

BC9-92-115

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☒ Description : paged ..A.... to paged	
☒ Claim(s) : paged ..A.... to paged	
☒ Drawing(s) : paged ..A.... to paged	
☒ Abstract : paged ..A.... to paged	
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**PERSONAL COMPUTER WITH MOTION VIDEO REAL TIME CAPTURE,
COMPRESSION, AND RECORDING**

This invention relates to the field of data processing, and more particularly to improvements in a personal computer system and method of operating the system to provide for the real time capture, compression, and recording of motion video.

Recording of digital motion video in real time without compression produces an excessively high data rate that exceeds the file I/O transfer capabilities of many personal computer systems. A high data rate produces large files that quickly exhaust disk storage thereby reducing the length of recordings that can be made with a given amount of disk storage. While real time compression of motion video during recording can be accomplished with compression assisted by specialized hardware, a software motion video compression algorithm that executes in real time in the main processor of recording practical when low-cost video capture devices, without hardware compression, are used.

Since the computational complexity of most software-only motion video compression algorithms is too great to execute in real time, motion video recording is often performed frame-by-frame, and the image data is compressed during the capture process. While this method generally produces high quality and compression, it has the disadvantage that recording requires costlier "frame stepping" source devices such as video disks which may also entail conversion of source media. This method of recording is time consuming and precludes capture from "live" sources such as video cameras.

Real time capture can be accomplished in a software only environment by capturing raw data and transferring it to disk, compressing it later in non-real time. One drawback to such approach is that capturing raw motion video data at an acceptable resolution and frame rate results in an excessively high data rate. For example, capturing a 160 x 120 image with 16-bits per pixel at 15 frames per second, results in a raw data capture rate of 576,000 bytes per second. This data rate exceeds the available disk file I/O rate of many commonly available personal computer systems. Furthermore, motion video capture is usually accompanied by a digital audio capture which further increases

the data rate. Even in systems that can sustain the required data transfer rates, the volume of data that is produced limits the length of time that can be recorded. A 200 megabyte hard disk holds only about five minutes at 576,000 bytes per second. Another drawback is that
5 second pass compression, which generally acceptable for capturing recorded video data, does not work for live video capture/playback applications such as video conferencing.

Specialized digital video capture adapters with hardware support for compression solve these problems by enabling real time compression
10 with compression. However, such adapters are relatively costly and have a smaller installed base than the more common video capture adapters that do not support specialized hardware-based compression.

It is therefore an object of the invention to provide improved real time motion video data compression and recording. This object is
15 achieved by the personal computer system claimed in claim 1.

An embodiment of the invention will now be described, by way of example, with reference to the accompanying drawings, wherein:

Fig. 1 is a block diagram of a personal computer system embodying
20 the invention;

Fig. 2 is a schematic diagram illustrating the primary data flow for capturing, compressing, and recording motion video data in the system shown in Fig. 1;

Fig. 3 is a schematic diagram illustrating phases of operation of
25 the embodiment for preselected modes of operation;

Fig. 4 is a diagram illustrating various data structures used for the compression of data in accordance with the embodiment;

Fig. 5 is a schematic block diagram illustrating data tables and how they are accessed; and

30 Figs. 6-9 are flow charts of different operating phases of the embodiment.

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Referring now to the drawings, and first to Fig. 1, there is shown an exemplary multimedia data processing system (DPS) comprising a personal computer 10 operable under a multitasking operating system such as OS/2 Version 2.0, to execute application programs. Computer 10
5 comprises a microprocessor 12 connected to a local bus 14 which, in turn, is connected to a bus interface controller (BIC) 16, a math coprocessor 18, and a small computer system interface (SCSI) adapter 20. Microprocessor 12 is preferably one of the family of 80xxx microprocessors, such as an 80386 or a 80486 microprocessor, and local
10 bus 14 includes conventional data, address, and control lines conforming to the architecture of such processor. Adapter 20 is also connected to a SCSI hard drive (HD) 24 which functions, among other functions, to store files of data compressed in accordance with the invention as described in more detail below.

15 BIC 16 performs two primary functions, one being that of a memory controller for accessing a random access memory (RAM) 36 and a read-only memory (ROM) 38. RAM 36 is a dynamic random access memory that function as the main memory for storing data and programs for execution by microprocessor 12 and math coprocessor 18. An address and control bus 37
20 connects BIC 16 with memory 36 and ROM 38. A data bus 39 connects memory 36 and ROM 38 with a data buffer 41 that is further connected to data bus 14D of bus 14. Control lines 45 interconnect BIC 16 and data buffer 41.

The other primary function of BIC 16 is to interface between bus 14 and an expansion bus 44 designed in conformance with Micro Channel (MC)
25 architecture. Bus 44 is further connected to an input/output controller (IOC) 46, a video signal processor (VSP) 48, a digital signal processor (DSP) 49, and a plurality of expansion connectors (EC) or slots 50. VSP 48 is further connected to a video RAM (VRAM) 60 and a multiplexor (MUX) 62. VRAM 60 stores text and graphic information for controlling what
30 appears on the screen of a monitor 68. MUX 62 is further connected to a digital to analog converter (DAC) 66 and to a connector or terminal 70 that is connectable to a video feature bus (VFB). DAC 66 is connected to monitor 68 that provides a conventional output screen or display for viewing by a user.

35 IOC 46 controls operation of plurality of I/O devices including a floppy disk drive 72, a printer 74, and a keyboard 76. Drive 72 comprises a controller (not shown) and a removable floppy disc or

diskette 73. IOC 46 also is connected to a mouse connector 78, a serial port connector 80, and a speaker connector 82 which allow various optional devices to be connected into the system.

DSP 49 is further connected to an instruction RAM 84, a data RAM 96, an analog interface controller (AIC) 88, and an audio controller (90). RAMs 84 and 86 respectively hold instructions and data used by DSP 49 for processing signals. Audio controller 90 controls various audio inputs and outputs and is connected to a plurality of connectors 92 by which various devices can be connected to the system. Such devices include a headphone, a microphone, a speaker, a musical instrument digitizing interface (MIDI), and devices requiring an audio line-in and line-out functions.

Memory 36 stores various programs for execution in the system, which programs include an operating system (OS) 102 and a motion video recording program (MVRP) 104. Program 104 is an application program that runs under the operating system and has various threads, discussed below, which are concurrently executed as multitasks to provide real time motion video recording of data from a video input device 96 such as a video camera. Device 96 is connected to a video digitizer 100 in a video capture adapter 94. A video buffer 98 is also included in adapter 94 and is connected to receive uncompressed motion video data from digitizer 100. Adapter 94 is connected through an expansion connector 50 to bus 44 and the rest of the system allowing the adapter and video input device to be operated under the control of motion video recording program 104.

The general operation of the system, while MVRP 104 is being executed, is schematically shown in Fig. 2, to which reference will now be made. The flow of data occurs along the thicker lines in this figure and starts with analog data from video source 96, which is transmitted into digitizer 98. Digitizer 98 converts the analog input into pages or frames of digitized data and transmits the frames into video buffer 100. Each frame comprises a number of pixel values corresponding to the number of pixels used to capture the momentary "picture" or image seen by the video source. Each digitized pixel value contains 16-bits (two Bytes) of information represented in the well known RGB16 (red-blue-green sixteen bit) format of five bits for the red value, six bits for the blue value, and five bits for the green value. The frames in video buffer 100 are uncompressed and are transmitted in an input data stream (IDS) as

uncompressed frames UF having a sequence of pixels values PV1-PVn (where "n" corresponds to the number of pixels per screen image) into a data input buffer 110 in RAM 36 to form a first-in, first-out (FIFO) queue of uncompressed frames UF1-UFn. After each frame has been processed and compressed, it is placed in an output buffer 112 of RAM 36 as a FIFO queue of compressed frames CF1-CFn from where the frames are sequentially transmitted in an output data stream (ODS) and recorded in a file on fixed disk 24. The files can be later uncompressed or expanded, following a reverse of the compression process, and transmitted to a viewing device, such as a monitor, for viewing the motion video thus recorded.

The general operation described in the preceding paragraph is under the control of microprocessor 12. When digitizer 98 converts enough samples of the analog input to complete a frame, it sends an interrupt signal to interrupt controller 99 which in turn transmits an interrupt request to microprocessor 12 causing an interrupt handler to produce a signal allowing a video input thread 105 to copy the completed frame to queue 110. Thread 105 may also provide scaling of the data. Thread 105 is part of MVRP which operates under the control of OS 102 along with a video compression thread 106 and a file writer thread 107, on a multitasking basis. These threads create a data stream in which raw digitized motion video data is inputted in the IDS from buffer 100 into RAM 36, compressed by video compression thread 106 in the manner described in detail below, and written to a file in disk 24 by file writer 107 on a real time basis. In a conventional way of multitasking, each of the threads is sequentially allotted a separate execution time by OS 102 so as to impart a perception to a user that all three threads are being executed simultaneously when in fact the microprocessor executes only one thread at a time. Video input thread 105 controls the filling of input buffer 110 with frames of digitized data from video buffer 100. Video compression thread 106 processes frames from buffer 110 with frames of digitized data from video buffer 100. Video compression thread 106 processes frames from buffer 110 one-at-a-time, compresses data therein as described below, and writes compressed frames to buffer 112. During the course of such processing, thread 106 accesses information in various data tables (DTs) 121 stored in RAM 36. File writer thread 107 writes or records the frames from buffer 112 in hard disk 24. The control over such functions is represented in Fig. 2 by the respective lines 113, 115, 117, and 119.

The operation of video compression thread 106 is selectively done for individual frames in either one of two modes, an inter-frame mode or an intra-frame mode. The inter-frame mode produces delta-frames and the intra-frame mode produces I-frames. An I-frame contains in itself all the information necessary to produce an image. A delta-frame, on the other hand, contains differences relative to previous frames and thus depends on and needs information in one or more previous frames to produce an image. When successive images are not changing rapidly, the inter-frame mode is advantageous because the delta-frames can be compressed to a greater degree than I-frames. The first frame of an ODS needs to be an I-frame but the remaining frames can be all delta-frames or a mixture of delta-frames and I-frames. A mixture may be used when the resultant file is to be played back with a fast forward feature. In such a case, I-frames can be inserted periodically, e.g., every second or every thirtieth frame, so that the maximum time to produce a complete image when fast forwarding occurs, is relatively short.

Referring to Fig. 3, when operating in an inter-frame mode, four phases (illustrated in section (A)) are used, and when operating in an intra-frame mode, three phases (illustrated in section (B)) are used. In both modes, the operation begins with Phase 1, described below with reference to Fig. 6, and then with Phase 2, described below with reference to Fig. 7. Then, in the inter-frame mode, Phase 3 follows Phase 2 and completes by branching to Phase 4 or to Phase 1, in the manner described below with reference to Fig. 9. In the intra-frame mode, Phase 4 follows Phase 2.. Phase 4 is described below with reference to Fig. 7. In both modes, Phase 4 completes by branching back to Phase 1. The four Phases are also designated respectively by numerals 116, 118, 122, and 124, in the drawings.

Various data structures are shown in sections (A) - (D) of Fig. 4. Referring to section (A), the input data stream (IDS) comprises a plurality of uncompressed frames (UFs) created from the start to the end of image creation by source 96 and digitizer 98. Each UF contains a plurality of "n" pixel values (PVs) corresponding in number to the number "n" of pixels in a screen image. Each PV contains two bytes (sixteen bits) of color information in an RGB format, with 5-bits for level of red intensity.

As shown in section (B), for compression processing, a screen image (SI) is divided into non-overlapping block groups (BGs) with each BG containing four 2x2 pixel groups (PGs) of pixel values respectively designated C0-C3. The four PGs in a BG may be logically mapped or
5 considered as quadrants of the BG, there being a northwest (NW) quadrant, a northeast (NE) quadrant, a southwest (SW) quadrant, and a southeast (SE) quadrant. Each BG thus represents the pixel values of sixteen adjacent pixels in the screen image.

The output data stream (ODS) flows from output buffer 112 to disk
10 24 and comprises a plurality of compressed frames (CFs) which vary in size dependent on the specific compression that takes place during processing. The number of CFs is the same as the number of UFs, there being a one-to-one correspondence between the two sets of frames. Each CF comprises a plurality of block group headers (BGHs) corresponding to
15 the number of BGs in a screen image SI. As shown in section (C), each BGH is one byte and has eight bits logically separated into four fields of two bits. Each field corresponds to a different one of the group block quadrants NW, NE, SW, and SE. Each two bit field defines the data for the corresponding 2x2 pixel block or quadrant, as follows:

- 20 00: 2x2 block unchanged, no succeeding pixel values for block
 01: 2x2 block is changed homogenous, one succeeding pixel value for block.
 10: 2x2 block is changed, not homogenous, four succeeding pixel values for block.
25 11: (no meaning)

In an inter-frame ODS, each preceding BGH is followed either by an immediately succeeding header or from one to sixteen pixel values from one or more of the quadrants. The number of pixel values following a header is dependent upon results of the compression processing as
30 described below and is in accordance with the information in the header. Thus, each header may be followed by 0-4 PVs for the NW quadrant, 0-4 PVs for the NE quadrant, 0-4 PVs for the SW quadrant, and 0-4 PVs for the SE quadrant. An exemplary inter-frame ODS is shown in (C) as containing the series of: BGH1; BGH2; one to four entries for PV(NW), PV(NE), P(SW),
35 PV(SE); and BGH4. In such series, there is no change in BG1 since there are no PVs following BGH1. For BG2, a change occurs in the NE quadrant. For BG3, changes occur in each of the quadrants. Obviously, differing

images and changes therein produce different series. An uncompressed block group contains sixteen, two byte color values, or a total of thirty two bytes. When compressed, the block group contains a one-byte BGH and from 0-to-16 color values and thus varies in size from 1-to-33 bytes.

- 5 The advantage of the invention is that during the course of recording a motion image, each frame contains a relatively large number of homogenous blocks that do not change from frame to frame. For example, with many images, most of the background remains the same and only the motion associated with an object of interest changes.

- 10 Fig. 4 section (D) shows a 32-bit YCrCb value, obtained from table 252 (Fig. 5) and loaded into a register R. The YCrCb value contains two words. The high order word has two bytes which contains 6-bit Cr and Cb values. The low order word contains a 5-bit Cr value, a 5-bit Cb value, and a 6-bit Y value, which word represents a standard YUV₁₆ format. The
15 contents of register R are logically ANDed with mask bits shown in register R1, to produce the results in register R'. The ANDing thus zeroes bits 15-6 and removes the low word chrominance values leaving only 6-bit values of YCrCb in register R'. Four such results are accumulated in SUM to produce 8-bit totals of Cr, Cb, and Y from which the averages
20 can be readily calculated.

- Referring to Fig. 5, the tables 121 stored in RAM 36 include a table 252 of 32-bit YCrCb values, a table 254 of luminance profile values, two tables 256 and 258 of threshold indicators, a buffer 260 of last update luminance profiles, and a buffer 262 of last update AVG YCrCb
25 values. Microprocessor 12 has a plurality of local registers including local registers 250 and 251. Register 251 is used as a base register into which the base address of a table can be loaded. Register 250 is used as an index register (IR) that is loadable with different indices or offsets for accessing all of the tables in 121. The combination of the
30 base address from 251 and the offset from 250 is used to selectively access entries in the tables. The various settings of the IR shown at (a)-(f) access the tables in the following manner. The RGB value of the raw data accesses table 252. Table 254 is accessed by placing the AVG Y per block value in the low byte and a pixel luminance value Y in the high
35 byte. Table 256 is accessed by placing the last update AVG luminance value in the low byte, and the current AVG luminance in the high byte. Tables 260 and 262 are accessed by placing a block number index in the IR.

Table 252 stores color values represented in luminance, chrominance (L/C) format YCrCb, where Y is the luminance value, and Cr and Cb are red and blue chrominance values. For RGB16 colors, the values of Y, Cr, and Cb stored in table 252, are calculated as follows:

$$\begin{aligned} 5 \quad Y &= 0.299R + 0.29356 + 0.14B \\ Cr &= 16 + 0.713(R-Y) \\ Cb &= 16 + 0.564(B-Y) \end{aligned}$$

where R is from 0 to 31, G is from 0 to 63, and B is from 0 to 31 dependent upon the values of their respective bits. The YCrCb values can
10 be converted in the reverse direction in accordance with the following formulas:

$$\begin{aligned} R &= Y + 1.403(Cr-16) \\ G &= 2Y - 1.43(Cr - 16) - 0.688(Cb-16) \\ B &= Y + 1.773(Cb - 16) \end{aligned}$$

15 Table 254 contains 64K luminance profile bytes. Each byte is of the following format:

Bits 7-3 0 (not used)
Bit 2 contrast bit- Set to 1 if (pixel Y - AVG Y) > contrast threshold, otherwise set to 0.
20 Bit 1 contrast bit- Set to 1 if (AVG y- pixel Y) > contrast threshold, otherwise set to 0.
Bit 0 not-homogenous bit- Set to 1 if (pixel Y - AVG y) > homogenous threshold, otherwise set to 0.

A 32-bit block luminance profile is created using table 254 by
25 performing four table look-ups, one for each pixel in a block. The use of the "not-homogenous" bit (conversely, the "homogenous" bit) should be fairly obvious. The homogeneity of a block is tested primarily by the luminance levels of each pixel value, and if the levels are all approximately the same, the block is considered homogenous. Thus a
30 threshold level is used, which if exceeded, produces a perception that the block is not homogenous. The smaller the threshold, the more uniform each pixel would appear. A threshold of "3" would be an exemplary value. The use of the contrast bits is not so obvious. Such bits are used in the inter-frame mode for the situation where even though the current

average block luminance level is about the same as the last update average luminance and within the threshold of the last update average luminance level for the block, the individual pixel luminance values differ greatly so that the two blocks (current block and last update
5 block) would have different appearances.

For example, suppose that an extreme exists in which black and white pixels alternate. Such a block would appear different or changed from a block in which the four pixels values are all around 32. The white pixels have a luminance of 64 while the black pixels have a luminance of
10 "0". Their block average is 32. The contrast threshold should be set at a higher level, e.g. "10" than the luminance threshold level. With such an example, contrast bit 2 is set if the pixel luminance is much greater than the block average luminance and thus would be set to a "1" for each white pixel. Contrast bit 1 is set if the pixel luminance level is much
15 less than the average block luminance level and thus would be a "1" for each black pixel.

Blocks 256 and 258 are each 64K- 1-bit blocks for luminance and chrominance threshold indicators the entries of which are set to 1 if the current average luminance or chrominance (high order index byte) exceeds
20 the last update average luminance or chrominance (low order index byte) by a threshold amount and are set to 0 if a threshold amount is not exceeded. Blocks 260 and 262 respectively contain a plurality of luminance profile and AVG YCrCb entries corresponding to the number of blocks in a frame. Such entries are stored each time a pixel change
25 occurs. A given entry may thus represent the value in the immediately preceding frame or what the value was, e.g., one hundred frames ago.

The use of the look-up tables speeds up processing compared to having to calculate values on-the-fly and make comparisons and decisions. It should also be obvious that the three tables 254, 256, and 258 can be
30 combined into a single table to eliminate two of the unused bits in table 254. In such case, the resultant table would be accessed using different indexes dependent upon what type of value is being read.

Referring to Fig.6, motion video data compression is accomplished by processing the 2x2 pixel groups PGs or blocks one-block-at-a-time. As
35 indicated above, each PG or block contains four pixel values respectively designated C0, C1, C2, and C3 each of which contains two bytes

representing the RGB color value of a pixel. These RGB input values into the conversion process, are considered to be in a "native hardware format". For each 2x2 block, the first step 126 in Phase 1 is to read the RGB pixel value C0 into the IR register for processing. Step 128
5 then combines such value with the base address of table 252 (Fig.5) to look-up the corresponding L/C value YCrCb0 in table 121. Step 130 then saves the luminance portion Y0 in a register. Step 132 then writes the color value C0 to the output data stream, and step 134 accumulates the YCrCb values in a variable named "SUM" (Fig. 4(D)). Similar steps 136-
10 144, 1436-154, and 156-164 are performed for each of the remaining pixel value C1, C2, and C3, with the result at the end of the remaining pixel values C1, C2, and C3, with the result at the end of Phase 1 that for each pixel in the block being processed, a luminance value Y has been stored, an L/C value YCrCb has been accumulated, and four pixel value C0-
15 C3 have been written to the output data stream. Alternatively, instead of outputting RGB values, the LUV format from the low order word of the YCrCb look-ups obtained in steps 128, 138, 148, and 158, can be outputted.

Phase 2 immediately follows Phase 1 and begins with step 168 (Fig. 7) which first calculates the average pixel luminance value AVG Y from
20 the accumulated luminance value in SUM, and places the AVG Y value in the low byte of register 250 (the IR). Step 168 then moves Y0 into the high byte of such register. Step 170 looks up the Y0 luminance profile bytes in table 254 and stores it in the first field of the 32-bit block
25 luminance profile. Similar steps 172 and 174, 176 and 178, and 180 and 182 are performed for Y1, Y2, and Y3 with the result that at the end of these steps, the block luminance contains four luminance profile bytes, one for each of the pixels in the 2x2 PG being processed. Following step 182, phase 3 or phase 4 is entered depending upon which mode is being
30 done, as previously indicated.

Referring to Fig. 9, if inter-frame (delta frame) processing is being done, Phase 3 immediately follows Phase 2 and begins with step 196 which reads from table 262 the last update average YCrCb for the block. Step 198 extracts and moves the last update AVG Y from such average YCrCb
35 and places it in the high byte of IR. Step 200 then performs a lookup into table 256 for the Y threshold indicator based on the last update AVG Y and the current AVG Y. Step 202 then makes a decision as to whether or not the absolute value of the (last update AVG Y minus the current AVG Y)

is greater than a Y delta threshold. Such decision is made by examining the threshold indicator. If step 202 results in a positive (yes) determination, it means that the average luminance value of the block is changed from the last update and processing proceeds in step 208 with Phase 4. If step 202 results in a negative determination (no), meaning the block is not changed since the last update thereof, step 204 is executed and it performs an update by reading the Cr threshold indicator from table 258 based on the last update AVG Cr and current AVG Cr. Step 206 then looks at the Cr threshold indicator and decides if the absolute value of the (last update AVG Cr minus the current AVG Cr) is greater than a Cr delta threshold. If step 206 results in a positive (yes) determination, it means that the average Cr value for the block is changed from the last update, and processing proceeds in step 208 with Phase 4. If step 206 results in a negative determination (no), meaning the average Cr of the block is not changed from the last update, step 210 is executed and it performs a similar for the Cb. Update based on the last update AVG Cb and current AVG Cb and current AVG Cb.

Step 212 then looks at the Cb threshold indicator and decides if the absolute value of the (last update AVG Cb minus the current AVG Cb) is greater than a Cb delta threshold. If step 212 results in a positive (yes) determination, it means that the average Cb of the block is changed from the last update and processing proceeds in step 208 with Phase 4. If step 212 results in a negative determination (no), meaning the block is not changed from the last update, step 214 then saves a copy of the current luminance profile for the block in a 32-bit register, and step 218 exchanges the current luminance profile for the block with the last update luminance profile for the block, in the buffer. Step 218 then performs the logical functions of exclusive ORing (XOR) the last update luminance profile value with the current luminance profile value and ANDing the result with a contrast bit mask and determines if the result is equal to zero. If 218 results in a negative determination, it means that the contrast bits of the luminance profile for the block the last time the block was updated, and processing proceeds in step 208 with Phase 4. If step 218 results in a positive determination, meaning the contrast bits are identical, the result means the block is unchanged since the last update. Step 220 sets the block bits in BGH to "00" to indicate the block is unchanged and then, without advancing an output stream pointer over colors written for this block, loops back to the

beginning of Phase 1 to process the next block. Thus, no pixel values are outputted for such block.

Referring to Fig. 8, the first step 184 of Phase 4 decides if the block currently being processed is homogenous or not. This is done by analyzing the current luminance profile for the block to see if any "not homogenous" bit is set. If no not-homogenous bit is set, meaning the block is homogenous, step 186 then advances the output stream pointer over one color and step 188 indicates in the output data stream BGH that the block is "changed, homogenous". Then a return is made in step 190 to the beginning of Phase 1 to process the next block. If step 184 detects at least one not-homogenous bit is set and produces a negative determination, meaning the block is not homogenous, step 192 advances the output stream pointer over four colors, instead of only one color as was done in step 186. Then, step 194 indicates in the BGH in the output data stream that the block is "changed, not homogenous" and step 189 updates the last update buffers 260 and 262 with the current values. Step 190 returns to Phase 1. The output stream pointer is set up in the EDI register of the microprocessor and indicates the point at which values are written into the output stream. It is to be recalled that during Phase 1, four colors C0-C3 were outputted, and when the output stream pointer advances over only one color, the remaining three colors are over written with pixel values from the next block. When the pointer is advanced over four colors, none of the four colors are over written and thus such pixel values are placed in the output data stream.

The various threshold values are adjustable (by using different values) to obtain the degree of compression/quality desired by a user. Increasing the threshold values results in greater compression, but reduces resolution and quality of resultant images. It should be apparent to those skilled in the art that many changes can be made in the details and arrangements of steps and parts without departing from the scope of the invention as defined in the appended claims.



CLAIMS

1. A personal computer system including a memory for storing data and programs including a multitasking operating system, a microprocessor for executing programs stored in said memory, and motion video recording
5 means comprising:

first means for generating and storing in said memory a succession of uncompressed frames of digitized motion video data defining pixel color values for pixels in a screen;

conversion means for converting said uncompressed frames into
10 compressed frames;

and recording means for storing said compressed frames;

said conversion means being operative to process said pixel color values one block at a time and comprising:

15 table lookup means in said memory including a table storing luminance and chrominance values YCrCb as a function of different pixel color values;

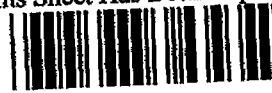
second means operative to look up in said table the luminance value Y for each pixel color value in a block and to accumulate an average pixel luminance value AVG Y for all of
20 the pixel values in a block;

third means operative to determine whether a block is homogenous or not-homogenous, a block being homogenous when all pixel luminance values Y in a block each differ from said AVG Y by an amount less than a homogenous threshold, a block
25 being not-homogenous when the Y of any one pixel value in a block differs from said AVG Y by an amount exceeding said homogenous threshold; and

fourth means responsive to results of said third means to output to said recording means a single pixel color value for
30 a homogenous block and a plurality of pixel color values for a not-homogenous block.

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2. A personal computer system in accordance with claim 1 wherein said third means comprises:

5 a second table in said table lookup means storing a plurality of homogenous bits as a function of Y and AVG Y, each bit being set to one state when the absolute value of $(Y - \text{AVG } Y)$ exceeds said threshold and set to a second state when such absolute value is equal to or less than said threshold;

10 means for accessing said second table using values of Y and AVG Y as a index into said second table to read said homogenous bits for all pixel values in a block and determine from such bits whether such block is homogenous or not-homogenous.

3. A personal computer system in accordance with claim 2 wherein:

15 said conversion means is operative to selectively convert compressed frames into I-frames and delta-frames, each I-frame including sufficient pixel information to produce a complete screen image therefrom, each delta-frame containing pixel information at least a part of which depends on pixel information obtained from one or more preceding frames to produce a complete screen image, said conversion means further comprising:

20 buffer means storing block update information, said buffer means being initialized with information from an I-frame and updated with new information each time a block has changed since its last update;

25 fifth means operative for delta-frames to determine whether a block has changed since its last update or is unchanged;

30 said third means being selectively operated in response to a determination by said fifth means that a block is changed to further determine whether such block is homogenous or not-homogenous; and

said fourth means being operative in response to a determination by said fifth means that a block is





unchanged, to output to said recording means an indication that such block is unchanged without providing any pixel value with such indication.

4. A personal computer system in accordance with claim 3 wherein said
5 fifth means comprises:

a third table in said table lookup means, said third table storing luminance threshold indicators as a function of current AVG Y and AVG Y-at-last-update of such block, each luminance threshold indicator indicating whether the absolute value of the difference between current
10 AVG Y and AVG Y-at-last-update of such block exceeds a predetermined luminance threshold and the block has consequently changed since the last update of such block, or that said absolute difference does not exceed such threshold and the block has consequently not changed since the last update of such block; and

- 15 first indexing means for accessing said third table as a function of current AVG Y and AVG Y-at-last update.

5. A personal computer system in accordance with claim 4 comprising:

a fourth table in said table lookup means storing values of AVG Y-at-last-update as a function of a block number identifying location of a
20 block in a frame, said AVG Y-at-last-update being updated whenever a current block has been determined to be changed since last update, said first indexing means obtaining said AVG Y-at-last-update from said fourth table.

6. A personal computer system in accordance with claim 5 comprising:

25 a fifth table in said table lookup means storing values of AVG CrCb-at-last-update as a function of a block number identifying location of a block in a frame, said AVG CrCb-at-last-update being updated whenever a current block has been determined to be changed since last update, said first indexing means obtaining said AVG CrCb-at-last-update
30 from said fifth table;

a sixth table in said table lookup means storing chrominance threshold indicators as a function of AVG CrCb-at-last-update and current





AVG CrCb, each chrominance threshold indicator indicating whether the absolute value of the chrominance difference between current AVG CrCb and AVG CrCb-at-last-update of such block exceeds a predetermined chrominance threshold and the block has consequently changed since the last update of such block, or that said absolute chrominance difference does not exceed such chrominance threshold and the block has consequently not changed since the last update of such block; and

second indexing means for accessing said sixth table using an AVG CtCb-at-last-update from said fifth table and current AVG CrCb.

10 7. A personal computer system in accordance with claim 6 wherein:

said blocks are further processed in a group of a predetermined number of blocks; and

said fourth means is further operative to create a group block header having an entry for each block in a group indicating whether such block is unchanged from a last update, changed and homogenous, or changed and not-homogenous, said groupblock header being transmitted to said recording means immediately ahead of any pixel values for such group of blocks.

8. A personal computer system in accordance with claim 7 wherein each said group of blocks contains four blocks of 2x2 pixel values.

9. A personal computer system in accordance with claim 6 wherein:

said second table further stores contrast bits with said homogenous bits, each contrast bit indicating if the difference between each pixel Y and AVG y for block, exceeds a predetermined contrast threshold;

25 said fourth table further storing contrast bits for a block at the last update; and

said conversion means further comprises means for determining whether a block has changed by deciding if the contrast bits in a current block are identical to the contrast bits in such block at the last update.





BC9-92-115

18

10. A method of operating a personal computer system having a memory for storing data and programs including a multitasking operating system, a microprocessor for executing programs stored in said memory, a source of uncompressed frames of motion video data comprising a series of digitized pixel color values, and an output device for recording compressed frames, wherein said method comprises the steps of:

(a) storing in said memory a lookup table containing luminance and chrominance values YCrCb as a function of different pixel color values;

(b) storing in said memory a succession of uncompressed frames from said source; and

(c) converting said uncompressed frames from said memory into compressed frames and transmitting said compressed frames to said output device, said converting being done one block at a time by steps comprising

(c1) looking up in said table the luminance value Y for each pixel color value in a block and accumulating an average pixel luminance value AVG Y for all of the pixel values in a block;

(c2) determining whether a block is homogenous or not-homogenous, a block being homogenous when all pixel luminance values Y in a block each differ from said AVG Y by an amount less than a homogenous threshold, a block being not-homogenous when the Y of any one pixel value in a block differs from said AVG Y by an amount exceeding said homogenous threshold; and (c3) transmitting to said recording means a single pixel color value for each homogenous block and a plurality of pixel color values for a not-homogenous block.

11. The method of operating a personal computer system in accordance with claim 10 wherein:

step (a) comprises storing in said memory a second lookup table containing a plurality of homogenous bits as a function of Y and AVG Y, each bit being set to one state when the absolute value of $(Y - \text{AVG } Y)$ exceeds said threshold and set to a second state when such absolute value is equal to or less than said threshold,

and step(c2) comprises





BC9-92-115

19

accessing said second table using values of Y and AVG Y as a index into said second table to read said homogenous bits for all pixel values in a block;

and determining from such bits whether such block is homogenous or
5 not-homogenous.

12. The method of operating a personal computer system in accordance with claim 11 wherein:

step (c) converts compressed frames into I-frames and delta-frames for transmission to said output device, each I-frame including sufficient
10 pixel information to produce a complete screen image therefrom, each delta-frame containing pixel information at least a part of which depends on pixel information obtained from one or more preceding frames to produce a complete screen image, said converting steps further comprising:

15 (c4) storing block update information in buffer means storing block update information, by initializing said buffer means with information from an I-frame and thereafter updating said buffer means with new information each time a block is changed from its last update; and

20 (c5) determining for delta frames whether a block is changed since its last update or is unchanged;

(c6) in response to a determination by step (c5) that a block is changed, performing steps (c2) and (c3);

25 and (c7) in response to a determination by step (c5) such block is unchanged, transmitting to said output device an indication that such block is unchanged, without providing any pixel value with such indication.

13. A method of operating a personal computer system in accordance with claim 12 comprising:

30 (a3) storing in said memory a third lookup table, said third table containing luminance threshold indicators as a function of current AVG Y and AVG Y-at-last-update of such block, each luminance threshold indicator indicating whether the absolute value of the difference between



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current AVG Y and AVG U-at-last-update of such block exceeds a predetermined luminance threshold and the block has consequently changed since the last update of such block;

and accessing said third table as a function of current AVG Y and
5 AVG Y-at-last-update.

14. A method of operating a personal computer system in accordance with claim 13 comprising:

(a4) storing the said memory a fourth lookup table, said fourth table containing values of AVG Y-at-last-update as a function of a block
10 number identifying location of a block in a frame, said AVG Y-at-last-update being updated whenever a current block has been determined to be changed since last update;

and accessing said third table by obtaining said AVG Y-at last update from said fourth table.

15 15. A method of operating a personal computer system in accordance with claim 14 comprising:

(a5) storing in said memory a fifth lookup table, said fifth table containing values of AVG CrCb-at-last-update as a function of a block number identifying location of a block in a frame, said AVG CrCb-at-last-
20 update being updated whenever a current block has been determined to be changed since last update, said first indexing means obtaining said AVG CrCb-at-last-update from said fifth table;

(a6) storing in said memory a sixth lookup table, said sixth table containing chrominance threshold indicators as a function of AVG CrCb-at-
25 last-update and current AVG CrCb, each chrominance threshold indicator indicating whether the absolute value of the chrominance difference between current AVG CrCb and AVG CrCb-at-last-update of such block exceeds a predetermined chrominance threshold and the block has consequently changed since the last update of such block, or that said
30 absolute chrominance difference does not exceed such chrominance threshold and the block has consequently not changed since the last update of such block;





and accessing said sixth table using an AVG CrCb-at-last-update from said fifth table and current AVG CrCb.

16. A method of operating a personal computer system in accordance with claim 15 comprising:

- 5 (c) processing said blocks in groups of a predetermined number of blocks; and

(c3-2) creating a group block header having an entry for each block in a group indicating whether such block is unchanged from a last update, changed and homogenous, or changed and not-homogenous, and transmitting
10 said group block header to said recording means immediately ahead of any pixel values for such group of blocks.

17. A method of operating a personal computer system in accordance with claim 16 wherein step (c) processes each said group of blocks and each group contains four blocks of 2x2 pixel values.

- 15 18. A method of operating a personal computer system in accordance with claim 16 wherein:

said second table further contains contrast bits along with said homogenous bits, each contrast bit indicating if the difference between each contrast bit indicating if the difference between each pixel Y and
20 AVG y for block, exceeds a predetermined contrast threshold;

said fourth table further contains contrast bits for a block at the last update;

and step (c5) further comprises determining whether a block has changed by deciding if the contrast bits in a current block are identical
25 to the contrast bits in such block at the last update.

