HEVC Software Media Player for Ultra-High-Quality Video: 8K and Beyond

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ABSTRACT

A software media player for ultra-high-quality video including 8K and 16K video is presented. It is based on a high-performance CPU-based HEVC decoder, and a high-quality GPU-based video rendering engine. Experimental results show that is possible to play up to 16Kp60 video using a single workstation PC system.

1 INTRODUCTION

A new generation of media applications is emerging that requires an unprecedented level of quality, creating, as a result, a stronger sensation of reality, and offering a much more immersive experience. Applications in this domain include Super-Hi-Vision 8K TV, next generation Virtual Reality with high-resolution Head Mounted Displays, and Large Screen Display systems with very-high resolutions including 8K and 16K [1].

These next generation media formats require very high resolution (8K and 16K), high frame rates (120 and 240 frames/s), and high-quality image formats including High Dynamic Range (HDR) and Wide Color Gamut (WCG); features that, in turn, requires high bit-depth video (10- and 12-bit) [2]. As a consequence, uncompressed video results in huge data rates, as shown in Table 1.

Advanced video codecs are required to handle this super high-resolution video. The High Efficiency Video Coding standard (HEVC), with its Range Extensions (RExt) addressed towards professional media, offers the required compression efficiency [3,4]. The main requirements of a HEVC implementation for highly immersive media are: i) to provide high compression and very high-quality, and, ii) at the same time, provide the performance required for real-time playback.

In this paper we describe a software media player with the capacity to decode and render very high-quality video including 8Kp120 and 16Kp60 video in real-time. The media player consists of a high-performance CPU-based HEVC decoder, and high-quality GPU-based video rendering engine, integrated into a complete media playback solution.

2 SYSTEM DESIGN AND EXPERIMENT

A software media player based on the HEVC video codec has been developed and optimized. The main components of the media player are the HEVC decoder and the Video Rendering Engine:

- **HEVC decoder**: we have developed an ultra-optimized HEVC decoder implementation. The decoder is able to process high-quality 16K video in real-time using a CPU-only software solution. The HEVC decoder software has been extensively optimized for modern CPUs in order to achieve very high performance.
- **Video Rendering Engine**: we have developed a rendering engine optimized for high resolution video playback. It has been implemented using the DirectX-12 graphics API for Microsoft Windows systems. The video rendering engine sends the decoded data from the decoder's output to the GPU, convert the decoder video format into a pixel render format, and handles the display of pixel data to the screen.

The main optimizations applied to the decoder and video renderer are:

2.1 Advanced Multithreading

Advanced multithreading has been implemented for maximum performance and scalability of HEVC decoding on multicore architectures with tens of processor cores. Optimizations include special support for multi-socket systems with NUMA memory architectures.

2.2 Advanced SIMD Library

An advanced library of SIMD optimized modules has been implemented for the SSE4, AVX2, and AVX-512 instruction sets, and for all main components of the HEVC decoder, including: inverse transform, intra prediction, motion compensation, deblocking filter, and sample adaptive offset filter.

2.3 Bit-Packed Pixel Formats

Conventionally pixels or video samples are stored in computer memory in multiple of 8-bits (byte). For the new media applications that require more than 8-bits per sample, the 10- and 12-bit samples are normally stored in 16-bits (2 bytes) of space.

Compared to 8-bit, in practice 10- and 12-bit doubles the required memory size and, more importantly, memory and PCIe bandwidth. To alleviate this, we introduced bit aligned formats where instead of storing the 10- or 12-bit samples in 2 bytes, the samples are stored directly after one another.

These formats can save potentially 37.5% and 25% on required bandwidth and memory for 10- and 12-bit respectively. Table 1 shows the bitrate of bit-packing formats compared to byte packing formats for different 8K and 16K video formats

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Table 1. Data rates for uncompressed 8K and 16K video

Resolution WxH frame rate	7680x 4320 60 Hz	7680x 4320 60Hz	7680x 4320 120 Hz	15360x 8640 60 Hz
Chroma format and bit depth	4:2:0 10-bit	4:4:4 12-bit	4:2:2 10-bit	4:2:0 10-bit
Bitrate byte packed [Gbit/s]	47.78	95.55	127.40	191.1
Bitrate bit packed [Gbit/s]	29.86	71.66	79.63	119.4

2.4 Texture Compression Formats

In some applications the gains provided by bit-packing are not enough to deliver the required performance.

For example, video playback with 16K resolution at 60 fps with a 4:2:0 10-bit format requires a bandwidth of 191.1 Gbit/s or 23.9 GB/s for planar format, and 119.4 Gbit/s or 14.9 GB/s MB/s for the bit-packed format. These data rates are, however, higher than the practical maximum data rate of the PCIe bus (which is 12 MB/s).

An extra reduction of memory bandwidth can be obtained by using lightweight compression methods such as texture compression. GPUs have native support for a range of compressed pixel formats. The most suitable we found for video use cases is the BC4 format [8].

3 RESULTS

After applying all the above-mentioned optimizations, it has been possible to playback very high-quality video including: 8Kp120 and 16Kp60 using a software solution based on commodity PC hardware.

Figures 1 and 2 present the performance impact of the bit-packing and BC4 compression formats respectively. For the experiments we used a platform with an Intel Core i9-7960x (16-core) processor, 4x 8GB 3200Mhz memory, and AMD Radeon WX 7100 GPU. The platform is based on Windows 10 OS, and we have used Spin Digital SDK v2.0

An 8K HEVC test sequence has been used with a bit rate of 1Mb/frame (this translates to 60Mbps at 60Hz, and 120Mbps at 120Hz).

The resulting performance for a complete media player for three different 8K video formats is presented in Figure 3 and compared to existing solutions. For this experiment we used a platform with an Intel Core i9-7960x (16-core) processor, 4x 8GB 3200Mhz memory, and a Nvidia Geforce GTX 1060 GPU. The software platform consists of Windows 10 OS and Spin Digital Media Player v1.4-dev.

4 DISCUSSION

The described HEVC media player is the first application able to decode, render, and playback ultra-high-quality video in 8K and 16K resolution using a software solution. Two main use cases and contributions are: i) playback of 8K video using compact desktop systems, and ii) playback of 16K video using workstation systems.

4.1 Compact 8Kp60 and 8Kp120 playback

The proposed solution is able to playback 8K video at 60 fps and 120 fps using a very compact solution based on a multicore desktop CPU and a mid-range GPU.

This is the first system that can perform 8K playback using desktop CPUs (as opposed to server and high-end workstation CPUs).

4.2 High-end 16Kp60 playback

The proposed solution is able to playback 16K video at 60 fps (4:2:0, 10-bit, 400 Mbps) using a workstation system based on dual-socket high performance CPUs and a high-end multi-GPU configuration.

4.3 High bit-depth and High bit-rates

In addition to high resolution and frame rate the proposed player also supports high bit-depth (up to 12-bit) required for HDR and WCG.

The proposed media player is based on a very flexible software solution. It supports multiple video formats including 4:2:0, 4:2:2, 4:4:4, and RGB. The performance scales very well with the number of CPU cores, allowing the playback of very high bitrate and therefore high quality 8K and 16K video.

4.4 Advances Beyond the State-of-the-Art

Compared to state-of-the-art solutions based on hardware GPU video decoders, the presented player achieves higher performance (both in terms of frames per second, and bitrate) and supports more formats as shown in Figure 3.

Compared to other works presented in the literature the proposed HEVC media player not only obtains higher performance HEVC decoding [6,7], but also includes an advanced video rendering engine, which together create a complete media playback solution for ultra-high-quality video.

5 CONCLUSIONS

An optimized software video player has been developed and evaluated. It consists of a HEVC decoder that runs on the CPU and a video render engine that runs on the GPU. By performing extensive optimizations, including, among others, compact pixel formats and lightweight pixel compression it has been possible to provide the performance required for 8K and 16K high quality video playback using standard computing systems.

6 ACKNOWLEDGEMENTS

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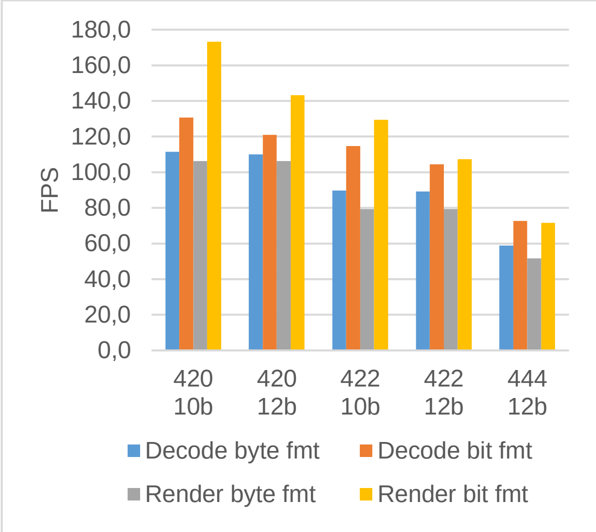

Fig. 1 Performance of compact pixel formats
Performance in frames per second [fps] of byte-aligned formats (unpacked) compared to the new bit packing formats for HEVC decoding (decode byte/bit fmt) and video rendering (Render byte/bit fmt), for different chroma formats and bitdepths

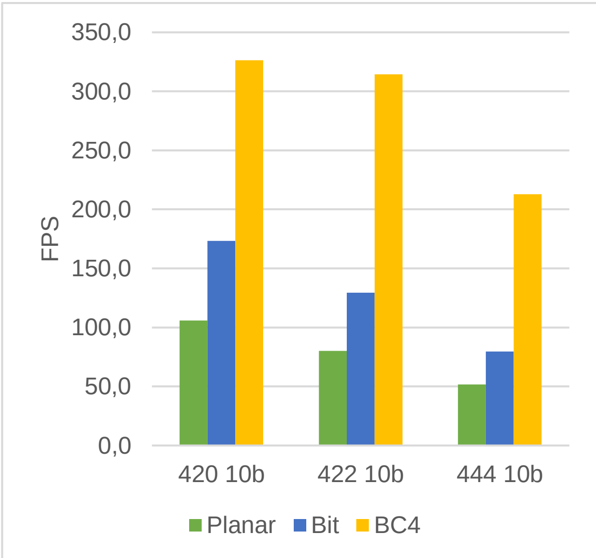

Fig. 2 Performance of compressed format
Performance in frames per second [FPS] for texture compressed formats (BC4) for video rendering compared to unpacked format (Planar) and bit packed format (Bit), for different chroma formats and bitdepths

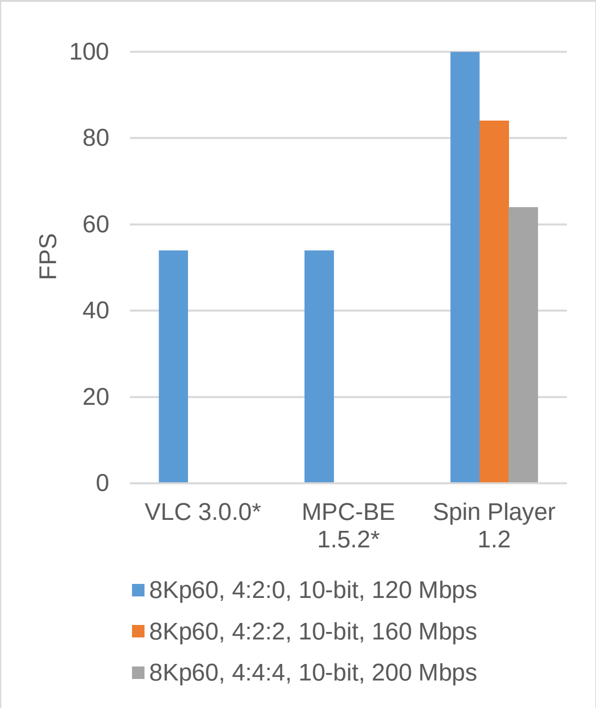

Fig. 3 Spin Digital Media Player Performance for 8K Video

Performance in frames per second [FPS] of Spin Digital Player (Spin Player) compared to two open source media players: VLC and MPC-BE which use HEVC hardware decoders based on GPU.