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(51) INT CL:
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(56) Documents Cited:
US 20110007979 A1 **US 20050271288 A1**

(58) Field of Search:
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Other: **Online: WPI, EPODOC, TXTE, Inspec, Internet**

(54) Title of the Invention: **Method and apparatus for chrominance processing in high efficiency video codecs**
Abstract Title: **Chrominance Processing in High Efficiency Video Codecs**

(57) For 4:2:2 and 4:4:4 chroma-subsampling schemes, a high efficiency video coding system may implement several aspects of its encoding method differently to when using a 4:2:0 chroma subsampling scheme, in recognition of the greater amounts of chroma information retained in these schemes and the resulting changes to prediction unit and transform unit block structures. Consequently aspects of the present invention variously split a largest coding unit to a unit of 4x4 pixels, adapt coding unit tree structures, chroma transform unit block size selection, chroma intra-prediction mode angles, chroma intra prediction unit interpolation, chroma motion vector derivation, chroma spatial frequency transforms, so-called `cipprime' flags, chroma quantisation parameters, and chroma. quantisation matrices.

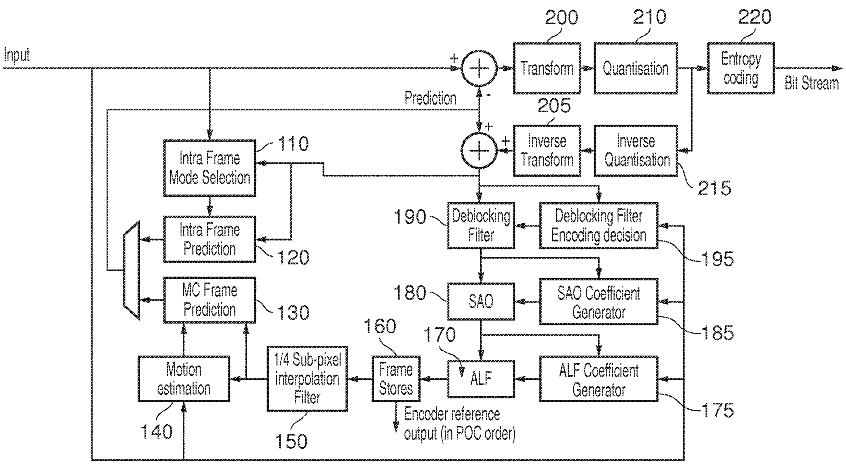

FIG. 6

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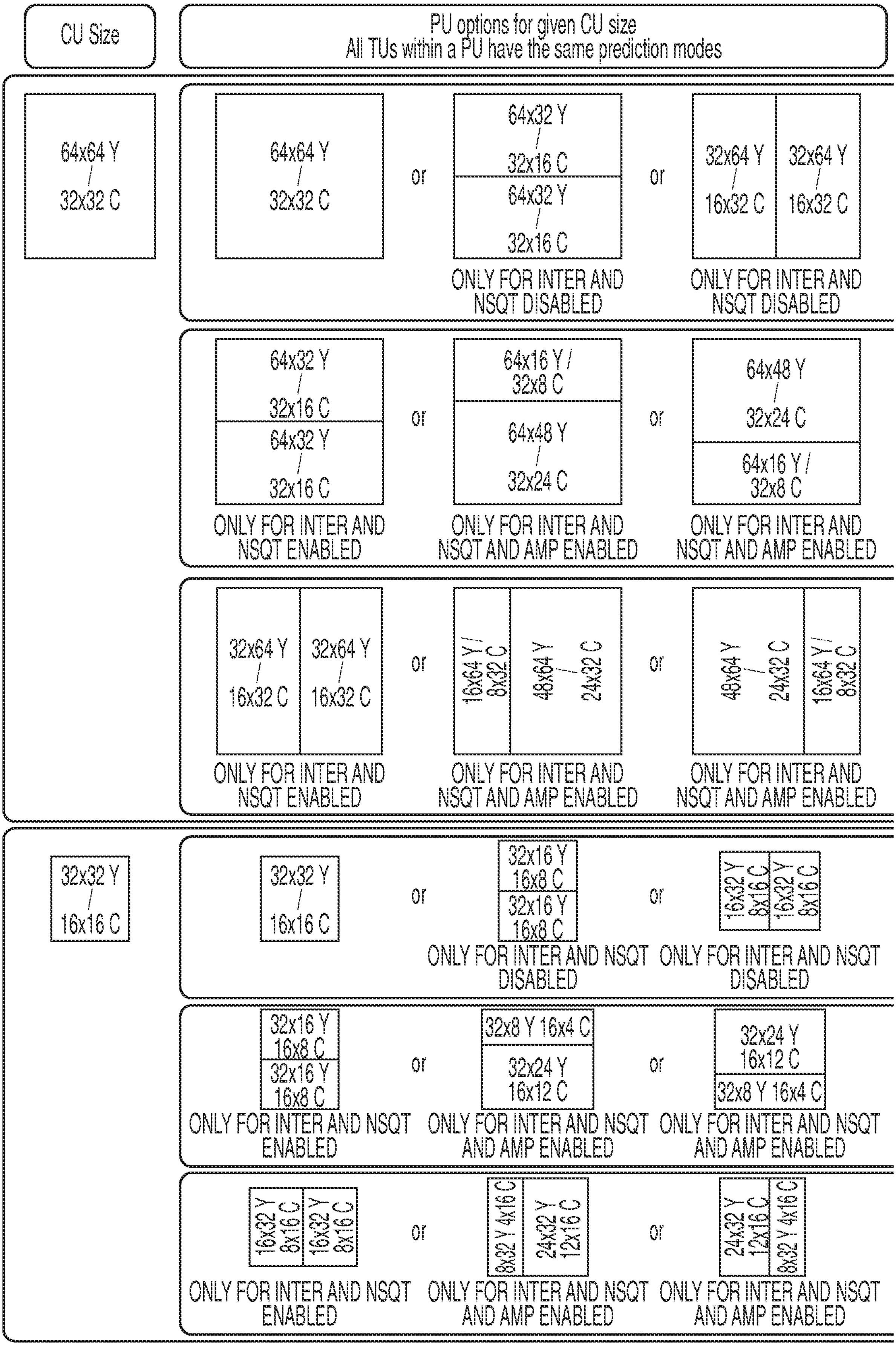

FIG. 1A

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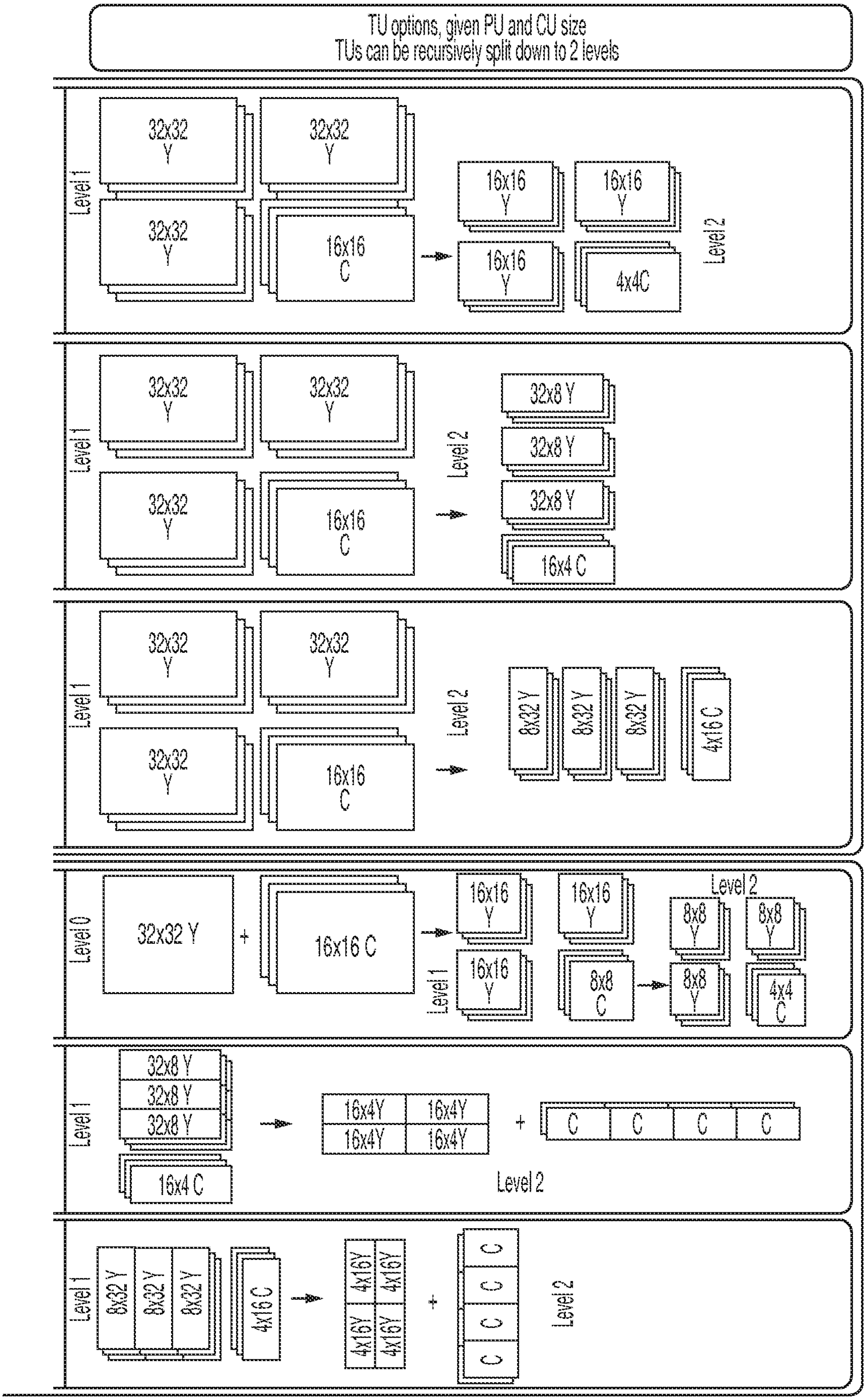

FIG. 1A (continued)

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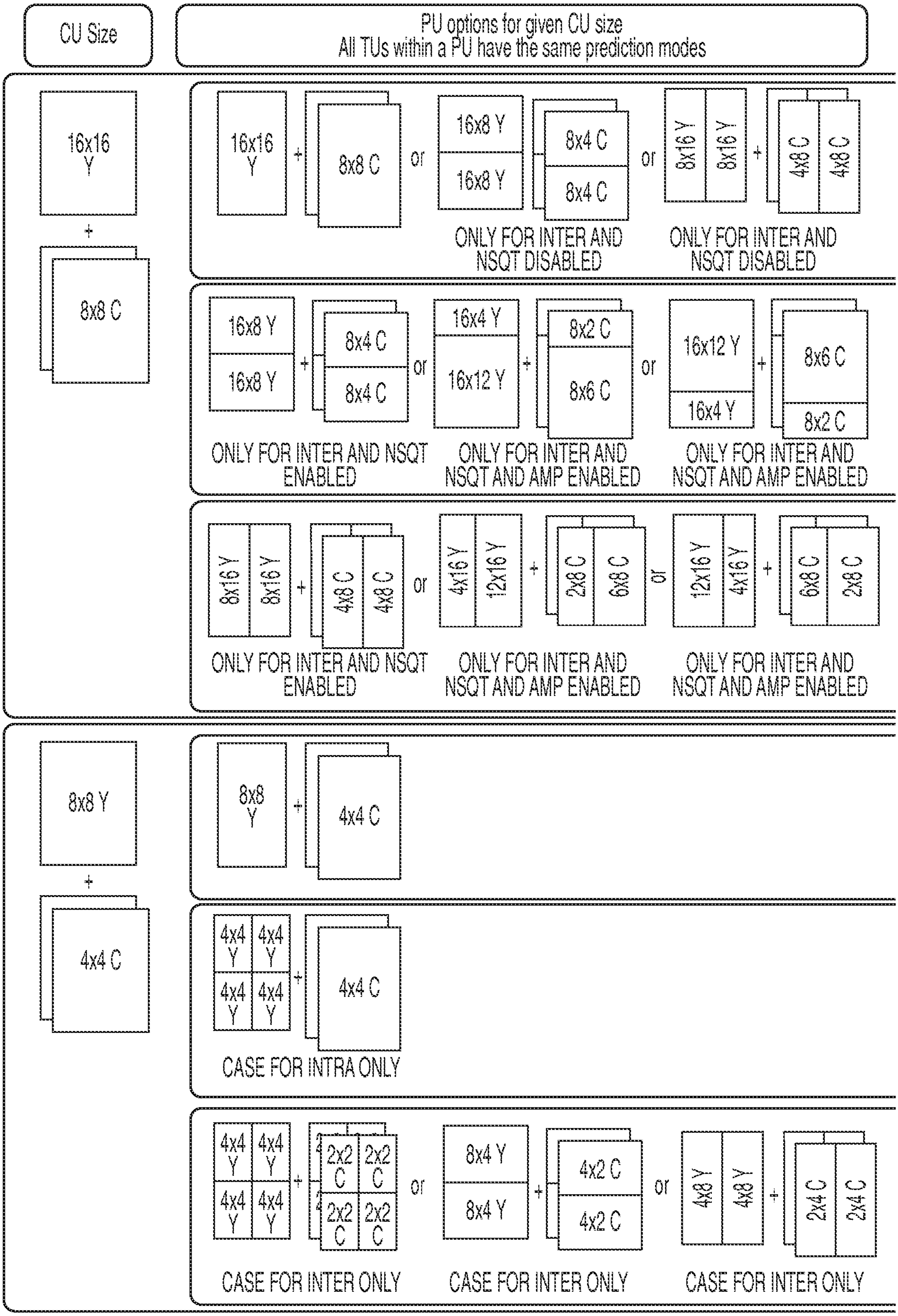

FIG. 1B

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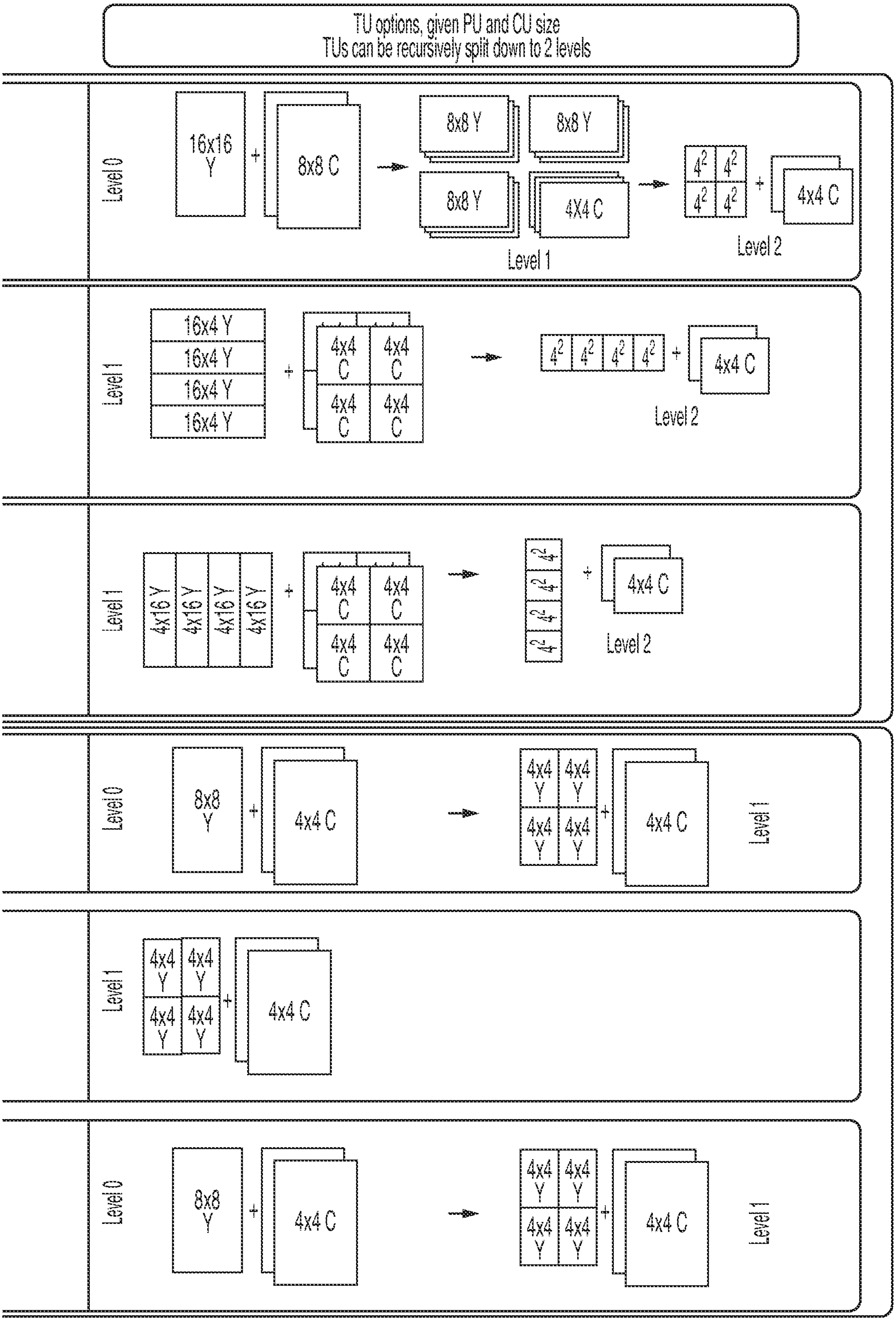

FIG. 1B (continued)

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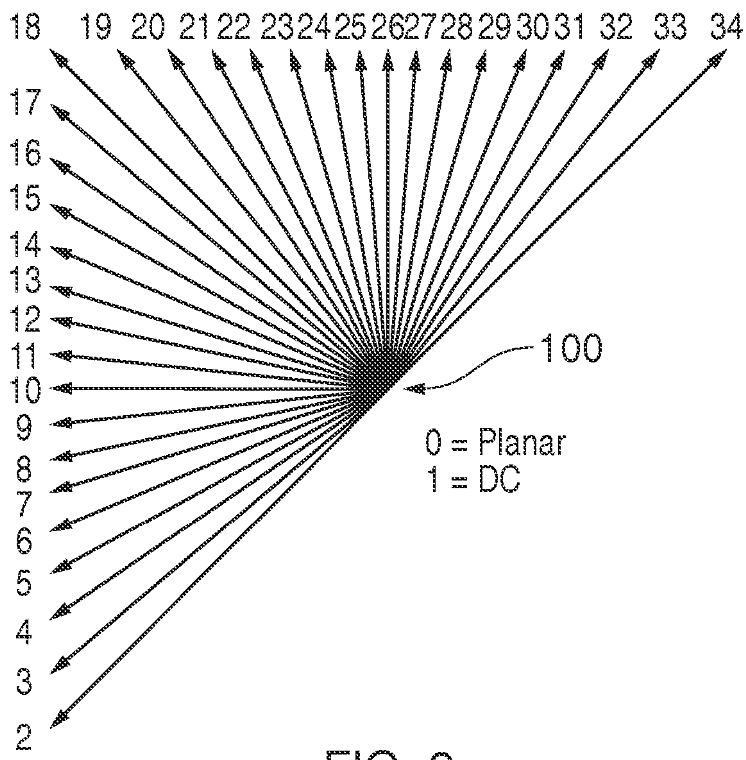

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17
16
15
14
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12
11
10
9
8
7
6
5
4
3
2
100
0 = Planar
1 = DC

FIG. 2

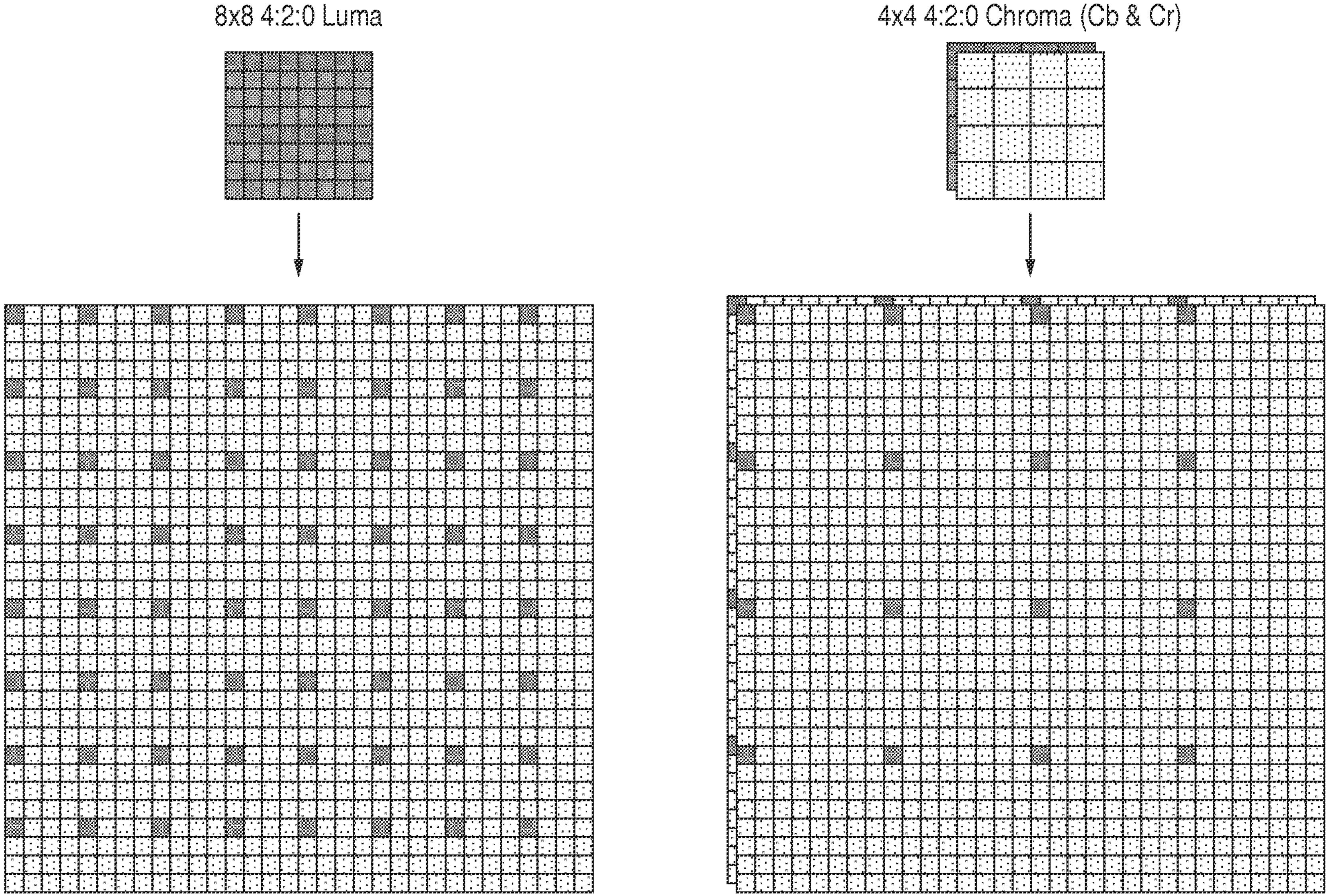

FIG. 3

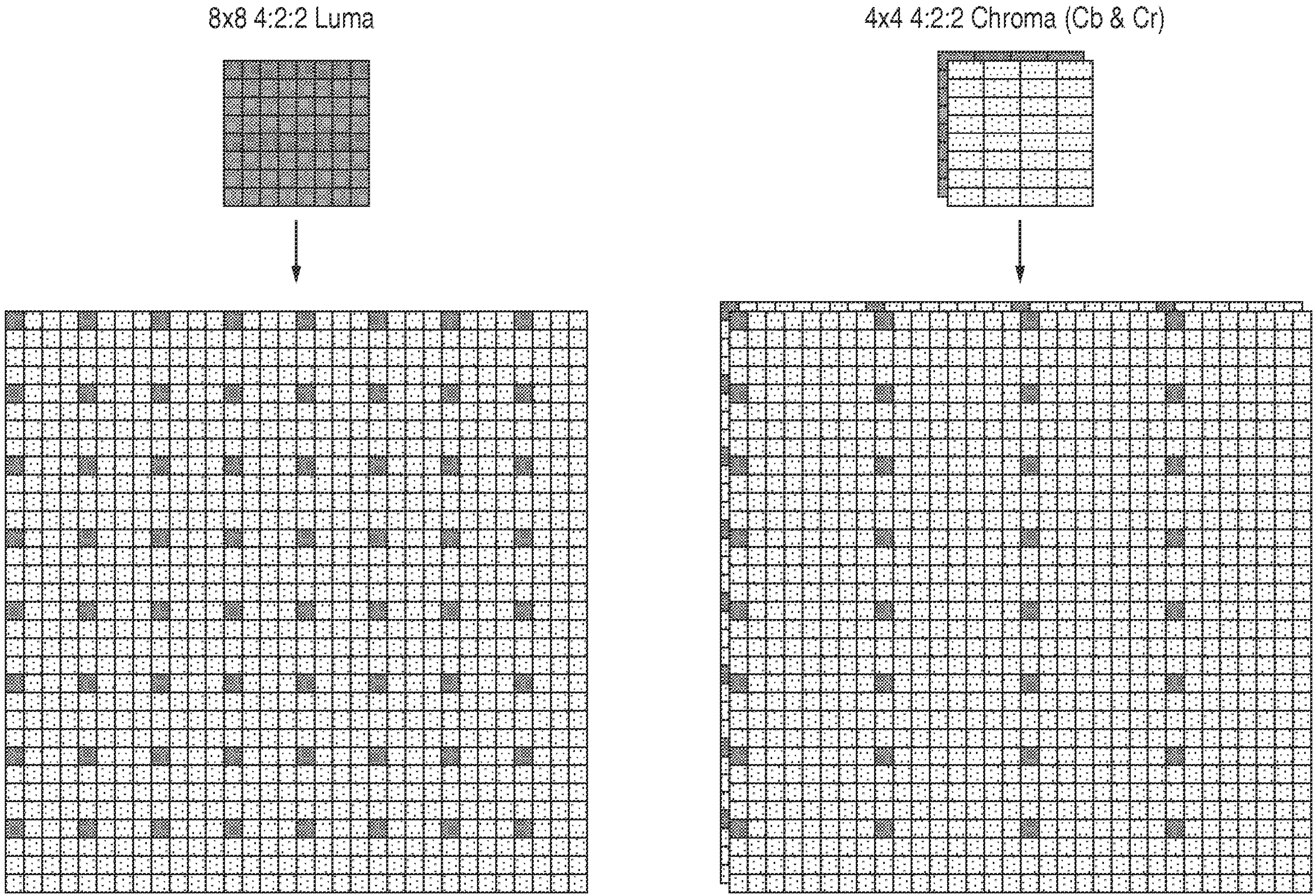

FIG. 4

Index	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Value	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25

Index	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51
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FIG. 5

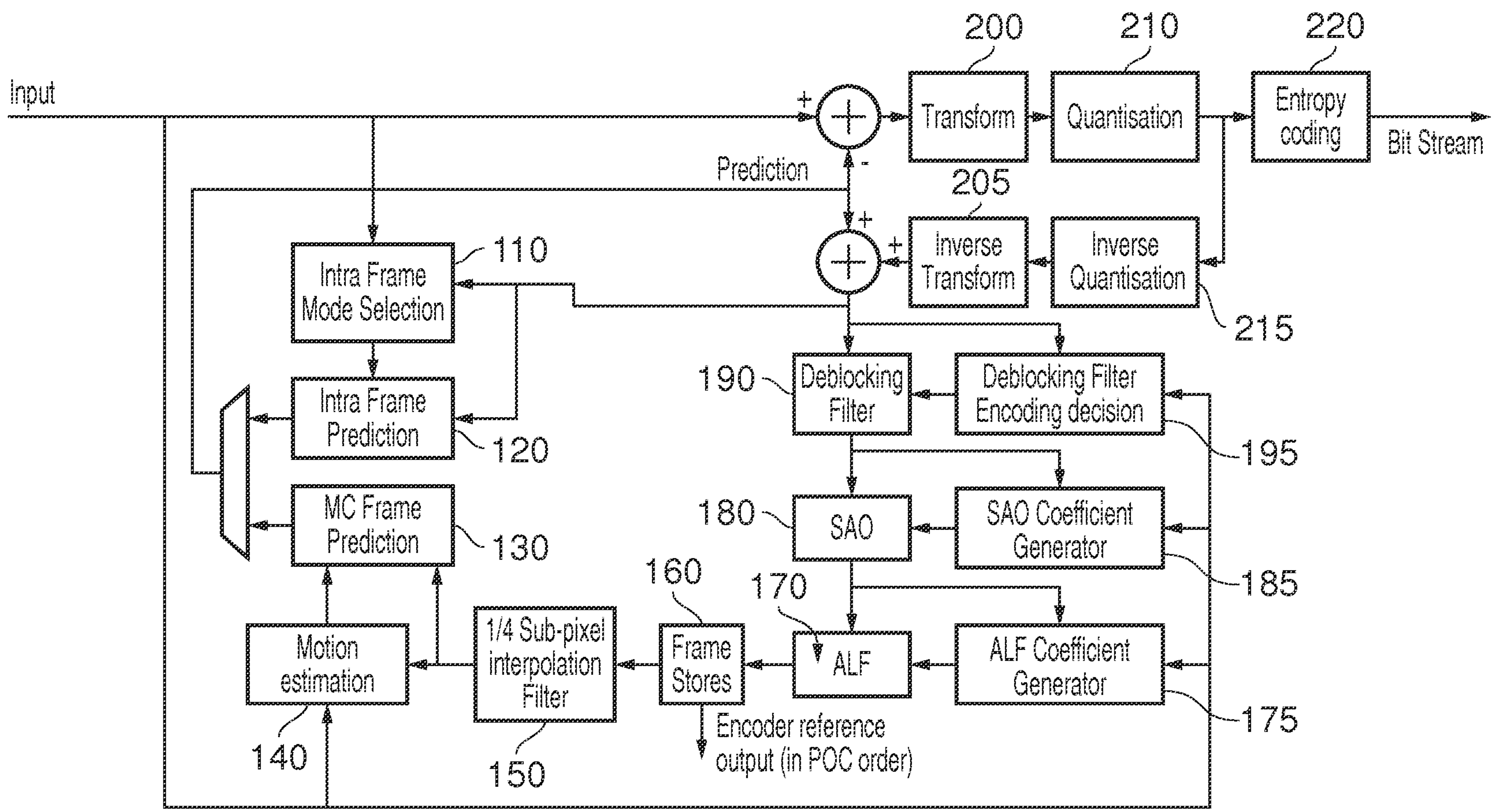
Input
Prediction
+
-
+
+
200
Transform
210
Quantisation
220
Entropy coding
Bit Stream
205
Inverse Transform
Inverse Quantisation
215
110
Intra Frame Mode Selection
Intra Frame Prediction
120
MC Frame Prediction
130
190
Deblocking Filter
Deblocking Filter Encoding decision
195
180
SAO
SAO Coefficient Generator
185
160
170
ALF
ALF Coefficient Generator
175
Frame Stores
Encoder reference output (in POC order)
1/4 Sub-pixel interpolation Filter
150
Motion estimation
140

FIG. 6

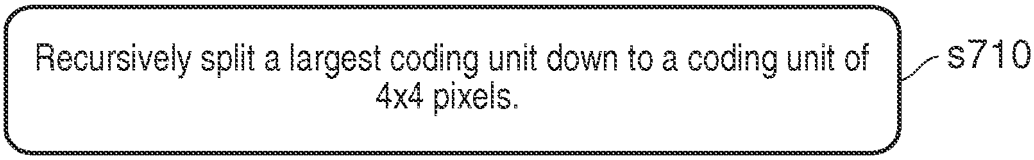

FIG. 7A

FIG. 7B

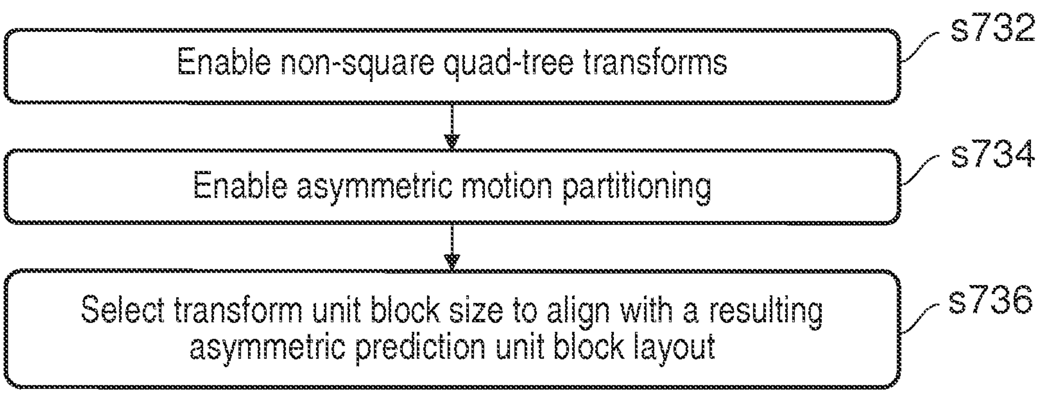

FIG. 7C

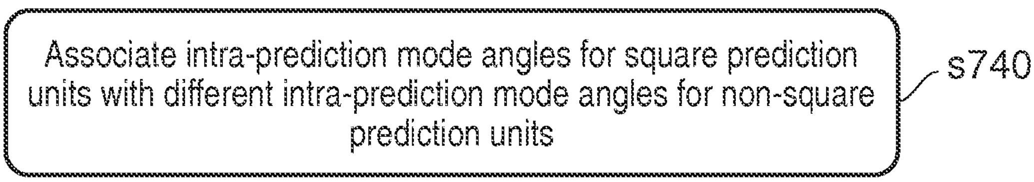

FIG. 7D

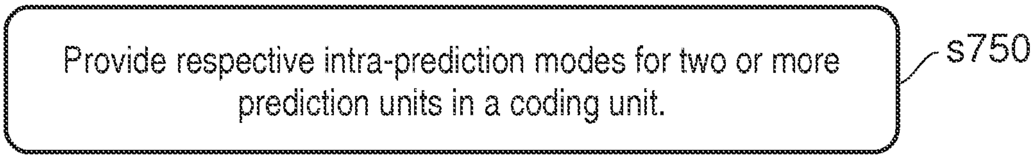

FIG. 7E

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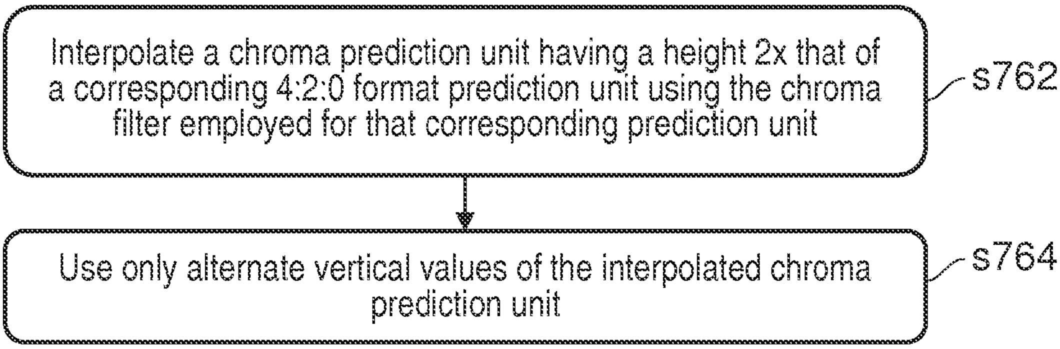

FIG. 7F

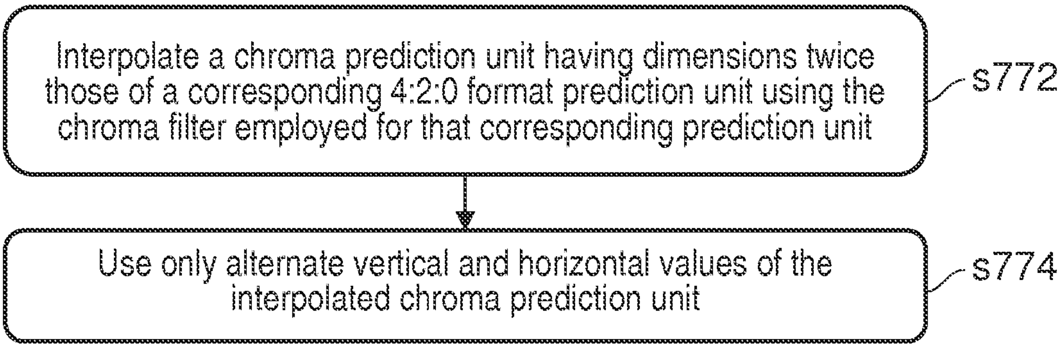

FIG. 7G

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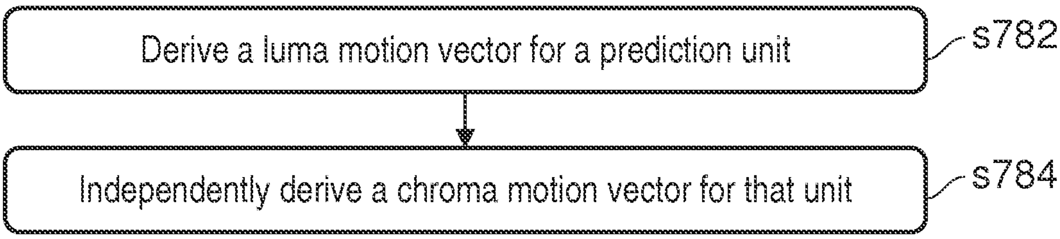

FIG. 7H

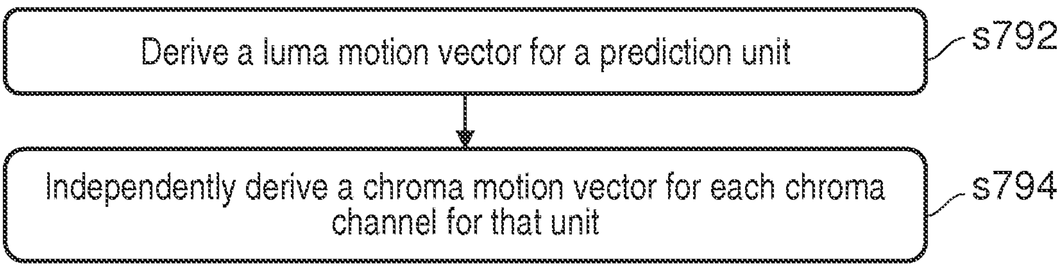

FIG. 7I

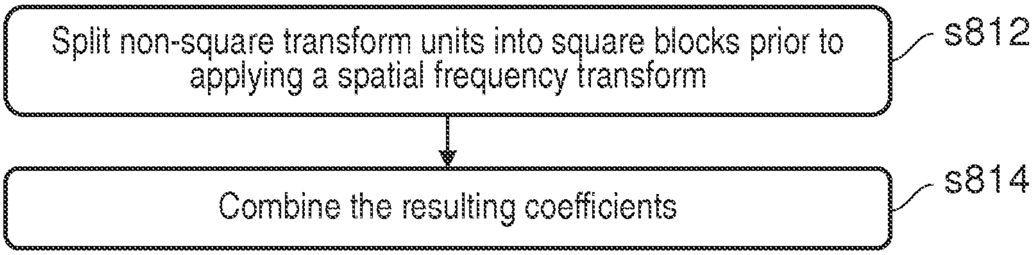

FIG. 7J

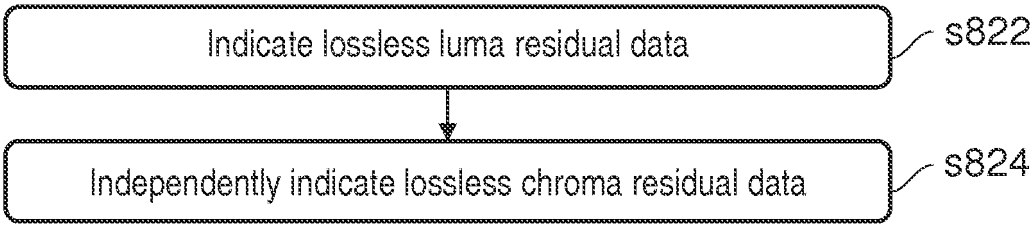

FIG. 7K

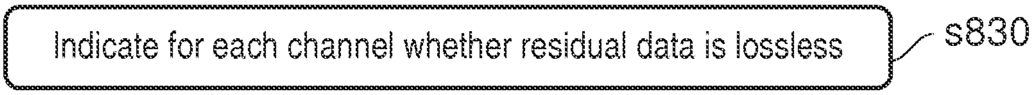

FIG. 7L

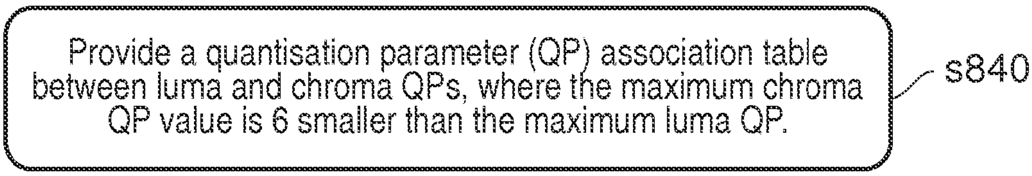

FIG. 7M

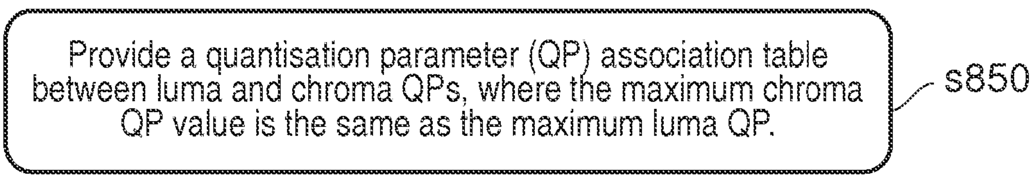

FIG. 7N

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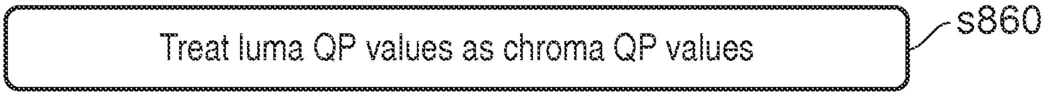

FIG. 7O

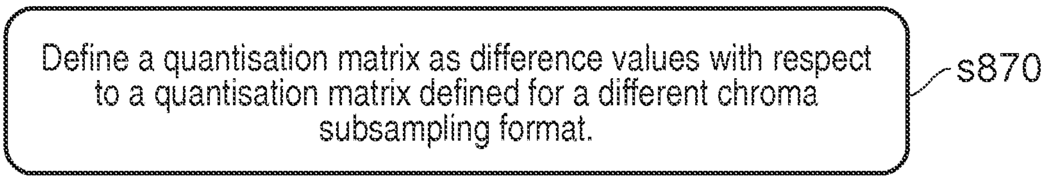

FIG. 7P

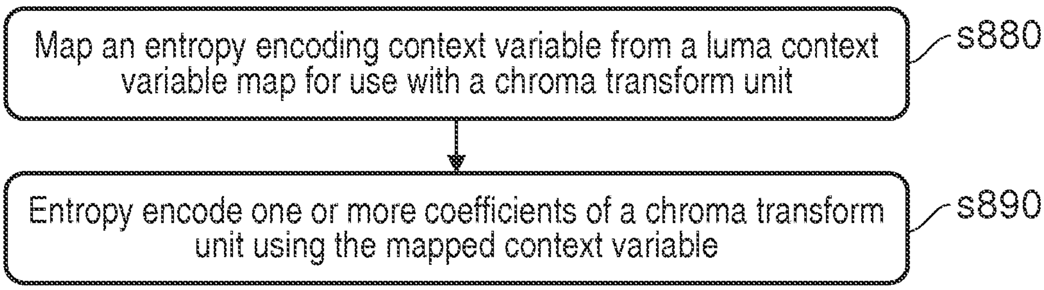

FIG. 7Q

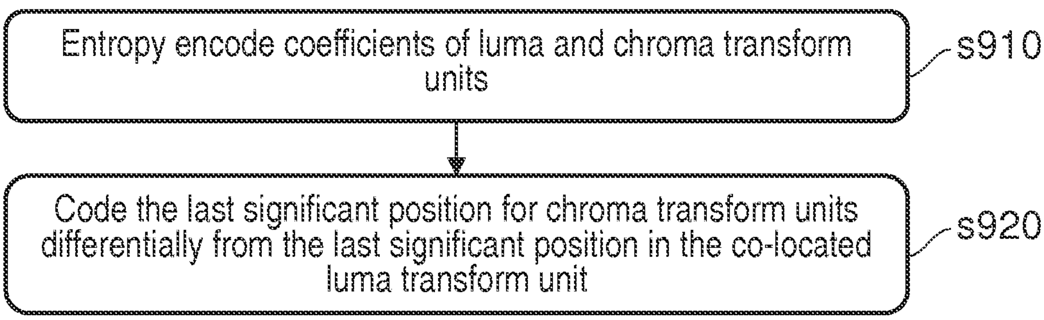

FIG. 7R

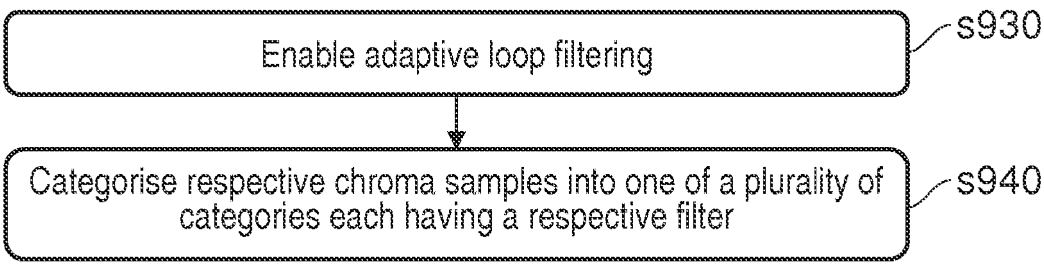

FIG. 7S

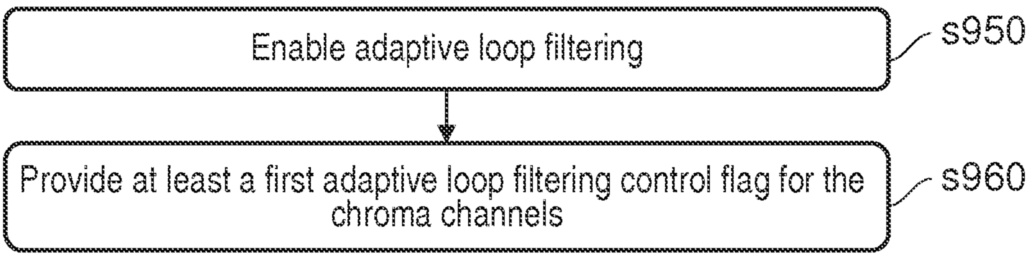

FIG. 7T

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METHOD AND APPARATUS FOR CHROMINANCE PROCESSING IN HIGH EFFICIENCY VIDEO CODECS

The present invention relates to a method and apparatus for chrominance processing in high efficiency video codecs.

Current video codecs such as H.264/MPEG-4 Advanced Video Coding (AVC) achieve data compression primarily by only encoding the differences between successive video frames. These codecs use a regular array of so-called macroblocks, each of which is used as a region of comparison with a corresponding macroblock in a previous video frame, and the image region within the macroblock is then encoded according to the degree of motion found between the corresponding current and previous macroblocks in the video sequence, or between neighbouring macroblocks within a single frame of the video sequence.

High Efficiency Video Coding (HEVC), also known as H.265 or MPEG-H Part 2, is a proposed successor to H.264/MPEG-4 AVC. It is intended for HEVC to improve video quality and double the data compression ratio compared to H.264, and for it to be scalable from 128 × 96 to 7680 × 4320 pixels resolution, roughly equivalent to bit rates ranging from 128kbit/s to 800Mbit/s.

HEVC replaces the macroblocks found in existing H.264 and MPEG standards with a more flexible scheme based upon coding units (CUs), which are variable size structures.

Consequently, when encoding the image data in video frames, the CU sizes can be selected responsive to the apparent image complexity or detected motion levels, instead of using uniformly distributed macroblocks. Consequently far greater compression can be achieved in regions with little motion between frames and with little variation within a frame, whilst better image quality can be preserved in areas of high inter-frame motion or image complexity.

Each CU contains one or more variable-block-sized prediction units (PUs) of either intra-picture or inter-picture prediction type, and one or more transform units (TUs) which contain coefficients for spatial block transform and quantization.

Moreover, PU and TU blocks are provided for each of three channels; Luma (Y), being a luminance or brightness channel, and which may be thought of as a greyscale channel, and two colour difference or chrominance (chroma) channels; Cb and Cr. These channels provide the colour for the greyscale image of the luma channel. The terms Y and luma are used interchangeably herein, and similarly the terms Cb and Cr, and chroma, are used interchangeably as appropriate.

In HEVC a so-called 4:2:0 block structure is proposed for consumer equipment, in which the amount of data used in each chroma channel is one quarter that in the luma channel. This is because subjectively people are more sensitive to brightness variations than to colour variations, and so it is possible to use greater compression and/or less information in the colour channels without a subjective loss of quality.

However, for professional broadcast and digital cinema equipment, it is desirable to have less compression (or more information) in the chroma channels, and this may affect how current HEVC processing operates.

The present invention addresses or mitigates problems arising from this processing.

In a first aspect, a method of high efficiency video coding is provided in accordance with claim 1.

In another aspect, a method of high efficiency video coding is provided in accordance with claim 2.

In another aspect, a method of high efficiency video coding is provided in accordance with claim 3.

In another aspect, a method of high efficiency video coding is provided in accordance with claim 4.

In another aspect, a method of high efficiency video coding is provided in accordance with claim 5.

In another aspect, a method of high efficiency video coding is provided in accordance with claim 6.

In another aspect, a method of high efficiency video coding is provided in accordance with claim 7.

In another aspect, a method of high efficiency video coding is provided in accordance with claim 8.

In another aspect, a method of high efficiency video coding is provided in accordance with claim 9.

In another aspect, a method of high efficiency video coding is provided in accordance with claim 10.

In another aspect, a method of high efficiency video coding is provided in accordance with claim 11.

In another aspect, a method of high efficiency video coding is provided in accordance with claim 12.

In another aspect, a method of high efficiency video coding is provided in accordance with claim 13.

In another aspect, a method of high efficiency video coding is provided in accordance with claim 14.

In another aspect, a method of high efficiency video coding is provided in accordance with claim 15.

In another aspect, a method of high efficiency video coding is provided in accordance with claim 16.

In another aspect, a method of high efficiency video coding is provided in accordance with claim 17.

In another aspect, a method of high efficiency video coding is provided in accordance with claim 18.

In another aspect, a method of high efficiency video coding is provided in accordance with claim 19.

In another aspect, a method of high efficiency video coding is provided in accordance with claim 20.

In another aspect, a computer program is provided in accordance with claim 21.

In another aspect, a high efficiency video coding encoder is provided in accordance with claim 22.

In another aspect, a high efficiency video coding decoder is provided in accordance with claim 23.

Further respective aspects and features of the invention are defined in the appended claims.

Embodiments of the present invention will now be described by way of example with reference to the accompanying drawings, in which:

Figure 1A is a schematic diagram of coding unit, prediction unit and transform unit block sizes for different 4:2:0 scheme CU sizes in HEVC.

Figure 1B is a schematic diagram of coding unit, prediction unit and transform unit block sizes for different 4:2:0 scheme CU sizes in HEVC.

Figure 2 is a schematic diagram of intra-prediction mode directions for the 4:2:0 scheme in HEVC.

Figure 3 is a schematic diagram illustrating 4:2:0 scheme luma and chroma PU interpolation for selection by motion vectors.

Figure 4 is a schematic diagram illustrating 4:2:2 scheme luma and chroma PU interpolation for selection by motion vectors in accordance with an embodiment of the present invention.

Figure 5 is a schematic diagram of a quantisation parameter association table for the 4:2:0 scheme in HEVC.

Figure 6 is a schematic diagram of a HEVC encoder in accordance with an embodiment of the present invention.

Figures 7A to 7T are flow diagrams for respective methods of high efficiency video coding in accordance with embodiments of the present invention.

An apparatus and methods for chrominance processing in high efficiency video codecs are disclosed. In the following description, a number of specific details are presented in order to provide a thorough understanding of the embodiments of the present invention. It will be apparent, however, to a person skilled in the art that these specific details need not be employed to practice the present invention. Conversely, specific details known to the person skilled in the art are omitted for the purposes of clarity where appropriate.

Block structure

As noted above, the proposed HEVC standard uses a particular chroma sampling scheme known as the 4:2:0 scheme. The 4:2:0 scheme can be used for domestic/consumer equipment. However, several other schemes are possible.

In particular, a so-called 4:4:4 scheme would be suitable for professional broadcasting, mastering and digital cinema, and in principle would have the highest quality and data rate.

Similarly, a so-called 4:2:2 scheme could be used in professional broadcasting, mastering and digital cinema with some loss of fidelity.

These schemes and their corresponding PU and TU block structures are described below.

In addition, other schemes include the 4:0:0 monochrome scheme.

In the 4:4:4 scheme, each of the three Y, Cb and Cr channels have the same sample rate. In principle therefore, in this scheme there would be twice as much chroma data as luma data.

Hence in HEVC, in this scheme each of the three Y, Cb and Cr channels would have PU and TU blocks that are the same size; for example an 8x8 luma block would have corresponding 8x8 chroma blocks for each of the two chroma channels.

Consequently in this scheme there would generally be a direct 1:1 relationship between block sizes in each channel.

In the 4:2:2 scheme, the two chroma components are sampled at half the sample rate of luma (for example using vertical *or* horizontal subsampling). In principle therefore, in this scheme there would be as much chroma data as luma data.

Hence in HEVC, in this scheme the Cb and Cr channels would have different size PU and TU blocks to the luma channel; for example an 8x8 luma block could have corresponding 4 wide x 8 high chroma blocks for each chroma channel.

Notably therefore in this scheme the chroma blocks would be *non-square*.

In the currently proposed HEVC 4:2:0 scheme, the two chroma components are sampled at a quarter of the sample rate of luma (for example using vertical *and* horizontal subsampling). In principle therefore, in this scheme there is half as much chroma data as luma data.

Hence in HEVC, in this scheme again the Cb and Cr channels have different size PU and TU blocks to the luma channel. For example an 8x8 luma block would have corresponding 4x4 chroma blocks for each chroma channel. Consequently in general all of the CU, PU and TU blocks in this scheme are square, in particular for intra-prediction.

The above schemes are colloquially known in the art as ‘channel ratios’, as in ‘a 4:2:0 channel ratio’; however it will be appreciated from the above description that in fact this does not always mean that the Y, Cb and Cr channels are compressed or otherwise provided in that ratio. Hence whilst referred to as a channel ratio, this should not be assumed to be literal. In fact, the ratios for the 4:2:0 scheme are 4:1:1 (the ratios for the 4:2:2 scheme and 4:4:4 scheme are in fact correct).

4:2:0 block structure

Referring to Figure 1, the different block sizes possible for the 4:2:0 scheme are summarised for CU, PU and TU blocks, with ‘Y’ referring to luma blocks and ‘C’ referring to both chroma blocks, and the numbers referring to pixels. ‘Inter’ refers to inter-frame prediction PUs (as opposed to intra-frame prediction PUs).

Briefly, the Largest Coding Unit (LCU) is the root picture object. It typically covers an area equivalent to 64x64 luma pixels and is recursively split to form a tree-hierarchy of Coding Units (CUs) being either 64x64, 32x32, 16x16 or 8x8 pixels. The three channels have the same CU tree-hierarchy. The smallest permitted recursion is down to a CU of 8x8 pixels.

The leaf CUs are then split into Prediction Units (PUs). The three channels have the same PU structure (with one possible exception where PUs are 4x4 luma Pixels for intra-prediction).

These leaf CUs are also split into Transform Units (TUs), which can in turn be split again, up to a maximum of 16 TUs per CU. Smallest TU size is 4x4 pixels; the largest is 32x32 pixels. The three channels have the same TU structure (again with one possible exception where TUs are 4x4 luma Pixels).

4:4:4 block structure variants

It has been appreciated that both 4:2:0 and 4:4:4 schemes have square PU blocks for intra-prediction coding. Moreover, currently the 4:2:0 scheme permits 4x4 pixel PU & TU blocks.

In an embodiment of the present invention, it is consequently proposed that for the 4:4:4 scheme the recursion for CU blocks is permitted down to 4x4 pixels rather than 8x8 pixels, since as noted above in the 4:4:4 mode the luma and chroma blocks will be the same size (i.e. the chroma data is not subsampled) and so for a 4x4 CU no PU or TU will need to be less than the already allowed minimum of 4x4 pixels.

Similarly, in the 4:4:4 scheme, in an embodiment of the present invention each of the Y, Cr, Cb channels, or the Y and the two Cr, Cb channels together, could have respective CU tree-hierarchies. A flag may then be used to signal which hierarchy or arrangement of hierarchies is to be used. This approach could also be used for a 4:4:4 RGB colour space scheme.

4:2:2 block structure variants

In the example of an 8x8 CU in the 4:2:0 scheme, this results in four 4x4 luma PUs and one 4x4 chroma PU. Hence in the 4:2:2 scheme, having twice as much chroma data, one option is in this case is to have two 4x4 chroma PUs. However, it is has been appreciated that using one non-square 4x8 chroma PU in this case would be more consistent with other non-square 4:2:2 PUs.

As can be seen from Figure 1, in the 4:2:0 scheme there are in principle some non-square TU blocks permitted for certain classes of inter-prediction coding, but not for intra-prediction coding. However in inter-prediction coding, when non-square quad-tree transforms (NSQT) are disabled (which is the current default for the 4:2:0 scheme), all TUs are square. Hence in effect the 4:2:0 scheme currently enforces square TUs. For example, a 16x16 4:2:0 luma TU would correspond with respective Cb & Cr 8x8 4:2:0 Chroma TUs.

However, as noted previously, the 4:2:2 scheme can have non-square PUs. Consequently in an embodiment of the present invention it is proposed to allow non-square TUs for the 4:2:2 scheme.

For example, whilst a 16x16 4:2:2 luma TU could correspond with two respective Cb & Cr 8x8 4:2:2 Chroma TUs, in this embodiment it could instead correspond with respective Cb & Cr 8x16 4:2:2 Chroma TUs.

Similarly, four 4x4 4:2:2 luma TUs could correspond with two respective 4x4 Cb+Cr 4:2:2 TUs, or in this embodiment could instead correspond with respective 4x8 Cb & Cr 4:2:2 TUs.

Having non-square chroma TUs, and hence fewer TUs, may be more efficient as they are likely to contain less information. However this may affect the transformation and scanning processes of such TUs, as will be described later.

Finally, for the 4:4:4 scheme it may be preferable to have the TU structure channel-independent, and selectable at the sequence, picture, slice or finer level.

As noted above, NSQT is currently disabled in the 4:2:0 scheme of HEVC. However, if for inter-picture prediction, NSQT is enabled and asymmetric motion partitioning (AMP) is permitted, this allows for PUs to be partitioned asymmetrically; thus for example a 16x16 CU may have a 4x16 PU and a 12x16 PU. In these circumstances, further considerations of block structure are important for each of the 4:2:0 and 4:2:2 schemes.

For the 4:2:0 scheme, in NSQT the minimum width/height of a TU is restricted to 4 luma/chroma samples:

Hence in a non-limiting example a 16x4/16x12 luma PU structure has four 16x4 luma TUs and four 4x4 chroma TUs, where the luma TUs are in a 1x4 vertical block arrangement and the chroma TUs are in a 2x2 block arrangement.

In a similar arrangement where the partitioning was vertical rather than horizontal, a 4x16/12x16 luma PU structure has four 4x16 luma TUs and four 4x4 chroma TUs, where the luma TUs are in a 4x1 horizontal block arrangement and the chroma TUs are in a 2x2 block arrangement.

For the 4:2:2 scheme, in NSQT as a non-limiting example a 4x16/12x16 luma PU structure has four 4x16 luma TUs and four 4x8 chroma TUs, where the luma TUs are in a 4x1 horizontal block arrangement; the chroma TUs are in a 2x2 block arrangement.

However, it has been appreciated that a different structure can be considered for some cases. Hence in an embodiment of the present invention, in NSQT as a non-limiting example 16x4/16x12 luma PU structure has four 16x4 luma TUs and four 8x4 chroma TUs, but now the luma *and* chroma TUs are in a 1x4 vertical block arrangement, aligned with the PU layout (as opposed to the 4:2:0 style arrangement of four 4x8 chroma TUs in a 2x2 block arrangement).

Similarly 32x8 PU can have four 16x4 luma TUs and four 8x4 chroma TUs, but now the luma and chroma TUs are in a 2x2 block arrangement.

Hence more generally, for the 4:2:2 scheme, in NSQT the TU block sizes are selected to align with the asymmetric PU block layout. Consequently the NSQT usefully allows TU boundaries to align with PU boundaries, which reduces high frequency artefacts that may otherwise occur.

Intra-prediction

4:2:0 intra-prediction

Turning now to Figure 2, for intra-prediction, HEVC allows for angular chroma prediction. Figure 2 illustrates 35 prediction modes, 33 of which specify directions to reference samples for a current predicted sample position 110.

HEVC allows chroma to have DC, Vertical, Horizontal, Planar, DM_CHROMA and LM_CHROMA modes.

DM_CHROMA indicates that the prediction mode to be used is the same as that of the co-located luma PU (i.e. one of the 35 shown in figure 2).

LM_CHROMA indicates that co-located luma samples are used to derive the predicted chroma samples. In this case, if the luma PU from which the DM_CHROMA prediction mode would be taken selected DC, Vertical, Horizontal or Planar, that entry in the chroma prediction list is replaced using mode 34.

It is notable that the prediction modes 2-34 sample an angular range from 45 degrees to 225 degrees; that is to say, one diagonal half of a square. This is useful in the case of the 4:2:0 scheme, which as noted above only uses square chroma PUs for intra-picture prediction.

<u>4:2:2 intra-prediction variants</u>

However, also as noted above the 4:2:2 scheme could have rectangular (non-square) chroma PUs.

Consequently, in an embodiment of the present invention, for rectangular chroma PUs, a mapping table may be required for the direction. Assuming a 1-to-2 aspect ratio for rectangular PUs, then for example mode 18 (currently at an angle of 135 degrees) may be re-mapped to 123 degrees. Alternatively selection of current mode 18 may be remapped to a selection of current mode 22, to much the same effect.

Hence more generally, for non-square PUs, a different mapping between the direction of the reference sample and the selected intra prediction mode may be provided compared with that for square PUs.

More generally still, any of the modes, including the non-directional modes, may also be re-mapped based upon empirical evidence.

It is possible that such mapping will result in a many-to-one relationship, making the specification of the full set of modes redundant for 4:2:2 chroma PUs. In this case, for example it may be that only 17 modes (corresponding to half the angular resolution) are necessary. Alternatively or in addition, these modes may be angularly distributed in a non-uniform manner.

Similarly, the smoothing filter used on the reference sample when predicting the pixel at the sample position may be used differently; in the 4:2:0 scheme it is only used to smooth luma pixels, but not chroma ones. However, in the 4:2:2 and 4:4:4 schemes this filter may also be used for the chroma PUs. In the 4:2:2 scheme, again the filter may be modified in response to the different aspect ratio of the PU, for example only being used for a subset of near horizontal modes. An example subset of modes is preferably 2-18 and 34, or more preferably 7-14.

<u>4:4:4 intra-prediction variants</u>

In the 4:4:4 scheme, the chroma and luma PUs are the same size, and so the intra-prediction mode for a chroma PU can be either the same as the co-located luma PU (so saving some overhead in the bit stream), or more preferably, it can be independently selected.

In this latter case therefore, in an embodiment of the present invention one may have 1, 2 or 3 different prediction modes for the PUs in a CU;

In a first example, the Y, Cb and Cr PUs may all use the same intra-prediction mode.

In a second example, the Y PU may use one intra-prediction mode, and the Cb and Cr PUs both use another independently selected intra-prediction mode.

In a third example, the Y, Cb and Cr PUs each use a respective independently selected intra-prediction mode.

It will be appreciated that having independent prediction modes for the chroma channels (or each chroma channel) will improve the colour prediction accuracy.

The selection of the number of modes could be indicated in the high-level syntax (e.g. at sequence, picture, or slice level). Alternatively, the number of independent modes could be derived from the video format; for example, GBR could have up to 3, whilst YCbCr could be restricted to up to 2.

In addition to independently selecting the modes, the available modes may be allowed to differ from the 4:2:0 scheme in the 4:4:4 scheme.

For example as the luma and chroma PUs are the same size, the chroma PU may benefit from access to all of the 35 + LM_CHROMA + DM_CHROMA directions available. Hence for the case of Y, Cb and Cr each having independent prediction modes, then the Cb channel could have access to DM_CHROMA & LM_CHROMA, whilst the Cr channel could have access to DM_CHROMA_Y, DM_CHROMA_Cb, LM_CHROMA_Y and LM_CHROMA_Cb, Where these replace references to the Luma channel with references to the Y or Cb chroma channels.

Where the luma prediction modes are signalled by deriving a list of most probable modes and sending an index for that list, then if the chroma prediction mode(s) are independent, it may be necessary to derive independent lists of most probable modes for each channel.

Finally, in a similar manner to that noted for the 4:2:2 case above, in the 4:4:4 scheme the smoothing filter used on the reference sample when predicting the pixel at the sample position may be used for chroma PUs in a similar manner to luma PUs.

Inter-prediction

Each frame of a video image is a discrete sampling of a real scene, and as a result each pixel is a step-wise approximation of a real-world gradient in colour and brightness.

In recognition of this, when predicting the Y, Cb or Cr value of a pixel in a new video frame from a value in a previous video frame, the pixels in that previous video frame are interpolated to create a better estimate of the original real-world gradients, to allow a more accurate selection of brightness or colour for the new pixel. Consequently the motion vectors used to point between video frames are not limited to an integer pixel resolution. Rather, they can point to a sub-pixel position within the interpolated image.

4:2:0 inter-prediction

Referring now to Figure 3, in the 4:2:0 scheme as noted above typically an 8x8 luma PU will be associated with Cb and Cr 4x4 chroma PUs. Consequently to interpolate the luma and chroma pixel data up to the same effective resolution, different interpolation filters are used.

For example for the 8x8 4:2:0 luma PU, interpolation is ¼ pixel, and so an 8-tap x4 filter is applied horizontally first, and then the same 8-tap x4 filter is applied vertically, so that the luma PU is effectively stretched 4 times in each direction, as shown in Figure 3. Meanwhile the corresponding 4x4 4:2:0 chroma PU is 1/8 pixel interpolated to generate the same eventual resolution, and so a 4-tap x8 filter is applied horizontally first, then the same 4-tap x8 filter is applied vertically, so that the chroma PUs are effectively stretched 8 times in each direction, as also shown in Figure 3.

4:2:2 inter-prediction variants

Referring now also to Figure 4, as noted previously, in the 4:2:2 scheme the chroma PU can be non-square, and for the case of an 8x8 4:2:2 luma PU, will typically be a 4 wide x 8 high 4:2:2 Chroma PU for each of the Cb and Cr channels, as shown in Figure 4.

Whilst it may be possible therefore to use the existing 8-tap x4 luma filter vertically on the chroma PU, in an embodiment of the present invention it has been appreciated that the existing 4-tap x8 chroma filter would suffice for vertical interpolation as in practice one is only interested in the even fractional locations of the interpolated chroma PU.

Hence Figure 4 shows the 8x8 4:2:2 luma PU interpolated as before with an 8-tap x4 filter, and the 4x8 4:2:2 chroma PUs interpolated with the existing 4-tap x8 chroma filter in the horizontal and vertical direction, but only with the even fractional results used for form the interpolated image in the vertical direction.

4:4:4 inter-prediction variants

By extension, the same principle of only using the even fractional results for the existing 4-tap x8 chroma filter can be applied both vertically and horizontally for the 8x8 4:4:4 chroma PUs.

Further inter-prediction variants

In one implementation of motion vector (MV) derivation, one vector is produced for a PU in a P-slice (and two vectors for a PU in a B-slice (where a P-slice takes predictions from a preceding frame, and a B-slice takes predictions from a preceding and following frame, in a similar manner to MPEG P and B frames). Notably, in this implementation in the 4:2:0 scheme the vectors are common to all channels, and moreover, the chroma data is not used to calculate the motion vectors. In other words, all the channels use a motion vector based on the luma data.

In an embodiment of the present invention, in the 4:2:2 scheme the chroma vector could be independent from luma (i.e. a vector for the Cb and Cr channels could be derived separately), and in the 4:4:4 scheme chroma vectors could further be independent for each of the Cb and Cr channels.

Transforms

In HEVC, most images are encoded as motion vectors from previously encoded/decoded frames, with the motion vectors telling the decoder where, in these other decoded frames, to copy good approximations of the current image from. The result is an approximate version of the current image. HEVC then encodes the so-called residual, which is the error between that approximate version and the correct image. This residual requires much less information than specifying the actual image directly. However, it is still generally preferable to compress this residual information to reduce the overall bitrate further.

In many encoding methods including HEVC, such data is transformed into the spatial frequency domain using an integer cosine transform (ICT), and typically some compression is then achieved by retaining low spatial frequency data and discarding higher spatial frequency data according to the level of compression desired.

4:2:0 transforms

The spatial frequency transforms used in HEVC are conventionally ones that generate coefficients in powers of 4 (for example 64 frequency coefficients) as this is particularly amenable to common quantisation/compression methods. The square TUs in the 4:2:0 scheme are all powers of 4 and hence this is straightforward to achieve.

Even in the case of the currently not-enabled NSQT, some non-square transforms are available for non-square TUs, such as 4x16, but again notably these result in 64 coefficients, i.e. again a power of 4.

4:2:2 and 4:4:4 transform variants

The 4:2:2 scheme can result in non-square TUs that are not powers of 4; for example a 4x8 TU has 32 pixels, and 32 is not a power of 4.

In an embodiment of the present invention therefore, a non-square transform for a non-power of 4 number of coefficients may be used, acknowledging that modifications may be required to the subsequent quantisation process.

Alternatively, in an embodiment of the present invention non-square TUs are split into square blocks having a power of 4 area for transformation, and then the resulting coefficients can be interleaved.

For example, for 4x8 blocks odd/even vertical samples can be split into two square blocks. Alternatively, for 4x8 blocks the top 4x4 pixels and the bottom 4x4 pixels could form two square blocks. Alternatively again, for 4x8 blocks a Haar wavelet decomposition can be used to form a lower and an upper frequency 4x4 block.

Any of these options may be made available, and the selection of a particular alternative may be signalled to or derived by the decoder.

<u>Other transform modes</u>

In the 4:2:0 scheme there is a proposed flag (the so-called 'qpprime_y_zero_transquant_bypass_flag') allowing the residual data to be included in the bit stream losslessly (i.e. without being transformed, quantised or further filtered). In the 4:2:0 scheme the flag applies to all channels.

In an embodiment of the present invention, it is proposed that the flag for the luma channel is separate to the chroma channels. Hence for the 4:2:2 scheme, such flags should be provided separately for the luma channel and for the chroma channels, and for the 4:4:4 scheme, such flags should be provided either separately for the luma and chroma channels, or one flag is provided for each of the three channels. This recognises the increased chroma data rates associated with the 4:2:2 and 4:4:4 schemes, and enables, for example, lossless luma data together with compressed chroma data.

For intra-prediction coding, mode-dependent directional transform (MDDT) allows the horizontal or vertical ICT (or both ICTs) for a TU to be replaced with an Integer Sine Transform depending upon the intra-prediction direction. In the 4:2:0 scheme this is not applied to chroma TUs. However in an embodiment of the present invention it is proposed to apply it to 4:2:2 and 4:4:4 chroma TUs.

<u>Quantisation</u>

In the 4:2:0 scheme, the quantisation calculation is the same for chrominance as for luminance. Only the quantisation parameters (QPs) differ.

QPs for chrominance are calculated from the luminance QPs as follows:

$$Qp_{Cb} = scalingTable\left[Qp_{luminance} + \texttt{chroma\_qp\_index\_offset}\right]$$

$$Qp_{Cr} = scalingTable\left[Qp_{luminance} + \texttt{second\_chroma\_qp\_index\_offset}\right]$$

Where the scaling table is defined as seen in Figure 5, and "chroma_qp_index_offset" and "second_chroma_qp_index_offset" are defined in the picture parameter set.

Chrominance channels typically contain less information than luminance and hence have smaller-magnitude coefficients; this limitation on the chrominance QP may prevent all chrominance detail being lost at heavy quantisation levels.

The QP-divisor relationship in the 4:2:0 is such that an increase of 6 in the QP is equivalent to a doubling of the divisor. Hence the largest difference in the scaling table of 51-39=12 represents a factor-of-4 change in the divisor.

However, in an embodiment of the present invention, for the 4:2:2 scheme, which potentially contains twice as much chroma information as the 4:2:0 scheme, the maximum chrominance QP value in the scaling table may be raised to 45 (i.e. halving the divisor). Similarly for the 4:4:4 scheme, the maximum chrominance QP value in the scaling table may be raised to 51 (i.e. the same divisor). In this case the scaling table is in effect redundant, but may be retained simply for operational efficiency (i.e. so that the system works by reference to a table in the same way for each scheme). Hence more generally in an embodiment of the present invention the chroma QP divisor is modified responsive to the amount of information in the coding scheme relative to the 4:2:0 scheme.

It is also notable that in the 4:2:0 scheme, the largest chroma TU is 16x16, whereas for the 4:2:2 scheme 16x32 TUs are possible, and for the 4:4:4 scheme, 32x32 chroma TUs are possible. Consequently in an embodiment of the present invention quantisation matrices (Qmatrices) for 32x32 chroma TUs are proposed. Similarly, Qmatrices should be defined for non-square TUs such as the 16x32 TU.

Qmatrices could be defined by any one of the following:

values in a grid (as for 4x4 and 8x8 Qmatrices);

interpolated spatially from smaller or larger matrices;

- in HEVC larger Qmatrices can be derived from smaller ones,

relative to other Qmatrices (i.e. difference values, or deltas);

- hence only the deltas need to be sent,

as a function of another Qmatrix;

- e.g. a scaling ratio relative to another matrix,
- hence only the coefficients of the functions need to be sent (such as the scaling ratio),

as an equation/function (e.g. piece-wise linear curve, exponential, polynomial);

- hence only the coefficients of the equations need to be sent to derive the matrix,

or any combination of the above.

Other useful information includes an optional indicator of to which other matrix the values are related, i.e. the previous channel or the first (primary) channel; e.g the matrix for Cr could be a scaled factor of a matrix for Y, or for Cb, as indicated.

The number of Q Matrices in HEVC 4:2:0 is currently 2 (Luma+Chroma) for each transform size. However, in an embodiment of the present invention 3 are provided for (Y+Cb+Cr) or (G+B+R) as applicable. Hence in the case of a 4:4:4 GBR scheme, it will be appreciated that either one set of quantisation matrices could be used for all channels, or three respective sets of quantisation matrices could be used.

A similar principle may be applied to MPEG4-SStP for GBR, where again 2 or 3 matrices per transform size maybe provided.

<u>Entropy encoding</u>

Basic entropy encoding comprises assigning codewords to input data symbols, where the shortest available codewords are assigned to the most probable symbols in the input data. On average the result is a lossless but much smaller representation of the input data.

This basic scheme can be improved upon further by recognising that symbol probability is often conditional on recent prior data, and consequently making the assignment process context adaptive.

In such a scheme, context variables (CVs) are used to determine the choice of respective probability models, and such CVs are provided for in the HEVC 4:2:0 scheme.

To extend entropy encoding to the 4:2:2 scheme, which for example will use 4x8 chroma TUs rather than 4x4 TUs for an 8x8 luma TU, optionally the context variables can be provided for by simply vertically repeating the equivalent CV selections.

However, in an embodiment of the present invention the CV selections are not repeated for the top-left coefficients (i.e. the high-energy, DC and/or low spatial frequency coefficients), and instead new CVs are derived. In this case, for example, a mapping may be derived from the luma map. This approach may also be used for the 4:4:4 scheme.

During coding, in the 4:2:0 scheme, a so-called zig-scan scans through the coefficients in order from high to low frequencies. However, again it is noted that the chroma TUs in the 4:2:2 scheme can be non-square, and so in an embodiment of the present invention a different chroma zig-scan is proposed with the angle of the scan be tilted to make it more horizontal, or more generally, responsive to the aspect ratio of the TU.

Similarly, the neighbourhood for significance map CV selection and the c1/c2 system for greater-than-one and greater-than-two CV selection may be adapted accordingly.

Likewise, in an embodiment of the present invention the last significant coefficient position (which becomes the start point during decoding) could also be adjusted for the 4:4:4 scheme, with last-significant positions for chroma TUs being coded differentially from the last-significant position in the co-located luma TU.

The coefficient scanning can also be made prediction mode dependent for certain TU sizes. Hence a different scan order can be used for some TU sizes dependent on the intra-prediction mode.

In the 4:2:0 scheme, mode dependent coefficient scanning (MDCS) is only applied for 4x4/8x8 luma TUs and 4x4 chroma TUs for intra prediction.

In an embodiment of the present invention, it is proposed that in the 4:2:2 scheme MDCS is applied to 4x8 and 8x4 chroma TUs for intra prediction. Similarly, it is proposed that in the 4:4:4 scheme MDCS is applied to 8x8 and 4x4 chroma TUs.

<u>In-loop filters</u>

<u>Deblocking</u>

Deblocking is applied to all CU, PU and TU boundaries, and the CU/PU/TU shape is not taken into account. The filter strength and size is dependent on local statistics, and deblocking has a granularity of 8x8 Luma pixels.

Consequently it is anticipated that the current deblocking applied for the 4:2:0 scheme should also be applicable for the 4:2:2 and 4:4:4 schemes.

Sample adaptive offsetting

In sample adaptive offsetting (SAO) each channel is completely independent. SAO splits the image data for each channel using a quad-tree, and the resulting blocks are at least one LCU in size. The leaf blocks are aligned to LCU boundaries and each leaf can run in one of three modes, as determined by the encoder ("Central band offset", "Side band offset" or "Edge offset"). Each leaf categorises its pixels, and the encoder derives an offset value for each of the 16 categories by comparing the SAO input data to the source data. These offsets are sent to the decoder. The offset for a decoded pixel's category is added to its value to minimise the deviation from the source.

In addition, SAO is enabled or disabled at picture level; if enabled for luma, it can also be enabled separately for each chroma channel. SAO will therefore be applied to chroma only if it is applied to luma.

Consequently the process is largely transparent to the underlying block scheme and it is anticipated that the current SAO applied for the 4:2:0 scheme should also be applicable for the 4:2:2 and 4:4:4 schemes.

Adaptive loop filtering

In the 4:2:0 scheme, adaptive loop filtering (ALF) is disabled by default. However, in principle (i.e. if allowed) then ALF would be applied to the entire picture for chroma.

In ALF, luma samples are sorted into one of 15 categories; each category uses a different Wiener-based filter.

By contrast, in 4:2:0 chroma samples are not categorised – there is just one Wiener-based filter for Cb, and one for Cr.

Hence in an embodiment of the present invention, in light of the increased chroma information in the 4:2:2 and 4:4:4 schemes, it is proposed that the chroma samples are categorised; for example with 7 categories for 4:2:2 and 15 categories for 4:4:4.

Whilst in the 4:2:0 scheme ALF can be disabled for luma on a per-CU basis using an ALF control flag (down to the CU-level specified by the ALF control depth), it can only be disabled for chroma on a per-picture basis.

Consequently in an embodiment of the present invention, the 4:2:2 and 4:4:4 schemes are provided with one or two channel specific ALF control flags for chroma.

Syntax

In HEVC, syntax is already present to indicate 4:2:0, 4:2:2 or 4:4:4 schemes, and is indicated at the sequence level. However, in an embodiment of the present invention it is proposed to also indicate 4:4:4 GBR coding at this level.

HEVC encoder

Referring now to Figure 6, in an embodiment of the present invention an HEVC encoder suitable for implementing the above techniques comprises an intra-frame mode selector 110 and an intra-frame mode predictor 120; a motion compensation frame predictor 130, a motion estimator 140 and a sub-pixel interpolation filter (e.g. a ¼ subpixel filter); frame stores 150; an adaptive loop filter 170 and an ALF coefficient generator 175; a sample adaptive offset unit 180 and SAO coefficient generator 185; a deblocking filter 190 and a deblocking filter encoding decision unit 195; a transform unit 200 and inverse transform unit 205; a quantisation unit 210 and inverse quantisation unit 215; and an entropy encoder 220.

HEVC decoder

An HEVC decoder corresponding to the above encoder will be understood by a person skilled in the art. Such a decoder may implement at least the methods summarised in Figures 7A-7I below.

Summary

In a summary embodiment of the present invention, an HEVC encoder as described above is operable to carry out methods described herein, including but not limited to the following.

Referring to Figure 7A, in an instance of the summary embodiment, for a 4:4:4 chroma subsampling format, recursively splitting s710 a largest coding unit down to a coding unit of 4x4 pixels.

Referring to Figure 7B, in an instance of the summary embodiment, for a 4:4:4 chroma subsampling format, providing s720 respective coding unit tree hierarchies for each channel (i.e. Y, Cb, Cr).

Referring to Figure 7C, in an instance of the summary embodiment, for a 4:2:2 chroma subsampling format, enabling s732 non-square quad-tree transforms, enabling s734 asymmetric motion partitioning, and selecting s736 transform unit block sizes to align with a resulting asymmetric prediction unit block layout.

Referring to Figure 7D, in an instance of the summary embodiment, for a 4:2:2 chroma subsampling format, associating s740 intra-prediction mode angles for square prediction units with different intra-prediction mode angles for non-square prediction units.

Referring to Figure 7E, in an instance of the summary embodiment, for a 4:4:4 chroma subsampling format, providing s750 respective intra-prediction modes for two or more prediction units in a coding unit.

Referring to Figure 7F, in an instance of the summary embodiment, for a 4:2:2 chroma subsampling format, interpolating s762 a chroma prediction unit having a height twice that of a corresponding 4:2:0 format prediction unit using the chroma filter employed for the corresponding 4:2:0 format prediction unit, and using s764 only alternate vertical values of the interpolated chroma prediction unit.

Referring to Figure 7G, in an instance of the summary embodiment, for a 4:4:4 chroma subsampling format, interpolating s772 a chroma prediction unit having dimensions twice those of a corresponding 4:2:0 format prediction unit using the chroma filter employed for the corresponding 4:2:0 format prediction unit, and using s774 only alternate vertical and horizontal values of the interpolated chroma prediction unit.

Referring to Figure 7H, in an instance of the summary embodiment, for a 4:2:2 chroma subsampling format and/or a 4:4:4 chroma subsampling format, deriving s782 a luma motion vector for a prediction unit, and independently deriving s784 a chroma motion vector for that prediction unit.

Referring to Figure 7I, in an instance of the summary embodiment, for a 4:4:4 chroma subsampling format, deriving s792 a luma motion vector for a prediction unit, and independently deriving s794 a respective chroma motion vector for each chroma channel for the prediction unit.

Referring to Figure 7J, in an instance of the summary embodiment, for a 4:2:2 chroma subsampling format, splitting s812 non-square transform units into square blocks prior to applying a spatial frequency transform, and then combining s814 (e.g. interleaving) the resulting coefficients.

Referring to Figure 7K, in an instance of the summary embodiment, for a 4:2:2 chroma subsampling format and/or a 4:4:4 chroma subsampling format, indicating s822 that luma residual data is to be included in a bitstream losslessly, and independently indicating s824 that chroma residual data is to be included in the bitstream losslessly.

Referring to Figure 7L, in an instance of the summary embodiment, for a 4:4:4 chroma subsampling format, independently indicating s830 for each channel whether residual data is to be included in a bitstream losslessly.

Referring to Figure 7M, in an instance of the summary embodiment, for a 4:2:2 chroma subsampling format, providing s840 a quantisation parameter association table between luma and chroma quantisation parameters, where the maximum chroma quantisation parameter value is 6 smaller than the maximum luma quantisation parameter.

Referring to Figure 7M, in an instance of the summary embodiment, for a 4:4:4 chroma subsampling format, providing s850 a quantisation parameter association table between luma and chroma quantisation parameters, where the maximum chroma quantisation parameter value is the same as the maximum luma quantisation parameter.

Referring to Figure 7O, in an instance of the summary embodiment, for a 4:4:4 chroma subsampling format, using or treating s860 luma quantisation parameter values as chroma quantisation parameter values.

Referring to Figure 7P, in an instance of the summary embodiment, for a 4:2:2 chroma subsampling format and/or a 4:4:4 chroma subsampling format, defining s870 one or more quantisation matrices as difference values with respect to quantisation matrices defined for a different (e.g. 4:2:0) chroma subsampling format.

Referring to Figure 7Q, in an instance of the summary embodiment, for a 4:2:2 chroma subsampling format and/or a 4:4:4 chroma subsampling format, mapping s880 an entropy encoding context variable from a luma context variable map for use with a chroma transform unit, and entropy encoding s890 one or more coefficients of a chroma transform unit using the mapped context variable.

Referring to Figure 7R, in an instance of the summary embodiment, for a 4:4:4 chroma subsampling format, entropy encoding s910 coefficients of luma and chroma transform units, and coding s920 the last significant position for chroma transform units differentially from the last significant position in the co-located luma transform unit.

Referring to Figure 7S, in an instance of the summary embodiment, for a 4:2:2 chroma subsampling format and/or a 4:4:4 chroma subsampling format, enabling s930 adaptive loop filtering, and categorising s940 respective chroma samples into one of a plurality of categories each having a respective filter.

Referring to Figure 7T, in an instance of the summary embodiment, for a 4:2:2 chroma subsampling format and/or a 4:4:4 chroma subsampling format, enabling s950 adaptive loop filtering, and providing s960 at least a first adaptive loop filtering control flag for the chroma channels (e.g. one for Cb and Cr together, or one for each of Cb and Cr).

Finally, it will be appreciated that the methods disclosed herein may be carried out on conventional hardware suitably adapted as applicable by software instruction and/or by the inclusion or substitution of dedicated hardware.

Thus the required adaptation to existing parts of a conventional equivalent device may be implemented in the form of a non-transitory computer program product or similar object of manufacture comprising processor implementable instructions stored on a data carrier such as a floppy disk, optical disk, hard disk, PROM, RAM, flash memory or any combination of these or other storage media, or in the form of a transmission via data signals on a network such as an Ethernet, a wireless network, the Internet, or any combination of these of other networks, or realised in hardware as an ASIC (application specific integrated circuit) or an FPGA (field programmable gate array) or other configurable circuit suitable to use in adapting the conventional equivalent device.

CLAIMS

1. A method of high efficiency video coding, comprising the steps of:
providing a 4:4:4 chroma subsampling format;
and for that format
recursively splitting a largest coding unit down to a coding unit of 4x4 pixels.

2. A method of high efficiency video coding, comprising the steps of:
providing a 4:4:4 chroma subsampling format;
and for that format
providing respective coding unit tree hierarchies for each channel.

3. A method of high efficiency video coding, comprising the steps of:
providing a 4:2:2 chroma subsampling format;
and for that format
enabling non-square quad-tree transforms;
enabling asymmetric motion partitioning; and
selecting transform unit block sizes to align with a resulting asymmetric prediction unit block layout.

4. A method of high efficiency video coding, comprising the steps of:
providing a 4:2:2 chroma subsampling format;
and for that format,
associating intra-prediction mode angles for square prediction units with different intra-prediction mode angles for non-square prediction units.

5. A method of high efficiency video coding, comprising the steps of:
providing a 4:4:4 chroma subsampling format;
and for that format,
providing respective intra-prediction modes for two or more prediction units in a coding unit.

6. A method of high efficiency video coding, comprising the steps of:

providing a 4:2:2 chroma subsampling format;

and for that format,

interpolating a chroma intra-prediction unit having a height twice that of a corresponding 4:2:0 format prediction unit using the chroma filter employed for the corresponding 4:2:0 format prediction unit; and

using only alternate vertical values of the interpolated chroma prediction unit.

7. A method of high efficiency video coding, comprising the steps of:

providing a 4:4:4 chroma subsampling format;

and for that format,

interpolating a chroma prediction unit having dimensions twice those of a corresponding 4:2:0 format prediction unit using the chroma filter employed for the corresponding 4:2:0 format prediction unit; and

using only alternate vertical and horizontal values of the interpolated chroma prediction unit.

8. A method of high efficiency video coding, comprising the steps of:

providing a 4:2:2 chroma subsampling format and/or a 4:4:4 chroma subsampling format;

and for either format,

deriving a luma motion vector for a prediction unit; and

independently deriving a chroma motion vector for that prediction unit.

9. A method of high efficiency video coding, comprising the steps of:

providing a 4:4:4 chroma subsampling format;

and for that format,

deriving a luma motion vector for a prediction unit; and

independently deriving a respective chroma motion vector for each chroma channel for the prediction unit.

10. A method of high efficiency video coding, comprising the steps of:

providing a 4:2:2 chroma subsampling format;

and for that format,

splitting non-square transform units into square blocks prior to applying a spatial frequency transform; and then

combining the resulting coefficients.

11. A method of high efficiency video coding, comprising the steps of:

providing a 4:2:2 chroma subsampling format and/or a 4:4:4 chroma subsampling format;

and for either format,

indicating that luma residual data is to be included in a bitstream losslessly; and

independently indicating that chroma residual data is to be included in the bitstream losslessly.

12. A method of high efficiency video coding, comprising the steps of:

providing a 4:4:4 chroma subsampling format;

and for that format,

independently indicating for each channel whether residual data is to be included in a bitstream losslessly.

13. A method of high efficiency video coding, comprising the steps of:

providing a 4:2:2 chroma subsampling format;

and for that format,

providing a quantisation parameter association table between luma and chroma quantisation parameters, where the maximum chroma quantisation parameter value is 6 smaller than the maximum luma quantisation parameter.

14. A method of high efficiency video coding, comprising the steps of:

providing a 4:4:4 chroma subsampling format;

and for that format,

providing a quantisation parameter association table between luma and chroma quantisation parameters, where the maximum chroma quantisation parameter value is the same as the maximum luma quantisation parameter.

15. A method of high efficiency video coding, comprising the steps of:

providing a 4:4:4 chroma subsampling format;

and for that format,

treating luma quantisation parameter values as chroma quantisation parameter values.

16. A method of high efficiency video coding, comprising the steps of:

providing a 4:2:2 chroma subsampling format and/or a 4:4:4 chroma subsampling format;

and for either format,

defining one or more quantisation matrices as difference values with respect to quantisation matrices defined for a different chroma subsampling format.

17. A method of high efficiency video coding, comprising the steps of:

providing a 4:2:2 chroma subsampling format and/or a 4:4:4 chroma subsampling format;

and for either format,

mapping an entropy encoding context variable from a luma context variable map for use with a chroma transform unit; and

entropy encoding one or more coefficients of a chroma transform unit using the mapped context variable.

18. A method of high efficiency video coding, comprising the steps of:

providing a 4:4:4 chroma subsampling format;

and for that format,

entropy encoding coefficients of luma and chroma transform units; and

coding the last significant position for chroma transform units differentially from the last significant position in the co-located luma transform unit.

19. A method of high efficiency video coding, comprising the steps of:

providing a 4:2:2 chroma subsampling format and/or a 4:4:4 chroma subsampling format;

and for either format,

enabling adaptive loop filtering; and

categorising respective chroma samples into one of a plurality of categories each having a respective filter.

20. A method of high efficiency video coding, comprising the steps of:

providing a 4:2:2 chroma subsampling format and/or a 4:4:4 chroma subsampling format; and for either format,

enabling adaptive loop filtering; and

providing at least a first adaptive loop filtering control flag for the chroma channels.

21. A computer program for implementing the steps of any preceding method claim.

22. A high efficiency video coding encoder arranged in operation to implement the steps of any preceding method claim.

23. A high efficiency video coding decoder arranged in operation to implement the steps of any one of claims 1 to 9.

24. A method of high efficiency video coding substantially as described herein with reference to the accompanying drawings.

25. A high efficiency video coding encoder substantially as described herein with reference to the accompanying drawings.

26. A high efficiency video coding decoder substantially as described herein with reference to the accompanying drawings.

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PROPERTY OFFICE

Application No: GB1207459.7 **Examiner:** Mr Iwan Thomas

Claims searched: 1 **Date of search:** 11 September 2012

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	1	US 2011/0007979 A1 (GOMA) See especially paragraphs [0049] & [0064]
X	1	US 2005/0271288 A1 (SUZUKI) See paragraphs [0075], [0077] & [0168] - [0179]

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
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&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^{X} :

Worldwide search of patent documents classified in the following areas of the IPC

H04N

The following online and other databases have been used in the preparation of this search report

Online: WPI, EPODOC, TXTE, Inspec, Internet

International Classification:

Subclass	Subgroup	Valid From
H04N	0011/00	01/01/2006