SunVideo and Digital Video

Technical White Paper

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SunVideo and Digital Video

The SunVideo™ board is a real-time video capture and compression subsystem designed for Sun Microsystems Computer Corporation (SMCC) SPARCstation™ systems. The single-wide SBus card captures, digitizes, and compresses NTSC or PAL video signals from video cameras, VCRs, videodisc players, and other sources. Compressed digital video produced with the SunVideo board is then available to be transmitted over networks, stored on disk, or displayed by the host CPU in a window on the workstation screen.

The SunVideo system is an essential enabling technology for implementing multimedia applications such as video conferencing, video mail, or compound document creation incorporating video clips for training or presentations.

This technology offers access to video as another data type to be manipulated by the computer for a host of applications. With a single card, video can be captured for use in presentations or as an element in a multimedia training or information system. Recipients of broadcasts of digital video for announcements or lectures do not need any special video hardware. Video conferencing applications supporting multiple simultaneous users are possible when the participants all have capture and compression capabilities, provided by the SunVideo board.

This paper provides information on the philosophy, design, and functionality of the SunVideo board. It reviews applications enabled by this technology. Then, since digital video is relatively new, it includes a brief background on video and video compression. The appendix lists applications that support the SunVideo board and includes a bibliography of in-depth references to topics covered.

Suns Video Strategy

The driving force behind video in the computer market is the ability to access and manipulate video for communication, training, or other information content. Viewing entertainment on workstations is not key to most of our customers. However, news feeds, corporate video broadcasts, and distance learning are being requested today as part of the digital data network traffic.

Video Implementation

Sun's approach has been to add as much video capability to the basic platform as possible without increasing cost to those who do not need video. The result is a separation of the capture and compression problem from the decompression and display problem (Figure 1). Far more users require decompression and display. The SPARC CPU and standard frame buffer provide the capability for video display on all Sun workstations today. This makes every Sun SPARCstation™ system video-capable when coupled with Solaris LIVE!™ multimedia software. Users who require capture and compression capability can purchase a SunVideo board, and not pay the extra cost for an additional frame buffer that may have lower graphics performance for their primary application, for example, CAD.

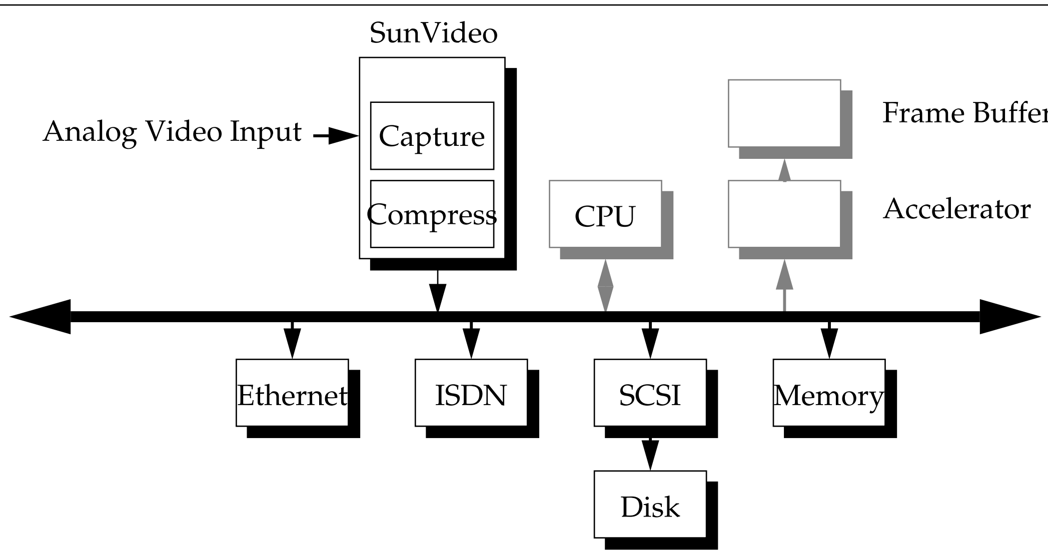

Figure 1. - Block diagram of SPARCstation with the SunVideo board installed.

The SunVideo card is not intended to provide simple “video in a window” capability. This capability is not particularly important to collaborative workgroup computing because you cannot process, transmit, or manipulate the video. Sun also expects third parties to continue to provide solutions for NTSC or PAL video output.

Hardware

The SunVideo board is supported on most SMCC SPARC desktops: SPARCclassic™, SPARCstation LX, SPARCstation 1, SPARCstation 1+, SPARCstation 2, SPARCstation IPC™, SPARCstation IPX™, SPARCstation 10. It is compatible with GX, TurboGXPlus™, ZX, and SX framebuffers. Solaris® 2.3 is the minimum required operating environment. A camera is not included, but is offered as a bundled option on the SMCC price list (X487A). The SunVideo board (X1085A) will begin shipment in November 1993.

The SunVideo board (block diagram shown in Figure 2) is a single-wide, fully compliant SBus card. Through applications, you can select from 2 composite and 1 S-Video inputs. The SunVideo card senses whether the source is NTSC or PAL and configures itself appropriately. The video is sampled as square pixels in 4:2:2 format. The compression engine is a C-Cube CL4000 multi-standard video codec. Microcode for the particular compression technique chosen is downloaded to the board.

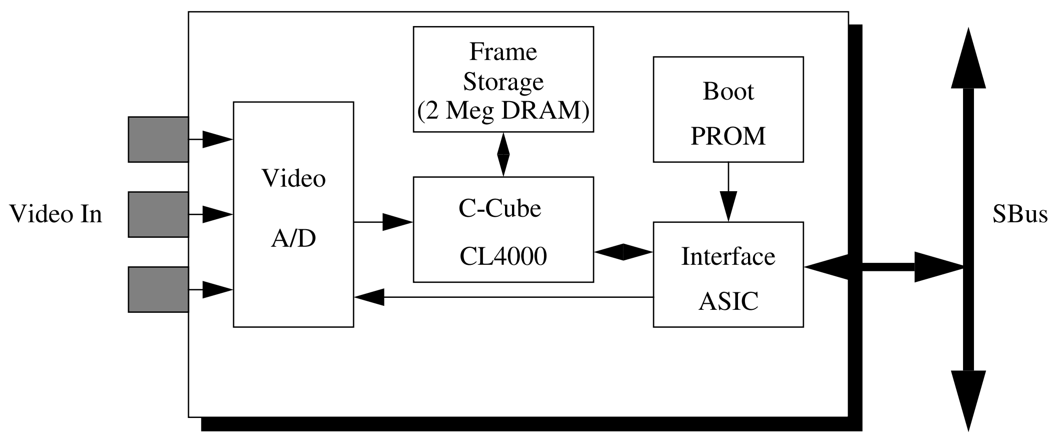

Figure 2. - Block diagram of the SunVideo SBus card showing the major components.

Software

The software interface to the SunVideo card is the XIL™ library version 1.1 bundled with Solaris® version 2.3. Algorithms supported are uncompressed capture, CellB, JPEG, and MPEG-1. Accelerated XIL molecules are included for the most common operations (for example, capture and dither to 8-bit indexed display).

The XIL 1.1 runtime routines enabling capture, compression and decompression as well as the SunVideo driver are bundled with the Solaris®2.3 operating system, so no additional software is included with the SunVideo board. The user simply uses the `pkgadd` command to install the software as documented in the user manual. Software developers require the Solaris SDK and SPARCworks ™ compilers tocreate applications for the board.

Example code (including source) is provided. It demonstrates how to capture and compress video, display it on the frame buffer, or transmit it over the net. Application software is not included, but provided by third parties. See the appendix for applications currently available.

Performance

Video performance is influenced by three factors: SunVideo/CL4000 compression capabilities, bus bandwidth, and workstation decompression performance. SunVideo capture and compression performance is presented in detail below. The board currently is capable of transferring data at 5 Mbytes per second over the SBus using programmed I/O. Decompression and display performance is influenced by:

- CPU capabilities (MIPS especially),
- whether the frame buffer accelerator has capabilities that can accelerate decompression (SX, for example),
- the SBus bandwidth to the frame buffer accelerator,
- whether there is a direct XIL port to the particular frame buffer (if not, Xlib™ software is used and performance is not as good), and
- the complexity in color, space and time of the particular data set.

Table 1 Table 1 gives functional performance of SunVideo for the different algorithms. These parameters are able to be set using the XIL library calls. The application will expose some of this to the user for control of the video performance.

Algorithm	Typical Bits/Pixel	Bandwidth 320 x 240 at 30 FPS in Mbit/sec	Scale	X,Y Start	Width, Height
Capture - 8 bit	8	17.6	1/x, x = 1 to 32	Any 4th pixel	Any 4th pixel
Capture - 24 bit	24	52.7	1/x, x = 1 to 32	Any 4th pixel	Any 4th pixel
CellB	0.8	1.8	1/x, x = 1 to 32	Any 4th pixel	Any 4th pixel
MPEG-1 I-Frame	1.5	3.3	1/2	0,0	320 x 240 (SIF)
MPEG-1 I,P-Frame	1.0	2.2	1/2	0,0	320 x 240 (SIF)
JPEG	0.8	1.8	1/2	0,0	320 x 240 (SIF)

Table 2 Table 2 gives raw SunVideo capture and compression performance. These are the rates at which data can be captured and sent to disk, or displayed *if the decompression performance were not the limiting factor.* These numbers are quoted for typical data sets. Performance may not meet these specifications

Algorithm	NTSC			PAL		
	Full Resolution 640 x 480	SIF 320 x 240	QSIF 160 x 120	Full Resolution 768 x 576	SIF 384 x 288	QSIF 192 x 144
CellB	12	30	30	7	25	25
MPEG-1 I-Frame	N/A	30	No	N/A	25	No
MPEG-1 I,P-Frame	N/A	17	No	N/A	12	No
JPEG	No	30	No	No	25	No
Capture only YUV	6	30	30	.1	24	25
Capture only RGB-8	6	30	30	.1	8	18
Capture only RGB-24	2	12	26	2	8	18

Table 3 Table 3 factors in the decompression performance and shows for a sample set of platforms simultaneous capture, compression, decompression, and display performance for SIF sized NTSC video in frames per second.

Algorithm	LX	SS10/40 GX	SS10/40 ZX 8 bit	SS10/40 ZX 24 bit	SS10/40 SX 8 bit	SS10/40 SX 24 bit
CellB	30	30	30	6	30	8
MPEG-1 I-Frame	6	9	9	5	9	5
MPEG-1 I, P Frame	6	9	9	5	9	5
JPEG	7	16	15	8	15	14
RGB capture only	30	30	18	5	28	12

Applications

The SunVideo card enables the capture and manipulation of video for use in a wide variety of application areas. Broadly speaking the areas can be categorized as:

- Collaborative communication: conferencing or corporate broadcasting;
- Distance learning: instructor or trainer either live or pre-recorded;
- Interactive services: video-on-demand or video library services.

Additional market segments that can take advantage of the SunVideo card include surveillance applications, manufacturing process control, telemedicine, and new markets that will take advantage of the growing global information highway.

The SunVideo board will not be shipped with any application software. The example areas discussed here are not meant to be an exhaustive list.

Video Conference and Groupware

Video conferencing can reduce the cost of doing business in the competitive global environment. Recent surveys have shown that companies spent $400 million on video conferencing in 1992, primarily room-type systems or services. The emergence of desktop video conferencing capabilities and interoperability standards (Px64 and H.261) has begun to shift the market toward this lower cost, personal approach. Industry estimates suggest that 13%

of the $712 million expenditure on video conferencing in 1993 will be on desktop systems. (Sources: Frost and Sullivan Market Intelligence, Arvai Group.)

Why desktop video conferencing? Users report that rooms dedicated to video conferencing are difficult to schedule, expensive to install and maintain, and disrupt the normal flow of work. Also, with desktop video conferencing you can share work with your remote sites, not just audio and video. This may ultimately be the more valuable enhancement to businesses. Most knowledge workers create reports, memos, spreadsheets, documents, and creative designs with the aid of their desktop equipment. The ability to share, review, and even modify materials in real time with a remote colleague is the most compelling advantage over room or roll-about video conference systems.

Distance Learning or Training

As companies spend more money and time training and retraining employees, education and employee support systems are finding greater use and interest. Training expenses today are dominated by the cost of delivery: down time for travel, training at multiple locations, train the trainer, and so on. Using on-line or remote linked training to a single facility has benefits that are repeated with every new hire or job transfer.

Video is an important element in training systems since it is inexpensive to tape an expert instructor with questions and answers from a live audience, then use this video for remote or later training needs. With SunVideo capabilities, digital video can be stored as part of the graphic slides and other course material to provide a rich learning environment on an as-needed basis rather than scheduled classroom activity. Some implementations include facilities to interactively communicate with an instructor or expert when the student requires additional information. This can be supported from a centralized facility.

Broadcast or Video Server

Recent activity in the cable, telephone, and entertainment industries has created tremendous interest in “video on demand” or interactive services. The SunVideo board enables the creation, in real-time, of quality MPEG1 video suitable for video archival applications. Libraries of VCR tapes can be stored as digital data and requested over the network using client/server video software.

Video Authoring

Software for creating video is now available at lower costs while offering functionality previously seen only in expensive post-production suites. The SunVideo card offers a platform for editing solutions with its ability to perform JPEG compression. Coupled with the external device control capabilities of Solaris LIVE™!, both non-linear and off-line editing applications are available in this application area.

Video Mail

Present desktop mail systems allow the attachment of graphics, audio, and other specialized multimedia objects to electronic mail. The SunVideo card enables creation of video clips to send through a mail system. This is a corollary to the video conferencing capability where the information is stored and forwarded to the recipient rather than being consumed in real-time.

Novel implementations of this concept enable project notes, video conferences, and relevant material to be stored on servers for access at any time by members of the project team. Video mail represents a portion of this capability.

Video on CD-ROM

Recent standardization of CD-Video, a file format that enables up to 72 minutes of full-motion video, is expected to increase the availability and use of video on CD. Titles are being developed now that can be played in standard audio CD players. With CD-ROM XA-capable equipment, the same discs provide video in addition to high-quality audio. Coupled with the new Sun CD-ROM drive with its XA and double-speed capabilities, the SunVideo card offers a platform for development and delivery of this new information.

Video Technology Review

Analog and Broadcast Standards

Video for broadcast or for use in consumer equipment typically conforms to either the NTSC (National Television System Committee) standard developed in 1953 and in use in the Americas and Japan, or the PAL (Phase Alternation Line) standard developed in Germany. (The SunVideo card supports both these standards but not the SECAM standard used in France and a few other countries.) NTSC video consists of alternating fields every 60th of a second which combine to form a complete video frame at 30 per second. PAL and SECAM provide fields at 50 per second or frames at 25 per second. The actual resolution in pixels and lines is slightly different but often approximated as 640x480. Most televisions do not support this full pixel resolution (unlike personal computer monitors and workstation displays) since the signal is interlaced and only half the lines are needed each sweep.

If video is stored as a sequence of “true-color” (24-bit) images without compression, each second would require approximately 27 megabytes (Mbytes) of storage. Translated to bits, this yields a staggering 216 megabits (Mbits) per second, well in excess of most commonly available network transmission bandwidth. (ATM or asynchronous transmission mode networks are now being deployed with speeds to the gigabit per second range.)

The coding for NTSC and PAL analog video takes advantage of the human visual system’s reduced ability to discriminate color in motion images and actually encodes fewer than 24 bits per pixel. By breaking the signal into luminance or brightness and chrominance or color and modulating the signal, analog video signals can be transmitted in 6 megahertz (Mhz) bands.

Analog video signals, whether composite or S-video, are digitized by sampling the waveform at about three times the nominal frequency of the incoming signal. For NTSC video (4.5 Mhz signal) this means a sampling rate of about 13.5 Mhz. The resulting sample is then quantized or digitized to discrete values for translation into a pixel representation.

The SunVideo board essentially conforms to the CCIR 601 standard 4:2:2 YUV representation of digital video as its captured format. This corresponds to 8 bits of luminance (Y) and 4 bits each for the chrominance (U and V). This produces an image indistinguishable from the original signal, when properly displayed, requiring one-third less data than the original 27 Mbytes per second estimate. Compression methods are needed to further reduce this 18 Mbytes per second stream of digital video in order not to swamp communications or bus links in the computer. (See the bibliography for further information on analog video and video capture.)

Note – Broadcast video and the computer graphics world are at odds on the representation for digital video. Computers deal with square pixels and video deals with an analog signal in the horizontal direction and discrete scan lines vertically. Strictly speaking, the CCIR 601 standard would result in non-square pixels. The SunVideo system and most computer video deals with a square pixel approximation, preserving the 4:3 aspect ratio of today's video format.

Bandwidth and Compression

All but the most advanced computer or network communication links are quickly loaded even with a 4:2:2 YUV stream of 18 Mbytes per second. On the Sun SPARCstation workstation, the peripheral bus system is an SBus capable of greater than 50 Mbytes per second in burst mode. Sustaining this rate to disk drives or a network while other processes are occurring is not presently possible. Further compression is a must for normal use.

Video may be reduced in bandwidth by simply reducing the frame rate and/or the frame size. Using an averaging and decimation process can yield a further reduction in bandwidth by a factor of 4. The result is a 320 by 240 data stream at 30 frames per second (fps) requiring 4.5 Mbytes per second. Using the capabilities of the SunVideo card this is one possible full motion stream available. Further reduction in frames size is typically not satisfactory.

Note – The standard interchange format (SIF) is 320 by 240 and is confused with the common interchange format (CIF) which has a size of 352 by 288.

Compression methods can be characterized as lossless or lossy. Lossless methods such as run-length encoding cannot reduce the data by more than a factor of 2 or 3. An advantage to such methods is their relative simplicity for both compression and decompression. The JPEG standard for still images includes several of these lossless methods. With lossy compression methods the errors in the decompressed image may not be noticeable, particularly in video applications where the individual frames are displayed at 30 fps and cannot be critically scanned.

Lossy methods such as those using the DCT (discrete cosine transform) method followed by quantization in both physical space and color space provide compression up to about 15:1 with little visible error. The SunVideo board creates JPEG compressed digital video in this manner. Methods where differences between successive frames is also encoded provide further compression advantage. Examples of these are MPEG, H.261, and Cell. Compression up to 200:1 is possible while still retaining reasonable quality upon playback.

Compression, if lossy, will introduce some artifacts in the resulting decoded image. The severity of the error can be controlled through the use of different lookup tables or Q factors for the spatial compression. In any case, compression ratios achieved vary depending on the quality of the input signal, the content of the video stream, and the parameters used in the compression steps. Compression ratios should be used as a range not as an absolute number.

Compression Techniques

The need for standards in digital video is obvious. One of the best examples of an image standard becoming rapidly adopted and integrated into everyday life are the fax standards Group III and Group IV. Unfortunately, the bandwidth requirements of video have not produced such a simple standard.

The SunVideo card is unique in its ability to handle multiple compression standards because of its powerful microcoded compression engine. This section briefly discusses three algorithms that are supported by the SunVideo card, and another that could be added in a future software release.

JPEG

As mentioned earlier, the Joint Photographic Experts Group (JPEG) standard actually consists of a host of algorithms for still image compression. Most implementations, however, are referring to the lossy DCT method that will be discussed in some detail here.

Originally designed for still images, the JPEG method performs compression for video sequences by compressing each frame as an individual image. Each band of the input digital uncompressed frame is first broken into blocks of 8-by-8 or 16-by-16 pixels. Each block is then transformed via the DCT (discrete cosine transform) method, producing coefficients describing the spatial complexity of the image. Low-frequency coefficients (large spatial extent) are quantized with more care than the higher frequency coefficients (small detail) to enable a greater compression. The frequency domain coefficients are then encoded using standard Huffman tables to reduce on average the number of bits required for the codes. Typically the user can alter the Q of the encoding. A low Q results in a more accurate representation of the image and hence a lower compression ratio. High-quality video can be produced with this method using 4-10 Mbits per second. This is within the bandwidth for disk drives and displays but beyond the range of CD-ROM or T1 communication lines. Since all the compression is on a frame by frame basis, the algorithm is nearly symmetric in the amount of work to encode or decode.

Only future general purpose CPUs will be able to keep up with the special purpose JPEG encoders and decoders on the market today. High-end workstations can decode JPEG in software at nearly 30 fps today. Many JPEG only encoder/decoder boards are available today and are used particularly for non-linear video editing applications.

MPEG

The Moving Picture Experts Group (MPEG) has agreed on the first of a series of standards, MPEG-1, geared for CD-ROM or T1 bit-rate transmission. At 1.5 Mbits per second, the algorithm uses both interframe and intraframe coding to achieve quality video at this lower bandwidth. The input to the process using the SunVideo board is SIF resolution data almost exactly one quarter of CCIR 601 (720 by 486).

MPEG-1 provides for three types of frames: I, P, and B. The I frames are essentially the same as JPEG frames. The complete information for the frame is encoded and transmitted. To get the reduction in bandwidth necessary to meet the CD-ROM speeds, adjacent frames are compared in macroblocks of 16-by-16 pixels to determine regions that have changed between frames. (This is a very compute intensive operation and can result in the introduction of motion artifacts.) A P frame is a predicted frame based on a past frame(s) while a B frame is interpolated from both directions. This interpolation and comparison process requires sufficient storage and delay to handle multiple frames, but results in a higher quality final image for a given bandwidth.

One of the effects of this interframe coding is that rewind and playback require significant computations and buffering, resulting in reduced speed. Getting to a particular frame may require decoding from the last I frame. In the worst case you may have to reconstruct 29 frames since the I frames can be placed as far as every 30 frames apart.

MPEG-1 is a highly asymmetric algorithm requiring much greater computation to encode than to decode. Even so, the demands on decoding are greater than that of JPEG. For the most demanding applications, dedicated decoding boards may be appropriate unless a multiprocessor configuration is used. Only the high-end Sun SPARCstation workstations provide full frame-rate decompression in software. Next-generation workstations are expected to handle 30 fps software decoding with power to spare.

H.261

This is the video component of a video conferencing standard known as Px64 that is meant to be utilized on communication lines that have multiples of 64 Kbit capacity. The larger the multiple of 64 (up to 29) the higher the bandwidth, and hence, the better the quality of the video. Below 384K or 6 times 64 it is difficult to get quality full-frame rate, CIF-size images. For this reason, H.261 is defined for both CIF (352 by 288) and QCIF (176 by 144). Tests have determined that the quality of image is less critical for video conferencing applications than for typical broadcast or authored applications. Instead, more attention is placed on other aspects, including audio quality and system level signalling.

Like JPEG and MPEG, H.261 is DCT- based. It uses motion estimation within a small radius (reducing the computation requirements on both encode and decode as compared with MPEG-1) but produces visible artifacts for fast-moving objects. These trade-offs were needed to stay within the low bandwidths allowed by ISDN and other low-speed wide area network links.

Px64 has been adopted by manufacturers of room-sized video conferencing equipment. This will enable desktop conferences to join with a group served by a large system such as Compression Labs or PictureTel. These companies offer an option to use the standard method rather than their own proprietary algorithms.

The initial release of the SunVideo board driver does not support H.261, but this support could be included in future releases. The SunVideo board would only addresses the video component, application developers are expected to work on the full H.320 family that includes audio and transmission layers.

Cell

CellA and CellB are compression techniques developed at Sun that enable extremely fast software decompression. The algorithm and bit-stream definitions are completely open. CellA is designed for applications such as CD-ROM playback or distance learning where the data is compressed once and used many times. Image quality for a given bit rate is high. Compression is performed in software using the XIL™ library. CellB is designed for applications such as video mail or video conferencing where the compression must be performed in real time. Image quality at low- bit rates is good. The SunVideo card supports CellB compression.

Both CellA and CellB represent each 4-by-4 pixel block with a 16-bit bitmask and two 8-bit vector quantized codebook indices. This produces a compression of 12:1 since each 16-pixel block is represented by 32 bits (16-bit mask, and two 8-bit codebook indices). Further compression is accomplished by checking current blocks against the spatially equivalent block in the previous frame. If the new block is "close enough" to the old block, the block is coded as a skip code. Consecutive skip codes are run-length encoded for further compression. Modifying the definition of "close enough" enables one to trade off quality and compression rates. Both versions of Cell typically compress video images to 0.8 to 0.4 bits per pixel.

Both versions of Cell have many similar steps in the early part of compression. For each 4-by-4 block, the compressor calculates the average luma of the 16 pixels. It then partitions the pixels into two groups: those whose luma is above the average and those whose luma is below. The compressor sets the 16-bit bitmask based on which pixels are in each partition. The compressor then calculates a color to represent each partition.

In CellA, the compressor calculates an average color of each partition and then does a vector quantization against the Cell codebook (a color-map). The encoded block is the 16-bit mask and the two 8-bit colormap indices. The compressor maintains statistics about how many errors each codebook entry is responsible for and how many times each codebook entry is used. It uses these numbers to adaptively refine the codebook on each frame. Changed codebooks are sent in the bitstream.

In CellB, the compressor calculates the average luma for each partition and the average chroma for the entire block. This results in two colors with representation in YUV: <Y_lo, Cb_ave, Cr_ave> and <Y_hi, Cb_ave, Cr_ave>. The pair <Y_lo, Y_hi> is vector quantized against the Y/Y codebook and the pair <Cb_ave, Cr_ave> is vector quantized against the Cr/Cb codebook. Here the encoded block is the 16-bit mask and the two 8-bit VQ indices. Both of CellB's codebooks are fixed, which allows the compressor and decompressor to use table lookups and therefore run at high speed. The entries in each codebook are not a uniform partition of the Y/Y and Cr/Cb color spaces, but are based on the eye's sensitivity to contrast.

Beyond SunVideo

Future enhancements of the SunVideo driver software which is accessed through the XIL™ library may include H.261 support, MPEG-1 I, P, and B frame support, and MPEG-1 performance improvements. Video playback performance will also be improved with XIL™ library enhancements and higher performance of future SMCC workstations.

Because the SunVideo board is a programmable compression engine, additional algorithms can be supported if there is sufficient market demand.

Appendix

Application Vendors

A number of independent software vendors (ISVs) have already created applications supporting the SunVideo board. This list will be updated as new systems are created.

The SunSolutions™ independent business unit within SMI has announced their support for the board for use in collaborative communications. Contact John Quist at (415) 336-9852.

InSoft offers several products including their Communique!™ package for conferencing and shared whiteboard. Contact Sales Support at (717) 730-9501.

Paradise Software offers a Client/Server Video solution offering live or stored video from network servers to be accessed by clients across the enterprise. Contact Paradise at (609) 275-4475.

Apunix has created ImageEdit a system for capturing and manipulating video for a variety of applications. Contact Apunix at (800) 8AP-UNIX.

AimTech provides multimedia authoring capabilities including VideoEdit for the creation of training, presentation or other interactive systems. Contact AimTech at (603) 883-0220.

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XIL 1.0 Programmer’s Manual

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