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Review on Modern Video Data Compression Techniques

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Abstract: Video compression technique is now mature as is proven by the large number of applications that make use of DWT and DCT technology. Now day's lot of video compression techniques proposed. With efficient compression techniques, a significant reduction in file size can be achieved with little or no adverse effect on the visual quality.This paper gives the idea about for video compression technique but not very much good for the real time video compression techniques either have a demerit of loosely techniques like DCT and DWT but here we are going to present a noble technique in which we will use object position change finding algorithm to get our video process in real time and having lossless decompressions. Compression is done in real time, such a way while maintaining the benefits of keeping all of the information of the source and also the benefits of compression during the production process. "Lossless" means that the output from the decompressor is bitfor-bit identical with the original input to the compressor. The decompressed video stream should be completely identical to original. In addition to providing improved coding efficiency in real time the technique provides the ability to selectively encode, decode, and manipulate individual objects in a video stream. The technique used results in video coding that a high compression ratio can be obtained without any loss in data in real time.

Keyword: Discrete Cosine Transform (DCT), Discrete Wavelet Transform (DWT), MPEG, Video Coding.

1. Introduction:

Over the past decades, video compression technologies have become an integral part of the way we create, communicate and consume visual information. Digital video communication can be found today in many applications such as broadcast services over satellite and terrestrial channels, digital video storage, wires and wireless conversational services and etc.

The data quantity is very large for the digital video and the memory of the storage devices and the bandwidth of the transmission channel are not infinite, so reducing the amount of data needed to reproduce video saves storage space, increases access speed and is the only way to achieve motion video on digital computers.

For instance, we have a 720 x 480 pixels per frame, 30 frames per second, total 90 minutes full color video, then the full data quantity of this video is about 167.96 G bytes. This raw video contains an immense amount of data, and communication and storage capabilities are limited and expensive. Thus, several video compression algorithms had been developed to reduce the data quantity and provide the acceptable quality as possible as they can. This tutorial starts with an explanation of the basic concepts of video compression algorithms and then introduces two international standards, known as MPEG-1 and MPEG-2.

Why can video be compressed? The reason is that video contains much spatial and temporal redundancy. In a single frame, nearby pixels are often correlated with each other. This is called spatial redundancy, or the intraframe correlation. Another one is temporal redundancy, which means adjacent frames are highly correlated, or called the interframe correlation. Therefore, our goal is to efficiently reduce spatial and temporal redundancy to achieve video compression.

2. The Rise of Efficient Compression:

The carousel of progress keeps on turning, and today's compression algorithms are much more effective than older ones. The Cinepak codec that powered early versions of both QuickTime and Windows Media video formats aimed no higher than getting 320x240 video resolution out of a standard CD-ROM drive, which means cramming 2.2Mbps plus audio and overhead into a 1.2Mbps traffic stream. Call it 50 percent compression on a good day.

If you never saw a digital video back in the 1990s, you're not alone. The files were large and the downloads were slow. And while the tiny hard drives of the era would have welcomed some video compression with open arms, the other parts of that equation were simply not there; an Intel 486 or Pentium would grind to a standstill trying to make sense of a simplistic Motion JPEG or MPEG-1 video, even at very low resolutions. But better days were just around the corner.

The popular MPEG-2 standard pretty much destroyed Cinepak, Intel Indeo, and other early codecs in the late 1990s by compressing video streams to as much as 1/30 of the original video size while still maintaining acceptable picture quality. That's hefty enough to let that old 1x CD-ROM handle a full, standard-resolution NTSC signal at about 1Mbps. This is the format used in DVD video, many digital broadcasts, and most online video streams.

MPEG-2 can present a 1080p video in a 2Mbps envelope, but with horrible blocking artifacts from all the compression if you take it that far. These codecs are lossy, which means that

you must always balance image quality against file size. HD video was not exactly what MPEG-2 was made for.
By the standards of modern hardware, like recent models of Texas Instruments' OMAP processors and anything from Intel or AMD, MPEG-2 encoding is a walk in the park. Newer formats, not so much. This is why TiVo box still stores DVR recordings in this age-old format.
A TiVo Series 3 can play H.264 video (more on those later), but does not have the muscle to make its own, so we stuck converting our videos elsewhere and sending them back to the TiVo again if we try on making the most of our hard drive. Since MPEG-2 videos can fill up a DVR in short order, many of us opt to simply hook up an external hard drive to the set-top box instead or roll our own home theater systems. Then come the MPEG-4 Part 2 format, more commonly known under the names of codec implementations like Xvid, DivX, 3ivx, or the QuickTime 6 version. Like MPEG-2 before it, MPEG-4/2 quickly caught on thanks to another step up in compression quality—the same video at comparable levels of picture quality will use about half the bandwidth of MPEG-2 when presented with an MPEG-4 Part 2 codec.
The rise of Xvid, DivX 3.11a, 3ivx, and others came at a time when broadband Internet service was coming into its own in the US, and along with the relentless march of technological advances in fields like hard drive storage and CPU power, digital video took off like a rocket.
File sharing sites like KaZaA, IMesh, and Gnutella made it easy to find and download video files. The small size and high quality of MPEG-4 Part 2 codecs made the format perfect for downloading, and the format quickly became ubiquitous. You could find full movies on file sharing networks before their theatrical premieres, and DVD rips before the discs hit store shelves—all at glorious full NTSC or better display resolutions.
In 2001, our desktop computer could sport gigahertz bragging rights on a Coppermine Pentium III or Palomino Athlon. These chips still needed help from our Radeon or GeForce to handle full-screen DVD playback, but they were powerful enough to pick apart MPEG-2 videos in smaller sizes. These machines were ready and able to fill up their massive 100GB hard drives with videos.
And the MPEG-4 Part 2 gravy train kept on rolling for years. When it comes to video encoders for personal use, it was the king of the hill from the early 2000s, and arguably still is. This is probably what you'd use for a hand-rolled media server today, running Windows Media Center, SageTV, Boxee, or MythTV.
MPEG-4 video is compressed enough to let us store and enjoy media in a plethora of new ways. Filling up a couple hundred gigabytes of hard drive space takes much longer with efficient compression, and a full-length movie often weighs in at less than 1GB. That's a mental barrier for many people, drawing a line in the sand between "huge" and "reasonable" files.
While the Apple iPhone and iPod lines don't support Divx-compatible formats directly, they can decode the equally efficient recent versions of QuickTime media and there are plenty of converters between the formats. Handheld media gadgets based on Windows Media or Android platforms have their ways of handling high-quality video streams too, which makes them useful for playing your own videos or streaming shows across WiFi or 3G connections. Mobile video would simply not be possible or palatable if not for compression techniques of the MPEG-4 magnitude.

3. A Brief History of Video Compression:

3.1 H.264:

Today, even MPEG-4 Part 2 is old hat. The new hotness is the H.264 compression standard, as implemented by the Blu-ray Disc specifications, Apple's iTunes Video Store, and recently, YouTube's high-definition videos. H.264 is also known as MPEG-4 Part 10 or Advanced Video Coding (AVC).
The dramatic improvements in compression and quality, which some tests peg as high as 4 times the objective quality of MPEG-4 Part 2, have ushered in a sea change in what we can do with digital video. It allows for broadcast-quality standard definition video at 1.5Mbps, which translates into something like 12 compressed channels in the bandwidth formerly occupied by one analog broadcast station. We could use H.264 compression to squeeze a high-definition movie onto a regular old DVD, or streaming VHS-quality video across a low-end ADSL connection at 600Kbps.
The codec is part of the ATSC digital broadcast standard, wrapped in an MPEG-2 container, but no cable or satellite company has implemented it yet. Since higher compression means more number crunching, you need an upgraded set-top box to handle this rougher stuff. That's a major expense for someone like Comcast, where 18 million digital cable customers often have more than one set-top box. The bill for replacing all this hardware with the latest and greatest from Cisco or Motorola would run into the billions.
DirecTV and Dish Network are both busy equipping their satellites to handle H.264 streams in preparation for all-HD-all-the-time and another conflagration of new channels in the next few years. At some point, the broadcasters will indeed have to bite the bullet and roll out refreshed set-top boxes everywhere—just don't hold your breath waiting for that day.
All told, H.264 signals another rebirth of digital media, and these are still the very early days of that revolution. We'll see a lot of new gadgets and services take advantage of its power. There will be full-motion video displays in mobile gadgets everywhere, from GPS systems and smartphones to the dashboard in your car. They will all show off beautiful high-resolution pictures without the blocky artifacts you got used to in the MPEG-2 days. Next-generation DVRs should make the leap too, powered by Snapdragons or Cortexes or high-end OMAPs, skipping right over the MPEG-4 Part 2 stage.
The dream of watching anything you like, anywhere you like, anytime at all is drawing ever closer, and that would not be the case if compression standards didn't evolve.

3.2 H.265:

The H.264 standard was rubber-stamped way back in 2003. It took several years for hardware improvements to catch up with the computational heft of the new standard, and the story is repeating itself again.

Right now, a standards committee is busy hammering out the details of the H.265 video standard, which is again supposed to cut bitrates in half when compared to the previous top-of-the-line solution and a similar image quality. But another 50 percent objective improvement is hard to come by after so many generations of amazing mathematical acrobatics. This time, the group will settle for a 20 percent improvement in mathematically objective measurements. The rest of the improvements will be subjective.

H.265 will be lossier than H.264, in other words, but lossy in ways that won't be too obvious to humans and our imperfect image-processing brains. Pause an H.265 video and break out the spyglass, and you'll find many technical imperfections compared to older codecs, but it's all about perceived quality when the moving picture is, well, moving.

Once again, the new standard will require more horses under the hardware hood in exchange for more efficient data storage and streaming display performance.

3.3 TV standards:

The first patent on a compression method for video content was filed in 1929 by Ray Kell. Though not implemented for many years, Kell's work is still in use today. The idea was to describe the difference between one image and the next rather than redrawing the whole screen from scratch, and nearly every important codec works on this principle to this day.

The concept is bad news for video recorders, though. H.264 and other new compression standards will not make your video camera much better, except by proxy. Video editing works much better on data streams that store every frame of the video in full, rather than calculating each frame from the previous one and a few keyframes. Our digital camcorder stores data on mini-DV tapes in a frame-by-frame format that is ready for editing. The DV format is a small step up from the Motion JPEG standard.

HDV video is MPEG-2 compression on a DV tape, available in many camcorders from JVC, Sony, and Canon. The compression does increase the recording capacity of a tape, but at the cost of MPEG artifacts introduced in the original recording as well as in the editing stage. It is possible to get around some of the editing issues by converting it to a lossless, full-frame format before saving it to disk, but then you have also converted the video one more time. Purists may not like the very idea of compressing original video for these reasons.

The analog TV signals we pick up with rabbit ears or analog cable were not compressed, which is why each channel of analog TV broadcast sucked up 6MHz of precious, precious radio spectrum bandwidth. 6MHz corresponds to an uncompressed video bitrate of about 18Mbps. And that's just for anemic standard-resolution NTSC signals, 30 interlaced frames per second of 720x486 visible pixels, FM-quality sound, and some metadata.

It was the miracle of high-quality video compression, the same 6MHz slice of spectrum can also house a full-on 1080p high-definition channel, or up to six compressed lo-fi stations—and they all come with 5.1 digital surround sound.

The ATSC (American Television Systems Committee) digital TV broadcast standard crams either MPEG-2 or high-powered H.264 compressed video and Dolby Digital AC-3 sound into an MPEG-2 media container. A 1080p channel would eat much more bandwidth using older and less efficient compression methods, so compression efficiency was absolutely a catalyst for the digital TV revolution and the explosion of channels that followed.

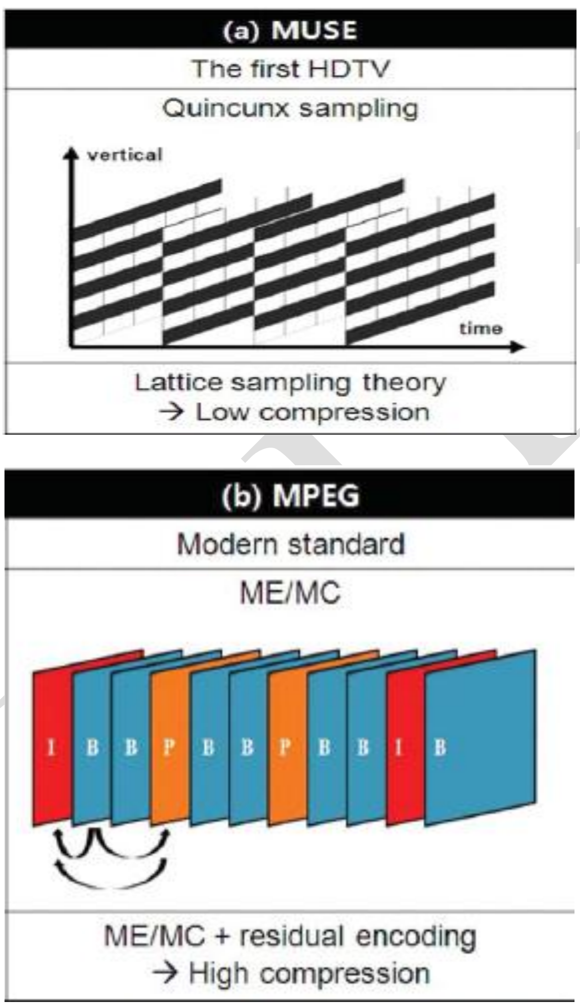
In 1992, Bruce Springsteen sang that there were 57 channels and nothing on TV. Today, we can get over 30 stations on rabbit ears in large markets like New York or Los Angeles. We have 358 channels available on the FiOS box in tiny Tampa, including over 100 high-definition channels and 16,000 on-demand videos. Bruce might be going through a lot of TV sets these days. And it's all because of video compression.

4. Review: Video Compression:

From compressed sensing perspective, sparsifying unknown images is essential to reduce the number of measurements. The exactly same goal has been extensively investigated from totally different context—the video compression. So, we will briefly review the history of video compression, which has been currently used for high definition television (HDTV) and Internet broadcasting. In HDTV, bit rate reduction is very important for a given bandwidth of the channel. As the first HDTV method, [12] proposed the MUSE (multiple sub-Nyquist encoding systems) technique, which uses quincunx sampling patterns in spatio-temporal domain (see Figure 2.2a). The main idea was that the spatio-temporal spectrum supports for video usually have low temporal frequency content due to relatively slow motion changes between frames as shown in Figure 2.3a. Therefore, by designing the spatio-temporal sampling pattern like quincunx sampling, the spectral supports do not overlap; hence, the spatio-temporal filtering can recover the full resolution image (see Fig. 2.3b). This HDTV was successfully launched in Japan during 1998 Nagano winter Olympic Games.

However, such lattice sampling is difficult to capture the local motion because the temporal redundancies are not fully exploited. Because of these inefficiencies, the MUSE was totally replaced by the modern standard, MPEG (Motion Picture Expert Group) [13] which achieves high compression rate using blockbased motion estimation and compensation (ME/MC) and discrete cosine transform (DCT)-based residual encoding. The general coding structure of MPEG is illustrated in Figure 2.2b. Note that there are three types of frames. First, the intra pictures (I) are compressed using DCT by exploiting only the spatial correlation as done in still image compression

[13] Then, P-frame (predicted frame) is compressed using ME/MC with residual encoding. More specifically, block-based motion estimation is performed to find the best match between I-frame and P-frame. When the search area is determined, the motion vectors for each blocks on individual dynamic P frame are calculated by minimizing the mean absolute are used as reference frames for ME and the forward and backward ME are performed. Among the available motion vectors, the vector that produces the least residual signal in the rate-distortion sense is chosen as the optimal vector. The remaining residual signal is then again encoded using DCT coding. If the average of two different blocks provides the smallest residual, two vectors are chosen. The area of video coding has been growing significantly for the late three decades. Currently, more highly efficient video codec such as H.26L [12] is now being investigated under standardization body. The main innovation of H.26L over the MPEG is mostly on the ME/MC. Now, variable block-size ME/MC, multiple motion vectors, fractional pel estimation, and multiple reference frames are routinely used [12].



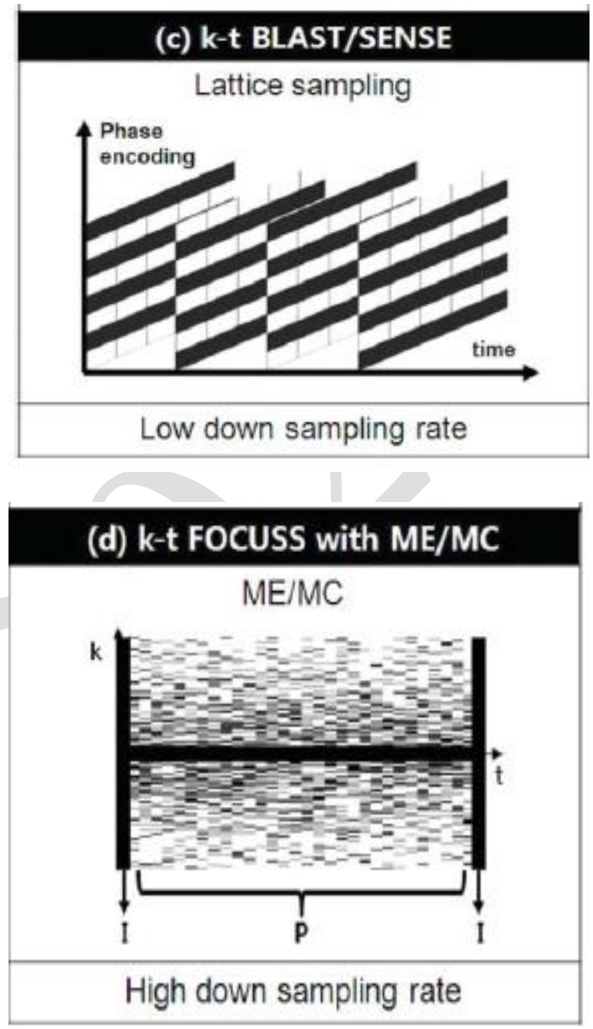


Fig 1. (a) MUSE, the first HDTV technique, has quincunx sampling pattern in spatio- emporal domain to decorrelate the temporal redundancy. (b) The modern standard, MPEG, achieves higher compression ratio using ME/MC technique. (c) k-t BLAST/SENSE and UNFOLD have the same spatio-temporal sampling pattern as in MUSE. (d) The sampling pattern for k-t FOCUSS with ME/MC with two fully sampled reference frames. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

5. Conclusion:

High-quality video compression of the MPEG-4 Part 2 era and later has made digital video a daily part of your entertainment menu, especially if you run your own media server at home, or like to watch video on your phone, media player, or other portable device. MPEG-2 is still clinging to life with stubborn determination, but the reasons for hanging onto that outdated technology will fade away over the next few years. When the last of the cable and satellite companies convert their digital set-top boxes to hardware powerful enough to both encode and decode H.264 video or better, there will be no reason to use MPEG-2 anymore. The future of entertainment is coming fast, and it is highly compressed.

References:

[1] Iain E. G. Richardson, H.264 and MPEG-4 Video Compression, Video Coding for Next-generation Multimedia, the Robert Gordon University, Aberdeen, UK, 2003.
[2] Ze-Nian Li and M. S. Drew, “Fundamentals of Multimedia, ” Prentice Hall, 2004.
[3] Yun Q.Shi and Huifang Sun, “Image and Video Compression for Multimedia Engineering: Fundamentals, Algorithms, and Standards”, CRC press, 2000.
[4] Yao Wand, Jorn Ostermann and Ya-Qin Zhang, “Video Processing and Communications”, Prentice Hall, 2007.
[5] Richardson, Lain E. G., “Video Codec Design: Developing Image and Video Compression Systems”, John Wiley & Sons Inc, 2002.
[6] Barry G, Haskell, Atul Puri and Arun N. Netravali, “Digital Video : An Introduction to MPEG-2”, Boston : Kluwer Academic, 1999.
[7] T. Wiegand, G. J. Sullivan, G. Bjontegaard, and A. Luthra, “Overview of the H.264/AVC video coding standard”, IEEE Trans. on Circuits and systems for video Technology, vol. 13, no. 7, pp. 560-576, July 2003.
[8] G. Sullivan and T. Wiegand, “Video Compression - From Concepts to theH.264/AVC Standard”, Proceedings of the IEEE, Special Issue on Advances in Video Coding and Delivery, December 2004.
[9] T. Sikora, “MPEG-4 video standard verification model,” IEEE Trans. Circuits Syst. Video Technol., vol. 7, no. 1, pp. 19-31, Feb 1997.
[10] R. Koenen, Editor, “Overview of the MPEG-4 Standard,” ISO/IEC JTC/SC29/WG21, MPEG-99-N2925, March 1999, Seoul, South Korea.
[11] T. Sikora, “MPEG-4 very low bit rate video,” IEEE International Symposium on Circuits and Systems, ISCAS ’97, vol. 2, pp. 1440-1443, 1997.
[12] Y. Ninomiya, Y. Ohtsuka, Y. Izumi, S. Gohshi, and Y. Iwadate, An HDTV broadcasting system utilizing a bandwidth compression technique-MUSE, IEEE Trans Broadcasting 33 (1987), 130–160.
[13] D. Le Gall, MPEG: A video compression standard for multimedia applications, Commun ACM 34 (1991), 46–58.
[14] H. Schwarz, and T. Wiegand, The emerging JVT/H. 26L video coding standard, Proc IBC, 2002.
[15] H. Jung, K. Sung, K.S. Nayak, E.Y. Kim, and J.C. Ye, k-t FOCUSS: A general compressed sensing framework for high resolution dynamic MRI, Magn Reson Med 61 (2009), 103–116.
[16] Z. Liang, and P. Lauterbur, An efficient method for dynamic magnetic resonance imaging, IEEE Trans Med Imaging 13 (1994), 677–686.
[17] H. Jung, J. Park, J. Yoo, and J.C. Ye, Radial k-t FOCUSS for high-resolution cardiac cine MRI, Magn Reson Med 63 (2010), 68–78.
[18] K. Ramchandran, A. Ortega, and M. Vetterli, Bit allocation for dependent quantization with applications to multiresolution and MPEG video coders, IEEE Trans Image Process 3 (1994), 533–545.
[19] B. Girod, A. Aaron, S. Rane, and D. Rebollo-Monedero, Distributed video coding, Proc IEEE 93 (2005), 71–83.