Video Coding Technologies and Standards: Now and Beyond

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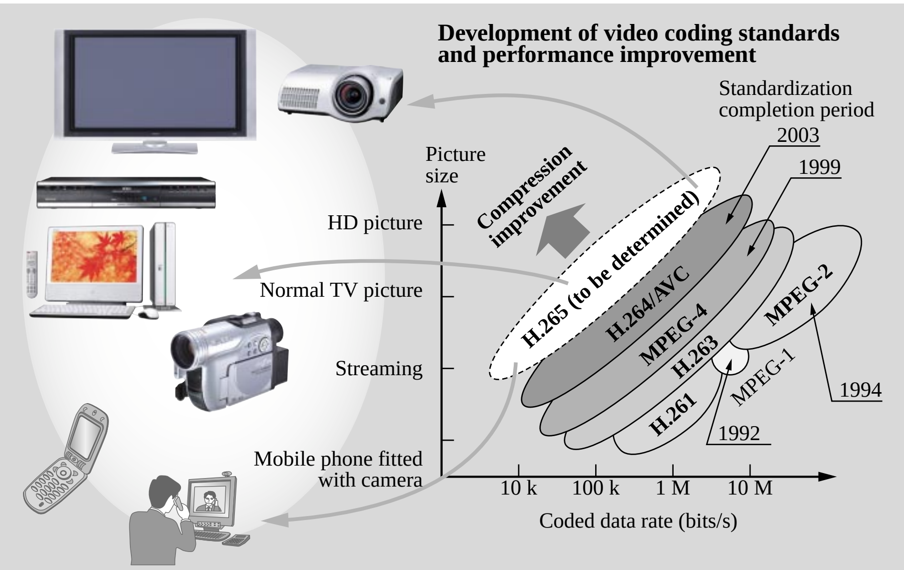
OVERVIEW: Video coding technology compresses digital images—composed of huge amount of data—so they can be recorded and transmitted. International standards—under the standardization bodies called the MPEG and the ITU-T—is applied to all kinds of devices, ranging from digital home appliances (like digital-broadcast receivers, DVD players and hard-disk recorders) to mobile phones. A main feature of the video coding technology that has currently become mainstream is so-called hybrid coding, which combines high picture quality with high compression performance. Nevertheless, at the standardization bodies mentioned above, aiming at attaining even higher compression and better functionality, the search for new technologies has begun. Consequently, discussions on future directions of standardization have started. Up until now, Hitachi has been actively involved in putting forward standardization proposals and developing technologies for implementing video coding technology. Moreover, at present, we are investigating ways of improving the image quality of the current H.264 coding method and looking at ways to extend its application range. This paper overviews current video coding technology, introduces the standardized technologies that we have proposed up till today, and presents some of our future research.

INTRODUCTION

VIDEO coding technology is used in many familiar imaging devices—ranging from DVDs (digital versatile discs) to hard-disk recorders for storing TV broadcasts, transmission systems for digital broadcasting, DVD cameras for clearly capturing family images, and image transmission via mobile phones. Even though these devices come from different manufacturers, they can accurately record and replay images transmitted from one another, because they comply with unified international standards.

International standardization of video coding



HD: high definition MPEG: Moving Picture Experts Group AVC: advanced video coding

Fig. 1—Standardized Video Coding Specifications by MPEG and VCEG (Video Coding Experts Group). Video coding technology has been re-standardized every several years, and every time, encoding performance has been improved. The latest coding standard, H.264/AVC, achieves a compression performance that is two to three times higher than that of MPEG-2 used in DVDs (digital versatile discs). From now onwards, it is anticipated that developments will be aimed at H.265, which will be incorporated into the latest technologies, thereby making it easy to enjoy even higher picture quality.

technology is laid down by the VCEG (Video Coding Experts Group) under ITU-T (International Telecommunication Union-Telecommunication Standardization Sector) and the MPEG (Moving Picture Experts Group) under the authority of the ISO (International Organization for Standardization) and the IEC (International Electrotechnical Commission). Hitachi is not only involved in commercial application of these standards but also actively involved in developing other standards.

As well as giving a simple overview of MPEG and VCEG video coding standards, this report presents the current activities of Hitachi regarding video coding standards and the future prospects for these standards.

OVERVIEW OF VIDEO CODING STANDARDS

The specifications standardized by MPEG and VCEG are shown in Fig. 1. The video coding standards laid down in MPEG consist of several categories: MPEG-1 for recording images and sound on CDs (compact discs); MPEG-2 for normal TV-size images up to HD (high-definition) images used in DVD and satellite broadcasts; and MPEG-4 used extensively for low-bit-rate applications such as sending images via mobile phones.

Moreover, the video coding standards laid down in VCEG are comprised of H.261 and H.263, which are mainly used for communication devices such as video-conferencing systems. The latest coding standard—H.264/AVC (advanced video coding)—has been drawn up by the JVT (Joint Video Team) under a collaboration between MPEG and ITU-T; it is referred to as “H.264” by ITU-T and “MPEG-4 AVC” by MPEG.

Video coding technology has been designated new standards every several years or so, and with each re-standardization, coding performance has been improved. The latest coding standard—H.264/AVC—attains two to three times higher compression performance than MPEG-2 (used for DVDs). From now onwards, H.265 will be further improved and implemented in the latest technologies, thereby making it easy to enjoy even higher picture quality.

These technologies (each shown in Fig. 2) form the base of so-called “hybrid video coding.” Already coded images are taken as reference pictures, and their movement is estimated. The difference between these images and the remaining original images is compressed by means of a DCT (discrete cosine transform).

Up until now, the coding performance of video coding technology has been improved with each new standardization. In the case of H.264, HD images can be recorded in high quality at a coding rate of approximately 8 Mbit/s; in other words, with a 400-Gbyte hard-disk recorder, it is possible to record over 110 hours of HD images.

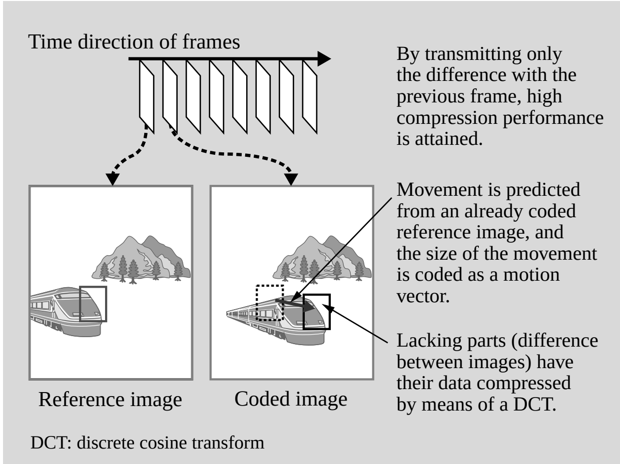


Fig. 2—Principle of Hybrid Coding.
According to a motion compensation calculation and DCT, by transmitting only the difference of the frame in question with an already coded frame, high compression performance is attained.

INTERNATIONAL STANDARDIZATION ACTIVITIES AND HITACHI’S RELATED EFFORTS

Hitachi’s Efforts Regarding Standardization Proposals

Hitachi has been participating in standardization activities since the initial stages of drawing up MPEG-4 in 1995, and we have been proposing new technologies and editing specification documents since then. Some of the proposed technologies incorporating MPEG-4 include motion-compensation error-controlling technology[1], high-speed-warping technology, and global-motion-compensation technology, and a technology incorporating H.264 is spatial direct motion prediction. As a good example of such a technology, motion-compensation error control is described in the following.

This technology can prevent the reddening of pictures caused by accumulation of errors in motion compensation. The occurrence of reddening is detected by rounding-up error processing to whole numbers, and a method for determining these numbers by means of implementing control variables was proposed. An example of the results from this method is shown in Fig. 3. This method has been adopted into the MPEG-4 standard.

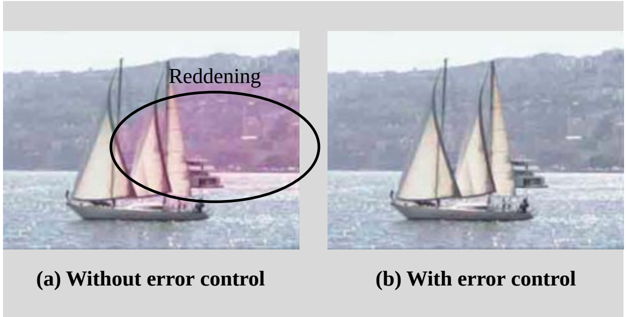


Fig. 3—Effect of Error-control Technique for Motion Compensation.
By introducing control variables, the reddening problem (due to accumulation of rounding errors by motion compensation) is solved.

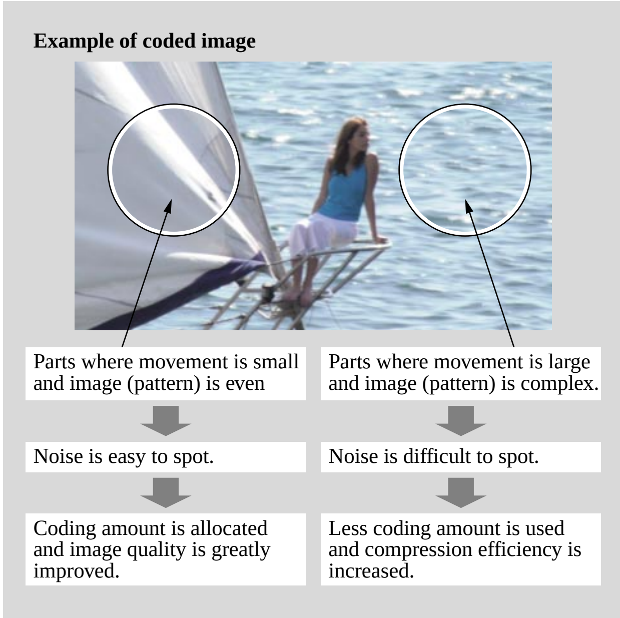


Fig. 4—Overview of High-quality Coding Method H.264/AVC.
As regards natural images, regions of easy-to-spot noise and not-so-easy-to-spot noise exist. By distinguishing these areas and giving them appropriate coding amount, coding with high-picture quality is possible.

Creating HD Pictures with H.264 Coding Method

The current video coding technology, i.e. H.264, is two to three times higher in terms of compression performance than MPEG-2. Accordingly, it is gaining a considerable degree of attention regarding its adoption as a video coding technology for the Blu-ray Disc and HD DVD formats as well as digital broadcasting. This technology, however, requires ten times the number of encoding calculations than MPEG-2; therefore, it is very important to work out how to do these calculations efficiently and how to raise the compression ratio while maintaining image quality. Focusing our attention on applications such as hard-disk recorders and DVD cameras, encoding LSIs, image-archiving systems, and video-surveillance systems, Hitachi is pushing forward the development of high-speed and high-quality H.264 coding methods.

As regards natural images, an image texture comprises complicated parts and even parts within a picture. And as regards moving images, the subject comprises points of sudden movement and other points of relatively slow movement. On coding such images by H.264, though noise in the images is generated by compression of the data volume, about regions with large movements where the image pattern is complicated, noise in the eyes of people is hard to spot, and about regions with small movements where the image pattern is even, noise in the eyes of people is easy to spot.

As shown in Fig. 4, with the developed coding method (i.e. H.264/AVC), the complexity of the image input at the time of coding is analyzed, and in the case that the regions where noise in the eyes of people is easy to spot, the coding amount is multiplied and allocated, and the image quality is improved. And in the case that the noise is easy to spot, the coding amount is cut back, and the compression efficiency is improved.

Moreover, by feeding back the relationship between the generated code quantity, the remaining hypothetical buffer of the decoder, and the target code quantity, this control method does not fail even if the picture moves rapidly[2].

In addition to the above method, we have developed a method that obtains the optimum quantization parameter for the coding amount and picture quality by iterative calculation, thereby improving compression efficiency[3]. And we are concentrating our efforts on developing technologies—such as realizing long-term recording that maintains image quality—aimed at product applications.

FUTURE TECHNOLOGIES FOR VIDEO CODING AND THEIR PROSPECTS

Future Video Coding Technologies

At the current MPEG/JVT meeting, on SVC (scalable video coding)—which is a coding technology for multi-resolution images—is being actively discussed as an extension to the H.264 standard. This transmission method multiplexes a number of image

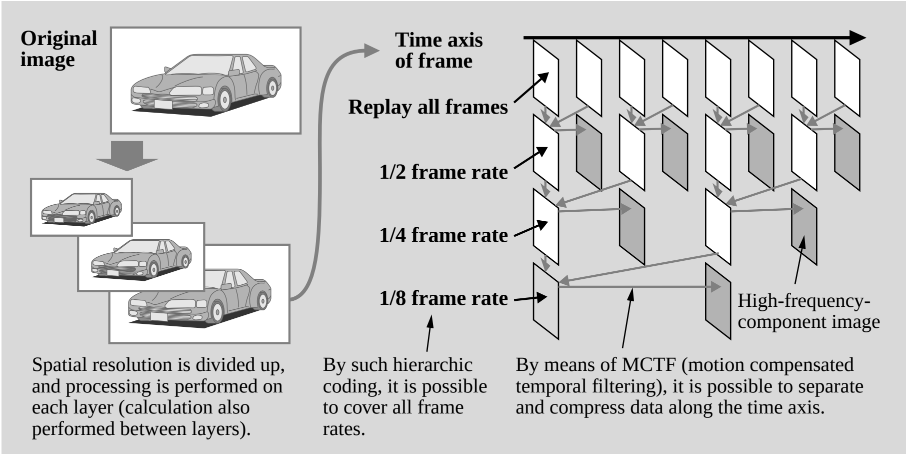


Fig. 5—Principle of Scalable Video Coding.
By division of spatial resolution and separation of time direction, it is possible to generate a coded stream with multiple resolutions and frame rates.

resolutions, frame rates, and image-quality precisions as a single bit stream, frame rate and resolution in a range are selected according to the performance of a particular device, and the images can be played back. The concept of SVC is shown schematically in Fig. 5.

In addition to SVC, MVC (multi-view video coding)—a method for efficiently coding image shots from multiple viewpoints—is being studied. This method is aimed at realizing so-called "free-viewpoint TV" (4), which allows a viewer to freely change the viewing angle while watching a TV program. In parallel with formulating the technical standard for this service, the standardization bodies are also discussing the future direction of video coding technology. Since the standardization of H.264 has finished, and H.264 has reached the maturity stage, hybrid video coding, which started with H.261 and MPEG-1, is at the stage at which new ways to further improve compression performance are being searched for.

As for MPEG, meetings such as the "Future Video Coding Workshop" for exploring future technologies have started. At these meetings, investigation strategies are being devised and new technologies are being introduced. At ITU-T VCEG, as part of the preliminary stage of formulating the new H.265 standard, a study group has been set up to look into improvement of compression efficiency, computational efficiency and error resiliency.

Hitachi's Efforts Aimed at Next-generation Technologies

As regards Hitachi, in addition to implementing and improving existing standards, we are investigating the next generation of coding technologies for the future. We have developed technologies that improve compression efficiency by extending H.264, thereby achieving even longer recording capacity and more effective utilization of the communication spectrum[5].

As regards the H.264 standard, a whole image is divided into so-called macroblocks in an area of 16×16 pixels, and each macroblock is coded in order from the top left of the image, and each code is output. At that time, since the image features similar information with respect to a certain range, each macroblock uses information from the already encoded neighboring block and performs a prediction. In this way, the data volume is decreased. As a result, the relation between image characteristics (such as arrangement of pixels and movement direction of the object) and encoding order of the macroblocks affect coding efficiency of the image.

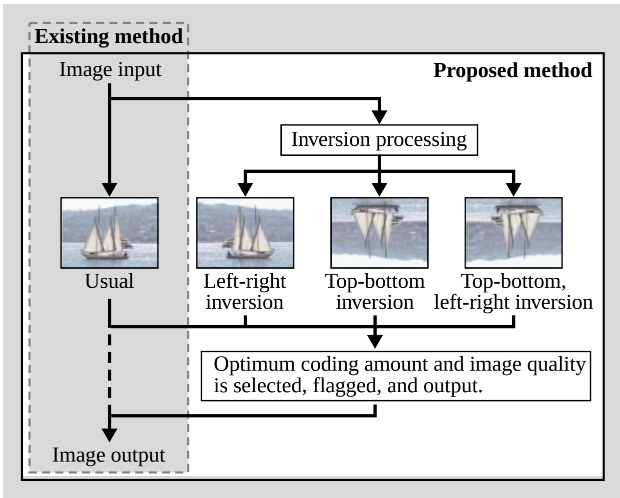


Fig. 6—Overview of H.264/AVC Extended Coding by Picture Inversion.
As regards H.264/AVC, degree of coding error depends on image orientation. By optimizing each frame, even higher compression ratio can be attained.

In the case of the proposed method, as shown in Fig. 6, the image can be input not only in the normal orientation but also in the left-right inverted, top-bottom inverted, or top-bottom left-right inverted orientations and coded once. The output code quantity and image quality are then matched, and the optimum image is selected and output.

As for “inter frame prediction” (that is, prediction between images), reverse processing is performed so that input image has the same orientation as the reference image. As for the orientation of the reversed image, a “reverse flag” showing the reverse orientation is registered in the bit stream and sent to the decoder. In this way, on the playback side, playback is possible at the correct image orientation as before. By using this method, we can see the effect of improved image quality at a wide range of bit rates. As regards coding amount, we experimentally confirmed that it can reduce the data amount by about 8%.

CONCLUSIONS

This paper overviewed video coding standardization, and presented Hitachi’s efforts and details of our research and development regarding standardization activities. From now onwards, we will continue our investigations on video coding technologies aimed at improving performance of image-processing devices. Furthermore, by putting our know-how of past standardization activities to good use, we plan to continue proposing new standardization to MPEG and ITU-T with the aim to further expand existing technologies.

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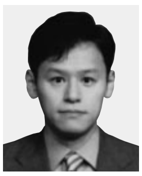

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