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# Quality of Experience Modeling for Cloud Gaming Services

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*This book is dedicated to my parents, and my wife, Nasim. I would not be here without the support, encouragement, and love from you. Thank you for everything!*

# Preface

The *gaming* industry has been one of the largest in the entertainment markets for the past several decades and is steadily growing with the introduction of emerging technologies such as hardware video encoding and the new generation of broadband cellular networks 5G. With these advancements, a new gaming paradigm called *cloud gaming* has emerged that makes gaming possible at any time, on any device, and at any place. Cloud gaming shifts the heavy computational tasks such as rendering to the cloud resources and streams a compressed video of players' gameplay back to the client in real time. Similar to other telecommunication services, cloud gaming is prone to network and compression degradations such as blockiness, blurring, and network latency. These degradations could negatively affect the quality of experience (QoE) of users. Therefore, it is of high interest for service and network providers to measure and monitor the QoE of cloud gaming services to potentially improve the satisfaction of their customers.

The present book aims at the development of a gaming quality model to predict the gaming QoE of players that could be used for planning the network service or quality monitoring of cloud gaming services. The model is developed following a modular structure approach that keeps the different types of impairment separately. Such a modular structure allows developing a sustainable model as each component can be updated by advances in that specific research area or technology. The book describes the steps toward planning and conducting subjective tests for game streaming services, analyzing the subjective data, and the process of modeling quality judgment ratings of users with different types of approaches.

This book is written for students, researchers, and engineers involved in the QoE assessment of video game streaming services. In addition, it might be useful for a person who is working on network planning and operation.

This book is the result of studies conducted during my PhD research, which was conducted in the Quality and Usability Lab at TU Berlin and Telekom Innovation Laboratories at Deutsche Telekom (known as T-Labs) between 2016 and 2021. The scope of this book was influenced by the ITU-T standard activities at Study Group 12, particularly the G.OMG work item ("Opinion model predicting gaming

quality of experience for cloud gaming services”), which resulted in an ITU-T recommendation G.1072, that author contributed between 2016 to 2020.

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# Acronyms

AC	Service Acceptance
ACM	Amount of Camera Movement
ACR	Absolute Category Rating
ACR-HR	ACR with Hidden Reference
AQ	Audio Quality
B-frames	Bidirectional-Frames
BIQI	Blind Image Quality Index
BM	Block Motion estimation
BRISQUE	Blind/Referenceless Image Spatial Quality Evaluator
CBR	Constant Bitrate
CGVDS	Cloud Gaming Video Quality DataSet
CH	Challenge
CN	Controllability
CNN	Convolutional Neural Network
CO	Competency
CQP	Constant Quantization Parameter
CRF	Constant Rate Factor
CSGO	Counter-Strike: Global Offensive
DBSQE-V	Dimension-Based Subjective Quality Evaluation Method
DMOS	Differential MOS
DSR	Dynamic Super Resolution
DoF	Degrees of Freedom
ECscale	Extended Continuous scale
EC-ACR	Extended Continuous ACR
EEG	Electroencephalography
EWMA	Exponentially Weighted Moving Average
FHD	Full High Definition
FL	Flow
FR	Full-Reference
GAN	Generative Adversarial Network
GEQ	Game Experience Questionnaire

GIPS	Gaming Input Quality Scale
GoP	Group of Picture
GVSET	Gaming Video Dataset
HEVC	H.265/High Efficiency Video Coding
HUD	Heads-Up Display
HVS	Human Visual System
IF	Impairment Factor
iGEQ	in-game Game Experience Questionnaire
IM	Immersion
IP	Internet Protocol
ISO	International Organization for Standardization
ISPs	Internet Service Providers International Telecommunication Union
ITU	Telecommunication Standardization Sector
KPIs	Key Performance Indicators
KUGVD	Kingston University Gaming Video Dataset
llhq	low latency high quality
MDS	Multidimensional Scaling
MGUE	Mobile Gaming User Experience
MLR	Multiple Linear Regression
MOS	Mean Opinion Score
NA	Negative Affect
NCA	Neighborhood Components Analysis
NFLX-PD	Netflix Public Dataset Subjective Video QoE Database
NFLX-SVQD	LIVE-NFLX-II
NIMA	Neural Image Assessment
NIQE	Natural Image Quality Evaluator
NR	No-Reference
NSS	Natural Scene Statistics
NVEnc	NVIDIA Encoder
PA	Positive Affect
PReLU	Parametric Rectified Linear Unit
PC	Personal Computer
PCA	Principal Component Analysis
PLC	Packet Loss Concealment
PR	Playing Performance
PLCC	Pearson Linear Correlation Coefficient
PSNR	Peak Signal to Noise Ratio
PX	Player Experience
QoE	Quality of Experience
QoS	Quality of Service
QP	Quantization Parameters
RBF	Radial Basis Function
RD	Rate-Distortion
RE	Responsiveness
Rec.	Recommendation

RF	Random Forest
RFE	Recursive Feature Elimination
RR	Reduced-Reference
RTP	Real-time Transport Protocol
RTSP	Real Time Streaming Protocol
SA	Static Areas
SGD	Stochastic Gradient Descent
SI	Spatial Information index
SLA	Service Level Agreement
SoA	State of the Art
SR	Super-Resolution
SRCC	Spearman's Rank Correlation Coefficient
SS	Single Stimulus
SSIM	Structural Similarity
SVR	Support Vector Regression
TC	Temporal Complexity
TE	Tension
TI	Temporal Information index
UDP	Datagram Protocol
UHD	4K/Ultra-High Definition-1
VBR	Variable Bitrate
VD	Video Discontinuity
VF	Video Fragmentation
VIFP	Visual Information Fidelity-Pixel Domain
VL	Suboptimal Video Luminosity
VMAF	Video Multimethod Assessment Fusion
VP9	Video Payload type 9
VQ	Video Quality
VQEG	Video Quality Expert Group
VR	Virtual Reality
VU	Video Unclearness
WebRTC	Web Real Time Communication