Complexity-Aware High Efficiency Video Coding

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Springer

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ISBN 978-3-319-25776-1 ISBN 978-3-319-25778-5 (eBook)
DOI 10.1007/978-3-319-25778-5

Library of Congress Control Number: 2015954576

Springer Cham Heidelberg New York Dordrecht London

Printed on acid-free paper

Springer International Publishing AG Switzerland is part of Springer Science+Business Media (www.springer.com)

Preface

In the last decades, the rapid advances of semiconductor technologies fostered a large development in the field of multimedia systems, mainly due to the continuous increase of computational resources and the availability of reliable communication infrastructures. Several video compression standards have been developed in this period, aiming at reducing transmission bit rates without decreasing the video quality. The High-Efficiency Video Coding (HEVC) standard, recently launched by the Joint Collaborative Team on Video Coding (JCT-VC), is the state of the art in video compression and is expected to gradually substitute its predecessor, the H.264/AVC standard. HEVC provides improved compression ratios in comparison to previous standards, but such gains are associated with large increases in the encoding computational complexity and consequently longer processing times, which may compromise the encoder operation in portable devices and in real-time systems, especially for high-resolution videos. This book addresses the subject of computational complexity of HEVC encoders with contributions extending from the analysis of HEVC compression efficiency and computational complexity to the reduction and scaling of its encoding complexity. Besides the introductory chapters, which present an overview of the HEVC standard and the state-of-the-art works on the field, this book also introduces four main contributions from the authors, which target on analysing and solving complexity-related issues in HEVC encoders. The first contribution is an investigation and detailed analysis of the HEVC encoding tools which allowed identifying the most computationally demanding operations of the encoding process. The second contribution of this book comprises a set of five new algorithms for reducing and dynamically scaling the encoding complexity of HEVC encoders. All of them take advantage from the flexibility of the frame partitioning structures allowed by the standard, namely, the coding units and the prediction units, which were identified as responsible for a large share of the encoding computational complexity. The best complexity scaling algorithm presented in this book allows downscaling the encoding complexity to 50 % of its original value with negligible loss of compression efficiency and down to 20 % with medium to small loss. The third book contribution consists of a set of early termination methods based on data mining techniques, which are able to reduce the computational

complexity required to find the best frame partitioning structures, namely, the coding trees, the prediction units and the residual quadtrees, in up to 65 % with very small compression efficiency loss. Finally, the fourth contribution of this book is an encoding time control system that employs the three previous contributions to adjust the encoding time whenever necessary and maintain it under a specified target. The system uses predefined encoding configurations created by combining the early termination schemes and by changing the parameterisation of the most computationally demanding tools of HEVC. Overall, the methods proposed in this book are especially useful in power-constrained portable multimedia devices to reduce energy consumption and to extend the battery life. Besides, they can also be applied to portable and non-portable multimedia devices operating in real time with limited computational resources.

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Contents

Abbreviations

AI	All intra
ALF	Adaptive loop filter
AMP	Asymmetric motion partition
ARFF	Attribute-relation file format
AVC	Advanced video coding
BD	Bjøntegaard delta
BD-rate	Bjøntegaard delta bit rate
BD-PSNR	Bjøntegaard delta PSNR
CABAC	Context-adaptive binary arithmetic coding
CB	Coding block
CBF	Coded block flag
CCUPU	Constrained coding units and prediction units
CIF	Common intermediate format
CTB	Coding tree block
CTC	Common test conditions
CTDE	Coding tree depth estimation
CTU	Coding tree unit
CU	Coding unit
DBF	Deblocking filter
DCT	Discrete cosine transform
DMV	Differential motion vector
DPB	Decoded picture buffer
DST	Discrete sine transform
EPZS	Enhanced predictive zonal search
Fc	Constrained frame
FDCR	Fixed depth complexity reduction
FME	Fast motion estimation
fps	Frames per second
FRME	Fractional motion estimation
FS	Full search
Fu	Unconstrained frame

GBFOS	Generalised Breiman, Friedman, Olshen and Stone Algorithm
GOP	Group of pictures
GPB	Generalised P and B picture
HD	High definition
HE	High efficiency
HETR	High-efficiency encoding time reduction
HEVC	High-efficiency video coding
HM	HEVC model
HP	High profile
I/O	Input/output
IBD	Internal bit depth
IBDD	Internal bit depth decrease
IBDI	Internal bit depth increase
IDR	Instantaneous decoding refresh
IGAE	Information gain attribute evaluation
IEC	International electrotechnical commission
IME	Integer motion estimation
IP	Intra-prediction
IQ	Inverse quantisation
ISO	International organisation for standardisation
IT	Inverse transform
JCT-VC	Joint collaborative team on video coding
KDD	Knowledge discovery from data
KLD	Kullback-Leibler divergence
LC	Low complexity
LCB	Largest coding block
LCTC	Low-complexity encoding time control
LD	Low delay
LDP	Low delay P
LM	Linear mode
MB	Macroblock
MC	Motion compensation
MCTDL	Motion-compensated tree depth limitation
MD	Mode decision
ME	Motion estimation
MPEG	Moving Picture Experts Group
MPM	Most probable modes
MSE	Mean-squared error
MSM	Merge/SKIP mode
MTDM	Maximum tree depth map
MV	Motion vector
MVP	Motion vector prediction
NSQT	Non-square transforms
PB	Prediction block
PRD	Power-rate-distortion

PRDO	Power-rate-distortion optimisation
PSNR	Peak signal-to-noise ratio
PU	Prediction unit
Q	Quantisation
QP	Quantisation parameter
QZB	Quasi-zero-blocks
RA	Random access
RAP	Random access point
R-D	Rate-distortion
R-D-C	Rate-distortion-complexity
RDCO	Rate-distortion-complexity optimisation
RDO	Rate-distortion optimisation
RDOQ	Rate-distortion optimised quantisation
RGB	Red, green and blue
RMD	Rough mode decision
RQT	Residual quadtree
SA	Search area
SAD	Sum of absolute differences
SAO	Sample adaptive offset
SATD	Sum of absolute transformed differences
SCB	Smallest coding block
SMP	Symmetric motion partition
SSE	Sum of squared error
SUMHexS	Simple unsymmetrical-cross multi-hexagon-grid search
T	Transform
TB	Transform block
TSS	Three-step search
TU	Transform unit
TZS	Test zone search
UMHexS	Unsymmetrical-cross multi-hexagon-grid search
VCEG	Video coding experts group
VDCR	Variable depth complexity reduction
VGA	Video graphics array
YCbCr	Luminance, blue chrominance and red chrominance
Y-PSNR	Luminance PSNR

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