Ittiam

Challenges in DVD Video Systems

Practical Solutions for Recording and Playback

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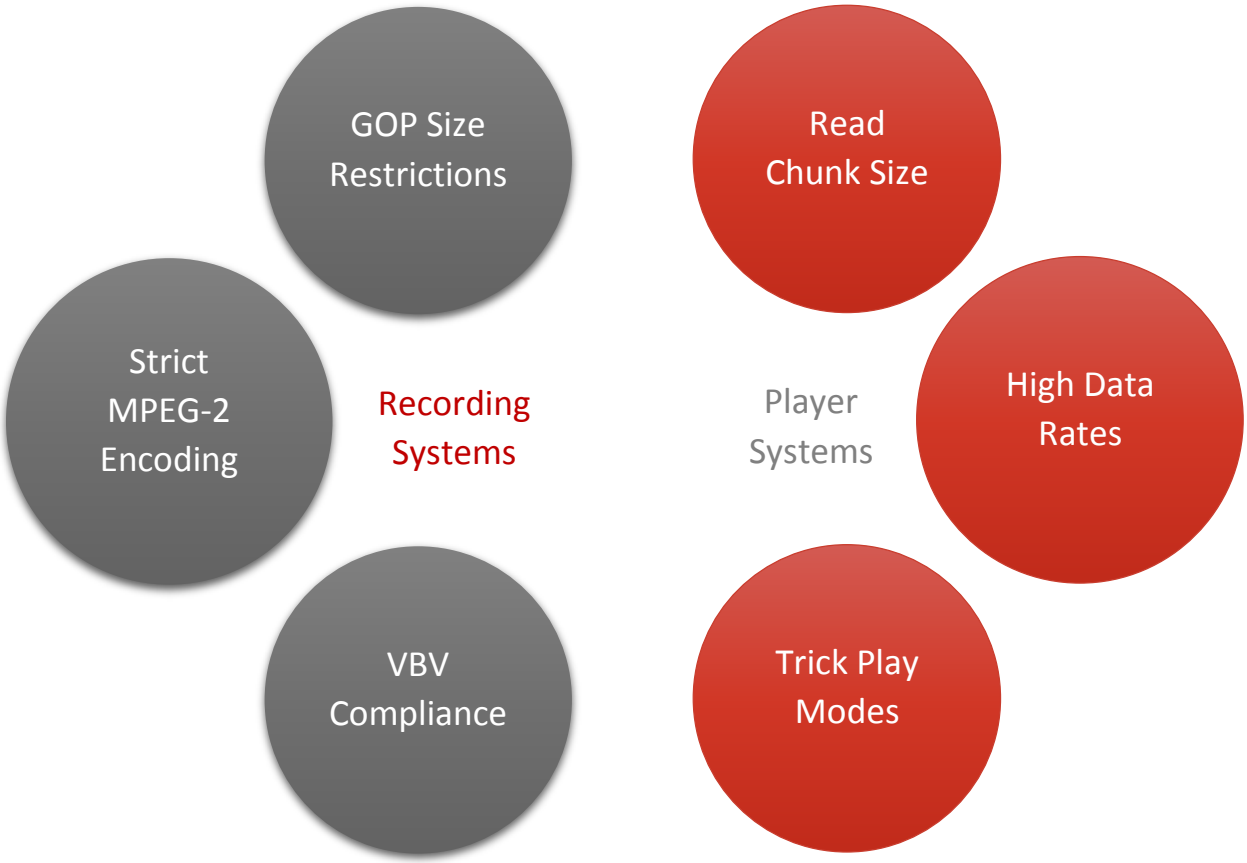
Abstract

Though quite ubiquitous, designing real-time Video DVD recorders and players involves addressing several key challenges. The accepted video compression standard for DVDs is MPEG-2 though more advanced compression techniques like H.264 are used in high-density disks Blu-ray. Though only a sub-set of the formats and structures defined by MPEG-2 need to be supported, DVDs require a strict implementation of these parts. For instance, a strict compliance to GOP-size and VBV, bitrates up to 9.8 Mbps, support for trick-play modes, etc. This paper looks at these and other video-related challenges in building a DVD recorder and player system. The paper concludes with a look at the DVD Video Recorder and Player systems from Ittiam, and the specific tuning and optimizations employed within them.



Contents

Figures

Tables

Introduction

DVD Video Recording and playback systems throw up several unique challenges that are not seen in conventional file or stream recording and playback. Conventional DVDs use MPEG-2 [1] as the preferred compression format, and operate at a resolution of D1 (720x480 for NTSC, 720x576 for PAL). With higher resolutions for high-definition becoming popular, encoding standards offering better degree of compression, such as H.264, are becoming relevant. This paper discusses several aspects involved in building conventional MPEG-2 based DVD systems. It describes the constraints, challenges involved in DVD Recording and the challenges of playing back DVDs.

Video Recording Challenges

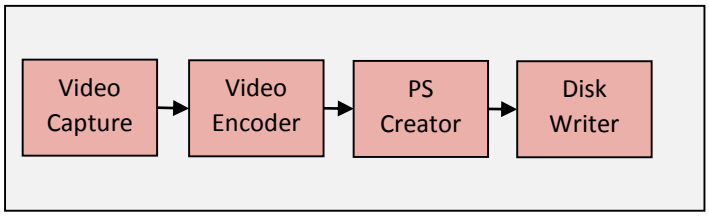


Figure 1: DVD Video Recording

A typical DVD Video Recording system is pictured in **Figure 1**. Video Capture module is responsible for interfacing with the live video source, and acquiring the digital image for further processing. Video Encoder block compresses the raw video as per the compression standard being used, while PS creator encapsulates the data into a Program Stream format. Disk Writer is concerned with the actual transcribing of the encoded data to the optical disk. Disk Writer is the block which interacts with the optical disk, and is concerned with actual disk operations such as movement of the head, reading of bits, etc. The specifics of Disk Writer are beyond the scope of this paper.

The major challenges in the Recording system relate to the Video Encoder. These may be classified as follows:

- Strict MPEG-2 Encoding
- GOP (Group-of-Pictures) size restrictions
- VBV (Video Buffering Verifier) compliance

The following sections look at the above points in greater detail.

Strict MPEG-2 Encoding

DVD-Video, according to the specification created by the DVD Forum, is an application of MPEG-1, MPEG-2 and other formats. The DVD-Video format defines subsets of these standards and formats to be applied in practice to make discs intended for DVD-Video players. Conventional DVDs use a subset of Main profile @ Main level of MPEG-2 standard. For example, only a few resolutions, frame-rates and aspect ratios are allowed. GOP sizes are fixed and strict VBV adherence is required. A table of the prescribed standards is given in Table 1.

Parameter	Restriction
Compression Standard	1. MPEG-1, with restrictions on the resolutions possible. 2. MPEG-2, Main Profile at Main Level.
Frame Rate	1. NTSC : 29.97 fps

	2. PAL : 25 fps
Television system	NTSC (525 lines, 60 Hz), or PAL (625 lines, 50 Hz).
Aspect Ratio	1. 4:3 – All video formats 2. 16:9 – All video formats except those with 352 pixels per line.
Display Mode	1. Pan and Scan 2. Letterbox
User Data	All user data is to be used for closed-captioning
Video Resolutions	1. PAL a) 720 x 576. b) 352 x 576 c) 352 x 288 2. NTSC : a) 720 x 480 b) 352 x 480 c) 352 x 240
GOP size	1. NTSC: 36 fields or 18 frames 2. PAL : 30 fields or 15 frames
Buffer size	1. MPEG-2 : 1.8535008 Mbits 2. MPEG-1: 327689 bits (maximum)
Transmission rate	1. MPEG-2: Variable and Constant bit-rates (VBR and CBR) are allowed. 2. MPEG-1: Only Constant Bit Rate(CBR) is permitted
Maximum bit-rate	9.8 Mbps

Table 1: MPEG-2 Restrictions

GOP-size Restrictions

In MPEG Video, a Group of Pictures (GOP) is a group of successive pictures, usually composed of an I - frame (Intra-coded frame), several P (Predictive coded) frames and possibly B (bi-directionally predictive coded) frames. GOP size refers to the number of frames composing a GOP; this corresponds to the gap between two I frames.

Optimal encoding processes take the liberty of varying the GOP size according to the complexity of the video and the bit-rate available. I-frames, being only spatially encoded, take up higher bandwidth; P- and B-frames, being temporally encoded as well are much smaller in size. Typical encoders during high-complexity sequences, such as scene changes, end up creating a lot of Intra macro-blocks (which are spatially coded and hence consume higher bits) within a P-frame and therefore restructure the GOP to delay the next I-frame.

However, one of the crucial requirements of DVD video is **strict adherence to GOP-size parameter**. DVD video allows a maximum of 18 frames for NTSC and 16 frames for PAL systems, which is quite restrictive considering that MPEG-2, MP@ML has no such restriction. Also, **GOP size once fixed cannot change during the course of encoding**. This requirement is in place to allow for easier random accesses within the disk. From the encoder's perspective, a severely fixed-size GOP is a restriction as I frames cannot be inserted or delayed whenever required. This can lead to problems such as spikes in bit-rate, low-quality pictures etc.

VBV Compliance

VBV, in the context of MPEG-encoded streams, is a buffer model followed by the compression and de-compression engines. The VBV model allows the encoder to predict the buffering being performed at the decoder, and to generate streams to confirm to the buffering available.

A crucial requirement of DVD video is **strict compliance to the VBV model**. This means that the **decoder buffer can neither overflow nor underflow**. One approach taken by non-DVD compliant encoders is usually to either restructure the GOP or skip the picture. The same approach cannot be taken by DVD-compliant encoders due to GOP size constraints. Therefore, strict VBV compliance along with strict adherence to GOP-size parameter creates the major challenge in single pass DVD-video encoding.

Video Playback Challenges

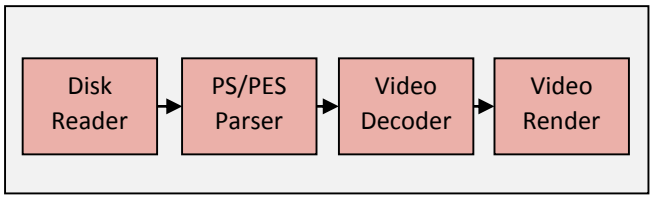


Figure 2: DVD Video Playback

A typical DVD Video playback system is composed of the building blocks depicted in **Figure 2** . Disk Reader is a complex module responsible for managing the actual "read" operation from the optical disk. It includes tracking of the drive heads, chunks, buffering, etc. Parser performs the function of decoding the Program Stream extracting the MPEG-2 Video elementary stream from it. Video Decoder performs the actual decompression of the MPEG-2 video, while Video Render performs the function of interfacing with the monitor and displaying the decoded video.

Some of the major points of interest in designing DVD players are the following:

- High data rates, up to 9.8 Mbps
- Handling 2KB chunk sizes
- Customized processing for Trick Play, etc.

High Data Rates

One of the primary challenges that Playback systems encounter is the high data rate of DVD systems. As mentioned above, the video can be encoded at bit-rates **as high as 9.8 Mbps for an NTSC or PAL video**. This implies that the disk-read process, and all subsequent processes, must be able to operate at 9.8 Mbps.

MPEG-2 video framing (the process of delimiting complete "frames" or "pictures" in the bit-stream) is a highly CPU-intensive process. Framing involves seeking through the bit-stream, byte by byte, to find special "header" patterns that mark the beginning of individual frames. This processing at 9.8 Mbps causes a lot of CPU load to the entire system.

There exist a few ways to optimize the above processing. DVDs often provide a frame **"look-up" index**, which completely eliminates the need for parsing the stream byte-by-byte. Even if required, the

parsing technique can be optimized to perform the same operation without reading every single byte in the stream. In case of multi-core processors, **shifting the parsing function to a secondary processor** can provide significant gains in the CPU on the primary core.

Chunk Size

The other challenge that DVD systems face is that of **handling the 2KB chunk size**. The program stream defines a packet size of 2KB; most disk read or write functions complete 2KB of read or write for every disk access. MPEG-2 video frames are of varying lengths, depending upon the bit-rate, the complexity of the sequence, and a host of other factors, and they rarely are of a multiple of 2KB in size. This often means that there are pockets of junk data occurring whenever a frame ends in the middle of the packet, and the next frame does not start at the next byte (**Figure 3: Arrangement of frames in a GO**). These gaps are especially visible at GOP boundaries

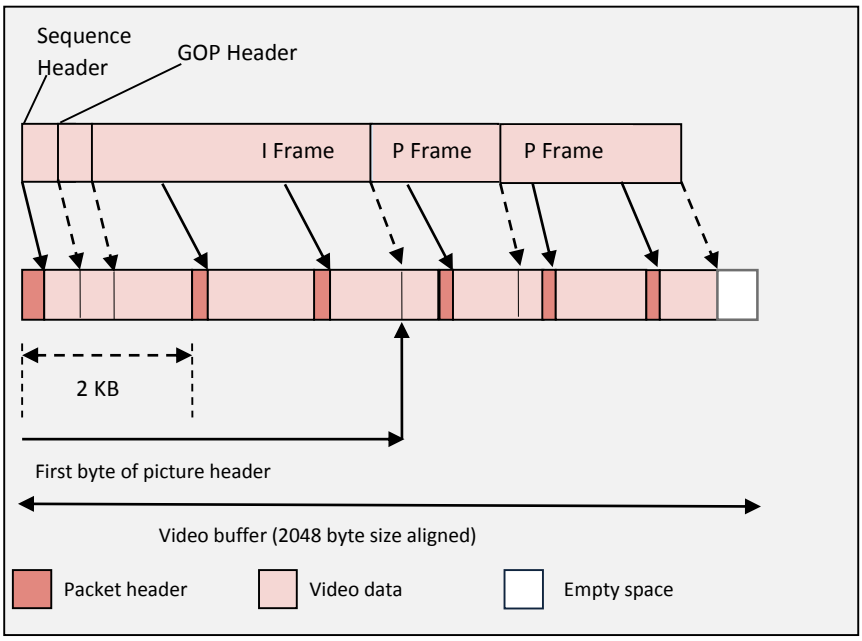


Figure 3: Arrangement of frames in a GOP

In such cases, it is essential that the system does not process the invalid data present in these pockets. Possible solutions for taking care of this are:

- The disk reader takes care to signal the end of valid data to the other components.
- The PS Parser or Video Decoder recognize the end of valid data, and discards the invalid data.

Trick-Play

Playback modes different from the normal, linear playback, such as High-speed playback, Fast-forward, rewind, frame-by-frame step, etc. are termed as “Trick-Play” modes. Trick-play modes are essential features of any DVD playback system.

The 2-KB chunk sizes pose even more of an issue in Trick-Play modes. Fast-forward and rewind functions require the playback of only I-frames, as opposed to continuous playback. As mentioned before, disk readers optimize the reading and writing operations to 2-KB chunks. Given the data arrangement of **Figure 3**, I frames sent to the decoder can also have the beginning of the next P-frame (**Figure 4**).

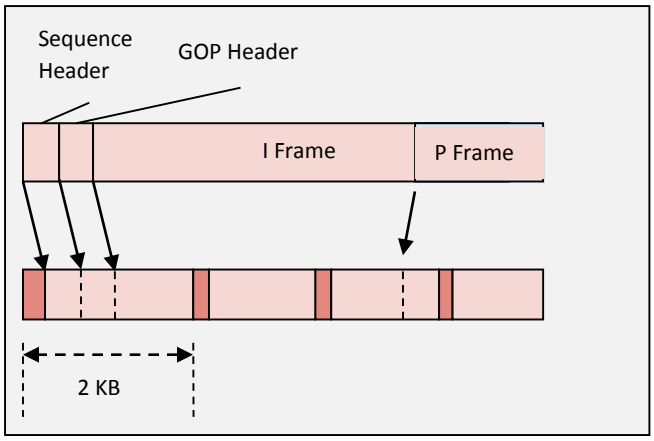


Figure 4: I-Frame position

Ittiam's DVD Solutions

Ittiam's DVD solutions, available on multiple embedded platforms, are tuned to the specific challenges of DVD Recording and Playback.

Ittiam's Recorder performs the functions of capturing video and encoding it using MPEG-2 compression, with full compliance to the various DVD restrictions. Ittiam provides features to either:

- Export the compressed stream directly, for further encapsulation into PS and writing into disk, or
- To encapsulate in PS and export for writing into disk.

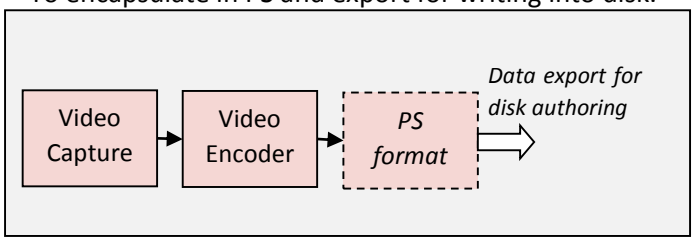


Figure 5: Ittiam DVD Recorder

To meet the specific challenges of DVD systems, the Ittiam's Recorder provides features such as:

- Optimized data export mechanisms to facilitate transfer rates of 9.8 Mbps.
- A highly optimized MPEG-2 encoder, that is further tuned for VBV buffer compliance. Encoder is partitioned into a ***'normal'* mode** and a ***'caution'* mode**. It enters the *caution* mode whenever a possible buffer-underflow condition is encountered. Key encoding decisions are taken when the encoder is in caution mode, to ensure that there is no buffer underflow. Similarly, VBV buffer overflow conditions are prevented using stuffing bits as specified by the MPEG-2 standard.

Ittiam's Player (**Figure 6**) performs the functions of decoding and playing back DVD video. The solution also provides interfaces customized for:

- Accepting PS inputs, and decoding the entire stream, or for
- Accepting PES input, and decoding further.

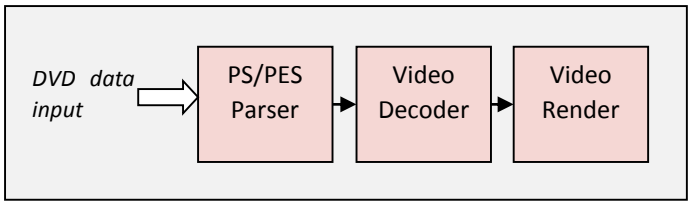


Figure 6: Ittiam DVD Player

Ittiam's Player provides the following features tuned to overcome the playback challenges.

- Optimized data transfer mechanisms, allowing for data transfers of 9.8 Mbps.
- Optimized parsing mechanisms, to efficiently parse MPEG-2 video at 9.8 Mbps bit rate.
- Special operating mode, SCAN, tuned to play back only I-frames. SCAN mode also enables identification and discarding of incomplete P-frames, ensuring that corrupted pictures are not decoded or displayed.
- Special operating mode, STEP, for frame-by-frame trick play.

With optimized data transfer and decoding mechanisms, Ittiam Player operates smoothly within the limits of CPU consumption.

Conclusion

DVD video systems encounter challenges like the demand for extremely strict compression parameters, encoding/decoding at high bit rates and requirements for trick-play which make the realization of media processing pipelines quite demanding. Ittiam Recorder and Player Systems for DVDs are tuned to the specific needs of such systems. Available on multiple embedded platforms, these systems provide high-performance, ready-made solutions for DVD applications.

References

[1] International Standard ISO/IEC 13818-2:2000: *Information technology — Generic coding of moving pictures and associated audio information: Video*

About Ittiam

Ittiam Systems is a global technology company with deep R&D driven solutions for media creation, management and consumption, providing advanced media codecs, software development platforms, systems and workflows for embedded and online applications. Its solutions are at the heart of tens of millions of lifestyle products that drive mobility, content access, networking and sharing. For more information about Ittiam products, please visit www.ittiam.com or contact us at mkt@ittiam.com.

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