Digital Video Concepts, Methods, and Metrics

Quality, Compression, Performance, and Power Trade-off Analysis

Shahriar Akramullah

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About the Author

Shahriar Akramullah is an expert in the field of video technology. He has worked in the video software industry for over 15 years, including about four years at Apple and six years at various Silicon Valley startups. He received his PhD degree in Electrical Engineering from Hong Kong University of Science and Technology in 1999, where he was also a postdoctoral fellow until 2000. A Commonwealth scholar, Dr. Akramullah has received many awards, including the best paper award in the IEEE (HK section) PG student paper contest in 1995.

Since the days of his graduate studies, he has been performing research and analysis on video compression, quality, and video coding performance on various computing platforms. Recently, he has done a comprehensive tradeoff analysis of visual quality and other factors using GPU-accelerated video coding capabilities of Intel processor graphics drivers. Before enabling new encoding features, his experiments and tradeoff evaluations led to a variety of optimizations in multiple Intel products. On this subject, the author has published several technical papers for various Intel conferences, such as DTTC, SWPC, VPG Tech Summit, and so on. He received a number of Intel awards, including the Intel Software Quality Award in 2013.

Shahriar holds several U.S. patents, and has written many research papers for international journals and conferences. His professional experience spans areas in video compression, communications, storage, editing, and signal processing applications. His general interests include video and image signal processing, parallel and distributed processing, video codec and video delivery algorithms, software and firmware implementation, tradeoff analysis and performance optimization of video codecs on various platforms ranging from Intel supercomputer Paragon to TI DSPs; Sun workstations to Intel servers; IBM PowerPC-based Macbooks to Intel x86-based personal computers; and Equator BSP-15 VLIW processors to Telairity's multicore vector processors. He is currently an architect for Intel's processor graphics software.

In his spare time, Shahriar loves to read religious texts and references, and spend time with his family.

About the Technical Reviewer

Scott Janus is a Principal Engineer at Intel Corporation, where he designs media, display, and security technologies for future computing platforms. He holds several patents. Additionally, he has authored multiple informative and entertaining books in both the technical and fiction domains.

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Preface

End-users of video applications are seeking and receiving increasingly more control over their operations. Uploading video to the Internet is only the beginning of a trend in which a consumer controls video quality by balancing various other factors. Emerging applications will give further control to the end-user, such as for video analysis and classification; open-source applications for private party content generation, editing, and archiving; and applications for cloud asset management. Thus, it is important to understand the concepts and methods for evaluating the various video measures.

Owing to characteristics of the human visual system (HVS), some loss in visual quality is perceptible, but much is not. Taking advantage of this fact, we know that digital video data can be compressed. In fact, in most digital video applications the video data is frequently compressed and coded for easier capture, storage, transmission, and display. Typical compression techniques result in some visual quality loss and require the use of powerful computing systems. The more the compression, the worse is the decline in quality. Therefore, a sweet spot needs to be found in balancing compression with perceptible visual quality, with the simultaneous goal of achieving a high coding speed. Likewise, optimization of power consumption is essential for getting the job done on inexpensive consumer platforms. Here, the goal is to keep the total system cost down while delivering a good user experience.

While tradeoffs can be made now, there needs to be a comprehensive set of engineering principles, strategies, methodologies, and metrics to enable greater understanding of such tradeoffs. This book addresses this shortfall with an explanatory approach, exposing readers to methods of evaluating various coding solutions in terms of their potential gains and losses. Further, it enables the reader to differentiate between two video coding solutions, and thereby better shape a perception of tradeoff potentials. For example, an informed video codec user may consider the requirements of a particular video use and opt to select the opportunities offered by the Intel (R) Quick Sync (TM) Video and its GPU-acceleration capabilities rather than choosing a competing solution.

One approach for such an evaluation of coding solutions, or a comparative study of multiple coding solutions, is to consider ways the video can reach the end-user; doing so, though, means comprehending the requirements of various video applications that dictate visual quality levels. To achieve acceptable visual quality, then, the minimum system capacity must be determined, which impacts performance and power requirements. On available platforms with GPU-acceleration capabilities, optimizations can be done to meet those requirements, which usually require tradeoffs among video measures, obtained by tuning the system and encoding the parameters. This book discusses various video measures and the tradeoff opportunities they offer, providing a solid background for evaluating various coding solutions.

Practical video applications include interactive digital video storage—for example, in Blu-ray discs; local and remote video playback on computer or television screens; video capture and recording; video broadcast over terrestrial, satellite, cable and telecommunication channels; video screencast over wireline or wireless channels to an appropriate display unit; video streaming over a network; cloud-based on-demand video services; video transcoding from one format or resolution to other formats and resolutions for burning to disc or for uploading to the Internet; video conferencing, video e-mail and other visual communication; video editing or video post-production and processing; digital cinema, home television theater, and remote video surveillance; telemedicine; electronic news gathering; and so on. Additionally, many more video applications are emerging, including virtual reality and synthetic video, video composition and analysis, and video classification and retrieval. Users of these existing and new video applications can take advantage of the information in this book to tune the various parameters to suit their needs.

Benefits to the Readers

The topics covered in this book are valuable for a wide range of engineers, codec architects, application developers, system validators, technical marketers, technical reviewers, and end-users. They are important in multiple industries and for platforms ranging from low-power mobile phones to high-end servers as long as they use video coding solutions, be they on the desktop, on cloud-based platforms, or through Internet streaming.

This book, therefore, is for anyone who wants to master the video coding concepts without sustaining the rigors of the underlying mathematics and signal processing; or who wants to tune a video coding solution for a particular video usage while making optimal use of available computing platforms and resources. Additionally, anyone who wants to assess a newly available video solution or compare and rank different solutions will find the material contained herein to be worthy.

As noted above, no standards exist for tradeoff analysis of methodologies or metrics for video codec evaluation. Existing benchmarks primarily deal with either visual quality or system performance. Rarely do they consider the power consumption of CPU-intensive applications. There are no comprehensive multimedia-centric calibration and benchmarking tools for considering visual quality, encoding speed, and power consumption simultaneously, particularly on GPU-accelerated platforms. However, this book attempts to fill that gap. It will guide all interested parties in avoiding erroneous comparisons and in understanding the true strengths and limitations of various coding solutions.

Furthermore, performance, power, and quality of video are important subjects both in the industry and in academia. To our knowledge, this is the first book to deal with tradeoff measures of video coding.

Owing to space limits, the book covers only the concepts, principles, methods, and metrics of video compression, quality, performance, and power use. If you need clarification of some information, find any errors, or have questions or comments, feel free to contact me at: shahriar.m.akramullah@intel.com.

Organization of the Book

The book comprises nine chapters and an appendix. Chapter 1 introduces some key concepts and various considerations for video encoding. It also presents the reasons for tradeoff analysis and the challenges and opportunities in doing such an analysis. Chapter 2 presents the HVS characteristics and how various digital video compression techniques can exploit the HVS to achieve compression. It also notes the factors influencing and characterizing the compression algorithms. Chapter 3 provides an overview of the most popular international video coding standards. Chapter 4 discusses visual quality issues and factors affecting the human observer's perceptual quality of video. Chapter 5 covers video coding speed and performance, as well as factors influencing performance, and it identifies the coding parameters to be tuned in any attempt to trade performance for visual quality. Chapters 6 and 7 present the power consumption aspects of video applications, mentioning the challenges especially encountered on low-power platforms with limited resources. Chapter 8 discusses the considerations for tradeoff analysis, focusing on three major areas of optimization—namely, performance, power, and visual quality. Specific examples of tradeoffs employing these measures are provided. Chapter 9 summarizes the key points of this book, and proposes some considerations for future work. In the appendix, well-known industry benchmarks and interesting references are listed, and their limitations are indicated.