A Multi-rate Video Compression Technology for DVR

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Many Digital Video Recorder (DVR) manufacturers claim that their network DVR (IP based) can do video recording and remote surveillance at the same time. While most of the DVRs perform reasonably well on video recording, however, their remote surveillance ability is far from satisfactory.

Most customers require DVR to do high quality video recording and at the same time also want to view the live or playback video through Internet or phone line. This is a dilemma situation for design engineers. Good quality recording requires high data rate which will be too high for efficient transmission and results in poor remote performance. To achieve fast remote transmission, it is necessary to tune the video coder for very high compression rate which inevitably degrade the quality and resolution of the video recording. Furthermore, the unsteady and bursty transmission channel often affects recording performance.

Traditional Video Coders

Most DVR in the market uses standard video compression technologies such as JPEG, JPEG2000, M-JPEG, MPEG-1, MPEG-2 or MPEG-4. All these standard video coders compress the incoming analog video and output a single digital video stream (Fig. 1). The DVR uses this digital video stream for both recording and transmission through the Ethernet port. With a single output video stream, users either choose (a) good video recording at high data rate and poor transmission or (b) good transmission performance at high compression rate and poor recording quality. It is therefore not possible to choose both good recording quality and good transmission at the same time.

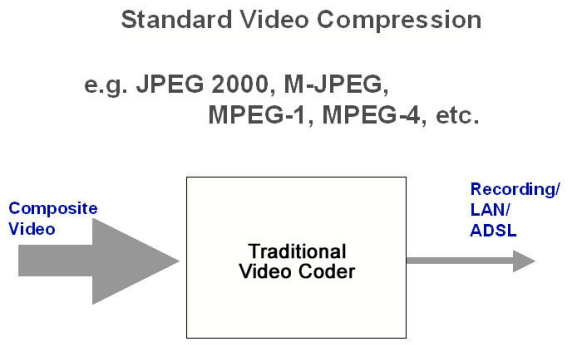

Fig.1 Traditional video coders - the single video stream is used for both recording and remote surveillance.

For DVR using traditional coders with only a single digital video stream, the recording performance is often affected by the unsteady video transmission through Internet which is a bursty channel with frequent traffic congestions. The unsteady recording performance due to the bursty Internet channel cannot be solved by DVR using a single traditional coder. Some manufacturers solve this problem by providing an optional second video coder for independent transmission and recording performance.

Multi-rate Video Coder: SMAC-M

SMAC-M is a coder specially designed for TeleEye RX series Video Recording Transmitters to solve the simultaneous recording and transmission requirements. SMAC-M is a multi-rate video coder that output 5 independent digital video streams at different bit rates (Fig. 2) to cover all commercial communication channels in the market. The independent video streams ensure that the recording performance will not be affected by remote surveillance through bursty channels. The independent streams also allow multiple remote users to obtain reasonable surveillance performance for their

respective channels without affecting each other.

The first video stream of an SMAC-M coder is reserved for real-time video recording. The other four video streams are designed for efficient transmission through LAN, broadband Internet, phone line and mobile channels (Fig. 2).

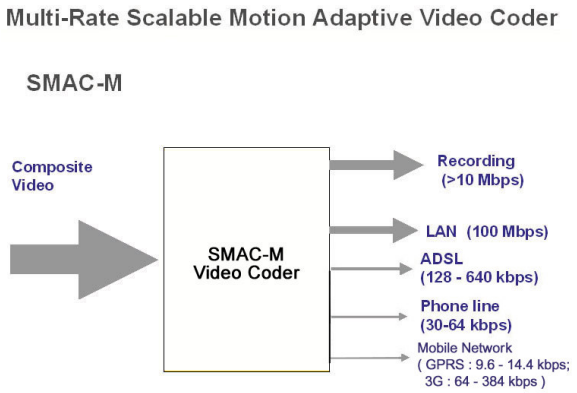

Fig.2 SMAC-M coder generates 5 independent video streams at different bit rates to suit various communication channels

Communication Channels

Local Area Network (LAN) – a properly designed LAN can achieve a data rate of 100 Mbps. One of the video streams of an SMAC-M coder is designed for LAN to allow real time video for multiple workstations. The high compression rate of SMAC-M coder allows the highest number of digital video streams to simultaneously transmitted through the same LAN.

Internet – Users can subscribe to broadband Internet either from telecom or cable TV providers. ADSL technology is by far the most popular connection available in the market. ADSL is an asymmetric transmission method where the downloading rate ranged from 1.5 Mbps to over 10 Mbps and the uploading rate ranged from 128 kbps to 640 kbps depending on the broadband service provider. For remote surveillance, the video is transmitted through the uploading channel which is much slower than the downloading channel used for Internet browsing. As many users use Internet, the traffic is highly bursty in nature with frequent congestion. The third video streams of SMAC-M coder can adapt to the harsh broadband Internet environment and provide a good quality video. Good error control is necessary for error free video.

Phone line – The fourth video stream of SMAC-M coder is designed for phone line channels with bit rates ranged from 14.4 to 128 kbps. Phone line connections are point-to-point connections. Depending on the modem used, it covers PSTN, ISDN and HSCSD of GSM services.

Mobile channels – The fifth stream of SMAC-M coder is optimized for effective viewing of remote activities using mobile phones. This video stream supports both the GPRS (9.6 kbps to 14.4 kbps) and the 3G (64 kbps to 384 kbps) mobile services. Mobile channels are error prone and often affected by the local reception quality.

The multiple video streams of SMAC-M coder are independent to each other. The congestion or errors in one channel, say the Internet stream, will not affect the video recording stream or the LAN video stream and vice versa.

The TeleEye RX DVR using SMAC-M technology can achieve high quality video recording and efficient remote video surveillance at the same time.

Review of Video Compression Technologies

In video compression research, there are three major schools, namely, transform-based method, wavelet-based method and vector quantization (VQ) method. Claude Shannon, the Father of Information Theory, in his classical work "*A Mathematical Theory of Communication*" has shown that Vector Quantization is the optimal and the best method for the compression of signal data. However, VQ is not

commonly used in video compression because of the many technical difficulties in practical implementation of a VQ based video coder. The research team of TeleEye Group has spent significant effort in the past fifteen years to perfect the VQ technology and developed the SMAC-M video coder for its RX series DVR.

JPEG is a transform-based still image compression method. It is an industrial standard image coder that gives good image quality under low to medium compression rate. At high compression rate, it has serious quality degradation. DVR using JPEG technology requires the largest data storage for the same video footage as compare to other coders. Surveillance performance through Internet is poorest and unacceptable.

JPEG2000 is a wavelet-based still image compression method developed to replace JPEG. It gives good image quality even when the compression rate is double that of JPEG. It does not have blocking effect at high compression rate, however, edge ringing effects and loss of textural details are common. It produces one of the best qualities in video recording but requires large hard disk space. Remote surveillance performance is poor with very low frame rate on Internet.

M-JPEG is a transform-based video compression method. Its compression rate is double that of JPEG and has blocking effect at high compression rate. It has fair recording performance and poor remote surveillance result.

MPEG-1 is a transform-based video compression standard designed for storage of video on VCD. Its bit rate is 1.5 Mbps at CIF resolution. Its recording quality is comparable to VHS videotape quality and is not suitable for transmission through the bursty Internet (ADSL). Annoying color patches appear on video when data loss or out of sync.

MPEG-2 is a transform-based video compression standard for DVD quality video. Its bit rate is from 6 to 10 Mbps at D1 resolution. Its recording quality is one of the highest but also requires large recording space. It is bandwidth-intensive and is not tolerant for data delay or loss often experienced in a bursty ADSL channel.

MPEG-4 is the latest video compression standard that covers a wide range of video applications. Similar to other MPEG standard, it uses a transform-based coding technique with motion compensation for extracting temporal redundancy. It covers a wide range of bit rates from low quality video of 64 kbps to DVD quality video of 6 Mbps or more

The MPEG-4 video stream consists of a sequence of Group of Picture (GOP). A GOP typically consists of 15 frames or more (Fig. 3). The starting frame (I-frame) of GOP is compressed by a still image compression method so that it is independent of other frames. Other frames of GOP are P-frames, the predictive frames which are generated from previous frames using motion compensation techniques. P-frames are dependent on I-frame and their previous frames and can not be decoded independently. The video quality of I-frame is noticeably higher than P-frames whose quality degrades as predictive errors accumulate over frames. The video quality of a MPEG4 video stream is, therefore, non-uniform (Fig. 3) with noticeable blocking effects (Fig. 4) at low

MPEG-4 Group of Pictures Structure

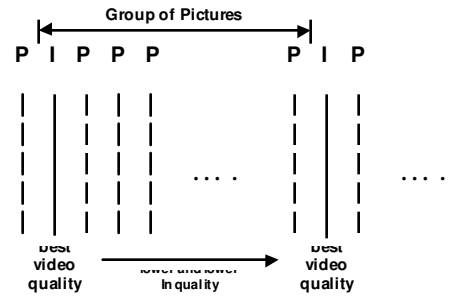

Fig. 3 Non-uniform video quality of a MPEG-4 coder is due to its GOP structure. I and P are the intra-frame and predictive frames respectively.

bit rates. In the occurrence of data error or data delay due to bursty Internet channels, the whole GOP can not be correctly decoded and annoying color patches may appear on the video (Fig. 5). The GOP structure is also the basic structure used in MPEG-1 and MPEG-2 which therefore have similar characteristics.

Fig. 4 Video quality degradation of a MPEG-4 P-frame

Fig. 5 Effects of transmission delay and/or error of a MPEG-4 coder in a bursty Internet channel

SMAC-M is a VQ based video coder. SMAC stands for Scalable Motion Adaptive Coder and –M stands for Multi-rate. It is a proprietary video compression technique optimized for DVR application that requires both good video recording and effective remote surveillance through a wide range of bandwidth requirements. It is resilient from channel errors and adaptive to bursty ADSL channels. At high compression rate, it does not have blocking effects of M-JPEG or the non-uniform video quality problems of MPEG-4. Its video quality is good throughout a wide range of bit rates (Fig. 6). SMAC-M coder is the most efficient video compression technology in the market.

(a) original image

(b) SMAC-M at excellent quality

(c) SMAC-M at low quality

Fig. 6 Video quality of SMAC-M coder: (a) original; (b) excellent; (c) low quality

Comparison of Video Coders

Several DVRs using various compression technologies are compared in terms of recording and remote surveillance performances. The same set of standard video sequences consisting of small, typical and high video activities is fed to each DVR in order to compare their performances. The DVRs used are 4 channel models. The measurement for SMAC-M coder is based on a TeleEye RX364 DVR (Fig. 7). The hard disk space required to record 24 hours continuously was measured and is shown in Fig. 8. The video recording quality was set at the highest quality. At this quality setting, the compressed videos of all coders have no noticeable

Fig. 7 TeleEye RX364 DVR with SMAC-M coder

artifacts. The result (Fig. 8) shows that at full resolution SMAC-M required 40% less hard disk space than MPEG-4 and used 4 times less space than M-JPEG. This implies that for a 200 GB hard disk, SMAC-M can record 8 days continuously while MPEG-4 and M-JPEG can only record for 5 and 2 days respectively.

Recording Comparison

	Recording Performance	
Coder	*Resolution: 720 x 576 Rate: 25fps*	*Recording duration for a 200 Gbyte HDD*
JPEG	170 GB / day	1.3 days
JPEG2000	100 GB / day	2 days
M-JPEG	100 GB / day	2 days
MPEG-4	40 GB / day	5 days
SMAC-M	**25 GB / day**	**8 days**

SMAC-M: 40% smaller than MEPG-4

Fig. 8 Recording space requirements for various coders; SMAC-M coder can record much longer using the same size HDD.

The bit rate requirements for a single camera at full resolution is shown in Fig. 9. Both SMAC-M and MPEG-4 coders can output video streams that cover a wide range of bandwidth requirements. While MPEG-4 can only generate a single stream at a certain bit rate, SMAC-M outputs multiple video streams that cover the bandwidth requirements of different channels.

The transmission frame rates were measured on LAN and ADSL channels and is shown in Fig. 10. The video quality was set at the highest quality for various coders. SMAC-M

Bit Rate Requirement

Coder	*Bit Rate*	*Technology*	*Applications*
JPEG	15 – 20 Mbps	DCT	Still Image Compression
JPEG2000	8 – 12 Mbps	Wavelet	Still Image Compression
M-JPEG	8 – 12 Mbps	DCT	Digital Video Recording
MPEG-1	1 – 1.5 Mbps	DCT	Video CD, VHS quality
MPEG-2	6 – 10 Mbps	DCT	DVD
MPEG-4	64k – 6 Mbps	Transform	Single video stream for recording and surveillance
SMAC-M	**9.6k – 5 Mbps**	**VQ**	**Five video streams for Remote video Surveillance & Recording**

* DCT stands for discrete cosine transform

Fig. 9 Bit rate requirements of a single camera at full resolution for various compression technologies.

is about 50% faster than MPEG-4 under ADSL environment. SMAC-M also requires the least bit rate on LAN for real-time videos.

Transmission Comparison

	Transmission on LAN at 100Mbps		Transmission on ADSL at 640kbps	
Coder	*Resolution: 720 x 576 Rate: 25fps*	*Resolution: 360 x 288 Rate: 25fps*	*Resolution: 720 x 576*	*Resolution: 360 x 288*
JPEG	16 Mbps	8 Mbps	1 fps	2 fps
JPEG2000	10 Mbps	6 Mbps	2 fps	4 fps
M-JPEG	10 Mbps	6 Mbps	2 fps	4 fps
MPEG-4	2 Mbps	1.2 Mbps	8 fps	16 fps
SMAC-M	**1.3 Mbps**	**0.8 Mbps**	**12 fps**	**21 fps**

Fig. 10 SMAC-M coder shows superior video transmission performance on LAN and ADSL channels

Conclusion

Various video compression technologies for DVR are compared. It is shown that SMAC-M coder is the first coder in the market that uses a multi-rate coding technology to solve the conflicting requirements of simultaneous recording and remote surveillance. It covers the widest range of communication media from Internet to mobile channels. The SMAC-M video coder is a VQ based coder with superior compression performance than standard MPEG compression techniques. The resulting TeleEye RX series of DVR outperforms other DVRs in terms of recording duration and video transmission efficiency.