Special issue on architectures and algorithms of high-efficiency video coding (HEVC) standard for real-time video applications

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An essential task in relation to multimedia research and development is the availability of a sufficiently large dataset. Many researchers tend to put (or re-direct) efforts into the creation of such corpus individually to carry out research on large-scale datasets. A promising trend of a united web-scale and distributed multimedia coding and data management is thus needed, which would benefit the entire multimedia research community. Much of the development of video communication and processing has been directed toward very high-quality and large-scale media services through high-efficiency video coding (HEVC).

Recently, HEVC has been developed as a new video coding standard, mainly focusing on the coding of ultrahigh definition (UHD) videos, noting that high-resolution and high-quality videos are getting increasingly utilized. HEVC is a draft video compression standard, a successor to H.264/MPEG-4 AVC. Market and user demands for advanced video services with high-quality standards are steadily increasing. UHD has a resolution of 4–8 K (such as 3840×2160 and 7680×4320), while HD has a resolution of 1920×1080 . The data rate for UHD is up to 4–16 times more than for HD video. This order of increasing data rate generates additional burden for all types of networks and services. HEVC is meant to meet the new demand in UHD TV which has large resolution, high frame rates and limited bandwidth.

This Special Issue (SI) of the Springer Journal of Real Time Image Processing (JRTIP) entitled “Architectures and Algorithms of High Efficiency Video Coding (HEVC) Standard for Real-Time Video Applications” highlights the latest research results on various signal processing algorithms, architectures and technologies for real-time approaches in ultrahigh definition (UHD) video and streaming services. This SI addresses both theoretical and practical problems along the real-time theme of JRTIP. It includes fast schemes and hardware implementations, as well as software/hardware co-design based on the HEVC standard technology.

The call for papers resulted in 33 submissions. For each submission, at least two reviewers examined its quality, together with the guest editors and editors-in-chief. Finally, 27 papers were selected for this special issue. The selected papers outlined below can be divided broadly into the following themes. The first theme involves fast-mode decisions and motion estimation algorithms to support real-time HEVC encoding systems. Eight papers fall into this theme. The second theme involves fast algorithms for VLSI, GPU and multi-core hardware-based real-time HEVC encoding, and another eight papers fall into this theme. The third theme has 11 papers and consists of real-time video networking and streaming techniques based on the HEVC standard. A summary of the papers is outlined below:

In the paper entitled “Square-Type-First Inter Coding Unit (CU) Tree Search Algorithm for Acceleration of HEVC Encoder” by Ahn and Sim, a fast method is presented based on the rate-distortion (RD) costs of the current CU only for square-type prediction units (PUs) in the top-down search of the depth-first-search (DFS). When the CU partition with the square-type PU is better than its sub-level CU partitions in terms of the RD cost in the bottom-up search of the DFS, the square type of current CU partition,

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along with its coding mode, is selected as the best partition. Otherwise, non-square-type PUs for the current CU level is evaluated.

The paper entitled “Fast Motion Estimation using Priority-based Inter Prediction Mode Decision Method in High Efficiency Video Coding” by Alex Lee et al. presents a priority-based interprediction mode decision method to reduce the complexity of motion estimation (ME) caused by interprediction. Priorities of all interprediction modes are computed and it is decided whether ME is performed or not.

In the paper entitled “Fast Intra Prediction Algorithm Based on Texture Analysis for 3D-HEVC Encoders,” by Thaísa Leal da Silva et al., a novel complexity reduction algorithm is developed to optimize the 3D-HEVC intra-mode decision targeting real-time video processing for consumer devices with limited computational power, such as 3D camcorders and smartphones equipped with multiple cameras and depth acquisition capabilities.

The paper entitled “Fast Encoding Algorithm for High Efficiency Video Coding (HEVC) System Based on Spatio-temporal Correlation” by J. Lee et al. presents a method for CU splitting based on rate-distortion cost of CU about the parent and current levels to terminate the CU decision early. In terms of PU, a fast PU decision is developed based on spatio-temporal and depth correlation at the PU level.

Mohammadreza Ramezanpour and Farzad Zargari suggest a solution for fast I-frame coding in HEVC standard by using homogeneity of coding units (CUs) in the paper entitled “Fast HEVC I-frame Coding based on Strength of Dominant Direction of CUs.” The proposed solution consists of two stages. In the first stage, they evaluate CU homogeneity by computing a parameter named dominant direction strength and predict CU size by its means. In the second stage, 11 modes out of 35 are selected as the specified CU size based on the dominant direction of the CU.

In the paper entitled “Entropy Difference-Based Early Skip Detection Technique for High Efficiency Video Coding” by Kalyan Goswami et al., an early skip detection technique is proposed for supporting real-time HEVC encoder. Their method is based on identifying the motionless and homogeneous regions in a video sequence. Moreover, a novel entropy difference-based calculation is proposed to predict the skip coding blocks more accurately in a natural video sequence.

The paper entitled “An Early Split and Skip Algorithm for Fast Intra CU Selection in HEVC” by Abdulkерim Oztekin and Ergun Ergelebi presents an early CU determination algorithm for fast encoder realization in order to reduce the encoding time which is the most important part of the standard demanding development. This method focuses on intra-CU selection in an efficient manner.

In the last paper of the first theme entitled “Parallelized Deblocking Filtering of HEVC Decoders based on

Complexity Estimation” by Hyunho Jo et al., a parallelization method is presented for a deblocking filter in a high-efficiency video coding (HEVC) decoder based on a complexity estimation. They estimate the computational complexity by utilizing the coding unit (CU) segment information and the on/off flag of the deblocking filter in advance. Then, the workload is distributed equally across all the threads.

In the first paper of the second theme entitled “Low Power HEVC Software Decoder for Mobile Devices” by Erwan Raffin et al., strategies for the power optimization of a real-time software HEVC decoder on the neon architecture is presented. These strategies include the exploitation of data and task-level parallelism, as well as the use of a new frequency control system to optimize the dynamic voltage and frequency scaling (DVFS) processor, based on an estimation of the decoding complexity. Extensive power measurement results are shown based on a multi-core ARM big.LITTLE processor, together with comparison to the state of the art.

The paper entitled “Low Complexity Heterogeneous Architecture for H.264/HEVC Video Transcoding” by Antonio Jesús Díaz Honrubia et al. presents a hybrid transcoding algorithm which makes use of soft computing techniques as well as parallel processing. A Naïve-Bayes (NB) probabilistic classifier is used that is determined by a supervised data mining process and a heterogeneous platform composed of a multi-core central processing unit (CPU) plus a graphics processing unit (GPU).

In the paper entitled “A Multiplierless Pruned DCT-like Transformation for Image and Video Compression that Requires 10 Additions Only” by Vítor Coutinho et al., an efficient transformation with a multiplierless pruned approximate eight-point discrete cosine transform (DCT) requiring only ten additions is proposed. With the proposed method, competitive performance with the state-of-the-art methods is reported.

Nasser Alqudami and Shin-Dug Kim suggest an efficient parallel implementation of the forward DCT and quantization algorithms for JPEG image compression using Open Computing Language (OpenCL) in the paper entitled “OpenCL-Based Optimization Methods for Utilizing Forward DCT and Quantization of Image Compression on a Heterogeneous Platform”. This OpenCL-based parallel implementation utilizes a multi-core CPU and a GPGPU to perform DCT and quantization computations.

The paper entitled “Fast motion estimation for HEVC on graphics processing unit (GPU)” by Dongkyu Lee et al. presents two new methods in ME: decision of a representative search center position (RSCP) and warp-based concurrent parallel reduction (WCPR). An RSCP employs motion vectors of a co-located coding tree unit (CTU) in a previously encoded frame to solve a dependency problem in parallel computation with a negligible coding loss.

In the paper entitled “Algorithm and Architecture Design of the Motion Estimation for the H.265/HEVC 4K UHD Encoder” by Grzegorz Pastuszek and Maciej Trochimiuk, an algorithm and its architecture are developed for the high-throughput motion estimation of the H.265/HEVC encoder. Synthesis results show that the design can operate at 200 and 400 MHz when implemented on FPGA Arria II and Taiwan Semiconductor Manufacturing Company (TSMC) 90 nm, respectively.

In the paper entitled “GPU-Assisted HEVC Intra Decoder,” Diego Felix de Souza et al. present a graphics processing units (GPUs)-based approach to accelerate the intra-decoding procedure in HEVC, encompassing the most demanding modules of the decoder (i.e., de-quantization, inverse transform, intra-prediction, de-blocking filter and sample adaptive offset).

In the last paper of the second theme entitled “Fast Algorithms and VLSI Architecture Design for HEVC Intra Mode Decision” by Xiaofeng Huang et al., several fast algorithms are proposed to remove the data dependency and to reduce the computational complexity, which include source signal-based rough mode decision (RMD), coarse to fine rough mode search, prediction mode interlaced (PMI), rate-distortion optimization (RDO) mode decision, parallelized context adaption and chroma-free coding unit (CU)/prediction unit (PU) decision. Then, the parallelized VLSI architecture with CU reordering and Chroma re-scheduling is proposed to improve the throughput.

The first paper in the third theme entitled “An Energy-Efficient Video Transport Protocol for Personal Cloud-Based Computing” by J. Baek and C. Kim describes a new reliable transport protocol to support video synchronization for the personal cloud video systems. To cope with battery limitation of many mobile devices in personal cloud system, the proposed protocol is designed to provide energy-efficient video communications.

In the paper entitled “Design a New Visual Cryptography for Human-Verifiable Authentication in Distributed Video Databases,” Ching-Nung Yang et al. deal with new participant-specific visual cryptographic scheme (PSVCS) to extend the authentication scenario from a single-client authentication in VCS-based authentication schemes to a group of clients with specific threshold property.

In the paper entitled “Stochastic Stable Buffer Control for Quality-Adaptive HEVC Video Transmission in Enterprise WLAN Architectures”, J. Kim and E. Ryu propose a new quality-aware video transmission method for company-wide enterprise WLAN architectures by combining video transmission technologies with a distributed stochastic buffering model (DSBM) that jointly controls power consumption and queue stabilization.

In the next paper, George Kokkonis et al. present the challenges and the synchronization techniques for

comparative tests between H.264 and HEVC standards in the paper entitled “Efficient Algorithm for Transferring a Real-Time HEVC Stream with Haptic Data Through the Internet”. They define the equations for the transfer delay of all the interprediction configurations of the HEVC. In this situation, measurements for the network conditions of the Internet are defined and carried out.

In the paper entitled “Encryption Algorithm for Efficient Transmission of HEVC Media,” Vasileios Memos and K. E. Psannis demonstrate a new encryption and transmission algorithm for efficient HEVC delivery. This algorithm is based on known algorithms proposed for previous compression standards, which are adapted properly so as to be applicable to the new standard.

In the paper entitled “Advanced Multimedia Service Provisioning based on efficient interoperability of adaptive streaming protocol and High Efficient Video Coding” by Jordi Mongay Batalla, a synergy framework between High Efficiency Video Coding (HEVC) and Dynamic Adaptive Streaming over HTTP (DASH) is presented to increase the compression capabilities of the encoder and opens new parallel encoding points for accelerating the video content coding and formatting processes. The synergy takes advantage of inter-motion prediction in HEVC for delimiting the segments of DASH protocol, which increases the motion compensation in each segment.

C. K. Kim et al. propose an efficient delay-constrained Automatic Repeat reQuest (ARQ) scheme, which is applicable to MPEG Media Transport (MMT) packet-based real-time video streaming service over IP networks based on the measured round-trip time (RTT), in the paper entitled “An Efficient Delay-constrained ARQ Scheme for MMT Packet Based Real-time Video Streaming over IP Networks.” In this ARQ scheme, the receiver buffer fullness at the time of packet loss detection is used to compute the arrival deadline, which is the maximum allowed time for completing the requesting and retransmitting of the lost MMT packet.

In the paper entitled “A DASH Based HEVC Multi-View Video Streaming System” by Tianyu Su et al., an HEVC Multi-View system using Dynamic Adaptive Streaming over HTTP (DASH) is proposed to overcome some challenges. For example, cameras are placed in pre-determined positions to capture the video from various views. Delivering such views with high quality over the Internet is a challenging prospect, as multi-view video (MVV) traffic is several times larger than traditional video since it consists of multiple video sequences, each captured from a different angle. Another problem is that end users’ devices have different capabilities in terms of computing power, display, and access link capacity, requiring MVV to be adapted to each user’s context. The proposed method uses an adaptive mechanism to adjust the video bitrate to

the variations of bandwidth in best effort networks. To do that, a novel scalable mechanism is proposed for the multi-view video and depth (MVD) content for 3D video in terms of the number of transmitted views.

In the paper entitled “A Client-driven Media Synchronization Mechanism for real-time transport protocol (RTP) Packet-based Video Streaming” by T. J. Jung and K. D. Seo, a precise client-driven media synchronization mechanism for an RTP packet-based multimedia streaming service is described. In this method, the server does not need to send any real-time transport control protocol (RTCP) sender report (SR) packets for synchronization. Instead, the client device derives the precise normal play time (NPT) for each video and audio stream from the received RTP packets containing an RTP timestamp.

An overview over the new characteristics which are likely to be used in HEVC in wireless environments is provided by K. E. Psannis, in the paper entitled “HEVC in Wireless Environments.” In addition, several research challenges are discussed. For example, the packet loss pattern may be different as encoding configurations such as Low-Delay and Random-Access. Through experimental

results, it is demonstrated that for low-delay wireless video communications, the HEVC codec is more effective compared to the previous H.264 codec.

In the last paper entitled “Design and Implementation of a Teleconferencing System Using Improved HEVC Coding” by Shaima Safaaldin and Ergun Erçelebi, a reliable teleconference system that utilizes an improved high-efficiency video codec (HEVC) H.265 technology with congestion control is proposed. The improvement based on CU size decision and entropy coding is obtained and speeded up the system performance by 57.8 %, which provides an adequate approach to enhance the real-time teleconferencing system with multiple access links for streaming audio, video, text, and control packets.

The guest editors would like to thank the authors, reviewers, the editorial staff at Springer and the editors-in-chief for supporting this special issue for its success. We hope that this special issue will have a broad impact on the image and video processing-based video coding expert groups, especially of benefit to those research communities involved in the HEVC standard technology.