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(54) Title: A DECODER

FIG. 17

INDEX	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	...	33
MODE	V	H	DC	V-8	V-4	V+4	V+8	H-4	H+4	H+8	V-6	V-2	V+2	V+6	H-6	H-2	H+2	H+6	...	
4X4	0	0	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0
8X8	0	0	0	1	1	2	2	2	1	1	0	0	0	0	0	0	0	0	0	0
16X16	0	0	0	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	0	0
32X32	0	0	0	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2

(57) Abstract: A decoder for decoding video comprising: (a) said decoder decoding a block of video frame received in a bit stream based upon other blocks of said video frame without using blocks of other frames; (b) said decoding based upon a directional prediction index received in said bit stream using a technique that is dependent on the size of said block; (c) wherein said index selectively indicates one of (1) a first technique based on non-filtered received pixel values; (2) a second technique based upon a first smoothing filter; and (3) a third technique based upon a second smoothing filter; (d) wherein said first smoothing filter and said second smoothing filter are based upon an edge determination.

DESCRIPTION

TITLE OF INVENTION: A DECODER

5 TECHNICAL FIELD

The present invention relates to a decoder, especially a system for parallel video coding techniques..

BACKGROUND ART

10 Existing video coding standards, such as H.264/AVC, generally provide relatively high coding efficiency at the expense of increased computational complexity. As the computational complexity increases, the encoding and/or decoding speeds tend to decrease. The use of parallel
15 decoding and parallel encoding may improve the decoding and encoding speeds, respectively, particularly for multi-core processors. Also, parallel prediction patterns that depend solely on the number of prediction units within the block may be problematic for coding systems using other block
20 structures because the number of prediction units may no longer correspond to the spatial size of the prediction unit.

SUMMARY OF INVENTION

25 One embodiment of the present invention discloses a decoder for decoding video comprising:

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(a) said decoder decoding a block of video frame received in a bit stream based upon other blocks of said video frame without using blocks of other frames;

5 (b) said decoding based upon a directional prediction index received in said bit stream using a technique that is dependent on the size of said block;

(c) wherein said index selectively indicates one of (1) a first technique based on non-filtered received pixel values; (2) a second technique based upon a first smoothing filter; and
10 (3) a third technique based upon a second smoothing filter;

(d) wherein said first smoothing filter and said second smoothing filter are based upon an edge determination.

The foregoing and other objectives, features, and advantages of the invention will be more readily understood
15 upon consideration of the following detailed description of the invention, taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF DRAWINGS

20 FIG. 1 illustrates encoding patterns.

FIG. 2 illustrates prediction modes.

FIG. 3A illustrates a intra-prediction mode.

FIG. 3B illustrates a intra-prediction mode.

FIG. 3C illustrates a intra-prediction mode.

25 FIG. 3D illustrates a intra-prediction mode.

FIG. 3E illustrates a intra-prediction mode.

FIG. 3F illustrates a intra-prediction mode.

FIG. 3G illustrates a intra-prediction mode.

FIG. 3H illustrates a intra-prediction mode.

5 FIG. 3I illustrates a intra-prediction mode.

FIG. 4 illustrates a 16 block macroblock with two partition groups.

FIG. 5A illustrates macroblocks with two partition groups.

10 FIG. 5B illustrates macroblocks with two partition groups.

FIG. 5C illustrates macroblocks with two partition groups.

15 FIG. 5D illustrates macroblocks with two partition groups.

FIG. 6A illustrates macroblocks with three partition groups.

FIG. 6B illustrates macroblocks with three partition groups.

20 FIG. 7 illustrates a macroblock with multiple partition groups.

FIG. 8 illustrates a coding unit split.

FIG. 9A illustrates spatial subdivision of a slice using various units and indices.

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FIG. 9B illustrates spatial subdivisions of a largest coding unit suitable for intra-prediction.

FIG. 10 illustrates size based parallel decoding.

FIG. 11 illustrates one prediction unit with an intra_split_flag.

FIG. 12 illustrates type based parallel decoding.

FIG. 13 illustrates tree based parallel decoding.

FIG. 14A illustrates spatial windows based parallel decoding.

FIG. 14B illustrates the relationship between a window and a largest prediction unit.

FIG. 15 illustrates intra prediction mode direction in HEVC draft standard.

FIG. 16 illustrates arbitrary directional intra prediction modes defined by (dx, dy).

FIG. 17 illustrates table of smoothing filter indices depending on block size and intra prediction modes.

FIG. 18 illustrates edge based filters.

FIG. 19 illustrates alternative edge based filters.

FIG. 20 illustrates a table selection mechanism.

FIG. 21 illustrates a H.264/AVC video encoder.

FIG. 22 illustrates a H.264/AVC video decoder.

DESCRIPTION OF EMBODIMENTS

While any video coder/decoder (codec) that uses entropy encoding/decoding may be accommodated by embodiments described herein, exemplary embodiments are described in relation to an H.264/AVC encoder and an H.264/AVC decoder merely for purposes of illustration. Many video coding techniques are based on a block-based hybrid video-coding approach, wherein the source-coding technique is a hybrid of inter-picture, also considered inter-frame, prediction, intra-picture, also considered intra-frame, prediction and transform coding of a prediction residual. Inter-frame prediction may exploit temporal redundancies, and intra-frame and transform coding of the prediction residual may exploit spatial redundancies.

FIG. 21 illustrates an exemplary H.264/AVC video encoder 102. An input picture signal 104, also considered a frame signal, may be presented for encoding. A predicted signal 106 and a residual signal 108 may be produced, wherein the predicted signal 106 may be based on either an inter-frame prediction signal 110 or an intra-frame prediction signal 112. The inter-frame prediction signal 110 may be determined by motion compensation unit 114 one or more stored, reference pictures signal 116, also considered reference frames signal, using motion information signal 119 determined by a motion estimation unit 118 process between the input frame signal 104 and the reference frames signal

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116. The intra-frame prediction signal 112 may be determined 120 using a reconstructed signal 122. The residual signal 108 may be determined by subtracting the predicted signal 106 from the input frame 104. The residual
5 signal 108 is generated by transformed, scaled and quantized unit 124, thereby producing quantized, transform coefficients signal 126. The reconstructed signal 122 may be generated by adding the predicted signal 106 to a signal 128 generated by inverse (transforming, scaling and quantizing) unit 130
10 from the quantized, transform coefficients 126. The motion information signal 119 and the quantized transform coefficients 126 may be entropy coded by entropy coding unit 132 and written to the compressed-video bitstream 134. An output image 138, for example a portion of the reference
15 frame signal, may be generated at the encoder 102 by de-blocking filter 136 from the reconstructed signal 122. This output frame signal may be used as a reference frame for the encoding of subsequent input pictures signal.

FIG. 22 illustrates an exemplary H.264/AVC video
20 decoder 150. An input signal 152, also considered a bitstream, may be presented for decoding. Received symbols may be entropy decoding unit 154, thereby producing motion information 156, intra-prediction information 157, and quantized, transform coefficients 158. The motion
25 information signal 156 may be combined 160 with a portion of

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one or more reference frames signal 184 which may reside in frame memory 164, and an inter-frame prediction signal 168 may be generated. The quantized, transform coefficients signal 158 may be inversed (quantized, scaled and transformed), thereby producing a decoded residual signal 170. The residual signal 170 may be added to a prediction signal: either the inter-frame prediction signal 168 or an intra-frame prediction signal 176. The intra-frame prediction information may be combined 174 with previously decoded information in the current frame, and an intra-frame prediction signal 176 may be generated. The combined signal 172 may be filtered 180 and the filtered signal 182 may be written to frame memory 164.

Intra-prediction based video encoding / decoding exploits spatial relationships within a frame, an image, or otherwise a block / group of pixels. At an encoder, a block of pixels may be predicted from neighboring previously encoded blocks of pixels, generally referred to as reconstructed blocks, typically located above and/or to the left of the current block, together with a prediction mode and a prediction residual for the block. A block may be any group of pixels that preferably shares the same prediction mode, the prediction parameters, the residual data and/or any other signaled data. At a decoder, a current block may be predicted, according to the prediction mode, from neighboring reconstructed blocks

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typically located above and/or to the left of the current block, together with the decoded prediction residual for the block. In many cases, the intra prediction uses, for example, 4x4, 8x8, 16x16, and 32x32 blocks of pixels.

5 Referring to FIG. 1, with respect to the H.264/AVC video encoding standard, a 16x16 macroblock may include four 8x8 blocks or sixteen 4x4 blocks. The processing order for a group of four 8x8 blocks 2 of a 16x16 macroblock and for a group of sixteen 4x4 blocks 4 of a 16x16 macroblock may
10 have a zig-zag processing order, or any other suitable order. Typically, the current block within the macroblock being reconstructed is predicted using previously reconstructed neighboring blocks and/or macroblocks. Accordingly, the processing of one or more previous blocks of a 16x16
15 macroblock is completed before other blocks may be reconstructed using its neighbors within the macroblock. The intra 4x4 prediction has more serial dependency in comparison to intra 8x8 and 16x16 prediction. This serial dependency may increase the number of operating cycles
20 within a processor therefore slowing down the time to complete the intra prediction, and may result in an uneven throughput of different intra prediction types.

Referring to FIG. 2, in H.264/AVC, the intra 4x4 prediction and 8x8 prediction have nine prediction modes 10. Pixel values in the current block may be predicted from pixels
25

values in a reconstructed upper and/or left neighboring block(s) relative to the current block. The direction of the arrow depicting a mode indicates the prediction direction for the mode. The center point 11 does not represent a direction so this point may be associated with a DC prediction mode, or otherwise referred to as "mode 2". A horizontal arrow 12 extending to the right from the center point 11 may represent a horizontal prediction mode, also referred to as "mode 1". A vertical arrow 13 extending down from the center point 11 may represent a vertical prediction mode, also referred to as "mode 0". An arrow 14 extending from the center point 11 diagonally downward to the right at approximately a 45 degree angle from horizontal may represent a diagonal down-right (DDR) prediction mode, also referred to as "mode 4". An arrow 15 extended from the center point 11 diagonally downward to the left at approximately a 45 degree angle from horizontal may represent a diagonal down-left (DDL) prediction mode, also referred to as "mode 3". Both the DDR and DDL prediction modes may be referred to as diagonal prediction modes. An arrow 16 extending from the center point 11 diagonally upward to the right at approximately a 22.5 degree angle from horizontal may represent a horizontal up (HU) prediction mode, also referred to as "mode 8". An arrow 17 extending from the center point 11 diagonally downward to the right at approximately a 22.5 degree angle

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from horizontal may represent a horizontal down (HD) prediction mode, also referred to as "mode 6". An arrow 18 extending from the center point 11 diagonally downward to the right at approximately a 67.5 degree angle from horizontal may represent a vertical down right (VR) prediction mode, also referred to as "mode 5". An arrow 19 extending from the center point 11 diagonally downward to the left at approximately a 67.5 degree angle from horizontal may represent a vertical down left (VL) prediction mode, also referred to as "mode 7". The HU, HD, VR, and VL prediction modes may be referred to collectively as intermediate angle prediction modes.

FIG. 3A illustrates an exemplary 4x4 block 20 of samples, labeled a-p that may be predicted from reconstructed, neighboring samples, labeled A-M. When samples are not available, such as for example when E-H are not available, they may be replaced by other suitable values.

Intra-prediction mode 0 (prediction mode direction indicated as 13 in FIG. 2) may be referred to as vertical mode intra prediction. In mode 0, or vertical mode intra prediction, the samples of a current block may be predicted in the vertical direction from the reconstructed samples in the block above the current block. In FIG. 3B, the samples labeled a-p in FIG. 3A are shown replaced with the label of the sample label from FIG. 3A from which they are predicted.

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Intra-prediction mode 1 (prediction mode direction indicated as 12 in FIG. 2) may be referred to as horizontal mode intra prediction. In mode 1, or horizontal mode intra prediction, the samples of a block may be predicted in the horizontal direction from the reconstructed samples in the block to the left of the current block. FIG. 3C illustrates an exemplary horizontal prediction of the samples in a 4x4 block. In FIG. 3C, the samples labeled a-p in FIG. 3A are shown replaced with the label of the sample label from FIG. 3A from which they are predicted.

Intra-prediction mode 3 (prediction mode direction indicated as 15 in FIG. 2) may be referred to as diagonal down left mode intra prediction. In mode 3, the samples of a block may be predicted from neighboring blocks in the direction shown in FIG. 3D.

Intra-prediction mode 4 (prediction mode direction indicated as 14 in FIG. 2) may be referred to as diagonal down right mode intra prediction. In mode 4, the samples of a block may be predicted from neighboring blocks in the direction shown in FIG. 3E.

Intra-prediction mode 5 (prediction mode direction indicated as 18 in FIG. 2) may be referred to as vertical right mode intra prediction. In mode 5, the samples of a block may be predicted from neighboring blocks in the direction shown in FIG. 3F.

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Intra-prediction mode 6 (prediction mode direction indicated as 17 in FIG. 2) may be referred to as horizontal down mode intra prediction. In mode 6, the samples of a block may be predicted from neighboring blocks in the direction shown in FIG. 3G.

Intra-prediction mode 7 (prediction mode direction indicated as 19 in FIG. 2) may be referred to as vertical left mode intra prediction. In mode 7, the samples of a block may be predicted from neighboring blocks in the direction shown in FIG. 3H.

Intra-prediction mode 8 (prediction mode direction indicated as 16 in FIG. 2) may be referred to as horizontal up mode intra prediction. In mode 8, the samples of a block may be predicted from neighboring blocks in the direction shown in FIG. 3I.

In intra-prediction mode 2, which may be referred to as DC mode, all samples labeled a-p in FIG. 3A may be replaced with the average of the samples labeled A-D and I-L in FIG. 3A.

The system may likewise support four 16x16 intra prediction modes in which the 16x16 samples of the macroblock are extrapolated from the upper and/or left hand encoded and reconstructed samples adjacent to the macroblock. The samples may be extrapolated vertically, mode 0 (similar to mode 0 for the 4x4 size block), or the samples may be extrapolated horizontally, mode 1 (similar to

mode 1 for the 4x4 size block). The samples may be replaced by the mean, mode 2 (similar to the DC mode for the 4x4 size block), or a mode 3, referred to as plane mode, may be used in which a linear plane function is fitted to the upper and left hand samples.

In order to decrease the processing delays, especially when using parallel processors, it is desirable to process selected blocks of pixels of a larger group of pixels, such as a macroblock, in a parallel fashion. A first group of blocks of pixels may be selected from a macroblock (or other larger set of pixels) and a second group of blocks of pixels may be selected from the remaining pixels of the macroblock. Additional or alternative groups of blocks of pixels may be selected, as desired. A block of pixels may be any size, such as an $m \times n$ size block of pixels, where m and n may be any suitable number. Preferably, each of the blocks within the first plurality of blocks are encoded using reconstructed pixel values from only one or more previously encoded neighboring macroblocks, and each of the blocks within the second plurality of blocks may be encoded using the reconstructed pixel values from previously encoded macroblocks and/or blocks associated with the first plurality of blocks. In this manner, the blocks within the first plurality of blocks may be decoded using reconstructed pixel values from only neighboring macroblocks, and then the blocks within the

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second plurality of blocks may be decoded using the reconstructed pixel values from reconstructed blocks associated with the first plurality of blocks and/or neighboring macroblocks. The encoding and decoding of one or more blocks may be, fully or partially, done in a parallel fashion.

For example, a macroblock with N blocks, the degree of parallelism may be $N/2$. The increased speed of 4x4 intra prediction for a 16x16 macroblock may be generally around a factor of 8, which is significant. Referring to FIG. 4, a macroblock has a size of $M \times N$, where M and N may be any suitable number. The sixteen blocks 41-56 may be grouped into two (or more) sets of eight blocks (or otherwise) each according to a checker board pattern (or other pattern). Eight blocks in a first set are shown as 42, 43, 46, 47, 50, 51, 54, and 55,, and the eight blocks shown in the other set are 41, 44, 45, 48, 49, 52, 53, and 56. The first set of blocks may be decoded, or encoded, in parallel using previously reconstructed macroblocks, and then the second set of blocks may be decoded, or encoded, in parallel using the reconstructed blocks associated with the first set and/or previously reconstructed macroblocks. In some cases, the second set of blocks may start being decoded before the first set of blocks are completely decoded.

Alternative partition examples are shown in FIGS. 5A-5D. Referring to FIG. 5A, blocks 61-76 may be grouped in two groups. The first group may include 65-68 and 73-76, while the second group may include 61-64 and 69-72. Referring to FIG. 5B, blocks 81-96 may be grouped in two groups. The first group may include 82, 83, 85, 88, 89, 92, 94, and 95, while the second group may include 81, 84, 86, 87, 90, 91, 93 and 96. Referring to FIG. 5C, blocks 101-116 may be grouped in two groups. The first group may include 109-116, while the second group may include 101-108. Referring to FIG. 5D, blocks 121-136 may be grouped in two groups. The first group may include 122, 124, 126, 128, 130, 132, 134, and 136, while the second group may include 121, 123, 125, 127, 129, 131, 133, and 135.

Alternatively, the macroblock may be partitioned into a greater number of partitions, such as three sets of blocks. Moreover, the partitions may have a different number of blocks. Further, the blocks may be the same or different sizes. In general, a first plurality of blocks may be predicted in the encoding process using reconstructed pixel values from only previously encoded neighboring macroblocks. A second plurality of blocks may be subsequently predicted in the encoding process using reconstructed pixel values from the previously encoded blocks associated with the first plurality of blocks and/or using reconstructed pixel values from

previously encoded neighboring macroblocks. The third plurality of blocks may be subsequently predicted in the encoding process using reconstructed pixel values from the previously encoded blocks associated with the first plurality of blocks, and/or reconstructed pixel values from the previously encoded blocks associated with the second plurality of blocks, and/or reconstructed pixel values from previously encoded neighboring macroblocks. FIGS. 6A and 6B depict exemplary three-group partitions of a 16x16 macroblock.

Referring to FIG. 6A, the first set includes eight blocks. The second set and the third set each include four blocks. Referring to FIG. 6B, the first set includes six blocks. The second set and the third set each include five blocks. In the case shown in FIG. 6A and 6B, for example, the first set of blocks may be predicted in the encoding process using reconstructed pixel values from only previously encoded neighboring macroblocks. Then the second set of blocks may be subsequently predicted in the encoding process using reconstructed pixel values from the previously encoded blocks associated with the first set of blocks and/or using reconstructed pixel values from previously encoded neighboring macroblocks. Then the third set of blocks may be subsequently predicted in the encoding process using reconstructed pixel values from the previously encoded blocks

associated with the first set of blocks, and/or reconstructed pixel values from the previously encoded blocks associated with the second set of blocks, and/or reconstructed pixel values from previously encoded neighboring macroblocks.

5 FIG. 7 shows an exemplary partition of 4x4 blocks in a 32x32 macroblock. Referring to FIG. 7, blocks may be grouped into nine sets. Also in the case of FIG. 7, the first set, the second set, and the third set may be predicted in this order. Note that in the case of FIG. 7, with an Nth set (where
10 $N \geq 4$), the Nth set is predicted with use of previously reconstructed macroblocks, also previously reconstructed blocks, i.e. first set, ... to (N-1)th set.

The bit stream may require signaling which encoding pattern is used for the decoding, or otherwise the default
15 decoding may be predefined. In some embodiments, the neighboring upper and left macroblock pixel values may be weighted according to their distance to the block that is being predicted, or using any other suitable measure.

Since Jan. 2010, ITU.T and MPEG has started
20 standardization effort on a HEVC (High Efficiency Video Coding) standard. In some cases, such as the HEVC working draft the video encoding does not use fixed block sizes, but rather includes two or more different block sizes within a macroblock. In some implementations, the partitioning of an
25 image may use the concepts of coding unit (CU), prediction

unit (PU), and prediction partitions. At the highest level, this technique divides a picture into one or more slices. A slice is a sequence of largest coding units (LCU) that correspond to a spatial window within the picture. The coding unit, may be for example, a group of pixels containing one or more prediction modes / partitions and it may have residual data. The prediction unit, may be for example, a group of pixels that are predicted using the same prediction type, such as intra prediction or intra frame prediction. The prediction partition, may be for example, a group of pixels predicted using the same prediction type and prediction parameters. The largest coding unit, may be for example, a maximum number of pixels for a coding unit. For example, a 64x64 group of pixels may correspond to a largest coding unit. These largest coding units are optionally sub-divided to adapt to the underlying image content (and achieve efficient compression). This division is determined by an encoder and signaled to the decoder, and it may result in a quad-tree segmentation of the largest coding unit. The resulting partitions are called coding units, and these coding units may also be subsequently split. Coding unit of size CuSize may be split into four smaller coding units, CU0, CU1, CU2 and CU3 of size $\text{CuSize} / 2$ as shown in FIG. 8. This may be accomplished by signaling a split_coding_unit_flag to specify whether a coding unit is split into coding units with half horizontal and vertical size. The

sub-division is recursive and results in a highly flexible partitioning approach.

Once no further splitting of the coding unit is signaled, the coding units are considered as prediction units. Each prediction unit may have multiple prediction partitions. For an intra coded prediction unit, this may be accomplished by signaling an `intra_split_flag` to specify whether a prediction unit is split into four prediction units with half horizontal and vertical size. Additional partitioning mechanisms may be used for inter-coded blocks, as desired. FIG. 9A illustrates an example spatial subdivision of one slice with various units.

Referring FIG. 9A, the `LARGEST_CU` is divided into four coding units `CU0`, `CU1`, `CU2`, and `CU3`. Further, each of the `CU1`, `CU2`, and `CU3` are divided into four coding units. The coding units achieved by the sub-division are considered as prediction units. For example, the coding units achieved by the sub-division of `CU1` are considered as `PU10`, `PU11`, `PU12` and `PU13`. In addition, `PU11` and `PU12` have multiple partitions. `PU11` has `PP110`, `PP111`, `PP112`, and `PP113`, and `PU12` has `PP120`, `PP121`, `PP122`, and `PP123`.

FIG. 9B illustrates spatial subdivisions of a largest coding unit suitable for intra-prediction. Referring FIG. 9B, `LCU` has `CU0`, `CU1`, `CU2`, and `CU3`. `CU1`, `CU2`, and `CU3` include multiple prediction units. In this case, the processing for multiple coding units are preferably done in parallel. In

addition, the processing for multiple prediction units are preferably done in parallel, such as CU20, CU21, CU22, CU23, of CU2; and such as the 4 divisions PU10, PU11, PU12 and PU13 of CU1.

5 In some embodiments referring to FIG. 10, preferably the system uses parallel intra prediction only for prediction units of the largest prediction unit that all contain partitions having the same size. The largest prediction unit, may be for example, the largest group of pixels being defined by a single
10 set of data. This may be determined by inspection of the largest prediction unit, or other set of prediction units. That may be signaled from within the bitstream by a flag, such as an intra_split_flag, for the prediction unit. That may be signaled from within the bitstream by a flag, such as an
15 intra_split_flag, for the prediction unit. When the intra_split_flag signals that the prediction unit is sub-divided into equally sized prediction partitions, then the parallel intra prediction system may be applied within that prediction unit. When the intra_split_flag does not signal that the prediction
20 unit is sub-divided into equally sized prediction partitions, then the parallel intra prediction system is preferably not applied. In this step, the default decoding is performed. An exemplary splitting of the prediction unit into four prediction partitions is illustrated in FIG. 11, which are then grouped
25 into two sets for parallel processing. For example, partitions

1 and 2 may be grouped to one set and partitions 0 and 3 may be grouped to another set. The first set is then predicted using the prediction unit neighbors while the second set is predicted using prediction unit neighbors as well as the neighbors in the first set.

In some embodiments referring to FIG. 12, in addition to the partitions having the same size, the system may further use parallel intra prediction across multiple prediction units that have prediction partitions that are of the same size and/or coding type (e.g., intra-coded vs. motion compensated).

More specifically, the largest prediction unit, may be for example, the largest group of pixels being defined by a single set of data. This may be determined by inspection of the largest prediction unit, or other set of prediction units (S121). When all prediction partitions have same size (YES in S122) and the same coding type (YES in S123), then the parallel intra prediction system may be applied within that prediction unit (S125). When all prediction partitions does not have same size (NO in S122) or the same coding type (NO in S123), then the default decoding is performed (S124).

Referring to FIG. 13, these prediction units preferably be spatially co-located within a coding unit that was subsequently split to create the multiple prediction units (S131). Alternatively, the multiple prediction units may be spatially co-located within a coding unit that was recursively

split to create the prediction units (S131). In other words, the prediction units have the same parent in the quad-tree. Since S132, S133, S134, and S135 are similar to S122, S123, S124 and S125 respectively, a description thereof is omitted here. Note that prediction partitions are originally of the same coding type. Accordingly, it is possible to omit the determination of the coding type, of S123 in Fig. 12 and S133 in Fig. 13.

In an embodiment the system may use parallel intra prediction across multiple coding units. The multiple coding units preferably have the same spatial size and prediction type (e.g., intra coded). Referring to FIG. 14A, in another embodiment, the parallel intra prediction technique may be based on the size of the prediction area. For example, the system may restrict the use of the parallel intra prediction technique to pixels within an NxN spatial window. For example, the system may restrict use of the parallel intra prediction technique only to pixels within a 16x16 spatial window. Referring to FIG 14B, the spatial window is labeled as LPU (largest prediction unit) and includes data from a first coding unit, CU0, and a second coding unit, CU1. Note that the data used for processing the pixels within the window may be located outside of the window.

As described above, the spatial window may be referred to as a parallel unit. Alternatively, it may be referred to as a

parallel prediction unit or parallel coding unit. The size of the parallel unit may be signaled in the bit-stream from an encoder to a decoder. Furthermore, it may be defined in a profile, defined in a level, transmitted as meta-data, or communicated in any other manner. The encoder may determine the size of the parallel coding unit and restricts the use of the parallel intra prediction technology to spatial pixels that do not exceed the size of the parallel unit. The size of the parallel unit may be signaled to the decoder. Additionally, the size of the parallel unit may be determined by table look, specified in a profile, specified in a level, determined from image analysis, determined by rate-distortion optimization, or any other suitable technique.

For a prediction partition that is intra-coded, the following technique may be used to reconstruct the block pixel values. First, a prediction mode is signaled from the encoder to the decoder. This prediction mode identifies a process to predict pixels in the current block from previously reconstructed pixel values. As a specific example, a horizontal predictor may be signaled that predicts a current pixel value from a previously reconstructed pixel value that is near and to the left of the current pixel location. As an alternative example, a vertical predictor may be signaled that predicts a current pixel value from a previously reconstructed pixel value that is near and above the current pixel location.

In general, pixel locations within a coding unit may have different predictions. The result is predicted pixel values for all the pixels of the coding unit.

Additionally, the encoder may send transform coefficient level values to the decoder. At the decoder, these transform coefficient level values are extracted from the bit-stream and converted to transform coefficients. The conversion may consist of a scaling operation, a table look-up operation, or any other suitable technique. Following the conversion, the transform coefficients are mapped into a two-dimensional transform coefficient matrix by a zig-zag scan operation, or other suitable mapping. The two-dimensional transform coefficient matrix is then mapped to reconstructed residual values by an inverse transform operation, or other suitable technique. The reconstructed residual values are added (or otherwise) to the predicted pixel values to form a reconstructed intra-predicted block.

The zig-zag scan operation and the inverse residual transform operation may depend on the prediction mode. For example, when a decoder receives a first prediction mode from an encoder for a first intra-predicted block, it uses the prediction process, zig-zag scan operation and inverse residual transform operation assigned to the first prediction mode. Similarly, when a decoder receives a second prediction mode from an encoder for a second intra-predicted block, it

uses the prediction process, zig-zag scan operation and inverse residual transform operation assigned to the second prediction mode. In general, the scan pattern used for encoding and decoding may be modified, as desired. In addition, the encoding efficiency may be improved by having the scan pattern further dependent on which group of the parallel encoding the prediction units or prediction partitions are part of.

In one embodiment the system may operate as follows: when a decoder receives a first prediction mode from an encoder for a first intra-predicted block that is assigned to a first partition, the decoder uses the prediction process, zig-zag scan operation and inverse residual transform operation assigned to the first prediction mode and the first partition. Similarly, when a decoder receives a second prediction mode from an encoder for a second intra-predicted block that is assigned to a second partition, the decoder uses the prediction process, zig-zag scan operation and inverse residual transform operation assigned the second prediction mode and said second partition. For example, the first and second partitions may correspond to a first and a second group for parallel encoding: Note that for the case that the first prediction mode and the second prediction mode have the same value but the first partition and the second partition are not the same partition, then the first zig-zag scan operation

and first inverse residual transform operation may not be the same as the second zig-zag scan operation and second inverse residual transform. This is true even if the first prediction process and second prediction process are the same. For example, the zig-zag scan operation for the first partition may use a horizontal transform and a vertical scan pattern, while the zig-zag scan operation for the second partition may use a vertical transform and a horizontal scan pattern.

There may be different intra prediction modes that are block size dependent. For block sizes of 8x8, 16x16, 32x32, there may be, for example, 34 intra prediction modes which provide substantially finer angle prediction compared to the 9 intra 4x4 prediction modes. While the 9 intra 4x4 prediction modes may be extended in some manner using some type of interpolation for finer angle prediction, this results in additional system complexity.

In the context of parallel encoding, including parallel encoding where the block sizes may have different sizes, the first set of blocks are generally predicted from adjacent macroblocks. Instead of extending the prediction modes of the 4x4 blocks to the larger blocks (e.g., 8x8, 16x16, 32x32, etc.), thereby increasing the complexity of the system, the system may reuse the existing prediction modes of the larger blocks. Therefore, the 4x4 block prediction modes may take advantage of the greater number of prediction modes

identified for other sizes of blocks, such as those of 8x8, 16x16, and 32x32.

In many cases, the intra prediction modes of the 4x4 block size and prediction modes of the larger block sizes may be different. To accommodate the differences, it is desirable to map the 4x4 block prediction mode numbers to larger block prediction mode numbers. The mapping may be according to the prediction direction. For example, the intra prediction of a 4x4 block may have 17 directional modes; while intra prediction of the 8x8 block size, the 16x16 block size, and the 32x32 block size may have 34 direction modes; the intra prediction of a 64x64 block may have 3 directional modes. Different angular prediction modes and the ADI prediction are shown in FIG. 15 and FIG. 16, respectively.

Moreover, 2 represents a DC prediction. All lines extending from a center of the 2 (DC) indicate a prediction direction respectively. The ADI is a prediction method indicating the prediction directions by a coordinate of (dx,dy), as illustrated in FIG. 16.

Even though the prediction modes of various blocks size may be different, for directional intra prediction, one mode may be mapped to another if they have the same or a close direction. For example, the system may map the value for mode 4 of the 4x4 block prediction to mode 9 of the 8x8 block prediction for the case that mode 4 related to a horizontal

mode prediction and mode 9 related to a horizontal mode prediction.

For a block the additional neighbors from the bottom and right may be used when available. Rather than extending the different prediction modes, the prediction from the bottom and the right neighbors may be done by rotating the block and then utilizing existing intra prediction modes. Predictions by two modes that are of 180 degree difference may be weighted interpolated as follows,

$$p(y,x) = w * p1(y,x) + (1-w) p2(y,x)$$

where p1 is the prediction that doesn't include the bottom and right neighbors, and p2 is the prediction that doesn't include the above and left neighbors, and w is a weighting factor. The weighting tables may be the weighted average process between the predictions from above and left neighbors, and neighbors from bottom and right neighbors as follows:

First, derive value yTmp at pixel (x,y) as weighted average of p1 and p2, where weight is according to the distance to the above and bottom neighbors

$$yTmp = (p1 * (N-y) + p2 * y) / N ;$$

Second, derive value xTmp at pixel (x,y) as weighted average of p1 and p2, where weight is according to the distance to the left and right neighbors

$$xTmp = (p1 * (N-x) + p2 * x) / N ;$$

Namely, weight are proportional to the distance between each predicted pixels and the top/bottom and left/right neighbor. The N is the block width, p1 is the prediction that doesn't include the bottom and right neighbors, and p2 is the prediction that doesn't include the above and left neighbors.

Third, the final predicted value at pixel (y,x) is a weighted average of xTmp and yTmp. The weight depends on the prediction direction. For each direction, represent its angle as (dx, dy), as represented in ADI mode in FIG. 16. For mode without direction, it is preferable to set dx=1, dy=1.

$$p(y,x) = (\text{abs}(dx) * xTmp + \text{abs}(dy) * yTmp) / (\text{abs}(dx)+\text{abs}(dy));$$

The intra prediction technique may be based, at least in part, upon applying filtering to the pixel values. For example, for a neighbor pixel p(i) to be used for intra prediction, the pixel may be filtered using a pair of filters. The pair of filters may be characterized by:

$$\text{Filter 1: } p1(i) = (p(i-1)+2*p(i)+p(i+1))>>2$$

$$\text{Filter 2: } p2(i) = (p1(i-1)+2*p1(i)+p1(i+1))>>2$$

As it may be observed, Filter 1 performs an averaging (e.g., smoothing) operation by summing the values of the previous pixel, the current pixel times 2, and the next pixel, the total sum of which is divided by four. As it may be observed, Filter 2 performs a further averaging (e.g., smoothing) operating by summing the values of the previous,

the current pixel filtered by Filter 1 times 2, and the next pixel, the sum of which is divided by four. Thus for selecting neighboring values to be used for intra prediction the system has the original pixels to select from (mode 0); the pixels as a result of Filter 1 to select from (mode 1); and the pixels as a result of Filter 2 to select from (mode 2).

Referring to FIG. 17, the video bit stream may include mode index values 400, such as intra prediction mode index values from 0 to 33. Each of the mode index values 400 has a corresponding intra prediction technique where the selected data from the filters is based upon block size. For example, for mode index value 8, 4x4 block size uses filter index 0 (e.g., original pixels), 8x8 block size uses filter index 1 (e.g., pixels from Filter 1), 16x16 block size uses filter index 2 (e.g., pixels from Filter 2), and 32x32 block size uses filter index 2 (e.g., pixels from Filter 2). Accordingly, the intra prediction technique for a particular index value is block size dependent. This technique is also known as Mode dependent intra smoothing. While this technique provides effective coding efficiency for many video sequences, the technique tends to decrease the resulting image quality with selected video sequences.

The table of FIG. 17 does not always provide an optimal solution to the intra prediction for a frame. While attempting all combinations of index values for a particular frame of a

video may improve the coding efficiency, it tends to result in a highly complex encoder. To increase the coding efficiency for an expanded breadth of video sequences, it is desirable to modify the filtering technique to accommodate additional characteristics of the image content. It was determined that if the neighbor pixels to an original pixel are on or otherwise adjacent to an edge of an object, then using the intra smoothing filters are likely to make the resulting encoded image worse.

Referring to FIG. 18, for a pixel $p(i)$ an edge based determination 420 is used. The edge based determination 420 may use a set of three pixels to determinate whether the absolute value of the difference between adjacent pixels is greater than a threshold. One characterization of the edge based determination 420 may be $\text{abs}(p(i-1)-p(i+1)) > \text{threshold}$. If the edge based determination 420 indicates the existence of an edge greater than the threshold, then the filtered lines being generated $p1(i)$ and $p2(i)$ 430 is set to the input pixels, such as $p(i)$. If the edge based determination 420 does not indicate the existence of an edge greater than the threshold, then the filtered lines being generated $p1(i)$ and $p2(i)$, are modified by a smoothing filter 440, such as $p1(i) = (p(i-1) + 2 * p(i) + p(i+1) + 2) >> 2$. The filter 440 performs an averaging (e.g., smoothing) operation by summing the values of the previous pixel, the current pixel times 2, and the next pixel,

plus 2 to account for rounding, the total sum of which is divided by four. The filter 450 performs a further averaging (e.g., smoothing) operation by summing the values of the previous pixel, the previously filtered pixel times 2, and the next pixel, plus 2 to account for rounding, the total sum of which is divided by four. The result is filtered lines of values $p1(i)$ and $p2(i)$ having a combination of the original pixel values, smoothed pixel values, and further smoothed pixel values.

The threshold value may be pre-defined value, a value provided in the bit stream, a value periodically provided in the bit stream, and/or determined based upon image content of the frame. The threshold may be dependent on the block size. For example, large block sizes tend to benefit from more intra smoothing. The threshold may be dependent on the image resolution. For example, the three pixel edge determination tends to work well for small resolution sequences but for larger resolution sequences additional pixels for the edge determination tends to work well. The threshold may also be dependent on the quantization parameter. Referring to FIG. 19, there may be a first threshold value (e.g., threshold1) for the first averaging filter and a different second threshold value (e.g., threshold2) for the second averaging filter. Preferably two different sets of data are generated, such as $p1(i)$ and $p2(i)$. As a general matter, for data that is not

calculated, any other available set of data may be used. In addition, it is to be understood that more than 3 neighbor pixels may be used with any of the techniques.

Referring to FIG. 20, in some cases it may be desirable to select between multiple different index tables (see FIG. 17), to further improve image encoding and decoding. The decoder may have one or more predefined index tables, one or more index tables received in the bit stream, one or more index tables determined based upon the image content, or otherwise. Each of the tables may be different from one another, or otherwise a portion of the index table may be modified, effectively providing a different index table. The decoder receives a table index from the bit stream or otherwise derives the index for the desired the table 500. In some cases, the index for the desired table may indicate that no table should be used (all filter index in the table is 0) and thus a default technique should be used. In some cases, the index for the desired table may indicate that no filter should be used for 4x4 block. The decoder also receives additional information related to block size, mode, etc. 510. This additional information 510 may be used in combination with the index 500 to select the appropriate filter index 520 from within the selected table. The filter index 530 is then used in the decoder to get the neighbor pixels for intra prediction. In some cases, the bit stream may indicate that selected block

sizes should not use the table, and thus a default technique should be used. In some cases, the bit stream may indicate an offset value for the filter index, such that additional tables do not necessarily need to be provided to the decoder. For example, an offset of 1 may indicate that the filter index 0 should use filter index 0, filter index 1 should use filter index 0, and that filter index 2 should use mode 1. Herein, a decoder for video coding based on edge determination is obtained.

The terms and expressions which have been employed in the foregoing specification are used therein as terms of description and not of limitation, and there is no intention, in the use of such terms and expressions, of excluding equivalents of the features shown and described or portions thereof, it being recognized that the scope of the invention is defined and limited only by the claims which follow.

Some embodiments of the present invention disclose a decoder in which said first smoothing filter may be based upon three pixels.

Said three pixels may include a center pixel, a pixel to the left, and a pixel to the right.

Said first smoothing filter may substantially averages said three pixels.

Said second smoothing filter may be based upon three pixels.

Said three pixels may include a center pixel, a pixel to the left, and a pixel to the right.

Said second smoothing filter may substantially averages said three pixels.

5 Said center pixel may be based upon the results of said first smoothing filter.

Said edge determination may be based upon a threshold value.

Said threshold value may be received in said bit stream.

10 Said first smoothing filter may have a first threshold for said edge determination, and said second smoothing filter may have a second threshold for said edge determination.

Said first threshold and said second threshold may be different each other.

15 Said first threshold may be provided in said bit stream.

Said threshold may be dependent on the size of said block.

Said threshold may be dependent on the content of said frame.

20 Said threshold may be dependent on the image resolution of said frame.

Said threshold may be dependent on the Quantization parameter of at least one of said frame and said block.

25 Said first threshold and said second threshold may be the same.

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Said decoder selects among a plurality of different sets of directional prediction indexes.

Said one of the plurality of direction prediction indexes may be a default set.

5 Said plurality of direction prediction indexes may be received in said bit stream.

Said plurality of direction prediction indexes may be derived from data in said bit stream.

10 at least one of modes of said plurality of direction prediction indexes may be indicated as not used.

The decoder may further include an offset related to said prediction indexes.

CLAIMS

1. A decoder for decoding video comprising:

(a) said decoder decoding a block of video frame
5 received in a bit stream based upon other blocks of said video
frame without using blocks of other frames;

(b) said decoding based upon a directional prediction
index received in said bit stream using a technique that is
dependent on the size of said block;

10 (c) wherein said index selectively indicates one of (1) a
first technique based on non-filtered received pixel values; (2)
a second technique based upon a first smoothing filter; and
(3) a third technique based upon a second smoothing filter;

(d) wherein said first smoothing filter and said second
15 smoothing filter are based upon an edge determination.

2. The decoder of claim 1 wherein said first smoothing
filter is based upon three pixels.

20 3. The decoder of claim 2 wherein said three pixels
include a center pixel, a pixel to the left, and a pixel to the
right.

4. The decoder of claim 3 wherein said first smoothing
25 filter substantially averages said three pixels.

5. The decoder of claim 1 wherein said second smoothing filter is based upon three pixels.

5 6. The decoder of claim 5 wherein said three pixels include a center pixel, a pixel to the left, and a pixel to the right.

7. The decoder of claim 6 wherein said second
10 smoothing filter substantially averages said three pixels.

8. The decoder of claim 7 wherein said center pixel is based upon the results of said first smoothing filter.

15 9. The decoder of claim 1 wherein said edge determination is based upon a threshold value.

10. The decoder of claim 9 wherein said threshold value is received in said bit stream.

20 11. The decoder of claim 1 wherein said first smoothing filter has a first threshold for said edge determination, and said second smoothing filter has a second threshold for said edge determination.

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12. The decoder of claim 11 wherein said first threshold and said second threshold are different.

13. The decoder of claim 11 wherein said first
5 threshold is provided in said bit stream.

14. The decoder of claim 11 wherein said threshold is dependent on the size of said block.

10 15. The decoder of claim 11 wherein said threshold is dependent on the content of said frame.

16. The decoder of claim 11 wherein said threshold is dependent on the image resolution of said frame.

15 17. The decoder of claim 11 wherein said threshold is dependent on the Quantization parameter of at least one of said frame and said block.

20 18. The decoder of claim 11 wherein said first threshold and said second threshold are the same.

25 19. The decoder of claim 1 wherein said decoder selects among a plurality of different sets of directional prediction indexes.

20. The decoder of claim 19 wherein one of said plurality of direction prediction indexes is a default set.

5 21. The decoder of claim 19 wherein said plurality of direction prediction indexes are received in said bit stream.

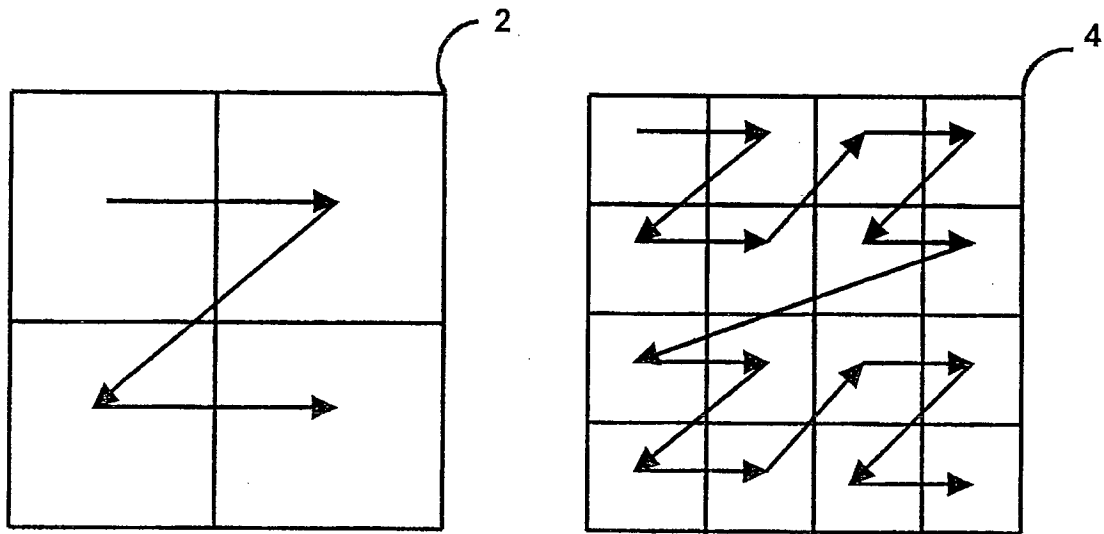
22. The decoder of claim 19 wherein said plurality of direction prediction indexes are derived from data in said bit stream.
10

23. The decoder of claim 19 wherein at least one of modes of said plurality of direction prediction indexes are indicated as not used.
15

24. The decoder of claim 19 further including an offset related to said prediction indexes.

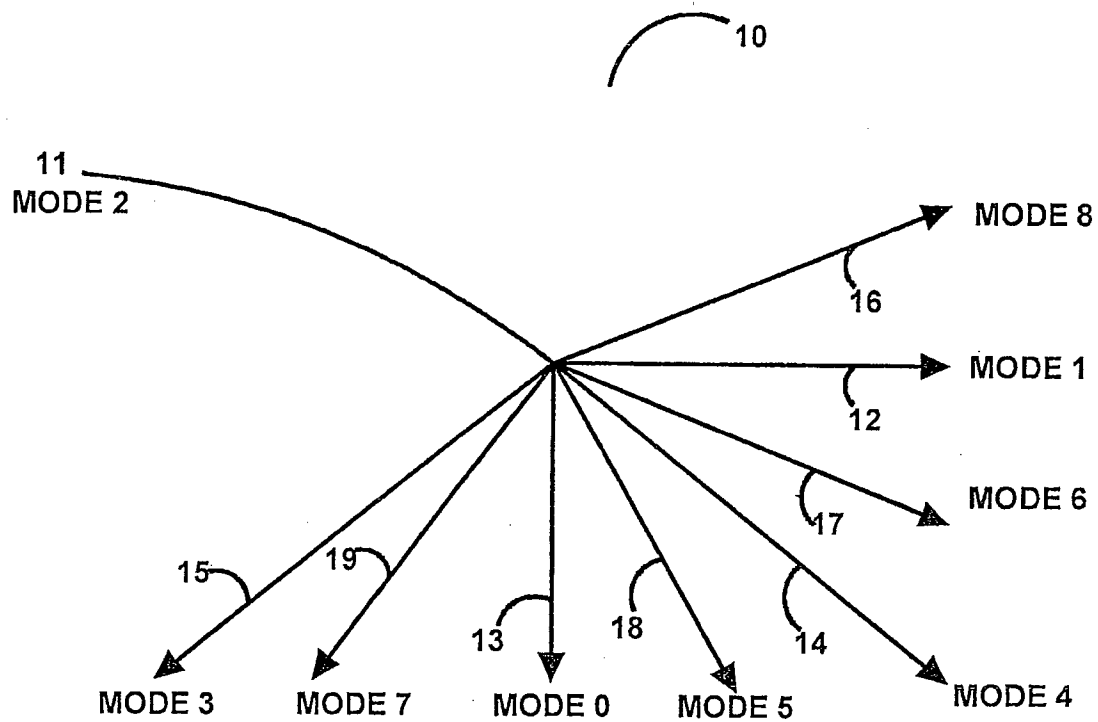
1/25

FIG. 1



PRIOR ART

FIG. 2



PRIOR ART

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FIG. 3A

M	A	B	C	D	E	F	G	H
I	a	b	c	d				
J	e	f	g	h				
K	i	j	k	l				
L	m	n	o	p				

PRIOR ART

FIG. 3B

M	A	B	C	D	E	F	G	H
I	A	B	C	D				
J	A	B	C	D				
K	A	B	C	D				
L	A	B	C	D				

PRIOR ART

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FIG. 3C

M	A	B	C	D	E	F	G	H
I	I	I	I	I				
J	J	J	J	J				
K	K	K	K	K				
L	L	L	L	L				

PRIOR ART

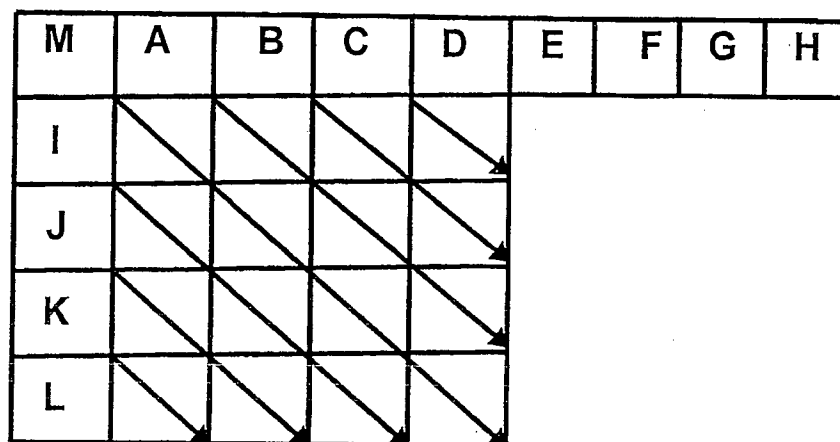
FIG. 3D

M	A	B	C	D	E	F	G	H
I								
J								
K								
L								

PRIOR ART

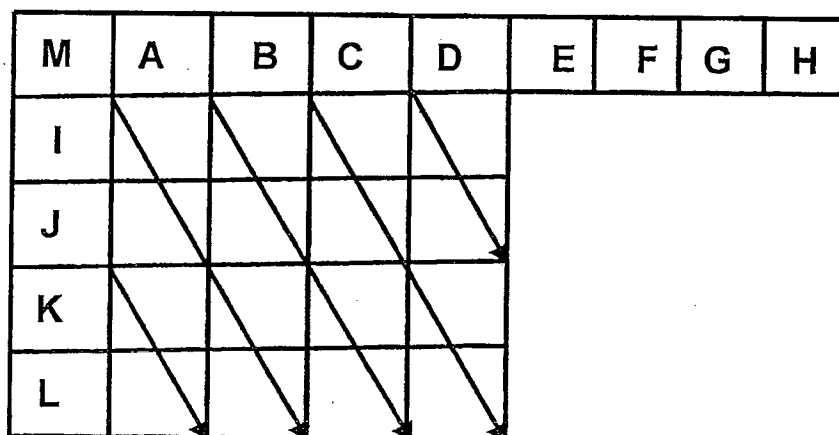
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FIG. 3E



PRIOR ART

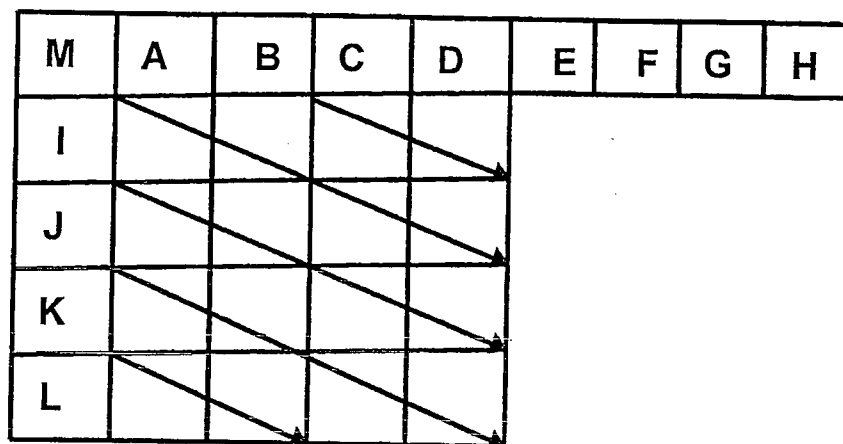
FIG. 3F



PRIOR ART

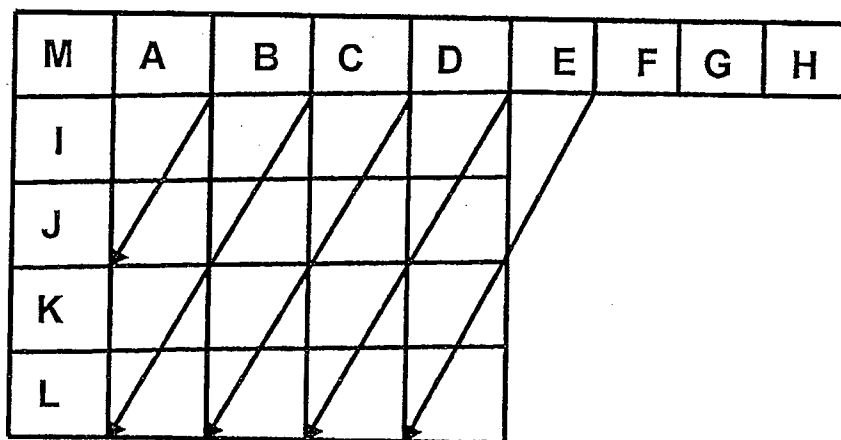
5/25

FIG. 3G



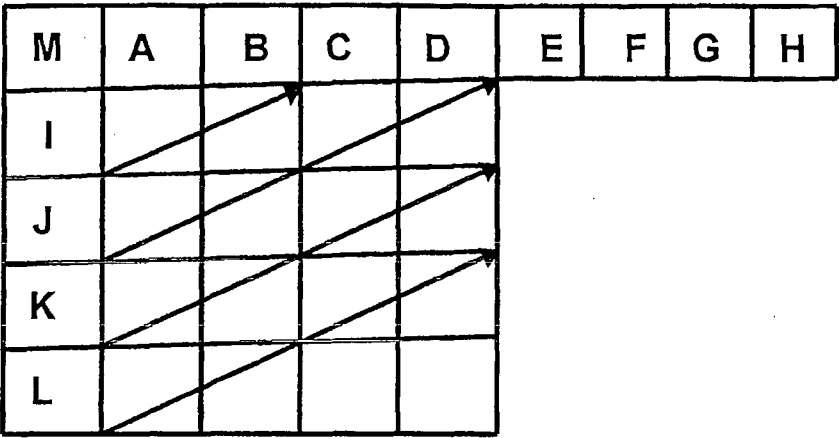
PRIOR ART

FIG. 3H



PRIOR ART

FIG. 3I



PRIOR ART

FIG. 4

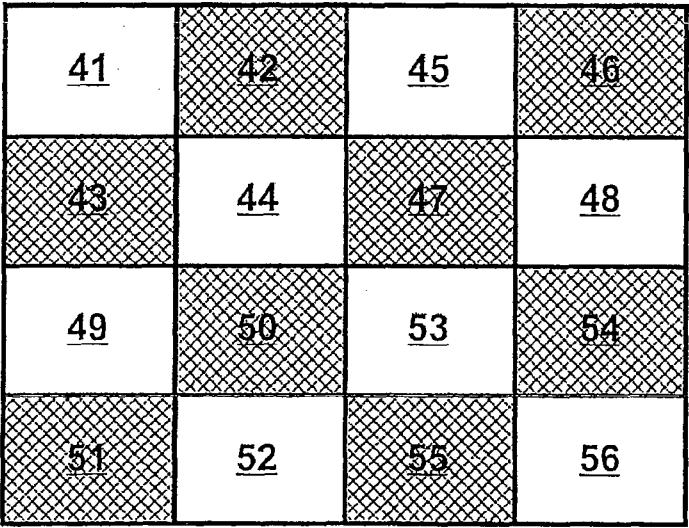


FIG. 5A

<u>61</u>	<u>62</u>	<u>63</u>	<u>64</u>
<u>65</u>	<u>66</u>	<u>67</u>	<u>68</u>
<u>69</u>	<u>70</u>	<u>71</u>	<u>72</u>
<u>73</u>	<u>74</u>	<u>75</u>	<u>76</u>

FIG. 5B

<u>81</u>	<u>82</u>	<u>83</u>	<u>84</u>
<u>85</u>	<u>86</u>	<u>87</u>	<u>88</u>
<u>89</u>	<u>90</u>	<u>91</u>	<u>92</u>
<u>93</u>	<u>94</u>	<u>95</u>	<u>96</u>

FIG. 5C

<u>101</u>	<u>102</u>	<u>103</u>	<u>104</u>
<u>105</u>	<u>106</u>	<u>107</u>	<u>108</u>
<u>109</u>	<u>110</u>	<u>111</u>	<u>112</u>
<u>113</u>	<u>114</u>	<u>115</u>	<u>116</u>

FIG. 5D

<u>121</u>	<u>122</u>	<u>123</u>	<u>124</u>
<u>125</u>	<u>126</u>	<u>127</u>	<u>128</u>
<u>129</u>	<u>130</u>	<u>131</u>	<u>132</u>
<u>133</u>	<u>134</u>	<u>135</u>	<u>136</u>

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FIG. 6A

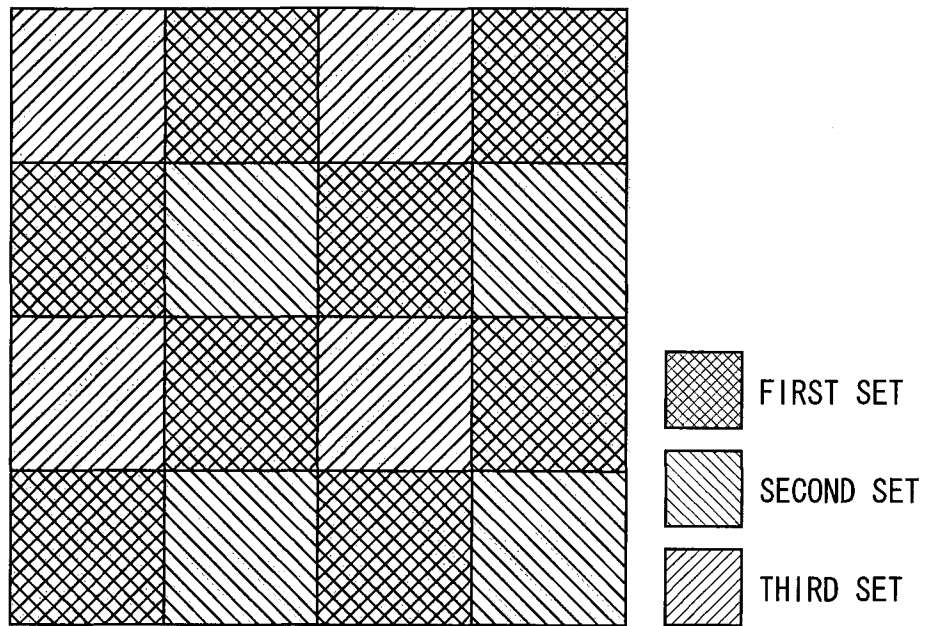
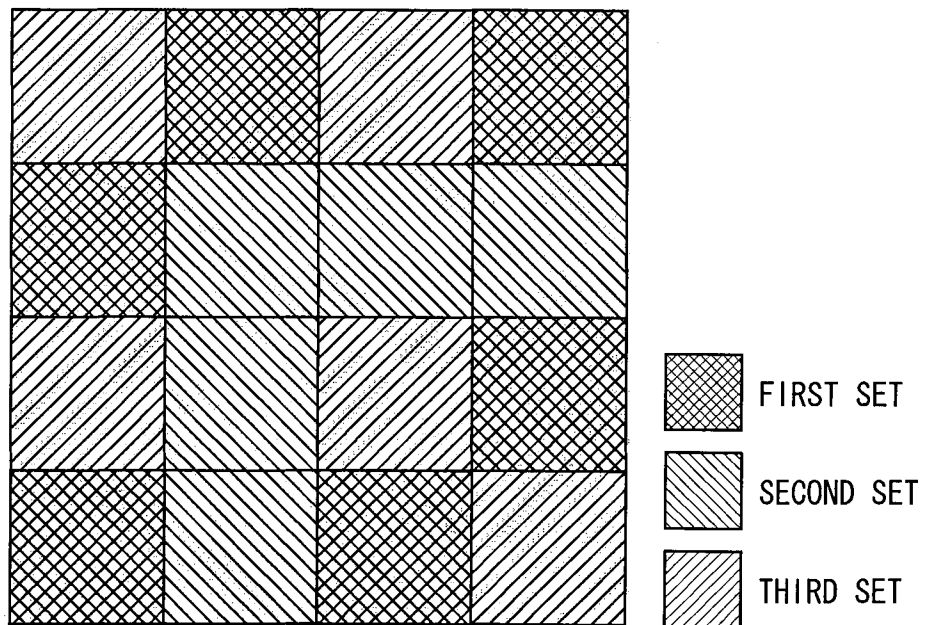
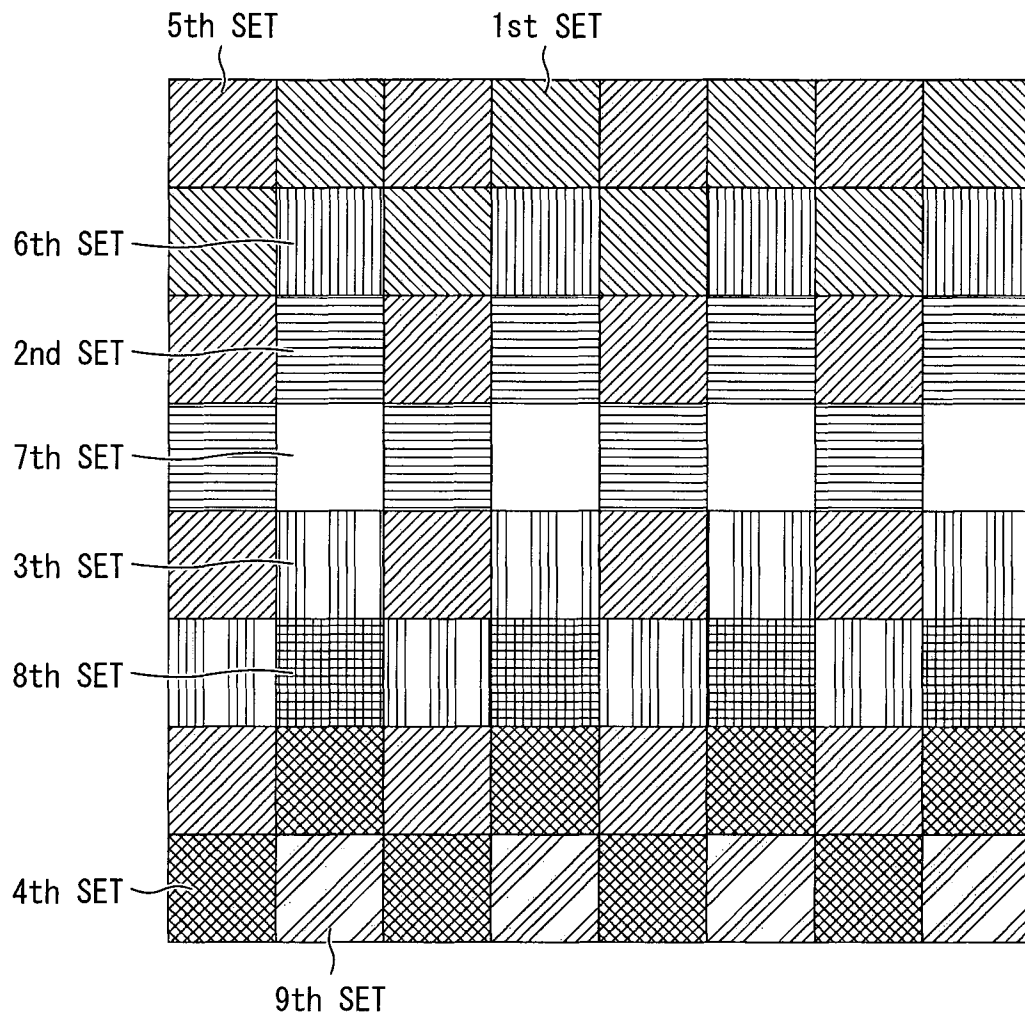


FIG. 6B



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FIG. 7



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FIG. 8

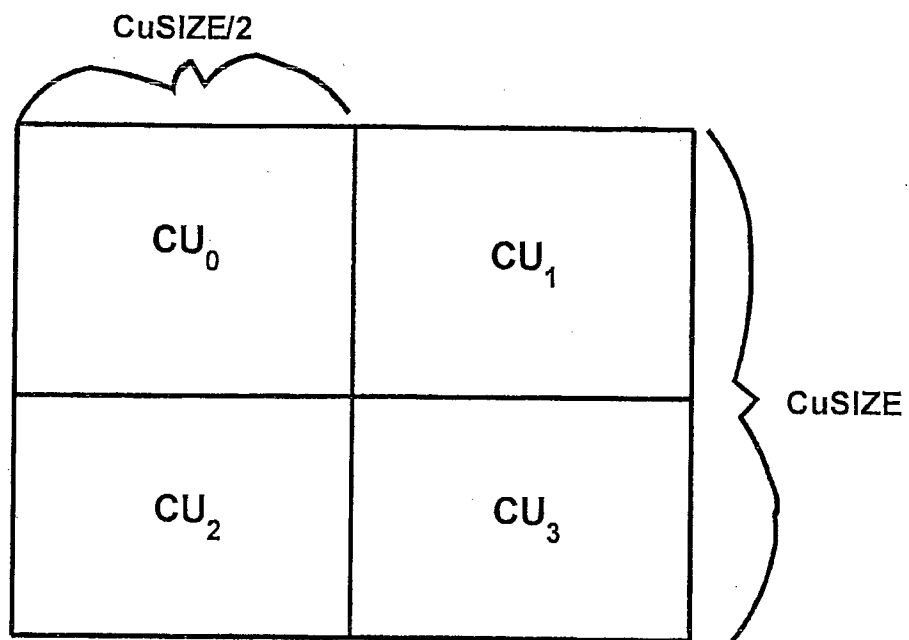
**CODING UNIT SPLIT**

FIG. 9A

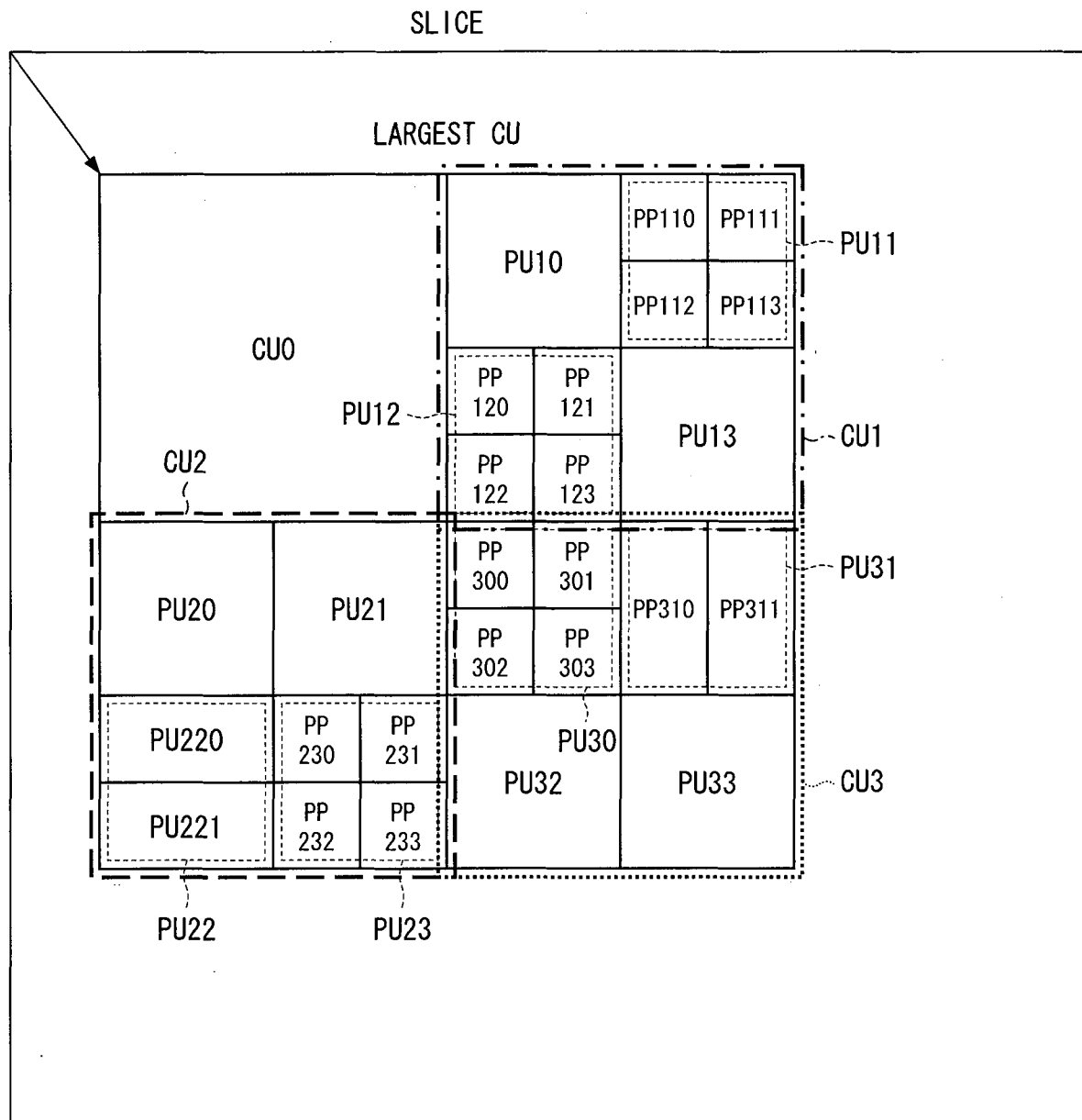
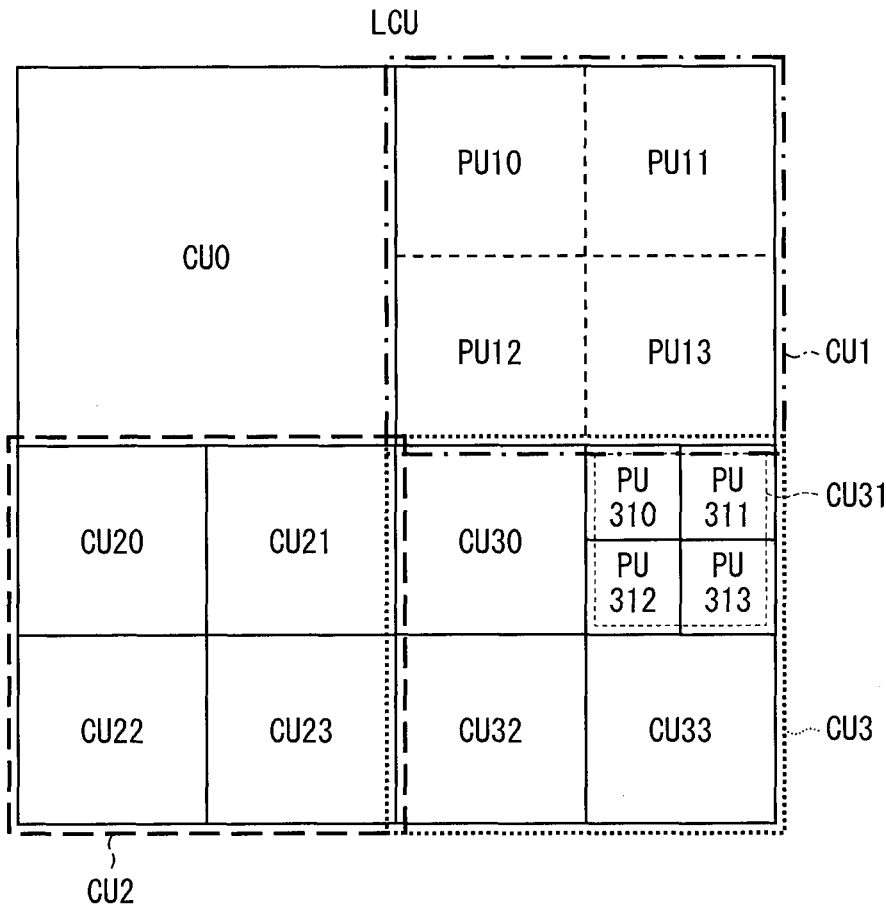


FIG. 9B



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FIG. 10

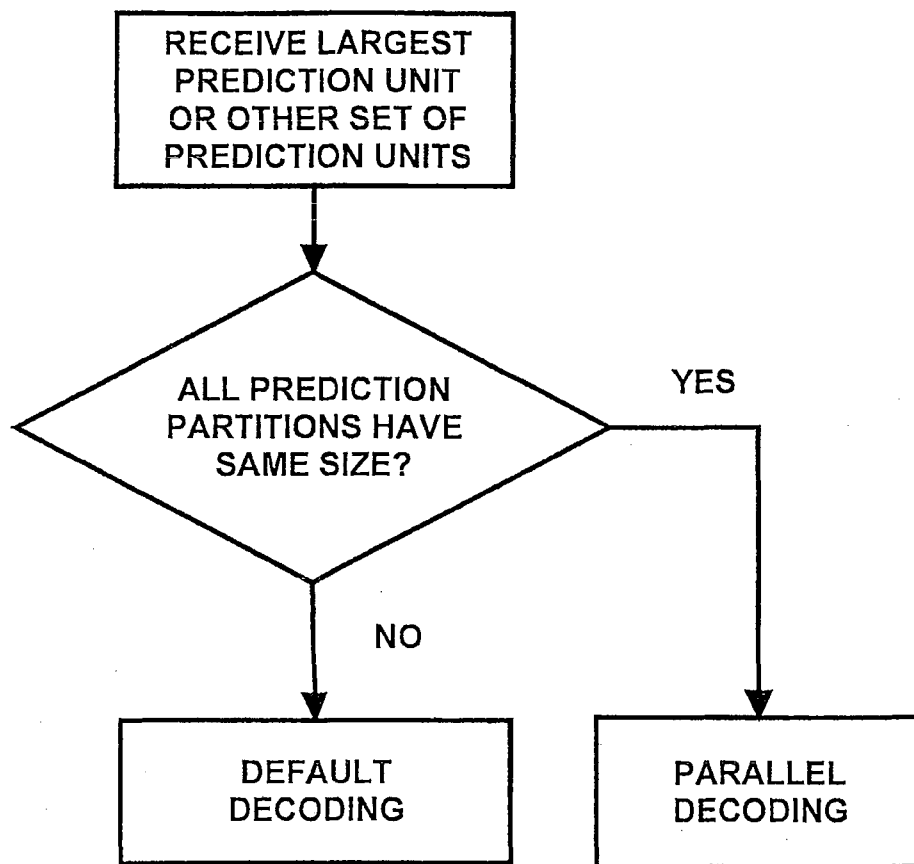
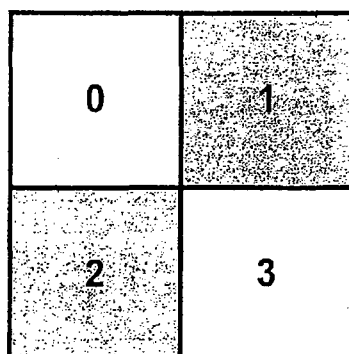
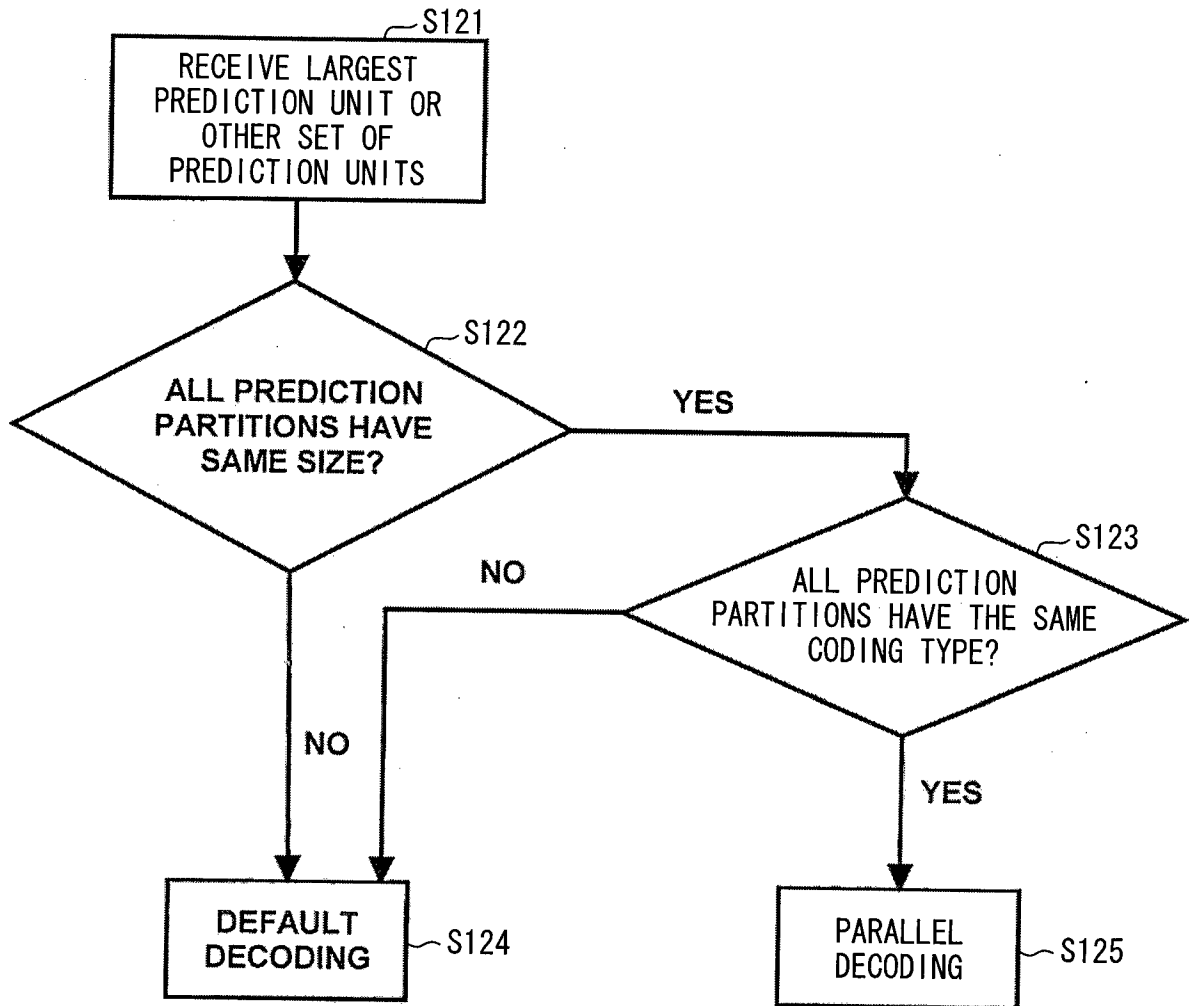


FIG. 11



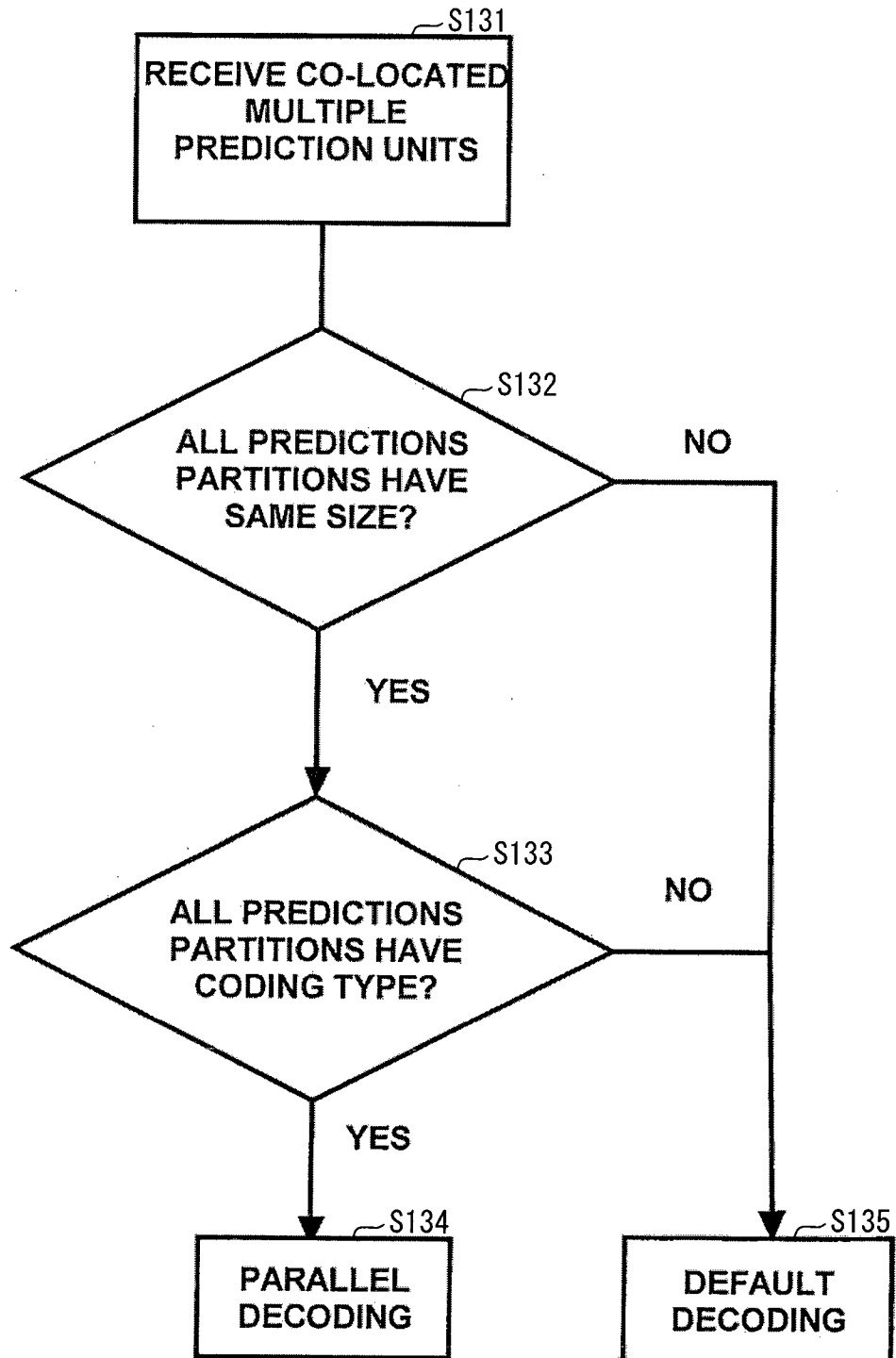
EXAMPLE OF ONE PREDICTION UNIT
WITH INTRA_SPLIT_FLAG

FIG. 12



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FIG. 13



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FIG. 14A

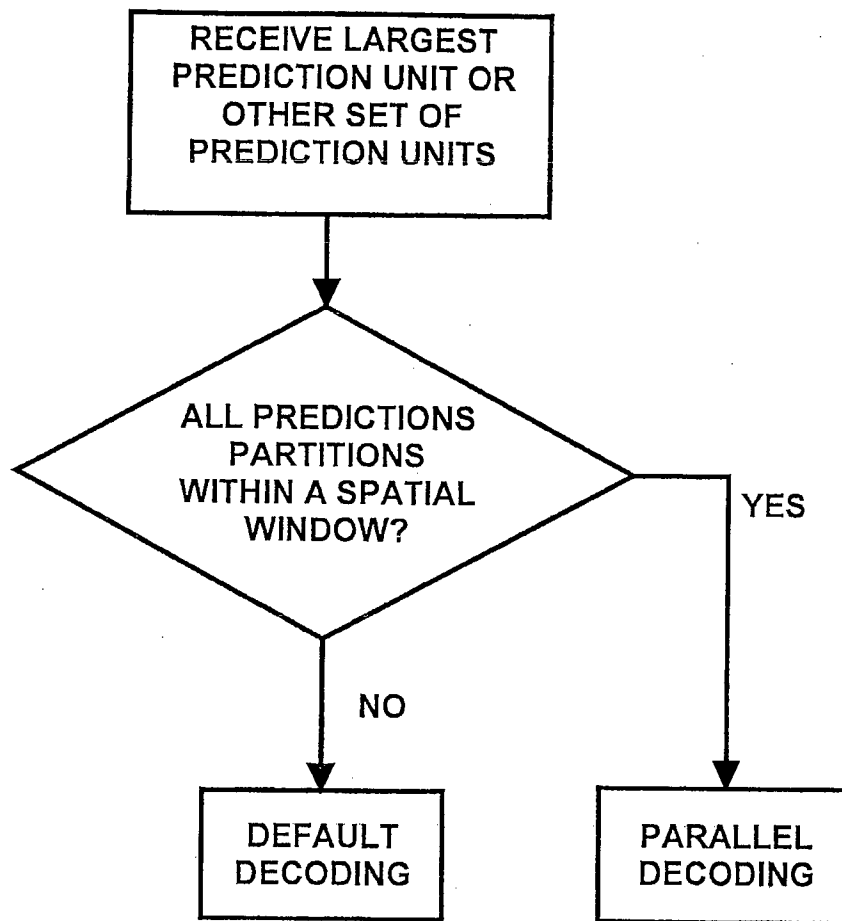
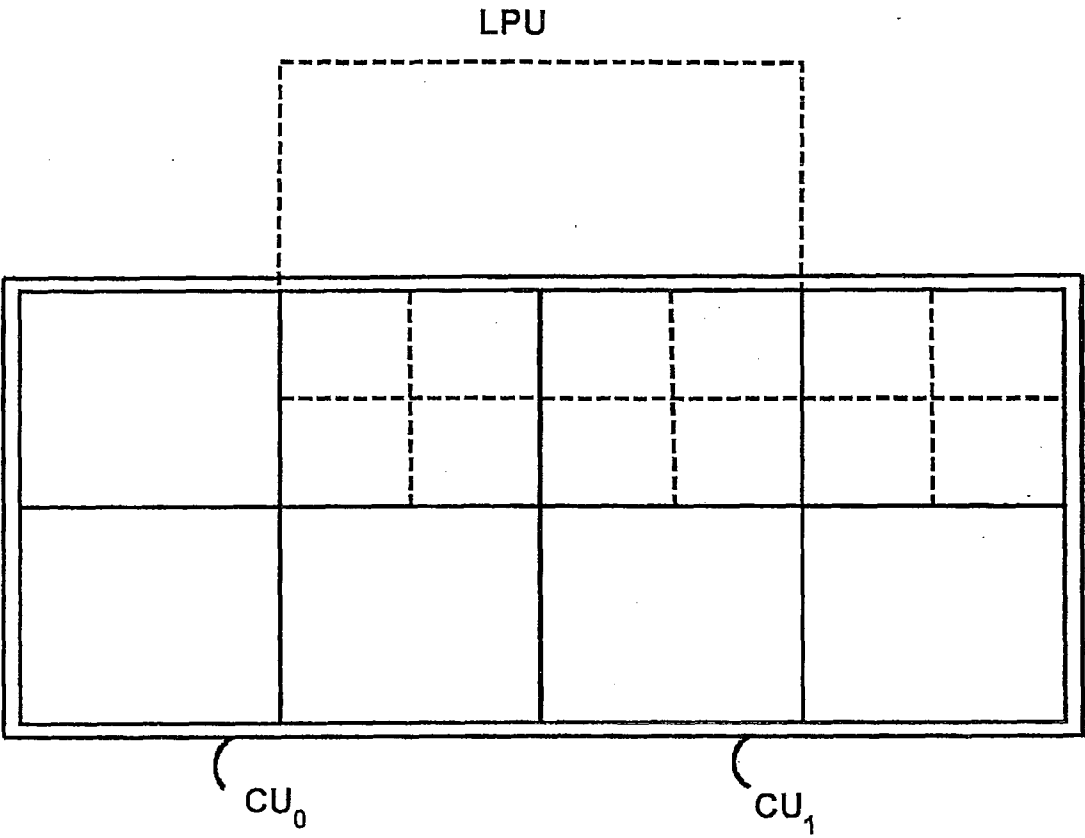
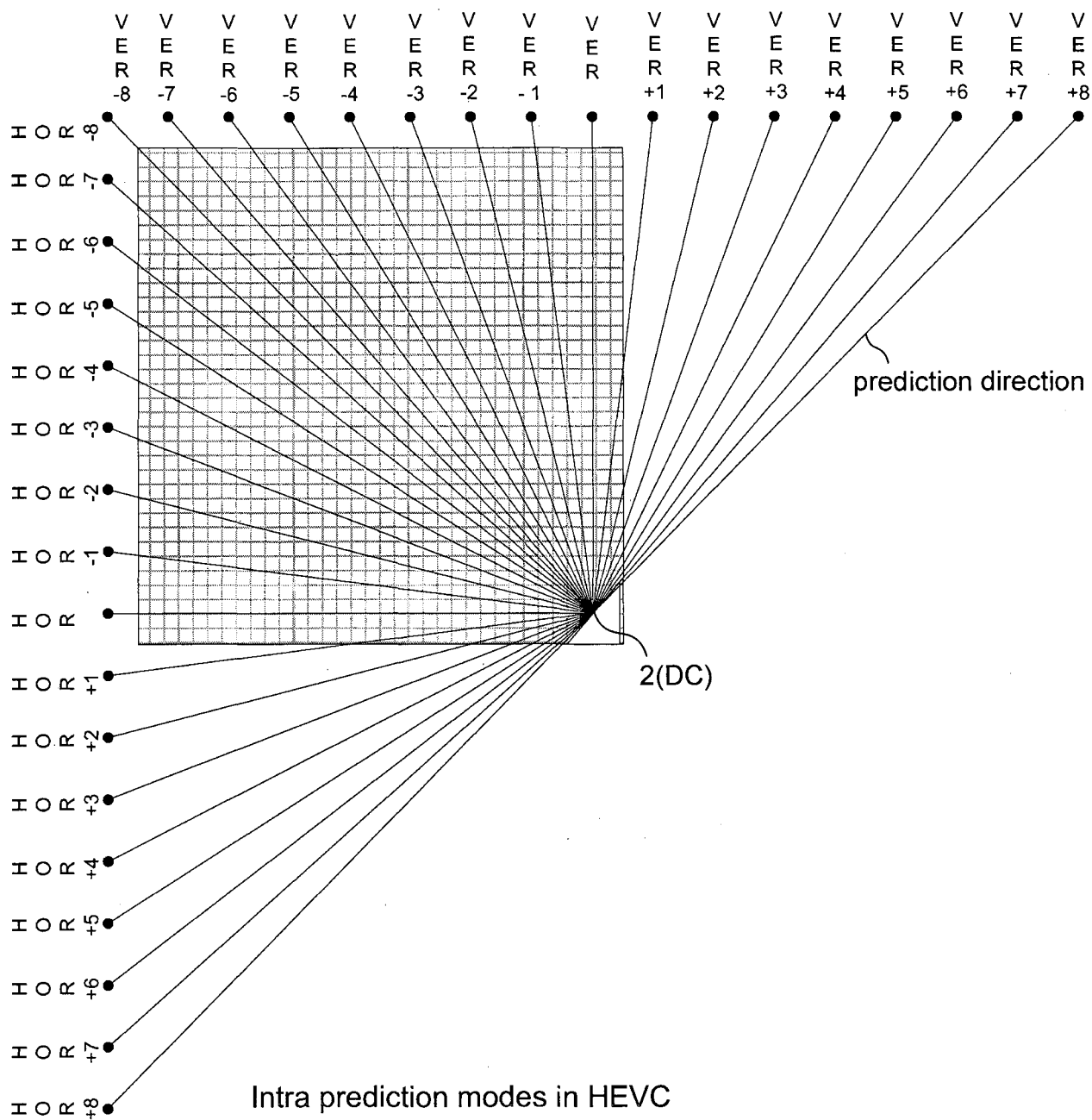


FIG. 14B



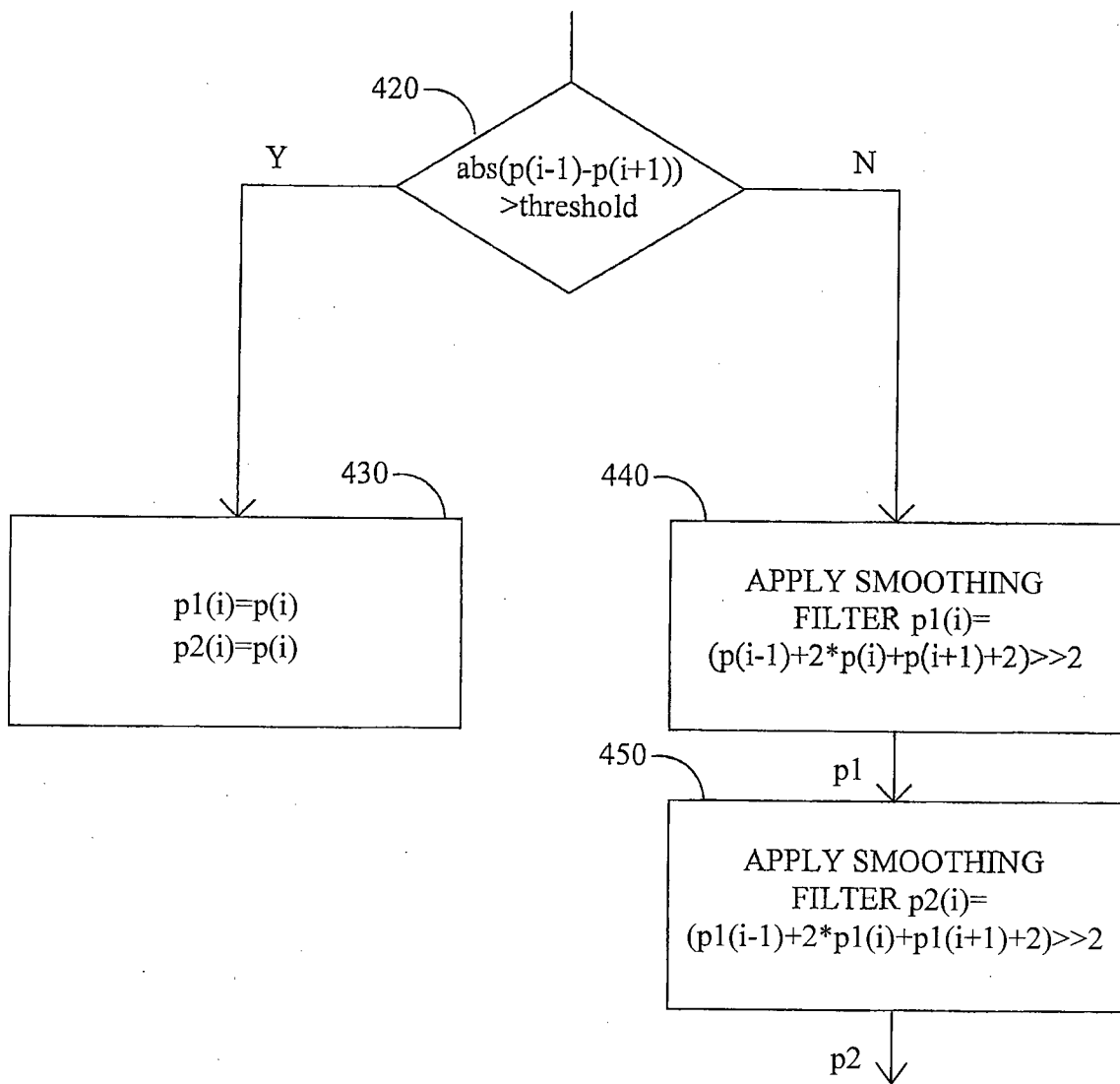
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FIG. 15



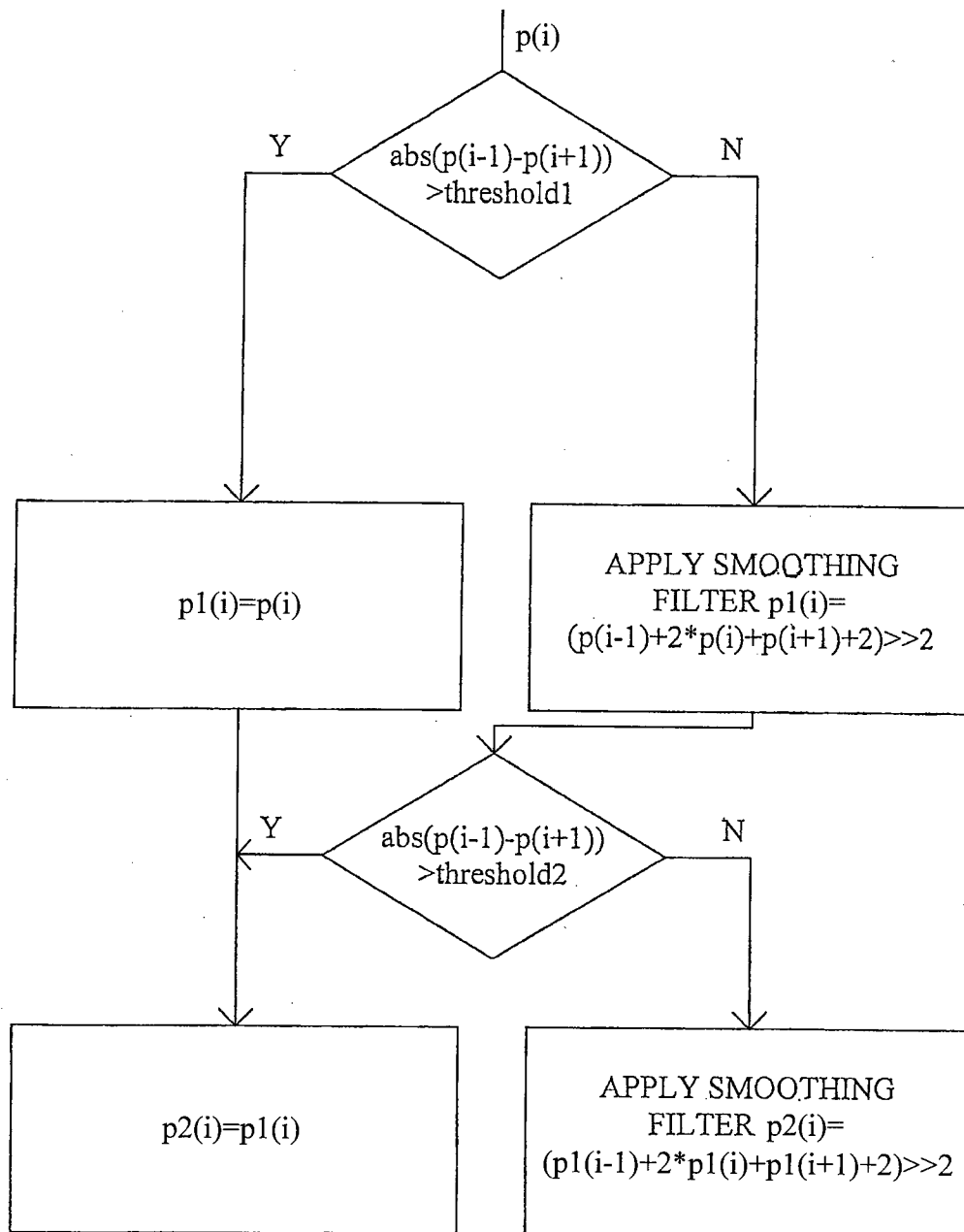
21/25

FIG. 18



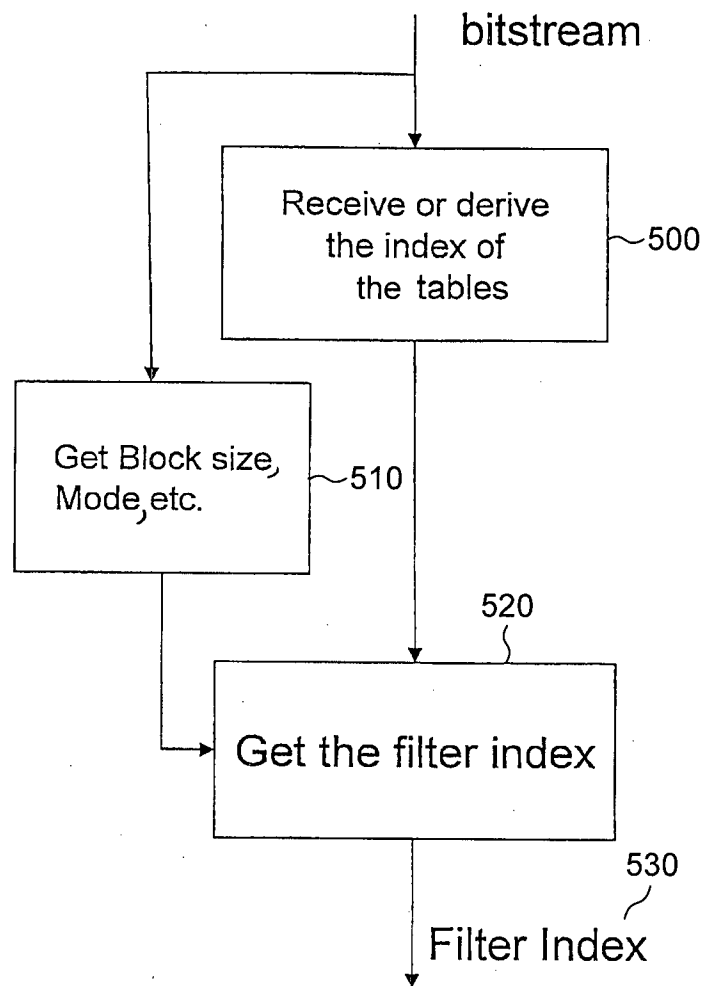
22/25

FIG. 19



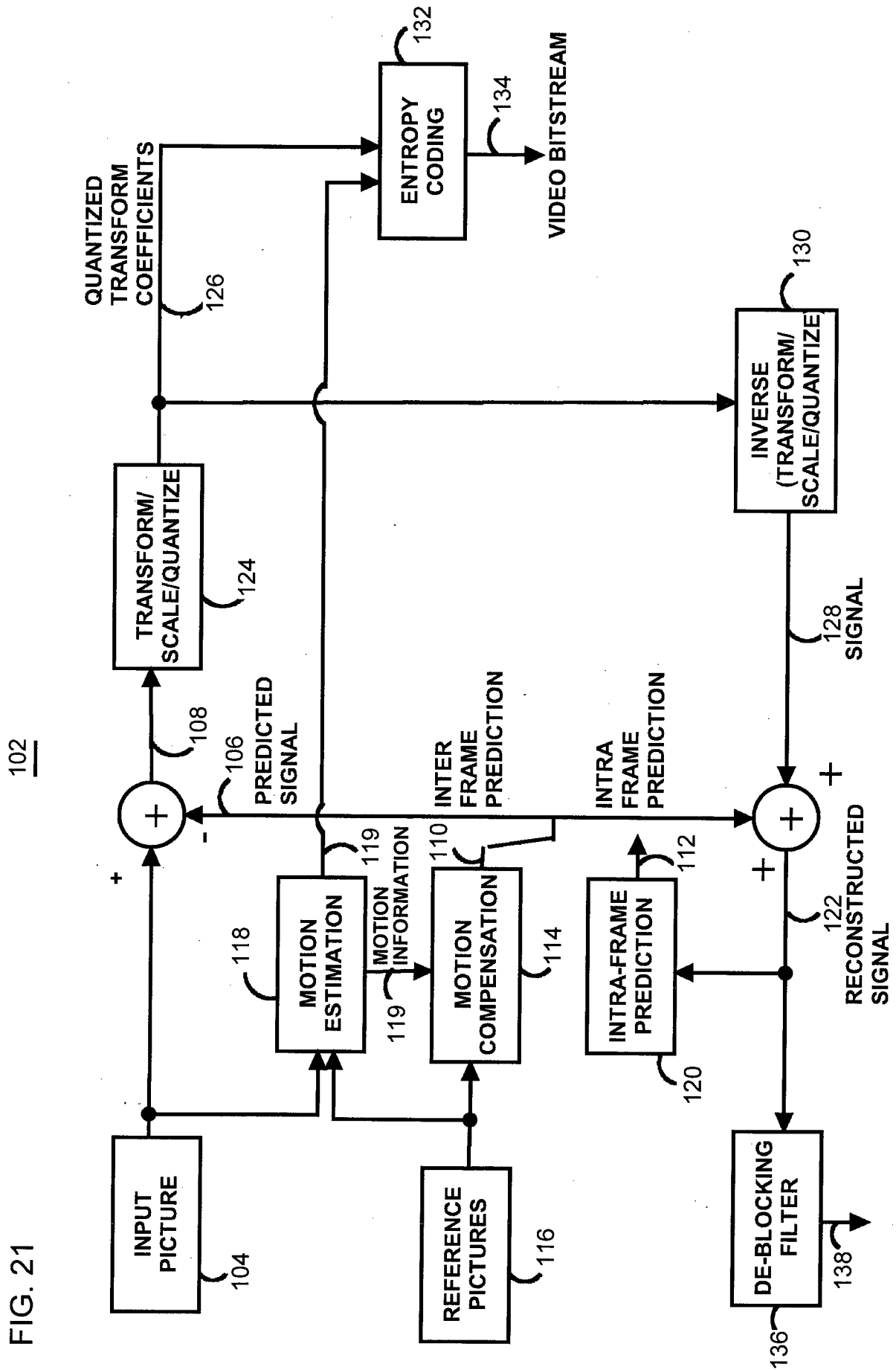
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FIG. 20



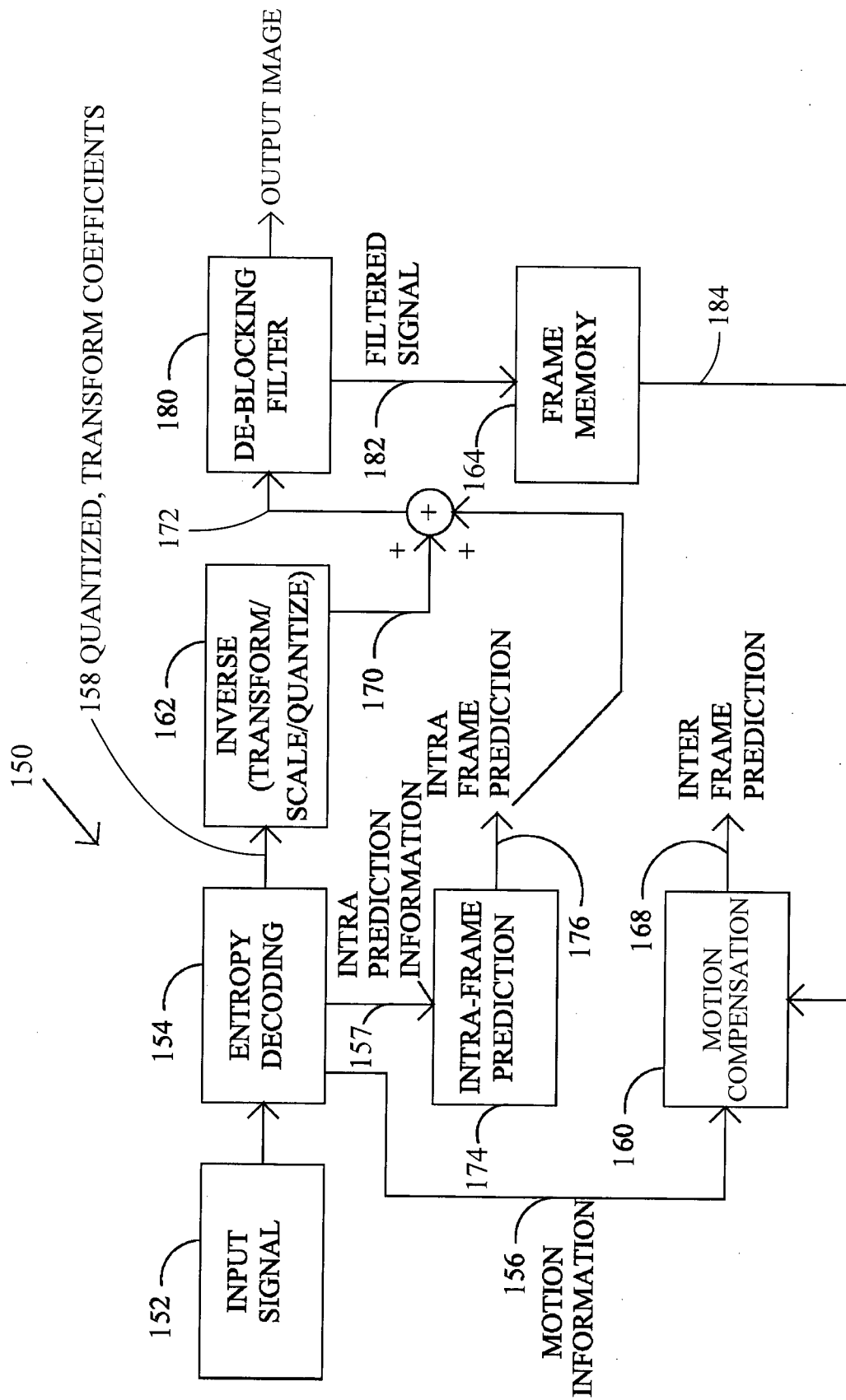
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FIG. 21



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FIG. 22



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2012/057244

A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl. H04N7/32 (2006.01) i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int.Cl. H04N7/24-7/68

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2012
Registered utility model specifications of Japan 1996-2012
Published registered utility model applications of Japan 1994-2012

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	Yunfei Zheng, Muhammed Coban, Marta Karczewicz, "CE13: Mode Dependent Hybrid Intra Smoothing", Joint Collaborative Team on Video Coding (JCT-VC) of ITU-T SG16 WP3 and ISO/IEC JTC1/SC29/WG11 4th Meeting: Daegu, KR, 20-28 January, 2011, [JCTVC-D282]	1-24
Y	JP 8-9370 A (SANYO ELECTRIC CO LTD) 1996.01.12, abstract (Family: none)	1-24
A	JP 9-233369 A (SHARP KABUSHIKI KAISHA) 1997.09.05, whole document (Family: none)	1-24

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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Date of the actual completion of the international search

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