Quality of Experience Effects in Video Delivery

CHEN Jinling, XU Yiwen, LIU Yisang, HUANG Huiwen, and ZHUANG Zhongwen

(Fuzhou University, Fuzhou, Fujian 350108, China)

Abstract: With the popularization of smartphones and high-speed networks, a larger number of users are getting used to watching videos online and have increasing requirements of video quality. Therefore, the video content delivery has become a progressively challenging task, especially for ultra-high-definition (UHD) videos and heterogonous networks. Recently, quality of experience (QoE), which represents the true visual experience of users, has shown its advantages in management of video delivery and thus attracted increasing attention. In a video delivery system, the user QoE can be greatly influenced by numerous effects from video sources to display terminals. In this paper, we first investigate the significant differences between quality of service (QoS) and QoE. In addition, we summarize the end-to-end QoE effects in video delivery and present their classification based on the deployment. We also specifically analyze the impacts of different kinds of factors on QoE in video transmission systems.

Keywords: QoE; QoS; video delivery; video quality

DOI: 10.12142/ZTECOM.201901005

http://kns.cnki.net/kcms/detail/34.1294.TN.20190221.1044.002.html, published online February 21, 2019

Manuscript received: 2018-08-13

1 Introduction

The recent development of high-speed networks and smart devices have brought a great need of multimedia services. As a result, it is necessary to develop quality metrics to measure the performance of video services. During the past decades, an increasing number of conventional quality metrics have been proposed to predict the quality of videos. The peak signal to noise ratio (PSNR) and structural similarity (SSIM) index [1], as the most widely used signal fidelity metrics, evaluate the quality of videos by the similarity between the reference and distorted video frames. In addition, quality of service (QoS) [2] has been developed to estimate video quality at system perspective and become the most suitable one for the measurement of performance and reliability of network elements.

This work is supported by the National Natural Science Foundation of China (Grant 61671152).

All above-mentioned quality metrics are limited to evaluate video quality from the perspective of signals and systems and do not take users' true visual experience into account. Therefore, quality of experience (QoE) [3] has been proposed to represent the true experience of a user, which has overtaken the traditionally used objective measures. It is defined as "the overall acceptability of an application or service, as perceived subjectively by the end user" [4]. It includes the complete end-to-end system effects and may be affected by user expectations and context. Then, to mitigate some of the problems related with the above definition, the following definition of QoE was developed: "Degree of delight of the user of a service. In the context of communication services, it is influenced by content, network, device, application, user expectations and goals, and context of use." [5] However, these definitions seem to only reflect the user's acceptance. Taking the limitations of the above definitions into account, a more accurate definition was proposed in 2013: "QoE is the degree of delight or annoyance of the user 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 users' personality and current state." [6]

The new definition of QoE emphasizes the subjective experience of users compared to the objective indicators. Due to its advantage, QoE has been widely used in video delivery. Hoβfeld et al. [7] studied YouTube video streaming in terms of the QoE impact of Internet delivery. Different QoE monitoring approaches were qualitatively compared and estimated considering the accuracy of QoE estimation. Rehman et al. [8] performed a subjective experiment to investigate the impacts of display device properties and viewing conditions on perceptual video QoE. They also proposed a full-reference (FR) video QoE metric, named SSIMplus, to predict the perceptual quality of a video. Maia et al. [9] analyzed the subjective, objective and hybrid QoE approaches in video streaming services. Zhao et al. [10] described the main QoE factors of video transmission and the modeling approaches of these factors, and surveyed the QoE assessment approaches, including subjective test and objective QoE monitoring. Li et al. [11] proposed a novel QoE-driven centralized scheduling framework for multiuser downlink networks.

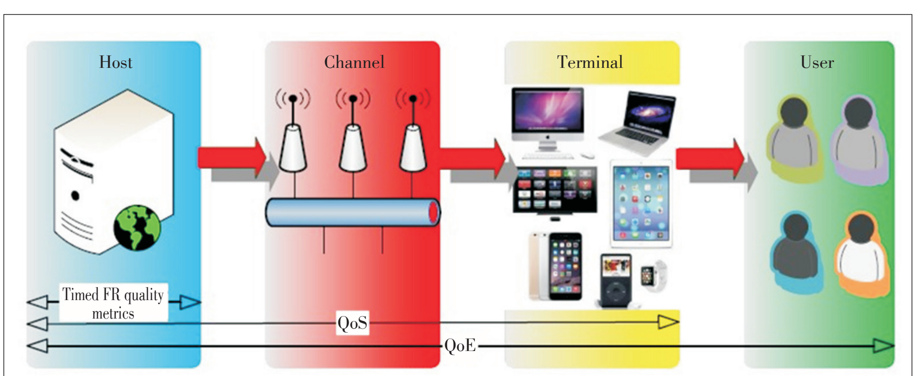
As introduced in the above studies, the increasing dominance of video traffic has driven the widespread use of QoE in video transmission. As a result, it is necessary to survey the end-to-end QoE effects in video delivery. In order to achieve the purpose, we first investigate the differences between QoS and QoE in Section 2. Then, the classification of QoE effects is provided in Section 3. Furthermore, we analyze the influencing factors of QoE in Section 4. Finally, Section 5 concludes the paper.

2 From QoS to QoE

In general, the conventional QoS metrics have been used to study the performance of online services and networked elements. QoS reflects the reliability of the network and its components, which was described by ITU as: "totality of characteristics of a telecommunications service that bear on its ability to satisfy stated and implied needs of the user of the service."[2] This definition implies several obvious differences from the concept of QoE. First, QoS handles the performance aspects of physical systems. Thus, it is a network-centric metric. The commonly used QoS metrics are throughput, bandwidth, packet loss, delay, and jitter. However, QoE is a user-centric metric that deals with the users' assessment of system performance, such as context, culture, user-specific characteristics, delivered content, and psychological profiles, among other factors. The second difference resides in the fact that QoS and QoE have different scopes. The QoS is usually focused on telecommunications and network services, while QoE covers more extensive areas, which is not limited to telecommunications and networks. QoE mainly faces users and business. The third difference between QoS and QoE is that QoS relies on the analytic approaches and empirical or simulative measurements, whereas QoE depends on multidisciplinary and multi-methodological approaches.

Despite of these differences, QoE is still dependent on QoS to a certain extent. The relationship between QoS and QoE can be obtained from **Fig. 1**. It can be seen that QoE covers more influence factors than QoS and the conventional timed video quality metrics. Therefore, QoE and QoS are not mutually exclusive; on the contrary, QoE is an extension of QoS, which takes subjective factors (e.g., user and context) into consideration on the basis of QoS. In recent years, researchers have tried to implement QoS to QoE mapping. Aroussi et al. [12] proposed a global correlation model between QoE and QoS based on the multiple linear regression (MLR). Alberti et al. [13] presented a nonlinear psychometric model to evaluate the mean opinion score (MOS) from the QoS parameters for dynamic adaptive streaming over HTTP (DASH) streaming systems. Mansouri et al. [14] developed an integrated QoS and QoE evaluation system in order to evaluate voice over IP (VoIP) service quality in a more comprehensive way. Anchuen et al. [15] estimated the satisfaction of users in terms of QoE using neural network approach, where the input of the proposed model was obtained by five QoS parameters. Ning et al. [16] analyzed the sensitivity of QoE to different QoS parameters and provided the mapping relationship between QoS to QoE. Garcła-Pineda et al. [17] used a statistical technique that employs all kinds of variables related to QoS, to evaluate the subjective QoE.

In summary, the main difference between QoS and QoE is that QoS depends on the network perspective, while QoE focuses on the users' perspective. However, QoS and QoE are not two independent metrics, because QoE adds the effects of context and human to the system factors that are widely studied on



FR: full reference QoS: quality of service QoE: quality of experience

▲Figure 1. Illustration of the impact of end-to-end system on QoE in video transmission.

QoS. Furthermore, the above studies indicate that it is possible to develop a real-time QoE metric based on QoS factors.

3 Classification of QoE Effects

As an overall metric, QoE can be influenced by various factors in the end-to-end video delivery system. In practice, these influence factors include video capture, coding, storage, delivery, decoding, rendering, display and context of use. Furthermore, QoE is also affected by user factors such as user personality and expectations. Apparently, all these factors have direct impact on the design of QoE-aware optimization techniques for video delivery. Here, we present a classification and an enumeration of all relevant influence factors of QoE in video delivery system in this section.

In [18], the contributions of QoE in video delivery were divided into three categories including content preparation, content delivery and the customer environment. In [10], the end-to-end influence factors of QoE in video transmission were summarized into three categories including system influence factors, context influence factors and human influence factors. Following these ideas, we classify the QoE influence factors based on their operational locations in the end-to-end video delivery system. We propose to partition the video delivery system into four major elements including host, channel, terminal, and user, as shown in Fig. 1. Correspondingly, we classify these influence factors into four categories accordingly: host factors, channel factors, terminal factors, and user factors. The major advantage of this classification is that it can support various QoE mappings and cross-layer optimization designs at different taxonomies of the video delivery system.

Base on the partition method mentioned above, the influence factors of QoE are summarized in **Table 1** and are discussed as follows.

(1) Host factors: These factors include video content factors and media factors. At the host, a source video is generally processed and/or coded before being transmitted in order to reduce the storage size and meet the bandwidth budget. In addition, the unimpaired source video is usually available at the host. Therefore, we can utilize it (or the features extracted from it) as a reference to measure the QoE loss during video processing and compression. The temporal and spatial samplings may also have impacts on the user's QoE.

(2) Channel factors: The channel factors are mainly network-related factors. It is known that the packet transmission can be influenced by different network configurations such as bandwidth, throughput, resource requirements, scheduling, and sometimes, zapping time and handoff. However, inappropriate network configurations or poor network conditions may cause packet delay, jitter, loss or error rate, which will degrade the user's QoE. For online video purchasing, the pricing model and the prices also affect the QoE. In addition, the channel factors and relevant host factors can be regarded as QoS parameters during video delivery process.

▼Table 1. QoE influence factors at different taxonomies of a video transmission system

Taxonomy		QoE influence factors
Host	Content factors	Temporal/spatial requirements, color depth, texture, 2D/3D, content reliability, artifacts, etc.
	Media factors	Encoding, resolution, sampling rate, frame rate, media synchronization, etc.
Channel	Network factors	Delay, jitter, loss, error rate, bandwidth, throughput, path selection, resource requirements, scheduling, zapping time, hand-off, etc.
	Other factors	Pricing, etc.
Terminal	Device factors	Decoding, error concealment, zooming, rendering, display size, screen resolution, color depth, user interface, CPU and memory, battery, etc.
	Other factors	Luminance, viewing distance, movement, interactivity, personalization, security, mobility, etc.
User	Physiological factors	Gender, age, heart rate, electrodermal activity, etc.
	Psychological factors	Attention, interest, personality, mood, pre-conceptions, user expectation/goal, etc.

CPU: central processing unit QoE: quality of experience

(3) Terminal factors: This category includes the device factors (e.g., decoding parameters, reception device settings, and display parameters) and environmental configurations (e.g., luminance, viewing distance, and movement). In addition, the usability and accessibility of graphic user interface (GUI) and video interactivity during playing are also considered as QoE factors drawn into this category. Furthermore, the security and personalization issues also belong to this category in some particular applications [6].

(4) User factors: The user factors are generally composed of physiological factors (e.g., gender, age, and heart rate) and psychological factors (e.g., attention, interest, and mood). In practice, the user factors, especially the psychological factors, are difficult to be directly measured, which leads to a great obstacle to the research of the influence of user factors on QoE. Luckily, in recent years, researchers have found some indirect ways to measure user factors and subsequently made several breakthroughs in the study of the impact of user factors on QoE, which will be discussed in detail in Section 4.

4 Further Analysis

In video delivery system, QoE covers the end-to-end factors, which are from host to users, to affect the users' experience on video services. In this section, we further analyze the specific impacts of these factors on QoE.

4.1 Impact of Host Factors

It is well known that the distortion is inevitably introduced to reduce the visual quality of videos in the process of acquisition, processing and compressed. Therefore, video quality assessment (VQA) methods have been extensively used to predict the impact of distortion on video quality. According to the available amount of reference information at the host, VQA can be also divided into three categories: FR, reduced-reference (RR) and no-reference (NR) methods. In an FR method, an unimpaired original video is compared frame by frame with the impaired video to obtain a VQA metric. Typical FR measures are PSNR, SSIM [1], etc. These FR methods achieve higher accuracy because of their reference original videos. However, compared with the other two methods, FR methods have a small scope of applications due to its demand for unimpaired videos, which are generally applicable only to the host. For the RR methods [19]–[21], they only need to extract some features from unimpaired original videos and transmit them along with the impaired videos. Thus they are more applicable than FR measures. How to extract features is the main challenge for them. The NR methods are completely independent of the original video information, which is both its advantage and its difficulty. In recent years, several NR methods have been proposed due to their practicality [22]–[24].

In addition, other influence factors at the host have been studied in the past years. The depth perception assessment metrics for 3D stereoscopic videos were proposed in [25] and [26]. Ou et al. [27] analyzed the impacts of spatial, temporal and amplitude resolution on the bit rate of a compressed video and proposed an analytical rate model. The effect of color depth for QoE was investigated in [28]. A determining method of frame rate and resolution was proposed to improve QoE [29]. In [30], the impact of video resolution was also discussed.

All of the above works study the influences of host factors on QoE, and lay the foundation for the development of VQA based on host factors. In recent years, VQA technology of ordinary video has become more mature, especially the FR methods. However, with the popularity of special videos (e.g., ultra-high-definition (UHD), high dynamic range (HDR), 3D, and 360-degree videos), how to measure the host factors in these video delivery has been an open question. In addition, since original special videos are usually unavailable in many real-world video applications, the RR and NR methods will play an important role in VQA. In summary, the impacts of host factors on QoE will be further investigated in the future.

4.2 Impact of Channel Factors

QoE can be affected by numerous channel factors when the video stream is transmitted over a channel, such as bandwidth and throughput. These can be considered as a part of the QoS parameters. Due to the measurability of QoS, QoE assessment approaches based on channel factors are widely used in video delivery system.

In [31], Frnda et al. discussed the impact of packet loss and delay variation on QoE and designed a prediction model for estimation of triple play services. Maeda et al. [32] investigated the influence of network delay on QoE in a networked haptic drum system. Nunome et al. [33] investigated the effect of two allocation methods of bandwidth on QoE in multiview video and audio transmission. Begluk et al. [34] proposed a machine-learning model to predict QoE based on network-related factors (e.g., delay, jitter, and loss) as input data. Gutierrez et al. [35] studied the impact of transmission errors in 3DTV and proposed a novel evaluation methodology for QoE.

These researchers extensively investigated the influence of channel factors on QoE, especially network factors. However, other factors (e.g., pricing) are still not well studied at present. They are also highly needed for the study of QoE. Furthermore, the development of heterogonous networks such as 5G network has improved the users' requirements for video transmission. For these new emerging networks, how to measure QoE is a new challenge and research direction. Therefore, the influences of channel factors on QoE will be widely studied on these networks.

4.3 Impact of Terminal Factors

When watching the same video in the same environment, there are some differences in the experience of users using different terminal devices. The reason for the difference of QoE is the influences of the terminal factors, including screen resolution, display size, luminance, viewing distance, etc. With the development of smart devices, more and more researchers have studied the influences of terminal factors on QoE.

Beyer et al. [36] observed a considerable impact of display size on overall quality. In [37], Vucic et al. studied the impacts of smartphone factors (including CPU, screen size and display resolution) on the QoE for multi-party video conferencing. Jeganatan et al. [38] studied the effect of user interfaces on QoE of multiview video and audio over IP networks. Edstrom et al. [39] mainly investigated environmental luminance at different levels and its impact on the user's viewing experience. Triyason [40] conducted a subjective experiment to prove screen size has an effect toward the QoE of remote cloud-based virtual desktop.

It should be pointed out that there are not many studies on the impacts of terminal factors on QoE. Most of the current studies are mainly based on device-related and environment-related. They seem to ignore the influences of other terminal factors on QoE, such as interactivity and personalization. However, with the development of smart devices (e.g., smartphones, tablets, and VR devices), users put forward higher requirements for the interactivity, personalization and security of video services. It suggests that the research of these terminal-related factors plays a pivotal role in VQA. Thereby, QoE research based on terminal-related factors will become an important research direction in the future.

4.4 Impact of User Factors

Since the human factors are strongly related to and may affect other factors, they play an increasingly important role in the impact of QoE. They can well reflect each user's personal experience. However, they are highly complex and not well comprehended because of their subjectivity and relevance [41].

In a study given in [42], Guntuku et al. found that personality and culture play a key role in predicting the intensity of negative affect. Murray et al. [43] evaluated the impact of users' age and gender on user QoE based on user perception of olfaction based mulsemedia. In addition, Murray et al. [44] proposed a model based on empirical data to estimate user QoE. The result indicates that human factors play an important role in perceptual multimedia quality of olfaction enhanced multimedia. Song et al. [45] developed a user-centric objective QoE evaluation model to predict QoE considering perceptual audiovisual quality and user interest in audiovisual content. In [46], Eynard et al. discussed the impact of verbal communication on the user experience in the context of virtual reality (VR).

All these works demonstrate that the human factors play a key role in QoE assessment. Since these factors differ QoE from QoS, an increasing number of researchers try to build QoE models based on the human factors to achieve more accurate video quality assessment. However, most of these factors are not measured directly. Thence, these studies are currently focused on users' touch, visual and other aspects in the special videos, especially immersive applications. Although these studies have made some progress, how to directly measure the impact of the human factors on QoE is still a challenge due to their complexity.

5 Conclusions

In this paper, we discuss three main differences between QoS and QoE and the possibility of QoS and QoE mapping. QoE can be influenced by various factors in the video delivery and we summarize these factors into four categories: host factors, channel factors, terminal factors, and user factors. In addition, we analyze the specific impacts of different types of factors on QoE. We hope our study may promote the development and application of VQA approaches.

References

[1] WANG Z, BOVIK A C, SHEIKH H R, et al. Image Quality Assessment: From Error Visibility to Structural Similarity [J]. IEEE Transactions on Image Processing, 2004, 13(4): 600–612. DOI: 10.1109/tip.2003.819861
[2] Definitions of Terms Related to Quality of Service: ITU - T Recommendation E.800 [S]. 2008
[3] MOLLER S, RAAKE A, Eds. Quality of Experience: Advanced Concepts, Applications and Methods [M]. Cham, Switzerland: Springer, 2014
[4] Definition of Quality of Experience (QoE), ITU TD 109rev2 (PLEN/12) [S]. 2007
[5] MOLLER S. Quality Engineering—Qualität kommunikationstechnischer Systeme [M]. Berlin, Heidelberg: Springer Berlin Heidelberg, 2010
[6] CALLET P L, MOLLER S, PERKIS A, et al. Qualinet White Paper on Definitions of Quality of Experience [R]. Novi Sad: European Network on Quality of Experience in Multimedia Systems and Services (COST Action IC 1003), 2013
[7] HOßFELD T, SCHATZ R, BIERSACK E, et al. Internet Video Delivery in YouTube: From Traffic Measurements to Quality of Experience [M]//HOßFELD T, SCHATZ R, BIERSACK E, et al. eds. Data Traffic Monitoring and Analysis. Berlin, Heidelberg: Springer Berlin Heidelberg, 2013: 264–301. DOI: 10.1007/978-3-642-36784-7_11
[8] REHMAN A, ZENG K, WANG Z. Display Device-Adapted Video Quality-of-Experience Assessment [C]//IS&T/SPIE Annual Symposium on Electronic Imaging. San Francisco, USA, SPIE 9394. DOI: 10.1117/12.2077917
[9] MAIA O B, YEHIA H C, DE ERRICO L. A Concise Review of the Quality of Experience Assessment for Video Streaming [J]. Computer Communications, 2015, 57: 1–12. DOI: 10.1016/j.comcom.2014.11.005
[10] ZHAO T S, LIU Q, CHEN C W. QoE in Video Transmission: A User Experience-Driven Strategy [J]. IEEE Communications Surveys & Tutorials, 2017, 19(1): 285–302. DOI: 10.1109/comst.2016.2619982
[11] LI T T, ZHANG H X, TIAN J, et al. QoE-Driven Centralized Scheduling for HTTP Adaptive Video Streaming Transmission over Wireless Networks [C]// 9th International Conference on Wireless Communications and Signal Processing (WCSP). Nanjing, China, 2017: 1–6. DOI: 10.1109/WCSP.2017.8171114
[12] AROUSSI S, BOUABANA - TEBIBEL T, MELLOUK A. Empirical QoE/QoS Correlation Model Based on Multiple Parameters for VoD Flows [C]//IEEE Global Communications Conference (GLOBECOM). Anaheim, CA, USA, 2012: 1963-1968. DOI: 10.1109/GLOCOM.2012.6503403
[13] ALBERTI C, RENZI D, TIMMERER C, et al. Automated QoE Evaluation of Dynamic Adaptive Streaming over HTTP [C]//Fifth International Workshop on Quality of Multimedia Experience (QoMEX). Klagenfurt am Wörthersee, Austria, 2013: 58–63. DOI: 10.1109/QoMEX.2013.6603211
[14] MANSOURI T, NABAVI A, ZARE RAVASAN A, et al. A Practical Model for Ensemble Estimation of QoS and QoE in VoIP Services via Fuzzy Inference Systems and Fuzzy Evidence Theory [J]. Telecommunication Systems, 2016, 61 (4): 861–873. DOI: 10.1007/s11235-015-0041-6
[15] ANCHUEN P, UTHANSAKUL P, UTHANSAKUL M. QOE Model in Cellular Networks Based on QOS Measurements Using Neural Network Approach [C]// 13th International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI-CON). Chiang Mai, Thailand, 2016: 1–5. DOI: 10.1109/ECTICon.2016.7561318
[16] NING Z L, LIU Y Q, WANG X J, et al. A Novel QoS-Based QoE Evaluation Method for Streaming Video Service [C]//IEEE International Conference on Internet of Things (IThings) and IEEE Green Computing and Communications (GreenCom) and IEEE Cyber, Physical and Social Computing (CPSCom) and IEEE Smart Data (SmartData). Exeter, UK, 2017: 956–961. DOI: 10.1109/iThings-GreenCom-CPSCom-SmartData.2017.147
[17] GARCÍA-PINEDA M, SEGURA-GARCÍA J, FELICI-CASTELL S. A Holistic Modeling for QoE Estimation in Live Video Streaming Applications over LTE Advanced Technologies with Full and Non Reference Approaches [J]. Computer Communications, 2018, 117: 13–23. DOI: 10.1016/j.comcom.2017.12.010
[18] VALERDI J, GONZÁLEZ A, GARRIDO F J. Automatic Testing and Measurement of QoE in IPTV Using Image and Video Comparison [C]//Fourth International Conference on Digital Telecommunications. Colmar, France, 2009: 75–81. DOI: 10.1109/ICDT.2009.21
[19] WANG M M, ZHANG F, AGRAFIOTIS D. A very Low Complexity Reduced Reference Video Quality Metric Based on Spatio-Temporal Information Selection [C]//IEEE International Conference on Image Processing (ICIP). Quebec City, Canada, 2015: 571–575. DOI: 10.1109/ICIP.2015.7350863
[20] AABED M A, ALREGIB G. Reduced - Reference Perceptual Quality Assessment for Video Streaming [C]//IEEE International Conference on Image Processing (ICIP). Quebec City, Canada, 2015: 2394–2398. DOI: 10.1109/ICIP.2015.7351231
[21] YU M, ZHENG K H, JIANG G Y, et al. Binocular Perception Based Reduced-Reference Stereo Video Quality Assessment Method [J]. Journal of Visual Communication and Image Representation, 2016, 38: 246– 255. DOI: 10.1016/j.jvcir.2016.03.010
[22] CHEN Q G, JIN Y H, YANG T. A Supervised No-Reference QOE Assessment Model on IPTV Services [C]//4th International Conference on Cloud Computing and Intelligence Systems (CCIS). Beijing, China, 2016: 272–277. DOI: 10.1109/CCIS.2016.7790268
[23] TORRES VEGA M, MOCANU D C, STAVROU S, et al. Predictive No-Reference Assessment of Video Quality [J]. Signal Processing: Image Communication, 2017, 52: 20–32. DOI: 10.1016/j.image.2016.12.001
[24] ZHANG H, LI F, LI N. Compressed-Domain-Based No-Reference Video Quality Assessment Model Considering Fast Motion and Scene Change [J]. Multimedia Tools and Applications, 2017, 76(7): 9485–9502. DOI: 10.1007/s11042-016-3558-0

[25] LEBRETON P, RAAKE A, BARKOWSKY M, et al. Evaluating Depth Perception of 3D Stereoscopic Videos [J]. IEEE Journal of Selected Topics in Signal Processing, 2012, 6(6): 710–720. DOI: 10.1109/jstsp.2012.2213236
[26] NUR YILMAZ G. A no Reference Depth Perception Assessment Metric for 3D Video [J]. Multimedia Tools and Applications, 2015, 74(17): 6937–6950. DOI: 10.1007/s11042-014-1945-y
[27] OU Y F, XUE Y Y, WANG Y. Q-STAR: A Perceptual Video Quality Model Considering Impact of Spatial, Temporal, and Amplitude Resolutions [J]. IEEE Transactions on Image Processing, 2014, 23(6): 2473–2486. DOI: 10.1109/tip.2014.2303636
[28] BOITARD R, POURAZAD M T, NASIOPOULOS P. Evaluation of Chroma Subsampling for High Dynamic Range Video Compression [C]//IEEE International Conference on Electronics, Circuits and Systems (ICECS). Monte Carlo, Monaco, 2016: 696–699. DOI: 10.1109/ICECS.2016.7841297
[29] LI M, SONG J B, HUI L. A Determining Method of Frame Rate and Resolution to Boost the Video Live QoE [C]//2nd International Conference on Multimedia and Image Processing (ICMIP). Wuhan, China, 2017: 206–209. DOI: 10.1109/ICMIP.2017.26
[30] ASAN A, ROBITZA W, MKWAWA I H, et al. Impact of Video Resolution Changes on QoE for Adaptive Video Streaming [C]//2017 IEEE International Conference on Multimedia and Expo (ICME). Hong Kong, China, 2017: 499–504. DOI: 10.1109/ICME.2017.8019297
[31] FRNDA J, VOZNAK M, SEVCIK L. Impact of Packet Loss and Delay Variation on the Quality of Real-Time Video Streaming [J]. Telecommunication Systems, 2016, 62(2): 265–275. DOI: 10.1007/s11235-015-0037-2
[32] MAEDA Y, ISHIBASHI Y, FUKUSHIMA N. QoE Assessment of Sense of Presence in Networked Virtual Environment with Haptic and Auditory Senses: Influence of Network Delay [C]//IEEE 3rd Global Conference on Consumer Electronics (GCCE). Tokyo, Japan, 2014: 679–683. DOI: 10.1109/GCCE.2014.7031181
[33] NUNOME T, FURUKAWA K. The Effect of Bandwidth Allocation Methods on QoE of Multi-View Video and Audio IP Transmission [C]//IEEE 22nd International Workshop on Computer Aided Modeling and Design of Communication Links and Networks (CAMAD). Lund, Sweden, 2017: 1–6. DOI: 10.1109/CAMAD.2017.8031625
[34] BEGLUK T, HUSIC J B, BARAKOVIC S. Machine Learning-Based QoE Prediction for Video Streaming over LTE Network [C]//17th International Symposium INFOTEH-JAHORINA (INFOTEH). East Sarajevo, Bosnia-Herzegovina, 2018: 1-5. DOI: 10.1109/INFOTEH.2018.8345519
[35] GUTIÉRREZ J, PÉREZ P, JAUREGUIZAR F, et al. Subjective Assessment of the Impact of Transmission Errors in 3DTV Compared to HDTV [C]//3DTV Conference: the True Vision—Capture, Transmission and Display of 3D Video (3DTV-CON). Antalya, Turkey, 2011: 1–4. DOI: 10.1109/3DTV.2011.5877209
[36] BEYER J, MIRUCĤNA V, MÖLLER Ś. Assessing the Impact of Display Size, Game Type, and Usage Context on Mobile Gaming QOE [C]//Sixth International Workshop on Quality of Multimedia Experience (QoMEX). Singapore, Singapore, 2014: 69–70. DOI: 10.1109/QoMEX.2014.6982297
[37] VUCIC D, SKORIN-KAPOV L. The Impact of Mobile Device Factors on QoE for Multi-Party Video Conferencing via WebRTC [C]//13th International Conference on Telecommunications (ConTEL). Graz, Austria, 2015: 1–8. DOI: 10.1109/ConTEL.2015.7231206
[38] JEGANATAN F, FRANCIS W, NUNOME T. QoE Assessment of Multi-View Video and Audio Simultaneous IP Transmission: The Effect of User Interfaces [C]//International Conference on Information and Communication Technology Convergence (ICTC). Busan, South Korea, 2014: 466–471. DOI: 10.1109/ICTC.2014.6983182
[39] EDSTROM J, CHEN D L, WANG J H, et al. Luminance-Adaptive Smart Video Storage System [C]//IEEE International Symposium on Circuits and Systems (ISCAS). Montreal, Canada, 2016: 734–737. DOI: 10.1109/ISCAS.2016.7527345
[40] TRIYASON T, KRATHU W. The Impact of Screen Size Toward QoE of Cloud-Based Virtual Desktop [J]. Procedia Computer Science, 2017, 111: 203–208. DOI: 10.1016/j.procs.2017.06.054
[41] BARAKOVIC S, SKORIN-KAPOV L. Survey of Research on Quality of Experience Modelling for Web Browsing [J]. Quality and User Experience, 2017, 2: 6. DOI: 10.1007/s41233-017-0009-2
[42] GUNTUKU S C, LIN W S, SCOTT M J, et al. Modelling the Influence of Personality and Culture on Affect and Enjoyment in Multimedia [C]//International Conference on Affective Computing and Intelligent Interaction (ACII). Xi´an, China, 2015: 236–242. DOI: 10.1109/ACII.2015.7344577
[43] MURRAY N, LEE B, QIAO Y S, et al. The Influence of Human Factors on Olfaction Based Mulsemedia Quality of Experience [C]//Eighth International Conference on Quality of Multimedia Experience (QoMEX). Lisbon, Portugal, 2016: 1–6. DOI: 10.1109/QoMEX.2016.7498975
[44] MURRAY N, MUNTEAN G M, QIAO Y S, et al. Modeling User Quality of Experience of Olfaction-Enhanced Multimedia [J]. IEEE Transactions on Broadcasting, 2018, 64(2): 539–551. DOI: 10.1109/tbc.2018.2825297
[45] SONG J R, YANG F Z, ZHOU Y C, et al. QoE Evaluation of Multimedia Services Based on Audiovisual Quality and User Interest [J]. IEEE Transactions on Multimedia, 2016, 18(3): 444–457. DOI: 10.1109/tmm.2016.2520090
[46] EYNARD R, PALLOT M, CHRISTMANN O, et al. Impact of Verbal Communication on User Experience in 3D Immersive Virtual Environments [C]// IEEE International Conference on Engineering, Technology and Innovation/International Technology Management Conference (ICE/ITMC). Belfast, UK, 2015: 1–8. DOI: 10.1109/ICE.2015.7438679

Biographies

CHEN Jinling received her bachelor of engineering from Fujian Agriculture and Forestry University, China in 2016. She is a master student at the College of Physics and Information Engineering, Fuzhou University, China. Her research interests include image/video processing and visual quality assessment.

XU Yiwen (xu yiwen@fzu.edu.cn) received his Ph.D. degree from Department of Electronic Engineering, Xiamen University, China in 2012. He has been an associate professor with the College of Physics and Information Engineering, Fuzhou University, China, since 2013. His research interests lie in multimedia information processing, video codec and transmission, and video quality assessment.

LIU Yisang received her bachelor of engineering from Fuzhou University, China in 2016. She is a master student at the College of Physics and Information Engineering, Fuzhou University. Her research interests lie in multimedia streaming, 3D video quality assessment, and 3D video streaming.

HUANG Huiwen received her bachelor of engineering from Fuzhou University, China in 2016. She is a master student at the College of Physics and Information Engineering, Fuzhou University. Her research interests lie in image/video processing and 360 degree video streaming.

ZHUANG Zhongwen received his bachelor of engineering from Fuzhou University, China in 2016. He is a master student at the College of Physics and Information Engineering, Fuzhou University. His research interest is video coding.