THE BIG SQUEEZE

Compression technology is the driving force behind the digital video revolution. Here's how the data-shrinking wizardry works.

BY RON GOLDBERG

Computer scientists worldwide are on a common quest, searching for the best way to compress the overwhelming amounts of information that result from video-to-digital conversion. Although they have recently agreed on one approach, the experts acknowledge that today's method will be supplanted by even more sophisticated methods tomorrow. For now, one thing is certain: It's crunch time in the R&D lab.

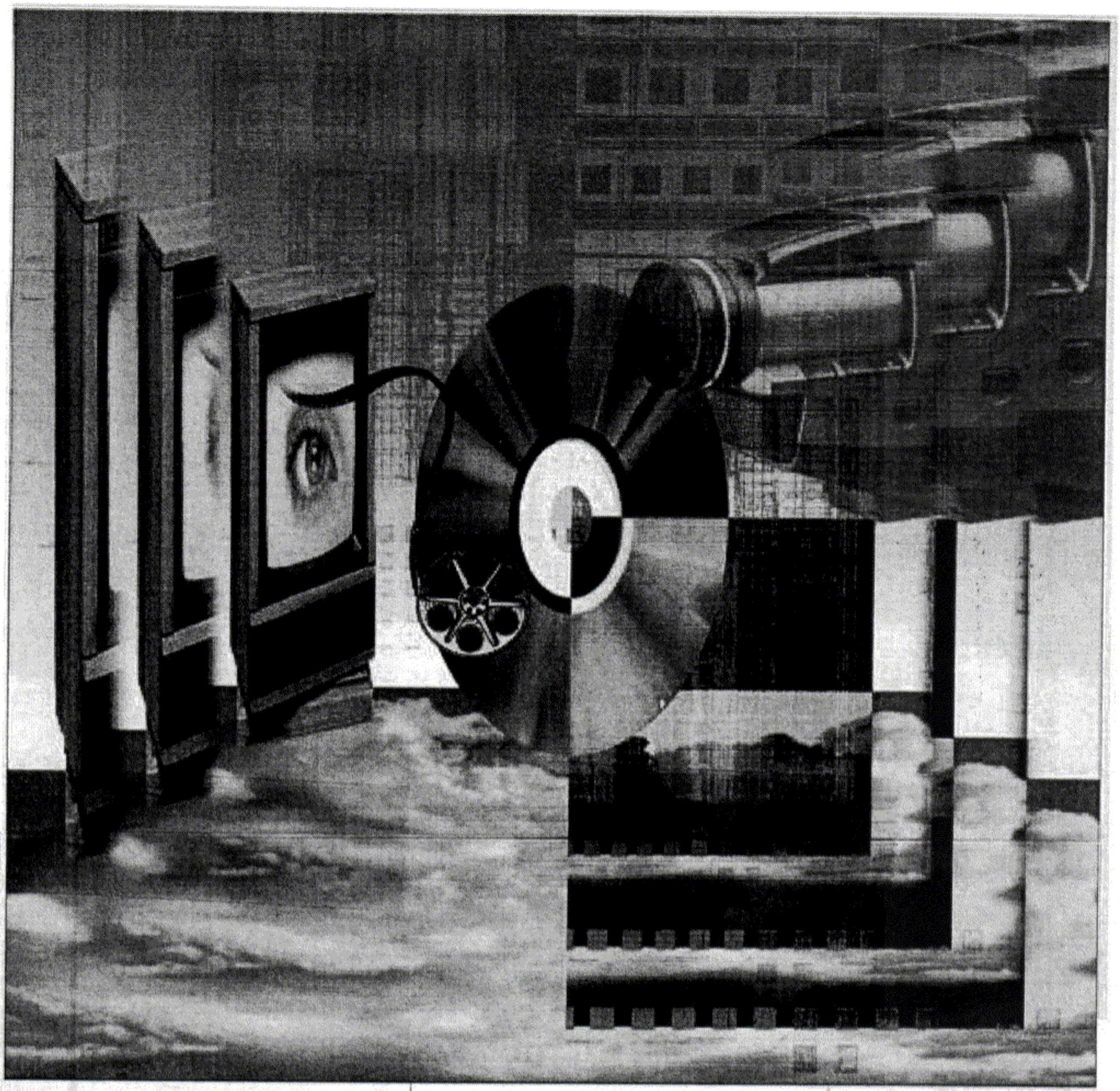
Video is one of the richest forms of communication for both passive and interactive programs, but it's extremely hard to deliver in digital form. It's possible to digitize analog video and store it as the ones and zeros of computer language, just as audio is stored on a compact disc. When video information is digitized, however, it takes up exponentially more space.

Just how much space is required? A garden-variety CD can hold some 75 minutes of music while using upwards of 600 megabytes of digital storage. A single frame of video digitized and stored in the same way would consume almost an entire megabyte. Multiply that by the 30 frames per second that you need for so-called full-motion video, and then again by the 120 or so minutes of a typical feature film. Now we're talking 216,000MB of space—roughly the equivalent of 360 CDs. Obviously, an enormous stack of discs containing one movie is hardly desirable when one analog videotape will do. Before video could enter the digital age, this problem needed a solution.

The answer is compression technology, the process of squeezing digital data down to more manageable file sizes. The search for an international standard has been likened to that for the Holy Grail, but recently two methods have found acceptance. One of these methods, optimized for the compression of still pictures, was devised by the Joint Photographic Experts Group (JPEG). The other method, which holds great promise for video, is named after a consortium of industry specialists called the Moving Picture Experts Group (MPEG).

JPEG and MPEG are languages for digital compression. Both are implemented through a dual-ended process, which means that source material is encoded (or rerecorded) with compression and later decoded (or decompressed) for playback. The amount of compression applied is up to the people who encode the signal. A wide range of compression ratios are available for either method; the higher the ratio, the less space the data takes up. There are tradeoffs at both ends of the spectrum, however. Use too much compression, and picture quality suffers. Use too little, and not enough space is saved.

For MPEG video, compression begins with encoding through high-speed comput-



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er hardware. Video is input and digitized, a process that at its simplest level is analogous to a photograph being projected through a fine screen, and each tiny square in the resulting mosaic or bitmap being assigned a value of 1 or 0 for "on" or "off."

The resulting stream of data has two layers: the *system layer* and the *compression layer*. The system layer is necessary because MPEG can compress and synchronize both video and audio signals, which are multiplexed together during the compression process. Timing information and other data needed to de-multiplex the sound and picture reside in the system layer. The compression layer, meanwhile, contains the actual compressed audio and video.

The MPEG system does not apply equal compression to all of the signal that passes through it. Although technically possible, that would require enormously powerful and expensive hardware to decode the video fast enough for a continuous-play program like a movie. Instead, MPEG intelligently decides which parts of a moving picture need to be compressed and which ones don't.

That may sound like cheating, but it actually makes a lot of sense. In many cases, much of the picture information in any given video scene is identical from frame to frame or even from second to second. Imagine, for example, a scene of someone walking across an open field. The only picture information that changes significantly during the scene is that of the person walking. Most of the visual information, such as the landscape and sky, remains stagnant. It would be a waste of computer power and storage to make digital copies of that identical information 30 times per second.

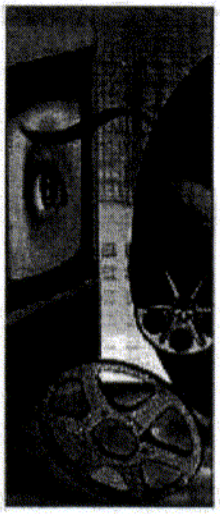
Instead, the MPEG system analyzes the digitized video information and assigns different levels of priority, so that compression is used when and where it's needed most. It all starts with the most basic building block and lowest common denominator of an MPEG video sequence: an individual image called a picture.

Since so much of the information in a video picture is the same as the information in adjacent pictures, MPEG represents some pictures in terms of their differences from a reference picture that has already been analyzed. This technique, called "*inter-picture*" coding, enables MPEG to operate with maximum speed and efficiency.

The reference pictures come in one of three flavors. The most important is an "*intra-picture*," also called an "I-picture." During the encoding process, the "decisions" made regarding compression come only from the information in the I-picture itself.

More compression is applied to the second kind of MPEG picture: a "*predicted*" or "*P-picture*." P-pictures are derived from information from the nearest I-picture through a technique called "*forward prediction*." The idea is actually quite simple. A full-information I-picture serves as the model on which later P-pictures are based. Since most of the information necessary to create a P-picture has already been recognized in the I-picture, a P-picture can be rendered very economically. In fact, by using more forward prediction, the information in a P-picture can serve later as the model for another P-picture. This saves a great deal of space, since it's a compression of a compression.

Maximum compression is saved for the last type of MPEG picture, called a "*bidirectional*" or "*B-picture*." These pictures use both past and future I-pictures or P-pictures as reference points. (See "How MPEG Works.")



The new Video CD format will speed the arrival of MPEG-compressed video as a mainstream product.

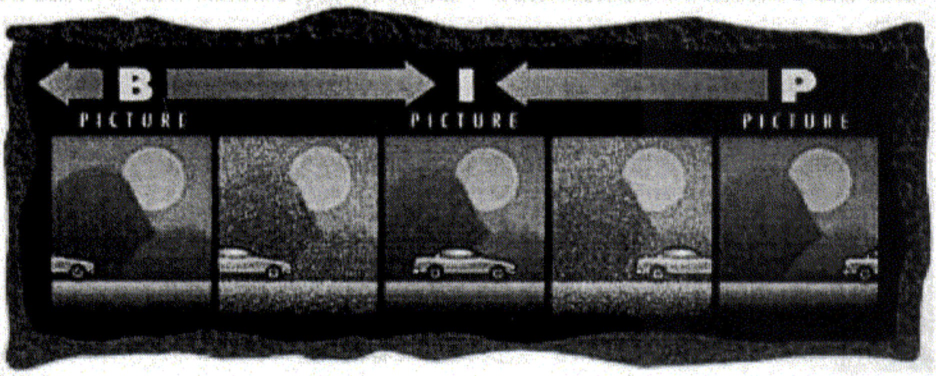
If inter-picture coding were all that was used to compress video, bandwidth and storage requirements would still be substantially reduced. But the MPEG system has more tricks up its sleeve. Between the compressed P-pictures and B-pictures, a lot of redundant information remains. To save even more space, MPEG uses another algorithm (or mathematical formula) called "*motion compression*."

Let's go back to our scene of someone walking across a field. As the legs move back and forth, MPEG can intelligently predict how to fill in the missing information without having to code an entirely new picture. By looking at reference pictures that are backward and forward in time, MPEG can re-create the missing information so quickly that we perceive the final result as smooth motion, much the way that the 30 still frames per second of a video fool our brains into seeing fluid motion. The result is video quality equal to that of VHS, but in a fraction of the space.

How small a space? Paramount Pictures and Dutch electronics giant Philips Electronics recently announced that they will release 50 Hollywood movies on MPEG-encoded compact discs. Each disc will be able to hold more than 72 minutes of MPEG video. So now, instead of requiring 360 discs, a feature film can be stored on two.

Initially, the movies will play only on Philips' interactive CD-I players, but many other players are waiting in the wings for these discs to catch on. A recent agreement between JVC, Matsushita (the parent company of Panasonic and others), Philips, and Sony has paved the way for a new video CD standard, called Video CD, that will speed the arrival of MPEG-compressed video as a mainstream product.

While the CD-movie format calls for a new technical protocol, Nimbus, a British firm, has developed a "black box" that will play back video CDs from any garden-variety CD player with a digital output. The output sends signals to the Nimbus decoder so that MPEG video can be played on a TV



HOW MPEG WORKS:
AN INTRA-PICTURE SERVES AS THE REFERENCE POINT FOR CALCULATING OTHER PICTURES IN THE VIDEO STREAM. THE BIDIRECTIONAL PICTURE ON THE LEFT HAS BEEN CREATED BY LOOKING AT PAST AND FUTURE INFORMATION. THE PREDICTED PICTURE

set. This technology, if adopted, would mean an already installed base of millions of players throughout the world and would rapidly bring five-inch CD movies to a mass market.

Despite its promise, MPEG is somewhat of a dirty word among movie production engineers concerned with preserving the quality of a presentation as intended by the filmmaker. They worry that viewers at home will come to accept the equivalent of VHS-resolution—or less—as "good enough" even though it's not as sharp as laser disc, Super VHS, or Hi-8 tape formats.

Yet for MPEG proponents, disc-based video programs are only the start. Because compressed video takes up much less bandwidth than a conventional broadcast signal, MPEG opens a world of possibilities for video services, even delivery over the copper-based telephone wires and coaxial cable TV lines that make up our communications infrastructure. MPEG compression makes most such video services possible without the expense of fiber-optic installation.

In fact, the delivery of hundreds of TV channels over plain old cable will likely be one of the first illustrations of video compression's vitality. Cable companies would provide new set-top boxes to decode the data stream.

Digitally compressed video will also make possible the first generation of direct-broadcast satellite (DBS) services to small home dishes. The first "bird," scheduled for space launch at the end of this year, is expected to provide about 200 channels of TV programming. Thomson Consumer Electronics will offer this technology under the name Digital Satellite Services (DSS). High-definition television (HDTV), incidentally, will also rely heavily on MPEG-based compression techniques. If other countries follow the United States in adopting digital HDTV, MPEG could serve as the basis for the first internationally compatible video signal.

Sometimes, all it takes to start a chain reaction is a simple idea. Although video compression via MPEG isn't simple in practice, in theory it's little more than the recipe for a new kind of brick, one that will allow immense technological structures to be built. Where these structures will lead us is one of the most intriguing questions we face. But wherever that is, it's clear that the digital deluge will increasingly take the form of compressed video. ■