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(54) **ERROR RESILIENT VIDEO CODING USING REVERSIBLE VARIABLE LENGTH CODES (RVLCS)**

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(60) Provisional application No. 60/041,398, filed on Mar. 18, 1997.

(51) **Int. Cl.**^{7} **H04N 7/12**

(52) **U.S. Cl.** **375/240.27**

(58) **Field of Search** 375/240.27, 240.01, 375/240.25, 240.26, 240.15; H04N 7/12

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M. J. Weinberger et al, "LOCO–I: A Low Complexity, Context–Based, Lossless Image Compression Algorithm," IEEE Data Compression Conference, Snowbird, UT, pp. 140–149.*

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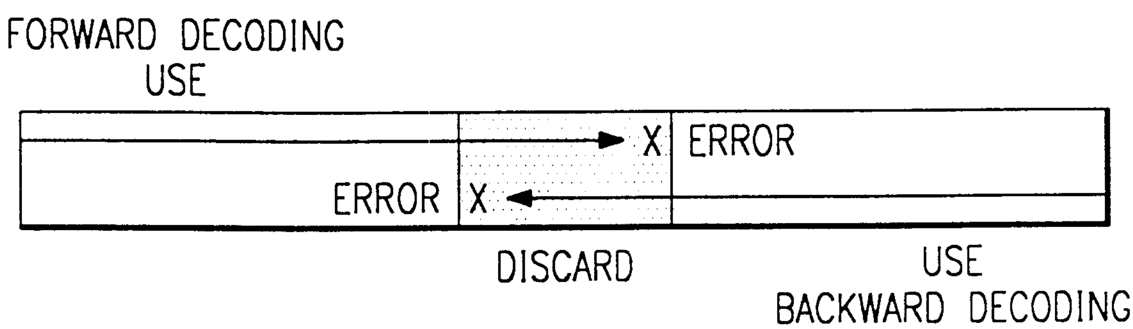
(57) **ABSTRACT**

Video compression coding with partitioning of data into motion vector data and texture data with reversible Golomb-Rice type codes for the data. Resynchronization markers separate the data types, and the reversible coding permits decoding in both forward and backward directions to minimize data discarded due to errors.

5 Claims, 2 Drawing Sheets



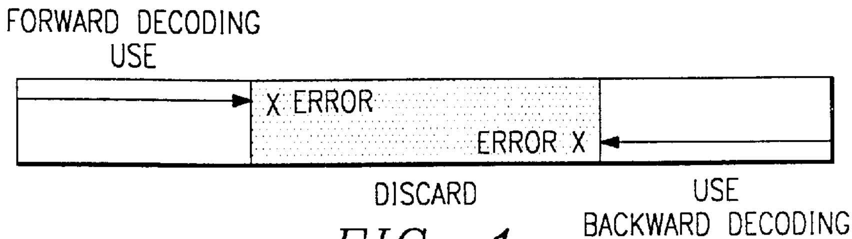


FIG. 1

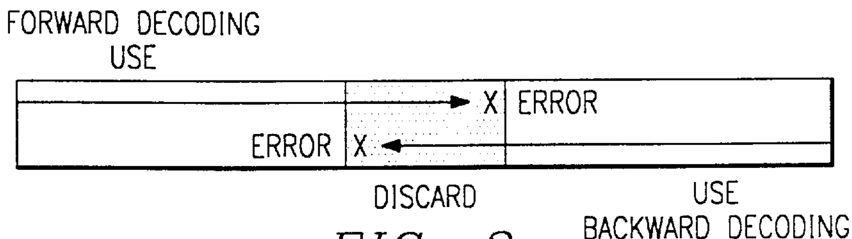


FIG. 2

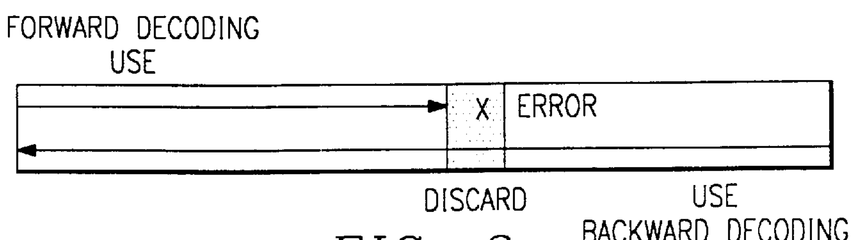


FIG. 3

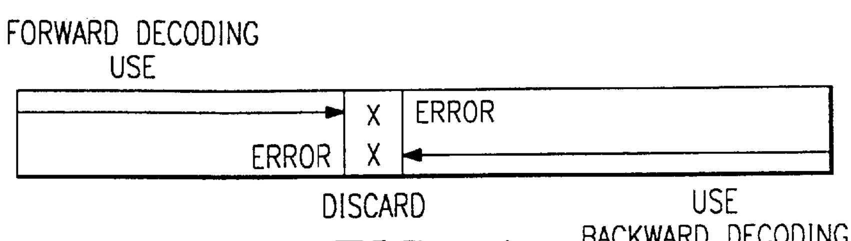


FIG. 4

ESCAPE xx...x1 m BITS	LAST X 1 BIT	RUN XXXXXX 6 BITS	LEVEL XXXXXXX 7 BITS	ESCAPE xx...xs m BITS

FIG. 5

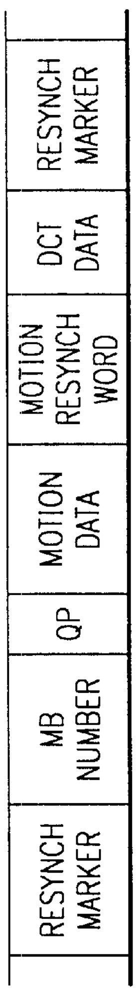


FIG. 6a

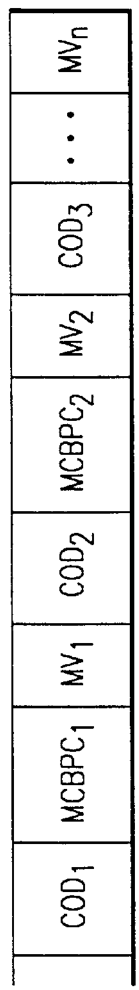


FIG. 6b

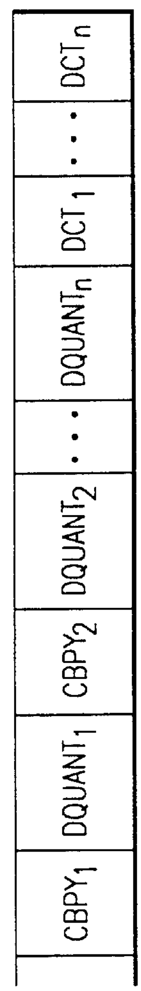


FIG. 6c

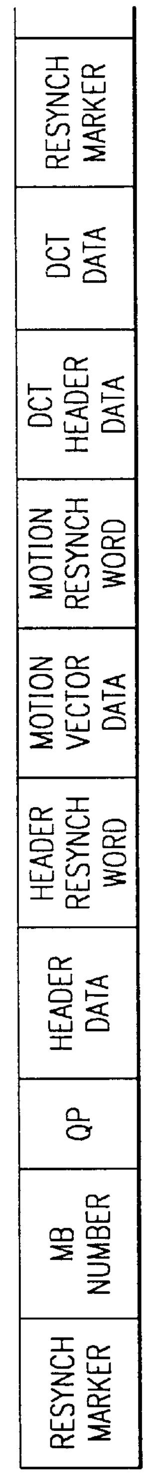


FIG. 7

ERROR RESILIENT VIDEO CODING USING REVERSIBLE VARIABLE LENGTH CODES (RVLCS)

CROSS-REFERENCE TO RELATED APPLICATIONS

Copending U.S. patent application Ser. No. 09/019,787, filed Feb. 6, 1998, discloses related subject matter. This application is a division of U.S. Ser. No. 09/040,676, filed Mar. 18, 1998, now U.S. Pat. No. 6,304,607, which claims benefit to U.S. Ser. No. 60/041,398, filed Mar. 18, 1999.

BACKGROUND

The present application relates to information encoding for transmission over noisy channels and storage, and more particularly to error resilient encoding.

Two common approaches to the mitigation of errors arising during the transmission of data over noisy channels exist: Automatic Retransmission Request (ARQ) and Forward Error Correction (FEC). ARQ type of mitigation typically would not be feasible in multicast or real-time applications such as video because of intolerable time delays or a lack of feedback channel. In such cases, a decoder can only decode the error corrupted bitstream, protected to an extent by error correction encoding, and must create from such bitstream. FEC provides mitigation by error correcting codes (e.g., Reed-Solomon). However, uncorrectable errors require further mitigated approaches.

In general, commonly used video compression methods have block-based motion compensation to remove temporal redundancy. Motion compensation methods encode only (macro)block motion vectors and the corresponding quantized residuals (texture); and variable length coding (VLC) of the motion vectors and residual increases coding efficiency. However, variable length coding often are highly susceptible to transmission channel errors and a decoder easily loses synchronization with the encoder when uncorrectable errors arise. The predictive coding methods, such as motion compensation, make matters much worse because the errors in one video frame quickly propagate across the entire video sequence and rapidly degrade the decoded video quality.

The typical approach of such block-based video compression methods to uncorrectable errors includes the steps of error detection (e.g., out-of-range motion vectors, invalid VLC table entry, or invalid number of residuals in a block), resynchronization of the decoder with the encoder, and error concealment by repetition of previously transmitted correct data in place of the uncorrectable data. For example, video compressed using MPEG1-2 has a resynchronization marker (start code) at the start of each slice of macroblocks (MBs) of a frame, and an uncorrectable error results in all of the data between correctly decoded resynchronization markers being discarded. This implies degradation in quality of the video stream, especially for predictive compression methods such as MPEG.

This compressed video is typically coded using Variable Length Code (VLC) tables such as Huffman codes. When the compressed video data is transmitted over noisy communication channels, it is corrupted by channel errors. VLC tables prove to be particularly sensitive to bit errors. This is because bit errors can make one codeword be incorrectly interpreted to be another codeword of a different length and hence the error is not detected. This makes the decoder lose synchronization with the encoder. Although the error may finally be detected due to an invalid VLC table entry, usually the location in the bitstream where the error is detected is not the same as the location where the error occurred. Hence, when the decoder detects an error, it has to seek the next resynchronization marker and discard all the data between this and the previous resynchronization marker. Thus, even a single bit error can sometimes result in a loss of a significant amount of data, and this is a problem of the known coding schemes.

Golomb-Rice codes (S. W. Golomb, "Run-length encodings," *IEEE Trans. Inf. Theory*, vol. IT-12, pp.399–401, July 1966 and R. F. Rice, "some practical universal noiseless coding techniques," *Tech. Rep.* JPL-79-22, Jet Propulsion Laboratory, Pasadena, Calif., March 1979) have been applied to lossless image compression; see M. J. Weinberger, G. Seroussi, and G. Sapiro, "LOCO-I: A low complexity, context based lossless image compression algorithm," *Proc.* 1996 *IEEE Data Comp. Conf.*, Snowbird, Utah, pp. 140–149, April, 1996.

These video compression and decompression methods may be implemented on special integrated circuits or on programmable digital signal processors or microprocessors.

SUMMARY OF THE INVENTION

The present invention uses reversible VLC (RVLC) tables based on Golomb-Rice codes to alleviate the error problems in motion compensated compressed video such as MPEG. These RVLC tables have the property that they can be uniquely decoded both in the forward and the backward (reverse) directions. This property enables a decoder to better isolate the location of the error and minimize the amount of data that needs to be discarded.

Preferred embodiments present different kinds RVLCs for each of (1) motion header data (COD+MCBPC) (for INTRA and INTER frames), (2) motion vector data, (3) INTRA DCT coefficient data. and (4) INTER DCT coefficient data.

This has the advantage of better performance with efficient codes.

BRIEF DESCRIPTION OF THE DRAWINGS

The drawings are heuristic for clarity.

FIGS. **1–4** shows error detection with reversible coding.

FIG. **5** shows syntax for fixed length code portions

FIGS. **6***a–c* shows a bitstream syntax for data partitioning.

FIG. **7** shows a bitstream syntax for data and header partitioning.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Data Partitioning

Enhanced error concealment properties for motion compensated compression, such as MPEG, can be achieved by using data partitioning. Consider a "video packet" to consist of the data between two consecutive resynchronization markers. In a data partitioning approach, the motion data and the texture (DCT) data within each of the video packets are separately encoded in the bitstream . Another resynchronization word (Motion Resync. Word) is imbedded between the motion data and the DCT data to signal the end of the motion data and the beginning of the DCT data. This data partitioning allows the decoder to use the motion data even if the DCT data is corrupted by undetectable errors. This provides advantages including partial recovery over uncorrectable error in a packet of compressed video data with little additional overhead. The error concealment that is made possible by the use of motion compensation by applying decoded motion vectors results in a much better decoded video quality. And this extends to object based compression in that object shape data can be separated from the motion data and texture data by a shape resynchronization word.

When using data partitioning the data within the video packet is organized to look as shown in FIGS. **6***a*–*c*: FIG. **6***a* shows the fields between two resynchronization markers and FIGS. **6***b*–*c* illustrate the motion data field and the texture data field in more detail by an example. In particular, the first field ("Resynch Marker") is a resynchronization marker, the second field ("MB No.") is the number in the frame of the first macroblock (16×16 block of pixels) in the video packet, the third field ("QP") is the default quantization parameter used to quantize the texture data (DCT coefficients) in the video packet, the fourth field ("Motion Data") is the motion data, the fifth field ("Motion Resynch Word") is the resynchronization marker between the motion data and the texture data, the sixth field ("DCT Data") is the texture data, and the last field ("Resynch Marker") is the ending resynchronization marker. Note that the resynchronization marker is taken to have 23 successive 0s, and that these resynchronization words can be created by a search process as described in copending U.S. patent application Ser. No. 09/019,787, filed Feb. 6, 1998.

FIG. **6***b* shows the motion data field consisting of a COD field, an MCBPC field, and an MV field for each the macroblocks in the packet. The COD field indicates whether the macroblock is coded or skipped (COD=0 macroblock is coded, COD=1 macroblock is skipped). The MCBPC field indicates (1) the mode of the macroblock and (2) which of the chrominance blocks in the macroblock are coded and which are skipped: the mode indicates whether there the current macroblock is coded INTRA (no motion compensation), INTER (motion compensated with one 16×16 motion vector), or INTER**4**V (motion compensated with four 8×8 motion vectors). Of course, if COD indicates the macroblock is not coded, then the MCBPC field is not present. The MV field is the actual motion vector data; either one vector or four vectors. Again, if COD indicates that the macroblock is not coded, then the MV field is not present.

FIG. **6***c* shows the texture (DCT Data) field as consisting of a CBPY field and a DQUANT field for each of the macroblocks followed by the DCT data for each of the macroblocks. The CBPY field indicates which of the luminance blocks of the macroblock are coded and which are skipped. The DQUANT field indicates the differential increment to the default quantizer value (QP) to compute the quantization value for the macroblock. The DCT fields are the run length encoded quantized DCT coefficient values of the macroblock.

Reversible VLC With Header

The preferred embodiment syntax of the bitstream within a video packet with headers and data using RVLC is shown in FIG. **7**. The Resynch Marker, MB No., QP, and Motion Resynchr Word fields are as in FIG. **6***a*; the Motion Vector Data field consists of the motion vector data **MV1**, **MV2**, . . . MVn as in FIG. **6***b*; the DCT Header Data field consists of the CBPY**1**, DQUANT**1**, . . . , CBPYn, DQUANTn of FIG. **6***c*; and the DCT Data field consists of the DCT**1**, DCT**2**, . . . , DCTn also of FIG. **6***c*.

The Header Data field consists of one RVLC entry for the combined COD and MCBPC data for each macroblock (see FIG. **6***b*), and the Header Resynchronization Word is a uniquely decoded word similar to the Motion Resynchronizatin Word. Thus sequences of RVLC entries occur in the Header Data, Motion Vector Data, DCT Header Data, and DCT Data fields; of course each field has its own RVLC table as detailed below.

If an error is detected by the decoder while decoding any of the RVLCs, the decoder seeks the next resynchronization word, (either Header Resync. Word or Motion Resync. Word or the Resync. Marker). It then decodes the RVLC data backwards. Now, one of the four possible cases shown below can occur and the decoder decides to discard the appropriate part of the bitstream shown shaded in the figures below.

Note that during the backward decoding, in addition to the usual checks for valid data, the decoder also flags the bitstream as being in error if the forward decoded and the backward decoded data do not match despite both directions being decoded without apparent errors.

1) Separated error detected points: MBs whose data are free from errors are used. The data between the error detected points in the forward decode and in the backward decode are discarded (shaded part in FIG. **1**).

2) Crossed error detected points: MBs whose data are free from errors are used. The data between the error detected points in the forward decode and in the backward decode are discarded (dark part in FIG. **2**).

3) Error is detected in one direction: The MB whose data is corrupted (shaded part in FIG. **3**) is discarded. The symmetrical situation of no error in the forward direction but an error in the reverse direction is treated similarly.

4) Error is detected in the same MB: Only the corrupted MB (shaded part in FIG. **4**) is discarded.

In all of the cases above using the RVLC and the reverse (backward) decoding, the decoder is able to salvage a significantly larger part of the bitstream that is not in error.

Design of the RVLCs

The preferred embodiment parameterized RVLCs have identical code length distributions to previously known, non-reversible VLCs that are known to be near-optimal for probability density functions (pdfs) that occur in coding of image data. The RVLCs presented are parameterized to allow them to be adapted to match a wide range of pdfs, and enable the advantages of two-way decoding while retaining the efficiency of traditional (non-reversible) variable length codes.

Begin with a reversible code with the same length distribution as GolombRice codes, which have recently been applied for coding of prediction errors in lossless image coding applications as noted in the background. Golomb-Rice codes are nearly optimal for coding of exponentially distributed non-negative integers, and describe an integer n in terms of a quotient and a remainder. For simplicity, the divisor is often chosen to be a power of 2, i.e., 2^k, and is parameterized by k. The quotient can be arbitrarily large and is expressed using a unary representation; the remainder is bounded by the range $[0,2^{k-1}]$ and is expressed in binary form using k bits. For example, for a Golomb-Rice code with k=2 the number 9 could be represented as 110 01. The "prefix" of the codeword, 110, identifies the quotient of $9/2^2$ as having value 2. The "suffix", 01, is a 2-bit binary expression of the remainder. Table 2 below gives Golomb-Rice codes for the first several integers for two choices of the parameter k.

To obtain an equivalent length reversible code, one can simply replace the prefix of each Golomb-Rice codeword with a prefix that begins and ends with a "1", with all other bits equal to "0". The exception to this is the prefix of length one, which is set to "0". The suffix in the RVLC remains the same as the suffix in the corresponding Golomb-Rice code. RVLCs constructed according to these rules are shown Table 1 for k=1 and k=2, and it is clear from the table that the length distributions of the RVLCs and the corresponding Golomb-Rice codes are identical. Although it is only the prefix, as opposed to the entire codeword, that is symmetric, these codes can easily be decoded bidirectionally because the nonreversible portions of the codewords have fixed length.

In contrast with the Golomb-Rice code in which the number of codewords at each length is constant, it is also possible to construct codes in which the number of codewords. of a given length grows exponentially with length. Compression of run lengths using such codes was described in a paper by Teuhola (J.Teuhola, "A compression method for clustered bit-vectors," *Information Processing Letters*, vol.7, pp308–311, October, 1978) using the term "exponential-Golomb" coding. Exp-Golomb codes are matched to pdfs having a higher peak and wider tails than typical exponential pdfs. Such a pdf is very well matched to the run-length coded data that occur in quantized image transforms. Exp-Golomb codes can be parameterized according to k, the number of bits in the suffix of the codeword. Table 2 illustrates the exp-Golomb code for k=1,2. It is possible, though less straightforward, to construct a reversible code that has the same length distribution as an exp-Golomb code. To do this again impose the constraint that the first and last bits of the prefix be "1.". As before, the prefix of length one is set to "0". Require that all odd-indexed bits in the prefix, with the exception of the first and last bit, be "0". For example, in all prefixes of length 5, the third bit is "0", and the first and fifth bits are "1". The even-indexed bits are allowed to vary arbitrarily, allowing $2^{l-1)/2}$ possible prefixes of length l, where l is odd. In constructing the code, each prefix is concatenated with the 2^k distinct suffixes of length k. Table 2 gives an RVLC constructed according to these rules. Again, it is clear that the length distribution of the RVLC is identical to that of the corresponding nonreversible code.

TABLE 1

Parameterized Golomb-Rice Code and Reversible Golomb-Rice Code

	k = 1				k = 2			
	Golomb-Rice		PRVLC		Golomb-Rice		PRVLC	
Index	Prefix	Suffix	Prefix	Suffix	Prefix	Suffix	Prefix	Suffix
0	0	0	0	0	0	00	0	00
1	0	1	0	1	0	01	0	01
2	10	0	11	0	0	10	0	10
3	10	1	11	1	0	11	0	11
4	110	0	101	0	10	00	11	00
5	110	1	101	1	10	01	11	01
6	1110	0	1001	0	10	10	11	10
7	1110	1	1001	1	10	11	11	11
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .

TABLE 2

Parameterized Exp-Golomb Code and Reversible Exp-Golomb Code (the bits in the RVLC that are not subject to symmetry constraints are italicized)

	k = 1				k = 2			
	Exp-Golomb		PRVLC		Exp-Golomb		PRVLC	
Index	Prefix	Suffix	Prefix	Suffix	Prefix	Suffix	Prefix	Suffix
0	0	0	0	0	0	00	0	00
1	0	1	0	1	0	01	0	01
2	100	0	101	0	0	10	0	10
3	100	1	101	1	0	11	0	11
4	101	0	111	0	100	00	101	00
5	101	1	111	1	100	01	101	01
6	11000	0	10001	0	100	10	101	10
7	11000	1	10001	1	100	11	101	11
8	11001	0	10011	0	101	00	111	00
9	11001	1	10011	1	101	01	111	01
10	11010	0	11001	0	101	10	111	10
11	11010	1	11001	1	101	11	111	11
12	11011	0	11011	0	11000	00	10001	00
13	11011	1	11011	1	11000	01	10001	01
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .

Design the complete codeword table as follows.

1. Make the probability table of most commonly occurring EVENTs.
2. For each k, assign codewords from the corresponding RVLC table to the EVENTs, with shorter codeword mapped to EVENT of higher probability. Then select the k, that gives the shortest average length.

Using this methodology the RVLCs were designed for each of (1) Header Data (COD+MCBPC) (for both INTRA and INTER frames), (2) Motion Vector Data, (3) INTRA frame DCT Data, and (4) INTER frame DCT Data. Use two classes of RVLCs. The first class of RVLC is used to code the header information (COD+MCBPC). One RVLC is used for the INTRA frames and one is used for the INTER frames. These are shown in Table 3 and Table 4 below.

TABLE 3

RVLC for COD + MCBPC for INTRA coded video packets

Index	MB Type	CBPC (56)	RVLC for Header Data COD + MCBPC: Codeword (Combined)	Length (Bits)
0	—	—	1	1
1	3	00	00	2
2	3	01	0110	4
3	3	10	01110	5
4	3	11	01010	5
5	4	00	011110	6
6	4	01	010010	6
7	4	10	0111110	7
8	4	11	0100010	7
9	Stuffing	—	0111111110	10

TABLE 4

RVLC for COD + MCBPC for INTER coded video packets

Index	MB Type	CBPC (56)	Proposed RVLC for Combined COD + MCBPC: Codeword (Combined)	Length (Bits)
0	—	—	1	1
1	0	00	010	2
2	0	01	011110	6
3	0	10	001100	6
4	0	11	0111110	7
5	1	00	0110	4
6	1	01	01111110	8
7	1	10	00111100	8
8	1	11	011111110	9
9	2	00	01110	5
10	2	01	00111100	8
11	2	10	001111100	9
12	2	11	000111000	9
13	3	00	0011100	7
14	3	01	0111111110	10
15	3	10	0011111100	10
16	3	11	000010000	9
17	4	00	0001000	7
18	4	01	0001111000	10
19	4	10	00111111100	11

TABLE 4-continued

RVLC for COD + MCBPC for INTER coded video packets

Index	MB Type	CBPC (56)	Proposed RVLC for Combined COD + MCBPC: Codeword (Combined)	Length (Bits)
20	4	11	01111111110	11
21	Stuffing	—	0000110000	10

The second class is an RVLC, which can be parameterized by a parameter k, will be used for the entropy coding of quantized DCT coefficients and also the coding of the motion vector data. Table 7 gives the code tables for the most commonly occurring EVENTs and codewords for k=1 and k=2 for the DCT efficients. In the table and generally, the last bit "s" denotes the sign of the level, "0" for positive and "1" for negative. The remaining EVENTs are coded with a fixed length code (FLC), as depicted in Error! Reference source not found. and Tables 5–6. Table 8 gives the code table for the motion vector data.

TABLE 5

FLC Table for RUN

RUN	CODE
0	000000
1	000001
2	000010
.	. . .
.	. . .
.	. . .
63	111111

TABLE 6

FLC table for Level

LEVEL	CODE
0	FORBIDDEN
1	0000000
2	0000001
.	. . .
.	. . .
.	. . .
127	1111111

TABLE 7

RVLCs for the DCT Coefficients. The INTRA column shall be used for INTRA luminance and the INTER column for INTER and INTRA chrominance and INTER luminance

	Intra			Inter				
Index	Last	Run	Level	Last	Run	Level	RVLC when k = 1	RVLC when k = 2
0	0	0	1	0	0	1	1s	11s
1	0	0	2	0	1	1	010s	10s
2	0	0	0	0	0	0	0001 ESCAPE	00001 ESCAPE

TABLE 7-continued

RVLCs for the DCT Coefficients. The INTRA column shall be used for INTRA luminance and the INTER column for INTER and INTRA chrominance and INTER luminance

	Intra			Inter				
Index	Last	Run	Level	Last	Run	Level	RVLC when k = 1	RVLC when k = 2
3	0	0	3	0	0	2	01110s	0100s
4	0	0	4	0	0	3	01100s	0001s
5	0	0	5	0	1	2	00110s	0101s
6	0	1	1	0	2	1	00100s	011101s
7	0	1	2	0	3	1	0111110s	011100s
8	0	2	1	0	4	1	0111100s	011001s
9	1	0	1	1	0	1	0110110s	011000s
10	0	0	6	0	0	4	0110100s	001101s
11	0	0	7	0	0	5	0011110s	001100s
12	0	0	8	0	0	6	0011100s	001001s
13	0	0	9	0	0	7	0010110s	001000s
14	0	0	10	0	1	3	0010100s	01111101s
15	0	0	11	0	1	4	011111110s	01111100s
16	0	1	3	0	2	2	011111100s	01111001s
17	0	1	4	0	3	2	011110110s	01111000s
18	0	1	5	0	4	2	011110100s	01101101s
19	0	2	2	0	5	1	011011110s	01101100s
20	0	3	1	0	5	2	011011100s	01101001s
21	0	3	2	0	6	1	011010110s	01101000s
22	0	4	1	0	7	1	011010100s	00111101s
23	0	5	1	0	8	1	001111110s	00111100s
24	0	6	1	0	9	1	001111100s	00111001s
25	0	7	1	0	10	1	001110110s	00111000s
26	0	8	1	0	11	1	001110100s	00101101s
27	1	0	2	1	0	2	001011110s	00101100s
28	1	1	1	1	1	1	001011100s	00101001s
29	1	1	2	1	2	1	001010110s	00101000s
30	1	2	1	1	3	1	001010100s	0111111101s
31	1	3	1	1	4	1	01111111110s	0111111100s
32	1	4	1	1	5	1	01111111100s	0111111001s
33	1	5	1	1	6	1	01111110110s	0111111000s
34	1	6	1	1	7	1	01111110100s	0111101101s
35	1	7	1	1	8	1	01111011110s	0111101100s
36	1	8	1	1	9	1	01111011100s	0111101001s
37	1	9	1	1	10	1	01111010110s	0111101000s
38	1	10	1	1	11	1	01111010100s	0110111101s
39	1	11	1	1	12	1	01101111110s	0110111100s
40	1	12	1	1	13	1	01101111100s	0110111001s
41	1	13	1	1	14	1	01101110110s	0110111000s
42	0	0	12	0	0	8	01101110100s	0110101101s
43	0	0	13	0	0	9	01101011110s	0110101100s
44	0	0	14	0	0	10	01101011100s	0110101001s
45	0	0	15	0	0	11	01101010110s	0110101000s
46	0	0	16	0	0	12	01101010100s	0011111101s
47	0	0	17	0	0	13	00111111110s	0011111100s
48	0	0	18	0	0	14	00111111100s	0011111001s
49	0	0	19	0	0	15	00111110110s	0011111000s
50	0	0	20	0	0	16	00111110100s	0011101101s
51	0	0	21	0	0	17	00111011110s	0011101100s
52	0	0	22	0	0	18	00111011100s	0011101001s
53	0	0	23	0	0	19	00111010110s	0011101000s
54	0	0	24	0	0	20	00111010100s	0010111101s
55	0	0	25	0	0	21	00101111110s	0010111100s
56	0	0	26	0	0	22	00101111100s	0010111001s
57	0	0	27	0	0	23	00101110110s	0010111000s
58	0	0	28	0	0	24	00101110100s	0010101101s
59	0	0	29	0	0	25	00101011110s	0010101100s
60	0	0	30	0	0	26	00101011100s	0010101001s
61	0	0	31	0	0	27	00101010110s	0010101000s
62	0	0	32	0	1	5	00101010100s	011111111101s
63	0	0	33	0	1	6	0111111111110s	011111111100s
64	0	0	34	0	1	7	0111111111100s	011111111001s
65	0	1	6	0	1	8	0111111110110s	011111111000s
66	0	1	7	0	1	9	0111111110100s	011111101101s
67	0	1	8	0	1	10	0111111011110s	011111101100s
68	0	1	9	0	1	11	0111111011100s	011111101001s
69	0	1	10	0	1	12	0111111010110s	011111101000s
70	0	1	11	0	2	3	0111111010100s	011110111101s
71	0	1	12	0	2	4	0111101111110s	011110111100s
72	0	1	13	0	2	5	0111101111100s	011110111001s

TABLE 7-continued

RVLCs for the DCT Coefficients. The INTRA column shall be used for INTRA luminance and the INTER column for INTER and INTRA chrominance and INTER luminance

	Intra			Inter				
Index	Last	Run	Level	Last	Run	Level	RVLC when k = 1	RVLC when k = 2
73	0	1	14	0	2	6	0111101110110s	011110111000s
74	0	1	15	0	2	7	0111101110100s	011110101101s
75	0	1	16	0	2	8	0111101011110s	011110101100s
76	0	2	3	0	3	3	0111101011100s	011110101001s
77	0	2	4	0	3	4	0111101010110s	011110101000s
78	0	2	5	0	3	5	0111101010100s	011011111101s
79	0	2	6	0	3	6	0110111111110s	011011111100s
80	0	2	7	0	4	3	0110111111100s	011011111001s
81	0	2	8	0	4	4	0110111110110s	011011111000s
82	0	3	3	0	4	5	0110111110100s	011011101101s
83	0	3	4	0	5	3	0110111011110s	011011101100s
84	0	3	5	0	5	4	0110111011100s	011011101001s
85	0	3	6	0	5	5	0110111010110s	011011101000s
86	0	3	7	0	6	2	0110111010100s	011010111101s
87	0	3	8	0	6	3	0110101111110s	011010111100s
88	0	3	9	0	6	4	0110101111100s	011010111001s
89	0	4	2	0	7	2	0110101110110s	011010111000s
90	0	4	3	0	7	3	0110101110100s	011010101101s
91	0	4	4	0	7	4	0110101011110s	011010101100s
92	0	4	5	0	8	2	0110101011100s	011010101001s
93	0	5	2	0	8	3	0110101010110s	011010101000s
94	0	5	3	0	8	4	0110101010100s	001111111101s
95	0	5	4	0	9	2	0011111111110s	001111111100s
96	0	5	5	0	9	3	0011111111100s	001111111001s
97	0	5	6	0	9	4	0011111110110s	001111111000s
98	0	5	7	0	10	2	0011111110100s	001111101101s
99	0	5	8	0	10	3	0011111011110s	001111101100s
100	0	6	2	0	11	2	0011111011100s	001111101001s
101	0	6	3	0	12	1	0011111010110s	001111101000s
102	0	6	4	0	12	2	0011111010100s	001110111101s
103	0	7	2	0	13	1	0011101111110s	001110111100s
104	0	7	3	0	13	2	0011101111100s	001110111001s
105	0	7	4	0	14	1	0011101110110s	001110111000s
106	0	7	5	0	14	2	0011101110100s	001110101101s
107	0	7	7	0	15	1	0011101011110s	001110101100s
108	0	8	2	0	15	2	0011101011100s	001110101001s
109	0	8	3	0	16	1	0011101010110s	001110101000s
110	0	9	1	0	17	1	0011101010100s	001011111101s
111	0	9	2	0	18	1	0010111111110s	001011111100s
112	0	9	3	0	19	1	0010111111100s	001011111001s
113	0	9	4	0	20	1	0010111110110s	001011111000s
114	0	9	5	0	21	1	0010111110100s	001011101101s
115	0	10	1	0	22	1	0010111011110s	001011101100s
116	0	10	2	0	23	1	0010111011100s	001011101001s
117	0	11	1	0	24	1	0010111010110s	001011101000s
118	0	11	2	0	25	1	0010111010100s	001010111101s
119	0	12	1	0	26	1	0010101111110s	001010111100s
120	0	13	1	0	27	1	0010101111100s	001010111001s
121	0	14	1	0	30	1	0010101110110s	001010111000s
122	0	15	1	0	31	1	0010101110100s	001010101101s
123	0	16	1	0	32	1	0010101011110s	001010101100s
124	1	0	3	1	0	3	0010101011100s	001010101001s
125	1	0	4	1	0	4	0010101010110s	001010101000s
126	1	0	5	1	0	5	0010101010100s	0111111111101s
127	1	0	6	1	1	2	01111111111110s	0111111111100s
128	1	1	3	1	1	3	01111111111100s	0111111111001s
129	1	1	4	1	2	2	01111111110110s	0111111111000s
130	1	1	5	1	2	3	01111111110100s	0111111101101s
131	1	1	6	1	3	2	01111111011110s	0111111101100s
132	1	2	2	1	4	2	01111111011100s	0111111101001s
133	1	2	3	1	5	2	01111111010110s	0111111101000s
134	1	3	2	1	6	2	01111111010100s	0111110111101s
135	1	3	3	1	7	2	01111101111110s	0111110111100s
136	1	4	2	1	8	2	01111101111100s	0111110111001s
137	1	5	2	1	9	2	01111101110110s	0111110111000s
138	1	5	3	1	10	2	01111101110100s	0111110101101s
139	1	6	2	1	11	2	01111101011110s	0111110101100s
140	1	6	3	1	12	2	01111101011100s	0111110101001s
141	1	7	2	1	13	2	01111101010110s	0111110101000s
142	1	7	3	1	15	1	01111101010100s	0111011111101s
143	1	8	2	1	16	1	01110111111110s	0111011111100s

TABLE 7-continued

RVLCs for the DCT Coefficients. The INTRA column shall be used for INTRA luminance and the INTER column for INTER and INTRA chrominance and INTER luminance

	Intra			Inter				
Index	Last	Run	Level	Last	Run	Level	RVLC when k = 1	RVLC when k = 2
144	1	9	2	1	17	1	011110111111100s	01111011111001s
145	1	9	3	1	18	1	011110111110110s	01111011111000s
146	1	10	2	1	19	1	011110111110100s	01111011101101s
147	1	11	2	1	20	1	011110111011110s	01111011101100s
148	1	11	3	1	21	1	011110111011100s	01111011101001s
149	1	12	2	1	22	1	011110111010110s	01111011101000s
150	1	13	2	1	23	1	011110111010100s	01111010111101s
151	1	13	3	1	24	1	011110101111110s	01111010111100s
152	1	13	4	1	25	1	011110101111100s	01111010111001s
153	1	14	1	1	26	1	011110101110110s	01111010111000s
154	1	14	2	1	27	1	011110101110100s	01111010101101s
155	1	15	1	1	28	1	011110101011110s	01111010101100s
156	1	16	1	1	29	1	011110101011100s	01111010101001s
157	1	17	1	1	30	1	011110101010110s	01111010101000s
158	1	18	1	1	31	1	011110101010100s	01101111111101s
159	1	19	1	1	32	1	011011111111110s	01101111111100s
160	1	20	1	1	33	1	011011111111100s	01101111111001s
161	1	21	1	1	34	1	011011111110110s	01101111111000s
162	1	22	1	1	35	1	011011111110100s	01101111101101s
163	1	23	1	1	36	1	011011111011110s	01101111101100s
164	1	24	1	1	37	1	011011111011100s	01101111101001s
165	1	25	1	1	38	1	011011111010110s	01101111101000s
166	1	26	1	1	39	1	011011111010100s	01101110111101s
167	1	27	1	1	40	1	011011101111110s	01101110111100s
168	1	28	1	1	45	1	011011101111100s	01101110111001s
169	1	30	1	1	46	1	011011101110110s	01101110111000s

TABLE 8

RVLCs for the Motion Vector Data

Absolute Value of Motion Vector Component (Vertical or Horizontal)	RVLC with k = 1		RVLC with k = 2	
	code	length	code	length
0	01	2	001	3
1	101s	4	01s	3
2	111s	4	1010s	5
3	10001s	6	1011s	5
4	10011s	6	1110s	5
5	11001s	6	1111s	5
6	11011s	6	100010s	7
7	1000001s	8	100011s	7
8	1000011s	8	100110s	7
9	1001001s	8	100111s	7
10	1001011s	8	110010s	7
11	1100001s	8	110011s	7
12	1100011s	8	110110s	7
13	1101001s	8	110111s	7
14	1101011s	8	10000010s	9
15	100000001s	10	10000011s	9
16	100000011s	10	10000110s	9
17	100001001s	10	10000111s	9
18	100001011s	10	10010010s	9
19	100100001s	10	10010011s	9
20	100100011s	10	10010110s	9
21	100101001s	10	10010111s	9
22	100101011s	10	11000010s	9
23	110000001s	10	11000011s	9
24	110000011s	10	11000110s	9
25	110001001s	10	11000111s	9
26	110001011s	10	11010010s	9
27	110100001s	10	11010011s	9
28	110100011s	10	11010110s	9
29	110101001s	10	11010111s	9

TABLE 8-continued

RVLCs for the Motion Vector Data

Absolute Value of Motion Vector Component (Vertical or Horizontal)	RVLC with k = 1		RVLC with k = 2	
	code	length	code	length
30	110101011s	10	1000000011s	11
31	10000000001s	12	1000000011s	11
32	10000000011s	12	1000000110s	11
33	10000001001s	12	1000000111s	11
34	10000001011s	12	1000010010s	11
35	10000100001s	12	1000010011s	11
36	10000100011s	12	1000010110s	11
37	10000101001s	12	1000010111s	11
38	10000101011s	12	1001000010s	11
39	10010000001s	12	1001000011s	11
40	10010000011s	12	1001000110s	11
41	10010001001s	12	1001000111s	11
42	10010001011s	12	1001010010s	11
43	10010100001s	12	1001010011s	11
44	10010100011s	12	1001010110s	11
45	10010101001s	12	1001010111s	11
46	10010101011s	12	1100000011s	11
47	11000000001s	12	1100000011s	11
48	11000000011s	12	1100000110s	11
49	11000001001s	12	1100000111s	11
50	11000001011s	12	1100010010s	11
51	11000100001s	12	1100010011s	11
52	11000100011s	12	1100010110s	11
53	11000101001s	12	1100010111s	11
54	11000101011s	12	1101000010s	11
55	11010000001s	12	1101000011s	11
56	11010000011s	12	1101000110s	11
57	11010001001s	12	1101000111s	11
58	11010001011s	12	1101010010s	11
59	11010100001s	12	1101010011s	11
60	11010100011s	12	1101010110s	11
61	11010101001s	12	0101010111s	11
62	11010101011s	12	100000000011s	13
63	1000000000001s	14	100000000011s	13
64	1000000000011s	14	100000000110s	13
65	1000000001001s	14	100000000111s	13
66	1000000001011s	14	100000010010s	13
67	1000000100001s	14	100000010011s	13
68	1000000100011s	14	100000010110s	13
69	1000000101001s	14	100000010111s	13
70	1000000101011s	14	100001000010s	13
71	1000010000001s	14	100001000011s	13
72	1000010000011s	14	100001000110s	13
73	1000010001001s	14	100001000111s	13
74	1000010001011s	14	100001010010s	13
75	1000010100001s	14	100001010011s	13
76	1000010100011s	14	100001010110s	13
77	1000010101001s	14	100001010111s	13
78	1000010101011s	14	100100000011s	13
79	1001000000001s	14	100100000011s	13
80	1001000000011s	14	100100000110s	13
81	1001000001001s	14	100100000111s	13
82	1001000001011s	14	100100010010s	13
83	1001000100001s	14	100100010011s	13
84	1001000100011s	14	100100010110s	13
85	1001000101001s	14	100100010111s	13
86	1001000101011s	14	100101000010s	13
87	1001010000001s	14	100101000011s	13
88	1001010000011s	14	100101000110s	13
89	1001010001001s	14	100101000111s	13
90	1001010001011s	14	100101000111s	13
91	1001010100001s	14	100101010011s	13
92	1001010100011s	14	100101010011s	13
93	1001010101001s	14	100101010111s	13
94	1001010101011s	14	110000000011s	13
95	1100000000001s	14	110000000011s	13
96	1100000000011s	14	110000000110s	13
97	1100000001001s	14	110000000111s	13
98	1100000001011s	14	110000010010s	13
99	1100000100001s	14	110000010011s	13

TABLE 8-continued

RVLCs for the Motion Vector Data

Absolute Value of Motion Vector Component (Vertical or Horizontal)	RVLC with k = 1 code	RVLC with k = 1 length	RVLC with k = 2 code	RVLC with k = 2 length
100	1100000100011s	14	110000010110s	13
101	1100000101001s	14	110000010111s	13
102	1100000101011s	14	110001000010s	13
103	1100010000001s	14	110001000011s	13
104	1100010000011s	14	110001000110s	13
105	1100010001001s	14	110001000111s	13
106	1100010001011s	14	110001010010s	13
107	1100010100001s	14	110001010011s	13
108	1100010100011s	14	110001010110s	13
109	1100010101001s	14	110001010111s	13
110	1100010101011s	14	110100000001s	13
111	1101000000001s	14	110100000011s	13
112	1101000000011s	14	110100000110s	13
113	1101000001001s	14	110100000111s	13
114	1101000001011s	14	110100010010s	13
115	1101000100001s	14	110100010011s	13
116	1001000100011s	14	110100010110s	13
117	1001000101001s	14	110100010111s	13
118	1001000101011s	14	110101000010s	13
119	1001010000001s	14	110101000011s	13
120	1001010000011s	14	110101000110s	13
121	1001010001001s	14	110101000111s	13
122	1001010001011s	14	110101010010s	13
123	1001010100001s	14	110101010011s	13
124	1001010100011s	14	110101010110s	13
125	1001010101001s	14	110101010111s	13
126	1001010101011s	14	10000000000010s	15
127	100000000000001s	16	10000000000011s	15

Alternative RVLCs and Uses

The foregoing preferred embodiment used preferred embodiment RVLCs within a preferred embodiment syntax in which the motion data was partitioned into header data and motion vector data and separated by a Header Resynchronization Word. The preferred embodiment RVLCs can also be used with the data partitioning as in FIG. **6***a* by using the codes of Table 7 for the DCT data (DCT**1**, DCT**2**, . . . DCTn) of FIG. **6***c*.

Further, an RVLC can be used to code the CBPY plus DQUANT fields.

An alternative preferred embodiment uses the RVLC of Table 8 for the motion vector data without also using the separated header data and header resynchronization word.

Lastly, for other resynchronization markers, other RVLCs can be made in analogous fashions. For example, following Tables 9–11 are other versions of foregoing Tables 4 and 7–8.

TABLE 9

RVLC for COD + MCBPC for INTER coded video packets

Index	MB Type	CBPC (56)	Proposed RVLC for Combined COD + MCBPC: Codeword (Combined)	Length (Bits)
0	—	—	1	1
1	0	00	00	2
2	0	01	0110	4
3	0	10	01110	5
4	0	11	010010	6

TABLE 9-continued

RVLC for COD + MCBPC for INTER coded video packets

Index	MB Type	CBPC (56)	Proposed RVLC for Combined COD + MCBPC: Codeword (Combined)	Length (Bits)
5	1	00	011110	6
6	1	01	0111110	7
7	1	10	0100010	7
8	1	11	0101010	7
9	2	00	01111110	8
10	2	01	01000010	8
11	2	10	01011010	8
12	2	11	011111110	9
13	3	00	010000010	9
14	3	01	0101101010	11
15	3	10	0111111110	10
16	3	11	0100000010	10
17	4	00	0101111010	10
18	4	01	0100110010	10
19	4	10	01111111110	11
20	4	11	01000000010	11
21	Stuffing	—	01011111010	11

TABLE 10

RVLCs for the DCT Coefficients. The INTRA column shall be used for INTRA luminance and the INTER column for INTER and INTRA chrominance and INTER luminance

	Intra			Inter			Sample Code when	Sample Code when
Index	Last	Run	Level	Last	Run	Level	k = 1	k = 2
0	0	0	1	0	0	1	0s	00s
1	0	0	2	0	1	1	101s	01s
2	0	0	0	0	0	0	1111 ESCAPE	10101 ESCAPE
3	0	0	3	0	0	2	10001s	1011s
4	0	0	4	0	0	3	10011s	1110s
5	0	0	5	0	1	2	11001s	1111s
6	0	1	1	0	2	1	11011s	100010s
7	0	1	2	0	3	1	1000001s	100011s
8	0	2	1	0	4	1	1000011s	100110s
9	1	0	1	1	0	1	1001001s	100111s
10	0	0	6	0	0	4	1001011s	110010s
11	0	0	7	0	0	5	1100001s	110011s
12	0	0	8	0	0	6	1100011s	110110s
13	0	0	9	0	0	7	1101001s	110111s
14	0	0	10	0	1	3	1101011s	10000010s
15	0	0	11	0	1	4	100000001s	10000011s
16	0	1	3	0	2	2	100000011s	10000110s
17	0	1	4	0	3	2	100001001s	10000111s
18	0	1	5	0	4	2	100001011s	10010010s
19	0	2	2	0	5	1	100100001s	10010011s
20	0	3	1	0	5	2	100100011s	10010110s
21	0	3	2	0	6	1	100101001s	10010111s
22	0	4	1	0	7	1	100101011s	11000010s
23	0	5	1	0	8	1	110000001s	11000011s
24	0	6	1	0	9	1	110000011s	11000110s
25	0	7	1	0	10	1	110001001s	11000111s
26	0	8	1	0	11	1	110001011s	11010010s
27	1	0	2	1	0	2	110100001s	11010011s
28	1	1	1	1	1	1	110100011s	11010110s
29	1	1	2	1	2	1	110101001s	11010111s
30	1	2	1	1	3	1	110101011s	1000000010s
31	1	3	1	1	4	1	10000000001s	1000000011s
32	1	4	1	1	5	1	10000000011s	1000000110s
33	1	5	1	1	6	1	10000001001s	1000000111s
34	1	6	1	1	7	1	10000001011s	1000010010s
35	1	7	1	1	8	1	10000100001s	1000010011s
36	1	8	1	1	9	1	10000100011s	1000010110s
37	1	9	1	1	10	1	10000101001s	1000010111s
38	1	10	1	1	11	1	10000101011s	1001000010s
39	1	11	1	1	12	1	10010000001s	1001000011s
40	1	12	1	1	13	1	10010000011s	1001000110s
41	1	13	1	1	14	1	10010001001s	1001000111s
42	0	0	12	0	0	8	10010001011s	1001010010s
43	0	0	13	0	0	9	10010100001s	1001010011s
44	0	0	14	0	0	10	10010100011s	1001010110s
45	0	0	15	0	0	11	10010101001s	1001010111s
46	0	0	16	0	0	12	10010101011s	1100000010s
47	0	0	17	0	0	13	11000000001s	1100000011s
48	0	0	18	0	0	14	11000000011s	1100000110s
49	0	0	19	0	0	15	11000001001s	1100000111s
50	0	0	20	0	0	16	11000001011s	1100010010s
51	0	0	21	0	0	17	11000100001s	1100010011s
52	0	0	22	0	0	18	11000100011s	1100010110s
53	0	0	23	0	0	19	11000101001s	1100010111s
54	0	0	24	0	0	20	11000101011s	1101000010s
55	0	0	25	0	0	21	11010000001s	1101000011s
56	0	0	26	0	0	22	11010000011s	1101000110s
57	0	0	27	0	0	23	11010001001s	1101000111s
58	0	0	28	0	0	24	11010001011s	1101010010s
59	0	0	29	0	0	25	11010100001s	1101010011s
60	0	0	30	0	0	26	11010100011s	1101010110s
61	0	0	31	0	0	27	11010101001s	1101010111s
62	0	0	32	0	1	5	11010101011s	100000000010s
63	0	0	33	0	1	6	1000000000001s	100000000011s
64	0	0	34	0	1	7	1000000000011s	100000000110s
65	0	1	6	0	1	8	1000000001001s	100000000111s
66	0	1	7	0	1	9	1000000001011s	100000010010s
67	0	1	8	0	1	10	1000000100001s	100000010011s
68	0	1	9	0	1	11	1000000100011s	100000010110s
69	0	1	10	0	1	12	1000000101001s	100000010111s

TABLE 10-continued

RVLCs for the DCT Coefficients. The INTRA column shall be used for INTRA luminance and the INTER column for INTER and INTRA chrominance and INTER luminance

	Intra			Inter			Sample Code when	Sample Code when
Index	Last	Run	Level	Last	Run	Level	k = 1	k = 2
70	0	1	11	0	2	3	1000000101011s	100001000010s
71	0	1	12	0	2	4	1000010000001s	100001000011s
72	0	1	13	0	2	5	1000010000011s	100001000110s
73	0	1	14	0	2	6	1000010001001s	100001000111s
74	0	1	15	0	2	7	1000010001011s	100001010010s
75	0	1	16	0	2	8	1000010100001s	100001010011s
76	0	2	3	0	3	3	1000010100011s	100001010110s
77	0	2	4	0	3	4	1000010101001s	100001010111s
78	0	2	5	0	3	5	1000010101011s	100100000010s
79	0	2	6	0	3	6	1001000000001s	100100000011s
80	0	2	7	0	4	3	1001000000011s	100100000110s
81	0	2	8	0	4	4	1001000001001s	100100000111s
82	0	3	3	0	4	5	1001000001011s	100100010010s
83	0	3	4	0	5	3	1001000100001s	100100010011s
84	0	3	5	0	5	4	1001000100011s	100100010110s
85	0	3	6	0	5	5	1001000101001s	100100010111s
86	0	3	7	0	6	2	1001000101011s	100101000010s
87	0	3	8	0	6	3	1001010000001s	100101000011s
88	0	3	9	0	6	4	1001010000011s	100101000110s
89	0	4	2	0	7	2	1001010001001s	100101000111s
90	0	4	3	0	7	3	1001010001011s	100101010010s
91	0	4	4	0	7	4	1001010100001s	100101010011s
92	0	4	5	0	8	2	1001010100011s	100101010110s
93	0	5	2	0	8	3	1001010101001s	100101010111s
94	0	5	3	0	8	4	1001010101011s	110000000010s
95	0	5	4	0	9	2	1100000000001s	110000000011s
96	0	5	5	0	9	3	1100000000011s	110000000110s
97	0	5	6	0	9	4	1100000001001s	110000000111s
98	0	5	7	0	10	2	1100000001011s	110000010010s
99	0	5	8	0	10	3	1100000100001s	110000010011s
100	0	6	2	0	11	2	1100000100011s	110000010110s
101	0	6	3	0	12	1	1100000101001s	110000010111s
102	0	6	4	0	12	2	1100000101011s	110001000010s
103	0	7	2	0	13	1	1100010000001s	110001000011s
104	0	7	3	0	13	2	1100010000011s	110001000110s
105	0	7	4	0	14	1	1100010001001s	110001000111s
106	0	7	5	0	14	2	1100010001011s	110001010010s
107	0	7	7	0	15	1	1100010100001s	110001010011s
108	0	8	2	0	15	2	1100010100011s	110001010110s
109	0	8	3	0	16	1	1100010101001s	110001010111s
110	0	9	1	0	17	1	1100010101011s	110100000010s
111	0	9	2	0	18	1	1101000000001s	110100000011s
112	0	9	3	0	19	1	1101000000011s	110100000110s
113	0	9	4	0	20	1	1101000001001s	110100000111s
114	0	9	5	0	21	1	1101000001011s	110100010010s
115	0	10	1	0	22	1	1101000100001s	110100010011s
116	0	10	2	0	23	1	1101000100011s	110100010110s
117	0	11	1	0	24	1	1101000100001s	110100010111s
118	0	11	2	0	25	1	1101000101011s	110101000010s
119	0	12	1	0	26	1	1101010000001s	110101000011s
120	0	13	1	0	27	1	1101010000011s	110101000110s
121	0	14	1	0	30	1	1101010001001s	110101000111s
122	0	15	1	0	31	1	1101010001011s	110101010010s
123	0	16	1	0	32	1	1101010100001s	110101010011s
124	1	0	3	1	0	3	1101010100011s	110101010110s
125	1	0	4	1	0	4	1101010101001s	110101010111s
126	1	0	5	1	0	5	1101010101011s	1000000000000010s
127	1	0	6	1	1	2	100000000000001s	10000000000011s
128	1	1	3	1	1	3	100000000000011s	10000000000110s
129	1	1	4	1	2	2	100000000001001s	10000000000111s
130	1	1	5	1	2	3	100000000001011s	10000000010110s
131	1	1	6	1	3	2	100000000100001s	10000000010011s
132	1	2	2	1	4	2	100000000100011s	10000000010110s
133	1	2	3	1	5	2	100000000101001s	10000000010111s
134	1	3	2	1	6	2	100000000101011s	10000001000010s
135	1	3	3	1	7	2	100000010000001s	10000001000011s
136	1	4	2	1	8	2	100000010000011s	10000001000110s
137	1	5	2	1	9	2	100000010001001s	10000001000111s
138	1	5	3	1	10	2	100000010001011s	10000001010010s
139	1	6	2	1	11	2	100000010100001s	10000001010011s
140	1	6	3	1	12	2	100000010100011s	10000001010110s

TABLE 10-continued

RVLCs for the DCT Coefficients. The INTRA column shall be used for INTRA luminance and the INTER column for INTER and INTRA chrominance and INTER luminance

	Intra			Inter			Sample Code when	Sample Code when
Index	Last	Run	Level	Last	Run	Level	k = 1	k = 2
141	1	7	2	1	13	2	100000010101001s	10000001010111s
142	1	7	3	1	15	1	100000010101011s	10000100000010s
143	1	8	2	1	16	1	100001000000001s	10000100000011s
144	1	9	2	1	17	1	100001000000011s	10000100000110s
145	1	9	3	1	18	1	100001000001001s	10000100000111s
146	1	10	2	1	19	1	100001000001011s	10000100010010s
147	1	11	2	1	20	1	100001000100001s	10000100010011s
148	1	11	3	1	21	1	100001000100011s	10000100010110s
149	1	12	2	1	22	1	100001000101001s	10000100010111s
150	1	13	3	1	24	1	100001000101011s	10000101000010s
151	1	13	3	1	24	1	100001010000001s	10000101000011s
152	1	13	4	1	25	1	100001010000011s	10000101000110s
153	1	14	1	1	26	1	100001010001001s	10000101000111s
154	1	14	2	1	27	1	100001010001011s	10000101010010s
155	1	15	1	1	28	1	100001010100001s	10000101010011s
156	1	16	1	1	29	1	100001010100011s	10000101010110s
157	1	17	1	1	30	1	100001010101001s	10000101010111s
158	1	18	1	1	31	1	100001010101011s	10010000000010s
159	1	19	1	1	32	1	100100000000001s	10010000000011s
160	1	20	1	1	33	1	100100000000011s	10010000000110s
161	1	21	1	1	34	1	100100000001001s	10010000000111s
162	1	22	1	1	35	1	100100000001011s	10010000010010s
163	1	23	1	1	36	1	100100000100001s	10010000010011s
164	1	24	1	1	37	1	100100000100011s	10010000010110s
165	1	25	1	1	38	1	100100000101001s	10010000010111s
166	1	26	1	1	39	1	100100000101011s	10010001000010s
167	1	27	1	1	40	1	100100010000001s	10010001000011s
168	1	28	1	1	45	1	100100010000011s	10010001000110s
169	1	30	1	1	46	1	100100010001001s	10010001000111s

TABLE 11

RVLCs for the Motion Vector Data

Absolute Value of Motion Vector Component (Vertical or	RVLC with k = 1		RVLC with k = 2	
Horizontal)	code	length	code	length
0	00	2	000	3
1	101s	4	01s	3
2	111s	4	1010s	5
3	10001s	6	1011s	5
4	10011s	6	1110s	5
5	11001s	6	1111s	5
6	11011s	6	100010s	7
7	1000001s	8	100011s	7
8	1000011s	8	100110s	7
9	1001001s	8	100111s	7
10	1001011s	8	110010s	7
11	1100001s	8	110011s	7
12	1100011s	8	110110s	7
13	1101001s	8	110111s	7
14	1101011s	8	10000010s	9
15	100000001s	10	10000011s	9
16	100000011s	10	10000110s	9
17	100001001s	10	10000111s	9
18	100001011s	10	10010010s	9
19	100100001s	10	10010011s	9
20	100100011s	10	10010110s	9
21	100101001s	10	10010111s	9
22	100101011s	10	11000010s	9
23	110000001s	10	11000011s	9
24	110000011s	10	11000110s	9
25	110001001s	10	11000111s	9
26	110001011s	10	11010010s	9

TABLE 11-continued

RVLCs for the Motion Vector Data

Absolute Value of Motion Vector Component (Vertical or Horizontal)	RVLC with k = 1 code	RVLC with k = 1 length	RVLC with k = 2 code	RVLC with k = 2 length
27	110100001s	10	11010011s	9
28	110100011s	10	11010110s	9
29	110101001s	10	11010111s	9
30	110101011s	10	1000000011s	11
31	10000000001s	12	1000000011s	11
32	10000000011s	12	1000000110s	11
33	10000001001s	12	1000000111s	11
34	10000001011s	12	1000010010s	11
35	10000100001s	12	1000010011s	11
36	10000100011s	12	1000010110s	11
37	10000101001s	12	1000010111s	11
38	10000101011s	12	1001000010s	11
39	10010000001s	12	1001000011s	11
40	10010000011s	12	1001000110s	11
41	10010001001s	12	1001000111s	11
42	10010001011s	12	1001010010s	11
43	10010100001s	12	1001010011s	11
44	10010100011s	12	1001010110s	11
45	10010101001s	12	1001010111s	11
46	10010101011s	12	1100000011s	11
47	11000000001s	12	1100000011s	11
48	11000000011s	12	1100000110s	11
49	11000001001s	12	1100000111s	11
50	11000001011s	12	1100010010s	11
51	11000100001s	12	1100010011s	11
52	11000100011s	12	1100010110s	11
53	11000101001s	12	1100010111s	11
54	11000101011s	12	1101000010s	11
55	11010000001s	12	1101000011s	11
56	11010000011s	12	1101000110s	11
57	11010001001s	12	1101000111s	11
58	11010001011s	12	1101010010s	11
59	11010100001s	12	1101010011s	11
60	11010100011s	12	1101010110s	11
61	11010101001s	12	0101010111s	11
62	11010101011s	12	100000000011s	13
63	1000000000001s	14	100000000011s	13
64	1000000000011s	14	100000000110s	13
65	1000000001001s	14	100000000111s	13
66	1000000001011s	14	100000010010s	13
67	1000000100001s	14	100000010011s	13
68	1000000100011s	14	100000010110s	13
69	1000000101001s	14	100000010111s	13
70	1000000101011s	14	100001000010s	13
71	1000010000001s	14	100001000011s	13
72	1000010000011s	14	100001000110s	13
73	1000010001001s	14	100001000111s	13
74	1000010001011s	14	100001010010s	13
75	1000010100001s	14	100001010011s	13
76	1000010100011s	14	100001010110s	13
77	1000010101001s	14	100001010111s	13
78	1000010101011s	14	100100000011s	13
79	1001000000001s	14	100100000011s	13
80	1001000000011s	14	100100000110s	13
81	1001000001001s	14	100100000111s	13
82	1001000001011s	14	100100010010s	13
83	1001000100001s	14	100100010011s	13
84	1001000100011s	14	100100010110s	13
85	1001000101001s	14	100100010111s	13
86	1001000101011s	14	100101000010s	13
87	1001010000001s	14	100101000011s	13
88	1001010000011s	14	100101000110s	13
89	1001010001001s	14	100101000111s	13
90	1001010001011s	14	100101010010s	13
91	1001010100001s	14	100101010011s	13
92	1001010100011s	14	100101010110s	13
93	1001010101001s	14	100101010111s	13
94	1001010101011s	14	110000000011s	13
95	1100000000001s	14	110000000011s	13
96	1100000000011s	14	110000000110s	13

TABLE 11-continued

RVLCs for the Motion Vector Data

Absolute Value of Motion Vector Component (Vertical or Horizontal)	RVLC with k = 1 code	RVLC with k = 1 length	RVLC with k = 2 code	RVLC with k = 2 length
97	1100000001001s	14	110000000111s	13
98	1100000001011s	14	110000010010s	13
99	1100000100001s	14	110000010011s	13
100	1100000100011s	14	110000010110s	13
101	1100000101001s	14	110000010111s	13
102	1100000101011s	14	110001000010s	13
103	1100010000001s	14	110001000011s	13
104	1100010000011s	14	110001000110s	13
105	1100010001001s	14	110001000111s	13
106	1100010001011s	14	110001010010s	13
107	1100010100001s	14	110001010011s	13
108	1100010100011s	14	110001010110s	13
109	1100010101001s	14	110001010111s	13
110	1101000000011s	14	110100000001s	13
111	1101000000001s	14	110100000011s	13
112	1101000000011s	14	110100000110s	13
113	1101000001001s	14	110100000111s	13
114	1101000001011s	14	110100010010s	13
115	1101000100001s	14	110100010011s	13
116	1001000100011s	14	110100010110s	13
117	1001000101001s	14	110100010111s	13
118	1001000101011s	14	110101000010s	13
119	1001010000001s	14	110101000011s	13
120	1001010000011s	14	110101000110s	13
121	1001010001001s	14	110101000111s	13
122	1001010001011s	14	110101010010s	13
123	1001010100001s	14	110101010011s	13
124	1001010100011s	14	110101010110s	13
125	1001010101001s	14	110101010111s	13
126	1001010101011s	14	10000000000010s	15
127	100000000000001s	16	10000000000011s	15

Object Based Compression

The foregoing RVLCs and bitstream syntax also extends to object based compression by just including the object shape data in a field (typically preceding the motion data) and optionally with a Shape Resynchronization Word to separate shape data from motion data.

What is claimed is:

1. A method of decoding a compressed video bit stream packet, comprising the steps of:

(a) interpreting codewords as reversible exp-Golomb type codewords; and

(b) decoding in both forward and backward directions when an error is indicated.

2. The method of claim **1**, wherein:

(a) portions of said packet between errors found in said forward and backward decodings are discarded.

3. The method of claim **1**, wherein:

(a) said reversible exp-Golomb type code has codewords with a symmetrical prefix portion plus a suffix portion of a first length.

4. The method of claim **1**, wherein:

(a) said reversible exp-Golomb type code has codewords including a portion with symmetrical odd-numbered bits.

5. The method of claim **4**, wherein:

(a) said portion has the format 1x0x0x . . . x0x1, where the x's represent information bits.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 6,385,251 B1 Page 1 of 1
DATED : May 7, 2002
INVENTOR(S) : Rajendra K. Talluri, Jiangtao Wen and John Villasenor

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Title page,
Item [73], Assignee, below "**Texas Instruments Incorporated**, Dallas, TX (US)" add -- **Regents of the University of California**, Oakland, CA (US) --.

Signed and Sealed this

Twenty-seventh Day of April, 2004

JON W. DUDAS
Acting Director of the United States Patent and Trademark Office