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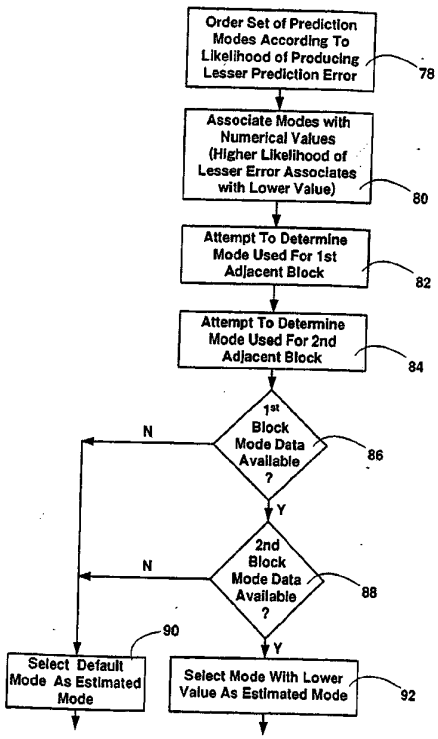
(54) Method and systems for image intra-prediction mode estimation, communication, and organization

(57) Embodiments of the present invention relate to methods and systems for estimating a pixel prediction mode to be used in a video encoding or decoding process, for communicating pixel prediction modes between video encoders and decoders, and for ordering pixel intra-prediction modes.

FIG.12



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Description

RELATED REFERENCES

[0001] This application claims the benefits of U.S. Patent Application Serial Number 60/319,272 filed May 28, 2002 and U.S. Patent Application Serial Number 607319,390 filed July 11, 2002.

BACKGROUND

[0002] Embodiments of the present invention relate to intra-prediction for an image.

[0003] Digital video requires a large amount of data to represent each and every frame of a digital video sequence (e.g., series of frames) in an uncompressed manner. It is not feasible for most applications to transmit uncompressed digital video across computer networks because of bandwidth limitations. In addition, uncompressed digital video requires a large amount of storage space. The digital video is normally encoded in some manner to reduce the storage requirements and reduce the bandwidth requirements.

[0004] - One technique for encoding digital video is interframe encoding. Interframe encoding exploits the fact that different frames of video typically include regions of pixels, normally selected as x by x blocks, that remain substantially the same. During the encoding process a motion vector interrelates the movement of a block of pixels in one frame to a block of similar pixels in another frame. Accordingly, the system is not required to encode the block of pixels twice, but rather encodes the block of pixels once and provides a motion vector to predict the other block of pixels.

[0005] Another technique for encoding digital video is intraframe encoding. Intraframe encoding encodes a frame or a portion thereof without reference to pixels in other frames. Typically intraframe encoding encodes the frame, or portions thereof, on a block by block basis. For example, in MEPG-2 the intraframe encoding makes use of discrete cosine transforms of a block of pixels and subsequent encoding of the transformed coefficients. Other intraframe encoding techniques exist, such as for example, wavelet encoding.

[0006] In general, these techniques employ relatively large data tables for referencing prediction modes. Memory for these data tables can be burdensomely expensive for many low cost machines. Moreover, it is also burdensomely expensive to provide sufficient memory within processing devices to store the data table. Also, the resulting system has increased complexity with the large data table.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] The following drawings depict only typical embodiments of the present invention and are not therefore to be considered to be limiting of its scope, the invention will be described and explained with additional specificity and detail through the use of the accompanying drawings in which:

FIG. 1 illustrates some forms of block adjacency;
FIG. 2 illustrates a block of pixels and the adjacent pixels for prediction;
FIG. 3 illustrates general prediction mode directions;
FIG. 4 illustrates the general directions of prediction modes in an embodiment of the present invention;
FIG. 5 illustrates the general directions of prediction modes in an embodiment of the present invention;
FIG. 6 illustrates the general directions of prediction modes in an embodiment of the present invention;
FIG. 7 illustrates the general directions of prediction modes in an embodiment of the present invention;
FIG. 8 illustrates the general directions of prediction modes in an embodiment of the present invention;
FIG. 9 is a block diagram illustrating mode estimation in some embodiments of the present invention;
FIG. 10 is a block diagram illustrating mode estimation in embodiments with an ordered set of prediction modes;
FIG. 11 is a block diagram illustrating mode estimation with ordered sets associated with numerical values;
FIG 12 is a block diagram illustrating mode estimation options when some adjacent block data is unavailable;
- FIG. 13 is a block diagram illustrating mode order modification in some embodiments of the present invention;
FIG. 14 is a block diagram illustrating the methods of an embodiment of the present invention in which an estimated mode is used to modify mode order usage; and
FIG. 15 is a block diagram illustrating the method of an embodiment of the present invention in which an estimate mode is used to modify mode order using specific designators.

DETAILED DESCRIPTION

[0008] Embodiments of the present invention comprise methods and systems related to intra-prediction of images. As all embodiments are related to intra-prediction, the terms "intra-prediction" and "prediction" may be used interchangeably to refer to intra-prediction processes.

[0009] Embodiments of the present invention use intraframe coding or intracoding to exploit spatial redundancies within a video image. Because adjacent blocks generally have similar attributes, the efficiency of the coding process is improved by referencing the spatial correlation between adjacent blocks. This correlation may be exploited by prediction of a target block based on prediction modes used in adjacent blocks.

[0010] A digital image may be divided into blocks for more efficient processing or for other reasons. As illus-

trated in Figure 1, a target block "C" 12 may be situated adjacent to adjacent block "A" 14 which is located immediately above target block "C" 12. Another adjacent block "B" 16 is located immediately to the left of target block "C" 12. Other blocks that share boundaries with target block "C" 12 may also be considered to be adjacent blocks to block "C" 12.

[0011] Blocks may comprise various numbers of pixels in different configurations. For example, a block may comprise a 4x4 array of pixels. A block may also comprise a 16x16 array of pixels or an 8x8 array. Other pixel configurations, including both square and rectangular arrays may also make up a block.

[0012] Each pixel in a target block may be predicted with reference to data regarding pixels in adjacent blocks. This adjacent pixel data or adjacent block data comprises the prediction modes used to predict those adjacent blocks or adjacent pixels. Specific adjacent pixels and pixels within a target block may be referenced using an alphanumeric index as illustrated in Figure 2. Figure 2 illustrates a 4x4 target block, such as block "C" 12 comprising 16 pixels designated by lower case alphabetic characters 22. Pixels in an adjacent block immediately above the target block are designated by capital alphabetic characters 24. Pixels in an adjacent block immediately to the left of the target block are designated by capital alphabetical characters 26.

[0013] Prediction modes may comprise instructions or algorithms for predicting specific pixels in a target block. These modes may refer to one or more adjacent block pixels as described in the following mode descriptions.

Prediction Modes

[0014]

Mode 0: vertical prediction

a, e, i, m may be predicted by A
b, f, j, n, may be predicted by B,
c, g, k, o, may be predicted by C
d, j, l, p may be predicted by D

Mode 1: horizontal prediction

a, b, c, d, may be predicted by I
e, f, g, h, may be predicted by J
i, j, k, l, may be predicted by K
m, n, o, p, may be predicted by L

Mode 2: DC prediction

If all samples A, B, C, D, I, J, K, L, are available, all samples may be predicted by (A+B+C+D+I+J+K+L+4)>>3. If A, B, C, and D are not available and I, J, K, and Lare available, all samples may be predicted by (I+J+K+L+2)>>2. If I, J, K, and L are not available and A, B, C, and D are available, all samples may be predicted by (A+B+C+D+2)>>2. If all eight samples are not available, the prediction for all luma samples in the block may be 128. A block may be always predicted in this mode.

Mode 3: diagonal down/left prediction

a may be predicted by (A+2B+C+I+2J+K+4)>>3
b, e may be predicted by (B+2C+D+J+2K+L+4)>>3
c, f, i may be predicted by (C+2D+E+K+2L+M+4)>>3
d, g, j, m may be predicted by (D+2E+F+L+2M+N+4)>>3
h, k, n may be predicted by (E+2F+G+M+2N+O+4)>>3
l, o may be predicted by (F+2G+H+N+2O+P+4)>>3
p may be predicted by (G+H+O+P+2)>>2

Mode 4: diagonal down/right prediction

m may be predicted by (J+2K+L+2)>>2
i, n may be predicted by (I+2J+K+2)>>2
e, j, o may be predicted by (Q+2I+J+2)>>2
a, f, k, p may be predicted by (A+2Q+I+2)>>2
b, g, 1 may be predicted by (Q+2A+B+2)>>2
c, h may be predicted by (A+2B+C+2)>>2
d may be predicted by (B+2C+D+2)>>2

Mode 5: vertical-right prediction

a, j may be predicted by (Q+A+1)>>1
b, k may be predicted by (A+B+1)>>1
c, l may be predicted by (B+C+1)>>1
d may be predicted by (C+D+1)>>1
e, n may be predicted by (I+2Q+A+2)>>2
f, o may be predicted by (Q+2A+B+2)>>2
g, p may be predicted by (A+2B+C+2)>>2
h may be predicted by (B+2C+D+2)>>2
i may be predicted by (Q+2I+J+2)>>2
m may be predicted by (I+2J+K+2)>>2

Mode 6: horizontal-down prediction

a, g may be predicted by (Q+I+1)>>1
b, h may be predicted by (I+2Q+A+2)>>2
c may be predicted by (Q+2A+B+2)>>2
d may be predicted by (A+2B+C+2)>>2
e, k may be predicted by (I+J+1)>>1
f, l may be predicted by (Q+2I+J+2)>>2
i, o may be predicted by (J+K+1)>>1
j, p may be predicted by (I+2J+K+2)>>2
m may be predicted by (K+L+1)>>1

n may be predicted by (J+2K+L+2)>>2

Mode 7: vertical-left prediction

a may be predicted by (2A+2B+J+2K+L+4)>>3
b, i may be predicted by (B+C+1)>>1
c, j may be predicted by (C+D+1)>>1
d, k may be predicted by (D+E+1)>>1
l may be predicted by (E+F+1)>>1
e may be predicted by (A+2B+C+K+2L+M+4)>>3
f, m may be predicted by (B+2C+D+2)>>2
g, n may be predicted by (C+2D+E+2)>>2
h, o may be predicted by (D+2E+F+2)>>2
p may be predicted by (E+2F+G+2)>>2

Mode 8: horizontal-up prediction

a may be predicted by (B+2C+D+2I+2J+4)>>3
b may be predicted by (C+2D+E+I+2J+K+4)>>3
c, e may be predicted by (J+K+1)>>1
d, f may be predicted by (J+2K+L+2)>>2
g, i may be predicted by (K+L+1)>>1
h, j may be predicted by (K+2L+M+2)>>2
l, n may be predicted by (L+2M+N+2)>>2
k, m may be predicted by (L+M+1)>>1
o may be predicted by (M+N+1)>>1
p may be predicted by (M+2N+O+2)>>2

[0015] The ordering process, which is based upon the likelihood of producing a lesser prediction error for each of the modes, increases the coding efficiently, reduces the memory requirements, and may be at least partially mathematically defined.

[0016] Each prediction mode may be described by a general direction of prediction as described verbally in each of the mode titles above (i.e., horizontal up, vertical and diagonal down left). A prediction mode may also be described graphically by an angular direction. This angular direction may be expressed through a diagram with arrows radiating outward from a center point as shown in Figure 3. In this type of diagram, each arrow and the center point may represent a prediction mode. The angle corresponding to a prediction mode has a general relationship to the direction from the weighted average location of the adjacent pixels used to predict the target pixel to the actual target pixel location. However, the modes are more precisely defined in the definitions above and in the JVT standard. In Figure 3, the center point 32 represents no direction so this point may be associated with a DC prediction mode. A horizontal arrow 34 may represent a horizontal prediction mode. A vertical arrow 36 may represent a vertical prediction mode. An arrow extending from the center point diagonally downward to the right at approximately a 45 degree angle from horizontal 38 may represent a Diagonal Down/Right (DDR) prediction mode. An arrow extending from the center point diagonally downward to the left at approximately a 45 degree angle from horizontal 40 may represent a Diagonal Down/Left (DDL) prediction mode. Both the DDR and DDL prediction modes may be referred to as diagonal prediction modes.

[0017] An arrow extending from the center point diagonally upward to the right at approximately a 22.5 degree angle from horizontal 42 may represent a Horizontal Up (HU) prediction mode. An arrow extending from the center point diagonally downward to the right at approximately a 22.5 degree angle from horizontal 44 may represent a Horizontal Down (HD) prediction mode. An arrow extending from the center point diagonally downward to the right at approximately a 67.5 degree angle from horizontal 46 may represent a Vertical Right (VR) prediction mode. An arrow extending from the center point diagonally downward to the left at approximately a 67.5 degree angle from horizontal 48 may represent a Vertical Left (VL) prediction mode. The HU, HD, VR and VL prediction modes may be referred to collectively as intermediate angle prediction modes.

[0018] Many other prediction modes may be created and described using this angular description scheme.

Prediction Mode Order

[0019] The present inventors have determined that prediction modes may be ordered in a manner generally consistent with their likelihood of producing a reduced prediction error. With the prediction modes ordered according to their general likelihood of producing a lesser prediction error, the resulting data itself may have a greater tendency to be more consistently ordered. Furthermore, communication of modes may take advantage of coding techniques that reduce memory and bandwidth requirements. For example, the present inventors determined that the horizontal prediction mode and the vertical prediction mode are generally more likely than diagonal prediction modes, which are generally more likely than intermediate angle prediction modes. In addition, a DC prediction mode (e.g., when an adjacent block is coded in inter mode) is generally less likely than horizontal and vertical prediction modes and generally more likely than diagonal prediction modes.

[0020] For blocks that do not border discontinuities such as image edges or swipe/swath boundaries, the order established in some embodiments of the present invention may be expressed, in general terms, as follows: vertical and horizontal prediction modes are more likely to produce a reduced prediction error than a DC prediction mode and that a DC prediction mode is more likely to produce a reduced prediction error than diagonal prediction modes and that diagonal prediction modes are more likely to produce a reduced prediction error than

intermediate angle prediction modes.

[0021] For blocks near edges or boundaries or where adjacent block or pixel prediction mode data is not available, the order established in some embodiments of the present invention may be expressed, in general terms, as follows: DC prediction mode is more likely to produce a reduced prediction error than vertical and horizontal prediction modes and vertical and horizontal prediction modes are more likely to produce a reduced prediction error than diagonal prediction modes and that diagonal prediction modes are more likely to produce a reduced prediction error than intermediate angle prediction modes.

[0022] In a first set of embodiments as illustrated in Figure 4, modes may be defined in order as follows:

Mode 0: Vertical prediction
Mode 1: Horizontal prediction
Mode 2: DC prediction
Mode 3: Diagonal Down/Left prediction
Mode 4: Diagonal Down/Right prediction
Mode 5: Horizontal Down prediction
Mode 6: Vertical Right prediction
Mode 7: Vertical Left prediction
Mode 8: Horizontal Up prediction

[0023] In a second set of embodiments, as illustrated in Figure 5, modes may be defined in order as follows:

Mode 0: Horizontal prediction
Mode 1: Vertical prediction
Mode 2: DC prediction
Mode 3: Diagonal Down/Left prediction
Mode 4: Diagonal Down/Right prediction
Mode 5: Horizontal Down prediction
Mode 6: Vertical Right prediction
Mode 7: Vertical Left prediction
Mode 8: Horizontal Up prediction

[0024] In a third set of embodiments, as illustrate in Figure 6, modes may be defined in order as follows:

Mode 0: Vertical prediction
Mode 1: Horizontal prediction
Mode 2: DC prediction
Mode 3: Diagonal Down/Left prediction
Mode 4: Diagonal Down/Right prediction
Mode 5: Vertical Right prediction
Mode 6: Horizontal Down prediction
Mode 7: Vertical Left prediction
Mode 8: Horizontal Up prediction

[0025] In a fourth set of embodiments, as illustrated in Figure 7, modes may be defined in order as follows:

Mode 0: Horizontal prediction
Mode 1: Vertical prediction
Mode 2: DC prediction
Mode 3: Diagonal Down/Left prediction
Mode 4: Diagonal Down/Right prediction
Mode 5: Vertical Right prediction
Mode 6: Horizontal Down prediction
Mode 7: Vertical Left prediction
Mode 8: Horizontal Up prediction

[0026] In a fifth set of embodiments, as illustrated in Figure 8, modes may be defined in order as follows:

Mode 0: DC prediction
Mode 1: Vertical prediction
Mode 2: Horizontal prediction
Mode 3: Diagonal Down/Left prediction
Mode 4: Diagonal Down/Right prediction
Mode 5: Vertical Right prediction
Mode 6: Horizontal Down prediction
Mode 7: Vertical Left prediction
Mode 8: Horizontal Up prediction

[0027] It should be noted that the mode order may vary beyond these exemplary orders in various other embodiments of the present invention.

[0028] In some embodiments of the present invention, the horizontal prediction (mode 0) and the vertical prediction (mode 1) may be reversed, if desired. Also, it is to be understood that the diagonal down/left prediction mode and the horizontal down prediction mode may be reversed, if desired. In addition, it is to be understood the diagonal down/right prediction (mode 5), the vertical right prediction (mode 6), the vertical left prediction (mode 7), and the horizontal up prediction (mode 8) may be reordered, if desired. Further, it is desirable that the DC prediction is between the mode 0/mode 1 set and the mode 3/mode 4 set, but may be located between mode 3/mode 4 set and mode 5/mode 6/mode 7/mode 8 set, if desired, or any other location. Moreover, the angled modes 3-8 may be renumbered as desired without significant impact on the encoding efficiency.

[0029] In some embodiments of the present invention, the prediction modes may be reordered for all of the respective blocks (e.g., those blocks using the described prediction scheme) using such a prediction basis. In addition, less than all of the respective blocks (e.g., those blocks using the described prediction scheme) may use such a prediction basis, for example, more than 50%, 75% or 90%, if desired. Also, the order of the prediction modes may be the same or varied for different blocks. Further, the reordering of each of the modes of such a prediction basis (e.g., in a predetermined consistent manner) is preferably at least 5 modes, 6 modes, or 7 modes, with the remaining being ordered in any other manner. In addition, the order of the prediction modes is preferably 0, 1, 2, 3, 4, 5, 6, 7, 8. Other predefined ordering of the prediction modes may likewise be employed.

[0030] Some embodiments of the present invention may comprise one or more data tables for organization

of mode data. With the modes being generally arranged in an ordered manner, this may be used together with each cell in a data table, to provide a more ordered set. For example, each entry in the data table may include the ordered set of numbers 0,1,2, 3, 4, 5, 6, 7,8, and 9. Alternatively, the ordered set of numbers in the data table may include 5, 6, 7, 8, or 9 sets of ordered numbers for each entry in the data table. For example, the data table entries may include the following sets of data entries {1, 2, 3, 5, 7}; {0, 1, 2, 3, 4, 5, 6}; {0, 1, 3, 5, 6, 7, 8}, where each of the numbers in the set are of increasing numerical value. Alternatively for example, the data table entries may include the following sets of data entries {1, 2, 3, 5, 7}; {0, 1, 2, 3, 4, 5, 6}; {0, 1, 3, 5,6, 7, 8}, where each set is included in at least 25%, or 35%, or 50%, or 75%, or 90%, or more, of the cells. In this manner, the table will have significantly more predictability than known data table methods, which decreases memory requirements.

[0031] The predetermined manner of the ordering of the sets of data entries should be independent of the prediction modes of adjoining sets of pixels (e.g. macroblocks). It is to be understood that the data table may be "static" in nature or may be effectively dynamically generated, in whole or in part, when needed based upon patterns in the data. Accordingly, a mathematical equation or an algorithm may be used to determine the entries, which in this case the "table" could be created by such a technique. Accordingly, a "data table" as used herein is not merely restricted to a static table, but further includes such a set of values, however determined, that are used for such prediction.

[0032] Unfortunately, the substitution of the previous mode numbers with the new mode numbers (e.g., a substitution of numbers into the cells of known data tables), while perhaps an improvement, still results in a generally unordered set of data.

Estimating a Pixel Prediction Mode Based on Adjacent Block Data

[0033] In contrast to the generally unordered set of data shown, even with substitutions, the present inventors came to the further realization that the most likely prediction mode should be ordered first, the second most likely prediction mode ordered second, if desired, followed by the remaining modes in a predetermined manner. The predetermined manner should be independent of the prediction modes of adjoining macroblocks. The preferred order of the remaining modes should be in a decreasing likelihood of occurrence of the remaining modes (most likely prediction mode, and if desired, second most likely prediction mode).

[0034] Based on the intra prediction modes of block A and block B, as shown in Figure 1, the intra prediction mode order for block C may be defined as follows:

(1) If both block A and block B are "outside" (e.g., not available), only DC prediction (mode 2) is permitted, therefore the intra prediction mode order for-block C is {2}.

(2) If block A is "outside" (e.g., not available) and block B is not "outside", only DC prediction (mode 2) and horizontal prediction (mode 0) are permitted for block C, therefore;

(i) if block B is 2, intra prediction mode order for block C is {2, 0};
(ii) otherwise, intra prediction mode order for block C is {0, 2}.

(3) If block A is not "outside" but block B is "outside", only DC prediction (mode 2) and vertical prediction (mode 1) are permitted for block C, therefore

(i) if block A is 2, intra prediction mode order for block C is {2, 1};
(ii) otherwise, intra prediction mode order for block C is {1, 2}.

(4) If neither block A nor block B is "outside",

(i) if the prediction mode of block A is less than the prediction mode of block B, then intra prediction mode order for block C is {intra prediction block mode A, intra prediction block mode B, other modes in ascending order};
(ii) if the prediction mode of block A is greater than the prediction mode of block B, then intra prediction mode order for block C is {intra prediction block mode B, intra prediction block mode A, other modes in ascending order};
(iii) if the prediction mode of block A equals the prediction mode of block B, then intra prediction mode order for block C is {intra prediction block mode A, other modes in ascending order}.

[0035] For example, if the prediction mode of block A is 3 and the prediction mode of block B is 1, then intra prediction mode order for block C is {1, 3, 0, 2, 4, 5, 6, 7, 8}. With the modes arranged in a generally decreasing likelihood (or increasing) of occurrence, then the automatic arrangement of the remaining modes of occurrence will still be generally arranged in the proper sequence. The ordering of the sequence from higher to lower probability increases the likelihood of the proper prediction toward the front. With entropy encoding this decreases the resulting encoded bit stream. Other arrangements may likewise be used.

[0036] Conceptually the aforementioned selection scheme is based upon the principle that if the prediction of block A is X and the prediction of block B is Y, then it is likely the prediction of block C is X or Y. The prediction for X and/or Y is located at the start of the list and the remaining modes are sequentially listed thereafter.

[0037] Stated another way, when the prediction modes of A and B are known (including the case that A or B or

both are outside the slice) the most probable mode of C is given, namely, the minimum of the modes used for blocks A and B. If one of the blocks A or B is "outside" the most probable mode is equal to prediction mode 2. The ordering of prediction modes assigned to blocks C is therefore the most probable mode followed by the remaining modes in the ascending order.

[0038] Embodiments of the present invention may be described with reference to Figure 9. In these embodiments, a target block is selected 50 for prediction. A prediction mode used for prediction of a first adjacent block, which is immediately adjacent to said target block, is then determined 52. A prediction mode used for prediction of a second adjacent block, which is also adjacent to said target block is also determined 54. These adjacent block prediction modes are then examined 56 to determine which is more likely to produce a lesser prediction error. -

[0039] In other embodiments of the present invention, as illustrated in Figure 10, a set of prediction modes is ordered 58 according to the modes' likelihood of producing a lesser prediction error. A target block is selected 60. The prediction mode used for a first adjacent block is determined 62 and the prediction mode used for a second adjacent block is also determined 64. These two prediction modes are then examined 66 to determine which occurs first in the ordered set of modes thereby corresponding to the mode with the higher likelihood of producing a lesser prediction error.

[0040] In further embodiments of the present invention, as illustrated in Figure 11, a set of prediction modes is ordered 68 by likelihood of producing a lesser prediction error. These modes in the ordered set are then associated 70 with numerical values such that modes with a higher likelihood of producing a lesser prediction error are associated with lower numerical values. The mode used to predict a first adjacent block is then determined 72 and the mode used to predict a second adjacent block is also determined 74. These adjacent block modes are then examined to determine which mode is associated with a lower numerical value. This mode is designated as the estimated mode for prediction of the target block.

[0041] In still further embodiments, as illustrated in Figure 12, a set of prediction modes is ordered 78 by likelihood of producing a lesser prediction error. These modes in the ordered set are then associated 80 with numerical values such that modes with a higher likelihood of producing a lesser prediction error are associated with lower numerical values. An attempt 82 is made to determine the mode used to predict a first adjacent block and an attempt 84 is made to determine the mode used to predict a second adjacent block. If the prediction mode used to predict the first adjacent block is not available 86, a default prediction mode, such as a DC prediction mode, may be designated 90 as an estimated prediction mode for the target block. Also, if the prediction mode used to predict the second adjacent block is not available 88, a default prediction mode, such as a DC prediction mode, may be designated 90 as an estimated prediction mode for the target block. When the adjacent block prediction modes are available, these adjacent block modes may be examined to determine which mode is associated with a lower numerical value. This mode is then designated 92 as the estimated mode for prediction of the target block.

Modification of Prediction Mode Order Based on Adjacent Block Data

[0042] In some embodiments of the present invention the prediction mode orders described above, which have been determined independently of the adjacent block data, may be modified with adjacent block data. Prediction mode estimates determined with reference to adjacent block data can be inserted into prediction mode orders to modify the orders to reflect the additional information obtained from adjacent block data.

[0043] In some of these embodiments, a prediction mode estimate, based on adjacent block data, can be inserted directly into a prediction mode order set. Typically, the prediction mode estimate will be inserted or prepended at the front of the prediction mode order at the position of the mode most likely to produce a reduced prediction error. However, in some embodiments the estimate may be inserted at different positions in the mode order.

[0044] In some embodiments of the present invention, as shown in Figure 13, a prediction mode order is selected 102 wherein the prediction mode order elements may be arranged according to their likelihood of producing a lesser prediction error. In other words, the first element in the order represents the prediction mode most likely to yield a lesser prediction error, the next element in the order represents the prediction mode that is the next most likely to yield a lesser prediction error and so on to the last element in the order, which represents the prediction mode in the order that is least likely to yield a lesser prediction error.

[0045] A prediction mode estimate is also determined 104, as described above. This estimate is determined using adjacent block data. Generally, the estimate is the prediction mode used in one or more adjacent blocks that is likely to yield a lesser prediction error. However, the estimate may be determined in other ways. When sufficient adjacent block prediction mode data is not available, such as at an image edge or a slice boundary, a prediction mode for the target block may be estimated based on the lack of one or more adjacent blocks or their prediction mode data. In many cases, a DC prediction mode will be estimated when adjacent block data is limited or unavailable.

[0046] In some embodiments, once the estimated prediction mode is estimated, the estimated prediction mode may be placed 106 into the mode order as the mode most likely to yield a lesser prediction error. In some embodiments, this will be the first mode in the order or the mode associated with the lowest numerical value.

[0047] In other embodiments, the estimated prediction mode may take precedence over the pre-selected mode order. In some of these embodiments, as illustrated in Figure 14, a pre-selected mode order is designated 110 at the encoder and the decoder. This order comprises a set of prediction modes arranged in order of likelihood of yielding a lesser prediction error or some other order. An estimated prediction mode is also determined 112 based on adjacent block data. This estimated prediction mode is determined at the encoder and the decoder according to the same algorithm or method. The encoder also determines the actual best prediction mode 114 for predicting a pixel based on motion vectors or other known techniques. The encoder may, then, compare 116 the actual best prediction mode to the estimated prediction mode to determine whether they are the same. If the estimated prediction mode is the same mode as the actual best prediction mode, the encoder may signal to the decoder that the estimated prediction mode is to be used 118. In some embodiments, this estimated prediction mode signal may be performed with a 1-bit flag to signify whether the estimated mode is to be used on not.

[0048] If the estimated prediction mode is not the actual best prediction mode, the encoder may signal to the decoder that another mode may be used 120. This may be performed by reference to the pre-established mode order. The encoder may determine which mode in the mode order is most equivalent to the actual best prediction mode and signal the decoder to use that mode.

[0049] When an ordered set of prediction modes is used, the set order may be rearranged once further data is obtained. For example, an ordered set of prediction modes may be re-ordered when an estimated prediction mode is determined or when a best actual prediction mode is determined. In these cases, the modifying mode may be interjected into the ordered set, placed ahead of the ordered set or, in some cases, removed from the ordered set.

[0050] In some embodiments of the present invention, each mode in the mode order may be associated with a numerical value according to the order. In these embodiments, the numerical value associated with the mode to be used may be sent to the decoder to signal the decoder to use that prediction mode. In some of these embodiments, as illustrated in Figure 15, a mode order comprising 9 prediction modes may be selected 130. An estimated prediction mode based on adjacent block data, and which is one of the 9 modes in the order, may also be determined 132. A best prediction mode may also be determined 134 by motion vector methods or other methods. The best prediction mode may then be compared to the estimated prediction mode 136. If the estimated prediction mode is substantially the same as the best prediction mode, the decoder may be signaled with a 1-bit designator to use the estimated prediction mode, which is already identified at the decoder. If the estimated prediction mode is not equivalent to the best prediction mode, the estimated prediction mode is essentially eliminated from the mode order 140. This elimination may be performed by re-ordering the set, skipping the estimated mode in the order or by other means. The remaining order will effectively comprise 8 modes, which can be represented by a 3-bit designator. This 3-bit designator may be sent to the decoder 142 to designate which mode to use for prediction.

[0051] The terms and expressions 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 that follow.

[0052] Aspects of the invention are set out below.

[0053] In a first aspect, the invention provides a method for estimating a pixel intra-prediction mode, said method comprising:

a. selecting a target block for prediction mode estimation;
b. determining a first prediction mode that has been used for a first adjacent block, said first adjacent block being adjacent to said target block;
c. determining a second prediction mode that has been used to predict a second adjacent block, said second adjacent block being adjacent to said target block;
d. determining an estimated prediction mode for said target block from among said first prediction mode and said second prediction mode, wherein said estimated prediction mode is the prediction mode that is most likely to yield the least prediction error.

[0054] In a second aspect, the invention provides a method for estimating a pixel intra-prediction mode that is more likely to result in a reduced prediction error, said method comprising:

a. ordering a set of potential prediction modes by associating a numerical value with each prediction mode such that the modes most likely to yield a lower prediction error are associated with the lowest numbers;
b. selecting a target block for prediction mode estimation;
c. receiving a first prediction mode that has been used for a first adjacent block, said first adjacent block being adjacent to said target block;
d. receiving a second prediction mode that has been used to predict a second adjacent block, said second adjacent block being adjacent to said target block;
e. determining a lesser prediction mode among said first prediction mode and said second prediction mode, wherein said lesser prediction mode is the prediction mode associated with the lesser value; and

f. using said lesser prediction mode as an estimated pixel prediction mode.

[0055] In a third aspect, the invention provides a method for estimating a pixel intra-prediction mode that is more likely to result in a reduced prediction error, said method comprising:

a. ordering a set of potential prediction modes by associating a numerical value with each prediction mode such that the modes most likely to yield a lower prediction error are associated with the lowest numbers;
b. selecting a target block for prediction mode estimation;
c. attempting to determine a first prediction mode that has been used for a first adjacent block, said first adjacent block being adjacent to said target block;
d. attempting to determine a second prediction mode that has been used to predict a second adjacent block, said second adjacent block being adjacent to said target block;
e. designating a DC prediction mode as an estimated prediction mode if any of said adjacent prediction modes is unavailable;
f. determining a lesser prediction mode among said first prediction mode and said second prediction mode, wherein said lesser prediction mode is the prediction mode associated with the lesser value; and
g. using said lesser prediction mode as an estimated pixel prediction mode.

[0056] In a fourth aspect, the invention provides an apparatus for estimating a pixel prediction mode, said apparatus comprising:

a. a memory for storing an ordered set of potential prediction modes ordered by their likelihood of yielding a lower prediction error;
b. a selector for selecting a target block for prediction mode estimation;
c. a first determiner for determining a first prediction mode that has been used for a first adjacent block, said first adjacent block being adjacent to said target block;
d. a second determiner for determining a second prediction mode that has been used to predict a second adjacent block, said second adjacent block being adjacent to said target block;
e. an estimator for estimating an estimated prediction mode for said target block from among said first prediction mode and said second prediction mode, wherein said estimated prediction mode is the prediction mode that is most likely to yield the least prediction error as determined by the mode's order in said ordered set.

[0057] In a fifth aspect, the invention provides a computer-readable medium comprising instructions for estimating a pixel prediction mode, said instructions comprising the acts of:

a. selecting a target block for prediction mode estimation;
b. determining a first prediction mode that has been used for a first adjacent block, said first adjacent block being adjacent to said target block;
c. determining a second prediction mode that has been used to predict a second adjacent block, said second adjacent block being adjacent to said target block;
d. determining an estimated prediction mode for said target block from among said first prediction mode and said second prediction mode, wherein said estimated prediction mode is the prediction mode that is most likely to yield the least prediction error.

[0058] In a sixth aspect, the invention provides a computer data signal embodied in an electronic transmission, said signal having the function of estimating a pixel prediction mode, said signal comprising instructions for completing the acts of:

a. selecting a target block for prediction mode estimation;
b. determining a first prediction mode that has been used for a first adjacent block, said first adjacent block being adjacent to said target block;
c. determining a second prediction mode that has been used to predict a second adjacent block, said second adjacent block being adjacent to said target block;
d. determining an estimated prediction mode for said target block from among said first prediction mode and said second prediction mode, wherein said estimated prediction mode is the prediction mode that is most likely to yield the least prediction error.

[0059] In a seventh aspect, the invention provides a method for modifying an ordered set of spatial pixel prediction modes, said method comprising:

a. establishing an ordered set of pixel prediction modes;
b. determining an estimated prediction mode;
c. modifying said ordered set by placing said estimated mode ahead of the order of said ordered set.

[0060] In an eighth aspect, the invention provides a method for communicating a pixel prediction mode to a decoder, said method comprising:

a. establishing a set of pixel prediction modes at an encoder and a decoder;
b. determining an estimated pixel prediction mode

at said encoder and said decoder, said estimated mode being a member of said set;

c. determining a best prediction mode at said encoder, said best prediction mode being a member of said set;

d. comparing said estimated mode to said best mode;

e. transmitting a first instruction, from said encoder to said decoder, to use said estimated mode when said estimated mode is substantially similar to said best mode; and

f. transmitting a second instruction, from said encoder to said decoder, to use another mode in said set other than said estimated mode when said estimated mode is not substantially similar to said best mode.

[0061] In a ninth aspect, the invention provides a method for communicating a pixel prediction mode to a decoder, said method comprising:

a. establishing an order set of pixel prediction modes at an encoder and a decoder wherein said set is ordered by likelihood of producing a lesser prediction error;

b. determining an estimated pixel prediction mode at said encoder and said decoder wherein said estimated mode is determined reference to adjacent block data and said estimated mode is a member of said set;

c. determining a best prediction mode at said encoder, said best mode being a member of said set;

d. comparing said estimated mode to said best mode;

e. transmitting a first instruction, from said encoder to said decoder, to use said estimated mode when said estimated mode is substantially similar to said best mode; and

f. communicating a second instruction, between said encoder and said decoder, to use another mode in said set other than said estimated mode when said estimated mode is not similar to said best mode.

[0062] In a tenth aspect, the invention provides a method for communicating a pixel prediction mode, said method comprising:

a. means for ordering a set of potential prediction modes by associating a numerical value with each prediction mode such that the modes most likely to yield a lower prediction error are associated with the lowest numerical values;

b. means for selecting a target block for prediction mode estimation;

c. means for determining a first prediction mode that has been used for a first adjacent block, said first adjacent block being adjacent to said target block;

d. means for determining a second prediction mode that has been used to predict a second adjacent block, said second adjacent block being adjacent to said target block;

e. means for determining an estimated prediction mode among said first prediction mode and said second prediction mode, wherein said estimated prediction mode is the prediction mode associated with the lesser numerical value;

f. means for determining a best prediction mode;

g. means for instructing a decoder to use said estimated prediction mode when said estimated prediction mode is substantially similar to said best prediction mode; and

h. means for instructing a decoder to use said best prediction mode when said estimated prediction mode is not substantially similar to said best prediction mode.

[0063] In an eleventh aspect, the invention provides an apparatus for communicating a pixel prediction mode to a decoder, said apparatus comprising:

a. an encoder memory for storing a set of pixel prediction modes at an encoder;

b. a decoder memory for storing said set of pixel prediction modes at a decoder;

c. an encoder estimator for determining an estimated pixel prediction mode at said encoder, said estimated mode being a member of said stored set;

d. a decoder estimator for determining said estimated pixel prediction mode at said decoder;

e. a predictor for determining a best prediction mode at said encoder, said best prediction mode being a member of said set;

f. a transmitter for transmitting instructions between an encoder and a decoder;

g. wherein said transmitter transmits a first instruction, from said encoder to said decoder instructing said decoder to use said estimated mode when said estimated mode is substantially similar to said best mode; and

h. wherein said transmitter transmits a second instruction, from said encoder to said decoder, to use said best mode when said estimated mode is not substantially similar to said best mode.

[0064] In a twelfth aspect, the invention provides a computer readable medium comprising instructions for communicating between a video encoder and a decoder, said instructions comprising the acts of:

a. establishing a set of pixel prediction modes at an encoder and a decoder;

b. determining an estimated pixel prediction mode at said encoder and said decoder, said estimated mode being a member of said set;

c. determining a best prediction mode at said encoder, said best prediction mode being a member of said set;

d. comparing said estimated mode to said best mode;
e. transmitting a first instruction, from said encoder to said decoder, to use said estimated mode when said estimated mode is substantially similar to said best mode; and
f. transmitting a second instruction, from said encoder to said decoder, to use another mode in said set other than said estimated mode when said estimated mode is not substantially similar to said best mode.

[0065] In a thirteenth aspect, the invention provides a computer data signal embodied in an electronic transmission, said signal having the function of communicating between a video encoder and decoder, said signal comprising instructions for:

a. establishing a set of pixel prediction modes at an encoder and a decoder;
b. determining an estimated pixel prediction mode at said encoder and said decoder, said estimated mode being a member of said set;
c. determining a best prediction mode at said encoder, said best prediction mode being a member of said set;
d. comparing said estimated mode to said best mode;
e. transmitting a first instruction, from said encoder to said decoder, to use said estimated mode when said estimated mode is substantially similar to said best mode; and
f. transmitting a second instruction, from said encoder to said decoder, to use another mode in said set other than said estimated mode when said estimated mode is not substantially similar to said best mode.

[0066] In a fourteenth aspect, the invention provides a method for ordering a set of spatial pixel intra-prediction modes, said method comprising:

a. selecting a set of pixel prediction modes; and
b. ordering said intra-prediction modes substantially according to their likelihood of providing a lesser prediction error.

[0067] In a fifteenth aspect, the invention provides a method for efficient communication of pixel intra-prediction modes, said method comprising:

a. selecting a set of pixel prediction modes;
b. ordering said set of prediction modes according to their likelihood of producing a lesser prediction error;
c. associating modes in said ordered set with increasing numerical values such that the mode most likely to produce a lesser prediction error is associated with the lowest numerical value and the next most likely mode for producing a lesser prediction error is associated with the next lower numerical value and so on throughout the set;
d. determining a best prediction mode for predicting a pixel, said mode being among said set;
e. indicating to a decoder to use said best mode using said numerical value associated with said best mode.

[0068] In a sixteenth aspect, the invention provides a method for organizing a set of pixel intra-prediction modes for more efficient communication of said modes, said method comprising:

a. selecting a set of pixel prediction modes comprising a plurality of modes taken from the group consisting of: a vertical prediction mode, a horizontal prediction mode, a DC prediction mode, a diagonal down left prediction mode, a diagonal down right prediction mode, a horizontal up prediction mode, a horizontal down prediction mode, a vertical right prediction mode and a vertical left prediction mode;
b. ordering at least a portion of said modes in said set into an ordered set wherein said ordering comprises placing said modes in an order as follows:

i. one mode taken from a first subset consisting of a horizontal prediction mode and a vertical prediction mode;
ii. the other mode of said first subset;
iii. a DC prediction mode; and
iv. a Diagonal Down Left prediction mode;

c. associating modes in said ordered set with increasing numerical values such that the mode most likely to produce a lesser prediction error is associated with the lowest numerical value and the next most likely mode for producing a lesser prediction error is associated with the next lower numerical value and so on throughout the set;
d. determining a best prediction mode for predicting a pixel, said best mode being among said set;
e. indicating to a decoder to use said best mode using said numerical value associated with said best mode.

[0069] In a seventeenth aspect, the invention provides an apparatus for efficient communication of pixel intra-prediction modes, said apparatus comprising:

a. an ordered set of pixel prediction modes wherein said ordered set comprises prediction modes in order as follows:

i. one mode taken from a first subset consisting of a horizontal prediction mode and a vertical prediction mode;
ii. the other mode of said first subset;
iii. a DC prediction mode; and

iv. a Diagonal Down Left prediction mode.

[0070] In an eighteenth aspect, the invention provides a computer readable medium comprising instructions for communicating an ordered set of pixel intra-prediction modes, said order comprising:

i. one mode taken from a first subset consisting of a horizontal prediction mode and a vertical prediction mode;
ii. the other mode of said first subset;
iii. a DC prediction mode;
iv. a Diagonal Down Left prediction mode;
v. one mode taken from a second subset consisting of a horizontal down mode, a diagonal down right mode and a vertical left mode;
vi. another mode taken from said second subset;
vii. the remaining mode from said second subset;
viii. a vertical left prediction mode; and
ix. a horizontal up prediction mode.

[0071] In a nineteenth aspect, the invention provides a computer data signal embodied in an electronic transmission, said signal having the function of communicating an ordered set of pixel intra-prediction modes, said ordered set comprising modes in the following order:

a. one mode taken from a first subset consisting of a horizontal prediction mode and a vertical prediction mode;
b. the other mode of said first subset;
c. a DC prediction mode;
d. a Diagonal Down Left prediction mode;
e. one mode taken from a second subset consisting of a horizontal down mode, a diagonal down right mode and a vertical left mode;
f. another mode taken from said second subset;
g. the remaining mode from said second subset;
h. a vertical left prediction mode; and
i. a horizontal up prediction mode.

Claims

1. An image decoding system for decoding a digital image comprising:

means for decoding each of blocks into which an image is divided;
intra-prediction means for predicting a pixel value of a target block to be decoded by using a pixel value of an adjacent block; and
prediction mode estimating means for estimating a prediction mode for the target block; wherein
the intra-prediction means includes a vertical prediction mode using a prediction value being a pixel value of a first block located adjacent to and above the target block;
a horizontal prediction mode using a prediction value being a pixel value of a second block located adjacent to the left side of the target block;
a DC prediction mode using a prediction value being an average of the pixel values of the first and second blocks;
a diagonal down/left prediction mode using the specified direction being diagonally downward to the left at a 45 degree angle from the horizontal;
a diagonal down/right prediction mode using the specified direction being diagonally downward to the right at a 45 degree angle from the horizontal;
a vertical right prediction mode using the predicting direction being specified by one pixel rightward and two pixels downward;
a horizontal down prediction mode using the predicting direction being specified by two pixels rightward and one pixel downward;
a vertical left prediction mode using the predicting direction being specified by one pixel leftward and two pixels downward;
a horizontal up prediction mode using the predicting direction being specified by two pixels rightward and one pixel upward;
the prediction modes are numbered with increasingly larger numbers, in order of the vertical prediction mode, the horizontal prediction mode, the DC prediction mode, the diagonal down/left prediction mode, the diagonal down/right prediction mode, the vertical right prediction mode, the horizontal down prediction mode, the vertical left prediction mode and the horizontal up prediction mode;
the prediction mode estimating means determines a prediction mode to have the lower mode number among the prediction mode of the first block and the prediction mode of the second block as the prediction mode for the target block;
the intra-prediction means decodes first information and second information;
the first information shows whether or not an actual prediction mode is equal to the prediction mode which has been estimated at the estimating means; and
the second information is decoded in a case where the actual prediction mode is different from the prediction mode which has been estimated at the estimating means to show the actual prediction mode; wherein
the second information is a reference to the mode order of a re-ordered prediction mode set made by eliminating the prediction mode estimated by the estimating means from the ordered set.

2. An image decoding method for decoding a digital image by decoding each of blocks into which an image is divided, the method comprising:

an intra-prediction step of predicting a pixel value of a target block to be decoded by using a pixel value of an adjacent block; and
a prediction mode estimating step of estimating a prediction mode for the target block; wherein
the intra-prediction step uses at least
a vertical prediction mode using a prediction value being a pixel value of a first block located adjacent to and above the target block;
a horizontal prediction mode using a prediction value being a pixel value of a second block located adjacent to the left side of the target block;
a DC prediction mode using a prediction value being an average of the pixel values of the first and second blocks;
a diagonal down/left prediction mode using the specified direction being diagonally downward to the left at a 45 degree angle from the horizontal;
a diagonal down/right prediction mode using the specified direction being diagonally downward to the right at a 45 degree angle from the horizontal;
a vertical right prediction mode using the predicting direction being specified by one pixel rightward and two pixels downward;
a horizontal down prediction mode using the predicting direction being specified by two pixels rightward and one pixel downward;
a vertical left prediction mode using the predicting direction being specified by one pixel leftward and two pixels downward;
a horizontal up prediction mode using the predicting direction being specified by two pixels rightward and one pixel upward;
the prediction modes are numbered with increasingly larger numbers, in order of the vertical prediction mode, the horizontal prediction mode, the DC prediction mode, the diagonal down/left prediction mode, the diagonal down/right prediction mode, the vertical right prediction mode, the horizontal down prediction mode, the vertical left prediction mode and the horizontal up prediction mode;
the prediction mode estimating step determines a prediction mode to have the lower mode number among the prediction mode of the first block and the prediction mode of the second block as the estimated prediction mode for the target block;
the intra-prediction step decodes first information and second information;
the first information shows whether or not an actual prediction mode is equal to the prediction mode which has been estimated at the estimating step; and
the second information is decoded in a case where the actual prediction mode is different from the prediction mode which has been estimated at the estimating step to show the actual prediction mode; wherein
the second information is a reference to the mode order of a re-ordered prediction mode set made by eliminating the prediction mode estimated by the estimating step from the ordered set.

FIG.1

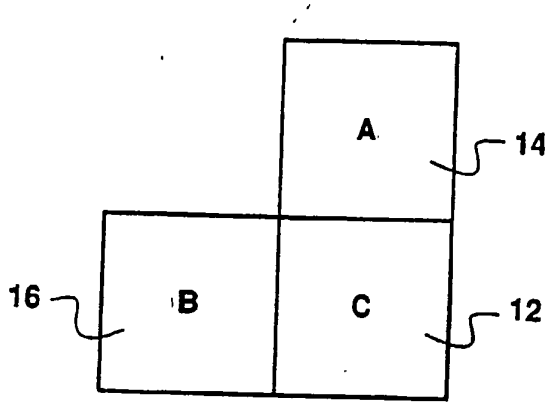

A
14
16
B
C
12

FIG.2

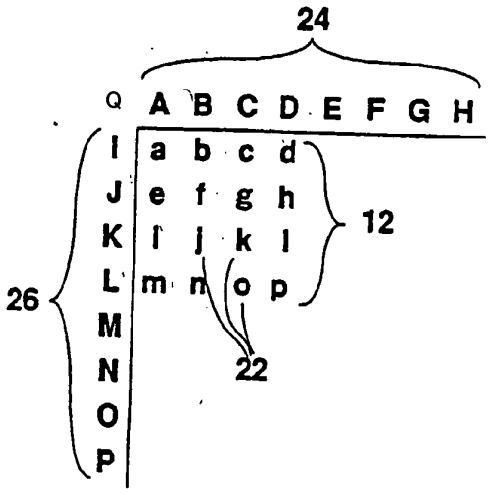

24
Q A B C D E F G H
I a b c d
J e f g h
K i j k l
L m n o p
M
N
O
P
12
26
22

FIG.3

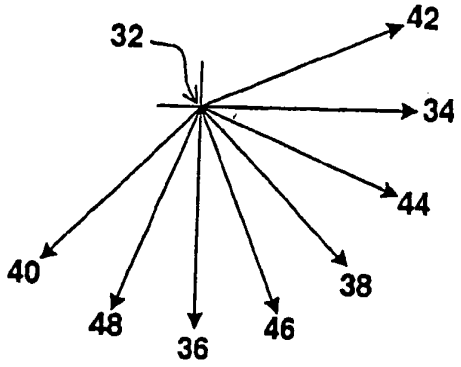


FIG.4

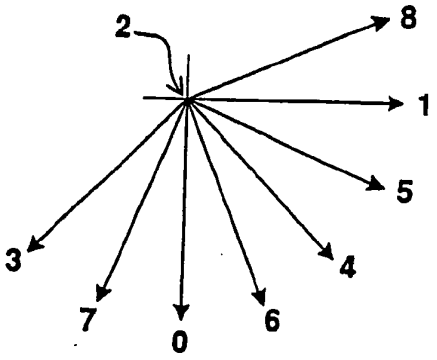


FIG.5

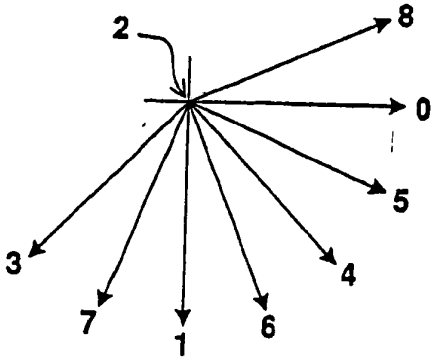


FIG.6

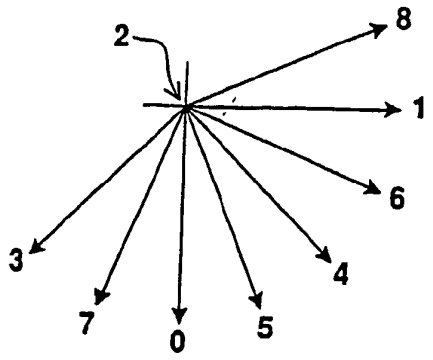


FIG.7

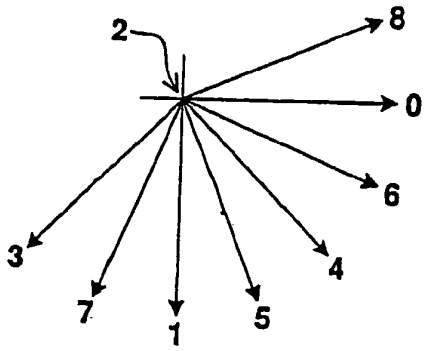


FIG.8

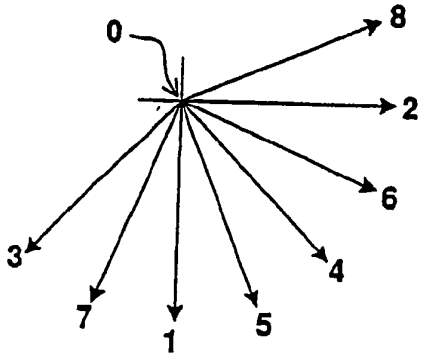


FIG.9

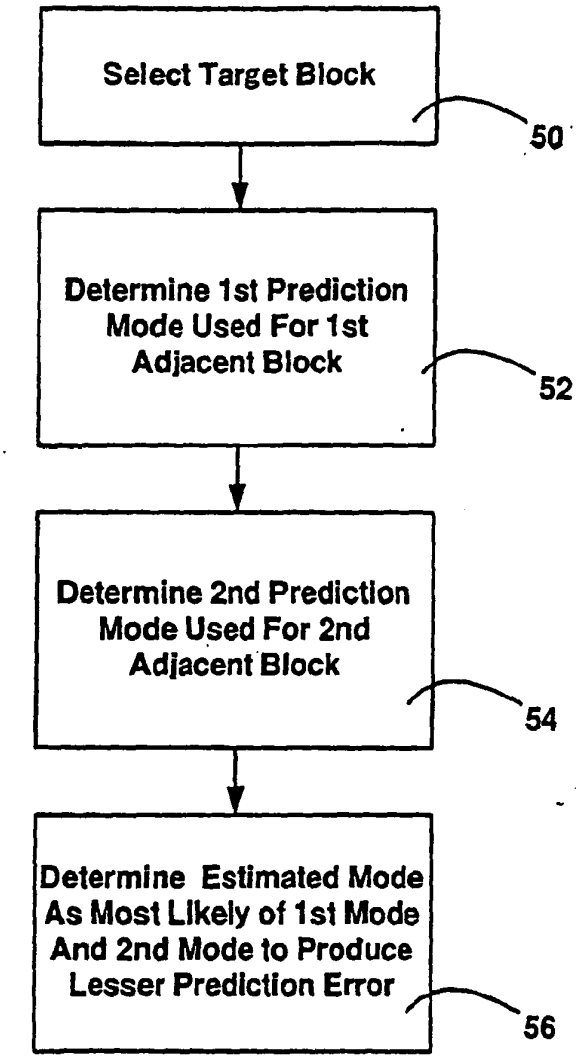

Select Target Block
50
Determine 1st Prediction Mode Used For 1st Adjacent Block
52
Determine 2nd Prediction Mode Used For 2nd Adjacent Block
54
Determine Estimated Mode As Most Likely of 1st Mode And 2nd Mode to Produce Lesser Prediction Error
56

FIG.10

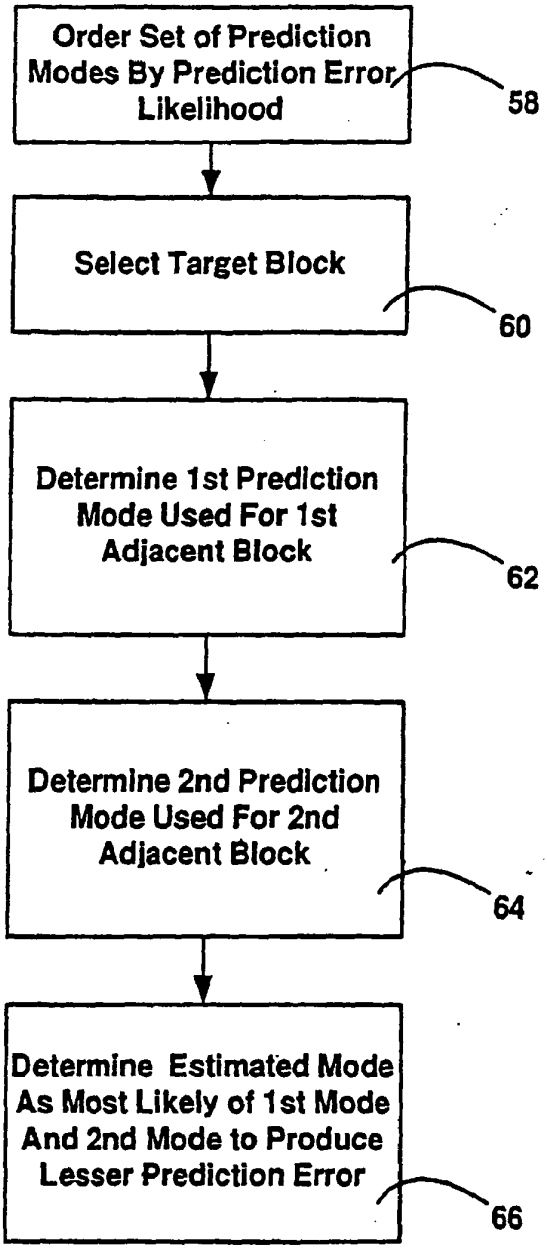

Order Set of Prediction Modes By Prediction Error Likelihood
58
Select Target Block
60
Determine 1st Prediction Mode Used For 1st Adjacent Block
62
Determine 2nd Prediction Mode Used For 2nd Adjacent Block
64
Determine Estimated Mode As Most Likely of 1st Mode And 2nd Mode to Produce Lesser Prediction Error
66

FIG.11

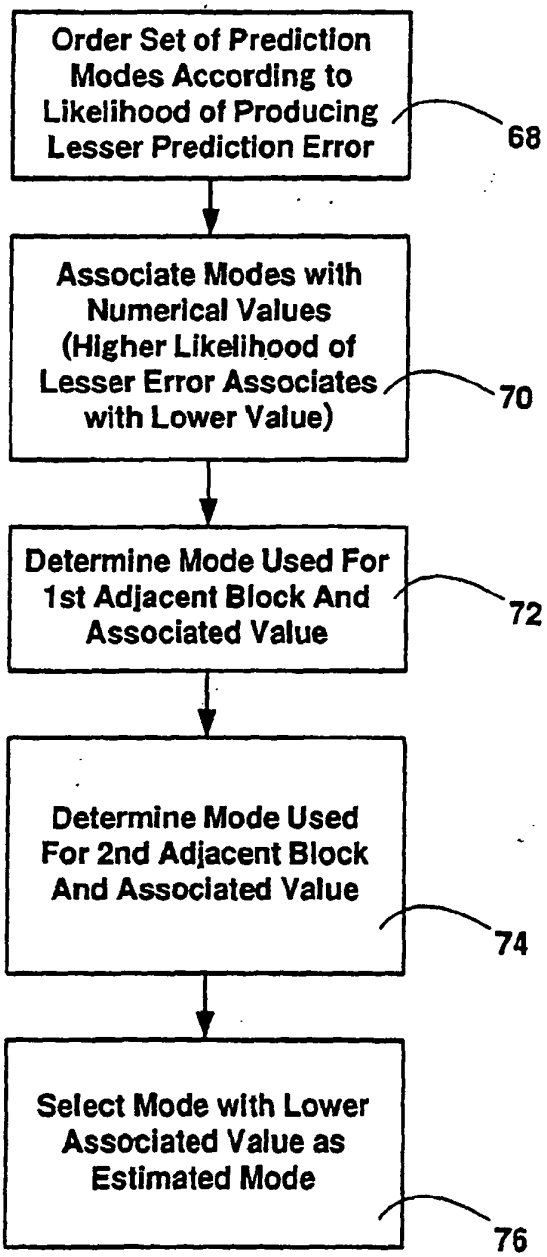

Order Set of Prediction Modes According to Likelihood of Producing Lesser Prediction Error
68
Associate Modes with Numerical Values (Higher Likelihood of Lesser Error Associates with Lower Value)
70
Determine Mode Used For 1st Adjacent Block And Associated Value
72
Determine Mode Used For 2nd Adjacent Block And Associated Value
74
Select Mode with Lower Associated Value as Estimated Mode
76

FIG.12

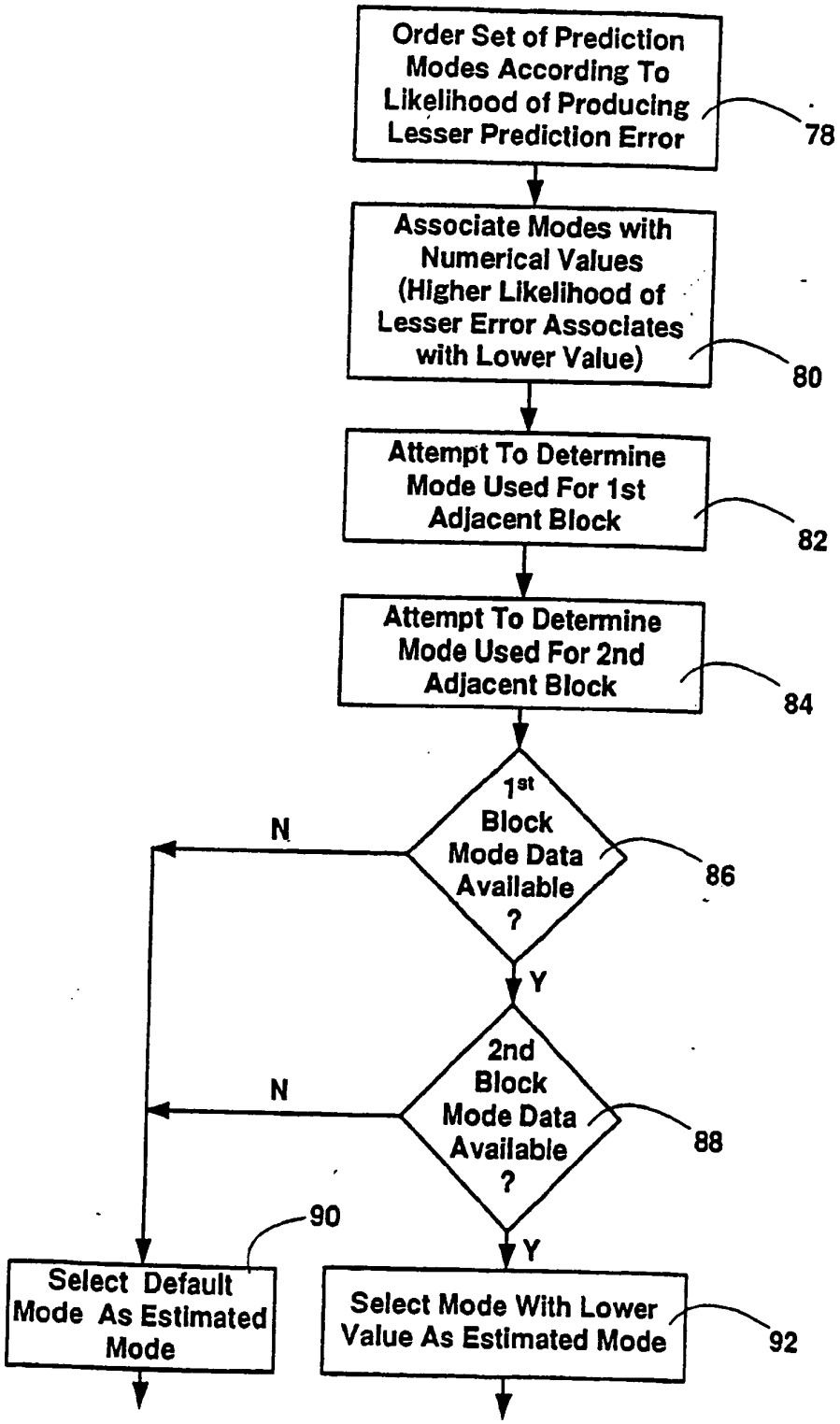

Order Set of Prediction Modes According To Likelihood of Producing Lesser Prediction Error
78
Associate Modes with Numerical Values (Higher Likelihood of Lesser Error Associates with Lower Value)
80
Attempt To Determine Mode Used For 1st Adjacent Block
82
Attempt To Determine Mode Used For 2nd Adjacent Block
84
1st Block Mode Data Available ?
86
N
Y
2nd Block Mode Data Available ?
88
N
Y
Select Default Mode As Estimated Mode
90
Select Mode With Lower Value As Estimated Mode
92

FIG.13

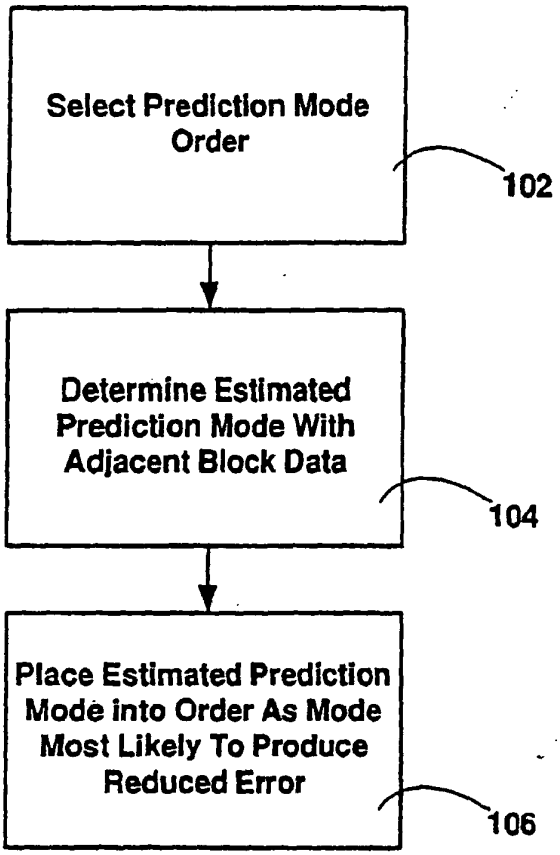

Select Prediction Mode Order
102
Determine Estimated Prediction Mode With Adjacent Block Data
104
Place Estimated Prediction Mode into Order As Mode Most Likely To Produce Reduced Error
106

FIG.14

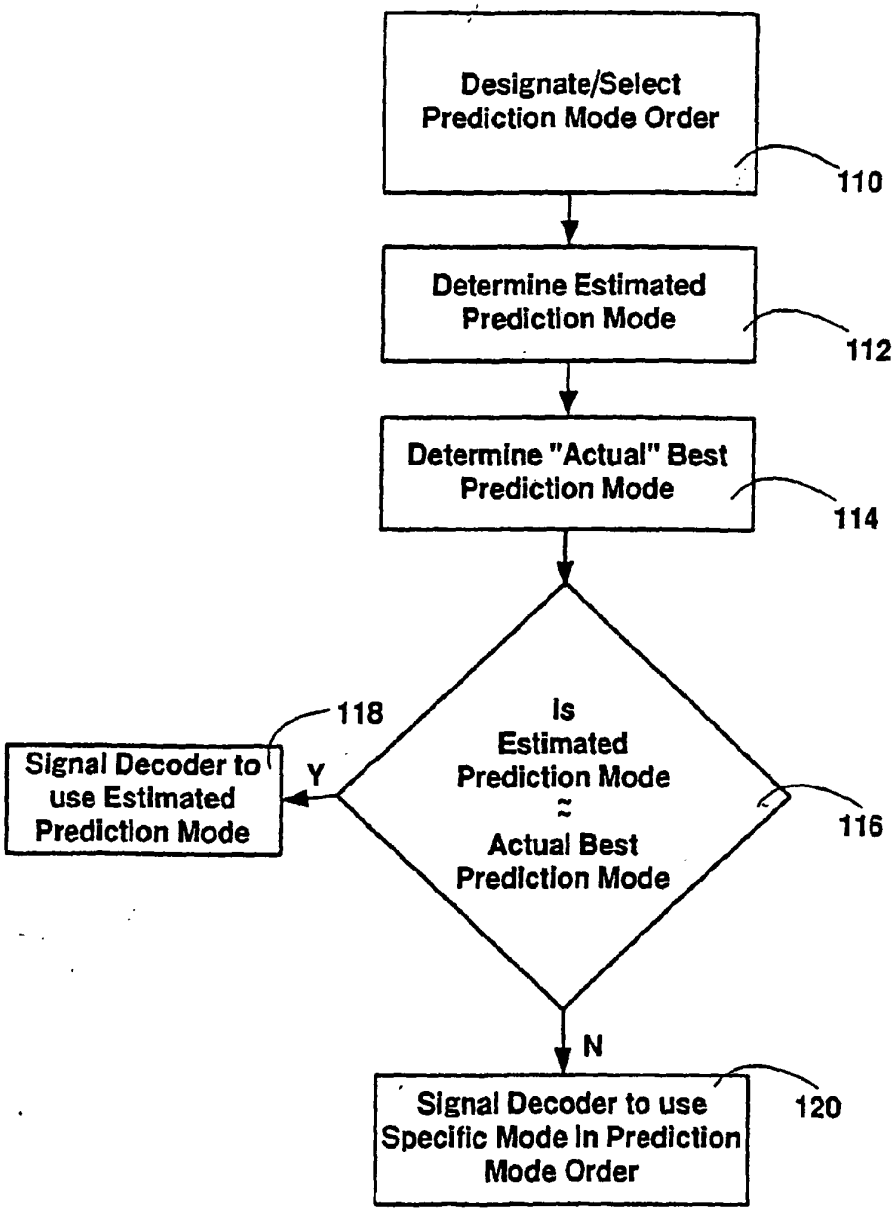
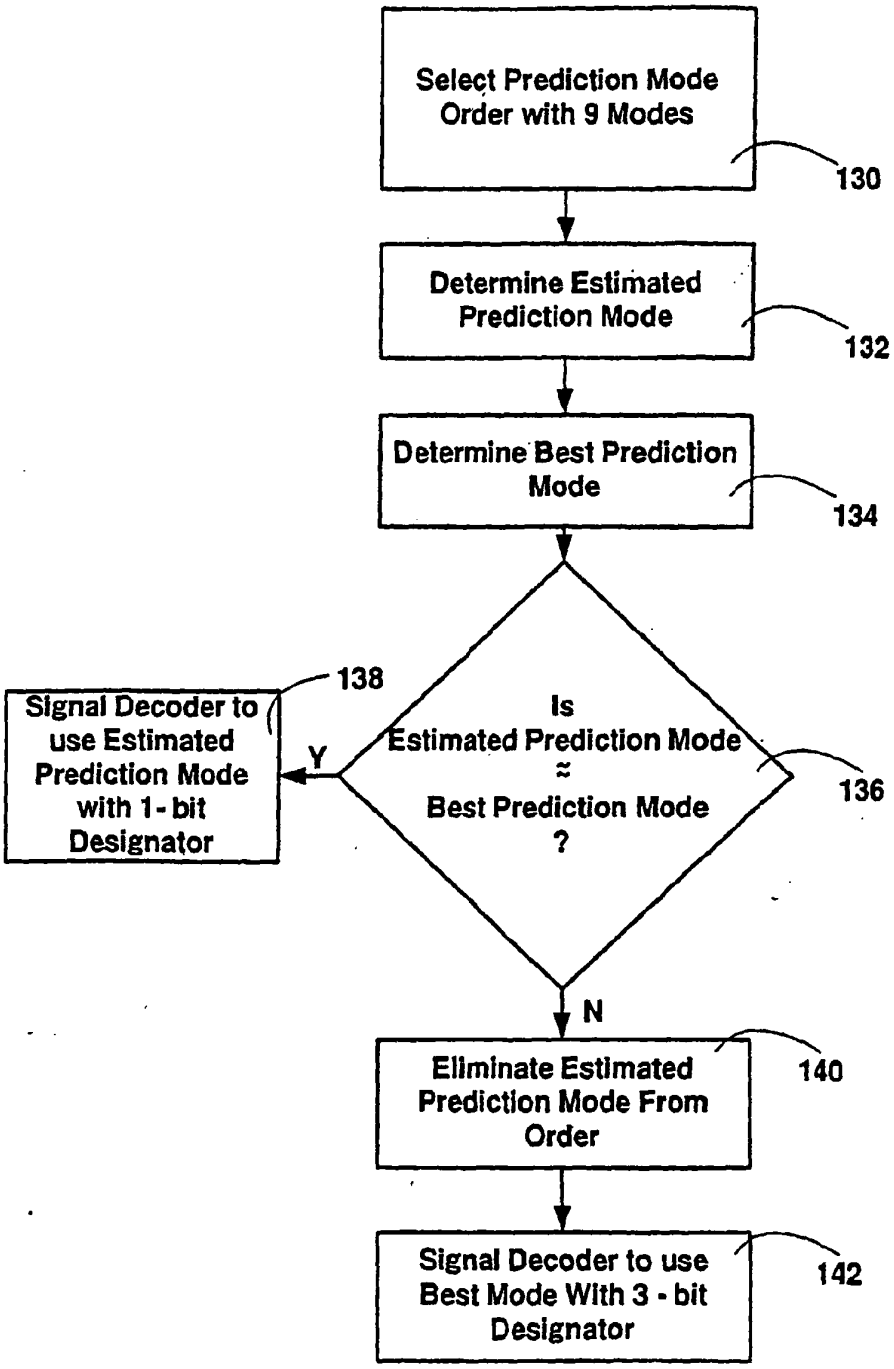

Designate/Select Prediction Mode Order
110
Determine Estimated Prediction Mode
112
Determine "Actual" Best Prediction Mode
114
Is Estimated Prediction Mode ≈ Actual Best Prediction Mode
116
Y
118
Signal Decoder to use Estimated Prediction Mode
N
Signal Decoder to use Specific Mode In Prediction Mode Order
120

FIG.15


Select Prediction Mode Order with 9 Modes
130
Determine Estimated Prediction Mode
132
Determine Best Prediction Mode
134
Is Estimated Prediction Mode ≈ Best Prediction Mode ?
136
Y
138
Signal Decoder to use Estimated Prediction Mode with 1-bit Designator
N
Eliminate Estimated Prediction Mode From Order
140
Signal Decoder to use Best Mode With 3 - bit Designator
142

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Application Number
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	27 February 2015	Lombardi, Giancarlo

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摘要

本发明的实施方式涉及用于估计在视频编码或者解码过程中待要使用的象素预测模式、用于在视频编码器和解码器之间传递象素预测模式、以及用于将象素内预测模式排序的方法和系统。

摘图中的文字翻译:

78 根据产生较少预测错误的可能性，对预测模式集合排序

80 将模式与数值关联（较少错误的较高可能性与较小值关联）

82 尝试确定第一邻接块所使用的模式

84 尝试确定第二邻接块所使用的模式

86 第一块模式数据是否可用？

88 第二块模式数据是否可用？

90 选择默认模式作为估计模式

92 选择具有较小值的模式作为估计模式

N: 否