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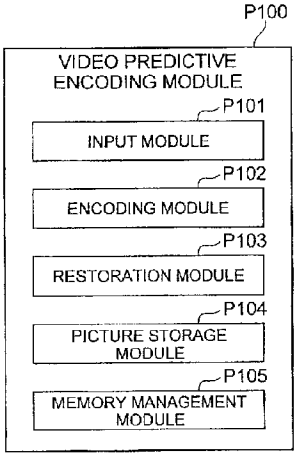


(57) Abrégé/Abstract:
A video predictive encoding device is provided with an encoding device which encodes each of a plurality of input pictures to generate compressed picture data including a random access picture, and which encodes data about display order information of each picture; a restoration device which decodes the compressed picture data to restore a reproduced picture; a picture storage device which stores the reproduced picture as a reference picture; and a memory management device which controls the picture storage device. Following completion of an encoding process of generating the random access picture, the memory management device refreshes the picture storage device by setting every reference picture in the picture storage device, except for the random access picture, as unnecessary immediately before or immediately after encoding a picture with display order information larger than the display order information of the random access picture.

ABSTRACT

A video predictive encoding device is provided with an encoding device which encodes each of a plurality of input pictures to generate compressed picture data including a random access picture, and which encodes data about display order information of each picture; a restoration device which decodes the compressed picture data to restore a reproduced picture; a picture storage device which stores the reproduced picture as a reference picture; and a memory management device which controls the picture storage device. Following completion of an encoding process of generating the random access picture, the memory management device refreshes the picture storage device by setting every reference picture in the picture storage device, except for the random access picture, as unnecessary immediately before or immediately after encoding a picture with display order information larger than the display order information of the random access picture.

MOVING IMAGE PREDICTION ENCODING DEVICE, MOVING IMAGE PREDICTION ENCODING METHOD, MOVING IMAGE PREDICTION ENCODING PROGRAM, MOVING IMAGE PREDICTION DECODING DEVICE, MOVING IMAGE PREDICTION DECODING METHOD, AND MOVING IMAGE PREDICTION DECODING PROGRAM

This application is a divisional of Canadian Patent Application No. 2,935,201 filed March 14, 2011, which is a divisional of Canadian Patent Application No. 2,793,168 filed March 14, 2011.

Technical Field

[0001] The present invention relates to a video predictive encoding device, method, and program and a video predictive decoding device, method, and program.

Background Art

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

[0003] In these encoding systems, a picture as an encoding target is divided into a plurality of blocks and each block is subjected to an encoding/decoding process. The predictive encoding methods as described below are used for enhancement of encoding efficiency. In intra-frame predictive encoding, a predicted signal is encoded. The predicted signal is generated using a neighboring previously-reproduced image signal (restored image signal from image data previously encoded) in the same frame as a target block and a difference signal obtained by subtracting the predicted signal from a signal of the target block. In inter-frame predictive encoding, a search for a displacement

signal is performed with reference to a previously-reproduced image signal in a frame different from a target block. A predicted signal is generated with compensation for the displacement signal identified in the search, and a difference signal obtained by subtracting the predicted signal from the signal of the target block is encoded. The previously-reproduced image signal used as the reference for the motion search and compensation is called a reference picture.

[0004] In bidirectional inter-frame prediction, reference can be made not only to past pictures that are to be displayed prior to a target picture in the display time order, but also future pictures to be displayed after the target picture (provided that the future pictures need to be encoded prior to the target picture and are preliminarily reproduced). Then a predicted signal acquired from a past picture and a predicted signal acquired from a future picture are averaged, which provides effects of allowing effective prediction for a signal of a newly-appearing object, and reducing noise included in the two predicted signals.

[0005] Furthermore, in the inter-frame predictive encoding of H.264, a predicted signal for a target block is produced with reference to a plurality of reference pictures previously encoded and reproduced, and a picture signal with the smallest error is selected as an optimum predicted signal by motion search. Then a difference is calculated between a pixel signal of the target block and this optimum predicted signal, and the difference is subject to discrete cosine transform, quantization, and entropy encoding. At the same time, a piece of information of a reference picture from which the optimum predicted signal for the target block is acquired (reference index) and a piece of

information of a region in the reference picture from which the optimum predicted signal is acquired (motion vector) are also encoded together. In H.264, four or five reproduced pictures are stored as reference pictures in a frame memory. In the present specification the frame memory is assumed to include a so-called reproduced picture buffer (decoded picture buffer).

[0006] The inter-frame predictive encoding allows efficient compression encoding by taking advantage of correlation between pictures, but dependence between frames is eliminated, in order to allow viewing from the middle of a video program, such as what can occur when a viewer is switching TV channels. A point without dependence between frames in a compressed bitstream of a video sequence will be referred to hereinafter as a "random access point." Besides the switching of TV channels, the random access points are also needed in cases of editing a video sequence and joining compressed data of different video sequences. In H.264, IDR pictures are designated, the designated instantaneous decoding refresh (IDR) pictures are encoded by the aforementioned intra-frame predictive encoding method, and at the same time, reproduced pictures stored in the frame memory are set as unnecessary, so that the reproduced pictures are not used for reference pictures, thereby substantially clearing the frame memory (or refreshing the frame memory). This process is called "memory refresh" and is also called "frame memory refresh" or "buffer refresh" in some cases.

[0007] Fig. 11 (A) is a schematic diagram showing a prediction structure of a motion video including an IDR picture. A plurality of

pictures 901, 902, ..., 909 shown in Fig. 11 (A) are part of a series of images constituting a video sequence. Each image is also called a "picture" or "frame." Each arrow indicates a direction of prediction. For example, for the picture 902, a predicted signal is acquired using pictures 903, 905 as reference pictures as indicated by the starting points of two arrows directed to the picture 902. The picture 901 in Fig. 11 (A) is assumed to be encoded with reference to past pictures not shown in Fig. 11 (A). Next, the pictures 902, 903, and 904 are encoded using the aforementioned bidirectional predictive encoding method in order to increase compression rates. Specifically, the picture 905 is first encoded and reproduced and then the picture 903 is encoded with reference to the previously-reproduced pictures 901 and 905 (an arrow from the picture 901 is omitted in Fig. 11 (A)). Thereafter, each of pictures 902 and 904 are encoded using the three reproduced pictures 901, 905, and 903 as reference pictures (an arrow from the picture 901 is omitted in Fig. 11 (A)). Likewise, pictures 906, 907, and 908 are encoded with reference to pictures 905 and 909. The compressed data of the pictures that are encoded (or compressed) in this manner is transmitted or stored in the order as described in Fig. 11 (B). The correspondence or relationship between the compressed data in Fig. 11 (B) and the pictures in Fig. 11 (A) is indicated by common identifiers such as P1, IDR5, and B3. For example, compressed data 910 is compressed data of picture 901 denoted by the same identifier "P1," and compressed data 911 is compressed data of picture 905 denoted by the same identifier "IDR5."

[0008] Now, with consideration to random access, let us consider a case

where the intra-frame predictive coding is carried out while designating the picture 905 as an IDR picture. In this case, according to the rule of IDR in H.264, immediately after reproduction of the picture 905 by decoding of compressed data 911 (or possibly immediately before the start of decoding of compressed data 911), all the reference pictures stored in the frame memory (i.e., the past reproduced pictures including the picture 901) are set as unnecessary so they are not used as reference pictures. As a result, the picture 901 in Fig. 11 (A) is prohibited from being a reference picture, and becomes unavailable for reference in encoding of pictures 902, 903, and 904. The processing associated with the IDR picture as described above is described, for example, in Non Patent Literature 1 below.

Citation List

Patent Literature

[0009] Patent literature 1: International Publication WO2005/006763A1

Non Patent Literature

[0010] Non Patent Literature 1: Iain E.G. Richardson, "H.264 and MPEG-4 Video Compression," John Wiley & Sons, 2003, section 6.4.2.

Summary of Invention

Technical Problem

[0011] Since the introduction of IDR pictures leads to elimination of reference pictures available for use in the foregoing prediction, efficient encoding of pictures before an IDR picture in the display order of pictures (the pictures 902, 903, and 904 in the example of Fig. 11 (A)) is not feasible. In order to solve this problem, Patent literature 1 discloses a method of delaying the timing of refreshment of the frame

memory (i.e., the timing of setting the reference pictures in the frame memory as unnecessary) until execution of encoding a picture to be encoded after the IDR picture occurs. When the timing of refreshment of the frame memory is delayed, the picture 901 remains in the frame memory at the time of execution of encoding the pictures 902, 903, and 904 in Fig. 11 (A), and therefore reference to the picture 901 is available when encoding the pictures 902, 903, and 904, in order to allow efficient encoding thereof.

[0012] Patent literature 1 discloses the methods described below, as methods of delaying the timing of the memory refreshment.

Method 1: add information about the number of pictures to be delayed, to each IDR picture.

Method 2: add to compressed data of each picture a signal that instructs execution of memory refreshment (flag), the signal corresponding to the timing of execution of memory refreshment.

Method 3: define a P picture (unidirectional predicted picture) first appearing after each IDR picture, as timing of refreshment.

[0013] However, the above methods have the following defects.

Defect 1: the above method 1 has such inconvenience that in editing of a video sequence, some pictures out of a plurality of pictures are discarded and other pictures are joined or inserted, so as to make inappropriate the "information about the number of pictures to be delayed" that is added to each IDR picture, causing malfunction.

Defect 2: the above method 2 has such inconvenience that, similarly, to the case of the flag being used, if compressed data of a corresponding picture is deleted by editing of the video sequence, the

flag added to the deleted compressed data is missed, causing malfunction.

Defect 3: the above method 3 has such inconvenience that since the sign (trigger) of memory refreshment is limited to the P pictures, encoding by other methods becomes unavailable. For example, a picture at a change of scene cannot be encoded by intra-frame prediction (I picture).

[0014] The "malfunction" as discussed herein means that a failure in execution of memory refreshment at appropriate timing causes a state in which there is no reference picture necessary for decoding of subsequent data in the frame memory and, as a consequence, a subsequent picture cannot be correctly reproduced.

[0015] The present invention has an object to solve the above-described problem, so as to achieve efficient compression encoding of pictures before and after a picture at a random access point and simultaneously resolve the inconveniences associated with the defects of the conventional technology.

Solution to Problem

[0016] In order to achieve the above object, a video predictive encoding device according to an embodiment of the present invention is a video predictive encoding device comprising: input means, which accepts input of a plurality of pictures constituting a video sequence; encoding means which encodes each of the input pictures by a method of either intra-frame prediction or inter-frame prediction to generate compressed picture data including a random access picture serving as a picture of random access, and which encodes data about display order information

of each of the pictures; restoration means which decodes the compressed picture data thus generated, to restore a reproduced picture; picture storage means which stores the reproduced picture thus restored, as a reference picture to be used for encoding of a subsequent picture; and memory management means which controls the picture storage means, wherein following completion of an encoding process to generate the random access picture, the memory management means refreshes the picture storage means by setting every reference picture stored in the picture storage means except for the random access picture as unnecessary immediately before or immediately after first encoding a picture with display order information larger than the display order information of the random access picture.

[0017] When encoding the display order information of the at least one encoding target that includes a picture which has display order information larger than the display order information of the random access picture and becomes the first encoding target after completion of the encoding process of generating the random access picture, the encoding means may encode a difference value between the display order information of at least one encoding target and the display order information of the random access picture.

[0018] When encoding the display order information of each picture in a sequence from a picture that becomes the next encoding target after the random access picture, to a picture having display order information larger than the display order information of the random access picture and that becomes the first encoding target after completion of the encoding process of generating the random access picture, the encoding

means may encode a difference value between the display order information of each picture and the display order information of the random access picture. [0019] A video predictive decoding device according to an embodiment of the present invention is a video predictive decoding device comprising: input means which accepts input of compressed picture data including a random access picture serving as a picture of random access, which was obtained by encoding each of a plurality of pictures constituting a video sequence by a method of either intra-frame prediction or inter-frame prediction, and display order encoded data obtained by encoding data providing display order information of each of the pictures; restoration means which decodes the compressed picture data to restore a reproduced picture and which decodes the display order encoded data to restore the display order information thereof; picture storage means which stores the reproduced picture thus restored, as a reference picture to be used for decoding of a subsequent picture; and memory management means which controls the picture storage means, wherein after completion of a decoding process of decoding the random access picture the memory management means refreshes the picture storage means by setting every reference picture stored in the picture storage means except for the decoded random access picture as unnecessary immediately before or immediately after first decoding a picture having display order information larger than the display order information of the random access picture.

[0020] When decoding display order information of at least one decoding target picture which has display order information larger than the display order information of the random access picture and which

becomes the first decoding target following completion of the decoding process of decoding the random access picture, the restoration means may restore the display order information of the decoding target picture by adding a difference value to the display order information of the random access picture. The difference value may represent a difference between the display order information of the decoding target picture and the display order information of the random access picture. The display order information of the decoding target picture may be obtained by decoding the display order encoded date of the decoding target picture.

[0021] When decoding display order information of each picture in a sequence from a picture which becomes a next decoding target after the random access picture, to a picture having display order information larger than the display order information of the random access picture, and which becomes the first decoding target after completion of a decoding process of generating the random access picture, the restoration means may restore the display order information of each picture by adding a difference value to the display order information of the random access picture. The difference value may represent a difference between the display order information of each picture and the display order information of the random access picture. The display order information of each picture may be obtained by decoding the display order encoded data of each picture.

[0022] A video predictive encoding method according to an embodiment of the present invention is a video predictive encoding method to be executed by a video predictive encoding device with

picture storage means for storing a reference picture to be used for encoding of a subsequent picture, comprising: an input step of accepting input of a plurality of pictures constituting a video sequence; an encoding step of encoding each of the input pictures by a method of either intra-frame prediction or inter-frame prediction to generate compressed picture data including a random access picture serving as a picture of random access, and encoding data about display order information of each of the pictures; a restoration step of decoding the compressed picture data thus generated, to restore a reproduced picture; a picture storage step of storing the reproduced picture thus restored, as a reference picture to be used for encoding of a subsequent picture; and a memory management step of controlling the picture storage means, wherein, following completion of an encoding process of generating the random access picture, in the memory management step, the video predictive encoding device refreshes the picture storage means by setting every reference picture stored in the picture storage means, except for the random access picture, as unnecessary, immediately before or immediately after encoding a picture having display order information larger than the display order information of the random access picture.

[0023] In the encoding step, the video predictive encoding device may encode a difference value. The difference value may be encoded as data providing display order information of at least one encoding target picture. The at least one encoding target picture may have display order information larger than the display order information of the random access picture and may become the first encoding target picture

following completion of the encoding process of generating the random access picture. The difference value may represent a difference between the display order information of the encoding target picture and the display order information of the random access picture.

[0024] In the encoding step, when encoding each picture in a sequence from a picture which becomes a next encoding target after the random access picture, to a picture which has display order information larger than the display order information of the random access picture, and becoming the first encoding target after completion of the encoding process of generating the random access picture, the video predictive encoding device may encode a difference value. The difference value may be encoded as data providing display order information of each picture. The difference value may represent a difference between the display order information of each picture and the display order information of the random access picture.

[0025] A video predictive decoding method according to an embodiment of the present invention is a video predictive decoding method to be executed by a video predictive decoding device with picture storage means for storing a reference picture to be used for decoding of a subsequent picture, comprising: an input step of accepting input of compressed picture data including a random access picture serving as a picture of random access, which was obtained by encoding each of a plurality of pictures constituting a video sequence by a method of either intra-frame prediction or inter-frame prediction, and display order encoded data obtained by encoding data about display order information of each of the pictures; a restoration step of decoding the

compressed picture data to restore a reproduced picture and decoding the display order encoded data to restore the display order information thereof; a picture storage step of storing the reproduced picture thus restored, as a reference picture to be used for decoding of a subsequent picture, into the picture storage means; and a memory management step of controlling the picture storage means, wherein, after completion of a decoding process of decoding the random access picture, in the memory management step, the video predictive decoding device refreshes the picture storage means by setting every reference picture stored in the picture storage means except for the random access picture as unnecessary, immediately before or immediately after decoding a picture which has display order information larger than the display order information of the random access picture.

[0026] In the restoration step, for display order information of at least one decoding target including a picture which has display order information larger than the display order information of the random access picture and which becomes the first decoding target after completion of the decoding process of decoding the random access picture, the video predictive decoding device may restore the display order information of the decoding target picture by adding a difference value to the display order information of the random access picture. The difference value may represent a difference between the display order information of the decoding target picture and the display order information of the random access picture. The display order information of the decoding target picture may be obtained by decoding the display order encoded data of the decoding target picture.

[0027] In the restoration step, when decoding the display order information of each picture in a sequence from a picture which becomes a next decoding target after the random access picture, to a picture having display order information larger than the display order information of the random access picture and which becomes the first decoding target after completion of a decoding process of generating the random access picture, the video predictive decoding device may restore the display order information of each picture by adding a difference value to the display order information of the random access picture. The difference value may represent a difference between the display order information of each picture and the display order information of the random access picture. The display order information of each picture may be obtained by decoding the display order encoded data of each picture.

[0028] A video predictive encoding program according to an embodiment of the present invention is a video predictive encoding program for letting a computer operate as: input means which accepts input of a plurality of pictures constituting a video sequence; encoding means which encodes each of the input pictures by a method of either intra-frame prediction or inter-frame prediction to generate compressed picture data including a random access picture serving as a picture of random access, and which encodes data about display order information of each of the pictures; restoration means which decodes the compressed picture data thus generated, to restore a reproduced picture; picture storage means which stores the reproduced picture thus restored, as a reference picture to be used for encoding of a subsequent picture;

and memory management means which controls the picture storage means, wherein after completion of an encoding process of generating the random access picture, the memory management means refreshes the picture storage means by setting every reference picture stored in the picture storage means except for the random access picture as unnecessary, immediately before or immediately after encoding a picture with display order information larger than the display order information of the random access picture.

[0029] A video predictive decoding program according to an embodiment of the present invention is a video predictive decoding program for letting a computer operate as: input means which accepts input of compressed picture data including a random access picture serving as a picture of random access, which was obtained by encoding each of a plurality of pictures constituting a video sequence, by a method of either intra-frame prediction or inter-frame prediction, and display order encoded data obtained by encoding data about display order information of each of the pictures; restoration means which decodes the compressed picture data to restore a reproduced picture and which decodes the display order encoded data to restore the display order information thereof; picture storage means which stores the reproduced picture thus restored, as a reference picture to be used for decoding of a subsequent picture; and memory management means which controls the picture storage means, wherein after completion of a decoding process of decoding the random access picture, the memory management means refreshes the picture storage means by setting every reference picture stored in the picture storage means except for the

random access picture as unnecessary, immediately before or immediately after decoding a picture with display order information larger than the display order information of the random access picture.

[0030] The present invention as described above achieves efficient compression encoding of pictures before and after a picture that is a random access point and, at the same time, resolves the inconveniences associated with the defects of the conventional technology.

Advantageous Effects of Invention

[0031] The present invention uses the information indicative of the display order attendant on each respective picture forming a video sequence or compression-encoded picture data (which will be referred to hereinafter as "display order information" (corresponding to the display time, temporal reference information, temporal reference, or the like, in the conventional technology)) to set the timing of memory refreshment. The memory refreshment may be carried out following an intra-frame predicted picture (intra frame) at a random access point to achieve efficient compression encoding of pictures before and after the random access picture in the display order and, at the same time, resolve the inconveniences associated with the defects of the conventional technology as described below.

[0032] Specifically, the display order information is attendant on each picture and therefore there is no need for transmission of new information (flag), thus resolving defect 2 of the conventional technology.

[0033] When a video sequence is edited (e.g., to discard some pictures, or to join other pictures), the display order information of each picture

forming the video sequence is appropriately set, so as to cause no malfunction, resolving defect 1 of the conventional technology.

[0034] Furthermore, the timing of memory refreshment by the present invention is not limited to P pictures and is independent of the encoding types of pictures (I pictures, P pictures, or B pictures), and therefore the processing can be performed in an encoding type with the best encoding efficiency, independent of the necessity of refreshment of the memory, resolving defect 3 of the conventional technology.

[0034a] According to one aspect of the present invention, there is provided a video predictive encoding device comprising: a processor; an input terminal executable by the processor to accept input of a plurality of pictures constituting a video sequence; a predicted signal generator executable by the processor to encode each of the input pictures by a method of either intra-frame prediction or inter-frame prediction to generate compressed picture data for each of the input pictures, the input pictures including a random access picture serving as a picture of random access, and the predicted signal generator further executable by the processor to encode data providing display order information of each of the pictures; a restoration unit executable by the processor to decode the generated compressed picture data to restore a plurality of reproduced pictures; and a frame memory to store the restored reproduced pictures as reference pictures, the reference pictures available for encoding of a subsequent picture in encoding order, and wherein the restoration unit is further executable by the processor to decode display order information and reference picture information included in each of the pictures comprising the compressed picture data, wherein the restoration unit is further executable by the processor to encode a first picture in accordance with the reference picture information using the reference picture, the first picture preceding the random access picture in display order and following the random access picture in encoding order, and encode a second picture that follows the random access picture in display order, the second picture encoded in accordance with the reference picture information using the random access picture as a reference picture without reference to any reference pictures preceding the random access picture in encoding order or in display order, and wherein immediately before the restoration unit encodes the second picture that follows the random access picture in display order, the frame memory is refreshed by setting every reference

picture stored in the frame memory except for the random access picture, as not used as reference pictures.

[0034b] According to another aspect of the present invention, there is provided a video predictive decoding device comprising: a processor; an input terminal executable by the processor to accept input of compressed picture data including a random access picture serving as a picture of random access, the compressed picture data obtained by encoding each of a plurality of pictures constituting a video sequence by a method of either intra-frame prediction or inter-frame prediction, and the input terminal further executable by the processor to accept input of display order encoded data obtained by encoding data providing display order information of each of the pictures; a restoration unit executable by the processor to decode the compressed picture data and restore a plurality of reproduced pictures, the restoration unit further executable by the processor to decode the display order encoded data to restore the display order information; and a frame memory to store the restored reproduced pictures as reference pictures, the reference pictures available for decoding of a subsequent picture in decoding order, wherein the restoration unit is further executable by the processor to decode display order information and reference picture information of each of the pictures included in the compressed picture data, wherein the restoration unit is further executable by the processor to decode a first picture in accordance with the reference picture information using the reference picture, the first picture preceding the random access picture in display order and following the random access picture in decoding order, and decode a second picture that follows the random access picture in display order, the second picture decoded in accordance with the reference picture information using the random access picture as a reference picture without reference to any reference pictures preceding the random access picture in decoding order or in display order, and wherein immediately before the restoration unit decodes the second picture that follows the random access picture in display order, the frame memory is refreshed by setting every reference picture stored in the frame memory except for the random access picture, as not used as reference pictures.

[0034c] According to still another aspect of the present invention, there is provided a video predictive encoding method to be executed by a video predictive encoding device with a frame memory to store reference pictures used to encode a subsequent picture, comprising: accepting, at the video predictive encoding device, input of a plurality of pictures constituting a video sequence; encoding, by the video predictive encoding device, each of the input pictures by either intra-frame prediction or inter-frame prediction to generate compressed picture data for each of the input pictures, the input pictures including a random access picture serving as a picture of random access, and encoding data providing display order information of each of the input pictures; decoding, by the video predictive encoding device, the generated compressed picture data to restore a plurality of reproduced pictures; and storing, by the video predictive encoding device, the restored reproduced pictures in the frame memory as the reference pictures used to encode the subsequent picture, and wherein decoding, by the video predictive encoding device, the generated compressed picture data further comprises, decoding display order information and reference picture information of each of the pictures included in the compressed picture data, wherein encoding, by the video predictive encoding device, comprises encoding, in accordance with the reference picture information, a first picture using the reference picture, the first picture preceding the random access picture in display order and following the random access picture in encoding order, and encoding a second picture that follows the random access picture in display order using the random access picture as a reference picture without reference to any reference pictures preceding the random access picture in encoding order or in display order, and wherein immediately before encoding the second picture that follows the random access picture in display order, the frame memory is refreshed by setting every reference picture stored in the frame memory except for the random access picture, as not used as reference pictures.

[0034d] According to yet another aspect of the present invention, there is provided a video predictive decoding method to be executed by a video predictive decoding device with a frame memory to store reference pictures used to decode a subsequent picture, comprising: accepting, at the video predictive decoding device, input of compressed picture data including a random access picture serving as a picture of random access, the compressed picture data obtained by encoding each of a plurality of pictures constituting a video sequence by either

intra-frame prediction or inter-frame prediction; accepting, by the video predictive decoding device, input of display order encoded data obtained by encoding data providing display order information of each of the pictures; decoding the compressed picture data with the video predictive decoding device to restore reproduced pictures, and decoding with the video predictive decoding device the display order encoded data to restore the display order information; and storing, in the frame memory, the restored reproduced pictures as the reference pictures, the reference pictures available for decoding of the subsequent picture, and wherein decoding further comprises decoding reference picture information of each of the pictures included in the compressed picture data, wherein decoding further comprises decoding, in accordance with the reference picture information, a first picture using the reference picture, the first picture preceding the random access picture in display order and following the random access picture in decoding order, and a second picture that follows the random access picture in display order using the random access picture as a reference picture without reference to any reference pictures preceding the random access picture in decoding order or in display order, and wherein immediately before decoding the second picture that follows the random access picture in display order, the frame memory is refreshed by setting every reference picture stored in the frame memory except for the random access picture, as not used as reference pictures.

Brief Description of Drawings

[0035] Fig. 1 is a functional block diagram showing a configuration of a video predictive encoding device according to an embodiment of the present invention.

Fig. 2 is a functional block diagram showing a configuration of a video predictive decoding device according to an embodiment of the present invention.

Fig. 3 is an operational flowchart showing a video predictive encoding/decoding method according to an embodiment of the present invention.

Fig. 4 is a schematic view for explaining the video predictive encoding/decoding method according to the embodiment of the present invention illustrated in Fig. 3.

Fig 5 is an operational flowchart showing a video predictive encoding/decoding method according to another example embodiment of the present invention.

Fig. 6 is a schematic view for explaining the video predictive encoding/decoding method according to the embodiment of the present

invention illustrated in Fig. 5.

Fig. 7 is a drawing showing a hardware configuration of a computer for executing a program recorded in a recording medium.

Fig. 8 is a schematic view of a computer for executing a program recorded in a recording medium.

Fig. 9 is a block diagram showing a configuration example of a video predictive encoding program.

Fig. 10 is a block diagram showing a configuration example of a video predictive decoding program.

Fig. 11 is a schematic view showing a prediction structure of the conventional video predictive encoding/decoding method.

Description of Embodiments

[0036] Embodiments of the present invention will be described below using Figs. 1 to 10.

[0037] [Regarding Video Predictive Encoding Device]

Fig. 1 is a functional block diagram showing a configuration of a video predictive encoding device 100 according to an embodiment of the present invention. As shown in Fig. 1, the video predictive encoding device 100 is provided with functional components of input terminal 101, block divider 102, predicted signal generator 103, frame memory 104, subtracter 105, transformer 106, quantizer 107, de-quantizer 108, inverse-transformer 109, adder 110, entropy encoder 111, output terminal 112, input terminal 113, and frame memory management unit 114. Operation of the respective functional components will be described in the below-described operation of the video predictive encoding device 100.

[0038] The operation of the video predictive encoding device 100 will be described below. A video signal of a video sequence consisting of a plurality of pictures as targets for an encoding process is fed into the input terminal 101 and the block divider 102 divides each picture into a plurality of regions. In the present embodiment, each picture is divided into a plurality of blocks each consisting of 8×8 pixels, but it may be divided into blocks of any block size or shape other than the foregoing. Next, for a target of a block as an object to be encoded (which will be referred to hereinafter as "target block"), a predicted signal is generated by a below-described prediction method. In the present embodiment, available prediction methods are two types of prediction methods, inter-frame prediction and intra-frame prediction, and the bidirectional inter-frame prediction described in the background art is also applicable to the inter-frame prediction. The respective fundamental operations of the inter-frame prediction and the intra-frame prediction will be summarized below.

[0039] In inter-frame prediction, a reproduced picture having been previously encoded and then restored is used as a reference picture and motion information (e.g., a motion vector) is obtained from the reference picture to provide a predicted signal with the smallest error for the target block. This process is called "motion detection." In some cases, the target block may be subdivided into small regions and the inter-frame prediction method may be determined for a target of each subdivided small region. In such cases, the most efficient division method is determined among a variety of division methods. The determined division method is used to subdivide the target block into

small regions and motion information of each small region for the entire target block are determined. In the present embodiment, the inter-frame prediction is carried out by the predicted signal generator 103. The target block is fed through line L102 to the predicted signal generator 103, while the reference picture is fed through line L104 to the predicted signal generator 103. Concerning the reference picture, a plurality of pictures having been previously encoded and then restored are used as reference pictures. The details thereof are the same as any one of the methods of MPEG-2, MPEG-4, and H.264, which are the conventional technologies. The determined division method information used to determine the small regions, and motion information of each small region are sent from the predicted signal generator 103 through line L112 to the entropy encoder 111. The entropy encoder 111 encodes the determined division method motion information and the motion information of each small region, and the encoded data is sent through line L111 out of output terminal 112. Information indicating from which reference picture the predicted signal is acquired out of the plurality of reference pictures (reference index) is also sent from the predicted signal generator 103 through line L112 to the entropy encoder 111. The reference picture indication information is encoded by the entropy encoder 111, and then the encoded data is sent through line L111 out of the output terminal 112. In the present embodiment, as an example, four or five reproduced pictures are stored in the frame memory 104 and used as reference pictures. The predicted signal generator 103 acquires a reference picture from the frame memory 104, based on the small-region division method, and the

reference picture and motion information for each small region, and generates a predicted signal from the reference picture and motion information (which is called "inter-frame predicted signal" in the sense that it is a predicted signal obtained by inter-frame prediction). The inter-frame predicted signal generated in this manner is sent through line L103 to the subtracter 105 and to the adder 110 for below-described processing.

[0040] On the other hand, the intra-frame prediction is to generate an intra-frame predicted signal, using previously-reproduced pixel values spatially adjacent to a target block. Specifically, the predicted signal generator 103 acquires previously-reproduced pixel signals in the same frame from the frame memory 104 and generates a predicted signal by extrapolation of the previously-reproduced pixel signals (which is called "intra-frame predicted signal" in the sense that it is a predicted signal obtained by intra-frame prediction). The intra-frame predicted signal thus generated is sent from the predicted signal generator 103 through line L103 to the subtracter 105. The method of generating the intra-frame predicted signal in the predicted signal generator 103 is the same as the method of H.264, which is the conventional technology. The information indicating the extrapolation method in the intra-frame prediction is sent from the predicted signal generator 103 through line L112 to the entropy encoder 111, where it is encoded by the entropy encoder 111, and the encoded data is sent out of the output terminal 112.

[0041] The above summarized the respective fundamental operations of the inter-frame prediction and the intra-frame prediction. In practice, for each target block, a predicted signal with the smallest error is

selected from the inter-frame and intra-frame predicted signals obtained as described above, and is sent from the predicted signal generator 103 through line L103 to the subtracter 105.

[0042] Incidentally, since there is no previous picture for the first picture to be encoded, all the target blocks in the first picture are processed by the intra-frame prediction. In preparation for switching of TV channels, all target blocks in a certain picture are periodically processed as a random access point, by the intra-frame prediction. Such pictures are called intra frames and they are called IDR pictures in H.264.

[0043] The subtracter 105 subtracts the predicted signal received through line L103, from the signal of the target block received through line L102, to generate a residual signal. This residual signal is transformed by discrete cosine transform by the transformer 106 and each of the transform coefficients are quantized by the quantizer 107. Finally, the quantized transform coefficients are encoded by the entropy encoder 111 and the resultant encoded data is sent along with the information about the prediction method through line L111 out of the output terminal 112.

[0044] On the other hand, for the intra-frame prediction or the inter-frame prediction for a subsequent target block, the quantized transform coefficients (encoded data of the target block) are de-quantized by the de-quantizer 108 and thereafter the transform coefficients are inversely transformed by inverse discrete cosine transform by the inverse-transformer 109, thereby restoring the residual signal. Then the adder 110 adds the restored residual signal to the

predicted signal sent through the line L103, to reproduce the signal of the target block, and the reproduced signal thus obtained is stored into the frame memory 104. The present embodiment employs the transformer 106 and the inverse-transformer 109, but any other transform process may be employed instead of these. Furthermore, the transformer 106 and the inverse-transformer 109 may be omitted in some cases.

[0045] Incidentally, the capacity of the frame memory 104 is limited and it is actually impossible to store all reproduced pictures. For this reason, only reproduced pictures used for encoding of a subsequent picture are stored in the frame memory 104. A unit to control the frame memory 104 is the frame memory management unit 114. The frame memory management unit 114 controls the frame memory 104 in such a manner that the oldest reproduced picture is deleted out of N (e.g., N=4) reproduced pictures stored in the frame memory 104, to allow the most recent reproduced picture used as a reference picture, to be stored in the frame memory 104. In fact, the frame memory management unit 114 receives input of display order information of each picture and type information for encoding of each picture (intra-frame predictive encoding, inter-frame predictive encoding, or bidirectional predictive encoding) from the input terminal 113, and the frame memory management unit 114 operates based on these pieces of information. At this time, the display order information of each picture is sent from the frame memory management unit 114 through line L114 to the entropy encoder 111, where it is encoded by the entropy encoder 111. The display order information thus encoded is sent

together with the encoded picture data through line L111 out of the output terminal 112. The display order information is information that is attendant on each picture, and may be information indicative of an order of the picture, or information indicative of a time of display of the picture (e.g., a display reference time of the picture (temporal reference)). In the present embodiment, for example, the display order information itself is encoded by binary encoding. The control method by the frame memory management unit 114 will be described later.

[0046] [Regarding Video Predictive Decoding Device]

Next, a video predictive decoding device according to the present invention will be described. Fig. 2 is a functional block diagram showing a configuration of video predictive decoding device 200 according to an embodiment of the present invention. As shown in Fig. 2, the video predictive decoding device 200 is provided with functional components of input terminal 201, data analyzer 202, de-quantizer 203, inverse-transformer 204, adder 205, predicted signal generator 208, frame memory 207, output terminal 206, and frame memory management unit 209. Operations of the respective functional component will be described in operation of the video predictive decoding device 200 described below. The means associated with decoding does not always have to be limited to the de-quantizer 203 and inverse-transformer 204. In other embodiments, any means other than these may be employed. In some example embodiments, the means associated with decoding may be composed of only the de-quantizer 203, without the inverse-transformer 204.

[0047] The operation of the video predictive decoding device 200 will

be described below. The compressed data obtained by the aforementioned encoding method is fed through the input terminal 201. This compressed data contains the residual signal of the target block, the prediction signal generation information describing generation of the predicted signal, the quantization parameter, the display order information of the picture, and the encoding type information indicating the encoding type of the picture. Among these, the prediction signal generation information, for example in the case of the inter-frame prediction, contains the information about block division (the small-region division method information (e.g., the size of block or the like)), the motion information of each small region, and the reference index. In the case of the intra-frame prediction, the prediction signal generation information contains the information about the extrapolation method.

[0048] The data analyzer 202 extracts the residual signal of the target block, the prediction signal generation information associated with the generation of the predicted signal, the quantization parameter, the display order information of the picture, and the encoding type information indicating the encoding type of the picture from the input compressed data. Among these, the residual signal of the target block and the quantization parameter are fed through line L202 to the de-quantizer 203, the de-quantizer 203 de-quantizes the residual signal of the target block on the basis of the quantization parameter, and the inverse-transformer 204 inversely transforms the result of the de-quantization by inverse discrete cosine transform. The residual signal restored in this manner is sent through line L204 to the adder 205.

[0049] On the other hand, the extracted prediction signal generation information describing the generation of the predicted signal is sent through line L206b to the predicted signal generator 208. The predicted signal generator 208 acquires an appropriate reference picture out of a plurality of reference pictures stored in the frame memory 207, based on the prediction signal generation information describing the generation of the predicted signal, and generates a predicted signal on the basis of the appropriate reference picture. The predicted signal thus generated is sent through line L208 to the adder 205, and the adder 205 adds the predicted signal to the restored residual signal, so as to reproduce the signal of the target block. The signal of the target block thus reproduced is output through line L205 from the output terminal 206 and, at the same time, it is stored as a reproduced picture into the frame memory 207.

[0050] Reproduced pictures used for decoding or reproduction of a subsequent picture are stored in the frame memory 207. The frame memory management unit 209 controls the frame memory 207 in such a manner that the oldest reproduced picture is deleted out of N (which is N=4 as an example herein, but may be any predetermined integer). The oldest reproduced picture stored in the frame memory 207 is deleted to allow the most recent reproduced picture used as a reference picture, to be stored into the frame memory 207. The frame memory management unit 209 operates based on the display order information of the target picture and the information about the encoding type of the picture, which are fed through line L206a. The control method by the frame memory management unit 209 will be described later.

[0051] An intra frame (intra-frame predicted picture) serving as a random access point is called an IDR picture (instantaneous decoder refresh) in H.264, and this name originates from the fact that the frame memory (decoder buffer) is refreshed instantaneously after encoding or decoding of an IDR picture. In contrast, the present invention executes refreshment of the frame memory after a temporary standby (or delay), instead of executing the refreshment of the frame memory immediately after encoding or decoding of an intra frame as a random access point (or immediately before the encoding or the decoding). Thus, in the present invention this picture is called a DDR picture (deferred decoder refresh or delayed decoder refresh). As described below in detail, the timing of refreshment of the frame memory is determined based on comparison between the display order information of a DDR picture and the display order information of a picture as a target for processing (encoding or decoding) (which will be referred to hereinafter as "processing target picture").

[0052] [Characteristic Processing Operations of Video Predictive Encoding Method and Video Predictive Decoding Method]

The operations of the video predictive encoding method and the video predictive decoding method according to the present invention will be described below using Figs. 3 and 4. Fig. 3 is a flowchart showing operation of the video predictive encoding/decoding method according to the present embodiment. Fig. 3 will be described below as the video encoding method. However, Fig. 3 is also applicable to the video decoding method.

[0053] First, meanings of variables used in Fig. 3 will be described.

TR means display order information, TR_DDR means display order information of a DDR picture, TR_CUR means display order information of a processing target picture at a point of interest or at a time of processing the processing target picture such that the processing target picture is the current target picture, and RP means a state variable indicative of whether refreshment of the frame memory 104 is in standby. A case of RP=1 indicates a state in which after a DDR picture becomes a processing target, refreshment of the frame memory 104 has not yet been executed (i.e., a state in which refreshment of the frame memory is in standby), and a case of RP=0 indicates a state in which refreshment of the frame memory 104 has already been executed, or a state in which the refreshment process is not needed.

[0054] In Fig. 3, at a start of encoding of a video signal, first, TR_DDR and RP are initialized to 0 (step 301). Step 302 is to check whether RP=1 and whether TR_CUR of the processing target picture is larger than TR_DDR of the DDR picture. When these conditions are met, it is indicated that the frame memory refreshment is in standby and that the processing target picture is a picture in the series of pictures after a DDR picture, and thus the refreshing process of the frame memory 104 (i.e., a process of setting reference pictures stored in the frame memory 104, as unnecessary) is executed (step 303). It is, however, noted that the reference pictures stored in the frame memory 107 that are set as unnecessary are only reference pictures with the display order information TR smaller than the display order information of the most recent DDR picture (TR_DDR). The most recent DDR picture (or intra-frame predictive encoded picture) stored in the frame memory 104

is not set to be unnecessary. After completion of the refreshing process as described above, the state variable RP is set to RP=0.

[0055] On the other hand, when the aforementioned conditions are not met in step 302, the operation proceeds to step 304 to check whether the current processing target picture is a DDR picture. It is assumed in the video predictive encoding device 100 that the encoding type information about the encoding type of the picture (DDR, inter-frame predictive encoding, or bidirectional predictive encoding) is supplied through the input terminal 113 in Fig. 1 from a control device (not shown). When it is determined in step 304 that the current processing target picture is a DDR picture, step 305 is carried out to set the display order information TR_CUR of the current processing target picture to TR_DDR and to set the state variable RP to RP=1, and then the operation proceeds to step 306. On the other hand, when the condition is not satisfied in step 304, the operation proceeds to step 306.

[0056] Step 306 is to obtain a reproduced picture corresponding to the processing target picture. In this step, the processing target picture is encoded to obtain compressed data that is compressed by the encoding method described with reference to Fig. 1, and the compressed data is further decoded to obtain a reproduced picture (the reproduced picture corresponding to the processing target picture). The compressed data obtained by encoding is sent to the outside of the video predictive encoding device 100. Alternatively, the compressed data may be stored in a memory (not shown) that may be included in the video predictive encoding device 100. Next step 307 is to determine whether the reproduced picture corresponding to the processing target picture is

to be used as a reference picture in a subsequent process. This determination is made based on the encoding type of the picture. It is assumed in the present embodiment that a DDR picture, a unidirectional predictive encoded picture, and a specific bidirectional predictive encoded picture all are determined to be used as reference pictures, which are stored. It is, however, noted that the present invention is not limited to these encoding types or determination method.

[0057] When it is determined in step 307 that the reproduced picture is not used as a reference picture, the reproduced picture is not stored in the frame memory 104 and the operation proceeds to step 309. On the other hand, if it is determined in step 307 that the reproduced picture is used as a reference picture, step 308 is carried out to store the reproduced picture in the frame memory 104, and then the operation proceeds to step 309.

[0058] At step 309 it is determined whether there is a next picture (unprocessed picture), and if there is a next picture, the operation returns to step 302 to repeat the processes of steps 302 to 308 for the next picture. The processes of steps 302 to 308 are repeatedly carried out until the last picture is processed. In this manner and, after completion of the processing for all the pictures, the processing of Fig. 3 is terminated.

[0059] By the above-described processing of Fig. 3, after completion of the processing of a random access picture (the most recent DDR picture herein), the frame memory 104 is refreshed at a time of processing a picture having display order information (TR) larger than TR_DDR (in fact, in step 303 before the process of step 306). The timing of

refreshing the frame memory may be at any time after completion of the processing of the random access picture (the most recent DDR picture herein) when processing a picture with the display order information TR larger than TR_DDR, and may occur immediately after the process of step 306.

[0060] The aforementioned processing of Fig. 3 corresponds to the overall processing of the video predictive encoding device 100 in Fig. 1, and, particularly, the processes of steps 302 to 305 are carried out by the frame memory management unit 114.

[0061] Fig. 3 was described as the video encoding method, but is also applicable to the processing of the video decoding method. In execution of the decoding processing, step 301 further includes receipt of data of a compression-encoded picture (bitstream). The display order information and encoding type of a target picture are extracted from the data and the operations of steps 302 to 305 are carried out by the same method as above. In execution of the decoding process, step 306 carries out a process of decoding the compressed data of the target picture to restore the picture. The processes of step 307 and the subsequent steps are as described above. This processing corresponds to the overall processing of the video predictive decoding device 200 in Fig. 2 and, particularly, the processes of steps 302 to 305 are carried out by the frame memory management unit 209.

[0062] Fig. 4 is a schematic diagram for explaining processing of the video predictive encoding/decoding method according to the present embodiment. Pictures 401 to 409 shown in Fig. 4 are some of a series of pictures constituting a video sequence, and the picture 401 indicates a

state in which there are n pictures prior thereto. Therefore, as shown in region 418 of Fig. 4, the display order information TR of picture 401 is represented by (n+1). Since the present embodiment is assumed to perform the encoding/decoding processing including bidirectional prediction, Fig. 4 shows a state in which the picture 402 with TR=(n+5) is first processed, and thereafter the pictures 403, 404, and 405, which are supposed to be displayed prior to the picture 402 are processed. For the same reason, the picture 403 with the display order of (n+3) is processed prior to the picture 404 with the display order of (n+2). This order is the same as in Fig. 11 (B). It is noted that "process a picture" hereinafter refers to "encode or decode a picture."

[0063] The identifiers written in frames of pictures 401 to 409 in Fig. 4 have the following meanings. Namely, "P" means a picture encoded by unidirectional prediction, "DDR" means a picture encoded as a DDR picture, and each of "B" and "b" means a picture encoded by bidirectional prediction. The pictures except for those indicated by uncapitalized b (i.e., pictures indicated by capitalized B, P, and DDR) all are assumed to be used as reference pictures. The value of RP for each picture in region 420 and the value of TR_DDR in region 419 in Fig. 4 are values immediately after completion of processing for each picture, but are not values at a start of processing for each picture (i.e., at the time of entry into step 302 in Fig. 3). For example, RP=0 at the start of the processing for the picture 402, but RP=1 immediately after completion of the processing for the picture 402.

[0064] In the processing of the picture 401, since the picture 401 is not a DDR picture, it results in RP=0. TR_DDR corresponding to the

picture 401 may take any value, except a value stored by the preceding processing is set. Since the picture 401 indicated by capitalized P1 is used as a reference picture, it is stored into the frame memory.

[0065] Subsequently, the processing of the picture 402 will be described with reference to Fig. 3. At this time, the reproduced picture P1 is stored in the frame memory, as shown in region 410 in the bottom row in Fig. 4. Since RP=0 at the time of the start of processing of the picture 402, step 302 results in negative determination and the operation proceeds to step 304. Since the picture 402 is a DDR picture, step 304 results in positive determination and step 305 is carried out to set RP=1 and TR_DDR=n+5. Since the picture 402 is used as a reference picture, it is stored into the frame memory.

[0066] At a point of starting processing of the next picture 403, as shown in region 411 in Fig. 4, the pictures P1 and DDR5 are stored in the frame memory. At this time, RP=1, but the display order TR (n+3) of the picture 403 is smaller than TR_DDR (n+5) and the picture 403 is not a DDR picture; therefore, steps 302, 304 result in a negative determination and the picture 403 is encoded or decoded as it is (step 306). Since the picture 403 is used as a reference picture, it is stored in the frame memory.

[0067] On the occasion of processing the pictures 404 and 405, refreshment of the frame memory is still in a standby state (RP=1). Since the pictures 404 and 405 are not used as reference pictures, the pictures 404 and 405 are not stored into the frame memory as shown in regions 412, 413 in Fig. 4, while the pictures P1, DDR5, and B3 remain stored therein.

[0068] RP=1 at a point of a start of processing of the picture 406; since the display order information TR (n+9) of the picture 406 is larger than TR_DDR (n+5), step 302 results in positive determination and step 303 is carried out to set the reference pictures as unnecessary, to refresh the frame memory, and set RP=0. The reference pictures set as unnecessary at this time are only the reference pictures with the display order information TR smaller than that of the most recent DDR picture 402, except for the most recent DDR picture 402. Therefore, as shown in region 414 in Fig. 4, storage areas of the picture P1 and the picture B3 are released in the frame memory, with the result that only the picture DDR5 remains stored. The picture 406, which is used as a reference picture, is stored into the frame memory after completion of the processing of the picture 406, as shown in region 415 in Fig. 4, and thereafter the refresh control of the frame memory is carried out in the same manner as above.

[0069] Since the reference picture in the frame memory (picture P1 in Fig. 4) is not set as unnecessary, immediately after or immediately before the processing of the DDR picture 402 as described above, reference can be made to the picture P1 in the processing of the pictures 403, 404, and 405 processed after the DDR picture 402, and this contributes to an improvement in encoding efficiency. Since the most recent DDR picture 402 (picture DDR5) is not set as unnecessary in execution of refreshment of the frame memory after the processing of the DDR picture 402, the most recent DDR picture 402 (picture DDR5) can be used as a reference picture in the processing of the subsequent pictures 407, 408, and 409.

[0070] As described above, the present embodiment makes use of the display order information included with each respective picture to set the timing of the memory refreshment that is carried out after the processing of the intra-frame predicted picture (DDR picture) serving as a point of random access. The timing of the memory refreshment is based on the display order information, thereby achieving efficient compression encoding of pictures before and after a random access picture. It also resolves the inconveniences associated with the defects of the conventional technology, as described below.

[0071] Namely, since the display order information is always includes with each respective picture, there is no need for transmission of new information (flag), which resolves the defect 2 of the conventional technology. Furthermore, in the case of editing of a video signal (e.g., to discard some of pictures or to join different pictures), pieces of display order information of the respective pictures constituting the video signal are also appropriately set so as to cause no malfunction, which resolves the defect 1 of the conventional technology. Furthermore, since the timing of the memory refreshment according to the present invention is not limited to P pictures, and is independent of the encoding types of pictures (I pictures, P pictures, and B pictures), each picture is processed in an encoding type with the highest encoding efficiency, independent of the necessity of refreshment of the memory, which resolves the defect 3 of the conventional technology.

[0072] [Regarding Modification Example Embodiment]

The foregoing embodiments describe the processing in the case where the display order information of each picture was encoded as an

"absolute value." In another embodiment, the display order information of each picture is encoded as "difference value," in order to increase the encoding efficiency. The below will describe the embodiment in which the display order information is encoded as "difference value," as a modification example.

[0073] Fig. 5 shows a flowchart of the modification example of the video predictive encoding/decoding method. In this embodiment the display order information of each picture is encoded as follows. Namely, for each picture that becomes a processing target during standby of refreshment of the frame memory (i.e. RP=1), a difference value between the display order information of the target picture and the display order information of the DDR picture is encoded. On the other hand, for each picture that becomes a processing target at a time when refreshment of the frame memory 104 has already been executed, or at a time when the refreshment process is not needed (i.e. RP=0), the display order information thereof is encoded by any method. For example, a difference from the display order information of the DDR picture may be encoded, or a difference from the display order information of an immediately preceding picture in the encoding order may be encoded.

[0074] In the modification example operation below, Fig. 5 will be described as the video decoding method, but it should be understood that Fig. 5 is also applicable to the video encoding method. Step 501 in Fig. 5 is to receive input data of a compression-encoded picture into the video predictive decoding device 200, and to extract from the data, a difference value (delta_TR) of the display order information of the target picture, and information about the encoding type of the picture.

At the same time, TR_DDR and RP are initialized to 0.

[0075] Next step 502 is to check whether RP=1. When this condition is met, it is meant thereby that the refreshment of the frame memory is on standby, and thus the operation proceeds to step 503. Step 503 is to set the display order information TR_CUR of the current processing target picture to the sum of TR_DDR and delta_TR.

[0076] Next, step 504 is to check whether TR_CUR is larger than TR_DDR. When this condition is met, it means that the refreshment of the frame memory is on standby (RP=1) and that the processing target picture is a picture after the DDR picture in the display order, and thus the refresh process of the frame memory 207 (i.e., a process of setting the reference pictures stored in the frame memory 207, as unnecessary) is executed (step 505). However, the reference pictures set as unnecessary are only the reference pictures with the display order information TR smaller than the display order information of the most recent DDR picture (TR_DDR). The most recent DDR picture (or intra-frame predictive encoded picture) is not set as unnecessary. After completion of the refresh process as described above, the state variable RP is set to RP=0. Thereafter, the operation proceeds to below-described step 507. When the aforementioned step 504 results in negative determination, the operation also proceeds to step 507.

[0077] On the other hand, when step 502 results in a negative determination(i.e. RP = 0), the operation proceeds to step 506 to set TR_CUR to the sum of the display order information TR_PREV of a previously processed picture and delta_TR, and then the operation proceeds to step 507.

[0078] Step 507 is to check whether the current processing target picture is a DDR picture. The video predictive decoding device 200 can obtain the encoding type information about the encoding type of the picture (DDR, inter-frame predictive encoding, or bidirectional predictive encoding) from the compression-encoded data input from the outside.

[0079] When it is determined in step 507 that the current processing target picture is a DDR picture, step 508 is carried out to set the display order information TR_CUR of the current processing target picture to TR_DDR and set the state variable RP to RP=1, and then the operation proceeds to step 509. On the other hand, when the condition is not met in step 507, the operation proceeds to step 509.

[0080] Step 509 is to obtain a reproduced picture corresponding to the processing target picture. In this case, the reproduced picture corresponding to the processing target picture is obtained by decoding the compressed data of the processing target picture by the decoding method described with reference to Fig. 2. The reproduced picture obtained herein is sent, for example, external to the video predictive decoding device 200. Next step 510 is to determine whether the reproduced picture corresponding to the processing target picture is to be used as a reference picture in subsequent processing. This determination is made based on the encoding type of the picture. In this case, a DDR picture, a unidirectional predictive encoded picture, and a specific bidirectional predictive encoded picture all are determined to be reference pictures. It is, however, noted that the present invention is not limited to these encoding types or determination

method.

[0081] When it is determined in step 510 that the reproduced picture is not used as a reference picture, the operation proceeds to step 512 without storing the reproduced picture into the frame memory 207. On the other hand, when it is determined in step 510 that the reproduced picture is used as a reference picture, step 511 is carried out to store the reproduced picture into the frame memory 207, and then the flow proceeds to step 512.

[0082] Step 512 is to set TR_CUR to TR_PREV, for the subsequent process of step 506, and then the operation proceeds to step 513. Step 513 is to determine whether there is a next picture (unprocessed picture), and if there is a next picture, the operation returns to step 502 to repeat the processes of steps 502 to 512 for the next picture. The processes of steps 502 to 512 are repeatedly carried out up to the last picture in this manner and after completion of the processing for all the pictures, the processing of Fig. 5 is terminated.

[0083] By the above-described processing operation of Fig. 5, after completion of the processing of a random access picture (the most recent DDR picture) the frame memory is refreshed at a time when a picture having display order information TR that is larger than TR_DDR is processed(in fact, in step 505 before the process of step 509). The timing of refreshment of the frame memory may be any time after completion of the processing of the random access picture (the most recent DDR picture herein), when processing a picture with display order information TR that is larger than TR_DDR, and may be a time immediately after the process of step 509.

[0084] The aforementioned processing of Fig. 5 corresponds to the overall processing of the video predictive decoding device 200 in Fig. 2 and, particularly, steps 502 to 508 are carried out by the frame memory management unit 209.

[0085] The operation of Fig. 5 was described as a video decoding method but it is also applicable to the processing of a video encoding method. In the case of execution of encoding processing, step 503 is to obtain delta_TR from the difference between TR_CUR and TR_DDR, and step 506 is to determine delta_TR from the difference between TR_CUR and TR_PREV, followed by entropy encoding. Furthermore, step 509 is to encode the target picture and then decode the picture. This processing corresponds to the overall processing of the video predictive encoding device 100 in Fig. 1 and, particularly, the processes of steps 502 to 508 are carried out by the frame memory management unit 114.

[0086] Fig. 6 is a schematic diagram for explaining the processing of the video predictive encoding/decoding method according to the modification example embodiment. Pictures 601 to 609 shown in Fig. 6 are some of a series of pictures constituting a video sequence and show the same processing as the pictures 401 to 409 described with reference to Fig. 4. However, Fig. 6 includes delta_TR shown in region 621, in addition to the regions of Fig. 4. As seen from region 621, determination of delta_TR is different depending upon the value of RP at a start of the encoding process of a target picture (the RP value of a previous picture). Namely, in the encoding processes of pictures 603 to 606, delta_TR is obtained as a difference value between TR of each

picture and TR_DDR. In the encoding processes of picture 607 and the subsequent pictures, delta_TR is obtained as a difference value between TR of a target picture and TR of a picture immediately before the target picture. For example, TR of picture 607 is subtracted from TR of picture 606 to obtain delta_TR of picture 607. On the other hand, when the display order information TR is restored from the difference value delta_TR in the decoding process of each picture, the display order information TR is restored by adding the difference value delta_TR obtained by decoding the compressed data of the difference value, to TR_DDR. The processing thereafter is the same as that in Fig. 4 and is thus omitted herein.

[0087] In Fig. 6, even if the pictures 603 to 605 are missed by editing, since the display order information TR of the picture 606 is determined from TR_DDR, it can be correctly reconstructed as TR = delta_TR + TR_DDR = 4 + (n + 5) = n + 9, and the refreshment of the frame memory can be controlled without malfunction. If delta_TR of every picture is obtained as a difference value between the display order information of the picture and the display order information of a picture immediately before it in the decoding order, and if the picture 603 is missed, the display order information cannot be correctly reproduced and refreshment of the frame memory will be executed at the timing of the picture 605 (though, originally, the timing of the picture 606 is correct timing).

[0088] In the case where the embodiment of Fig. 6 is applied to the video encoding process, when encoding the display order information of each picture (pictures 603-606) and awaiting refreshment of the frame

memory, after completion of the processing of the random access picture (the most recent DDR picture herein), the difference value delta_TR between the display order information TR of the current picture and the display order information TR_DDR of the DDR picture may be encoded, instead of encoding the display order information TR of the current picture itself, to thereby correctly decode the timing of refreshment of the frame memory. For this reason, even if a picture waiting for refreshment of the frame memory is lost, malfunction can be avoided, achieving an effect of high error resistance.

[0089] As still another example, the difference value delta_TR may be encoded for at least one picture which includes a picture for which the display order information TR is larger than the TR_DDR (picture 606 in Fig. 6), and which comes after the random access picture (the most recent DDR picture herein),. Namely, when encoding the display order information of at least one picture which has display order information TR larger than TR_DDR (picture 606 in Fig. 6), and which comes after the random access picture (the most recent DDR picture herein), the difference value delta_TR between the display order information TR of the pertinent picture and the display order information TR_DDR of the DDR picture may be encoded, instead of encoding the display order information TR of the pertinent picture itself.

[0090] [Regarding Video Predictive Encoding Program and Video Predictive Decoding Program]

The invention of the video predictive encoding device can also be interpreted as the invention of a video predictive encoding program for controlling a computer to function as the video predictive encoding

device. Likewise, the invention of the video predictive decoding device can also be interpreted as the invention of a video predictive decoding program for controlling a computer to function as the video predictive decoding device.

[0091] The video predictive encoding program and the video predictive decoding program are provided, for example, as stored in a recording medium. Examples of such recording media include recording media such as flexible disks, CD-ROMs, and DVDs, or recording media such as ROMs, or semiconductor memories or the like.

[0092] Fig. 9 shows modules of the video predictive encoding program for controlling a computer to function as the video predictive encoding device. As shown in Fig. 9, the video predictive encoding program P100 is provided with input module P101, encoding module P102, restoration module P103, picture storage module P104, and memory management module P105.

[0093] Fig. 10 shows modules of the video predictive decoding program for controlling a computer to function as the video predictive decoding device. As shown in Fig. 10, the video predictive decoding program P200 is provided with input module P201, restoration module P202, picture storage module P203, and memory management module P204.

[0094] The video predictive encoding program P100 and the video predictive decoding program P200 configured as described above can be stored in a recording medium 10 shown in Fig. 8 and are executed by computer 30 described below.

[0095] Fig. 7 is a drawing showing a hardware configuration of a

computer for executing a program recorded in a recording medium and Fig. 8 is a schematic view of a computer for executing a program stored in a recording medium. The computer may be, a DVD player, a set-top box, a cell phone, etc. which are provided with a CPU and are configured to perform processing and control by software.

[0096] As shown in Fig. 7, the computer 30 can be 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 for storing programs and data, which may also or alternatively be stored elsewhere such as in the recording medium 10, a monitor unit 18 like a display, a mouse 20 and a keyboard 22 as input devices, a communication device 24 for transmission and reception of data or the like, and a CPU 26 for controlling execution of programs. For example, when the recording medium 10 is put into the reading device 12, the computer 30 becomes accessible to the video predictive encoding program stored in the recording medium 10, through the reading device 12 and becomes able to operate as the video predictive encoding device according to the present invention, based on the video predictive encoding program. Similarly, in another example, when the recording medium 10 is put into the reading device 12, the computer 30 becomes accessible to the video predictive decoding program stored in the recording medium 10, through the reading device 12 and becomes able to operate as the video predictive decoding device according to the present invention, based on the video predictive decoding program.

[0097] As shown in Fig. 8, the video predictive encoding program or

the video predictive decoding program may be provided in the form of computer data signal 40 superimposed on a carrier wave, through a network. In this case, the computer 30 can execute the program after the video predictive encoding program or the video predictive decoding program received by the communication device 24 is stored into the memory 16.

List of Reference Signs

[0098] 10: recording medium; 30: computer; 100: video predictive encoding device; 101: input terminal; 102: block divider; 103: predicted signal generator; 104: frame memory; 105: subtracter; 106: transformer; 107: quantizer; 108: de-quantizer; 109: inverse-transformer; 110: adder; 111: entropy encoder; 112: output terminal; 113: input terminal; 114: frame memory management unit; 200: video predictive decoding device; 201: input terminal; 202: data analyzer; 203: de-quantizer; 204: inverse-transformer; 205: adder; 206: output terminal; 207: frame memory; 208: predicted signal generator; 209: frame memory management unit; P100: video predictive encoding program; P101: input module; P102: encoding module; P103: restoration module; P104: picture storage module; P105: memory management module; P200: video predictive decoding program; P201: input module; P202: restoration module; P203: picture storage module; P204: memory management module.

1. A video predictive encoding device comprising:

a processor;

an input terminal executable by the processor to accept input of a plurality of pictures constituting a video sequence;

a predicted signal generator executable by the processor to encode each of the input pictures by a method of either intra-frame prediction or inter-frame prediction to generate compressed picture data for each of the input pictures, the input pictures including a random access picture serving as a picture of random access, and the predicted signal generator further executable by the processor to encode data providing display order information of each of the pictures;

a restoration unit executable by the processor to decode the generated compressed picture data to restore a plurality of reproduced pictures; and

a frame memory to store the restored reproduced pictures as reference pictures, the reference pictures available for encoding of a subsequent picture in encoding order, and

wherein the restoration unit is further executable by the processor to decode display order information and reference picture information included in each of the pictures comprising the compressed picture data,

wherein the restoration unit is further executable by the processor to encode a first picture in accordance with the reference picture information using the reference picture, the first picture preceding the random access picture in display order and following the random access picture in encoding order, and encode a second picture that follows the random access picture in display order, the second picture encoded in accordance with the reference picture information using the random access picture as a reference picture without reference to any reference pictures preceding the random access picture in encoding order or in display order, and

wherein immediately before the restoration unit encodes the second picture that follows the random access picture in display order, the frame memory is refreshed by setting every reference picture stored in the frame memory except for the random access picture, as not used as reference pictures.

2. A video predictive decoding device comprising:

a processor;

an input terminal executable by the processor to accept input of compressed picture data including a random access picture serving as a picture of random access, the compressed picture data obtained by encoding each of a plurality of pictures constituting a video sequence by a method of either intra-frame prediction or inter-frame prediction, and the input terminal further executable by the processor to accept input of display order encoded data obtained by encoding data providing display order information of each of the pictures;

a restoration unit executable by the processor to decode the compressed picture data and restore a plurality of reproduced pictures, the restoration unit further executable by the processor to decode the display order encoded data to restore the display order information; and

a frame memory to store the restored reproduced pictures as reference pictures, the reference pictures available for decoding of a subsequent picture in decoding order,

wherein the restoration unit is further executable by the processor to decode display order information and reference picture information of each of the pictures included in the compressed picture data,

wherein the restoration unit is further executable by the processor to decode a first picture in accordance with the reference picture information using the reference picture, the first picture preceding the random access picture in display order and following the random access picture in decoding order, and decode a second picture that follows the random access picture in display order, the second picture decoded in accordance with the reference picture information using the random access picture as a reference picture without reference to any reference pictures preceding the random access picture in decoding order or in display order, and

wherein immediately before the restoration unit decodes the second picture that follows the random access picture in display order, the frame memory is refreshed by setting every reference picture stored in the frame memory except for the random access picture, as not used as reference pictures.

3. A video predictive encoding method to be executed by a video predictive encoding device with a frame memory to store reference pictures used to encode a subsequent picture, comprising:

accepting, at the video predictive encoding device, input of a plurality of pictures constituting a video sequence;

encoding, by the video predictive encoding device, each of the input pictures by either intra-frame prediction or inter-frame prediction to generate compressed picture data for each of the input pictures, the input pictures including a random access picture serving as a picture of random access, and encoding data providing display order information of each of the input pictures;

decoding, by the video predictive encoding device, the generated compressed picture data to restore a plurality of reproduced pictures; and

storing, by the video predictive encoding device, the restored reproduced pictures in the frame memory as the reference pictures used to encode the subsequent picture, and

wherein decoding, by the video predictive encoding device, the generated compressed picture data further comprises, decoding display order information and reference picture information of each of the pictures included in the compressed picture data,

wherein encoding, by the video predictive encoding device, comprises encoding, in accordance with the reference picture information, a first picture using the reference picture, the first picture preceding the random access picture in display order and following the random access picture in encoding order, and encoding a second picture that follows the random access picture in display order using the random access picture as a reference picture without reference to any reference pictures preceding the random access picture in encoding order or in display order, and

wherein immediately before encoding the second picture that follows the random access picture in display order, the frame memory is refreshed by setting every reference picture stored in the frame memory except for the random access picture, as not used as reference pictures.

4. A video predictive decoding method to be executed by a video predictive decoding device with a frame memory to store reference pictures used to decode a subsequent picture, comprising:

accepting, at the video predictive decoding device, input of compressed picture data including a random access picture serving as a picture of random access, the compressed picture data obtained by encoding each of a plurality of pictures constituting a video sequence by either intra-frame prediction or inter-frame prediction;

accepting, by the video predictive decoding device, input of display order encoded data obtained by encoding data providing display order information of each of the pictures;

decoding the compressed picture data with the video predictive decoding device to restore reproduced pictures, and decoding with the video predictive decoding device the display order encoded data to restore the display order information; and

storing, in the frame memory, the restored reproduced pictures as the reference pictures, the reference pictures available for decoding of the subsequent picture, and

wherein decoding further comprises decoding reference picture information of each of the pictures included in the compressed picture data,

wherein decoding further comprises decoding, in accordance with the reference picture information, a first picture using the reference picture, the first picture preceding the random access picture in display order and following the random access picture in decoding order, and a second picture that follows the random access picture in display order using the random access picture as a reference picture without reference to any reference pictures preceding the random access picture in decoding order or in display order, and

wherein immediately before decoding the second picture that follows the random access picture in display order, the frame memory is refreshed by setting every reference picture stored in the frame memory except for the random access picture, as not used as reference pictures.

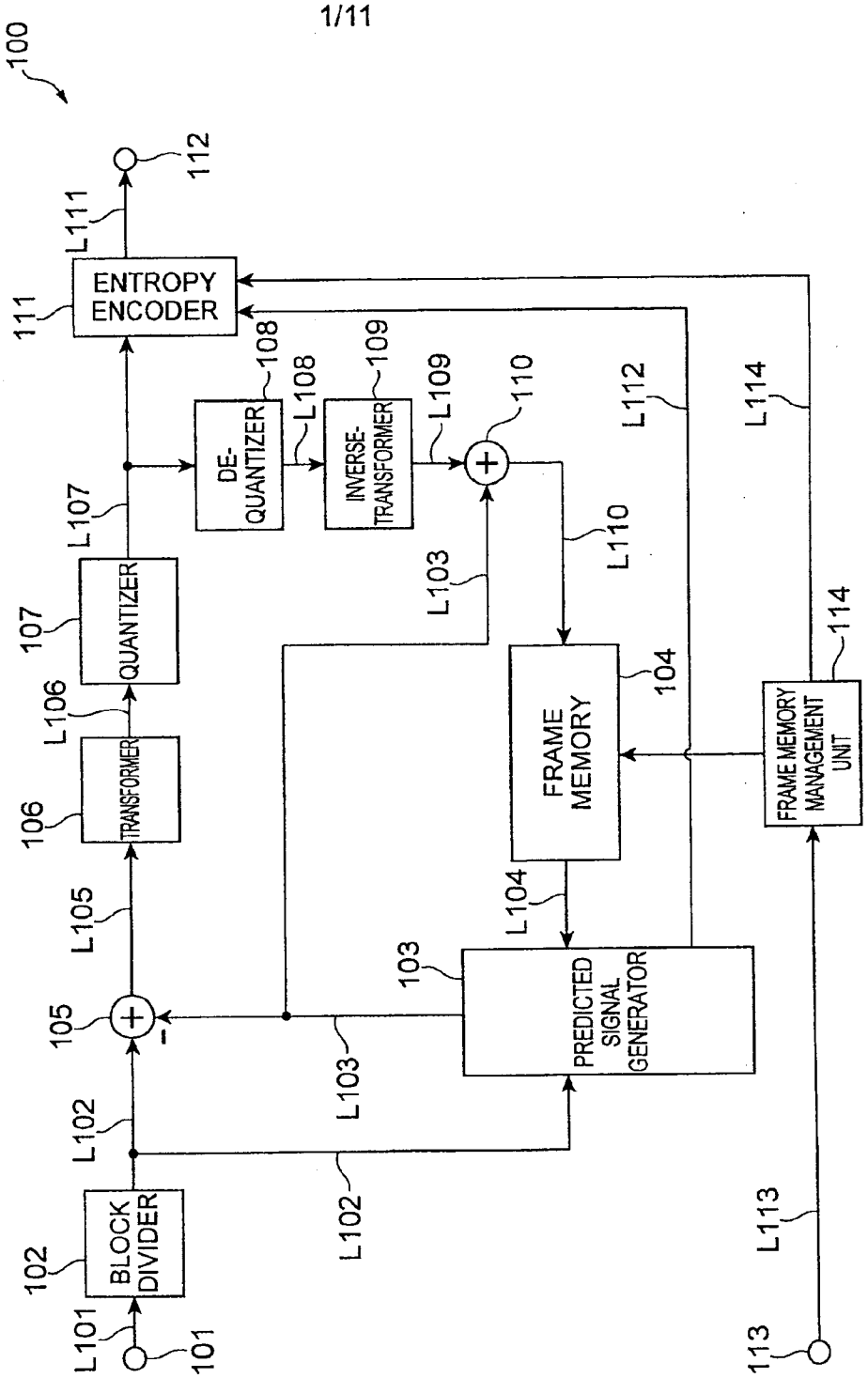

100
ENTROPY ENCODER
111
112
L111
DE-QUANTIZER
108
L108
INVERSE-TRANSFORMER
109
L109
110
L112
L114
L107
QUANTIZER
107
L103
L110
FRAME MEMORY
104
114
L106
TRANSFORMER
106
FRAME MEMORY MANAGEMENT UNIT
L105
L104
105
103
PREDICTED SIGNAL GENERATOR
L103
L102
L102
BLOCK DIVIDER
102
L113
L101
101
113

Fig.1

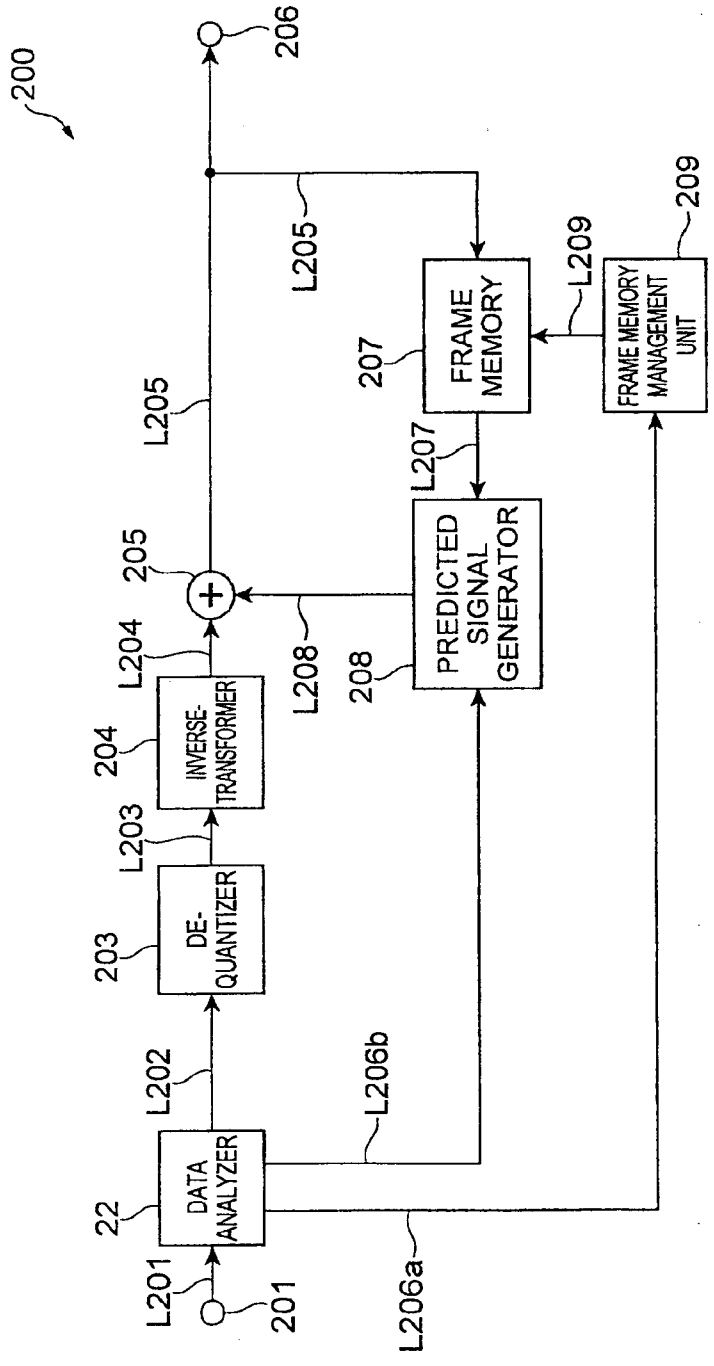

200
206
L205
209
L209
FRAME MEMORY MANAGEMENT UNIT
207
FRAME MEMORY
L205
L207
205
PREDICTED SIGNAL GENERATOR
L204
L208
208
204
INVERSE-TRANSFORMER
L203
203
DE-QUANTIZER
L202
L206b
22
DATA ANALYZER
L201
201
L206a

Fig.2

Fig.3

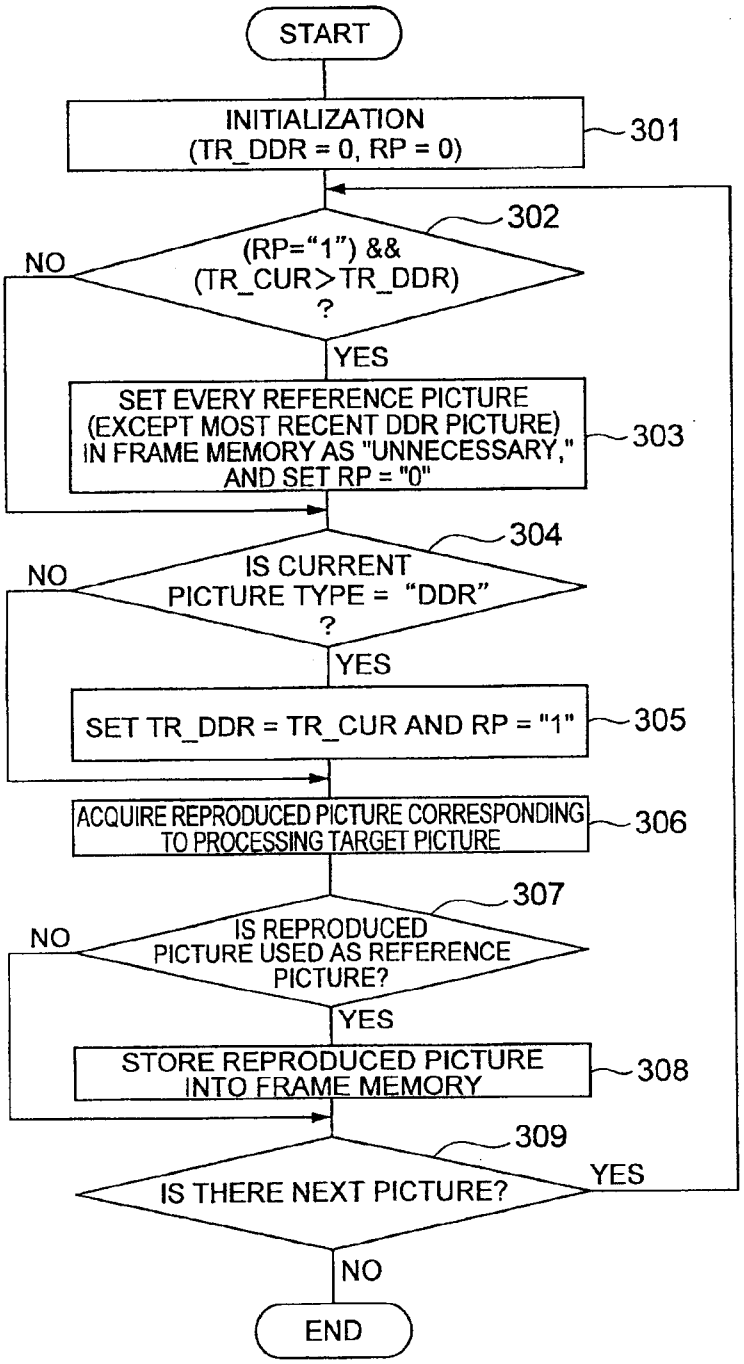

START
INITIALIZATION
(TR_DDR = 0, RP = 0)
301
302
(RP="1") &&
(TR_CUR>TR_DDR)
?
NO
YES
SET EVERY REFERENCE PICTURE
(EXCEPT MOST RECENT DDR PICTURE)
IN FRAME MEMORY AS "UNNECESSARY,"
AND SET RP = "0"
303
304
IS CURRENT
PICTURE TYPE = "DDR"
?
NO
YES
SET TR_DDR = TR_CUR AND RP = "1"
305
ACQUIRE REPRODUCED PICTURE CORRESPONDING
TO PROCESSING TARGET PICTURE
306
307
IS REPRODUCED
PICTURE USED AS REFERENCE
PICTURE?
NO
YES
STORE REPRODUCED PICTURE
INTO FRAME MEMORY
308
309
IS THERE NEXT PICTURE?
YES
NO
END

Fig.4

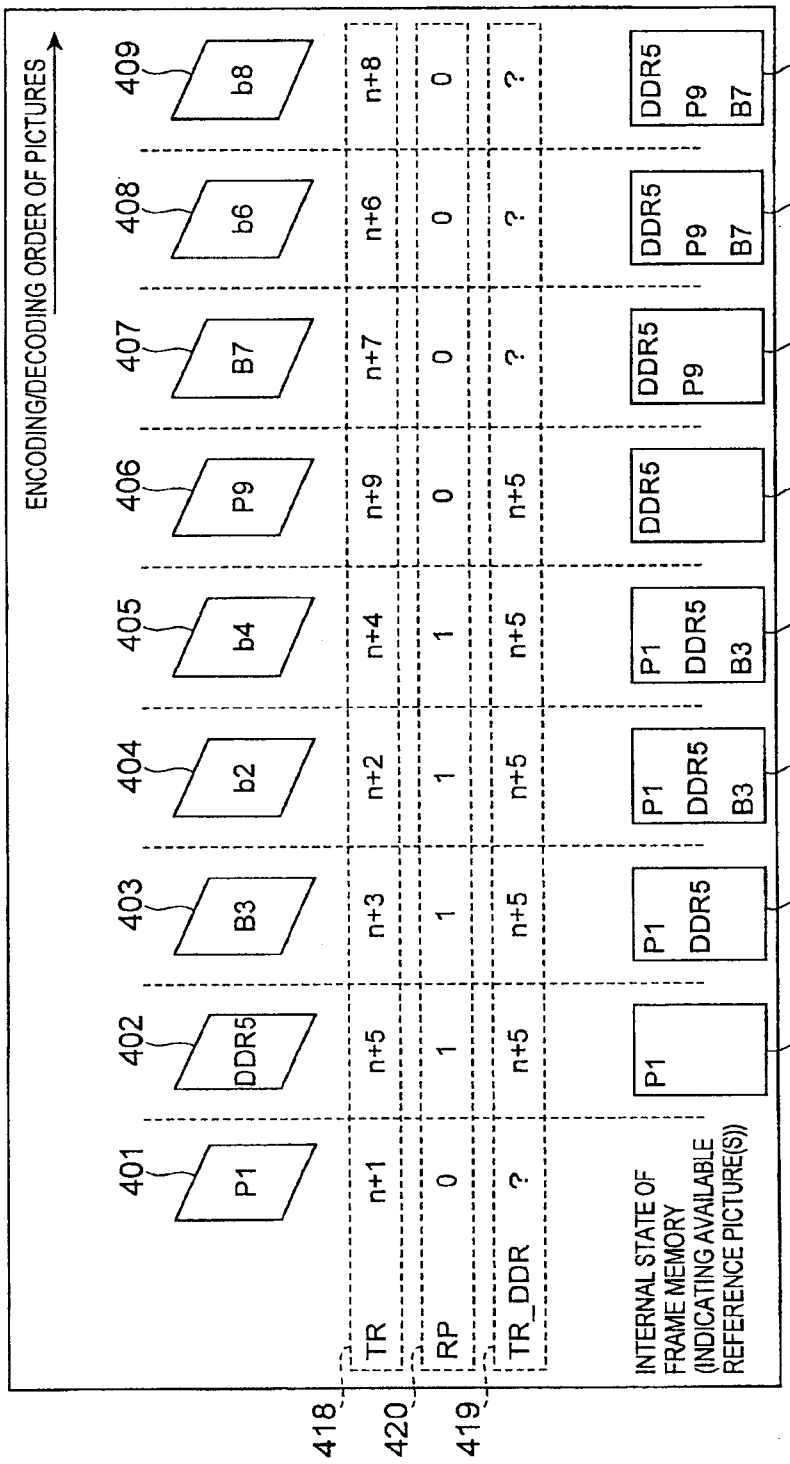

ENCODING/DECODING ORDER OF PICTURES
401
P1
402
DDR5
403
B3
404
b2
405
b4
406
P9
407
B7
408
b6
409
b8
TR
n+1
n+5
n+3
n+2
n+4
n+9
n+7
n+6
n+8
RP
0
1
1
1
1
0
0
0
0
TR_DDR
?
n+5
n+5
n+5
n+5
n+5
?
?
?
INTERNAL STATE OF FRAME MEMORY (INDICATING AVAILABLE REFERENCE PICTURE(S))
P1
P1
DDR5
P1
DDR5
B3
P1
DDR5
B3
DDR5
DDR5
P9
DDR5
P9
B7
DDR5
P9
B7
410
411
412
413
414
415
416
417
418
420
419

Fig.5

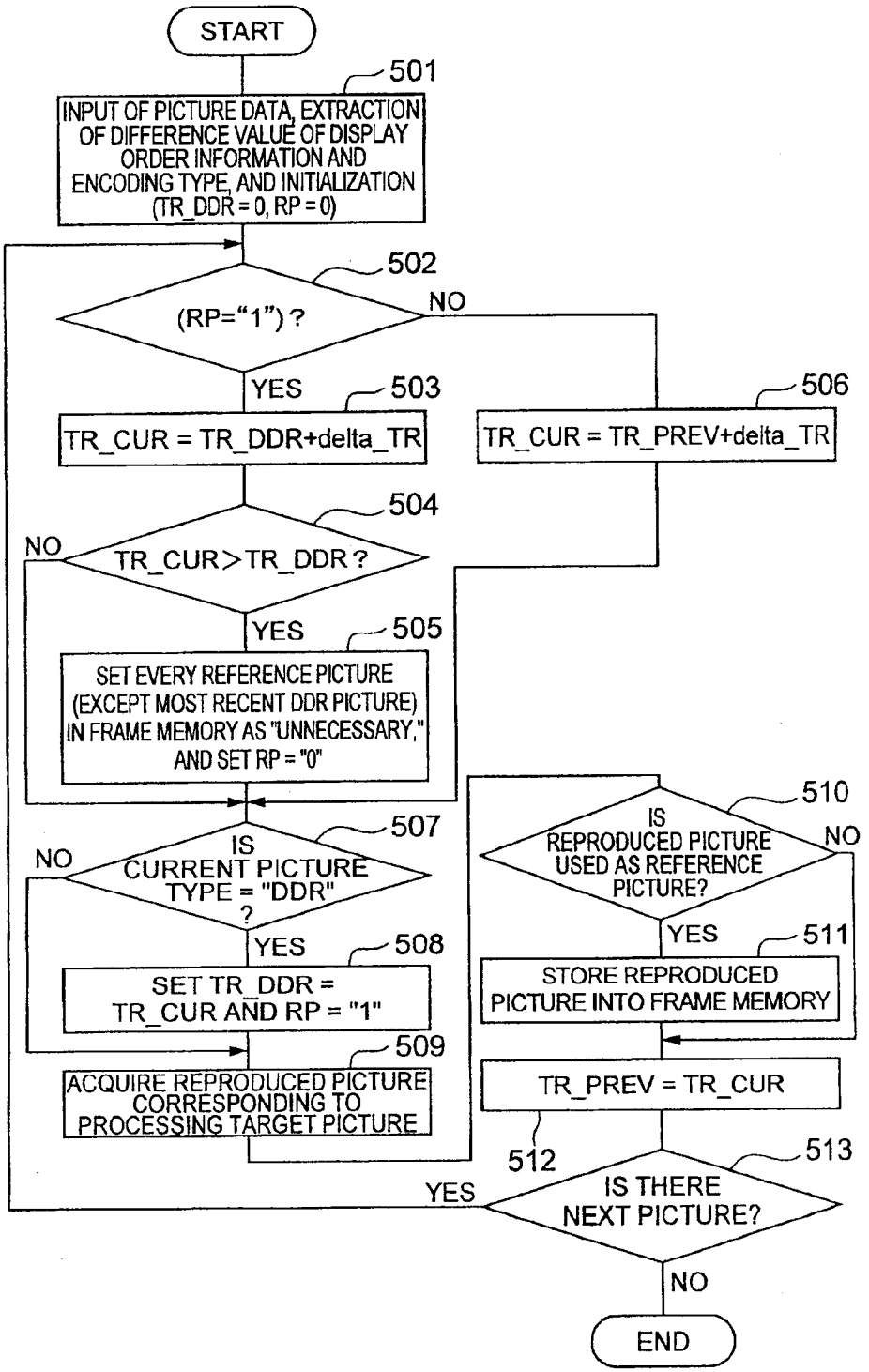

START
501
INPUT OF PICTURE DATA, EXTRACTION OF DIFFERENCE VALUE OF DISPLAY ORDER INFORMATION AND ENCODING TYPE, AND INITIALIZATION (TR_DDR = 0, RP = 0)
502
(RP="1")?
NO
YES
503
TR_CUR = TR_DDR+delta_TR
506
TR_CUR = TR_PREV+delta_TR
504
NO
TR_CUR>TR_DDR?
YES
505
SET EVERY REFERENCE PICTURE (EXCEPT MOST RECENT DDR PICTURE) IN FRAME MEMORY AS "UNNECESSARY," AND SET RP = "0"
507
NO
IS CURRENT PICTURE TYPE = "DDR" ?
YES
508
SET TR_DDR = TR_CUR AND RP = "1"
509
ACQUIRE REPRODUCED PICTURE CORRESPONDING TO PROCESSING TARGET PICTURE
510
IS REPRODUCED PICTURE USED AS REFERENCE PICTURE?
NO
YES
511
STORE REPRODUCED PICTURE INTO FRAME MEMORY
TR_PREV = TR_CUR
512
513
IS THERE NEXT PICTURE?
YES
NO
END

Fig.6

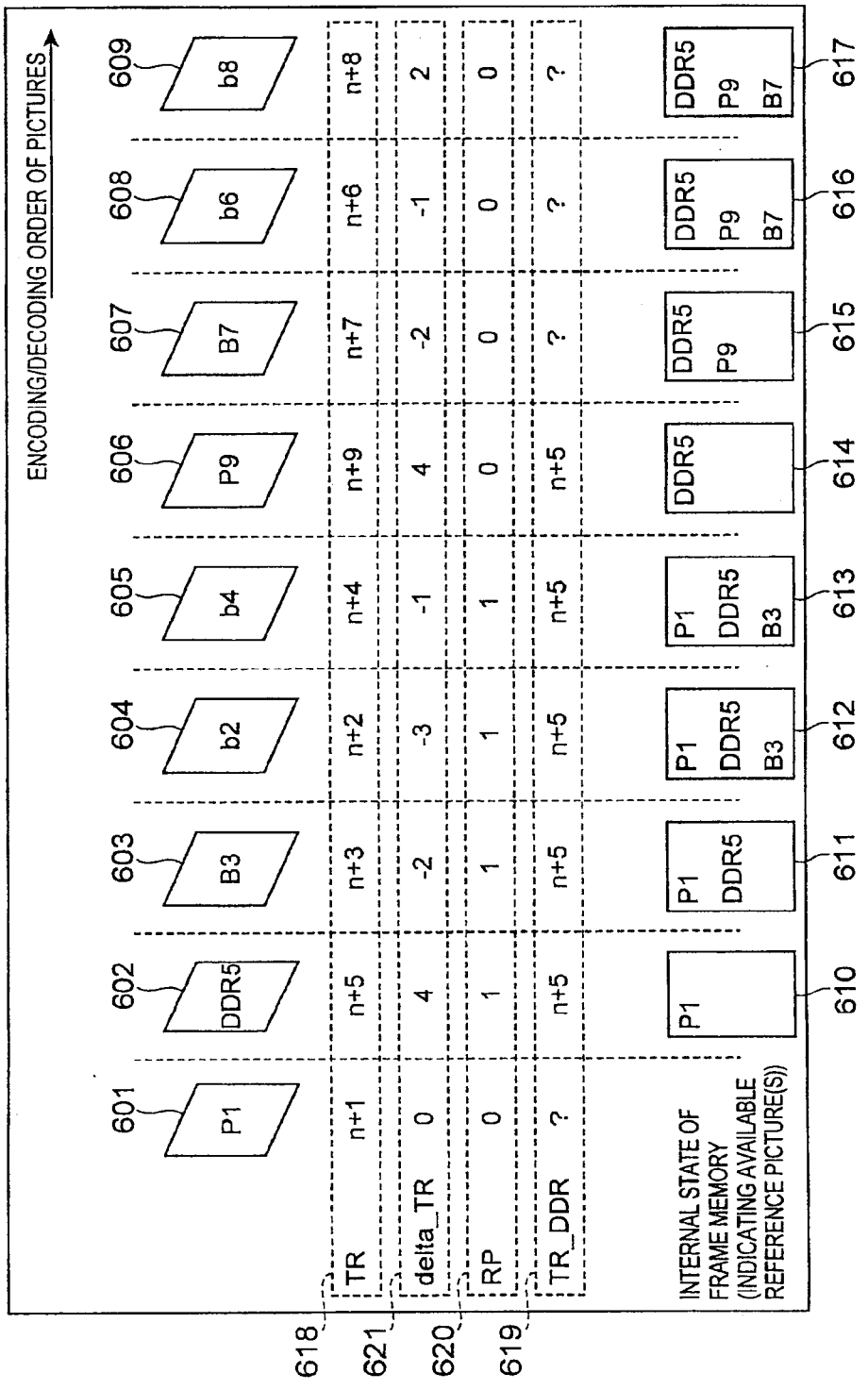

ENCODING/DECODING ORDER OF PICTURES
601
P1
602
DDR5
603
B3
604
b2
605
b4
606
P9
607
B7
608
b6
609
b8
618
TR
n+1
n+5
n+3
n+2
n+4
n+9
n+7
n+6
n+8
621
delta_TR
0
4
-2
-3
-1
4
-2
-1
2
620
RP
0
1
1
1
1
0
0
0
0
619
TR_DDR
?
n+5
n+5
n+5
n+5
n+5
?
?
?
INTERNAL STATE OF FRAME MEMORY (INDICATING AVAILABLE REFERENCE PICTURE(S))
P1
610
P1
DDR5
611
P1
DDR5
B3
612
P1
DDR5
B3
613
DDR5
614
DDR5
P9
615
DDR5
P9
B7
616
DDR5
P9
B7
617

Fig.7

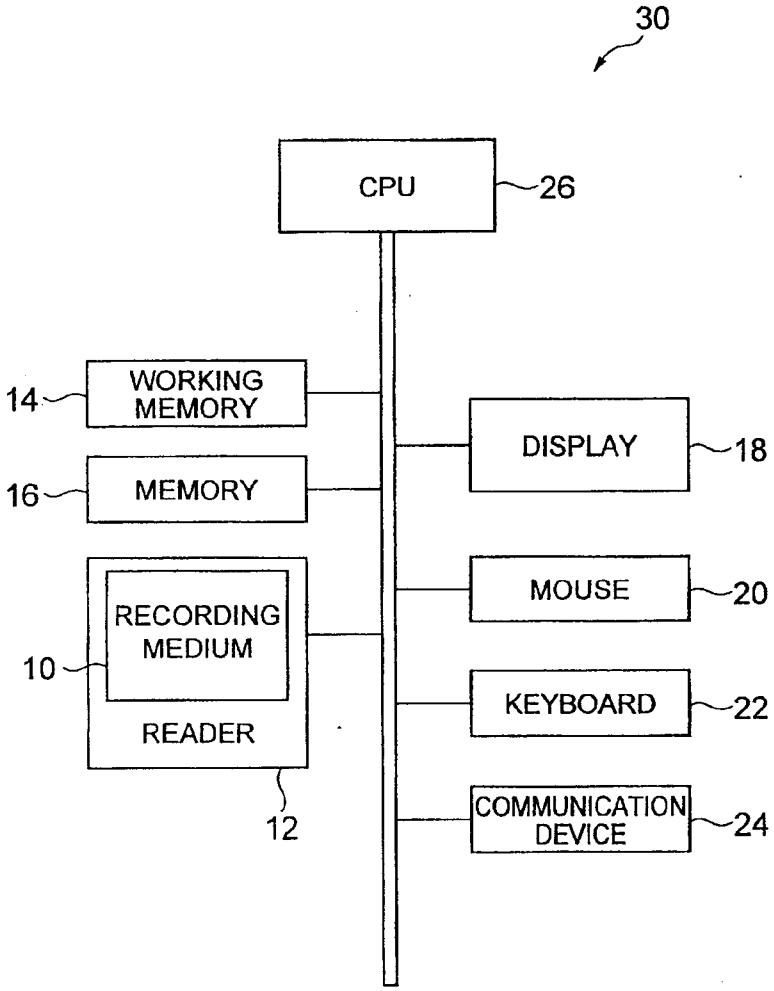

30
CPU
26
14
WORKING MEMORY
16
MEMORY
10
RECORDING MEDIUM
READER
12
DISPLAY
18
MOUSE
20
KEYBOARD
22
COMMUNICATION DEVICE
24

Fig.8

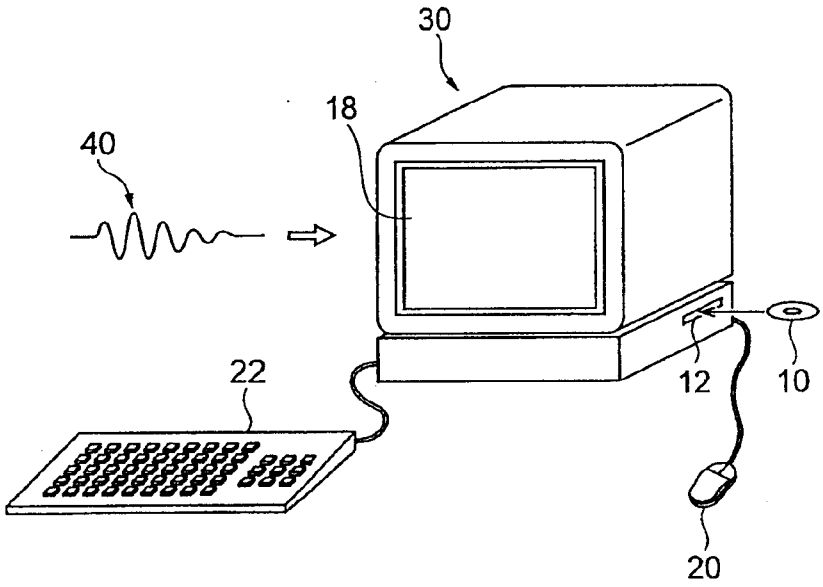


Fig.9

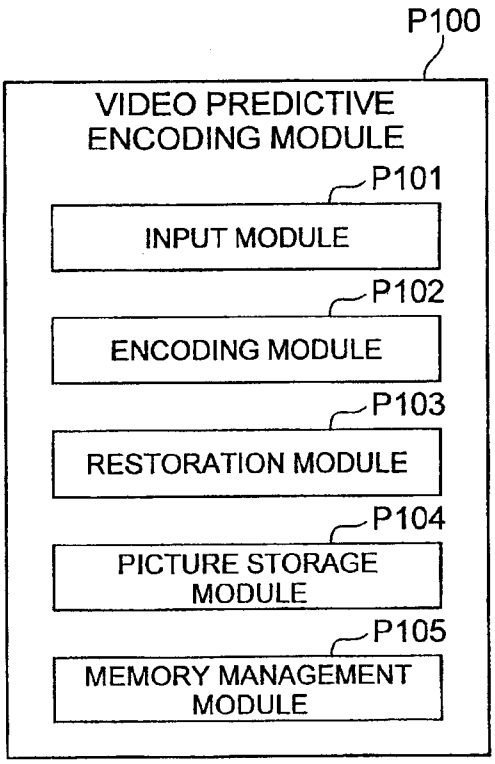

P100
VIDEO PREDICTIVE ENCODING MODULE
P101
INPUT MODULE
P102
ENCODING MODULE
P103
RESTORATION MODULE
P104
PICTURE STORAGE MODULE
P105
MEMORY MANAGEMENT MODULE

Fig.10

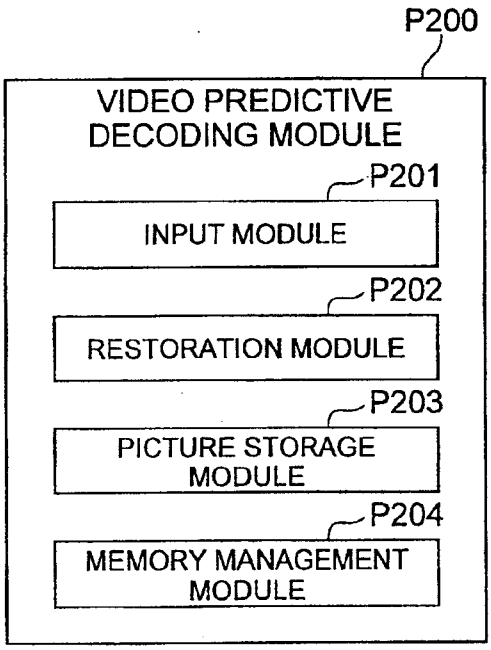
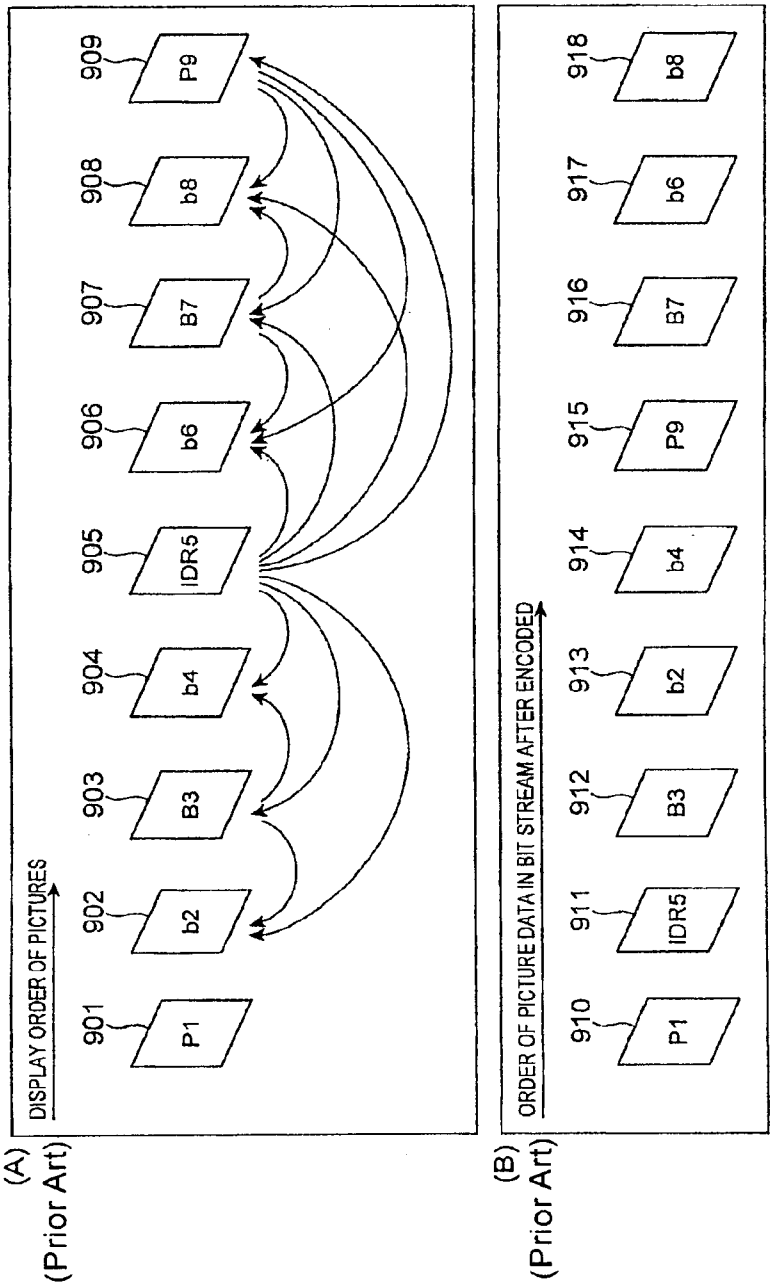
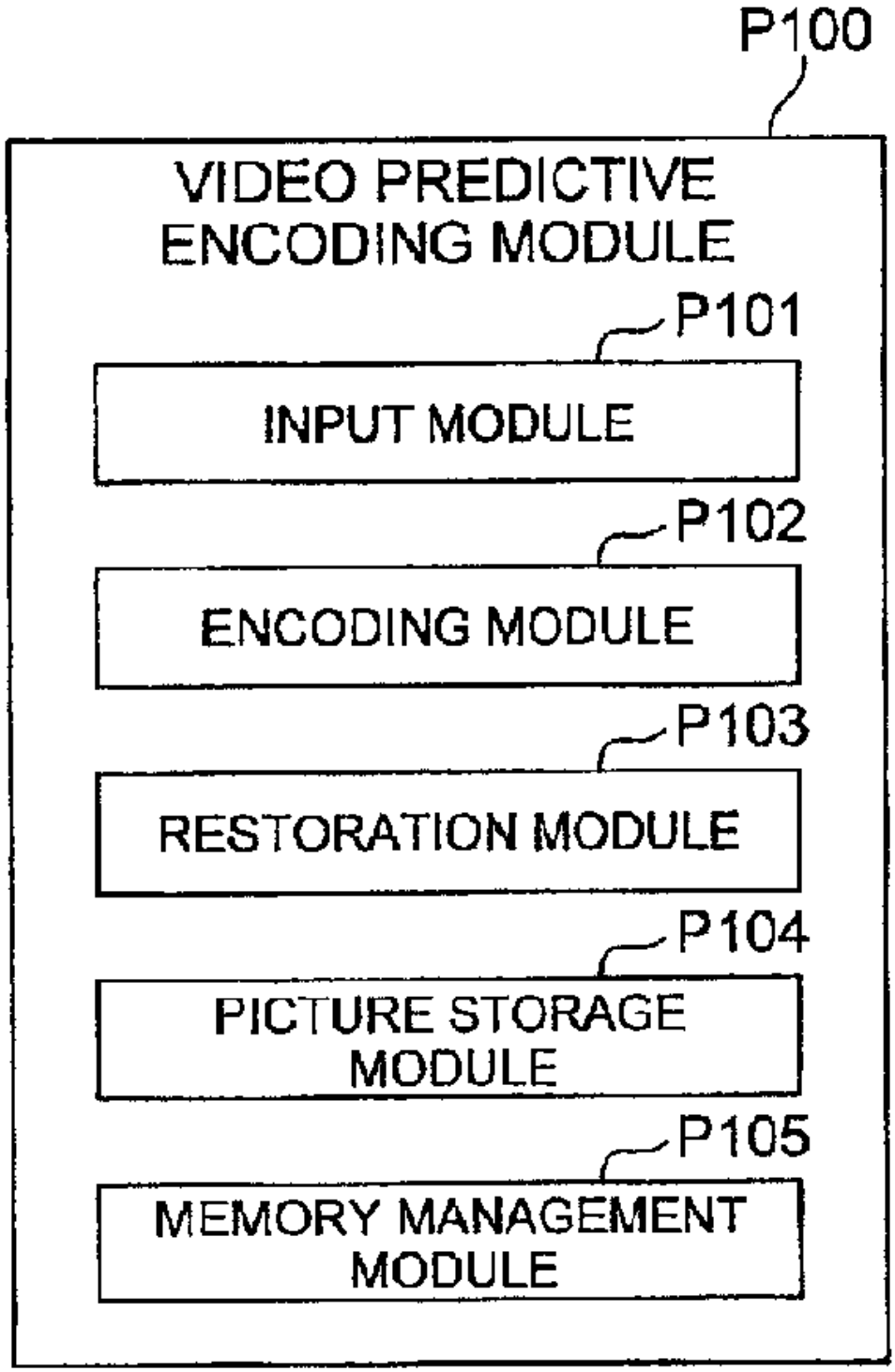

P200
VIDEO PREDICTIVE DECODING MODULE
P201
INPUT MODULE
P202
RESTORATION MODULE
P203
PICTURE STORAGE MODULE
P204
MEMORY MANAGEMENT MODULE

Fig.11


(A)
(Prior Art)
DISPLAY ORDER OF PICTURES
901
P1
902
b2
903
B3
904
b4
905
IDR5
906
b6
907
B7
908
b8
909
P9
(B)
(Prior Art)
ORDER OF PICTURE DATA IN BIT STREAM AFTER ENCODED
910
P1
911
IDR5
912
B3
913
b2
914
b4
915
P9
916
B7
917
b6
918
b8


P100
VIDEO PREDICTIVE ENCODING MODULE
P101
INPUT MODULE
P102
ENCODING MODULE
P103
RESTORATION MODULE
P104
PICTURE STORAGE MODULE
P105
MEMORY MANAGEMENT MODULE