Kvazaar: HEVC/H.265 4K30p Intra Encoder

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***Abstract*—This paper demonstrates the usage of Kvazaar open-source HEVC intra encoder in 4K real-time video encoding. In this setup, a raw 4K video is shot by an action camera, captured by an HDMI capture card, encoded in real-time by Kvazaar ultrafast preset on a 22-core Intel Xeon processor, sent to a laptop, and decoded by OpenHEVC decoder for playback. The encoding process is visualized on the fly by Kvazaar run-time visualizer.**

Keywords-High Efficiency Video Coding (HEVC); real-time video coding; 4K ultra HD resolution; Kvazaar HEVC encoder

I. INTRODUCTION

Live Internet video is estimated to grow 15-fold in five years, accounting for 13% of all Internet video traffic by 2021 [1]. This growth inevitably sparks a need for efficient real-time video compression with high quality. The latest international video coding standard, *High Efficiency Video Coding* (*HEVC*/*H.265*) [2], [3], is developed to address these needs.

This demonstrator paper focuses on the *all-intra* (*AI*) coding configuration [4] of HEVC Main Profile. HEVC AI coding is reported to attain 23 % better coding efficiency over that of the preceding mainstream standard AVC/H.264 [5] for the same objective visual quality but at a cost of over threefold increase in encoding complexity [6]. Therefore, implementing a real-time HEVC intra encoder with a reasonable coding efficiency requires efficient encoder optimizations and powerful computing platforms. Typically, real-time HEVC encoding speed for 4K video is attained through several software encoder instances [7] or through hardware acceleration [8]-[10]. However, the presented demonstrator shows that 4K30p HEVC encoding speed is also attainable with a single optimized software encoder on a high-end multicore processor. Contrary to the proprietary reference implementations, the proposed software approach is completely open-source.

Currently, there exist three noteworthy open-source HEVC encoders: *HEVC reference encoder* (*HM*) [11], x265 [12], and our Kvazaar [13]. HM supports all HEVC coding tools and it achieves high coding efficiency but its speed is far from real-time. x265 is probably the most well-known practical open-source HEVC encoder at the moment. However, our previous measurements with offline test video sequences have shown that Kvazaar is the fastest practical open-source HEVC intra encoder [14]. Therefore, our live demonstrator is built on Kvazaar.

II. KVAZAAR REAL-TIME SETUP

Kvazaar intra encoder supports HEVC Main profile for 8-bit 4:2:0 video with ten presets, out of which the ultrafast preset is used in this work. The ultrafast preset seeks the highest coding speed by disabling or limiting configurable encoder features at a cost of some loss in coding efficiency. Furthermore, the complexity of Kvazaar has been tackled by using multithreading and *single instruction multiple data* (*SIMD*) optimizations [14].

The characteristics of Kvazaar ultrafast preset are tabulated in Table I. Kvazaar uses a logarithmic search for 16×16 and 8×8 prediction units to choose the best intra mode out of the DC, planar, and 33 angular modes. For 32×32 or 64×64 prediction units, Kvazaar performs a quick search where the mode selected for the top-left quadrant of the unit is applied to the whole unit if it indicates better coding efficiency.

The choice of intra mode is based on the *sum of absolute transformed differences* (*SATD*) whereas the decision of coding unit sizes is based on the *sum of squared differences* (*SSD*) and the CABAC coding cost of the coefficients. Integer DCT is used as a transform. Out of the two in-loop filters, SAO is disabled and only deblocking is enabled. Sign bit hiding, *rate-distortion optimized quantization* (*RDOQ*), and transform skip are all disabled. Parallel encoding is implemented with *wavefront parallel processing* (*WPP*) and picture-level parallel processing. In this experiment, we set the quantization parameter to 37.

III. KVAZAAR 4K30P INTRA CODING DEMONSTRATOR

Fig. 1 depicts the individual components of the demonstrator. An Epiphan AV.io HDMI capture card is used to capture raw 4K RGB video (3840×2160) at 30 frames per second from a Sony FDR X1000V 4K action camera. The RGB video is converted by FFmpeg to YUV 4:2:0 format. Kvazaar encodes the YUV video in real-time on a 22-core Intel Xeon E5-2699 v4 processor whose features are listed in Table II. The encoded HEVC bit stream is encapsulated by another FFmpeg instance to MPEG-2 TS format and sent to two laptops over two Ethernet cables. According to our measurements, the average bit rate is 21 Mb/s.

On the first laptop, the TS stream is decoded in real-time by OpenHEVC decoder. The media player used for playback is MPC-HC. The second laptop also decodes the stream but then re-encodes it, using Kvazaar visualizer to visualize the encoding process. Compared with the real-time encoding, the visualization is shown at a greatly reduced speed, i.e., only a part of the frames are visualized.

The visualizer lets us select visualization elements of particular interest. Illustrated components are 1) block partitioning; 2) intra prediction; and 3) block reconstruction.

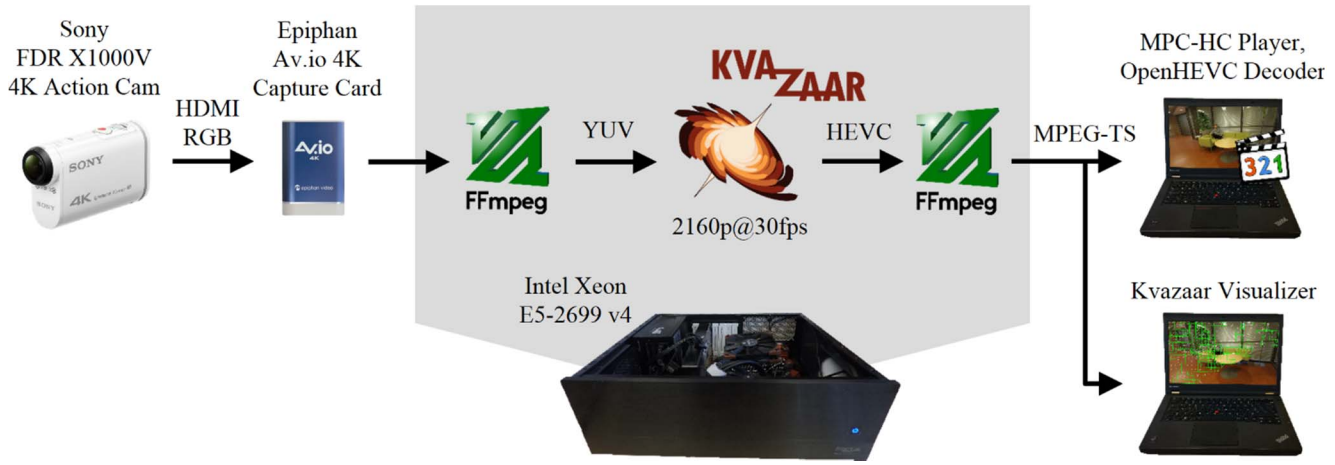

Figure 1. Demonstration setup for Kvazaar live HEVC 4K30p intra coding with visualization.

TABLE I. KVAZAAR SETTINGS FOR REAL-TIME INTRA CODING

Feature	Kvazaar parametrization
Coding unit sizes	8×8, 16×16, 32×32, 64×64
Prediction unit sizes	8×8, 16×16, 32×32, 64×64
Transform unit sizes	8×8, 16×16, 32×32
Intra prediction modes	35 (DC, planar, 33 angular)
Mode decision metric	SATD, SSD, CABAC
Transform	Integer DCT
SAO	Disabled
Deblocking filter	Enabled
Sign bit hiding	Disabled
RDOQ	Disabled
Transform skip	Disabled
Parallelization	WPP, Picture-level
Quantization parameter	37

The block reconstruction is used as the background layer whereas the other layers can be toggled on and off. WPP and picture-level parallel processing are visualized by marking the block borders with distinct colors to make identification of the individual pictures easier. In our previous work [15], this tool was introduced with offline test videos but here it is validated with live video.

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TABLE II. FEATURES OF THE MULTICORE PROCESSOR

Processor	Intel Xeon E5-2699 v4 (22 × 2.20 GHz)
Memory	64 GB
L1 cache	22 × 32 KB (instruction) + 22 × 32 KB (data)
L2 cache	22 × 256 KB
L3 cache	55 MB
Compiler	MS Visual Studio 14.0.25431.01 Update 3
Operating system	64-bit MS Windows 10

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