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SERIES G: TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

Multimedia Quality of Service and performance – Generic and user-related aspects

Influence factors on gaming quality of experience

Recommendation ITU-T G.1032

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Recommendation ITU-T G.1032

Influence factors on gaming quality of experience

Summary

Recommendation ITU-T G.1032 presents a list of factors which may influence the quality of experience (QoE) of cloud gaming and online gaming. The factors are grouped into user, system, and context factors. They should be taken into account when planning and implementing online gaming services, and when evaluating their quality of experience with subjective methods or instrumental quality prediction models.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
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Keywords

Quality of experience, QoE, game, influence factor.

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FOREWORD

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The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

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Introduction

In addition to voice, video and web browsing, increasingly popular services running on IP-based networks are online computer games. However, in comparison to the aforementioned services, less information exist on factors (and their interactions) influencing the quality of experience experienced by the user (player) of such online computer games. Knowledge of such influence factors is important to apply subjective methods for assessing gaming of the QoE, or for building instrumental quality prediction models. This Recommendation is the basis of the related ITU Recommendations that describe subjective evaluation methods for gaming quality as well as prediction models for gaming quality.

Recommendation ITU-T G.1032

Influence factors on gaming quality of experience

1 Scope

This Recommendation is intended to present a list of potential influencing factors for gaming QoE assessment. The list of influencing factors can be considered for several purposes including, but not limited to, interactive and passive gaming QoE assessment, steps during the game development circle, and network service providers for (cloud) online gaming.

2 References

None.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following term defined elsewhere:

3.1.1 frame rate [b-ITU-T H.262]: The rate at which frames are output from the decoding process.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 cloud gaming: Cloud gaming is characterized by game content delivered from a server to a client as a video stream with game controls sent from the client to the server. The execution of the game logic, rendering of the virtual scene, and video encoding are performed at the server, while the client is responsible for video decoding and capturing of client input.

3.2.2 critical flicker fusion threshold: A threshold that is referring to the frequency at which an intermittent light stimulus appears to be completely steady to the average human observer.

3.2.3 eSport: A form of sports where the primary aspects of the sport are facilitated by electronic systems; the input of players and teams as well as the output of the eSports system are mediated by human-computer interfaces.

3.2.4 game bricks: A rule-based game classification splitting the games into several fundamental elements such as moving and shooting. In total, ten "gameplay bricks" in two categories are proposed by [b-Djaouti], rules stating goals, including avoid, match, and destroy, and rules defining the means and constraints to reach the goals consisting of create, manage, move, random, select, shoot, and write.

3.2.5 genre: A classification of games where games are grouped according to their gameplay characteristics.

3.2.6 online gaming: A service that enables a video game to be either partially or primarily played over a broadband network. The service renders the game at the client device while the updated states of game are transferred over a broadband network.

3.2.7 refresh rate: The rate at which frames can be displayed on monitor.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

CBR Constant Bit Rate

CQP	Constant Quantization Parameter
CRF	Constant Rate Factor
FPS	First Person Shooter
GoP	Group of Pictures
HD	High-Definition video
LED	Light-Emitting Diode
LCD	Liquid-Crystal Display
MMORPGs	Massively-Multiplayer Online Role-Playing Games
QoE	Quality of Experience
QP	Quantization Parameter

5 Conventions

In his Recommendation, online gaming is understood to be a service that renders the game at the client device while the updated states of the game are transferred over a broadband network. In contrast, in cloud gaming there is no processing (execution of the game logic, rendering of the virtual scene) on the client. Within the scope of this Recommendation, the person interacting with a game is referred to as player, whereas the software that is used in cloud gaming set-ups to display a remotely rendered game video stream is referred to as a client.

6 Categorization of influence factors

[b-Le Callet] defines the quality of experience (QoE) influence factor as:

"Any characteristic of a user, system, service, application, or context whose actual state or setting may have influence on the Quality of Experience for the user."

In this Recommendation, the factor groups proposed is in accordance with [b-Le Callet] are: human influence factors (clause 7), system influence factors (clause 8) and context influence factors (clause 9).

QoE of an online gaming service can be measured through subjective tests as a passive viewing-and-listening (watching videos of recorded game play) or interactive scenario (participants are playing the game). In addition, an experiment could aim to investigate either cloud gaming or online gaming services. Based on the design and aim of the experiment, some of the factors may have a significant impact on the QoE. For example, video-encoding factors are not relevant for an experiment aimed at online gaming. The list of relevant influence factors for each test paradigm is shown in Table 1. Detailed information on each factor is presented in clauses 7 to 9.

Table 1 – List of relevant influencing factors based on test paradigm

	Test paradigm		
Factors	**Passive viewing-and-listening**	**Interactive online gaming**	**Interactive cloud gaming**
User influencing factors			
Experience	X	X	X
Intrinsic and extrinsic motivation	X	X	X

Table 1 – List of relevant influencing factors based on test paradigm

	Test paradigm		
Factors	**Passive viewing-and-listening**	**Interactive online gaming**	**Interactive cloud gaming**
Static and dynamic human factors	X	X	X
Human vision	X	X	X
System influencing factors (Game)			
Game genre	X	X	X
Game mechanics and rules		X	X
Temporal and spatial accuracy		X	X
Temporal and spatial video complexity	X		X
Pace		X	X
Visual perspective of the player		X	X
Aesthetics and design characteristics	X	X	X
Learning difficulty		X	X
System influencing factors (Playing device)			
Device portability	X	X	X
Handheld device size		X	X
Input modalities		X	X
Output modalities	X	X	X
Display	X	X	X
System influencing factors (Network transmission)			
Delay		X	X
Jitter		X	X
Bandwidth	X	X (Note)	X
Packet loss	X	X (Note)	X
System influencing factors (Compression)			
Frame rate	X		X
Resolution	X		X
Rate controller modes	X		X
GoP	X		X
Motion range search	X		X
Audio compression	X		X
Context influencing factors			
Physical environment factors	X	X	X

Table 1 – List of relevant influencing factors based on test paradigm

	Test paradigm		
Factors	**Passive viewing-and-listening**	**Interactive online gaming**	**Interactive cloud gaming**
Social context	X	X	X
Service factors		X	X
Novelty	X	X	X
NOTE – Minor impact expected.			

7 Human influence factors

A Human influence factor is "any variant or invariant property or characteristic of a human user. The characteristic can describe the demographic and socio-economic background, the physical and mental constitution, or the user's emotional state" [b-Le Callet].

Experience with gaming in general: Both in scientific and in popular literature a classification of "hardcore gamer" and "casual gamer" is widely used, distinguishing the classes based on the average time of playing per time period. Despite the division's broad adoption, no common threshold exists to delimit the two groups. Another popular distinction exists between "newbie" and "pro gamer" based on the experience with a particular game or game genre. These characteristics are related to the gamer's skill, and change dynamically. It must be noted that a well-experienced player may rate the QoE differently compared to causal gamers.

Experience with a specific game or genre: Each service is best evaluated by users who are familiar with how it should function. Digital games are a very broad term and the complexity of the game under test can vary. For simple games, the knowledge of the player about the game under test may not matter because the gameplay is simple and easy to understand. On the other hand, in more complex games such as massively multiplayer online role-playing games (MMORPGs) it is intuitive that the users which are using it should normally be the ones which can best evaluate its quality, because some aspects of the system may not function properly and if the testing player does not know how it should function he/she cannot notice the degradation.

Intrinsic and extrinsic motivation: Intrinsic and extrinsic motivation can have a strong influence on the QoE of gaming since the high diversity of games offers different kinds of fun and motivation to play them. For example, players who want to prove themselves by beating other players may not be satisfied when playing a purely artificial intelligence controlled game. According to the self-determination theory, intrinsic motivation is the core type of motivation underlying sports and play [b-Frederick]. Nevertheless, the external validity of lab studies with paid test participants playing games without intrinsic motivation remains potentially problematic. In the context of massively-multiplayer online role-playing games, ten motivation sub-components can be grouped into the overarching components achievement, social, and immersion as explained in [b-Yee]. Therefore, as stated in [b-Yee]: "MMORPGs appeal to many players because they are able to cater to many different kinds of play styles".

Static and dynamic human factors: Static human factors are the static characteristics of a player such as age, gender and native language, while dynamic factors refer to emotional status including boredom, distraction, curiosity and so forth.

Human vision: Visual perception varies depending to the characteristics of the visual stimulus. The sensitivity of a user to video/network artifacts differs between users. As an example, sensitivity to frame rate as encoding parameter depends on a user's critical flicker fusion threshold. See [b-Davis].

8 System influence factors

System influence factors refer to "properties and characteristics that determine the technically produced quality of an application or service" [b-Jumisko-1]. The factors in this section contain not only the game, which is being played by the user, but also the whole setup and user-perceivable design of the hardware and software. Depending on the kind of gaming system the relevant factors differ. Since, for example, online (multi-player) gaming typically uses online connectivity just for state synchronization with a server, video compression-related factors do not apply in this case. Furthermore, technologies such as stereoscopic 3D through head-mounted displays introduce new influence factors and likely impact the effect of other factors.

8.1 Game

As with other types of media, the content of a game (e.g., mechanics, dynamics, aesthetics [b-Hunicke]) decidedly influence a player's gaming experience. However, differing from other types of media, the content and the underlying technical implementation are strongly interwoven: even games from the same genre often employ entirely different stacks of software to generate the gaming experience. This influences the perceivable effects of variations of influence factors as different compensation strategies may be implemented.

The game content has a major influence on QoE especially when other influencing factors are considered. In fact, the sensitivity to parameters like delay is more influential to some types of games than to others. Therefore, the selection of appropriate content for a subjective test is an important part of any experiment design. In this clause, the parameters that must be considered for the selection of the game type are explained.

Game genre: Genre classification is a broad term and is not precise enough to characterize the games. However, in the absent of an appropriate game classification, game genres can be used as a basic criterion of content selection in the experimental design. It must be noted that several game interactions (game bricks) such as shooting, moving, and avoiding could be a part of a single game (genre) while the impact of technical parameters such as delay for each of these interactions most likely is not the same. Thus, the game genre alone will not be sufficient to characterize the sensitivity of the game towards technical parameters.

Game mechanics and rules: These largely influence and determine game outcomes and are individual to each game.

Temporal and spatial accuracy: Temporal accuracy is defined as the time required to complete an action. Spatial accuracy is the degree of accuracy required to complete the interaction successfully. These two factors might determine the playability of a certain game under delay. The broad classification of games on the temporal accuracy (deadliness) and spatial accuracy (precision) plane was suggested in [b-Claypool-1]. It should to be noted that these factors play an important role when investigating the temporal factors such as delay and frame rates.

Temporal and spatial video complexity: Video complexity plays an important role in streaming services especially when bitrate and other encoding factors are considered. Video games with different spatial and temporal complexity might have a different degree of perceptual quality. Video content with high complexity may suffer more from network parameters like bandwidth, packet loss and encoding artifacts than low-complexity content. Consequently, the bandwidth itself cannot sufficiently characterize the quality degradation of a game video sequence, even if all the other parameters have been fixed. In other words, for the same bandwidth due to the difference of video complexity, different qualities may be perceived for two video games.

Pace: Pace refers to the speed of a gameplay. Although this factor seems to be similar to the two previously mentioned factors (the temporal accuracy concept as well as temporal complexity of games), there is a small difference between pace and the two other factors. First, pace has to be seen as a speed in one game type (or one game genre in general) which means that there could be two

games with the same temporal complexity while their paces are not comparable (e.g., a racing game and shooting game with same temporal complexity). In addition, a game with high-required reaction time does not necessarily have a high pace (e.g., a static scene with some blinking points that has to be hit). Overall, pace has to be seen as a speed of a gameplay in a particular type of game (or genre), but there is no classification of pace in the literature. Pace should to be considered as an influencing factor especially when investigating the temporal factors such as delay and frame rate.

Visual perspective of the player: Based on the perspective of the camera, games have been classified into First-person Linear Perspective, Third-person Linear Perspective, and Third-person Isometric Perspective [b-Claypool-2]. The perspectives of the game are very important in cloud gaming and an interplay with the video coding can be assumed.

Aesthetics and design characteristics: Aesthetics is the sensory experience that the system elicits, and the extent to which this experience fits individual goals and spirit [b-Vilnai]. Aesthetics and design characteristics describe the design of a game, which can be experienced by the player, and is commonly specified by design experts. There is no known classification for game designs. However, there might be a strong influence on player experience considering both the variety in addressed types of "fun" [b-Hunicke] and the effort that is being invested into creating a distinguished visual and audible appearance of games.

Learning difficulty: The required time to learn how to play a game is a critical criterion when aiming at short interactive test. Games such as racing games do not necessarily need a long time to learn the game rules, actions and game elements because of limited number of control buttons and game rules. On the contrary, there are games that need a long time (even days and weeks) to achieve the goals and learn the elements of the game . Such games should be avoided for short interactive tests.

8.2 Playing devices

Portability: The continued success of portable gaming devices suggests that the benefit of mobility outweighs the limitations of a portable device for a group of players. The success of smartphone gaming may also be attributed partly to the portability of the devices, but a quantification of that particular influence is challenging and attempts are currently limited.

Size: The size of a handheld device has been shown to exert an influence on playing test participants' ratings [b-Beyer-1]. Unless it is the object of investigation in a study, it should therefore remain constant.

Input modalities: Modalities used for game input differ vastly in terms of attributes such as precision, speed and feedback. In the past, new forms of input (e.g., gesture control) have repeatedly enabled new playing paradigms. However, in some contexts different controls can be used interchangeably (e.g., inertial vs button control in racing games, touch-screen overlay buttons vs physical keyboards or pads) and likely influence the experience of a game unless it explicitly adapts to the different modalities (e.g., in terms of reduced difficulty).

Output modalities: The availability of output modalities and their technical attributes confine the perceivable experiences. A comparative study showed that participants wearing a VR headset perceive higher levels of immersion than players of the same simulation game using a conventional 2D screen [b-Hupont].

Display: For video quality assessment, it was shown [b-Winkler] that the perceived quality is strongly influenced by the viewing distance, display size, brightness, contrast, sharpness, screen resolution, refresh rate and color. If the frame rate is high the size of the display as well the refresh rate of the display can bring higher quality. If the high-definition (HD) video games are targeted for the test, a full HD resolution display needs to be used.

The display size is an important aspect whenever control elements are placed directly on the screen. A device that is too small influences the usability of the game. An outcome of the study [b-Beyer-2] shows that a screen size for mobile games should always be larger than 5″. However, the screen size

should also not be too large as this would result in a scenario with a negative impact on reaction times or cause less awareness. For that reason, in the eSport domain a screen size for PC games of 24″ is commonly used.

Regarding the monitor refresh rate, the technology is evolving at a fast pace. For interactive applications such as gaming, a high frame rate and refresh rate is expected. Additionally, new methods to synchronize the GPU rendering and monitor refresh rate (G-Sync and Free-Sync) are available on the market. When using such a new technology, it should be noted that there will most likely be a large difference when compared to older technologies, especially when coding parameter or very fast-paced games are considered.

In addition, game content can be represented to users in different ways such as using head-mounted displays, mobile displays, light-emitting diode (LED) displays, liquid-crystal display (LCD) displays, etc. The impact of using head-mounted displays on gaming QoE, especially on immersion, has been proven and it should be considered when comparing results between platforms [b-Hupont], [b-Tan].

8.3 Network transmission

Given the highly interactive nature of online games, a network distortion can negatively influence the user's experience. There is a distinction between studies focusing on online gaming and cloud gaming in terms of network transmission distortion, whereby online gaming mostly suffers from delay, jitter and packet loss, while cloud gaming additionally has to deal with a limited bandwidth.

Delay: The delay perceived by an end user corresponds to the delay from the execution of the user commands to visible game event shown on the display. While most studies focus on the impact of networking delays, often the consideration of additional system components contributing to overall end-to-end delay are neglected (e.g., system tick rate, processing and rendering delay).

The influence of delay on the QoE strongly depends on game factors, as discussed earlier. Therefore, investigating delay as an influencing factor of QoE without considering the characteristics of the game is not valid, and results are not comparable with other studies. In addition to game characteristics, the perceived delay may differ considerably depending on the input devices used for playing.

Jitter: Jitter has a perceivable influence on online gaming and cloud gaming experience [b-Ries], [b-Quax]. It is also a concern in cloud gaming settings as high levels of jitter may introduce delays due to additional buffering or cause packet loss if data is delivered too late for rendering. Depending on the client implementation, jitter may also result in a less smooth visual appearance of the game as frames are displayed at varying intervals.

Bandwidth: The impact of bandwidth restrictions on QoE in the context of cloud gaming has been proven in numerous studies (e.g., [b-Beyer-3]-[b-Wen]) and has been shown to be a contributing influence factor to gaming QoE. Depending on employed mechanism to deal with limited bandwidth, it could result in packet loss, delay (due to buffering mechanism) and video artifact due to video compression.

Packet loss: Network packet loss has a significant impact on gaming QoE while playing intensive games such as first person shooter (FPS), with packet loss less than 1% causing serious degradation of user experience [b-Chen]. Increased packet loss causes severe degradation of the graphics quality of the games, culminating with lower frame rate and unplayable gaming experience. In a non-cloud-gaming setting, the effects of packet loss are less homogenous and depend strongly on the implementation of a game and the effectiveness of the countermeasures it employs.

8.4 Compression

Given bandwidth limitations, different QoE-driven codec configuration strategies may be specified for various types of games. These strategies also interact with the delay influence factor as many redundancy reduction strategies in modern video codecs benefit from additional buffering which is

detrimental to low-latency video transmission. The most important encoding parameters linked to cloud gaming QoE are:

Frame rate: The frame rate has a significant impact on a user's performance and consequently influences the QoE. However, perceiving the difference between very high frame rates strongly depends on human vision abilities, a player's commonly used gaming setup, and game characteristics (especially the game pace). It should be noted that display specifications such as display size and refresh rate would be substantial when investigating the impact frame rate on the QoE.

Resolution: The encoding resolution is an important parameter, which affects the video quality in all streaming applications while it has little impact on the user performance [b-Claypool-3]. For a given resolution, an increasing bit rate may increase the quality up to a specific level; beyond this level, increasing the bit rate cannot further improve the quality. Therefore, for users with a high bandwidth, a higher resolution is needed instead of improving other encoding parameters such as quantization parameter (QP).

Rate controller modes: There are some strategies to control the video streaming rates in order to reach a certain target quality with a given bandwidth. Three different rate controller modes were implemented in x264 (VBR is excluded since it is out of the scope of cloud gaming services) including constant quantization parameter (CQP), constant rate factor (CRF) and constant bit rate (CBR); all of them resulted in a different quality. CQP is the straightforward strategy which encodes the video based on constant QP and leads to variable bit rate and quality. CRF attempts to keep the quality at a certain level by adjusting the QP for each frame. Finally, CBR tries to encode the video by keeping the bit rate constant. Rate control strategies do not only affect the QoE, but they also have an impact on the overall delay of a gaming service. It should be noted that, after deciding on a rate controller strategy, other parameters linked to the selected rate controller strategy should be investigated. For example, the overall quality of a video generated by using a CQP strategy depends on the chosen quantization parameter.

Group of Pictures: Group of Pictures (GoP) is a structure that specifies the order of inter and intra frames (I, B and P frames) in a video sequence. There are two terminologies related to the GoP. The GoP *value* is determined by the distance between two anchor frames (number of frames between an I-frame and the next P-frame). The GoP *length* is determined by the distance between two I-frames. The selection of the GoP length is a trade-off between the propagation error and the video compression. A small GoP length may lead to a higher bitrate for encoding, since more I-frames are involved in the encoding process. On the other hand, a larger GoP length increases the chance of error propagation, since in the case of a transmission loss, more frames are needed to receive an I-frame to correct the error. As a result, the GoP length may affect the perceived quality, and the impact of GoP size should be investigated for video gaming service.

Motion range search: A motion estimation algorithm has an influence on the efficiency of coding, and indirectly impacts the overall quality of a gaming service. Besides the motion estimation algorithm, the motion range search needs to be determined based on the video content, which may significantly impact the QoE (see discussion above). For highly dynamic video content a wider-range motion search is desirable, and for mostly static content a smaller motion range should be chosen to reduce the computation time.

Audio compression: A similar influence as the video compression factor is assumed for audio. However, audio compression in the context of cloud gaming has so far not been subjected to the same degree of scientific scrutiny as video compression.

9 Context influence factors

Context influence factors "are factors that embrace any situational property to describe the user's environment in terms of physical, temporal, social, economic, task, and technical characteristics" [b-Jumisko-1], [b-Jumisko-2]. While in some rare cases, such as special car or airplane simulators,

the player's environment is formed, lit, and even moved in a way to resemble the corresponding original, the ordinary case is that it lies outside the reach of the games designers. Besides these physical environmental factors, the success of online multiplayer games (e.g., MMORPGs) or party games (e.g., various karaoke) have demonstrated the significance of the social context.

Physical environment factors: Physical factors refer to room characteristics (space, acoustics, and lighting) and usage situation (in-house, on the move, etc.). The physical environment may influence gaming QoE and must be chosen in a way that represents the real gaming environment.

Social context: Relationships to other players who are involved in the game, potential parallel activities of the player, privacy and security issues, which might be particularly relevant in multiplayer games. The social context is one of the influential QoE factors that is difficult to measure objectively. Therefore, the influence of other factors (especially technical factors) on gaming QoE are hard to measure if social context is also considered. Hence, it is recommended to avoid this factor in gaming QoE studies, unless the main focus of the work is to study the influence of such factors.

Service factors: [b-Yang] discusses the influence of service factors (e.g., ease of access, availability, pricing) on customer satisfaction for online game services, which is likely to be present especially in the context of cloud gaming.

Novelty: Novelty, which means that the user experience is improved when a new technology is introduced, has an impact on quality judgments, not because of any actual improvement in learning or achievement, but in response to an increased interest in the new technology [b-Meline]. Thus, it can be expected that the impact of quality factors on perceived quality will be different with any "new" technologies and services.

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