Video for CD-ROM Publication

How to Create Great-Looking Indeo™

Indeo™ Video Technical Marketing
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Introduction

Purpose

This paper will discuss techniques for capturing, editing, and compressing high-quality PC-based digital video using Intel's Smart Video Recorder and Smart Video Recorder Pro hardware and Indeo™ Video software technologies.

Intended Audience

The readers who will benefit most from this discussion are multimedia applications developers and title publishers, especially those using CD-ROM as the delivery and playback environment for digital video files.

Prerequisites

This discussion will assume that the reader has at least a basic knowledge of Microsoft Windows* 3.1 and Video for Windows. The use of acronyms and terminology also assumes at least a slight understanding of video digitizing hardware and software for the PC.

Which Compression Method to Use: Real-Time vs. Offline

The Intel Smart Video Recorder (hereafter abbreviated as iSVR) and the new iSVR Pro are rather unique among low-cost video digitizing boards in that they are capable of capturing video and compressing it in real time using Indeo video technology. As each frame of video is digitized it is also compressed before being written to memory or hard disk. This results in a lower data rate and a much smaller file size; it also enables Intel486™ and Pentium™ processor based PCs to capture a 320 x 240 pixel video stream at up to 15 frames per second (using the iSVR) or 30 frames per second (using the iSVR Pro) without dropping any frames.

In order to achieve this real-time performance, however, the Intel Smart Video Recorder boards must trade off some compression performance for speed. Indeo video is a powerful and complex compression algorithm, capable of executing many different "modes" of compression, and of combining any of those modes within a frame (intra-frame, or "key frame" encoding) and between frames (inter-frame, or "delta frame" encoding). This complex encoding process requires that the Indeo video compressor analyze each frame of video with great precision, and also execute detailed comparisons between frames. This degree of analysis is not possible in real time.

Therefore, Intel's Smart Video Recorders' real-time compressor encodes data using a subset of the Indeo video algorithm. It executes only some of Indeo video's compression modes, using a fixed set of compression parameters, and creates only intra-frame encoded "key frames". This process still results in very high quality video at data rates playable from most average hard disks; a typical Indeo video file at 320 x 240 resolution, 15 fps, will have a data rate of approximately 400 Kbytes per second.

But video intended for CD-ROM playback needs to be at lower data rates, typically 90–135 Kbytes per second for single-spin CD-ROM drives, or 200–240 Kbytes per second for double-spin drives. In order to create files at this data rate, and still maintain the highest possible visual quality, it is necessary to compress the video offline, in a non-real-time fashion, using Indeo video's CD-ROM rate compressor.

Offline compression assumes the existence of a video source file on hard disk, which is then compressed in a non-real-time fashion using a Video for Windows* editing application such as Microsoft VidEdit*, Adobe Premiere for Windows*, or Asymetrix Digital Video Producer*. In this offline, non-real-time mode the CD-ROM rate compressor has time to execute all of the various modes and permutations of Indeo video described above. The result is video of significantly higher visual quality

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at lower data rates, suitable for delivery and playback from an MPC-level CD-ROM drive.

The remainder of this paper will discuss analog video quality issues, detail the steps used to capture video in preparation for offline compression, and the

steps used to offline compress the video using the Indeo video CD-ROM rate compressor.

Analog Video Quality

The quality of the original source video tape will determine more than anything else the quality of the resulting compressed digital video file. Compression algorithms analyze the digitized video input stream searching for redundant or predictable data patterns, which can be compressed and reconstructed later. Any noise or artifacts digitized from the analog source video will be interpreted by the compressor as important non-redundant non-predictable data, and the compressor will waste valuable data storage and CPU cycles attempting to store and reproduce these deficiencies. In fact the deficiencies will look worse after lossy compression than before. Video compression technology has created a new variation on an old computer saying: garbage in, garbage *squared* out.

Videotape Formats

The best source video formats to use are those based on *component* (also known as luminance/ chrominance, or Y/C) color space, rather than *composite*. Component signals carry the luminance (brightness) and chrominance (color) signals seperately, resulting in higher signal bandwidth and improved signal-to-noise ratio. Composite video sources modulate the luminance and chrominance together on one signal, lowering both the signal bandwidth and signal-to-noise ratio. Composite video signals are also subject to video artifacts such as color bleeding.

Component video formats include (ordered from highest to lowest quality): D1, Digital Betacam, Betacam SP, Hi8, and Super-VHS. D1 and Digital Betacam actually store video information digitally, rather like an audio CD. Both formats are broadcast quality, but on the expensive side of even a professional budget. Betacam SP is the most widely used analog recording format for video creation and post-production; it's high quality and ubiquity make it an ideal choice for professional and semi-pro multimedia authoring. Hi8 and S-VHS are consumer formats and therefore inexpensive and available; while both will produce reasonably good results for desktop and consumer use, they are markedly inferior to formats like Betacam SP and should be avoided for serious publication use.

Composite video formats include (ordered from highest to lowest quality): D2, 1″ Type C, 3/4" U-Matic, laserdisc, and VHS. D2 is the digital composite cousin of D1, and it is similar to D1 in both its quality and expense. 1″ and 3/4″ literally refer to the width of the recording tape used in each format; 1″ is an open reel-to-reel format, 3/4″ a cartridge format. Both are older professional studio formats, and while both will produce better results than consumer formats they have been almost entirely supplanted by the markedly superior Betacam SP format. Laserdisc, despite being a composite format (some laserdisc players provide S-Video outputs, but the original signal is still composite), still provides good qualiy. VHS is of course the familiar home consumer format; its composite signal and low-cost recording and playback mechanisms make it the lowest in quality of any available format, and it should be avoided for all but the most casual uses (e.g., prototyping, demos).

Capture Studio Video Equipment

In addition to selecting the proper videotape format, the selection of certain features in a video deck, as well as the judicous selection of some key supplemental equipment, will allow the developer to send the highest possible quality analog video signal into the iSVR board for digital capture.

When purchasing or using a component video deck, check to see that it has a Y/C (also known as S-Video) output connector. This is a circular 5-pin DIN connector like the one on the back of both the iSVR and iSVR Pro. Connecting the S-Video output of a component video source to the S-Video input on the capture board will ensure the highest possible video capture quality.

An invaluable hardware addition to any video capture studio will be a waveform monitor and vectorscope. This equipment, a staple of any video post-production facility, allows the output signal from a video deck to be balanced against a standard set of NTSC television test patterns. This allows the user to make sure that the video signal going into the Intel Smart Video Recorder is properly balanced for color and brightness.

Another useful piece of studio hardware to consider purchasing is a digital Time Base Corrector. Digital TBC's are inserted in the signal chain between the source video deck and the video digitizing board,

and can correct some of the signal deficiencies sometimes created by lower-end video equipment.

One common problem that TBC's are designed to correct is weak or inaccurate synchronization signals from the source video deck, particularly common in VHS and other consumer-grade equipment. This will appear as "tearing" along the top or bottom edge of the video capture window. More fully-featured TBC's also include the ability to adjust the color and brightness of the incoming video signal, and can be used in conjunction with a waveform monitor and vectorscope to properly balance the video output signals of video decks that lack their own brightness and color controls (such as VHS and Hi8).

Many higher-quality video decks, including Betacam SP and even some of the better S-VHS and Hi8 equipment, feature built-in digital time base correction. Also note that vectorscopes require a time base corrected input signal; therefore, if your video deck doesn't have built-in time base correction an external TBC will be required in the signal chain between the video deck and the vectorscope.

Digital Video Capture Format

Both the iSVR and iSVR Pro support the ability to digitize video using two different compression formats, and the choice of format will determine the quality of the compressed video. The following discussion assumes that the reader has some basic experience in running a video digitizing application such as Microsoft VidCap, or the video capture modules in Adobe Premiere for Windows or Asymetrix Digital Video producer. These applications are very similar in functionality, and have many of the same options, menus, and dialog boxes.

Selecting which compression format to use during capture is done under a menu usually called "Video Format". When using the iSVR or iSVR Pro two capture formats are possible.

Indeo™ Video R 3.2

This is the real-time capture and compression mode discussed previously. Since the assumption is that the reader wants to create video at CD-ROM playable data rates, real-time capture and compression may not be the ideal choice. This because that while both the real-time and the CD-ROM rate compressors are lossy, the former is more lossy than the latter, because it uses only a subset of Indeo video's possible compression techniques. This means that real-time-compressed files will have a degree of "lossy-ness" imposed upon them that will hinder the CD-ROM rate compressor's ability to create the highest possible quality images. In fact, when real-time-compressed video is recompressed using the CD-ROM rate compressor, any visual artifacts created by the real-time compressor can actually be amplified by the CD-ROM rate compressor. In the video production world this is analogous to making a tape of a tape - generation loss (degraded video quality) occurs.

Indeo™ Video Raw

In this mode Intel's Smart Video Recorder digitizes the incoming video frames but does not compress them. Rather each video frame is converted into Indeo video's 9 bit per pixel YUV color space (YUV9) and then written directly to memory or to hard disk.

Raw capture will produce much higher quality source video files, but at a price: increased data rate. A single 320 x 240 frame of video in Indeo Video Raw's YUV9 format occupies 86,400 bytes; assuming a video stream of 320 x 240 resolution at 15 fps, the data rate of Indeo Video Raw video will be around 1.2 MBytes per second (sans audio). This is too high a data rate to be captured to most PC hard disks in real time without dropping frames, so in general using Indeo Video Raw requires capturing into system memory, and limiting the size (i.e. the length in time) of captured files to that which will fit into the available system memory on the capture PC.

For example, at 1.2 MBytes per second data rate a PC equipped with 32 MBytes of system memory can capture a video file of about 23 seconds without dropping any frames (VidCap and Windows overhead consumes some of the available system memory); a 48-Mbyte system can capture about 36 seconds; and a 64-Mbyte system can capture about 50 seconds. Capturing audio simultaneously, even at the default minimum settings of 11-KHz/ 8-bit/mono, reduces the length of the file that can be captured without dropping frames, and increasing the audio sampling rate, sample word size, or number of audio channels will reduce the possible "dropless" capture time even further.

Clearly using Indeo Video Raw capture requires higher system performance, and the PC intended for use as a video capture and compression workstation should be equipped with as much memory as

possible (32 Mbyte minimum recommended), the fastest CPU possible (a Pentium™ Processor of 66 Mhz or above will work best), and the fastest

hard disk subsystem possible (a PCI-based SCSI 2 card will work best). However there is no question that Indeo Video Raw capture will allow subsequently offline-compressed video to achieve the highest possible visual quality at the lowest possible data rates.

Capturing Video

This section will review some important "checklist" items, and discuss several tips for optimizing video captures. It is assumed that the reader has some basic experience in running a video digitizing application such as Microsoft VidCap, or the video capture modules in Adobe Premiere* for Windows or Asymetrix Digital Video Producer*. These applications are very similar in functionality, and have many of the same options, menus, and dialog boxes.

Creating the Capture File

Before capturing video files it is recommended that you de-fragment your hard disk. Having large amounts of contiguous disk space available for capture reduces the potential for dropped frames.

The file into which to capture the video is created using an option usually called "Set Capture File". Some video applications attempt to preallocate a file which may be larger than actually needed; in this situation, you should generally ignore the default suggested by the application and set the file size to 1 Mbyte. Whether you are using Indeo Video Raw and capturing into memory, or using real-time compression and capturing to disk, the larger file is unnecessary and will waste space. If the application allocates (for example) a 60 Mbyte file, and you capture only 2 Mbytes of video, the resulting file will still be 60 Mbytes in size.

There is one capture-and-edit technique which does involve creating a single, very large capture file. It's a useful technique if you want to capture a series of clips all at once but compress them later, and can be used to minimize disk fragmentation.

After de-fragmenting your hard disk, allow the capture application to pre-allocate a large capture file, slightly larger than your largest anticipated capture (or if your application doesn't support pre-allocation, simply capture a long video clip). This large file can be used as a "capture buffer", into which you can repeatedly capture each of your individual clips. Now, capture a video segment into the "buffer" file. Open the buffer file with your editing application, and do any necessary editing (for example, the first few and last few frames of any captured clip will generally need to be trimmed off). Then save the edited clip out under a different name, being careful not to compress or recompress the file as its being saved (assuming you don't want to compress it yet; see "Editing Compressed Video" below). Repeat this procedure for each video clip you capture.

Repeatedly capturing into the same capture "buffer", and trimming any excess frames from your individual clips before saving them to disk, reduces both disk space consumption and fragmentation.

Capturing to Memory vs. Capturing Directly to Hard Disk

If available this option, usually called "Capture Method", should be set to "Capture to Memory". The capture application will use all of the available system memory as an input "cache", helping to reduce or eliminate dropped frames. If you capture a file that's less than or equal to the amount of available system memory in size, a suitably fast PC can capture Indeo Video Raw videos at up to 320 x 240 at 15 fps (using the iSVR) or at 30 fps (using the iSVR Pro) without dropping frames, as discussed previously in the "Video Capture Formats" section.

Selecting the Audio Format

Using the minimum audio requirements of 8-bit, mono audio, sampled at 11 KHz will maximize the portion of the data stream that can be allocated to video, thus resulting in higher video quality. Increasing the audio sampling rate to 22 KHz will result in "smoother" sounding audio with more high frequency detail and less hiss, but will also reduce the amount of data bandwidth available for video by 11 Kbytes per second. Changing any one of the audio format parameters doubles the audio data rate.

Input Video Source Settings

For most video captures the default slider settings for Brightness, Contrast, Saturation, and Tint, under the "Video Source" menu will be acceptable. The default values used by the iSVR and iSVR Pro boards were created by using the board to capture electronically-generated NTSC television test

patterns, analyzing the captured test patterns with a vectorscope, and then tuning the software settings appropriately. The board should capture an accurately balanced signal; any noticable shift in the brightness, contrast, or color of the captured signal is probably due to problems in the analog video signal itself and not the capture board.

If the analog source video you're capturing is monochrome (black and white), turn the "Tint" and "Saturation" sliders in the "Video Source" menu down to zero. There's no color data in the source signal anyway; turning these controls off ensures that all zeroes are written into the U and V color planes of each Indeo video frame. The results will be better looking video and better compression rates; this will also prevent any analog imperfections in the source video tape, video deck, or even the video capture board itself, from being recorded into the U and V color planes as erroneous color data.

Previewing the Incoming Video Signal

Most video capture applications have an option called "Preview Video", which must be enabled in order to see the incoming video signal in the display window. Because the Intel Smart Video Recorder uses a "soft" preview window, where the video is compressed into memory and then de-compressed back over the system bus to the graphics controller for display, the preview window will sometimes run slowly or even stop completely (particularly when capturing); this is normal, and does not mean that frames are being dropped. To maximize the speed with which the video preview window can display, set your Windows display mode to 8-bit (256 color). Running your Windows display in 16- or 24-bit mode will make the preview window look better, but update more slowly. Changing your Windows display mode between 8, 16, or 24-bit depth has no effect on the capture quality of Indeo video, which is always stored in full-color format.

Compressing the Video: Video for Windows Applications and the CD-ROM Rate Compressor

After the YUV9 Raw video has been captured to hard disk and any editing or post-processing applied, the video is ready to be offline compressed, by using the Indeo video CD-ROM rate compressor (also known as the offline compressor) within a Video for Windows editing application. By virtue of having shipped bundled with virtually every PC-based video digitizing board sold to date, Microsoft's

VidEdit is by far the most ubiquitous editing package supporting offline video compression. However Microsoft stopped shipping both VidCap and VidEdit on August 1, 1994, and so other editing applications which support offline compression have evolved, including Adobe Premiere for Windows, Asymetrix Digital Video Producer, ATI MediaMerge*, and In:sync Razor*. Besides video editors, some other multimedia software packages also offer the ability to output .avi files with compressed video bitstreams, including Gryphon Morph*, North Coast Software PhotoMorph 2*, Caligari TrueSpace*, and CorelDRAW* version 5.

The degree to which each of these applications successfully integrate and support Video for Windows functionality and the Indeo video CD-ROM rate compressor varies. As both Video for Windows and Indeo video evolve not every application is able to immediately upgrade to support new features. Microsoft VidEdit is a bit unique in that it is Microsoft's "reference compressor"; that is, since it is provided by Microsoft one can be fairly assured that it supports all of the latest Video for Windows software revisions and features.

In fact a significant feature added to Video for Windows 1.1, involving an internal message that an application uses to send important compression data to a video compressor, was initially supported only by VidEdit and the Indeo video CD-ROM rate compressor. Applications have shipped from other ISVs that do not support sending this new message to the Indeo video CD-ROM rate compressor, and the impact on the user is that while these packages will create compressed Indeo video files those files will be of a lower visual quality than files created by VidEdit. These applications also suffer from less accurate data rate control and CD-ROM padding support.

Therefore, VidEdit has been for some time the best way to create compressed files at the highest visual quality and with the most accurate data rate control. Contact the Indeo Technology Support group for the latest information on using other applications to create compressed Indeo video files.

Compressing the Video: Selecting Compression Options

Most editing applications have a menu referred to as "Video Compression" or "Compression Options", where the user sets some critical variables, including the desired average data rate for the compressed file,

the video compressor to be used, the audio/video interleave, the key frame interval, and CD-ROM playback preparation. Some applications break the last two items out into a separate menu called "Output Format". This section will discuss how to properly set all of these variables; the "Supplemental Reading" section at the end of the paper provides some more in-depth explanations about what some of the settings mean, and how you should select particular variables to meet your compression needs.

Setting the Target Data Rate

Most editing applications provide a selector box called "Data Rate", and a numerical entry box into which the desired average data rate is entered. Select the box and key in an average data rate value, expressed in Kbytes per second. For more discussion on how to decide on a target data rate see the "Supplemental Reading" section at the end of this paper.

The offline compressor will attempt to output compressed data at an average data rate as close to the selected target data rate as possible. It usually won't be exact, because compression is very content-dependent. For example, computer-generated animation sequences which might consist of very simple backgrounds, low detail, and low motion, typically compress extremely well; the offline compressor might not need to use any more than 50 to 100 Kbytes/second to compress such sequences. However, live video sequences of (for example) sporting events, featuring complex backgrounds and lots of motion, will demand more data rate. On average the offline compressor will achieve an average data rate within 10 to 20 percent of the desired target.

The "Data Rate" control usually works in concert with a "Quality" slider located in the same menu. There are two different ways in which these controls work together to control the target data rate of the compressed file.

If the "Data Rate" box is selected and a non-zero value keyed into the numerical entry box, then the "Quality" slider is ignored. Most applications don't actually gray out the slider, but it is *effectively* grayed out. Setting the "Data Rate" and "Quality" controls in this fashion will enable the Indeo video CD-ROM rate compressor to its fullest capacities, and result in files of the highest possible visual quality, at the lowest possible data rates, and with the most precise possible target data rate control.

If the "Data Rate" box is de-selected, or if it is selected and a value of 0 is keyed into the numerical entry box, then the "Quality" slider becomes active. Now the value of the slider does matter, and the higher the slider is set the better the visual quality of the resulting file — and the higher the data rate. The important difference here is that the "Quality" slider does not exercise the offline compressor to its fullest capacities; rather, it picks a subset of the possible compression parameters, very much in the same manner as the real-time compressor in the iSVR and iSVR Pro. The benefit to this approach is speed: using the "Quality" slider allows the Indeo video compressor to run faster. The tradeoff is that the resulting files will not have the high visual quality or low data rate of files created using the "Data Rate" control, and because of this CD-ROM developers are encouraged to use the "Data Rate" control, not the "Quality" slider.

Compression Method

Enter the "Video Compression" or "Compression Options" menu in your editing application. This allows you to select which video compressor will be used to compress the video stream. If you have the latest version of Indeo video on your system, the offline compression option entry should read "Intel Indeo™ Video R3.2". If the entry reads "Intel Indeo™ Video R3.1," or if you have any question as to whether or not you have the latest version of Indeo video, contact the Indeo Technology Support group at the numbers listed at the end of this document.

Most of this discussion will assume that the user is editing and compressing an Indeo video Raw file. It is possible to edit video material which has already been compressed, but some care should be exercised to avoid recompressing the data after it's edited. See the "Editing Compressed Video" section below for more details.

Interleaving Audio and Video

The parameter usually referred to as "Interleave" controls the grouping of audio and video frames on a CD-ROM or hard disk. This should always be set to 1, also referred to as interleaving the file at 1:1. Video for Windows reads in frames from the CD-ROM drive one at a time; if each frame's audio

and video are not stored right next to each other on the disc (i.e. if the “Interleave” parameter is set higher than 1) then the CD-ROM drive must skip

back and forth to collect this data for each frame. This is an excessively time-consuming process, and playback will virtually grind to a halt. Files interleaved at greater than 1:1 will not play back at all from CD-ROM; they will play back reasonably well from hard disk, but the audio and video may not play back with good synchronization.

Most video capture applications do not have time to interleave audio and video together during capture, and so the frames are interleaved at an interval much higher than 1:1. Such captured files which have not been re-interleaved will not play back at all from CD-ROM; they will play back reasonably well from hard disk, but the audio and video may not play back with good synchronization.

To determine whether or not an existing file was interleaved at 1:1, open the file in Media Player. Pull down the "Device" menu and select "Configure". A dialog box will appear containing several useful pieces of information about the file, including something labled "File Type". If the "File Type" says "AVI Interleaved" the file is interleaved at 1:1. If the "File Type" says "AVI Default File Handler" then the file is probably not interleaved at 1:1, and will not play from CD-ROM.

Any existing file can be re-interleaved, simply by editing the file, setting the "Interleave" parameter to 1, and re-saving the file back to disk. If the video in the file being re-interleaved is already compressed care should be exercised not to recompress the data; see the "Editing Compressed Video" section below for more details.

Setting the Key Frame Interval

This parameter controls the occurrence of "key frames" and "delta frames" within the compressed file. The periodicity and location of key frames and delta frames control a file's video quality and data rate. An in-depth discussion of key frames and delta frames is included in the "Supplemental reading" section at the end of this paper. Most editing applications' displays indicate the position of key frames within a video clip.

Indeo video's default "Key frame" setting is 4; this means that every fourth frame in the compressed video file will be a key frame. So in this example, the very first frame of the file is a key frame (because the very first frame of every compressed file is a key frame, by necessity), and the next three frames are deltas. Then the fifth frame is another key, the next three frames are deltas, and so on:

```
Kddd  Kddd  Kddd ...
```

The Indeo video default key frame interval of 4 will usually provide a good balance between video quality, data rate control, and CD-ROM playback performance. Developers can experiment with other settings in order to maximize video quality and playback performance of individual clips, since different types of video material may present special challenges and work well at different key frame intervals. Setting the key frame interval to an even number (Key Frame Every 4, 6, etc.) will generally produce files of higher visual quality and provide the decoder with better opportunities to drop frames when necessary. (For more information on dropping frames, see the discussion in the "Supplemental Reading" section.)

To determine the key frame interval of an existing file, open the file in Media Player. Pull down the "Device" menu and select "Configure". A dialog box will appear containing several useful pieces of information about the file, including the key frame interval.

Unlike audio/video interleave, the key frame interval of a compressed file cannot be changed without recompressing some or all of the file. Key frame interval must be set when a file is originally compressed; if you want to change the key frame interval of a compressed file it is best to recompress the file from the original Indeo video Raw source file.

Selecting CD-ROM Padding

This option should be selected if the file being compressed is intended to be played back from a CD-ROM drive; it should be de-selected if CD-ROM playback capability is not required. A more thorough explanation of what CD-ROM padding is and why it improves CD-ROM playback is included in the "Supplemental Reading" section at the end of the paper.

Editing Compressed Video

In general, editing already-compressed material can be complicated, and should be avoided. Edit your files while they're still in the Indeo video Raw domain. However, when necessary compressed files can be edited, but it's best to be aware of a few safety tips.

Avoiding Forced Recompression in Microsoft's VidEdit Application

When editing a video file that has been already compressed, it is important if possible to avoid recompressing the video when you save any newly created files or file segments to disk. If you open a file in VidEdit the was already compressed using Indeo video, the "Compression Method" will be initialized to "Intel Indeo™ Video R3.2". If you then edit and save a new file or file segment, the data will be de-compressed and compressed again using whatever compressor is selected in the "Compression Method" menu - in this case "Indeo™ Video R3.2". As previously discussed in the "Video Capture Formats" section, recompressing video which has already been compressed is analagous to making a tape of a tape; generation loss (degraded video quality) occurs. It also takes a lot longer, which is a good way to determine if recompression is occuring: if after editing a compressed file it takes a long time to save it back to disk, it's being recompressed.

To avoid forced recompression in VidEdit, select "No Recompression" in the "Compression Method" menu, and then use "Save", "Save as", or "Extract" to save the edited data to disk in a new file. The compressed video data will be saved back to disk "as is", without recompression.

If "No Recompression" does not appear as a "Compression Method" menu option, there are two possible reasons. First, you may have performed editing operations on the file which require that the data be recompressed. Such operations include changing the Target, Data rate, Key frame, or Quality settings; converting the playback frame rate; and cropping or resizing the video window. Performing any one of these operations will force recompression of the existing data, and as such this type of editing is best performed on Indeo video Raw files.

Second, you may have created a new file or video segment that does not start with a key frame. Here is an example of an editing situation which will force VidEdit to recompress the file:

Example #1: Creating a New File that Starts with a Delta Frame (Incorrect)

Source file (key frame interval is 4):

```
Kddd  Kddd  Kdd d  ...
0123  4567  891011  ...
```

1. "Mark in" on Frame #0
2. "Mark out" on Frame #1
3. Hit the "Delete" key on your keyboard, or select "Edit" and "Cut"
4. The new file will now look like this:

```
ddd  Kddd  Kdd d  ...
123  4567  891011  ...
```

This is no longer a valid file, because it does not start with a key frame, and if you pull down the "Compression Method" menu "No Recompression" will not appear as an option. VidEdit must decompress the new first frame (the first of the three delta frames) and recompress it as a key frame, using the old key frame you trimmed off as a reference. Also, the second and third delta frames are no longer valid, because they were compressed based on the original key frame; they too must be decompressed and recompressed as new delta frames, using the newly created key frame as a reference.

Once the next key frame (Frame #4 in the example) is encountered further recompression is unnecessary, because the key frame is self-contained and doesn't reference any previous frames. Applications like Adobe Premiere and Asymetrix Digital Video Producer support what might be called "limited recompression" and in those applications recompression would stop right here (this is explained in the next section), but VidEdit does not support this feature; instead it de-compresses and recompresses every frame in the file (this is why the "No Recompression" option doesn't even appear on the menu in this situation). The visual quality of the resulting file will suffer, and the recompression process takes more time than saving to disk without recompression.

To avoid forced recompression in VidEdit, always make sure that any new files or file segments created during an editing session start with a key frame. Here are some examples showing how to do this.

Example #2: Deleting Frames from the Front of an Existing File (Correct)

Source file (key frame interval is 4):

```
Kddd  Kddd  Kdd d  ...
0123  4567  891011 ...
```

5. "Mark in" on the first frame of the existing file (Frame #0)

6. Locate a key frame in the existing file that you want to be the first frame of the new, edited file (e.g., Frame #4)
7. "Mark out" on that key frame
8. Hit the "delete" key on the keyboard, or pull down the "Edit" menu and select "Cut"
9. The file will now look like this:

```
Kddd  Kdd d  ...
4567  891011  ...
```

VidEdit does not delete the frame you "Marked out" on, so it will now be the first frame of your new, edited file. Since the new first frame is a key frame VidEdit can save the new file back to disk without recompressing any data. If you pull down the "Compression Method" menu after executing the above steps, "No Recompression" will appear as an option.

Example #3: Extracting a Section of an Existing File to Create a New File (Correct)

Source file:

```
Kddd  Kddd  Kdd d  ...
0123  4567  891011  ...
```

10. Locate a key frame in the existing file that you want to be the first frame of the new, edited file (e.g., Frame #4)
11. "Mark in" on that key frame
12. Locate the frame in the existing file (key or delta, it doesn't matter) that you want to be the last frame of the new file (e.g., Frame #9)
13. "Mark out" on the frame after the "new last frame" (e.g., Frame #10)
14. Pull down the "Compression Options" menu and select "No Recompression" as the "Compression Method"
15. Pull down the "File" menu, select "Extract", and save the "Marked" section to disk under a new name.
16. The new, extracted file will now look like this:

```
Kddd  Kd
4567  89
```

Since you marked in on a key frame the new file starts with a key frame, and VidEdit doesn't have to recompress the extracted data.

Using Other Applications to Edit Compressed Video

As mentioned above, you should always try to avoid extensively editing material which has already been compressed. Should however you find it necessary to do so, and furthermore find it necessary to break the rules discussed above and create video segments that start with delta frames, all is not lost. In such circumstances applications like Asymetrix Digital Video Producer and Adobe Premiere come to the rescue by supporting what might be called "limited recompression", where only that recompression which is absolutely necessary occurs.

For example, assume an existing compressed source file with a key frame interval of 4:

```
Kddd  Kddd  Kdd d  ...
0123  4567  891011
```

Further assume that a segment consisting of frames 5 through 11 has been marked for extraction

```
ddd  Kdd d
567  891011
```

This sequence starts with a delta frame, which is invalid. The application therefore must decompress Frame #5 and recompress it as a key frame, using Frame #4 from the source file as a reference. Then Frames #6 and #7 must be decompressed and recompressed as new delta frames, using the newly created key frame as a reference. When Frame #8 is encountered recompression can stop. The new file will look like this:

```
Kdd  Kdd d  ...
567  891011  ...
```

The new file starts with a recompressed key frame and two recompressed delta frames; the rest of the file remains intact and experiences no recompression. It isn't perfect, but assuming the premise that it is necessary to edit compressed material and create a new file that starts with what was originally a delta frame, this technique will produce the best possible outcome.

Note that some editing applications, like Premiere and Digital Video Producer, do not feature an explicit "No Recompression" option in their "Compression" dialog boxes. To avoid recompression of (for example) Indeo video files select "Indeo Video" as the compressor when saving files to disk. The application will compare the format of the compressed input files to the output format selected and automatically not recompress

the data, or (as described above) compress only what is absolutely necessary.

Finally, it's a good idea to avoid editing together files compressed in different formats. For example, if you join together a file compressed using Indeo video and a file compressed using Microsoft's RLE* compressor, and select Indeo video as the save format, the RLE data must be decompressed and recompressed as Indeo video. Avoiding recompression is impossible when editing together files compressed in different formats.

Conclusion

Obviously, capturing and compressing digital video on the PC is a complex process. However, once the ideas presented in this discussion are assimilated, and some time is spent practicing the techniques described, the process will become second nature.

The important concepts that the reader should take away from this discussion are:

17. When creating video for CD-ROM publication capture the video using a high-quality format such as Indeo video Raw, and then compress offline using the Indeo video CD-ROM rate compressor.
18. When running the CD-ROM rate compressor under a Video for Windows editing package, proper selection of menu options and numerical settings is important to ensure the highest quality video at the lowest possible data rates.
19. Wherever possible editing should be performed on Indeo video Raw files. Editing compressed files is possible, but more complicated, and can result in recompression.
20. For help and advice on capturing and compressing Indeo video, and to obtain the latest software updates and technical information, contact the Indeo Technology Support group.

Supplemental Reading

Selecting a Target Data Rate

What data rate value to choose depends on a combination of factors; the selection process is an art, a science, and even a game of chance. The variables involved all relate to the system performance of the target playback environment,

and the most important of these is CD-ROM performance.

CD-ROM drives come predominantly in two flavors, "single-spin" (those theoretically capable of sustaining a data transfer rate of 150 Kbytes/second) and "double-spin" (those theoretically capable of sustaining a data transfer rate of 300 Kbytes/second). Triple- and quad-spin drives have recently hit the market, but they will be ignored in this discussion. Single-spin drives have been shipping since the mid-1980s, and as such still represent a large portion of the installed base; however sales of double-spin drives have skyrocketed by over 800% in 1993 and 1994, and no major manufacturer is currently selling any single-spin drives. Double-spin drives should represent the majority of the installed base by the end of 1994.

For the title developer and CD-ROM publisher the data rate choice comes down to this: a title authored for playback on a single-spin drive will run on more systems, but a title authored for double-spin playback will look and perform infinitely better. As a data point, Intel's Indeo Video Marketing and Technology Support groups have varying levels of contact and involvement with literally hundreds of CD-ROM publishers and multimedia title developers, and most of them now claim to be authoring titles aimed specifically at double-spin playback.

Are the numbers 150 Kbytes/second and 300 Kbytes/second real? Not really. There is a large difference between what most drives can deliver in hardware versus what they can actually deliver in a software applications environment. The problem is this: Windows uses DOS-based I/O to read a CD-ROM drive. This means that the CPU is involved in transferring every byte of data from the CD-ROM drive over the system bus and into system memory, and then processing the data (in this case, decoding the compressed video data) after it gets there. So slower CPUs, which might use more than 50% of their available cycles just decoding and displaying the compressed video data, will have fewer cycles left over to use in transfering data from the CD-ROM and are therefore limited to lower average data rates. Faster CPU's, which might use only 20%–35% of their available cycles for decode and display, will have more cycles left over with which to transfer data from the CD-ROM and can therefore support higher sustained data rates.

So how are target data rates determined? Mostly through testing and experience. As an example, Microsoft's Home applications like Ancient Lands* use video with an upper data rate limit of 90 Kbytes per second. Video at this data rate seems to play back on virtually any low-end system with a single-spin CD-ROM drive. In order to get acceptable video quality at this fairly low data rate, the video files are created at a resolution of 240 x 180, at 10 frames per second.

For double-spin playback many developers seem to have settled on 200 Kbytes/second. This is a high enough data rate that even video at 320 x 240 resolution, 15 fps, can be compressed with very high visual quality, but it is also a low enough data rate that even low-end CPU's can play the files from a double-spin drive without dropping frames. Applications targeted for higher-end systems, particularly those equipped with a Pentium™ Processor, can probably use data rates as high as 240 Kbytes/second.

To determine the average data rate of an existing file, open the file in Media Player*. Pull down the "Device" menu and select "Configure". A dialog box will appear containing several useful pieces of information about the file, including the average data rate in Kbytes per second.

Key Frames and Delta Frames

As previously mentioned in the "Real-Time vs. Offline Compression" section, Indeo video's CD-ROM rate compressor uses a combination of intra-frame and inter-frame encoding, in order to maximize visual quality while still being able to maintain CD-ROM-playable data rates. "Key frames" are frames which are only intra-frame encoded; that is, they are essentially still images, containing all of the visual information needed to display that video frame. "Delta frames" are frames which are also inter-frame encoded; that is, they do not contain all of the visual information necessary to display that video frame, but rather contain only information representing the parts of the frame that moved or changed from the previous frame.

Both types of frames serve very useful purposes, and both have trade-offs. Key frames are usually much larger in size than delta frames, but help to establish high image quality. Also, since key frames are self-contained and do not depend on any prior frame for decoding, they are randomly accessible within a file; file playback can begin from any key frame. Delta frames are usually much smaller in size than key frames, and as such provide an excellent way to control the data rate. However, delta frames

reference prior delta or key frames for decoding and so are not randomly accessible.

The first frame of every video file is a key frame, by necessity. After the first frame the CD-ROM rate compressor intersperses key frames periodically between strings of delta frames, to "refresh" the image quality. And this is what the "Key frame every" parameter controls: the periodicity with which those key frames occur.

For example, a file using the Indeo video default key frame interval of four will look like this:

```
Kddd Kddd Kdd d  ....
0123 4567 891011 ....
```

This default key frame interval of four will usually provide a good balance between video quality, data rate control, and CD-ROM playback performance. Developers can experiment with other settings in order to maximize video quality and playback performance of individual clips, since different types of video material may present special challenges and work well at different key frame intervals.

Besides balancing video quality with data rate control, another good reason to mix key frames and delta frames has to do with playback performance. Sometimes during video playback the video decode and display will start to lag behind the audio playback. This can be caused by systems with excessively slow CPU's and/or CD-ROM drives, or by files that were compressed at too high a data rate for a particular playback environment. When this slowdown occurs Video for Windows will attempt to speed up video playback, to allow the video to catch up with the audio. This acceleration is accomplished in one of two ways: by decoding but not displaying some video frames; or by not decoding some video frames at all. The interrelationship between key and delta frames becomes significant when frames are "dropped" (neither decoded nor displayed) during playback.

The effect of dropping a frame depends in part on what type of frame it is, and in part on the key frame interval. If a key frame is dropped (something which Video for Windows and the Indeo video decoder attempt to avoid at all costs) then every subsequent delta frame must be dropped until the next key frame is encountered. Files with higher key frame intervals will drop more frames. For example, a file with a default key frame interval of four would look like this:

```
Kddd Kddd Kddd  ...
0    4    8
```

If Frame #4 were dropped, then Frames #5 through #7 would have to be dropped; the next frame that could be decoded and displayed would be Frame #8.

But a file with a key frame interval of 12 would look like this:

```
Kddddddddddd Kddddddddddd Kddddddddddd ...
0            12           24           ...
```

If Frame #12 were dropped, then Frames #13 through 23 would have to be dropped; the next frame that could be decoded and displayed would be Frame #24.

If a delta frame is dropped the effect can vary. Some delta frames can be dropped without impacting the decode of any subsequent delta frames; some delta frames contain information about subsequent delta frames, and if one such delta frame is dropped the other subsequent delta frames must also be dropped.

In setting a key frame interval the goal is a good balance between visual quality, data rate control, and playback performance. Setting the interval to a more conservative value like the default of 4 will ensure that even in poor performance situations the dropping of key frames will not result in the dropping of an excessive number of delta frames. If CD-ROM playback performance is acceptable (which is more likely to occur, for example, when authoring for double-spin CD-ROM playback) then increasing the key frame interval can improve both data rate control and visual quality.

Finally, setting the key frame interval to an even number (Key Frame Every 4, 6, etc.) will generally produce files of higher visual quality, and provide the decoder with better opportunities to drop frames when necessary.

CD-ROM Padding

CD-ROM padding is "null" data which an application adds to the end of a compressed frame of video in order to adjust its frame size; after padding the size of each frame in a file will be an exact multiple of 2 Kbytes. In other words, padding essentially "rounds up" the size of each frame to the next highest multiple of 2 Kbytes. Note that padding does *not*, as popular misconception has it, make every frame the same size. After padding frames will still be varied in size, but they will all be an exact multiple of 2 Kbytes in size. Even though padding actually makes the file slightly larger, it

allows the file to play more efficiently from CD-ROM.

The reason for this improved efficiency has to do with the mechanics of CD-ROM data formatting and I/O software. The data on an ISO 9660-format CD-ROM is laid out in 2 Kbyte data "sectors". When an application requests that a piece of data (such as a video frame) be read from the CD-ROM disc, the CD-ROM driver software issues a "seek" command to the CD-ROM drive hardware looking for the requested data. "Seek" commands search for data by first locating the beginning of the 2-Kbyte sector in which that data resides. If the beginning of the data happens to start exactly at the beginning of the 2-Kbyte sector, the search for the data takes less time. If the beginning of the data lies somewhere within the 2-Kbyte sector, the search for the data will take longer. Therefore, a video file could be read with optimum efficiency from a CD-ROM drive if all of its frames started exactly at the beginning of 2-Kbyte sectors.

That's exactly what CD-ROM padding enables. When "Pad frames for CD-ROM playback" is selected, the editing application and the Indeo video CD-ROM rate compressor work together to ensure that the total frame size (the sum of the bytes in the audio chunk, compressed video chunk, RIFF headers, etc.) will be very close in size to an even multiple of 2 Kbytes. The application then writes a very small amount of "null" data into the frame to pad its size to an exact multiple of 2 Kbytes. When the file is written to CD-ROM all of its frames will start exactly at the beginning of 2-Kbyte sectors, resulting in faster playback and fewer dropped frames.

Contacting Intel

Organization	Type	Access	Notes
Indeo Video Developer Support Group	Voice	800-628-8686 Outside North America: +916-356-3551	Prompts 1-3-1; Ask operator for Indeo Video Developer Support
	CompuServe		GO INTELA, “Intel Arch. Labs” forum
	BBS	916-356-3600	Multimedia File Area
Smart Video Recorder Product Support	Voice	503-629-7000	
	CompuServe		GO INTELF, Intel Forum
	BBS	503-645-6275	
Document FAXBack	Fax	800-628-2283	
Literature Request	Voice	800-548-4725	
Service & Repair (U.S.)	Voice	800-INTEL-4-U	
Indeo Video Updates	CompuServe		GO INTELA, i750/Indeo(TM) Library
	BBS	916-356-3600	Multimedia file area
	Internet FTP	ftp.intel.com	/pub/IAL/Indeo_video /pub/PCandNetworkSupport/Smart_Video_Recorder
	AppleLink	Intel Updates Folder	Third Parties, 3rd Party Demos/Updates, Software Updates, Companies E-J, Intel Corporation
Europe: Support and Service	Voice	+44 793 431144	Indeo™ Video, iSVR, iSVR Pro, ProShare