DESCRIPTION

TITLE OF THE INVENTION

IMAGE PREDICT CODING METHOD, IMAGE PREDICT CODING DEVICE, IMAGE PREDICT CODING PROGRAM, IMAGE PREDICT DECODING METHOD, IMAGE PREDICT DECODING DEVICE, AND IMAGE PREDICT DECODING PROGRAM

Technical Field

[0001] The present invention relates to image predictive encoding and decoding methods, devices, and programs and, more particularly, to methods, devices, and programs for predictive encoding and decoding using a signal in a frame.

Background Art

[0002] The compression encoding technologies are used for efficient transmission and storage of still pictures and video data. The systems of MPEG1 to MPEG4 and H.261 to H.264 are commonly used for video data.

[0003] In these encoding systems, a picture as an encoding target is divided into a plurality of blocks and then an encoding/decoding process thereof is carried out. In MPEG4 and H.264, to further increase encoding efficiency, intra-frame predictive encoding is carried out in such a manner that a predicted signal is generated using a neighboring previously-reproduced pixel signal (restored signal of compressed picture data) present in the same frame as a target block, and then a difference signal obtained by subtracting the predicted signal from a signal of the target block is encoded. In inter-frame predictive encoding, compensation for motion is made with reference

to another previously-reproduced picture signal present in a frame different from that of a target block to generate a predicted signal, and a difference signal obtained by subtracting the generated predicted signal from a signal of the target block is encoded.

[0004] Specifically, the intra-frame predictive encoding of H.264 adopts a method of extrapolating previously-reproduced pixel values neighboring a block as an encoding target, in predetermined directions to generate the predicted signal. Fig. 13 is a schematic diagram for explaining the intra-frame prediction method used in H.264. In Fig. 13 (A), a block 1302 is a target block and a pixel group consisting of pixels A-M (1301) neighboring a boundary of the target block is a neighboring region, which is a picture signal previously reproduced in past processing. In this case, the predicted signal is generated by downwardly duplicating the neighboring pixels (A-D) located immediately above the target block 1302. In Fig. 13 (B), the predicted signal is generated by rightwardly duplicating previously-reproduced pixels (I-L) located to the left of target block 1304. The specific methods for generation of the predicted signal are described, for example, in Patent Literature 1. A difference is calculated between each of nine predicted signals generated by the methods shown in Fig. 13 (A) to (I) in this manner, and the pixel signal of the target block, and a method to provide the smallest difference is defined as an optimum prediction method. These extrapolation methods can be brought together as shown in Fig. 14. In Fig. 14, arrows indicate extending directions of previously-reproduced pixels and numbers for the respective directions are identification numbers of

the respective prediction modes. An identification number for prediction by an average of surrounding previously-reproduced pixels is 2 and is denoted by DC in Fig. 14. These identification numbers are also referred to as identification information about the intra-frame prediction method, or as mode information, or simply as prediction modes.

[0005] The prediction mode of a block undergoing the intra-frame prediction needs to be sent to the transmission side. On that occasion, the intra-frame prediction mode of the target block is encoded with reference to the intra-frame prediction modes of an upper neighboring block and a left neighboring block for the target block. Namely, a comparison is made between the intra-frame prediction modes of the upper neighboring block and the left neighboring block and the block with a smaller value is determined as reference mode information (most probable mode). The intra-frame prediction mode of the target block is encoded based on this reference mode information.

[0006] Specifically, a symbol to indicate whether the intra-frame prediction mode of the target block is identical to the reference mode information is encoded. When the symbol is 1, the intra-frame prediction mode of the target block is the same as the reference mode information. When the symbol is 0, information about the intra-frame prediction mode of the target block is encoded. However, if a number indicative of the intra-frame prediction mode of the target block is larger than a number of the reference mode information, encoding is performed after subtracting one from the number indicative of the intra-frame prediction mode of the target block.

[0007] On the reproduction side, the symbol is first decoded in the intra-frame predicted target block. When the symbol is 1, it is meant thereby that the intra-frame prediction mode of the target block is the same as the reference mode information. When the symbol is 0, the information about the intra-frame prediction mode is further decoded. However, if the number of the decoded prediction mode is equal to or larger than the reference mode information, the intra-frame prediction mode of the target block is determined by adding one.

Citation List

Patent Literature

[0008] Patent Literature 1: U.S. Patent No. 6,765,964

SUMMARY OF THE INVENTION

Technical Problem

[0009] Incidentally, it is known that the accuracy of the intra-frame prediction is improved by providing more intra-frame prediction modes than in the conventional technology. Namely, it is effective to provide options of extrapolation for the predicted signal from intermediate angles (directions), in addition to the nine modes shown in Fig. 14.

[0010] However, the increase of prediction methods leads to a problem of reduction in encoding efficiency of the identification information (prediction mode) to specify the intra-frame prediction method when using the conventional technology.

[0011] A reason for the encoding efficiency is that the increase in the number of intra-frame prediction modes results in statistical reduction in probability of correlation between the prediction mode of the target

block and the reference mode information (most probable mode). In addition, the encoding of the prediction mode itself, in the case of disagreement with the reference mode information, requires a larger bit count because the number of intra-frame prediction modes is increased.

[0012] An object of the present invention is to solve the above problem, thereby providing a method, device, and program for efficient encoding of the mode information to identify the intra-frame prediction method of the target block even in the case where a larger number of prediction modes are provided in the method of generation of intra-frame predicted signals. A further object of the present invention is to provide a method, device, and program for efficient decoding of encoded mode information.

Solution to Problem

[0013] In order to achieve the above object, an image predictive encoding method according to the present invention is an image predictive encoding method comprising: a region division step of dividing an input picture into a plurality of blocks; a predicted signal generation step of determining, for pixel signals contained in a target block selected from a plurality of blocks, an optimum prediction mode with the smallest difference from among a plurality of prediction methods and generating a prediction signal according to the optimum prediction signal, and generating a predicted signal in accordance with the optimum prediction mode; a residual signal generation step of obtaining a residual signal representing a difference between the pixel signal of the target block and the predicted signal; a signal encoding step of encoding the residual signal to generate a compressed signal; a

prediction mode encoding step of encoding the optimum prediction mode; and a storage step of restoring the compressed signal and storing a restored signal as a reproduced pixel signal, wherein the prediction mode encoding step comprises: generating a candidate prediction mode list containing elements of optimum prediction modes of a plurality of previously-reproduced blocks neighboring the target block; encoding a flag to indicate whether the candidate prediction mode list contains an element corresponding to the optimum prediction mode; further encoding an index to the corresponding element in the candidate prediction mode list when there is a corresponding element,; when there is no corresponding element, encoding with a number using the optimum prediction mode, after each element in the candidate prediction mode list is removed.

[0014] An image predictive decoding method according to the present invention is an image predictive decoding method comprising: an input step of accepting input of compressed picture data containing a residual signal generated by dividing a picture into a plurality of blocks and performing predictive encoding of a target block, and encoded information about a prediction mode indicative of a generation method of a predicted signal of the target block; a restoration step of extracting the residual signal of the target block from the compressed picture data to restore a reproduced residual signal; a prediction mode decoding step of restoring the encoded information about the prediction mode to generate an optimum prediction mode; a predicted signal generation step of generating the predicted signal of the target block, based on the optimum prediction mode; a picture restoration step of adding the

predicted signal to the reproduced residual signal to restore a pixel signal of the target block; and a storage step of storing the restored pixel signal as a reproduced pixel signal, wherein the prediction mode decoding step comprises: generating a candidate prediction mode list containing elements of optimum prediction modes of a plurality of previously-reproduced blocks neighboring the target block; decoding a flag to indicate whether the candidate prediction mode list contains an element corresponding to the optimum prediction mode; when the flag indicates that "there is a corresponding element", further decoding an index that indexes the candidate prediction mode list and defines an element indicated by the index as the optimum prediction mode; when the flag indicates that "there is no corresponding element", further decoding information about an REM mode and defining, as the optimum prediction mode, a value of the REM mode, which is converted based on the candidate prediction mode list.

Effects of the Invention

[0015] According to the present invention, when the prediction mode information of the target block is encoded in the image predictive encoding method by performing intra-frame prediction using more intra-frame prediction modes than in the conventional technology, since the candidate prediction mode list consisting of a plurality of prediction modes is prepared, and an identifier of an element coincident with the prediction mode of the target block from the prepared candidate prediction mode list is encoded; the probability that the element is coincident with the prediction mode of the target block becomes higher, and thus the prediction mode information can be

encoded by a smaller bit count. In other words, there is only one "most probable mode" in the conventional technology, whereas a plurality of "most probable modes" are prepared in the present invention; therefore, the present invention provides an effect of increasing the probability of occurrence of a "most probable mode" coincident with the prediction mode of the target block.

[0016] If the prediction mode of the target block is absent in the candidate prediction mode list, the prediction mode of the target block itself is encoded but, in that case, since a plurality of prediction modes in the candidate prediction mode list are excluded and new identification numbers are assigned to the remaining prediction modes, the prediction mode of the target block can be expressed by a smaller number, allowing encoding with a smaller bit length.

[0017] Namely, the present invention provides an effect of enabling more efficient encoding of the information about the prediction mode in the case where the intra-frame prediction is carried out by more intra-frame prediction modes than in the conventional technology.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] Fig. 1 is a block diagram showing an image predictive encoding device according to an embodiment of the present invention.

Fig. 2 is a schematic diagram showing pixel extrapolation directions corresponding to intra-frame prediction modes used in the image predictive encoding device according to an embodiment of the present invention.

Fig. 3 is a flowchart showing processing of an intra-frame prediction mode encoder according to an embodiment of the present

invention.

Fig. 4 is a schematic diagram showing an example for explaining an encoding process of an intra-frame prediction mode according to an embodiment of the present invention.

Fig. 5 is a flowchart showing a generation process of REM mode number (step 360) in the processing of the intra-frame prediction mode encoder (Fig. 3) according to an embodiment of the present invention.

Fig. 6 is a schematic diagram for explaining the generation process of REM mode number in the processing of the intra-frame prediction mode encoder (Fig. 3) according to an embodiment of the present invention.

Fig. 7 is a block diagram showing an image predictive decoding device according to an embodiment of the present invention.

Fig. 8 is a flowchart showing processing of an intra-frame prediction mode decoder according to an embodiment of the present invention.

Fig. 9 is a flowchart showing a generation process of a prediction mode of a target block (step 860) in the processing of the intra-frame prediction mode decoder (Fig. 8) according to an embodiment of the present invention.

Fig. 10 is a schematic diagram describing process of an intra-frame prediction mode encoding method using two candidate prediction modes, according to an embodiment of the present invention.

Fig. 11 is a drawing showing a hardware configuration of a

computer for executing a program recorded in a recording medium.

Fig. 12 is a perspective view of a computer for executing a program stored in a recording medium.

Fig. 13 is a schematic diagram showing methods of generating a predicted signal of a target block by the conventional technology.

Fig. 14 is a schematic diagram in which a plurality of methods for generation of the predicted signal of the target block by the conventional technology are brought together in a view.

Fig. 15 is a block diagram showing modules of an image predictive encoding program.

Fig. 16 is a block diagram showing modules of an image predictive decoding program.

Embodiments of the Invention

[0019] Embodiments of the present invention will be described below using Figs. 1 to 12.

[0020] Fig. 1 is a block diagram showing an image predictive encoding device according to an embodiment of the present invention. The image predictive encoding device is provided with input terminal 101, block divider 102, inter-frame predicted signal generation method determiner 103, inter-frame predicted signal generator 104, intra-frame predicted signal generation method determiner 105, intra-frame predicted signal generator 106, changeover switch 109, subtracter 110, transformer 111, quantizer 112, de-quantizer 113, inverse-transformer 114, adder 115, frame memory 116, intra-frame prediction mode encoder 117, entropy encoder 118, and output terminal 119.

[0021] Below is a description of the operation of the image predictive

encoding device configured as described above. A signal of a video sequence consisting of a plurality of pictures is fed into the input terminal 101. A picture as an encoding target is divided into a plurality of regions by the block divider 102. In the embodiment according to the present invention, each picture is divided into blocks, where each block consists of 8×8 pixels, but each picture may be divided into blocks of any other size or shape. Then a predicted signal is generated for a region as an encoding target (hereinafter referred to as "target block"). In the embodiment according to the present invention, it is generated using two types of prediction methods, the inter-frame prediction and intra-frame prediction.

[0022] In the inter-frame prediction, a reproduced picture having a different display time than that of a target picture, and which has been encoded and then restored in the past, is used as a reference picture, and motion information which provides a predicted signal with the smallest error from the target block is determined from the reference picture. Depending upon the situation, it is also possible to adopt a method of subdividing the target block into small regions and determining the inter-frame prediction method for each subdivided small region. In this case, the most efficient division method from among a variety of division methods, and corresponding motion information are determined for the entire target block. In the embodiment of the present invention, this processing is carried out by the inter-frame predicted signal generation method determiner 103, the target block is fed via line L102, and the reference picture is fed via L119. With regard to the reference picture, a plurality of pictures that

have been encoded and restored in the past are used as reference pictures. The details are the same as in any one of the methods of MPEG-2, 4 and H.264, which are the conventional technologies. The motion information and small region division method determined as described above are fed via line L104 to the inter-frame predicted signal generator 104. These pieces of information are also fed via line L103 to the entropy encoder 118 and are encoded thereby, and the encoded data is output from the output terminal 119. The inter-frame predicted signal generator 104 acquires reference signals from the frame memory 116 (via line L119), based on the small region division method and the motion information corresponding to each small region, and generates a predicted signal for each small region. The inter-frame predicted signal generated in this manner is sent via terminal 107 to the next process block.

[0023] In the intra-frame prediction, an intra-frame predicted signal is generated using previously-reproduced pixel values neighboring a target block in the same frame. A generation method of the intra-frame predicted signal is determined by the intra-frame predicted signal generation method determiner 105. The processing of the intra-frame predicted signal generation method determiner 105 will be described later. Information (prediction mode) about the intra-frame prediction method determined in this manner is sent via line L106 to the intra-frame predicted signal generator 106. The information (prediction mode) about the intra-frame prediction method is also sent via line L105 to the intra-frame prediction mode encoder 117. The processing of the intra-frame prediction mode encoder 117 will be

described later. The results of the processing are sent to the entropy encoder 118 to be encoded thereby, and the encoded data is sent from the output terminal 119. The intra-frame predicted signal generator 106 acquires neighboring previously-reproduced pixel signals in the same frame from the frame memory 116 (via line L116), based on the information about the prediction method, and generates a predicted signal by a predetermined method. The intra-frame predicted signal generated in this manner is sent via terminal 108 to the next process block.

[0024] From the inter-frame and intra-frame predicted signals obtained as described above, the changeover switch 109 selects the predicted signal with the smallest error and sends it to the subtracter 110. However, since there is no past picture for the first picture, all target blocks are at first processed by the intra-frame prediction. In this case, the switch 109 is always connected to the terminal 108 during processing of the picture. The intra-frame prediction method and intra-frame prediction mode encoding method described below are also applicable to encoding and decoding of still pictures.

[0025] The subtracter 110 subtracts the predicted signal (fed via line L109) from the signal of the target block (fed via line L102) to generate a residual signal. This residual signal is transformed by a discrete cosine transform by the transformer 111 and coefficients thereof are quantized by quantizer 112. Finally, the entropy encoder 118 encodes the quantized transform coefficients and sends the encoded data along with the information about the prediction method (prediction mode) and other information from the output terminal 119.

[0026] For the intra-frame prediction or the inter-frame prediction of a subsequent target block, it is necessary to perform inverse processing and restoration of the compressed signal of the target block. Namely, the de-quantizer 113 performs de-quantization of the quantized transform coefficients and the inverse-transformer 114 performs an inverse discrete cosine transform of the transform coefficients, thereby restoring a residual signal. The adder 115 adds the restored residual signal to the predicted signal fed through line L109, to reproduce a picture signal of the target block, which is stored into the frame memory 116.

[0027] The following will describe the intra-frame predicted signal generation method determiner 105 used in the present invention. Fig. 2 is a schematic diagram showing pixel extrapolation methods corresponding to intra-frame prediction modes used in an embodiment of the present invention. In the present embodiment, intra-frame predicted signals are generated by a total of sixteen methods. Numbers in Fig. 2 are identification numbers to identify the respective intra-frame prediction methods and are referred to as prediction mode information or unit prediction modes. In the respective prediction modes (from number 0 to number 15), previously-reproduced pixel signals neighboring a target block are extrapolated in directions indicated by respective arrows in Fig. 2, to generate the intra-frame predicted signals. Specific extrapolation methods about the prediction modes 0 to 8 are shown in Fig. 13 and the calculation methods thereof are described in Patent Literature 1. In each of the prediction modes 9 to 15, similarly, the intra-frame predicted signal is also generated by

linear interpolation from surrounding previously-reproduced pixel signals to duplicate interpolated values in a direction of a corresponding arrow. The present embodiment employs the sixteen intra-frame prediction methods, but it should be noted that the encoding and decoding methods of prediction mode according to the present invention can also be applied to cases using the other numbers of prediction modes and other generation methods of predicted signal.

[0028] The intra-frame predicted signal generation method determiner 105 generates sixteen intra-frame predicted signals, based on these sixteen prediction modes, and, for each signal, calculates a difference thereof from the pixel signal of the target block sent via line L102. It determines a prediction mode which provides the smallest difference, as an intra-frame prediction mode of the target block.

[0029] As described above, either the intra-frame prediction or the inter-frame prediction is selected for the target block (by switch 109) and, when the intra-frame prediction is selected, the intra-frame prediction mode encoder 117 processes the intra-frame prediction mode of the target block. In the encoding method of the intra-frame prediction mode according to the present invention, it is necessary to use the intra-frame prediction modes (identification numbers) of previously-encoded blocks, and therefore the intra-frame prediction mode encoder 117 is provided with a storage memory (not shown), for storage of the intra-frame prediction modes (identification numbers) of previously-encoded blocks.

[0030] Fig. 3 is a flowchart showing the processing of the intra-frame prediction mode encoder 117 according to an embodiment of the

present invention. Step 310 is first to generate a list of candidate prediction modes. Elements in this list are prediction modes of a plurality of previously-reproduced blocks located around the target block. In the present embodiment, prediction modes possessed by surrounding previously-reproduced blocks 410-450, which are neighboring target block 400 shown in Fig. 4 are defined as elements in the candidate prediction mode list. Fig. 6 (A) is an example of the candidate prediction mode list and numerical values in respective boxes represent identification numbers of the prediction modes corresponding to the respective surrounding blocks (410 to 450). In this example, the surrounding blocks (410 to 450) have respective prediction modes that are different from each other, but if the same prediction mode appears in multiple of the elements, it can be handled as one element. For example, if blocks 410 and 420 have the same prediction mode, the number of elements in the candidate prediction mode list is not 5 but 4. Namely, the number of elements in the candidate prediction mode list can be at most 5 and at least 1. Particularly, if the surrounding blocks neighboring the target block are "inter-frame" predicted ones, there is no intra-frame prediction mode. In the present embodiment, mode 2 (DC prediction) is the only element in the candidate prediction mode list. Fig. 6 (A) shows an arrangement of the values of the elements in the candidate prediction mode list in increasing order, but the candidate prediction mode list may be configured in decreasing order. In order to construct the candidate prediction mode list for encoding of the prediction mode of the subsequent block, the intra-frame prediction mode encoder 117 stores the prediction mode of the current target

block into the aforementioned storage memory.

[0031] Next, step 320 is to compare the intra-frame prediction mode of the target block with each of the elements in the candidate prediction mode list to check whether there is a coincident element.

[0032] When the intra-frame prediction mode of the target block is found in the candidate prediction mode list, the processing proceeds to step 330. In this step, "1" is encoded. This "1" indicates that the intra-frame prediction mode of the target block is included in the candidate prediction mode list. The next step is to encode an identifier (index) to the element in the candidate prediction mode list coincident with the prediction mode of the target block (step 340). In the present embodiment, 0, 1, 2, 3, and 4 are assigned to respective indices of the boxes from the left in Fig. 6 (A) and, in the case where the prediction mode of the target block is "8", 2 is encoded as an index. These indices are encoded by base-1 codes (unary codes). Namely, codes of (0, 01, 001, 0001, 00001) are assigned to (0, 1, 2, 3, 4), respectively. The last bit in the code of the maximum index may be discarded. Namely, the code "00001" for "4" can be "0000". Another applicable method is to encode the indices by fixed-length codes. In that case, the code length of fixed codes may be varied depending upon the size of the candidate prediction mode list (the number of elements). For example, in the case where the size of the candidate prediction mode list is 4, the indices are encoded by two bits, and in the case where the size is 2, the indices are encoded by one bit. Efficient coding is coding of indices based on the size of the candidate prediction mode list (the number of elements).

[0033] When it is determined in step 320 that the intra-frame prediction mode of the target block is absent in the candidate prediction mode list, the processing proceeds to step 350. In this step, "0" is encoded. This "0" indicates that the intra-frame prediction mode of the target block is not included in the candidate prediction mode list. In this case, it is necessary to encode the prediction mode of the target block. In the present embodiment the prediction mode of the target block is encoded as "REM mode". Since it is known that the prediction mode of the target block is absent in the candidate prediction mode list, an identification number to be encoded herein is not the original identification number of the prediction mode, but is instead one of identification numbers reassigned to the remaining prediction modes after exclusion of the elements in the candidate prediction mode list. This will be described using Fig. 6. Fig. 6 (A) shows the elements in the candidate prediction mode list, which does not include an element corresponding to the prediction mode of the target block. Therefore, the remaining prediction modes after exclusion of these prediction modes are shown in Fig. 6 (B). The result of reassignment of 0, 1, 2, 3, 4... to the respective boxes from the left in this Fig. 6 (B) is shown in Fig. 6 (C). For example, in the case where the prediction mode of the target block is "9", "9" is not encoded, but "6" is encoded as REM mode because "6" in Fig. 6 (C) is reassigned to "9" in Fig. 6 (B). Namely, the same prediction mode of the target block can be encoded by a smaller numerical value, or a smaller bit count. The reassignment of the identification number of the prediction mode in this manner is carried out in step 360 in Fig. 3.

[0034] Another execution method of step 360 is shown in Fig. 5. In step 510 the identification number of the intra-frame prediction mode for the determined target block is used as the REM mode. In step 520, the largest element among elements in the candidate prediction list which are not yet used in comparison is defined as X. Step 530 is to compare the REM mode with X. When the REM mode is larger than X, step 540 is carried out to subtract 1 from the value of the REM mode. Step 550 is to check whether there is a not-yet-compared element in the candidate prediction list; if yes, the processing returns to step 520; if no, the processing is terminated.

[0035] As a modification of the processing of Fig. 5, step 520 is configured to define the smallest element as X and step 530 is changed to "intra-frame prediction mode of target block $\leq$ X?", with the same result. In this case, when the answer of "intra-frame prediction mode of target block $\leq$ X?" is no, the processing is immediately terminated.

[0036] The value of the REM mode generated in this manner is encoded in step 370. In the present embodiment the value of the REM mode is encoded by a fixed-length code, but it is also possible to encode the value of the REM mode by a variable-length code. The code length of these values of the REM mode may be based on the number of elements in a complementary set of the candidate prediction mode list.

[0037] The present embodiment describes the case where the size S of the candidate prediction mode list (the number of elements) was at most 5, but S may be an arbitrary number. It is, however, noted that the encoding device and decoding device need to generate this list by

the same method. In the case where the candidate prediction mode list is generated from the prediction modes of the upper block (420) and the left block (440) with respect to the target block 400 in Fig. 4, S=2. In this case, there are two types of candidate prediction mode lists. When the two surrounding blocks both are intra-frame predicted ones, the list contains two elements; when only one of the surrounding blocks is an intra-frame predicted one, the list contains one element. The case of one list element is shown in Fig. 10 (A) and the case of two list elements is shown in Fig. 10 (B).

[0038] Node 80 in Fig. 10 (A) indicates whether the candidate prediction mode list contains an element coincident with the prediction mode of the target block. When there is no coincident element, the REM mode is encoded (82). When there is a coincident element (81), there is no need for encoding of an index because the list contains only one element. In Fig. 10 (B), similarly, the REM mode is encoded when there is no coincident element in the list (94). When there is a coincident element (91), there are two elements and therefore an index to indicate which is coincident between the first and second candidates is encoded.

[0039] Next, an image predictive decoding method according to the present invention will be described. Fig. 7 is a block diagram showing an image predictive decoding device according to an embodiment of the present invention. The image predictive decoding device is provided with input terminal 700, data analyzer 701, de-quantizer 702, inverse-transformer 703, adder 704, predicted signal generator 705, frame memory 706, intra-frame prediction mode

restoration unit 707, and output terminal 708.

[0040] Describe below is the operation of the image predictive decoding device configured as described above. Compressed data resulting from the compression encoding by the foregoing method is input through the input terminal 700. This compressed data contains the residual signal resulting from the prediction and encoding of the target block obtained by division of a picture into a plurality of blocks, and the mode information about the prediction method. The data analyzer 701 analyzes the compressed data to extract the residual signal of the target block, the information about the prediction method, the quantization parameter, and the motion information in the case of the inter-frame prediction, or encoded information about the aforementioned intra-frame prediction mode for an intra-frame predicted block. The residual signal and quantization parameter of the target block are sent (via line L701) to the de-quantizer 702, to be subjected to de-quantization. The result is transformed by an inverse discrete cosine transform by the inverse-transformer 703.

[0041] When the data analyzer 701 determines that the target block is an inter-frame predicted one, the motion information is fed via line L709 to the predicted signal generator 705. The predicted signal generator 705 acquires a predicted signal from previously-reproduced pictures in the frame memory 706, based on the motion information. On the other hand, when the data analyzer 701 determines that the target block is an intra-frame predicted one, the mode information about the intra-frame prediction is sent via line L710 to the intra-frame prediction mode restoration unit 707 and the intra-frame prediction

mode is restored and sent to the predicted signal generator 705. The predicted signal generator 705 acquires previously-reproduced pixel signals in the same frame from the frame memory 706, based on the intra-frame prediction mode, to generate a predicted signal. Specific generation methods of intra-frame predicted signals were described above with reference to Fig. 2. The details of the intra-frame prediction mode restoration unit 707 will be described later.

[0042] The predicted signal generated by the predicted signal generator 705 is sent via line L705 to the adder 704, and the adder 704 adds the restored residual signal to the predicted signal to reproduce a pixel signal of the target block. The reproduced picture is output via line L704 and, at the same time, is stored via line 708 into the frame memory 706.

[0043] Next, the processing of the intra-frame prediction mode restoration unit 707 according to the present embodiment will be described. The output from the intra-frame prediction mode restoration unit 707 is an identification number of the intra-frame prediction mode of the target block and is output via line L707 and, at the same time, is stored into a memory (not shown) in the intra-frame prediction mode restoration unit 707 because it is necessary for restoration of the prediction mode of the subsequent block.

[0044] Fig. 8 is a flowchart showing the processing of the intra-frame prediction mode decoder according to an embodiment of the present invention. Step 810 is first to generate a list of candidate prediction modes. Elements in this list are prediction modes of a plurality of previously-reproduced blocks (410 to 450) located around the target

block 400 shown in Fig. 4. The specific description is the same as that of step 301 in Fig. 3. The encoding device and decoding device need to generate this candidate prediction mode list by the same method.

[0045] Next step 820 is to decode one bit. When this one bit is transmitted via line L710 from the data analyzer 701, actual decoding processing is carried out by the data analyzer 701. This one bit indicates whether the intra-frame prediction mode of the target block is included in the candidate prediction mode list. Then, step 830 is to perform a comparison to determine whether this one bit is "1". If the one bit is "1", the processing proceeds to step 840. Otherwise, the processing proceeds to step 850.

[0046] Since the intra-frame prediction mode of the target block is included in the candidate prediction mode list, step 840 is configured to further decode the identifier (index) indicating which element in the candidate prediction mode list coincides with the intra-frame prediction mode of the target block. The element in the candidate prediction mode list indicated by the index is the prediction mode of the target block. For example, when the index is "2", the mode identification number "8" in the third box from the left in Fig. 6 (A) is the prediction mode of the target block. In the present embodiment, this index is decoded as a base-1 code (unary code). As another method, where the encoding method used is one in which the bit length of the index is determined based on the size of the candidate prediction mode list (the number of elements), the size of the candidate prediction mode list (the number of elements) needs to be sent to the data analyzer 701 (line

L711).

[0047] Since the intra-frame prediction mode of the target block is not included in the candidate prediction mode list, step 850 is configured to decode the value of the REM mode. In the present embodiment it is restored as a numerical value of a fixed-length code. The value of the REM mode is different from the actual identification number of the prediction mode (as described with reference to Fig. 5) and therefore, step 860 is to remap the value to the actual identification number to obtain the intra-frame prediction mode of the target block.

[0048] Fig. 9 shows an execution method for returning the REM mode to the actual identification number of the prediction mode. Step 910 is to substitute the decoded value of REM mode into a PRED mode. This PRED mode is a variable for the intra-frame prediction mode of the target block.

[0049] Step 920 is to define an element as X, which is the smallest number among elements not used in comparison yet in the candidate prediction mode list. Step 930 is to compare the PRED mode with X. When the PRED mode is larger than or equal to X, step 940 is carried out to add 1 to the value of the PRED mode. Step 950 is to check whether there is a not-yet-compared element in the candidate prediction list; if yes, the processing returns to step 920; if no, the processing is terminated. The PRED mode after completion of this processing provides the actual identification number of the prediction mode of the target block.

[0050] Instead of the processing of Fig. 9, it is also possible to adopt a method of creating the complementary set of Fig. 6 (A) as shown in Fig.

6 (B) and defining the (N+1)th (N = the value of REM mode) element from the left, as the prediction mode of the target block.

[0051] The intra-frame prediction mode restoration unit 707 is depicted as an independent function block in Fig. 7, but it may be incorporated into the data analyzer 701. In this case, the line L710 is connected directly to the predicted signal generator 705 and the intra-frame prediction mode is sent via the line L710 to the predicted signal generator 705.

[0052] The above embodiment describes the encoding of the prediction mode information about the intra-frame prediction, but the same encoding and decoding methods can also be applied to the inter-frame prediction case. The information about the prediction mode in the inter-frame prediction case may also be encoded and decoded using the candidate prediction mode list. In this case, the candidate prediction mode list contains elements of information of inter-frame prediction modes of surrounding previously-reproduced blocks. Furthermore, the motion information in the inter-frame prediction case can also be similarly encoded and decoded. In this case, the candidate prediction mode list contains elements of motion information of surrounding previously-reproduced blocks.

[0053] An image predictive encoding program for letting a computer execute the image predictive encoding method according to the present invention is provided as stored in a recording medium. Furthermore, an image predictive decoding program for letting a computer execute the image predictive decoding method according to the present invention is also provided as stored in a recording medium. Examples

of recording media include recording media such as flexible disks, CD-ROMs, DVDs, or ROMs, or semiconductor memories, or the like.

[0054] Fig. 15 is a block diagram showing modules of the image predictive encoding program capable of executing the image predictive encoding method. The image predictive encoding program P100 is provided with region division module P101, predicted signal generation module P102, residual signal generation module P103, signal encoding module P104, prediction mode encoding module P105, and storage module P106. Functions implemented upon execution of the above respective modules by a computer are the same as the functions of the above-described image predictive encoding device. Fig. 16 is a block diagram showing modules of the image predictive decoding program capable of executing the image predictive decoding method. The image predictive decoding program P200 is provided with input module P201, restoration module P202, prediction mode decoding module P203, predicted signal generation module P204, picture restoration module P205, and storage module P206. Functions implemented upon execution of the above respective modules by a computer are the same as the functions of the above-described image predictive decoding device. The image predictive encoding program P100 and the image predictive decoding program P200 configured as described above are stored in a recording medium and executed by a computer described below.

[0055] Fig. 11 is a drawing showing a hardware configuration of a computer for executing a program recorded in a recording medium and Fig. 12 a perspective view of a computer for executing a program

stored in a recording medium. The computer embraces a DVD player, a set-top box, a cell phone, etc. provided with a CPU and configured to perform processing and control based on software.

[0056] As shown in Fig. 11, computer 30 is provided with a reading device 12 such as a flexible disk drive unit, a CD-ROM drive unit, or a DVD drive unit, a working memory (RAM) 14 in which an operating system is resident, a memory 16 storing programs stored in the recording medium 10, a monitor device 18 such as a display, a mouse 20 and a keyboard 22 as input devices, a communication device 24 for transmission and reception of data and others, and a CPU 26 to control execution of the programs. When the recording medium 10 storing the program P100 is put into the reading device 12, the computer 30 becomes accessible to the image predictive encoding program P100 stored in the recording medium 10, through the reading device 12, and becomes able to operate as the image predictive encoding device according to the present invention, based on the image predictive encoding program P100. When the recording medium 10 storing the image predictive decoding program P200 is put into the reading device 12, the computer 30 becomes accessible to the image predictive decoding program P200 stored in the recording medium 10, through the reading device 12, and becomes able to operate as the image predictive decoding device according to the present invention, based on the image predictive decoding program P200.

List of Reference Signs

[0057] 101: input terminal; 102: block divider; 103: inter-frame predicted signal generation method determiner; 104: inter-frame

predicted signal generator; 105: intra-frame predicted signal generation method determiner; 106: intra-frame predicted signal generator; 109: changeover switch; 110: subtracter; 111: transformer; 112: quantizer; 113: de-quantizer; 114: inverse-transformer; 115: adder; 116: frame memory; 117: intra-frame prediction mode encoder; 118: entropy encoder; 119: output terminal; 700: input terminal; 701: data analyzer; 702: de-quantizer; 703: inverse-transformer; 704: adder; 705: predicted signal generator; 706: frame memory; 707: intra-frame prediction mode restoration unit; 708: output terminal.

CLAIMS

1. An image predictive encoding device comprising:

region division means for dividing an input picture into a plurality of blocks;

predicted signal generation means for determining, from a plurality of prediction modes, an optimum prediction mode with a smallest difference for a pixel signal in a block, the block being a processing target from among the plurality of blocks, and the predicted signal generation means being for generating a predicted signal in accordance with the determined optimum prediction mode;

residual signal generation means for generating a residual signal representing a difference between the pixel signal of the block and the predicted signal;

signal encoding means for encoding the residual signal to generate a compressed signal;

prediction mode encoding means for encoding the optimum prediction mode; and

storage means for restoring the compressed signal and storing a restored signal as a reproduced pixel signal,

wherein the prediction mode encoding means generates a candidate prediction mode list by adding, as elements, optimum prediction modes of a plurality of previously-reproduced blocks neighboring the block, the candidate prediction mode list containing no duplicate prediction modes as the elements, and

wherein the prediction mode encoding means encodes a flag to indicate whether the candidate prediction mode list contains an element

corresponding to the optimum prediction mode.

2. An image predictive encoding method executed by an image predictive encoding device, the image predictive encoding method comprising:

a region division step of dividing an input picture into a plurality of blocks;

a predicted signal generation step of determining, from a plurality of prediction methods, an optimum prediction mode with the smallest difference for a pixel signal in a block, and generating a predicted signal in accordance with the optimum prediction mode, the block being a processing target from among the plurality of blocks;

a residual signal generation step of generating a residual signal representative of a difference between the pixel signal of the block and the predicted signal;

a signal encoding step of encoding the residual signal to generate a compressed signal;

a prediction mode encoding step of encoding the optimum prediction mode; and

a storage step of restoring the compressed signal and storing a restored signal as a reproduced pixel signal,

wherein the prediction mode encoding step comprises:

generating a candidate prediction mode list by adding, as elements, optimum prediction modes of a plurality of previously-reproduced blocks neighboring the block, the candidate prediction mode list containing no duplicate prediction modes as the

elements, and

encoding a flag to indicate whether the candidate prediction mode list contains an element corresponding to the optimum prediction mode.

3. An image predictive decoding device comprising:

input means for accepting input of compressed picture data containing a residual signal and encoded information about a prediction mode, the residual signal being generated by dividing a picture into a plurality of blocks and performing predictive encoding of a block, and the encoded information about the prediction mode being indicative of a generation method of a predicted signal of the block;

restoration means for extracting the residual signal of the block from the compressed picture data to restore a reproduced residual signal;

prediction mode decoding means for restoring the encoded information about the prediction mode to generate an optimum prediction mode;

predicted signal generation means for generating the predicted signal of the block based on the optimum prediction mode;

picture restoration means for adding the predicted signal to the reproduced residual signal to restore a pixel signal of the block; and

storage means for storing the restored pixel signal as a reproduced pixel signal,

wherein the prediction mode decoding means generates a candidate prediction mode list by adding, as elements, optimum

prediction modes of a plurality of previously-reproduced blocks neighboring the block, the candidate prediction mode list containing no duplicate prediction modes as the elements, and

wherein the prediction mode decoding means decodes a flag that indicates whether or not the candidate prediction mode list contains an element corresponding to the optimum prediction mode.

4. An image predictive decoding method executed by an image predictive decoding device, the image predictive decoding method comprising:

an input step of accepting input of compressed picture data containing a residual signal and encoded information about a prediction mode, the residual signal being generated by dividing a picture into a plurality of blocks and performing predictive encoding of a block, and the encoded information about the prediction mode being indicative of a generation method of a predicted signal of the block;

a restoration step of extracting the residual signal of the block from the compressed picture data to restore a reproduced residual signal;

a prediction mode decoding step of restoring the encoded information about the prediction mode to generate an optimum prediction mode;

a predicted signal generation step of generating the predicted signal of the block based on the optimum prediction mode;

a picture restoration step of adding the predicted signal to the reproduced residual signal to restore a pixel signal of the block; and

a storage step of storing the restored pixel signal as a reproduced pixel signal,

wherein the prediction mode decoding step comprises:

generating a candidate prediction mode list by adding, as elements, optimum prediction modes of a plurality of previously-reproduced blocks neighboring the block, the candidate prediction mode list containing no duplicate prediction modes as the elements; and

decoding a flag that indicates whether or not the candidate prediction mode list contains an element corresponding to the optimum prediction mode.

5. An image predictive encoding program that causes a computer to function as:

region division means for dividing an input picture into a plurality of blocks;

predicted signal generation means for determining, from a plurality of prediction modes, an optimum prediction mode with a smallest difference for a pixel signal in a block, the block being a processing target from among the plurality of blocks, and the predicted signal generation means being for generating a predicted signal in accordance with the determined optimum prediction mode;

residual signal generation means for generating a residual signal representing a difference between the pixel signal of the block and the predicted signal;

signal encoding means for encoding the residual signal to

generate a compressed signal;

prediction mode encoding means for encoding the optimum prediction mode; and

storage means for restoring the compressed signal and storing a restored signal as a reproduced pixel signal,

wherein the prediction mode encoding means generates a candidate prediction mode list by adding, as elements, optimum prediction modes of a plurality of previously-reproduced blocks neighboring the block, the candidate prediction mode list containing no duplicate prediction modes as the elements, and

wherein the prediction mode encoding means encodes a flag to indicate whether the candidate prediction mode list contains an element corresponding to the optimum prediction mode.

6. An image predictive decoding program that causes a computer to function as:

input means for accepting input of compressed picture data containing a residual signal and encoded information about a prediction mode, the residual signal being generated by dividing a picture into a plurality of blocks and performing predictive encoding of a block, and the encoded information about the prediction mode being indicative of a generation method of a predicted signal of the block;

restoration means for extracting the residual signal of the block from the compressed picture data to restore a reproduced residual signal;

prediction mode decoding means for restoring the encoded

information about the prediction mode to generate an optimum prediction mode;

predicted signal generation means for generating the predicted signal of the block based on the optimum prediction mode;

picture restoration means for adding the predicted signal to the reproduced residual signal to restore a pixel signal of the block; and

storage means for storing the restored pixel signal as a reproduced pixel signal,

wherein the prediction mode decoding means generates a candidate prediction mode list by adding, as elements, optimum prediction modes of a plurality of previously-reproduced blocks neighboring the block, the candidate prediction mode list containing no duplicate prediction modes as the elements, and

wherein the prediction mode decoding means decodes a flag that indicates whether or not the candidate prediction mode list contains an element corresponding to the optimum prediction mode.