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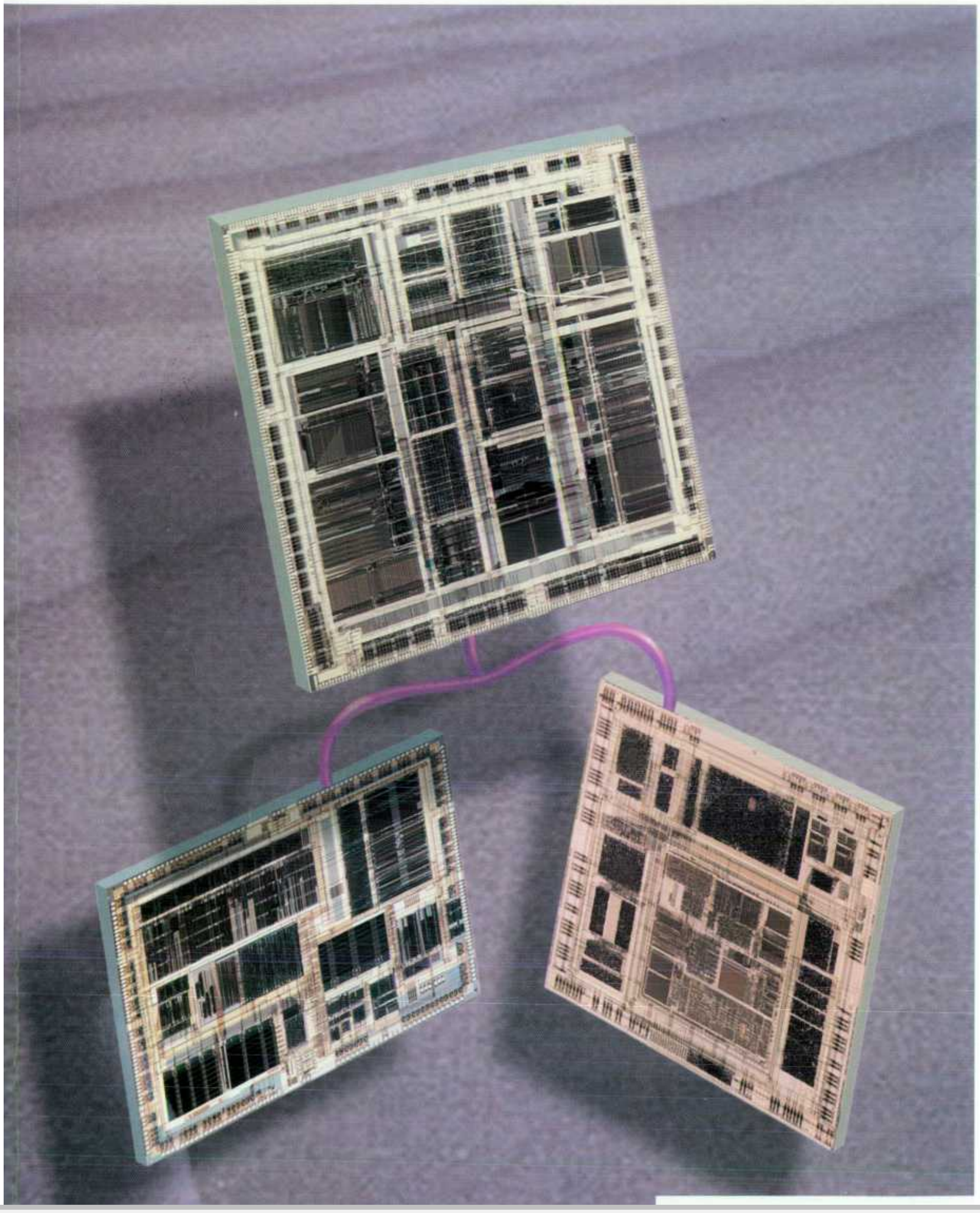

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Articles

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Real-Time Software MPEG Video Decoder on Multimedia-Enhanced PA 7100LC Processors

With a combination of software and hardware optimizations, including the availability of PA-RISC multimedia instructions, a software video player running on a low-end workstation is able to play MPEG compressed video at 30 frames/s.

by Ruby B. Lee, John P. Beck, Joel Lamb, and Kenneth E. Severson

Traditionally, computers have improved productivity by helping people compute faster and more accurately. Today, computers can further improve productivity by helping people communicate better and more naturally. Towards this end, at Hewlett-Packard we have looked for more natural ways to integrate communication power into our desktop machines, which would allow a user to access distributed information more easily and communicate with other users more readily.

We felt that adding audio, images, and video information would enrich the information media of text and graphics normally available on desktop computers such as workstations and personal computers. However, for such enriched multimedia communications to be useful, it must be fully integrated into the user's normal working environment. Hence, as the technology matured we decided to integrate increasing levels of multimedia support into both the user interface and the basic hardware platform.

In terms of user interface, we integrated a panel of multimedia icons into the HP VUE standard graphical user interface, which comes with all HP workstations. These multimedia icons are part of the HP MPower product.[1] HP MPower enables a workstation user to receive and send faxes, share printers, access and manipulate images, hear and send voice and CD-quality stereo audio, send and receive multimedia email, share an X window or an electronic whiteboard with other distributed users, and capture and play back video sequences. The HP MPower software is based on a client/server model, in which one server can service around 20 clients, which can be workstations or X terminals.

In terms of hardware platforms, we integrated successive levels of multimedia support into the baseline PA-RISC workstations.[2,3,4] First, we integrated support for all the popular image formats such as JPEG (Joint Photographic Experts Group)† compressed images.[5] Then, we added hardware and software support for audio, starting with 8-kHz voice-quality audio, followed by support for numerous audio formats including A-law, μ-law, and 16-bit linear mode, with up to 48-kHz mono and stereo. This allowed high-fidelity, 44.1-kHz stereo, 16-bit CD-quality audio to be recorded, manipulated, and played back on HP workstations. At the same time, we supported uncompressed video capture and playback.

In January 1994, HP introduced HP MPower 2.0 and the entry-level enterprise workstation, the HP 9000 Model 712, which is based on the multimedia-enhanced PA-RISC processor known as the PA 7100LC.[6,7,8] The video player integrated in the MPower 2.0 product is the first product that achieves real-time MPEG-1 (Moving Picture Experts Group)[9] video decompression via software running on a general-purpose processor. Typically real-time MPEG-1 decompression is achieved via special-purpose chips or boards. Previous attempts at software MPEG-1 decompression did not attain real-time rates.[10] The fact that this is achieved by the low-end Model 712 workstation is significant.

In this paper, we discuss the support of MPEG-compressed video as a new (video) data type. In particular, we discuss the technology that enables the video player integrated into the HP MPower 2.0 product to play back MPEG-compressed video at real-time rates of up to 30 frames per second.

Digital Video Standards

We decided to focus on the MPEG digital video format because it is an ISO (International Standards Organization) standard, and it gives the highest video fidelity at a given compression ratio of any of the formats that we evaluated. MPEG also has broad support from the consumer electronics, telecommunications, cable, and computer industries. The high compression capability of MPEG translates into lower storage costs and less bandwidth needed for transmitting video on the network. These characteristics make MPEG an ideal format for addressing the need for detail in the video used in technical workstation markets and computer-based training in commercial workstation markets.

MPEG is one of several algorithmically related standards shown in Fig. 1. All of these digital video compression standards use the discrete cosine transform (DCT) as a fundamental component of the algorithm. Alternatives to discrete cosine-based algorithms that we looked at include vector quantization, fractals, and wavelets. Vector quantization

† JPEG is an international digital image compression standard for continuous-tone (multi-

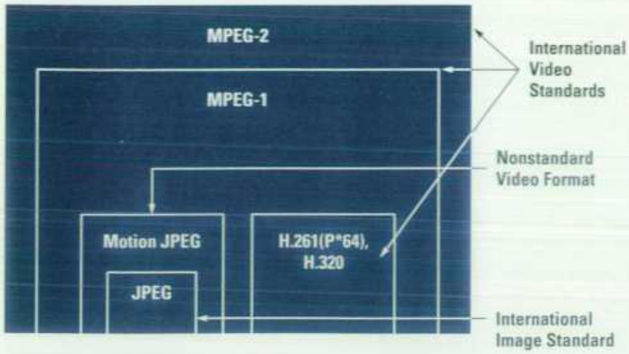

Fig. 1. Digital video standards based on the discrete cosine transform.

algorithms are popular on older computer architectures because they require less computing power to decompress, but this advantage is offset by poorer image quality at low bandwidth (high compression) compared to MPEG for practical vector quantization methods. Algorithms based on wavelet and fractal technology have the potential to deliver video fidelity comparable to MPEG, but there is presently a lack of industry consensus on standardization, a key requirement for our use.

Another advantage of a high-performance implementation of MPEG is the ability to leverage the improvements to the other DCT-based algorithms. Although the relationships shown in Fig. 1 do not represent a true hierarchy of algorithms is useful for illustrating increased complexity as one moves from JPEG to MPEG-2, or from H.261 to MPEG-2.

All of these formats have much in common, such as the use of the DCT for encoding. The visual fidelity of the algorithms was the key selection criterion and not ease of implementation or performance on existing hardware.

Although JPEG supports both lossy and lossless compression, the term JPEG is typically associated with the lossy specification.† The primary goal of JPEG is to achieve high compression of photographic images with little perceived loss of image fidelity. Although it is not an ISO standard, by convention, a sequence of JPEG lossy images to create a digital video sequence is called motion JPEG, or MJPEG.

H.261 is a digital video standard from the telecommunications standards body ITU-TSS (formerly known as CCITT). H.261 is one of a suite of conferencing standards that make up the umbrella H.320 specification. H.261 is often referred to as P*64 (where P is an integer) because it was designed to fit into multiples of 64 kbits/s bandwidth. The first frame (image) of an H.261 sequence is for all practical purposes a highly compressed lossy JPEG image. Subsequent frames are built from image fragments (blocks) that are either JPEG-like or are differences from the image fragments in previous frames. Most video sequences have high frame-to-frame coherence. This is especially true for video conferencing. Because the encoding of the movement of a piece of an image requires less data than an equivalent JPEG fragment, H.261 achieves higher visual fidelity for a given bandwidth than does motion JPEG. Since the encoding of the differences is always based on the previous frames, the technique is called *forward differencing*.

The MPEG-1 specification goes even further than H.261 in allowing sophisticated techniques to achieve high fidelity with fewer bits. In addition to forward differencing, MPEG-1 allows backward differencing (which relies on information in a future frame) and averaging of image fragments. (Forward and backward differencing are described in more detail in the next section.) MPEG-1 achieves quality comparable to a professionally reproduced VHS videotape even at a single-speed CD-ROM data rate (1.5 Mbits/s).[9,11] MPEG-1 also specifies encodings for high–fidelity audio synchronized with the video.

MPEG-2 contains additional specifications and is a superset of MPEG-1. The new features in MPEG-2 are targeted at broadcast television requirements, such as support for frame interleaving similar to analog broadcast techniques. With widespread deployment of MPEG-2, the digital revolution for video may be comparable to the digital audio revolution of the last decade.

The approximate bandwidths required to achieve a level of subjective visual fidelity for motion JPEG, H.261, MPEG-1, and MPEG-2 are shown in Fig. 2. Motion JPEG will primarily be used for cases in which accurate frame editing is important such as video editing. H.261 will be used primarily for video conferencing, but it also has potential for use in video mail. MPEG-1 and MPEG-2 will be used for publishing, where fidelity expectations have been set by consumer analog video tapes, computer-based training, games, movies on CD, and video on demand.

MPEG Compression

MPEG has two classes of frames: intracoded and nonintracoded frames (see Fig. 3). Intracoded frames, also called *I-frames*, are compressed by reducing spatial redundancy within the frame itself. I-frames do not depend on comparisons with past or "reference" frames. They use JPEG-type compression for still images.[5]

† In lossless compression, decompressed data is identical to the original image data. In lossy compression, decompressed data is a good approximation of the original image data.

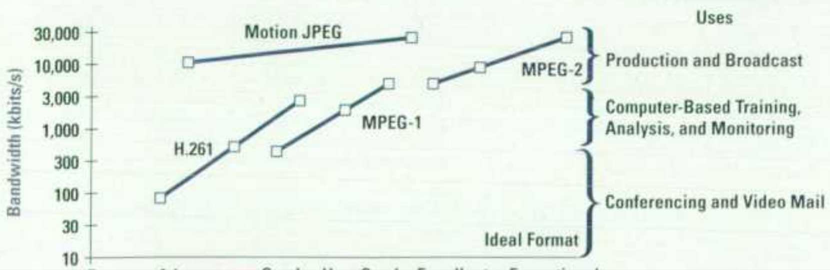

Fig. 2. Compressed video bandwidth versus subjective visual fidelity. The ideal format achieves

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