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High Efficiency Video Coding and Other Emerging Standards

K.R. Rao, J.J. Hwang and D.N. Kim

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High Efficiency Video Coding and Other Emerging Standards provides an overview of high efficiency video coding (HEVC) and all its extensions and profiles. There are nearly 300 projects and problems included, and about 400 references related to HEVC alone. Next generation video coding (NGVC) beyond HEVC is also described. Other video coding standards such as AVS2, DAALA, THOR, VP9 (Google), DIRAC, VC1, and AV1 are addressed, and image coding standards such as JPEG, JPEG-LS, JPEG2000, JPEG XR, JPEG XS, JPEG XT and JPEG-Pleno are also listed.

Understanding of these standards and their implementation is facilitated by overview papers, standards documents, reference software, software manuals, test sequences, source codes, tutorials, keynote speakers, panel discussions, reflector and ftp/web sites – all in the public domain. Access to these categories is also provided.

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Foreword

"HIGH EFFICIENCY VIDEO CODING AND OTHER EMERGING STANDARDS", by K. R. Rao, J. J. Hwang and D. N. Kim. 308 pages. River Publishers, 2017. ISBN 978-87-93609-03-7.

Review by Ashraf A. Kassim, Professor, Department of Electrical and Computer Engineering, National University of Singapore, Singapore.

K. R. Rao, Professor of Electrical Engineering at the University of Texas at Arlington and a well-known leading authority in the field of video coding, has teamed up once more with Dr. *J. J. Hwang* of Kunsan National University (South Korea) and Dr. *D. N. Kim* of Barun Technologies Corporation (South Korea) to come up with this new book which focuses on *high efficiency video coding* (HEVC) also known as H.265. This is very relevant today as the proportion of digital video content in on-line Internet data traffic is expected to increase even further in the coming years as major content providers move rapidly into the realm of 4K video. The ability of HEVC to provide huge gains in compression efficiency is expected to speed up its adoption and help it to overtake H.264/AVC which is the de-facto current standard for most on-line video content.

This book is very timely as it discusses various recent developments in the standards arena for HEVC including range extensions and new profiles as well as a number of recently finalized HEVC codecs. It is well positioned to be a comprehensive and up-to-date resource on HEVC as the authors discuss relevant research and reference a number of resources. This includes standards documents, HEVC range extensions and new profiles (3D, multi view, scalability, screen content coding) open source software, review papers, and keynote speeches, but also provide a long list of *projects* that would help graduate students and others to develop a deeper understanding of the HEVC and emerging image coding standards including JPEG LS, JPEG XR, JPEG-XT and JPEG XS. Also presented in detail is *screen content coding* (SCC) which is an extension of HEVC standard with several new tools, including an intra-picture motion estimation/compensation used in natural

video coding, palette coding, adaptive color transform, and adaptive motion vector resolution. The authors also provide a glimpse of future video coding beyond HEVC/H.265 and discuss MPEG-4 internet video coding, AVS2 and related codecs including DAALA, THOR, AV1, VP10 (Google), VC1, real media HD, and DSC.

Once again the authors have come up with a very useful resource for researchers, developers and graduate students in the video coding field, enabling them to keep abreast of latest developments.

Dr. Ashraf A. Kassim is a Professor with the Electrical and Computer Engineering Department of the National University of Singapore. His research interests include video/image processing and compression, computer vision and machine learning.

Preface

Originally this book was planned to be the revised/updated version of our book

"K. R. Rao, D. N. Kim and J. J. Hwang, "Video coding standards: AVS China, H.264/MPEG-4 Part 10, HEVC, VP6, DIRAC and VC-1", published by Springer in 2014. The present book "High efficiency video coding and other emerging standards", stands by itself and is not a II Edition. Chapter 5 is now completely revised and updated. Chapter 8 focusses on screen content coding – HEVC extension. There is no specific reason why this is called Chapter 8.

The main focus now, however, is on High Efficiency Video Coding (HEVC) which is the latest international video coding standard. A detailed description of the tools and techniques that govern the encoder indirectly and the decoder directly is intentionally avoided as there are already number of books (specially by those specialists who are directly involved in proposing/ contributing/evaluating/finalizing the detailed processes that constitute the standards) in this field, besides the overview papers, standards documents, reference software, software manuals, test sequences, source codes, tutorials, keynote speakers, panel discussions, reflector and ftp/web sites – all in the public domain. Access to these categories is also provided. Since 2014 in the standards arena in HEVC, range extensions and new profiles (3D, multi view, scalability, screen content coding – SCC) have been finalized. Also others such as MPEG-4 Internet Video Coding (ISO/IEC 14496-33) and AVS2 (IEEE 1857-4) have been standardized. Similarly industry also has finalized codecs such as, DAALA, THOR, VP9 (Google), VC1 (SMPTE), real media HD (Real Networks), and DSC (display stream compression) by VESA (Video Electronics Standards Association). AV1 (Alliance for Open Media, AOM) and VP10 (Google) are being finalized. This book provides access to all these developments.

Brief description of future video coding beyond HEVC/H.265 is provided. About 400 references related to HEVC are added along with 300 projects/problems. The later are self-explanatory and govern the spectrum

from a 3-hour graduate credit to research at the masters and doctoral levels. Some require the dedication of groups of researchers with extensive computational (software) and testing facilities. Additional projects/problems based on image coding standards (both developed and some in final stages) such as JPEG LS, JPEG XR, JPEG-XT, JPEG XS (call for proposals for a low-latency lightweight image coding system issued in March 2016 by JPEG) and JPEG-PLENO are added. References, overview papers, panel discussions, tutorials, software, test sequences, conformance bit streams etc. emphasizing these topics are also listed. Brief description related to joint video exploration team (JVET) a.k.a. next generation video coding (NGVC), established by both MPEG and VCEG is targeted for a potential new standard by 2020. Also VESA issued a "call for technology" with the objective to standardize a significantly more complex codec called ADSC (advanced DSC) that is visually lossless at a bit rate lower than DSC. AVS workgroup of China is on a fast forward track in adding SCC capability to AVS2. All these developments can immensely help the researchers, academia and graduate students and provide food for thought to delve deeply into the fascinating world of multimedia compression.

The reader is now well aware that this book is mainly at the research/reference level rather than as a textbook. It challenges the academic/research/industrial community regarding not only the present state-of-the-art but also, more specifically, the future trends and projections. Hence it is an invaluable resource to this community.

Acknowledgements

This book is the result of long-term association of the three authors, K. R. Rao, J. J. Hwang and D. N. Kim. Special thanks go to their respective families for their support, perseverance and understanding. Both Dr. Hwang and Dr. Kim were visiting professors in the multimedia processing lab (MPL) at the University of Texas at Arlington (UTA) whose significant and sustained contributions made this book possible. The first author likes to acknowledge the support provided in various forms by Dr. Peter Crouch, Dean COE, Dr. Jean-Pierre Bardet, Former Dean, College of Engineering (COE), Dr. J. W. Bredow, Chair, Department of Electrical Engineering, and colleagues all in UTA. Dr. G. J Sullivan, Microsoft, Dr. Nam Ling, University of Santa Clara, Dr. Ankur Saxena and Dr. Zhan Ma (both from Samsung Research Labs), Dr. Wen Gao, Peking University, Dr. M. Budagavi, Samsung Research America (SRA), Dr. M. T. Sun, University of Washington, Dr. H. Lakshman Fr. D. Grois of Fraunhofer HHI, Dr. T. Borer, BBC, Dr. Deshpande, Sharp Labs, Dr. Bankoski and Dr. D. Mukherjee (both from Google) Dr. Y. Reznik, Brightcove, Dr. H. Kalva, Florida Atlantic University, Dr. E. Izquierdo, Queen Mary University of London, Dr. E. Magli, Dept. of Electronics and T1elecommunications, Politecnico di Torino, Italy, Dr. W.-K. Cham, Chinese University of Hong Kong, Hong Kong and P. Topiwala, FastVDO for providing various resources in this regard. Constructive review by Dr. Ashraf Kassim, National University of Singapore, is highly valuable. Shiba Kuanar, Harsha Nagathihalli Jagadish and Swaroop Krishna Rao at UTA contributed countless hours in tying up all loose ends (references/copy right releases, proof reading and million other details). The graduate students and alumnae in multimedia processing lab (MPL) at UTA in various ways have made constructive comments.

List of Abbreviations

2D	Two dimension
3D	Three dimension
AAC	Advanced Audio Coding
ACM MoVid	Association for Computer Machinery Mobile Video
ACQP	Adaptive Chroma Quantization Parameter
ACT	Adaptive Color Transform
ADSC	Advanced DSC
AI	All Intra
AHG	Ad Hoc Groups
AIF	Adaptive Interpolation Filter
ALF	Adaptive Loop Filter
AMVP	Advanced Motion Vector Prediction
AOM	Alliance for Open Media
APIF	Adaptive Pre-Interpolation Filter
APSIPA	Asia Pacific Signal and Information Processing Association
AR	Augmented Reality
ARM	Advanced RISC Machines
ASIC	Application-Specific Integrated Circuit
ASIP	Application Specific Instruction Set Processor
ASO	Arbitrary Slice Order
ATR	Average Time Reduction
ATSC	Advanced Television Systems Committee
AVC	Advanced Video Coding—the official MPEG name is ISO/IECIEC 14496-10–MPEG-4 Part 10, and ITU-T name is ITU-T H.264
AVS	Audio Video Standard
AU	Access Unit
BBC	British Broadcasting Corporation
BD	Bjontegaard Distortion
BH	Beyond HEVC
BL	Base Layer
BLA	Broken Link Access
BMSB	Broadband Multimedia Systems and Broadcasting
bpp	Bits per pixel
BRISQUE	Blind/reference-less image spatial quality evaluator

BS	Boundary Strength
BSTM	Butterfly Style Transform Matrices
BTC	Block Truncation Coding
BV	Block vector
BVP	Block vector prediction
CABAC	Context Adaptive Binary Arithmetic Coding
CAVLC	Context-adaptive variable-length coding
CBF	Coded block flag
CCP	Cross Component prediction
CE	Consumer Electronics, Core Experiment
CfE	Call for Evidence
CfP	Call for Proposal
CI	Confidence Interval
CIC	Compound Image Compression
CIF	Common Intermediate Format
COFDM	Co-orthogonal Frequency Division Multiplexing
CPU	Central Processing Unit
CRA	Clean Random Access
CRI	Color Remapping Information
CSVT	Circuits and Systems for Video Technology
CTC	Common Test Conditions
CU	Coding Unit
CUDA	Compute Unified Device Architecture
CWSSIM	Complex-Wavelet Structural Similarity Index
DASH	Dynamic Adaptive Streaming over HTTP
DATE	Design, automation and test in Europe
DCC	Data Compression Conference
DCT	Discrete Cosine Transform
DCTIF	Discrete Cosine Transform Interpolation Filters
DDCT	Directional Discrete Cosine Transform
DF	Deblocking Filter
DIP	Digital Image Processing
DiOR	Digital Operating Room
DIQA	Document Image Quality Assessment
DMB	Digital Multimedia Broadcasting
DMVD	Decoder side Motion Vector Derivation
DMOS	Difference Mean Opinion Score
DPCM	Differential Pulse Code Modulation
DR	DIRAC (BBC)
DSC	Display Stream Compression
DSCQS	Double Stimulus Continuous Quality Scale

DSIS	Double Stimulus Impairment Scale
DSP	Digital Signal Processing
DST	Discrete Sine Transform
DTM	Directional Template Matching
DTT	Discrete Tchebichef Transform
DTV	Digital Television
DVB-H	Digital Video Broadcasting - Handheld
EBU	European Broadcasting Union
EC	Error Concealment
EE	Electrical Engineering
EGK	Exp. Golomb Kth order
EI	Electronic Imaging
EL	Enhancement Layer
EPFL	Ecole Polytechnique Fédérale de Lausanne
ETRI	Electronics and Telecommunications Research Institute
EURASIP	European Association for Signal Processing
FCC	False Contour Candidate
FDAM	Final Draft Amendment
FDIS	Final Draft International Standard
FF	File Format
FIR	Finite Impulse Response
FMO	Flexible Macroblock Ordering
FPGA	Field Programmable Gate Array
fps	Frames per second
FSIM	Feature Similarity
GPU	Graphics Processing Unit
HD	High Definition
HDR	High Dynamic Range
HDTV	High Definition Television
HE-AAC	High Efficiency Advanced Audio Coder
HEIF	High Efficiency Image File Format
HEVC	High efficiency video coding—the official MPEG name is ISO/IEC 23008-2 MPEG-H Part 2 and ITU-T name is ITU-T H.265
HEVStream	High Efficiency Video Stream
HHI	Heinrich Hertz Institute
HLS	High Level Syntax
HM	HEVC Test Model
HOR	Horizontal
HP	High Profile
HTTP	Hyper Text Transfer Protocol
IASTED	International Association of Science and Technology for Development

IBC	Intra Block Copy
ICASSP	International Conference on Acoustics, Speech, and Signal Processing
ICCE	International Conference on Consumer Electronics
ICIEA	IEEE Conference on Industrial Electronics and Applications
ICIP	International Conference on Image Processing
ICME	International Conference on Multimedia and Expo
ICPC	International Conference on Pervasive Computing
ICPR	International Conference on Pattern Recognition
ICT	Integer Cosine Transform
IDR	Intra Decoding Refresh
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
ILR	Inter Layer Interference
INTDCT	Integer Discrete Cosine Transform
intra HE	Intra High Efficiency
IPTV	Internet Protocol Television
IQA	Image Quality Assessment
IS & T	Information Systems and Technology
ISCAS	International Symposium on Circuits and Systems
ISCCSP	International Symposium on Communications, Control and Signal Processing
ISDB-T	Integrated Services Digital Broadcasting - Terrestrial
ISO	International Organization for Standardization
ISOBMFF	ISO Based Media File Format
ITS	International Telecommunication Symposium
ITU-T	Telecommunication Standardization Sector of the International Telecommunication Union
IVC	Internet Video Coding
ITM	Internet Video Coding Test Model
IVMSP	Image, Video, and Multidimensional Signal Processing
J2K	JPEG 2000
JCI	JND-based compressed image
JCTVC	Joint Collaborative Team on Video Coding
JEM	Joint Exploration Test Model
JETCAS	Journal on Emerging and Selected Topics in Circuits and Systems
JLS	JPEG-LS
JM	Joint Model
JMKTA	JM Key Technology Areas
JND	Just Noticeable Distortion
JPEG	Joint Photographic Experts Group
JPEG-XR	JPEG extended range