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**Bjontegaard et al.**

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(54) **CONTEXT-ADAPTIVE VLC VIDEO TRANSFORM COEFFICIENTS ENCODING/DECODING METHODS AND APPARATUSES**

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(51) **Int. Cl.**
***H04B 1/66*** (2006.01)

(52) **U.S. Cl.** ..... **375/240**; 375/240.23; 375/240.25; 375/240.24; 382/246; 382/245; 382/247; 382/233; 382/235

(58) **Field of Classification Search** ..... 375/240, 375/240.23, 240.25, 240.24; 382/246, 245, 382/247, 233, 235
See application file for complete search history.

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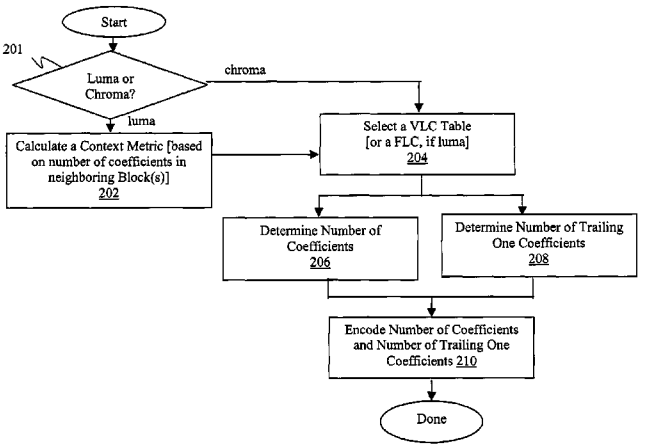
(Continued)

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(57) **ABSTRACT**

Transform coefficients of sample blocks of a macroblock of a video picture are encoded by adaptively encoding in combination, the number of non-zero coefficients before the trailing one coefficients and the number of trailing one coefficients. The transform coefficients may be further encoded by adaptively encoding one or more of the signs of the trailing one coefficients, the level measures of the non-zero coefficients, the total number of zero coefficients interposed in the non-zero coefficients, and the respective run lengths of the zero coefficients. Adaptive encoding of the number and trailing one coefficients may be performed in view of one or more neighboring sample blocks, whereas adaptive encoding of level measures may be performed in view of quantization parameters of a macroblock and previously encoded level measures. Decoding may be performed in an inverse manner.

**12 Claims, 7 Drawing Sheets**




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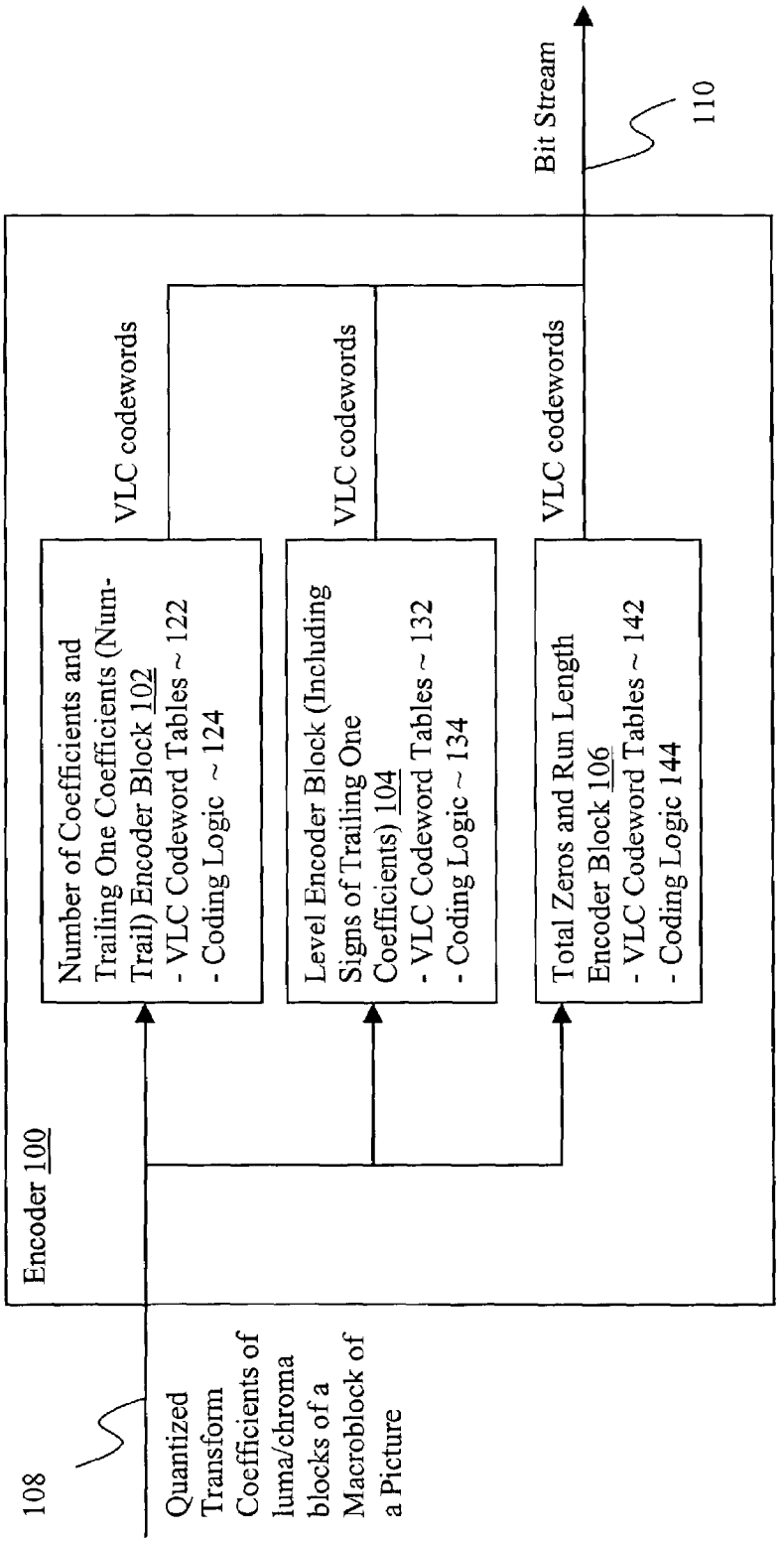

Encoder 100
108
Quantized Transform Coefficients of luma/chroma blocks of a Macroblock of a Picture
Number of Coefficients and Trailing One Coefficients (Num-Trail) Encoder Block 102
- VLC Codeword Tables ~ 122
- Coding Logic ~ 124
Level Encoder Block (Including Signs of Trailing One Coefficients) 104
- VLC Codeword Tables ~ 132
- Coding Logic ~ 134
Total Zeros and Run Length Encoder Block 106
- VLC Codeword Tables ~ 142
- Coding Logic 144
VLC codewords
VLC codewords
VLC codewords
Bit Stream
110

Figure 1

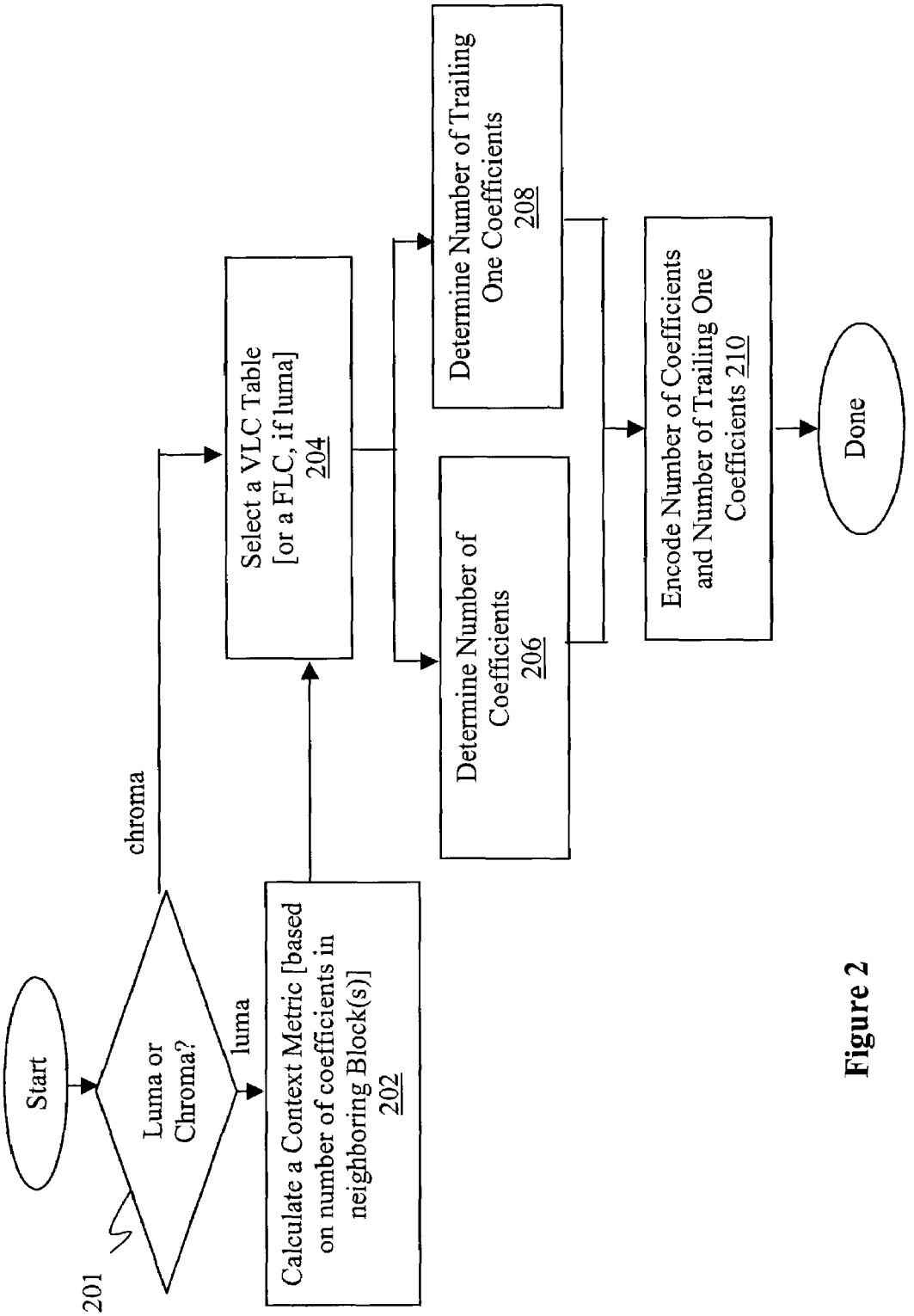

Start
Luma or Chroma?
201
luma
chroma
Calculate a Context Metric [based on number of coefficients in neighboring Block(s)] 202
Select a VLC Table [or a FLC, if luma] 204
Determine Number of Coefficients 206
Determine Number of Trailing One Coefficients 208
Encode Number of Coefficients and Number of Trailing One Coefficients 210
Done

Figure 2

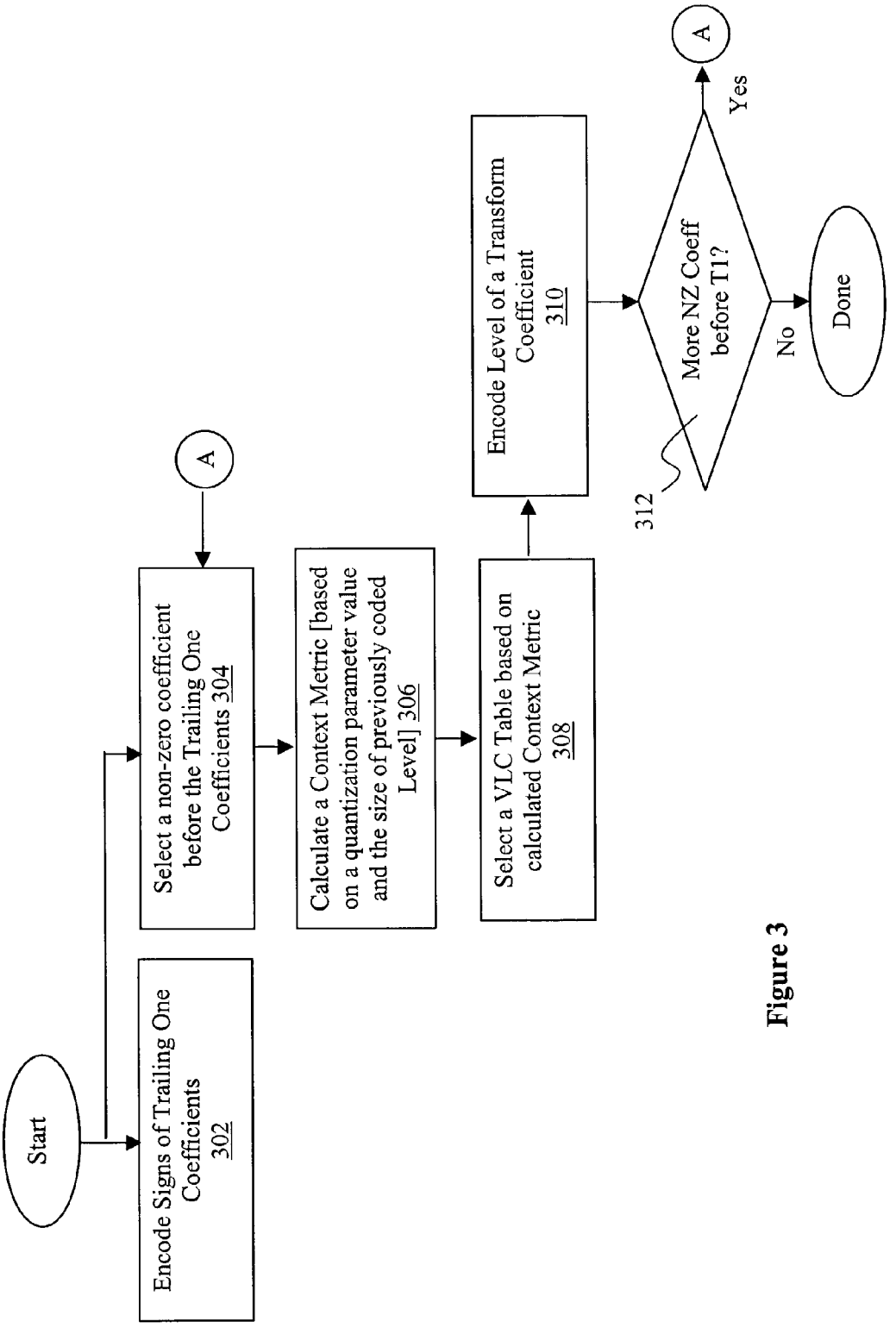
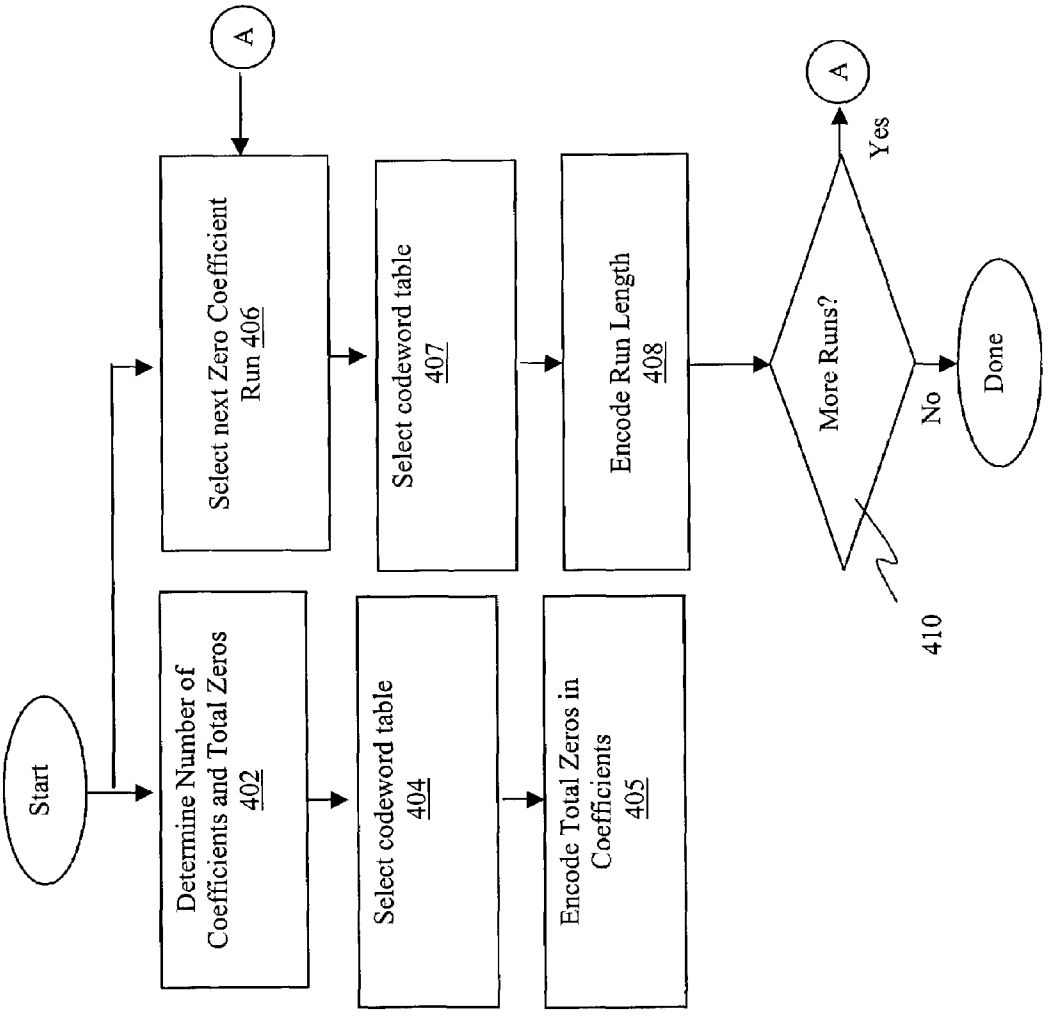

Start
Encode Signs of Trailing One Coefficients 302
Select a non-zero coefficient before the Trailing One Coefficients 304
Calculate a Context Metric [based on a quantization parameter value and the size of previously coded Level] 306
Select a VLC Table based on calculated Context Metric 308
Encode Level of a Transform Coefficient 310
More NZ Coeff before T1?
312
Yes
No
A
A
Done

Figure 3

Figure 4


Start
Determine Number of Coefficients and Total Zeros 402
Select codeword table 404
Encode Total Zeros in Coefficients 405
A
Select next Zero Coefficient Run 406
Select codeword table 407
Encode Run Length 408
More Runs?
Yes
No
A
Done
410

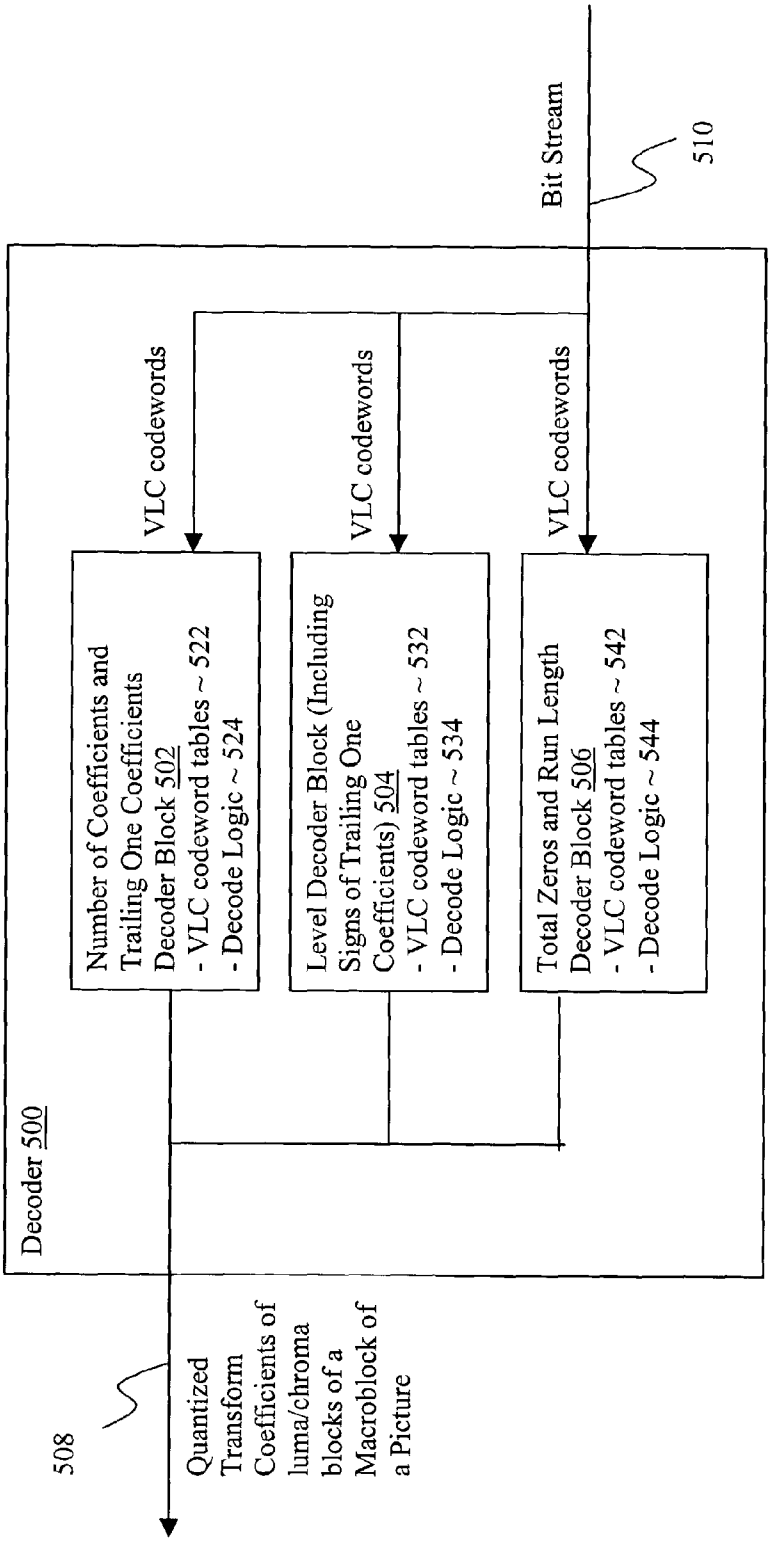

Bit Stream
510
Decoder 500
VLC codewords
VLC codewords
VLC codewords
Number of Coefficients and Trailing One Coefficients Decoder Block 502
- VLC codeword tables ~ 522
- Decode Logic ~ 524
Level Decoder Block (Including Signs of Trailing One Coefficients) 504
- VLC codeword tables ~ 532
- Decode Logic ~ 534
Total Zeros and Run Length Decoder Block 506
- VLC codeword tables ~ 542
- Decode Logic ~ 544
508
Quantized Transform Coefficients of luma/chroma blocks of a Macroblock of a Picture

Figure 5

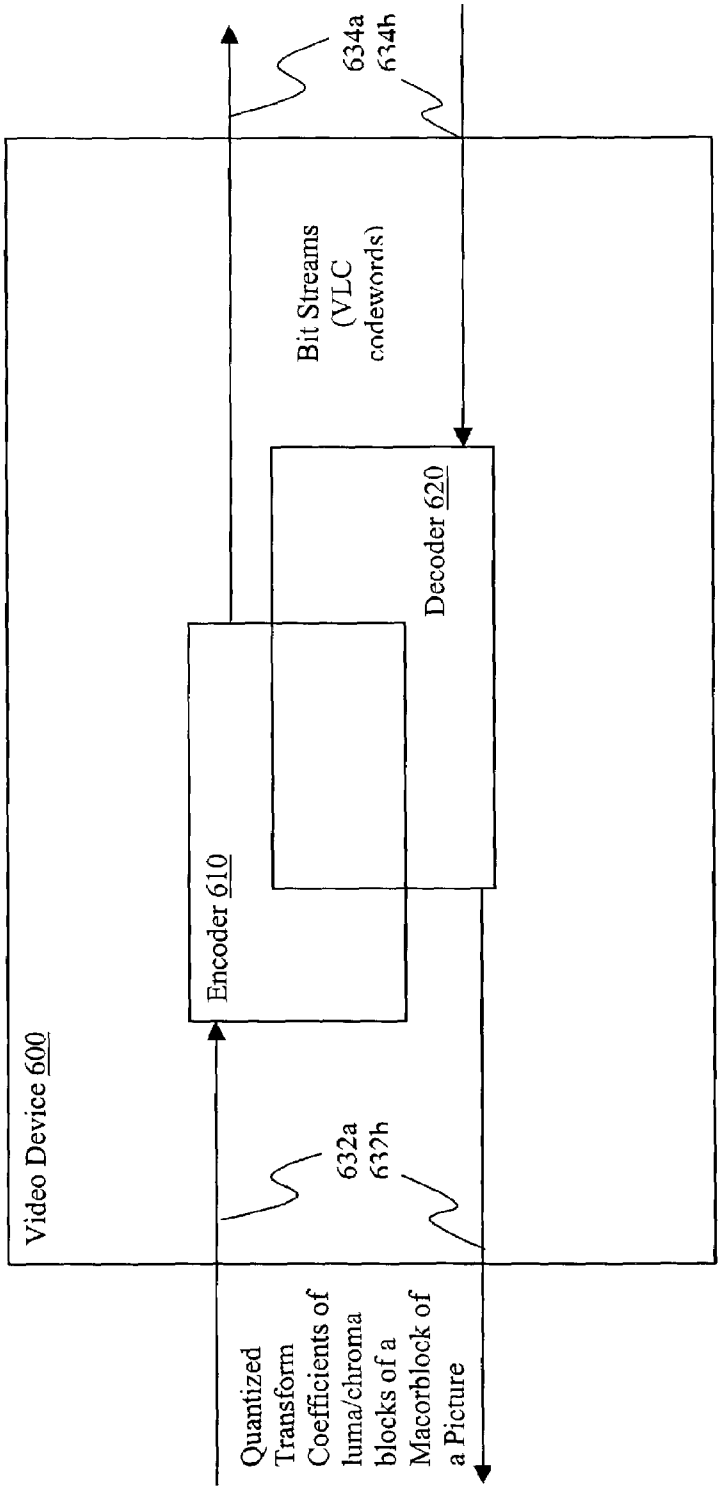

Video Device 600
Encoder 610
Decoder 620
Bit Streams (VLC codewords)
634a
634b
632a
632b
Quantized Transform Coefficients of luma/chroma blocks of a Macorblock of a Picture

Figure 6

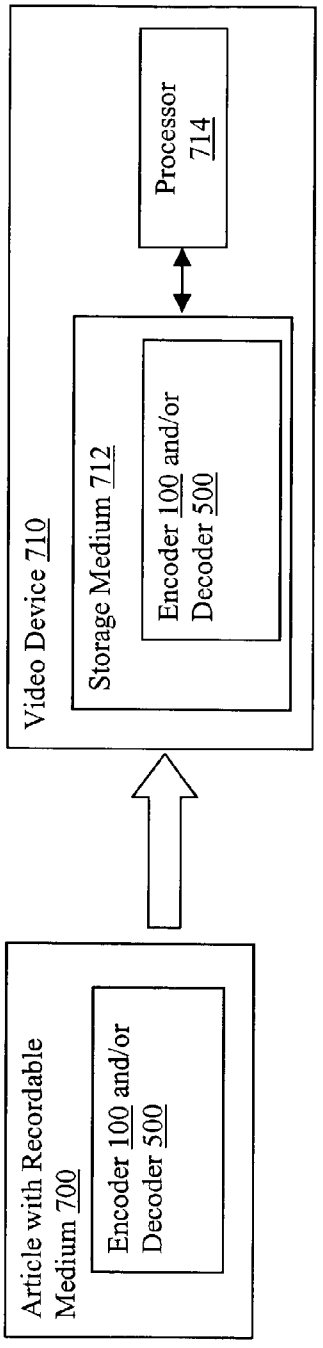



Figure 7

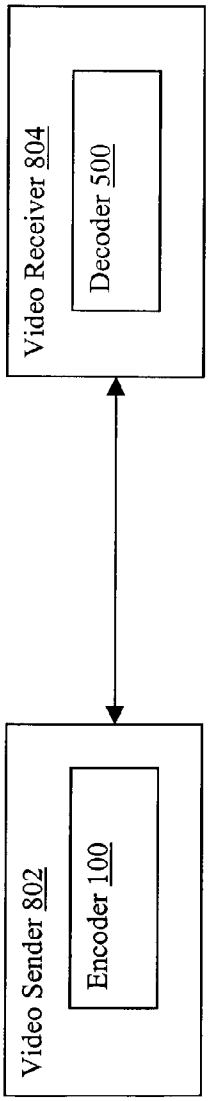



Figure 8

# CONTEXT-ADAPTIVE VLC VIDEO TRANSFORM COEFFICIENTS ENCODING/DECODING METHODS AND APPARATUSES

## RELATED APPLICATION

The present application is a non-provision application of provisional application No. 60/367,032, filed on Mar. 22, 2002, and claims priority to said provisional application, which specification is hereby fully incorporated by reference.

## FIELD OF THE INVENTION

The present invention relates to the field of video encoding/decoding. More specifically, the present invention is related to the encoding of transform coefficients of (luma/chroma) blocks of a macroblock of a picture, and decoding of the encodings.

## BACKGROUND OF THE INVENTION

Advances in microprocessor and video related technologies have led to wide spread deployment and adoption of numerous types of video devices. Examples of such video devices include but are not limited to digital camcorders, digital versatile disk (DVD) players, video enabled laptop and desktop computing devices as well as servers, and so forth.

Advances in networking, telecommunication, satellite and other related technologies have also led to increase in on demand and/or real time online delivery of video, including delivery over public networks, such as the Internet.

Whether videos are delivered offline (e.g. from a DVD player) or online (e.g. from a video server), high quality video inherently requires a high volume of data. Thus, video delivery and rendering often involve encoding and decoding to reduce the amount of data to be stored, retrieved and/or transmitted.

Encoding/decoding of a video often involves processing the video as a stream of pictures. Each picture may be a field or a frame (typically consisting of two interleaved fields), and decomposed into a number of macroblocks. Each macroblock is often sub-divided into blocks of various sizes, which are transformed and quantized into a number of samples, luma and/or chroma samples of various types.

A number of encoding/decoding techniques are known in the art. For example, one technique encodes the various parameters of a macroblock using a single variable length coding (VLC) scheme. The technique is simple to practice, however the amount of reduction in data, i.e. compression, is only moderately effective.

Other techniques, such as Context-based Adaptive Binary Arithmetic Coding (CABAC), employ context adaptation and arithmetic coding to improve overall effectiveness. However, techniques such as CABAC are complex, memory demanding, and difficult to practice.

What is needed is a context-adaptive technique that is more effective than conventional non-context-adaptive techniques, but less complex to practice than context-adaptive techniques known to-date.

## BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be described by way of exemplary embodiments, but not limitations, illustrated in the accompanying drawings in which like references denote similar elements, and in which:



FIG. **1** illustrates an overview of a context-adaptive VLC encoder of the present invention for encoding transform coefficients of (luma/chroma) blocks of a macroblock of a picture, in accordance with one embodiment;

FIG. **2** illustrates the operational flow of the relevant aspects of the encoder block of FIG. **1** for encoding in a combined manner, number of coefficients and number of trailing one coefficients of a series of transform coefficients of (luma/chroma) blocks of a macroblock of a picture, in accordance with one embodiment;

FIG. **3** illustrates the operational flow of the relevant aspects of the encoder block of FIG. **1** for encoding level measures of transform coefficients of (luma/chroma) blocks of a macroblock of a picture, in accordance with one embodiment;

FIG. **4** illustrates the operational flow of the relevant aspects of the encoder block of FIG. **1** for encoding number of zero coefficients interposed among non-zero coefficients and their respective run lengths of transform coefficients of (luma/chroma) blocks of a macroblock of a picture, in accordance with one embodiment;

FIG. **5** illustrates an overview of a context-adaptive VLC decoder of the present invention for decoding transform coefficients encoded in accordance with encoding principles similar to that of the encoder of FIG. **1**, in accordance with one embodiment;

FIG. **6** illustrates a video device having an encoder and a decoder incorporated with the encoding/decoding teachings of the present invention, in accordance with one embodiment;

FIG. **7** illustrates an article of manufacture with a recordable medium having a software implementation of the encoder/decoder of the present invention, designed for use to program a device to equip the device with the encoding/decoding capability of the present invention, in accordance with one embodiment; and

FIG. **8** illustrates a system having a video sender device and a video receiver device incorporated with the encoding/decoding teachings of the present invention, in accordance with one embodiment.

## DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

The present invention includes a context-adaptive VLC transform coefficient encoder, a complementary decoder, devices equipped with these encoders and/or decoders, systems made up of such devices, and methods of operations of these elements, devices and systems, and related subject matters.

In the following description, various aspects of the present invention will be described. However, it will be apparent to those skilled in the art that the present invention may be practiced with only some or all aspects of the present invention. For purposes of explanation, specific numbers, materials and configurations are set forth in order to provide a thorough understanding of the present invention. However, it will be apparent to one skilled in the art that the present invention may be practiced without the specific details. In other instances, well-known features are omitted or simplified in order not to obscure the present invention.

### Terminology

Parts of the description will be presented in video encoding and decoding terms, such as picture, macroblock, block, sample, luma, chroma, transform coefficients, zig-zag scan order, numbers, signs, levels, run lengths and so forth, consistent with the manner commonly employed by those skilled in the art to convey the substance of their work to

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others skilled in the art. These terms are well understood by those skilled in the art. In particular, in a video device, these quantities take the form of electrical, magnetic, or optical signals capable of being stored, transferred, combined, and otherwise manipulated through electrical and/or optical components of a processor, and its subsystems.

In various video encoding/decoding standards, encodings are organized in accordance with certain syntactical rules, thus they are also referred to as "syntax elements".

## Section Headings, Order of Descriptions and Embodiments

Section headings are merely employed to improve readability, and they are not to be construed to restrict or narrow the present invention.

Various operations will be described as multiple discrete steps in turn, in a manner that is most helpful in understanding the present invention, however, the order of description should not be construed as to imply that these operations are necessarily order dependent. In particular, these operations need not be performed in the order of presentation.

The phrase "in one embodiment" is used repeatedly. The phrase generally does not refer to the same embodiment, however, it may. The terms "comprising", "having" and "including" are synonymous, unless the context dictates otherwise.

## Overview

FIG. **1** illustrates an overview of a context-adaptive VLC encoder of the present invention for encoding transform coefficients of (luma/chroma) blocks of a macroblock of a picture, in accordance with one embodiment. As illustrated, for the embodiment, context-adaptive VLC encoder **100** includes encoder blocks **102**–**106**, which are coupled to input **108** of encoder **100** in parallel to receive quantized transform coefficients of (luma/chroma) blocks of macroblocks of pictures of a video. In response, encoder blocks **102**–**104** encode the received transform coefficients of the (luma/chroma) blocks into VLC codewords, and output the VLC codewords as a bit stream at output **110**. VLC codewords are also referred as "encodings" of the transform coefficients (or "syntax elements").

More specifically, encoder block **102** is equipped with VLC codeword tables **122** and coding logic **124** to adaptively select one of the VLC codeword tables **122** to encode in a combined manner, the number of coefficients and the number of trailing one coefficients in each block of a macroblock (Num-Trail). That is, the number of coefficients and the number of trailing one coefficients in each block of a macroblock is advantageously encoded by a single VLC codeword. Encoder block **102** is referred to as Num-Trail encoder block **102** for short.

"Trailing one coefficients", as the term suggests, refers to the "**1**" value coefficients at the "back" of a block's transform coefficients, which are typically arranged in accordance with a zig-zag scan order. A zig-zag scan order is a sequential ordering of the transform coefficients from (approximately) the lowest spatial frequency to the highest. The orientation of "front" and "back" is seen from the "order" perspective. For example, if the sample blocks' transform coefficients are 5001201101001111, the last four "1" transform coefficients (counting from the back) are referred to as the trailing one coefficients, or T1s.

In one embodiment, the length of the trailing one coefficients is clipped at 3 (counting from the "back" of the series of transform coefficients). That is, for the embodiment, for the purpose of encoding, the longest length of the T1 coefficients is limited to **3**. The "excluded" trailing one coefficients are encoded "normally" as "non-zero coefficients" before the trailing one coefficients.

In alternate embodiments, the present invention may be practiced with greater, or smaller, longest length for the T**1** coefficients.

Encoder block **104** is equipped with VLC codeword tables **132** and coding logic **134** to adaptively select one of the VLC codeword tables **132** to encode the level measure (or simply, level) of each non-zero coefficient before the trailing one coefficients of the sample blocks (including the "excluded" or "clipped" trailing one coefficients, if any). In other words, under the present invention, unlike the prior art, number of coefficients and levels of the non-zero coefficients are advantageously encoded separately. Encoder block **104** is referred to as Level encoder block **104** for short.

In one embodiment, Level encoder block **104** is also equipped to encode the signs of the T**1** coefficients (Sign-Trail). In alternate embodiments, encoding of the signs of the T**1** coefficients may e.g. be encoded by the Num_Trail encoder **102** instead.

Encoder block **106** is equipped with VLC codeword tables **142** and coding logic **144** to encode the total number zero coefficients interposed between non-zero coefficients of a block, and their respective run lengths (TotalZeros and RunLengths). In the earlier example, there are a total of 6 zeros interposed among the non-zero, and their respective run lengths are 2, 1, 1, 2. Encoder block **106** is referred to as TotalZero-RunLength encoder block **106**.

In one embodiment, each macroblock comprises 16 (4×4) blocks of luma samples, eight corresponding 4×4 chroma AC blocks, and two 2×2 chroma DC blocks. The corresponding output formats are as follows:

Luma

{[NumTrail Sign-Trail Levels(16) TotalZeros RunLengths]*4}*4

Chroma DC

[NumTrail Sign-Trail Levels(4) TotalZeros RunLengths]*2

Chroma AC

{[NumTrail Sign-Trail Levels(15) TotalZeros RunLengths]*4}*2

For macroblock types known as Intra 16×16, there is one Intra 16×16 DC sample block and 16 Intra 4×4 AC sample blocks, the corresponding output formats are as follows:

Intra 16×16 DC

NumTrail Sign-Trail Levels(16) TotalZeros RunLengths

Intra 16×16 AC

[NumTrail Sign-Trail Levels(15) TotalZeros RunLengths]*16 (4×4 blocks)

Except for the novel VLC codeword tables **122**, **132** and **142**, and coding logics **124**, **134** and **144** to adaptively select the appropriate VLC codeword table provided to encoder blocks **102**–**106**, other aspects of encoder **100**, including other aspects of encoder blocks **102**–**106** are known, and will not be further described.

In various embodiments, encoder **100** including encoding blocks **102**–**106** may be implemented in hardware, e.g. via application specific integrated circuit (ASIC) or in software, e.g. in programming languages such as C, or a combination of both.

## Number and Trailing One Coefficient Encoder Block

In various embodiments, Num-Trail encoder block **102** includes three (3) VLC codeword tables for encoding trans-

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form coefficients of luma sample blocks, and one (1) VLC codeword table for encoding transform coefficients of chroma sample blocks.

More specifically, in one embodiment, the three codeword tables for encoding form coefficients of luma sample blocks are:

TABLE 1

| | Luma Num-VLC0 | | | |
|---|---|---|---|---|
| | T1 | | | |
| NumCf | 0 | 1 | 2 | 3 |
| 0 | 1 | — | — | — |
| 1 | 000011 | 01 | — | — |
| 2 | 00000111 | 0001001 | 001 | — |
| 3 | 000001001 | 00000110 | 0001000 | 00011 |
| 4 | 000001000 | 000001011 | 000000101 | 000010 |
| 5 | 0000000111 | 000001010 | 000000100 | 0001011 |
| 6 | 00000000111 | 0000000110 | 0000001101 | 00010101 |
| 7 | 000000001001 | 00000000110 | 0000001100 | 00010100 |
| 8 | 000000001000 | 00000001001 | 000000001010 | 000000111 |
| 9 | 0000000000111 | 000000001011 | 000000000101 | 0000000101 |
| 10 | 0000000000110 | 0000000001101 | 0000000001111 | 00000001000 |
| 11 | 00000000000011 | 0000000001100 | 0000000001110 | 000000000100 |
| 12 | 00000000000010 | 00000000000100 | 00000000000110 | 0000000000101 |
| 13 | 00000000000101 | 00000000000111 | 0000000000010001 | 00000000001001 |
| 14 | 000000000000011 | 000000000000010 | 000000000010000 | 0000000000000011 |
| 15 | 00000000000000001 | 00000000000000011 | 00000000000000010 | 00000000000000101 |
| 16 | 00000000000000000 | 00000000000000001001 | 0000000000000010001 | 0000000000000010000 |

TABLE 2

| | Luma Num-VCL1 | | | |
|---|---|---|---|---|
| | T1s | | | |
| NumCf\ | 0 | 1 | 2 | 3 |
| 0 | 11 | — | — | — |
| 1 | 000011 | 011 | — | — |
| 2 | 000010 | 00011 | 010 | — |
| 3 | 001001 | 001000 | 001010 | 101 |
| 4 | 1000001 | 001011 | 100101 | 0011 |
| 5 | 00000111 | 1000000 | 1000010 | 00010 |
| 6 | 00000110 | 1000011 | 1001101 | 10001 |
| 7 | 000001001 | 10011101 | 10011100 | 100100 |
| 8 | 000001000 | 000001011 | 000000101 | 1001100 |
| 9 | 0000000111 | 000001010 | 000000100 | 10011111 |
| 10 | 0000000110 | 0000001101 | 0000001100 | 10011110 |
| 11 | 00000000101 | 00000000111 | 00000001001 | 000000111 |
| 12 | 00000000100 | 00000000110 | 00000001000 | 0000000101 |
| 13 | 000000000011 | 000000000010 | 000000000100 | 000000000111 |
| 14 | 0000000000011 | 000000000101 | 0000000000010 | 0000000001101 |
| 15 | 00000000000001 | 00000000000000 | 000000000000111 | 0000000001100 |
| 16 | 000000000000101 | 000000000000100 | 0000000000001101 | 0000000000001100 |

TABLE 3

| | Luma Num-VLC0 | | | |
|---|---|---|---|---|
| | T1s | | | |
| NumCf\ | 0 | 1 | 2 | 3 |
| 0 | 0011 | — | — | — |
| 1 | 0000011 | 0010 | — | — |
| 2 | 0000010 | 101110 | 1101 | — |
| 3 | 000011 | 101001 | 010110 | 1100 |
| 4 | 000010 | 101000 | 010001 | 1111 |
| 5 | 101101 | 101011 | 010000 | 1110 |
| 6 | 101100 | 101010 | 010011 | 1001 |
| 7 | 101111 | 010101 | 010010 | 1000 |
| 8 | 0110101 | 010100 | 011101 | 00011 |
| 9 | 0110100 | 010111 | 011100 | 00010 |
| 10 | 0110111 | 0110110 | 0110000 | 011111 |
| 11 | 01111001 | 0110001 | 01111010 | 0110011 |

TABLE 3-continued

| | Luma Num-VLC0 | | | |
|---|---|---|---|---|
| | T1s | | | |
| NumCf\ | 0 | 1 | 2 | 3 |
| 12 | 01111000 | 01111011 | 01100101 | 01100100 |
| 13 | 000000011 | 000000010 | 000000100 | 000000111 |
| 14 | 0000000011 | 000000101 | 0000001101 | 0000001100 |
| 15 | 0000000010 | 00000000011 | 00000000010 | 00000000001 |
| 16 | 0000000000001 | 000000000001 | 00000000000001 | 00000000000000 |

The single codeword table for encoding transform coefficients of chroma sample blocks is:

TABLE 4

| | Chroma Num-VLC | | | |
|---|---|---|---|---|
| | T1s | | | |
| NumCf\ | 0 | 1 | 2 | 3 |
| 1 | 0001 | 1 | — | — |
| 2 | 00001 | 00111 | 01 | — |
| 3 | 00110 | 000001 | 001010 | 00100 |
| 4 | 0000001 | 00000000 | 00000001 | 001011 |

In alternate embodiments, different number of VLC codeword tables and different VLC codewords, including the manner the VLC codewords are stored, may be used. More specifically, in some embodiments, the VLC codewords may themselves be stored in a storage space saving form of {p, L}, where p stands for the explicitly enumerated portion of a codeword, and L stands for the length of the particular codeword. The non-enumerated portion of a VLC codeword is zero filled from the front when the VLC codeword is used, e.g. "0100 8" becomes 00000100.

In particular, in one alternate embodiment, the VLC codeword tables for encoding transform coefficients of luma sample blocks are:

TABLE 5

| | Luma Num-VLC0' | | | |
|---|---|---|---|---|
| | T1s | | | |
| NumCfeff | 0 | 1 | 2 | 3 |
| 0 | 1 1 | — | — | — |
| 1 | 0101 6 | 01 2 | — | — |
| 2 | 0111 8 | 0100 6 | 0001 3 | — |
| 3 | 0111 9 | 0110 8 | 0101 7 | 0011 5 |
| 4 | 0111 10 | 0110 9 | 0101 8 | 0011 6 |
| 5 | 0111 11 | 0110 10 | 0101 9 | 0100 7 |
| 6 | 1111 13 | 0110 11 | 0101 10 | 0100 8 |
| 7 | 1011 13 | 1110 13 | 0101 11 | 0100 9 |
| 8 | 1000 13 | 1010 13 | 1101 13 | 0100 10 |
| 9 | 1111 14 | 1110 14 | 1001 13 | 0100 11 |
| 10 | 1011 14 | 1010 14 | 1101 14 | 1100 13 |
| 11 | 1111 15 | 1110 15 | 1001 14 | 1100 14 |
| 12 | 1011 15 | 1010 15 | 1101 15 | 1000 14 |
| 13 | 1111 16 | 0001 15 | 1001 15 | 1100 15 |
| 14 | 1011 16 | 1110 16 | 1101 16 | 1000 15 |
| 15 | 0111 16 | 1010 16 | 1001 16 | 1100 16 |
| 16 | 0100 16 | 0110 16 | 0101 16 | 1000 16 |

TABLE 6

| | Luma Num-VLC1' | | | |
|---|---|---|---|---|
| | T1s | | | |
| NumCoeff | 0 | 1 | 2 | 3 |
| 0 | 11 2 | — | — | — |
| 1 | 1011 6 | 10 2 | — | — |
| 2 | 0111 6 | 0111 5 | 011 3 | — |
| 3 | 0111 7 | 1010 6 | 1001 6 | 0101 4 |
| 4 | 0111 8 | 0110 6 | 0101 6 | 0100 4 |
| 5 | 0100 8 | 0110 7 | 0101 7 | 0110 5 |
| 6 | 0111 9 | 0110 8 | 0101 8 | 1000 6 |
| 7 | 1111 11 | 0110 9 | 0101 9 | 0100 6 |
| 8 | 1011 11 | 1110 11 | 1101 11 | 0100 7 |
| 9 | 1111 12 | 1010 11 | 1001 11 | 0100 9 |
| 10 | 1011 12 | 1110 12 | 1101 12 | 1100 11 |
| 11 | 1000 12 | 1010 12 | 1001 12 | 1000 11 |
| 12 | 1111 13 | 1110 13 | 1101 13 | 1100 12 |
| 13 | 1011 13 | 1010 13 | 1001 13 | 1100 13 |
| 14 | 0111 13 | 1011 14 | 0110 13 | 1000 13 |
| 15 | 1001 14 | 1000 14 | 1010 14 | 0001 13 |
| 16 | 0111 14 | 0110 14 | 0101 14 | 0100 14 |

TABLE 7

| | Luma Num-VLC2' | | | |
|---|---|---|---|---|
| | T1s | | | |
| NumCf | 0 | 1 | 2 | 3 |
| 0 | 1111 4 | — | — | — |
| 1 | 1111 6 | 1110 4 | — | — |
| 2 | 1011 6 | 1111 5 | 1101 4 | — |
| 3 | 1000 6 | 1100 5 | 1110 5 | 1100 4 |
| 4 | 1111 7 | 1010 5 | 1011 5 | 1011 4 |
| 5 | 1011 7 | 1000 5 | 1001 5 | 1010 4 |
| 6 | 1001 7 | 1110 6 | 1101 6 | 1001 4 |
| 7 | 1000 7 | 1010 6 | 1001 6 | 1000 4 |
| 8 | 1111 8 | 1110 7 | 1101 7 | 1101 5 |
| 9 | 1011 8 | 1110 8 | 1010 7 | 1100 6 |
| 10 | 1111 9 | 1010 8 | 1101 8 | 1100 7 |
| 11 | 1011 9 | 1110 9 | 1001 8 | 1100 8 |
| 12 | 1000 9 | 1010 9 | 1101 9 | 1000 8 |
| 13 | 1101 10 | 0111 9 | 1001 9 | 1100 9 |
| 14 | 1001 10 | 1100 10 | 1011 10 | 1010 10 |
| 15 | 0101 10 | 1000 10 | 0111 10 | 0110 10 |
| 16 | 0001 10 | 0100 10 | 0011 10 | 0010 10 |

The codeword table for encoding transform coefficients of chroma sample blocks is:

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TABLE 8

| | Chroma Num-VLC' | | | |
|---|---|---|---|---|
| | T1s | | | |
| NumCoeff | 0 | 1 | 2 | 3 |
| 0 | 01 2 | — | — | — |
| 1 | 111 6 | 1 1 | — | — |
| 2 | 100 6 | 110 6 | 001 3 | — |
| 3 | 011 6 | 011 7 | 010 7 | 101 6 |
| 4 | 010 6 | 011 8 | 010 8 | 000 7 |

FIG. **2** illustrates the operational flow of the relevant aspects of the encoder block of FIG. **1** for encoding in a combined manner, number of coefficients and number of T**1** coefficients of a series of transform coefficients of (luma/chroma) blocks of a macroblock of a picture, in accordance with one embodiment. As illustrated, for the embodiment, upon receipt of the transform coefficients of (luma/chroma) blocks of a macroblock of a picture, coding logic **124** of Num-Trail encoder block **102** first determines if the sample block is a luma or a chroma sample block, block **201**. In various embodiments, information denoting whether the current transform coefficients are coefficients of luma or chroma sample blocks is provided in conjunction with the coefficients, and coding logic **124** determines the sample block type based on the companion information provided.

For the 3 luma and 1 chroma VLC codeword table embodiment, upon determining the sample block is a chroma sample block, coding logic **124** of Num-Trail encoder block **102** proceeds to select the chroma VLC codeword tables to encode the transform coefficients, block **204**.

However, if the current sample block is a luma sample block, coding logic **124** of Num-Trail encoder block **102** first determines a context metric for use to assist in the context adaptive selection of one of the multiple luma VLC codeword tables provided. In various embodiments, coding logic **124** of Num-Trail encoder block **102** computes an average number of transform coefficients in one or more selected neighboring sample blocks as the context metric (Avg). More specifically, in one embodiment (where the sample blocks of a macroblock are provided in the conventional zig-zag manner), coding logic **124** calculates Avg of the sample block above and the sample block to the left of the current sample block as the context metric.

In the degenerate case where there is no sample block above, Avg is set to the number of transform coefficients in the sample block to the left of the current sample block. In like manner, in the degenerate case where there is no sample block to the left of the current sample block, Avg is set to the number of transform coefficients in the sample block above. In the degenerate case where there is no sample block above nor sample block to the left of the current sample block, Avg is set to zero.

In one embodiment, coding logic **124** of Num-Trail encoder block **102** selects the VLC codeword tables as follows:

if (0<=Avg<2) select codeword table Num-VLC0/Num-VLC0';

if (2<=Avg<4) select codeword table Num-VLC1/Num-VLC1';

if (4<=Avg<8) select codeword table Num-VLC2/Num-VLC2'; and

if (8<=Avg) generate a 6 bit fixed length codeword (FLC) xxxxyy, where xxxx denotes the number of coefficients, and yy denotes T1.

In one embodiment, when Avg is =>8, and the number of coefficients for the current sample block is 0, the special codeword 000011 is used.

Continuing to refer to FIG. **2**, thereafter, i.e. upon selecting the VLC codeword table (or the FLC, in the case of a luma sample block), coding logic **124** proceeds to determine the number of coefficients and T**1** for the current sample block, blocks **206**–**208**. Then, logic **124** encodes the number of coefficients and T**1** of the current sample block accordingly, using the selected VLC codeword table (or the FLC, in the case of a luma sample block).

Level Encoder Block

In various embodiments, Level encoder block **103** includes multiple VLC codeword tables for encoding levels of transform coefficients of luma as well as chroma sample blocks.

More specifically, in one embodiment, the multiple VLC codeword tables are "derived" from five (5) structured codeword tables, and the structured codeword tables are:

TABLE 9

| Lev-VLC0 |
|---|
| 1 |
| 0 1 |
| 0 0 1 |
| . . . |
| 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 |
| 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 x x x x |
| 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 x x x x x x x x x x x x |

TABLE 10

| Lev-VLC1 |
|---|
| 1 x |
| 0 1 x |
| 0 0 1 x |
| . . . |
| 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 x |
| 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 x x x x |
| 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 x x x x x x x x x x x x |

TABLE 11

| Lev-VLC2 |
|---|
| 1 x x |
| 0 1 x x |
| 0 0 1 x x |
| . . . |
| 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 x x |
| 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 x x x x |
| 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 x x x x x x x x x x x x |

TABLE 12

| Lev-VLC3 |
|---|
| 1 x x x |
| 0 1 x x x |
| 0 0 1 x x x |
| . . . |

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TABLE 12-continued

| Lev-VLC3 |
|---|
| 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 x x x x |
| 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 x x x x x |
| 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 x x x x x x x x x x x x x |

TABLE 13

| Lev-VLC4 |
|---|
| 1 x x x x |
| 0 1 x x x x |
| 0 0 1 x x x x |
| . . . |
| 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 x x x x |
| 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 x x x x x x x x x x x x x |

The codewords in each VLC codeword table increase according to the number of leading zeros, and the string of xxx represents the order of possible combinations, e.g. for the codewords represented as 01xxxx, the codewords are 010000, 010001, 010010, . . . , 011111.

Levels are assigned according to ascending code number pairs. Positive value of a Level receives the lower code number and negative value of a Level receives the higher code number of a code number pair.

The last two entries in each table can be considered escape codes. The first escape code, with four "x"'s, is used to code the 8 levels above the last regularly coded level. The next escape code, with 12 "x"'s, is used to code all remaining levels.

Generally, levels to be coded take values ±1, ±2 etc (Level). However, for the first coefficient to be coded (after T1s, processing from the back of a series of transform coefficients), if T1s<3 or Number_of_coefficients=T1s, levels to be coded may take values ±2, ±3 etc (Level'). Thus, if Lev-VLC0 or Lev-VLC1 is employed to encode the first coefficient (after T1s, processing from the back) the levels may start at ±2.

To illustrate, consider the following example "derived" VLC codeword tables, where a selection of codewords for each Lev-VLC table is listed.

| Code no. | Code | Level (±1, ±2 . . . ) | Level' (±2, ±3 . . . ) |
|---|---|---|---|
| Lev-VLC0' | | | |
| 0 | 1 | 1 | 2 |
| 1 | 01 | −1 | −2 |
| 2 | 001 | 2 | 3 |
| 3 | 0001 | −2 | −3 |
| 4 | 00001 | 3 | 4 |
| . . . | . . . | . . . | . . . |
| 13 | 00000000000001 | −7 | −8 |
| 14 | 000000000000001xxxx | ±8 to ±15 | ±9 to ±16 |
| 15 | 000000000000001xxxxxxxxxxx | ±16-> | ±17-> |
| Lev-VLC1' | | | |
| 0 | 10 | 1 | 2 |
| 1 | 11 | −1 | −2 |
| 2 | 010 | 2 | 3 |
| 3 | 011 | −2 | −3 |
| 4 | 0010 | 3 | 4 |
| 5 | 0011 | −3 | −4 |
| . . . | . . . | . . . | . . . |
| | 000000000000010 | 14 | 15 |
| | 000000000000011 | −14 | −15 |

-continued

| Code no. | Code | Level (±1, ±2 . . . ) | Level' (±2, ±3 . . . ) |
|---|---|---|---|
| | 000000000000001xxxx | ±15 to ±22 | ±16 to ±23 |
| | 000000000000001xxxxxxxxxxx | ±23-> | ±24-> |
| Lev-VLC2' | | | |
| 0 | 100 | 1 | |
| 1 | 101 | −1 | |
| 2 | 110 | 2 | |
| 3 | 111 | −2 | |
| 4 | 0100 | 3 | |
| 5 | 0101 | −3 | |
| 6 | 0110 | 4 | |
| 7 | 0111 | −4 | |
| 8 | 00100 | 5 | |
| . . . | . . . | . . . | |
| | 0000000000000110 | 28 | |
| | 0000000000000111 | −28 | |
| | 000000000000001xxxx | ±29 to ±36 | |
| | 000000000000001xxxxxxxxxxx | ±37-> | |
| Lev-VLC3' | | | |
| 0 | 1000 | 1 | |
| 1 | 1001 | −1 | |
| 2 | 1010 | 2 | |
| 3 | 1011 | −2 | |
| 4 | 1100 | 3 | |
| 5 | 1101 | −3 | |
| 6 | 1110 | 4 | |
| 7 | 1111 | −4 | |
| 8 | 01000 | 5 | |
| . . . | . . . | . . . | |
| | 00000000000001110 | 56 | |
| | 00000000000001111 | −56 | |
| | 000000000000001xxxx | ±57 to ±64 | |
| | 000000000000001xxxxxxxxxxx | ±65-> | |
| Lev-VLC4' | | | |
| 0 | 10000 | 1 | |
| 1 | 10001 | −1 | |
| 2 | 10010 | 2 | |
| 3 | 10011 | −2 | |
| . . . | . . . | . . . | |
| | 11110 | 8 | |
| | 11111 | −8 | |
| | 010000 | 9 | |
| . . . | . . . | . . . | |
| | 0000000000000011110 | 120 | |
| | 0000000000000011111 | −120 | |
| | 000000000000001xxxxxxxxxxx | ±121-> | |

FIG. **3** illustrates the operational flow of the relevant aspects of the Level encoder block of FIG. **1** for encoding level measures of transform coefficients of (luma/chroma) blocks of a macroblock of a picture, in accordance with one embodiment. As illustrated, for the embodiment, upon receipt of the transform coefficients of (luma/chroma) blocks, coding logic **134** of Level encoder block **104** first encodes the signs of T**1**s, block **302**. For the embodiment, 1-bit is employed to encode each sign.

Additionally, coding logic **134** of Level encoder block **104** starts level coding with the first non-zero coefficient after T**1**s (processing from the back), block **304**. For the embodiment, coding logic **134** of Level encoder block **104** computes a context metric to assist in the adaptive selection of an appropriate level VLC codeword table to perform the encoding, block **306**. In various embodiments, the context metric is the quantization parameter value of the current macroblock, and the value is also provided in conjunction with the number of coefficients in the block, and the levels of the transform coefficients of the block.

In one embodiment, Level encoder block **104** selects the Level VLC codeword table as follows:

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If Inter macroblock has any quantization parameter, or Intra macroblock has a quantization parameter value >=9,

```
for the first coefficient, select Lev-VLC0,
    for the next coefficient, select Lev-VLC1, and
        thereafter, if the absolute value of Level is > 3,
        select the next "higher"
            Lev-VLCx codeword table,
            up to 2 codeword tables "higher";
```

If Intra macroblock has a quantization parameter value <9,

```
if (number of coefficients > 10)
    for the first coefficient, select Lev-VLC1,
        for the next coefficient, select Lev-VLC2,
else
    for the first coefficient, select Lev-VLC0,
        for the next coefficient, select Lev-VLC1,
            thereafter, if the absolute value of Level is > 3 and the VLC
                    codeword table is Lev-VLC1, select Lev-VLC2,
                if the absolute value of Level is > 5 and the VLC
                    codeword table is >= Lev-VLC2, select the next
                    "higher" Lev-VLCx codeword table, up to 4
                    codeword tables "higher".
```

Continuing to refer to FIG. **3**, upon selecting the appropriate VLC codeword table, coding logic **134** encodes the level of the current non-zero transform coefficient to be coded, block **310**.

Next, coding logic **134** determines if all non-zero coefficients before the T**1** coefficients have all been level coded, block **312**. If not, coding logic **134** continues operation at block **304** as earlier described. If all non-zero coefficients before the T**1** coefficients have been level coded, coding logic **134** terminates the level coding process for the current sample block.

Total Zeros and Run Length Encoder Blocks

In various embodiments, TotalZero-RunLength encoder block **106** includes multiple VLC codeword tables for encoding the number of zero coefficients interposed among and the non-zero coefficients and their respective run lengths.

More specifically, in one embodiment, TotalZero-RunLength encoder block **106** includes two VLC codeword tables for encoding "total zeros", one for transform coefficients of luma sample blocks and another for transform coefficients of chroma sample blocks, and a VLC codeword table for encoding "run lengths" for either type of sample blocks. The VLC codeword tables are:

TABLE 14

Luma Total Zeros VLC Codeword Table

| NumCoeff TotZeros | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 0 | 1 | 111 | 0010 | 111101 | 01000 | 101100 | 111000 |
| 1 | 011 | 101 | 1101 | 1110 | 01010 | 101101 | 111001 |
| 2 | 010 | 011 | 000 | 0110 | 01011 | 1010 | 11101 |
| 3 | 0011 | 001 | 010 | 1010 | 1110 | 001 | 1001 |
| 4 | 0010 | 000 | 1011 | 000 | 011 | 010 | 1111 |
| 5 | 00011 | 1000 | 1111 | 100 | 100 | 000 | 00 |
| 6 | 00010 | 0101 | 011 | 110 | 1111 | 110 | 01 |
| 7 | 000011 | 1001 | 100 | 1011 | 110 | 111 | 101 |
| 8 | 000010 | 1100 | 0011 | 010 | 101 | 100 | 110 |
| 9 | 0000011 | 01000 | 1110 | 001 | 001 | 011 | 100 |
| 10 | 0000010 | 11011 | 1010 | 0111 | 000 | 10111 | — |
| 11 | 00000001 | 11010 | 11000 | 1111 | 01001 | — | — |
| 12 | 00000000 | 010010 | 110011 | 111100 | — | — | — |
| 13 | 00000011 | 0100111 | 110010 | — | — | — | — |
| 14 | 000000101 | 0100110 | — | — | — | — | — |
| 15 | 000000100 | — | — | — | — | — | — |

| NumCoeff TotZeros | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|
| 0 | 101000 | 111000 | 10000 | 11000 | 1000 | 100 | 00 | 0 |
| 1 | 101001 | 111001 | 10001 | 11001 | 1001 | 101 | 01 | 1 |
| 2 | 10101 | 11101 | 1001 | 1101 | 101 | 11 | 1 | — |
| 3 | 1011 | 1111 | 101 | 111 | 0 | 0 | — | — |
| 4 | 110 | 00 | 01 | 0 | 11 | — | — | — |
| 5 | 00 | 01 | 11 | 10 | | — | — | — |
| 6 | 111 | 10 | 00 | — | — | — | — | — |
| 7 | 01 | 110 | — | — | — | — | — | — |
| 8 | 100 | — | — | — | — | — | — | — |
| 9 | — | — | — | — | — | — | — | — |
| 10 | — | — | — | — | — | — | — | — |
| 11 | — | — | — | — | — | — | — | — |
| 12 | — | — | — | — | — | — | — | — |
| 13 | — | — | — | — | — | — | — | — |
| 14 | — | — | — | — | — | — | — | — |
| 15 | — | — | — | — | — | — | — | — |

TABLE 15

Chroma Total Zeros VLC Codeword Table

| TotZeros | NumCoeff 1 | 2 | 3 |
|---|---|---|---|
| 0 | 1 | 1 | 1 |
| 1 | 01 | 01 | 0 |
| 2 | 001 | 00 | — |
| 3 | 000 | — | — |

TABLE 16

Run Length VLC Codeword Table

| ZerosLeft Run Length | 1 | 2 | 3 | 4 | 5 | 6 | >6 |
|---|---|---|---|---|---|---|---|
| 0 | 1 | 1 | 01 | 01 | 01 | 01 | 000 |
| 1 | 0 | 01 | 00 | 00 | 00 | 00 | 010 |
| 2 | — | 00 | 11 | 11 | 11 | 101 | 101 |
| 3 | — | — | 10 | 101 | 101 | 100 | 100 |
| 4 | — | — | — | 100 | 1001 | 111 | 111 |
| 5 | — | — | — | — | 1000 | 1101 | 110 |
| 6 | — | — | — | — | — | 1100 | 0011 |
| 7 | — | — | — | — | — | — | 0010 |
| 8 | | — | — | — | — | — | 00011 |
| 9 | — | — | — | — | — | — | 00010 |
| 10 | — | — | — | — | — | — | 00001 |
| 11 | — | — | — | — | — | — | 0000011 |
| 12 | — | — | — | — | — | — | 0000010 |
| 13 | — | — | — | — | — | — | 0000001 |
| 14 | — | — | — | — | — | — | 00000001 |

Similarly, in alternate embodiments, different number of VLC codeword tables as well as different VLC codewords, including different manner of storing the VLC codewords, may be used to practice the present invention. In particular, in one embodiment, the present invention may be practiced with the following three VLC codeword tables instead.

TABLE 14

Luma Total Zeros VLC Codeword Table

| NumCoeff TotZeros | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 0 | 11 | 1113 | 1014 | 0115 | 1014 | 0016 | 0016 |
| 1 | 0113 | 1103 | 1113 | 1113 | 1004 | 0015 | 0015 |
| 2 | 0103 | 1013 | 1103 | 1014 | 0114 | 1113 | 1013 |
| 3 | 0114 | 1003 | 1013 | 1004 | 1113 | 1103 | 1003 |
| 4 | 0104 | 0113 | 1004 | 1103 | 1103 | 1013 | 0113 |
| 5 | 0115 | 1014 | 0114 | 1013 | 1013 | 1003 | 112 |
| 6 | 0105 | 1004 | 1003 | 1003 | 1003 | 0113 | 0103 |
| 7 | 0116 | 0114 | 0113 | 0114 | 0113 | 0103 | 0014 |
| 8 | 0106 | 0104 | 0104 | 0113 | 0104 | 0014 | 0013 |
| 9 | 0117 | 0115 | 0115 | 0104 | 0015 | 0013 | 0006 |
| 10 | 0107 | 0105 | 0105 | 0105 | 0014 | 0006 | — |
| 11 | 0118 | 0116 | 0016 | 0015 | 0005 | — | — |
| 12 | 0108 | 0106 | 0015 | 0005 | — | — | — |
| 13 | 0119 | 0016 | 0006 | — | — | — | — |
| 14 | 0109 | 0006 | — | — | — | — | — |
| 15 | 0019 | — | — | — | — | — | — |

| NumCoeff TotZeros | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|
| 0 | 0016 | 0016 | 0015 | 0004 | 0004 | 0003 | 002 | 01 |
| 1 | 0014 | 0006 | 0005 | 0014 | 0014 | 0013 | 012 | 11 |
| 2 | 0015 | 0014 | 0013 | 0013 | 012 | 11 | 11 | — |
| 3 | 0113 | 112 | 112 | 0103 | 11 | 012 | — | — |
| 4 | 112 | 102 | 102 | 11 | 0013 | — | — | — |
| 5 | 102 | 0013 | 012 | 0113 | — | — | — | — |
| 6 | 0103 | 012 | 0014 | — | — | — | — | — |
| 7 | 0013 | 0015 | — | — | — | — | — | — |
| 8 | 0006 | — | — | — | — | — | — | — |
| 9 | — | — | — | — | — | — | — | — |
| 10 | — | — | — | — | — | — | — | — |
| 11 | — | — | — | — | — | — | — | — |
| 12 | — | — | — | — | — | — | — | — |
| 13 | — | — | — | — | — | — | — | — |
| 14 | — | — | — | — | — | — | — | — |
| 15 | — | — | — | — | — | — | — | — |

TABLE 14-continued

Luma Total Zeros VLC Codeword Table

TABLE 15

Chroma Total Zeros VLC Codeword Table

| NumCoeff TotZeros | 1 | 2 | 3 |
|---|---|---|---|
| 0 | 1 1 | 1 1 | 1 1 |
| 1 | 01 2 | 01 2 | 0 1 |
| 2 | 01 3 | 00 2 | — |
| 3 | 00 3 | — | — |

TABLE 16

Run Length VLC Codeword Table

| ZerosLeft RunLength | 1 | 2 | 3 | 4 | 5 | 6 | >6 |
|---|---|---|---|---|---|---|---|
| 0 | 1 | 1 | 11 | 11 | 11 | 11 | 111 3 |
| 1 | 0 | 01 | 10 | 10 | 10 | 000 | 110 3 |
| 2 | — | 00 | 01 | 01 | 011 | 001 | 101 3 |
| 3 | — | — | 00 | 001 | 010 | 011 | 100 3 |
| 4 | — | — | — | 000 | 001 | 010 | 011 3 |
| 5 | — | — | — | — | 000 | 101 | 010 3 |
| 6 | — | — | — | — | — | 100 | 001 3 |
| 7 | — | — | — | — | — | — | 001 4 |
| 8 | | — | — | — | — | — | 001 5 |
| 9 | — | — | — | — | — | — | 001 6 |
| 10 | — | — | — | — | — | — | 001 7 |
| 11 | — | — | — | — | — | — | 001 8 |
| 12 | — | — | — | — | — | — | 001 9 |
| 13 | — | — | — | — | — | — | 001 10 |
| 14 | — | — | — | — | — | — | 001 11 |

The VLC codewords of Tables 14–16 are expressed in the same earlier described space saving format.

FIG. **4** illustrates the operational flow of the relevant aspects of coding logic **144** of TotalZero-Run Length encoder block **142** for encoding number of zero coefficients interposed among non-zero coefficients and their respective run lengths of transform coefficients of (luma/chroma) blocks of a macroblock of a picture, in accordance with one embodiment.

As illustrated, for the embodiment, upon receipt of the transform coefficients of (luma/chroma) blocks, coding logic **144** determines the number of zero coefficients interposed among the non-zero coefficients (Total Zeros), block **402**. Next, coding logic **144** selects the appropriate codeword table corresponding to the number of coefficients in the block and the sample block type, block **404**. In other embodiments, other criteria may be used to select the codeword table. Next, coding logic **144** encodes the Total Zeros information using the selected codeword table.

Additionally, coding logic **144** selects the first run of the interposed zeros (processing from the back, or in an alter-

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native embodiment, processing from the front), and determines the run length (Run Length), blocks **406**–**408**. Next, coding logic **144** selects the appropriate codeword table based on the number of zeros left to be interposed, block **407**. Next, coding logic **144** encodes the Run Length information using the selected Run Length codeword table. Coding logic **144** then determines if all interposed zero runs have been coded, block **410**. If not, coding logic **144** continues back at block **406** as earlier described. If all interposed zero runs have been coded, the Total Zero and Run Length encoding process terminates.

## Decoder

FIG. **5** illustrates an overview of a context-adaptive VLC decoder of the present invention for decoding transform coefficients encoded in accordance with encoding principles similar to that of the encoder of FIG. **1**, in accordance with one embodiment. As illustrated, for the embodiment, context-adaptive VLC decoder **500** is similarly constituted as encoder **100**, having decoder blocks **502**–**506**, which are coupled to input **510** of decoder **500** in parallel to receive a bit stream of VLC codewords encoding quantized transform coefficients of (luma/chroma) blocks of macroblocks of pictures of a video. In response, decoder blocks **502**–**506** decode the received encodings of the transform coefficients of the (luma/chroma) blocks back into their quantized forms, and output them at output **108**.

For the embodiments, decoder blocks **502**–**506** are similar constituted as encoder blocks **102**–**106**. That is, decoder block **502** includes VLC codeword tables **522** and coding logic **524** for decoding combined VLC codewords of the number of coefficients and T1 coefficients in a series of transform coefficients of (luma/chroma) blocks of a macroblock of a picture. Further, decoder block **504** includes VLC codeword tables **532** and coding logic **534** for decoding VLC codewords of the levels of transform coefficients of the (luma/chroma) blocks. Similarly, decoder block **506** includes VLC codeword tables **532** and coding logic **534** for decoding VLC codewords of the Total Zeros and the respective "Zero" Run Lengths in the non-zero transform coefficients of the (luma/chroma) blocks.

## Example Applications of the Present Invention

FIG. **6** illustrates a video device incorporated with the teachings of the present invention, in accordance with one embodiment. As illustrated, video device **600** includes encoder **610** and decoder **620** coupled to the inputs and outputs of the device. As described earlier, encoder **610** is designed to receive quantized transform coefficients **632***a* of (luma/chroma) blocks of macroblocks of pictures of a video, and to adaptively encode them in response, into VLC codewords **634***a*. Decoder **620** is designed to receive VLC codewords **634***b* of the transform coefficients of (luma/chroma) blocks of macroblocks of pictures of another video, and to adaptively decode in response the codewords back into coefficients **632***b*.

Encoder **610** and decoder **620** are similarly constituted as the earlier described encoder **100** and decoder **500**. In various embodiments, encoder **610** and decoder **620** may share at least in part their constituting tables and coding logics (as denoted by the intersecting blocks of encoder **610** and decoder **620**).

In various embodiments, video device **600** may be a digital camera, a DVD player, a video surveillance camera, a video conferencing device, a medical imaging device, and other video devices of the like. In other embodiment, video device **600** may be a wireless mobile phone, a palm sized computing device, such as a personal digital assistant, a laptop computing device, a desktop computing device, a set top box, a server, and other computing devices of the like. Applications executing one these video devices **600** may include instant messaging and/or email that includes video. In yet other embodiments, video device **600** may be a circuit board component, such as a video "add-on" circuit board (also referred to as a daughter circuit board), a motherboard, and other circuit boards of the like.

FIG. **7** illustrates an article of manufacture including a recordable medium **700** having programming instructions implementing a software embodiment of the earlier described encoder **100** and/or decoder **500**. Programming instructions implementing a software embodiment of encoder **100** and/or decoder **500** are designed for use to program video device **710** to equip video device **710** with the encoding and decoding capabilities of the present invention.

For the embodiment, video device **710** include storage medium **712** to store at least a portion of a working copying of the programming instructions implementing the software embodiment of encoder **100** and/or decoder **500**, and at least one processor **714** coupled to storage medium **712** to execute the programming instructions.

Video device **712** may be any one of the earlier enumerated example device devices or other video devices of the like. Article **710** may e.g. be a diskette, a compact disk (CD), a DVD or other computer readable medium of the like. In other embodiments, article **710** may be a distribution server distributing encoder **100** and/or decoder **500** on line, via private and/or public networks, such as the Internet. In one embodiment, article **710** is a web server.

FIG. **8** illustrates an example system having video sender **802** and video receiver **804** communicatively coupled to each other as shown, with video sender **802** encoding a video in accordance with the teachings of the present invention, and providing the encoded video to video receiver **802**, and video receiver **802**, in turn decoding the encoded video to render the video. Video sender **802** and video receiver **804** are equipped with the earlier described encoder **100** and decoder **500** respectively.

An example of video sender **802** is a video server, whereas an example of a video receiver **804** is a client device coupled to video sender **802**.

## CONCLUSION AND EPILOGUE

Thus, it can be seen from the above descriptions, a novel method for encoding and decoding transform coefficients of (luma/chroma) blocks of a macroblock of a picture, including encoders, decoders, devices and systems incorporated with the method have been described.

While the present invention has been described in terms of the foregoing embodiments and example applications, those skilled in the art will recognize that the invention is not limited to the embodiments and example application described. The present invention can be practiced with modification and alteration within the spirit and scope of the appended claims. For examples, different number of encoder/decoder blocks, different number of codeword tables in the various encoder/decoder blocks, different codeword tables, different codeword table selection logic, and different coding directions may be practiced instead.

Thus, the description is to be regarded as illustrative instead of restrictive on the present invention.

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What is claimed is:

1. An apparatus comprising:

storage medium; and

a plurality of codeword tables stored in said storage medium, with each of said plurality of codeword tables having a plurality of codewords to be selectively accessed, based at least in part on a sample block type, for performing at least one of

encoding in a combined manner, a number of coefficients and a number of trailing one coefficients in a series of transform coefficients of sample blocks of a macroblock of a picture; and

decoding a combined encoding of a number of coefficients and a number of trailing one coefficients in a series of transform coefficients of sample blocks of a macroblock of a picture.

2. The apparatus of claim 1, wherein at least a selected one of said codeword tables comprises codewords to be selectively accessed for luma sample blocks of a macroblock of a picture, to perform at least one of encoding in combination and decoding a combined encoding of a number of coefficients and a number of trailing one coefficients in a series of transform coefficients of the luma sample blocks.

3. The apparatus of claim 2, wherein the codeword tables comprise at least one codeword table having a majority of codewords of a selected one of

| T1s NumCfeff | 0 | 1 | 2 | 3 |
|---|---|---|---|---|
| 0 | 1 1 | — | — | — |
| 1 | 0101 6 | 01 2 | — | — |
| 2 | 0111 8 | 0100 6 | 0001 3 | — |
| 3 | 0111 9 | 0110 8 | 0101 7 | 0011 5 |
| 4 | 0111 10 | 0110 9 | 0101 8 | 0011 6 |
| 5 | 0111 11 | 0110 10 | 0101 9 | 0100 7 |
| 6 | 1111 13 | 0110 11 | 0101 10 | 0100 8 |
| 7 | 1011 13 | 1110 13 | 0101 11 | 0100 9 |
| 8 | 1000 13 | 1010 13 | 1101 13 | 0100 10 |
| 9 | 1111 14 | 1110 14 | 1001 13 | 0100 11 |
| 10 | 1011 14 | 1010 14 | 1101 14 | 1100 13 |
| 11 | 1111 15 | 1110 15 | 1001 14 | 1100 14 |
| 12 | 1011 15 | 1010 15 | 1101 15 | 1000 14 |
| 13 | 1111 16 | 0001 15 | 1001 15 | 1100 15 |
| 14 | 1011 16 | 1110 16 | 1101 16 | 1000 15 |
| 15 | 0111 16 | 1010 16 | 1001 16 | 1100 16 |
| 16 | 0100 16 | 0110 16 | 0101 16 | 1000 16 |

| T1s NumCoeff | 0 | 1 | 2 | 3 |
|---|---|---|---|---|
| 0 | 11 2 | — | — | — |
| 1 | 1011 6 | 10 2 | — | — |
| 2 | 0111 6 | 0111 5 | 011 3 | — |
| 3 | 0111 7 | 1010 6 | 1001 6 | 0101 4 |
| 4 | 0111 8 | 0110 6 | 0101 6 | 0100 4 |
| 5 | 0100 8 | 0110 7 | 0101 7 | 0110 5 |
| 6 | 0111 9 | 0110 8 | 0101 8 | 1000 6 |
| 7 | 1111 11 | 0110 9 | 0101 9 | 0100 6 |
| 8 | 1011 11 | 1110 11 | 1101 11 | 0100 7 |
| 9 | 1111 12 | 1010 11 | 1001 11 | 0100 9 |
| 10 | 1011 12 | 1110 12 | 1101 12 | 1100 11 |
| 11 | 1000 12 | 1010 12 | 1001 12 | 1000 11 |
| 12 | 1111 13 | 1110 13 | 1101 13 | 1100 12 |
| 13 | 1011 13 | 1010 13 | 1001 13 | 1100 13 |
| 14 | 0111 13 | 1011 14 | 0110 13 | 1000 13 |
| 15 | 1001 14 | 1000 14 | 1010 14 | 0001 13 |
| 16 | 0111 14 | 0110 14 | 0101 14 | 0100 14 |

-continued

| T1s NumCf | 0 | 1 | 2 | 3 |
|---|---|---|---|---|
| 0 | 1111 4 | — | — | — |
| 1 | 1111 6 | 1110 4 | — | — |
| 2 | 1011 6 | 1111 5 | 1101 4 | — |
| 3 | 1000 6 | 1100 5 | 1110 5 | 1100 4 |
| 4 | 1111 7 | 1010 5 | 1011 5 | 1011 4 |
| 5 | 1011 7 | 1000 5 | 1001 5 | 1010 4 |
| 6 | 1001 7 | 1110 6 | 1101 6 | 1001 4 |
| 7 | 1000 7 | 1010 6 | 1001 6 | 1000 4 |
| 8 | 1111 8 | 1110 7 | 1101 7 | 1101 5 |
| 9 | 1011 8 | 1110 8 | 1010 7 | 1100 6 |
| 10 | 1111 9 | 1010 8 | 1101 8 | 1100 7 |
| 11 | 1011 9 | 1110 9 | 1001 8 | 1100 8 |
| 12 | 1000 9 | 1010 9 | 1101 9 | 1000 8 |
| 13 | 1101 10 | 0111 9 | 1001 9 | 1100 9 |
| 14 | 1001 10 | 1100 10 | 1011 10 | 1010 10 |
| 15 | 0101 10 | 1000 10 | 0111 10 | 0110 10 |
| 16 | 0001 10 | 0100 10 | 0011 10 | 0010 10 |

4. The apparatus of claim 2, wherein the apparatus further comprises logic coupled to the storage medium to select one of said codeword tables and a FLC to encode/decode a series of transform coefficients of luma sample blocks of a macroblock of a picture.

5. The apparatus of claim 4, wherein the logic is equipped to select one of said codeword tables and a FLC to encode/decode a series of transform coefficients of luma sample blocks of a macroblock of a picture in an adaptive manner, based at least in part on the number of coefficients in one or more series of transform coefficients of one or more neighboring luma sample blocks of the macroblock of the picture.

6. The apparatus of claim 5, wherein the one or more neighboring luma sample blocks of the macroblock of the picture comprise at least one of an above neighbor luma sample block, and a left neighbor luma sample block of the macroblock of the picture.

7. The apparatus of claim 1, wherein at least a selected one of the codeword tables comprises codewords to be selectively accessed to perform at least one of encoding in combination and decoding a combined encoding of a number of coefficients and a number of trailing one coefficients in a series of transform coefficients of chroma sample blocks of a macroblock of a picture.

8. The apparatus of claim 5, wherein the codeword tables comprise at least one codeword table having a majority of the codewords of

| T1s NumCoeff | 0 | 1 | 2 | 3 |
|---|---|---|---|---|
| 0 | 01 2 | — | — | — |
| 1 | 111 6 | 1 1 | — | — |
| 2 | 100 6 | 110 6 | 001 3 | — |
| 3 | 011 6 | 011 7 | 010 7 | 101 6 |
| 4 | 010 6 | 011 8 | 010 8 | 000 7 |

9. The apparatus of claim 1, wherein the apparatus further comprises logic to perform at least one of

encoding signs of trailing one coefficients of a series of transform coefficients of sample blocks of a macroblock of a picture; and

decoding encodings of signs of trailing one coefficients of a series of transform coefficients of sample blocks of a macroblock of a picture.

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10. The apparatus of claim 1, wherein the apparatus further comprises a processor coupled to the storage medium to selectively access said codewords of said codeword tables to perform said encoding/decoding.

11. The apparatus of claim 1, wherein the apparatus comprises a selected one a palm sized computing device, a wireless mobile phone, a digital personal assistant, a laptop computing device, a desktop computing device, a set-top box, a server, a compact disk player, a digital versatile disk player, a television, and a display monitor.

12. The apparatus of claim 1, wherein the apparatus comprises a video daughter card and a motherboard having integrated video capability.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

# CERTIFICATE OF CORRECTION



| | |
|---|---|
| PATENT NO. | : 7,099,387 B2 |
| APPLICATION NO. | : 10/232337 |
| DATED | : August 29, 2006 |
| INVENTOR(S) | : Gisle Bjontegaard and Karl O. Lillevold |

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

On the Title Page, Item (75)
The name of the second inventor "Karl O. Lilleyold, Seattle, WA (US)" should be changed to
--Karl O. Lillevold, Seattle, WA (US)--

Signed and Sealed this
Twelfth Day of April, 2011

David J. Kappos
*Director of the United States Patent and Trademark Office*

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