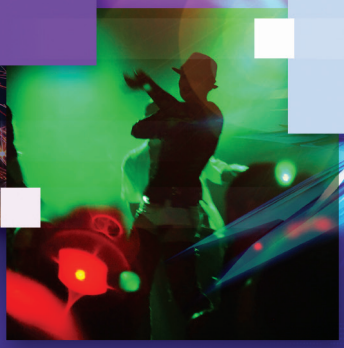
Media Production, Delivery and Interaction for Platform Independent Systems

Format-Agnostic Media



Editors

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FORMAT-AGNOSTIC MEDIA

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List of Abbreviations

2D	Two-dimensional
3D	Three-dimensional
3GPP	3rd Generation Partnership Project
4D	Four-dimensional
4K	Horizontal resolution on the order of 4000 pixels, e.g. 3840×2160 pixels (4K UHD)
7K	Horizontal resolution on the order of 7000 pixels, e.g. 6984×1920 pixels
AAML	Advanced Audio Markup Language
ACES	Academy Color Encoding System
ADR	Automatic Dialogue Replacement
ADSL	Asymmetric Digital Subscriber Line
AIFF	Audio Interchange File Format
API	Application Programming Interface
AMPAS	Academy of Motion Picture Arts and Sciences
APIDIS	Autonomous Production of Images based on Distributed and Intelligent Sensing
ARMA	Auto Regressive Moving-Average model
ARN	Audio Rendering Node
ASDF	Audio Scene Description Format
ATM	Asynchronous Transfer Mode
AudioBIFS	Audio Binary Format for Scene Description
AV	Audio-visual
AVC	Advanced Video Coding
BBC	British Broadcasting Corporation
BWF	Broadcast Wave Format
CCD	Charge Coupled Device
CCFL	Cold Cathode Fluorescent Lamp
CCIR	Comité Consultatif International des Radiocommunications
CCN	Content-Centric Networking
CCU	Camera Control Unit
CDF	Content Distribution Function
CDFWT	Cohen-Daubechies-Feauveau Wavelet Transform
CDN	Content Delivery Network
CG	Computer Graphics
CGI	Computer Generated Imagery

CIF	Common Intermediate Format
CMOS	Complimentary Metal-Oxide Semiconductor
COPSS	Content Oriented Publish/Subscribe System
CPU	Central Processing Unit
CRT	Cathode Ray Tube
CUDA	Compute Unified Device Architecture
DASH	Dynamic Adaptive Streaming over HTTP
dB	Decibel
DBMS	Data Base Management System
DCI	Digital Cinema Initiative
DLNA	Digital Living Network Alliance
DLP	Digital Light Processing
DMD	Digital Micromirror Device
DMIPS	Dhrystone Million Instructions Per Second
DOCSIS	Data Over Cable Service Interface Specification
DONA	Data-Oriented Network Architecture
DPX	Digital Picture Exchange
DSL	Digital Subscriber Line
DSLAM	Digital Subscriber Line Access Multiplexer
DSLR	Digital Single-Lens Reex
DSP	Digital Signal Processor
DTAK	Dynamic Time Alignment Kernel
DTW	Dynamic Time Warping
DVB	Digital Video Broadcasting
DVD	Digital Versatile Disc
EBU	European Broadcasting Union
EBUCore	Basic metadata set defined by the EBU
EMD	Earth Mover's Distance
ENG	Electronic News Gathering
EOFOV	Edges Of Field Of View
EOTF	Electro-Optical Transfer Function
EPG	Electronic Program Guide
ESPN	Entertainment and Sports Programming Network
ESS	Extended Spatial Scalability
EXR	High Dynamic Range Image Format
FascinatE	Format-Agnostic SCript-based INterAcTive Experience
FCC	Fast Channel Change
FMO	Flexible Macro-block Ordering
FRN	Flexible Rendering Node
FSM	Finite State Machines
FTTH	Fibre-to-the-Home
FullHD	HD resolution of 1920×1080 pixels
GB	Gigabyte
GOP	Group Of Pictures
GPU	Graphical Processing Unit
GUI	Graphical User Interface

HAS	HTTP Adaptive Streaming
HBB	Hybrid Broadcast Broadband
HBBTV	Hybrid Broadcast Broadband TV
HD	High-Definition
HDMI	High-Definition Multimedia Interface
HDR	High Dynamic Range
HDTV	High-Definition Television
HEVC	High Efficiency Video Coding
HI	Hearing Impaired
HLFE	High-Level Feature Extraction
HMM	Hidden Markov Model
HOA	Higher Order Ambisonics
HOG	Histograms of Oriented Gradients
HQ	High Quality
HRTF	Head Related Transfer Function
HTML5	HyperText Markup Language 5
HTTP	HyperText Transfer Protocol
IBC	International Broadcasting Convention, annual industrial fair, Amsterdam, The Netherlands
IBR	Image-Based Rendering
ICP	Iterative Closest Point
ID	Identity
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IGMP	Internet Group Management Protocol
IMAX	Image Maximum (motion picture film format)
I/O	Input/Output
IP	Internet Protocol
IPTV	Internet Protocol Television
IROI	Interactive Region-Of-Interest
ISO	International Standards Organisation
IT	Information Technology
ITU	International Telecommunications Union
iTV	Interactive TV
JND	Just Noticeable Difference
JPEG	Joint Photographic Experts Group
JPIP	JPEG2000 over Internet Protocol
JSIV	JPEG2000-based Scalable Interactive Video
JVT	Joint Video Team
kB	kilo Bytes
KLT	Tracking approach proposed by Kanade, Lucas, Tomasi
KLV	Key, Length, Value; a binary encoding format used in SMPTE standards
kNN	k-Nearest Neighbour
LBP	Local Binary Patterns
LCD	Liquid Crystal Display
LCS	Longest Common Subsequence

LDR	Low-Dynamic Range
LED	Light Emitting Diode
LF	Light Field
LFE	Low Frequency Effects
LIDAR	Light Detection And Ranging
LSR	Layered Scene Representation
MAD	Mean Absolute Difference
MAP	Mean Average Precision
MDA	Multi-Dimensional Audio
MLD	Multicast Listener Discovery
MOCA	Multimedia over Coax
MP4	MPEG-4 Part 14
MPD	Media Presentation Description
MPEG	Moving Picture Experts Group
MPLS	Multiprotocol Label Switching
MVC	Multiview Video Coding
MXF	Material eXchange Format
NAB	National Association of Broadcasters, synonym for the annually held industrial convention in Las Vegas, USA
NAT	Network Address Translation
NDN	Named Data Networking
NHK	Nippon Hoso Kyokai (Japan Broadcasting Corporation)
NTSC	National Television System Committee (analogue television standard used on most of American continent)
NTT	Nippon Telegraph and Telephone Corporation (Japanese Telecom)
NVIDIA	an American global technology company based in Santa Clara, California
OB	Outside Broadcast
OLED	Organic Light-Emitting Diode
OmniCam	Omni-directional camera by Fraunhofer HHI
OpenCV	Open source Computer Vision libary
OpenEXR	a high dynamic range (HDR) image file format
OPSI	Optimized Phantom Source Imaging
OSR	On-Site Rendering
OTT	Over-The-Top
OVP	Online Video Platform
OWL	Web Ontology Language
P2P	Peer to Peer
PC	Personal Computer
PCI	Peripheral Component Interconnect (standard computer interface)
PDP	Plasma Display Panel
PiP	Picture-in-Picture
PSE	Production Scripting Engine
PSIRP	Publish-Subscribe Internet Routing Paradigm
PSNR	Peak Signal-to-Noise Ratio
PTS	Presentation Time Stamps
PTZ	Pan-Tilt-Zoom

pub/sub	Publish/subscribe
PVR	Personal Video Recorder
QoE	Quality of Experience
QoS	Quality of Service
RADAR	Radio Detection and Ranging
RAID	Redundant Array of Independent Disks
RANSAC	Random Sample Consensus
RF	Random Forest
RGB	Red-Green-Blue colour space
RGBE	RGB with a one byte shared exponent
RO	Replay Operator
ROI	Region-of-Interest
RSS	Rich Site Summary
RTP	Real-time Transport Protocol
RUBENS	Rethinking the Use of Broadband access for Experience-optimized Networks and Services
SAOC	Spatial Audio Object Coding
SD	Standard Definition
SHD	Super High-Definition
sid	Spatial Identifier
SIFT	Scale-Invariant Feature Transform
SLA	Service-Level Agreement
SMIL	Synchronised Multimedia Integration Language
SMPTE	Society of Motion Picture and Television Engineers
SN	Scripting Node
SNR	Signal to Noise Ratio
SpatDIF	Spatial sound Description Interchange Format
SQL	Structured Query Language
STB	Set-Top Box
SVC	Scalable Video Coding
SVM	Support Vector Machine
SXGA	Super eXtended Graphics Adapter referring to resolution of 1280×1024 pixels
SXGA+	SXGA at resolution of 1400×1050 pixels
TCP	Transmission Control Protocol
TDOA	Time Difference Of Arrival
TIFF	Tagged Image File Format
TOF	Time Of Flight
TRECVID	TREC (Text Retrieval Conference) Video Track
TV	Television
UCN	User Control Node
UDP	User Datagram Protocol
UHD	Ultra High Definition
UHDTV	Ultra High Definition TV
UI	User Interface
UPnP	Universal Plug and Play
USB	Universal Serial Bus

VBAP	Vector Based Amplitude Panning
VBR	Video Based Rendering
VDSL	Very High Speed Digital Subscriber Line
VFX	Visual Effects
VM	Vision Mixer
VOD	Video On Demand
VRML	Virtual Reality Modelling Language
VRN	Video Rendering Node
VTR	Video Tape Recorder
VVO	Virtual View Operator
WF	Wave Field
WFS	Wave Field Synthesis
XML	Extensible Markup Language
XPath	XML Path Language
xTV	Explorative TV
YUV	Luminance and chrominance color space

Notations

General

- Scalar value $x; y$ in italic lower case. Coordinate values are scalars.
- 2D homogeneous vector $\mathbf{m}$ as lower case standard bold mathematical font.
- 3D homogeneous vector M as italic upper case standard mathematical font.
- Matrix $\mathbf{M}$ as upper case boldface font.
- $|\cdot|$ denotes the norm of a vector, length of a sequence or number of bins of a histogram.
- Vector of arbitrary dimension $\vec{\boldsymbol{x}}$ as lower case standard bold math font with arrow.
- $\mathrm{X} = (\vec{\boldsymbol{x}}_1, \ldots, \vec{\boldsymbol{x}}_n)$ is an ordered sequence of n feature vectors.
- $\chi = \{\mathrm{X}_1, \ldots, \mathrm{X}_k\}$ denotes a set of k feature vectors of sequences.

Specfic Symbols

Chapter 3 Video Acquisition

$\mathbf{m} = (x, y)^T$	Euclidean 2D point
$M = (x, y, z)^T$	Euclidean 3D point
$\mathbf{m} = (u, v, 1)^T$	Homogeneous 2D point
$M = (x, y, z, 1)^T$	Homogeneous 3D point
$\mathbf{A}$	Intrinsic matrix
$\mathbf{R}$	Rotation matrix
$\mathbf{I}$	Identity matrix
$\mathbf{t}$	Translation vector
f	Focal length
κ	Radial distortion coefficient
k_u, k_v	Horizontal/vertical scale factor
$u_0,\ v_0$	Horizontal/vertical offset
α_u	Focal length in multiples of the pixel width
C	Optical center
$\mathbf{P} = \mathbf{A}[\mathbf{R}\|\mathbf{t}]$	Camera projection matrix
$I_{1,2}$	Image plane of camera 1 = left and 2 = right camera
B	Baseline, interaxial distance between two cameras
$\mathbf{m}_{1,2}$	Corresponding 2D points
$[\mathbf{t}]\times$	Skew-symmetric matrix of vector $\mathbf{t}$
$\mathbf{H}$	Projective transformation/homography

$\mathbf{m}_1, \mathbf{m}_2, \ldots, \mathbf{m}_N$	Corresponding 2D points
δ	Disparity
π	Projective plane
H_π	Homography related to a plane π
λ	Projective parameter
w_h	Sensor width
N_p	Horizontal pixel resolution
Δq	Pixel width
$H_{R,G,B}$	Histogram of the R, G, B colour component

Chapter 5 Semi-Automatic Content Annotation

$\kappa(\vec{x}, \vec{y})$	Kernel function applied to a pair of feature vectors $\vec{x}$, $\vec{y}$.
$\kappa_f(\vec{x}, \vec{y})$	Appropriate kernel function for feature f applied to a pair of feature vectors $\vec{x}$, $\vec{y}$.
$\mathbf{H}$	Histogram
T_c	Runtime complexity of component c
U	Support vector of a model c
$O(\cdot)$	describes the upper bound of the runtime complexity of an algorithm ("big O notation").
τ	Time point
δ	Time offset

Chapter 7 Scalable Delivery of Navigable and Ultra-High Resolution Video

r_i	Bitrate assigned to tile i
s_i	Aggregated saliency score of tile i
α	Multiplicative factor that converts saliency values into rate values
λ	Impact factor of saliency on rate
BW	Bandwidth budget
M	Number of columns of a regular grid of tiles
N	Number of rows of a regular grid of tiles
Z	Overlapping factor of tiling scheme

1

Introduction

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The consumption of audio-visual media has changed rapidly in the past decade. Content is now viewed on a variety of screens ranging from cinema to mobile devices. Even on mobile devices, today's user expects to be able to watch a personal view of a live event, for example, with a level of interactivity similar to that of typical web applications. On the other hand, current video and media production technology has not kept up with these significant changes. If we consider the complete media processing chain, the production of media, the delivery of audio-visual information via different kinds of distribution channels and the display and interaction at the end user's terminal, many challenges have to be addressed. The major challenges are the following.

Due to reuse of video content for different distribution channels, there is a *need for conversion and post-production* of the content in order to cope with different screen sizes. It is widely accepted that a movie production for cinema is recorded in a significantly different way to that intended for smaller screens. However, production budgets are limited; hence complex and costly re-purposing must be avoided. A good example is the production of 3D movies, where the aim is to develop camera technologies that allow 2D and 3D capture at the same time. Approaches to multiformat production that require parallel shooting or significant manual re-editing are no longer financially viable.

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The convergence of broadcast and Internet requires future media production approaches *to embrace the changes brought by web-based media*. The habits of media consumption have changed drastically, partially due to the availability of user interaction with users freely navigating around web pages and interactively exploring maps and views of the street for example. Hence, future media production and delivery must support interactivity.

Although the overall bandwidth available for media delivery is continuing to increase, future media services will still face limitations, particularly if the end user at home or on-the-go is considered. Hence, new distribution formats are required to allow for *the provision of audio-visual media beyond current HDTV formats*, to support interactivity by the end user and to support intelligent proxies in the network that are capable of performing processing, which cannot be offered by low capacity devices. First developments towards resolution beyond HD are already appearing commercially, such as 4K camera and display technologies.

In addition, the user wants to decide when, where and on which device to watch audio-visual media as nowadays a variety of devices are available (including mobiles, TV at home and immersive large projection systems in cinemas). All of these devices must be supported by media delivery and rendering. Therefore, *a large variety of audio-visual formats* must be provided for the full spectrum of terminals and devices taking their special capabilities and limitations into account.

Even in live events, a lot of human operators such as directors or cameramen are involved in content creation and capturing the event from different viewpoints. Due to the increasing number of productions, *automated viewpoint selection* may be able to make a significant contribution to limiting production costs.

A new concept appearing on the horizon that could provide answers to these issues and challenges is referred to as *format-agnostic media production*. The basic idea is to define a new approach to media production that supports the necessary flexibility across the whole production, delivery and rendering chain. A key aspect of this approach is to acquire a representation of the whole audio-visual scene at a much higher fidelity than traditional production systems, and to shift closer to the user-end the decision of how the content is experienced. This idea allows end users to experience new forms of immersive and interactive media by giving them access to audio-visual content with the highest fidelity and flexibility possible. This book discusses current challenges, trends and developments along the whole chain of technologies supporting the format-agnostic approach. This approach could lead to a gradual evolution of today's media production, delivery and consumption patterns towards fully interactive and immersive media.

In Chapter 2 "State-of-the-art and Challenges in Media Production, Broadcast and Delivery", we give an overview on the current situation in audio-visual acquisition, coding and delivery and the evolution of terminal devices at the end-user side in current media production and delivery. Based on the review of the state-of-the-art and a summary of current and upcoming challenges, the format-agnostic concept is explained. This concept offers the capability to deal successfully with the new requirements of current and future media production.

The acquisition and processing of audio-visual media following a format-agnostic approach is discussed in two separate chapters, Chapter 3 and Chapter 4. In Chapter 3 "Video Acquisition", the three major video format parameters, spatial resolution, temporal resolution and colour depth (i.e., the dynamic range) are investigated with respect to the benefits they offer for future immersive media production. Due to the large variety of future video formats moving towards higher resolution, frame rate and dynamic range, the need for a format-agnostic

concept is particularly helpful in supporting media production and rendering independent of the specific format. The composition and merging of visual information from different sensors will lead to more appealing and higher quality images. In Chapter 4 "Platform-Independent Audio", the current challenges faced in audio broadcast using a channel-based approach and sound scene reproduction techniques such as wave field synthesis are reviewed. The problem of having many competing audio formats is addressed at both the production and reproduction (user) ends. The concept of object-based audio representation is introduced and several example implementations are presented in order to demonstrate how this can be realised.

In Chapter 5 "Semi-automatic Content Annotation", both manual and automatic content annotation technologies that support format-agnostic media production are discussed. The specific requirements on those tools, in particular under real-time constraints of live scenarios are investigated. Relevant video processing approaches such as detection and tracking of persons as well as action detection are presented. Finally, user interfaces in media production are discussed, which help the production team to perform semi-automatic content annotation.

One of the advanced concepts of media production currently under discussion and development is presented in Chapter 6 "Virtual Director". This concept builds on various audio-visual processing techniques that allow for automatic shot framing and selection to be used at the production side or by the end user. Approaches are discussed for addressing the semantic gap between data from low-level content analysis and higher-level concepts – a process called *Semantic Lifting*, finally leading to content and view selection that fulfils the desires of the user.

Chapter 7 "Scalable Delivery of Navigable and Ultra-High Resolution Video" deals with the main challenges in delivering a format-agnostic representation of media. As the final decision on how content will be presented is moved closer to the end user, two factors have a significant impact on delivery: higher data rate at the production side and higher levels of interactivity at the end-user side. The chapter focuses on coding and delivery techniques, which support spatial navigation based on the capture of higher resolution content at the production side. Methods for content representation and coding optimisation are discussed in detail. Finally, architectures for adaptive delivery are presented, showing how ultra-high resolution video can be efficiently distributed to interactive end users.

Chapter 8 "Interactive Rendering" starts with a list of challenges for end user devices resulting from increased interaction with the content supported by the format-agnostic media production and delivery concept. Gesture-based interaction is one of the recent trends in interactive access to media, and this is discussed in detail. A number of technologies already on the market and currently under development are presented. This chapter concludes with user studies of gesture interfaces showing that technology development must coincide with continuous evaluation in order to meet user requirements.

Finally, Chapter 9 "Application Scenarios and Deployment Domains" discusses the format-agnostic concept from an application point of view. Based on the technologies described in the previous chapters, various application scenarios are derived. An analysis is presented of the impact of the format-agnostic concept and related new technologies in the production, network, device and end user domains. Based on this future outlook, this chapter concludes the book.

This book offers a comprehensive overview of current trends, developments and future directions in media production, delivery and rendering. The format-agnostic concept can be considered as a paradigm shift in media production, moving the focus from image to scene

representation and from professionally-produced programmes to interactive live composition driven by the end user. Therefore, this will influence how media is produced, delivered and presented leading to more efficient, economic and user-friendly ways for media to be produced, delivered and consumed. Offering new services, better accessibility to content and putting the user in control are the main aims.

The idea for this book was born in the European FP7 research project FascinatE (Grant agreement no.: FP7 248138, http://www.fascinate-project.eu), which was proposing and investigating the format-agnostic concept for the first time. Beside the editors and the co-authors, which contributed to this book, there are several other colleagues to be mentioned. Without their expertise, their ideas and the fruitful discussion over more than 5 years, this book would not have been possible. Therefore we gratefully thank the following colleagues from several institutions and companies in Europe: R. Schäfer, P. Kauff, Ch. Weissig, A. Finn, N. Atzpadin and W. Waizenegger (Fraunhofer Heinrich Hertz Institute, Berlin Germany); G. Kienast, F. Lee, M. Thaler and W. Weiss (Joanneum Research, Graz, Austria); U. Riemann (Deutsche Thomson OHG, Hannover, Germany); A. Gibb and H. Fraser (BBC R&D, London, United Kingdom); I. Van de Voorde, E. Six, P. Justen, F. Vandeputte, S. Custers and V. Namboodiri (Alcatel-Lucent Bell Labs, Antwerp, Belgium); J.R. Casas, F. Marqués and X. Suau (University Politecnica Catalunya, Barcelona, Spain); O. Juhlin, L. Barkhuus and E. Önnevall (Interactive Institute, Stockholm, Sweden); I. Drumm (University of Salford, Manchester, United Kingdom); and F. Klok, S. Limonard, T. Bachet, A. Veenhuizen and E. Thomas (TNO, Delft, The Netherlands).

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