaginary) with others.

- In a way, it all started with **story telling** and **wall drawing** around the fire in the caves of early men.

- **Modern multimedia systems** are evolved versions of the good old story telling and wall drawing, which hopefully offer increasingly **richer experiences**.

- The **degree of richness of the experience** may be measured by **Quality of Experience (QoE)**.
Evolving Quality Paradigms

Change

The Future
NEXT EXIT

IEEE Distinguished Lecture
San Diego, 26 August 2016
What do People Talk about when they Talk about QoE?

- “The degree of fulfillment of an intended experience on a given user.”
  by Touradj Ebrahimi, 2001

- “perceived user experience is psychological in nature and changes in different environmental conditions and with different multimedia devices.”
  from QoMEX 2009 Call for Papers

- “The overall acceptability of an application or service, as perceived subjectively by the end user.”
  as defined by the ITU

The term ‘experience’ is appealing because it implicitly promises individual engagement … Looks good, sounds good, and feels good!
QUALINET QoE Definition

- **Quality of Experience (QoE)** is the degree of delight or annoyance of the user (persona) of an application or service. It results from the fulfillment of his or her expectations with respect to the utility and/or enjoyment of the application or service in the light of the user’s personality and current state (context).

- **Experience**: An experience is an individual’s stream of perception and interpretation of one or multiple events.

- **QoE feature**: A perceivable, recognized and namable characteristic of the individual’s experience of a service which contributes to its quality.

From “Qualinet White Paper on Definitions of Quality of Experience”, March 2013.

In the context of communication services, QoE can be influenced by factors such as service, content, network, device, application, and context of use.
Moving to Quality of Experience

- **Quality of Service**: Value of the average user’s service richness estimated by a service/product/content provider

- **Quality of Experience**: Value (estimated or actually measured) of a specific user’s experience richness

Quality of Experience is the dual (and extended) view of Quality of Service!

QoS=provider-centric
QoE=user-centric
Factors Impacting Quality of Experience

- **System/Technical Influence Factors**
- **Human/User Influence Factors**
- **Context Influence Factors**
- **Content Influence Factors**
- **Social and Psychological Influence Factors**
Experiences are Individual!

- Applications and Services may have to be designed to provide individual experiences ...
- This involves capabilities allowing the user to gain control, e.g. interaction, personalization, recommendation, etc.
- In fact, the user contributes to build is own experience ... If the system/service allows ...
How Shall a Multimedia User Experience Be?

Depending on the specific application, it may have to be

- **Faithful** - accuracy
- **Truthful** – realistic if relevant, synchronization
- **Immersive** – natural, multimodal consistency
- **Contextual** - adaptive
- **Engaging** – fun, intense, emotional
- **Effective** – fast, recognition
- **Useful** – task performing
- **Interactive** – natural, short delay
- **Intuitive, Easy** – interfaces
- …
QoE modeling may consider more or less influence factors depending on the service/application, each with a different weight on the overall assessment.

QoE is multi-dimensional, multi-modal and multi-sensorial.

User centered influence factors are expected to be dominating.

- **System factors**
  - technical properties (as in QoS)

- **Human/User factors**
  - individual properties
  - sensorial properties
  - perceptual properties
  - emotional properties

- **Context factors**
  - environmental/physical properties
  - temporal properties
  - service properties
  - economic properties
  - social properties

- **Content factors**
  - ...
A Practical QoE Model Example: IPTV

- Video quality
- Audio quality
- Audiovisual synchronization
- Stall occurrence
- Error resilience
- Random access
- Channel hopping delay
- Interface usability
- Navigation capabilities
- Personalization capabilities
- Metadata quality
- Immersion effectiveness
- …
QoE: Not an Easy Target … Why Should it be?

QoS/P/E: Quality of Service/Perception/Experience
Experiences are multisensorial ...
Consumption of multimedia content can include also other senses
- Vision or hearing
- Olfaction, mechanoreception, thermoception, …

Annotation with metadata providing so-called sensory effects that steer appropriate devices capable of rendering these effects … giving users the sensation of being part of the particular multimedia ↔ immersive, rich experience
Building Multisensorial Immersion ...

Feel-around, from Kentucky Fried Movie
QoE Assessment: Again Subjective and Objective
QoS versus QoE

- **Scope**: QoS typically focuses on telecommunications services, whereas QoE covers a much broader domain, which sometimes does not even involve telecommunications.

- **Focus**: QoS deals with performance aspects of physical systems, whereas QoE deals with the users' assessment of system performance, as colored by context, culture, the users' expectations with respect to the system or service and their fulfillment, socio-economic issues, and psychological profiles, among other factors.

- **Methods**: QoS has a very technology-oriented approach, whereas QoE requires a multi-disciplinary and multi-methodological approach for its understanding.

- **But it is also important to remember that QoE is, in a large part of instances, highly dependent on QoS.**

  From “Qualinet White Paper on Definitions of Quality of Experience”, March 2013
QoE is like a (Bigger) Elephant …

It’s a Fan!

It’s a Wall!

It’s a Rope!

It’s a Spear!

It’s a Snake!

It’s a Tree!

The blind men and the elephant, Poem by John Godfrey Saxe
QoE in Networked Multimedia

Context
Content
Social and psychological factors

QoS

QoE

Source quality
Encoding quality
Network performance
Decoding, loss concealment, error correction performance
Representation quality
QoE Related Standardization Efforts

- Standardization efforts in quality assessment and metrics
  - ITU-T SG 12 (*Performance, QoS and QoE*)
  - MPEG/ITU-T (*High Efficiency Video Coding, HEVC*)
  - MPEG (*3D video coding, FTV, HDR*)
  - Video Quality Experts Group (*VQEG*)
  - JPEG (*AIC, JPEG XR, JPEG XT, JPEG XS, JPEG PLENO*)
  - ...

QUALINET established links and deep collaborations with all of them!
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QoE is Becoming Inevitable …

○ Digital world has (re-)discovered the notion of quality
  – Lower quality content is less and less tolerated by end-users in some environments
  – However, other environments seem to accept much lower quality and still be successful

○ Increasing interest in QoE
  – Extending from device-centric and system-centric quality optimization to end-to-end and especially user-centric optimization
QoE Holistic Approach

- Marketing
- Business model, e.g. prices, fidelization
- System factors
- Context factors
- Human factors
- Personalization
- Content (and metadata)
- Interface
- Client support
- ...

Hello! My name is Happy Client 😊
NOS UMA: an example

- Ultra HD 4K
- Portability across terminals, *i.e.* follows you
- Voice control (voice recognition ?), *i.e.* recognizes you
- User profiles within same family, *i.e.* individualizes you
- Recommendations based on user characterization, *i.e.* targets you
- Complementary content for the favourite series, *i.e.* thinks for you
- Time warping, *i.e.* helps you
- ...

A TV that knows you!
QoE in Industry

- QoE is becoming mainstream.
- Many companies now speak about QoE.
- Personalization, interaction and recommendation capabilities **empower the user** to create more individual experiences!
- However, QoE has a **budget impact** in terms of network and system design, dimensioning, operation, maintenance, etc.
- But QoE is becoming **more affordable** in many application domains …
- Embracing QoE principles may bring **revenue**, e.g. by **increasing viewing times and reducing churn**.
Challenges Ahead

- Content-dependent quality assessment methods and metrics
- Context-dependent quality assessment methods and metrics
- Quality assessment methods and metrics beyond AV (haptics, smell, …)
- Multi-modal quality assessment methods and metrics (AV, …)
- 3D quality assessment methods and metrics (3D sound, 3D video, …)
- New modalities content quality assessment methods and metrics
- Interaction quality metrics (closely related to usability)
- Presence/immersion quality metrics
- Role of emotions
- Virtual reality immersive experiences
- …
New Sensors ...
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A Light Field Image

Behind each microlens, a micro-image (MI) is formed...
Light Field Photography: Array of Cameras
New Displays

USC light field display

Holografika HoloVizio light field display

Oculus Rift

Microsoft Hololens

InnoVision Diamond Series holographic projector
QoE for Virtual Reality

- Compelling immersive and realistic visual experiences!
- Provides visual depth cues, such as stereopsis, binocular occlusions, vergence, full motion parallax and natural view-dependent lighting.
- High resolution and high frame rate.
- Low latency spatial random access.
- Low motion-to-photon latency.

On current HMDs, the closest depth for an object of interest is recommended to be at 0.75m without causing excessive eyestrain.
Holoportation: Virtual 3D Teleportation

SITE A

Capture

Depth estimation & segmentation

Volumetric fusion

Network

Mesh, color, audio streams

Color Rendering

REMOTE RENDERING

SITE B

RGB

Depth

Mask

8 Pods

courtesy of P. Chou, Microsoft
What Does this all Mean?

- Era of user-centric multimedia has already started … **User is King/Queen**!

- It is not anymore sufficient to merely add new features and functionalities to multimedia systems.

- True added value in terms of impact on user’s experience of such features and functions should be evaluated and demonstrated.

- Quality of Experience plays a central role in this new game! Already targeting revenue …
Assessing Quality of Experience … A Bit Like Measuring ‘Happiness’ …
2. Towards the Concept of Quality of Life

A. Beyond Quality of Experience

B. The age of wearables

C. Ingredients of a modern assessment of Quality of Life
• Prediction is very difficult, especially about the future

→ Niels Bohr (1885-1962): Physics Nobel Prize Winner 1922
Trends in user-centric multimedia

- Consequences of Moore’s law
  - Better and richer content
  - Larger bandwidth networks
  - Bigger storage capacities
  - More sophisticated codecs/processing

- Better integration
  - Art, design
  - Psychology, psychophysics, neuroscience
  - Sociology, humanities
  - Technology and engineering
Trends in user-centric experiences

- New media experiences
- Personal well-being and personal health
- Big data and social media
New media experiences

- UHD, HDR, HFR, 3D, ...
- Light field imaging
- Integral imaging
- Holographic imaging
- Haptics
- Virtual, Augmented, Mixed reality
- Immersive media
- Multi-sensory media
- …
Major trends in multimedia

- Wearables
- Internet of Things
- New Media

- Big data
- Social media
- Processing

Multimedia experiences
Major trends in multimedia

- Sensor
- Wearables
- Internet of Things
- New Media
- Content
- Big data
- Social media
- Life
- Multimedia experiences
2. Towards the Concept of Quality of Life

A. Beyond Quality of Experience
B. The age of wearables
C. Ingredients of a modern assessment of Quality of Life
Generation-0 (smart) wearables
Mobile phones as wearables
Smart watches as wearables
Personal well-being wearables
Not any wearable should be smart!
Smart watches versus watches
Other wearables for user sensing