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(54) Abstract Title
Differential encoding and decoding

(57) An encoding apparatus operable to encode video data representing successive images, each image comprising a plurality of pixels, comprises a differential encoder arranged to encode each image as one or more predetermined image regions, each image region being encoded as a reference value and at least one differential pixel value, the differential pixel value(s) being derived in dependence on the reference value and/or other differential pixel value(s) in accordance with an order of encoding dependency; in which, for each image region, the differential encoder is operable in a first encoding mode for a first subset of the images to encode the image region using a first order of encoding dependency and in a second encoding mode for a second, different, subset of the images to encode the image region using a second, different, order of encoding dependency, and in which the first and second subsets of images are arranged with respect to one another so that, from image to image, each image region is encoded in accordance with a predetermined sequence of orders of encoding dependency.

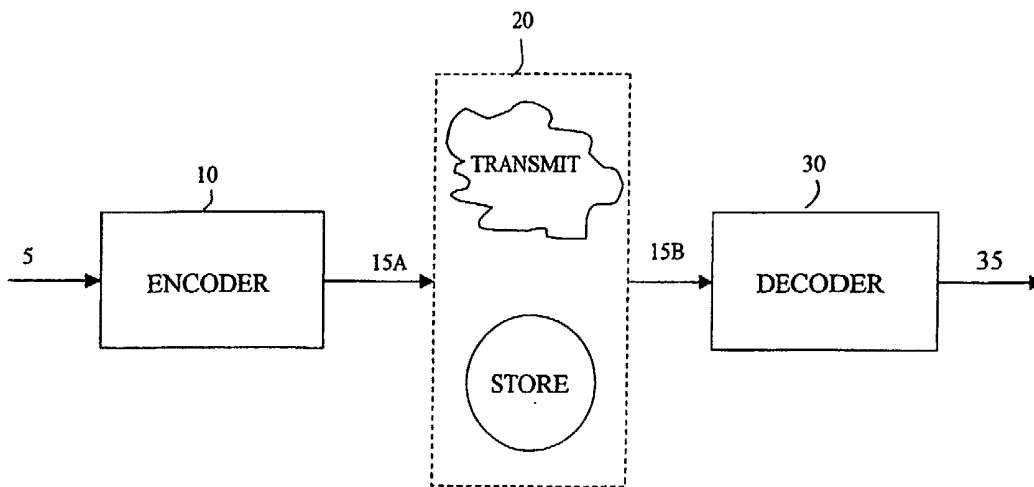


FIGURE 1

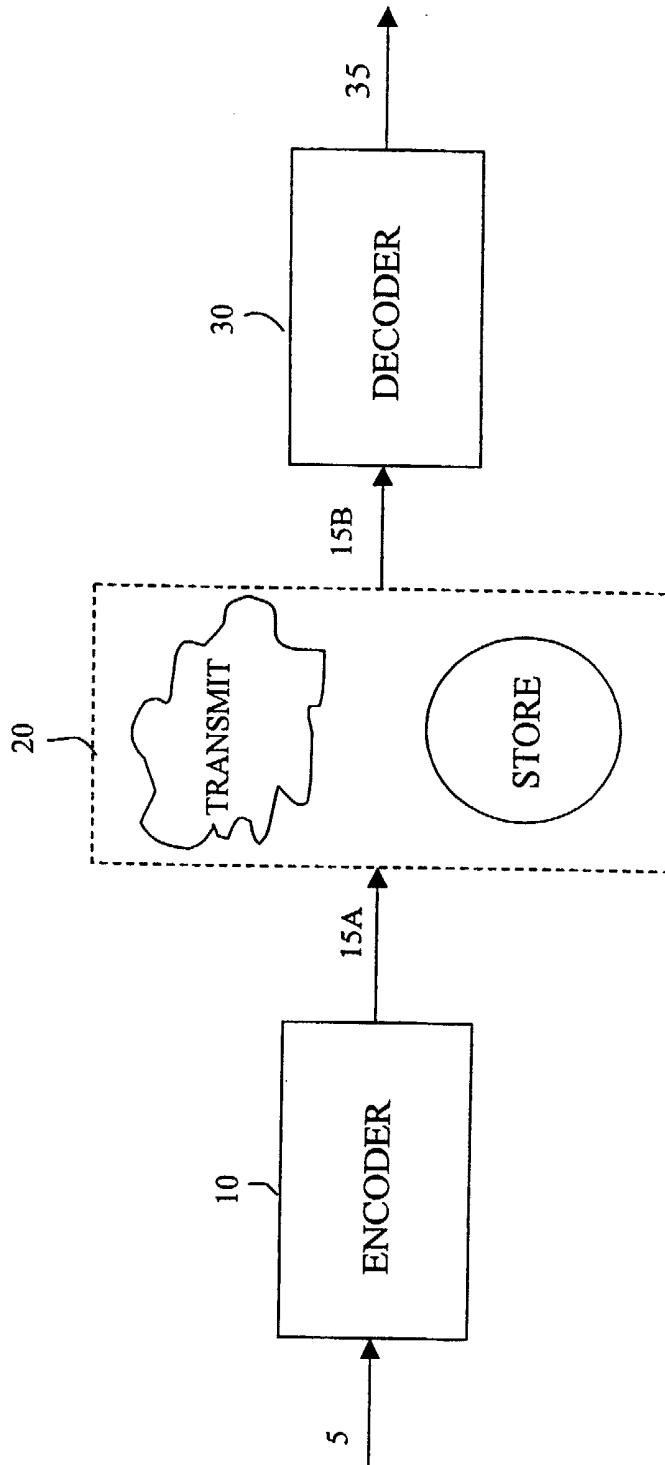
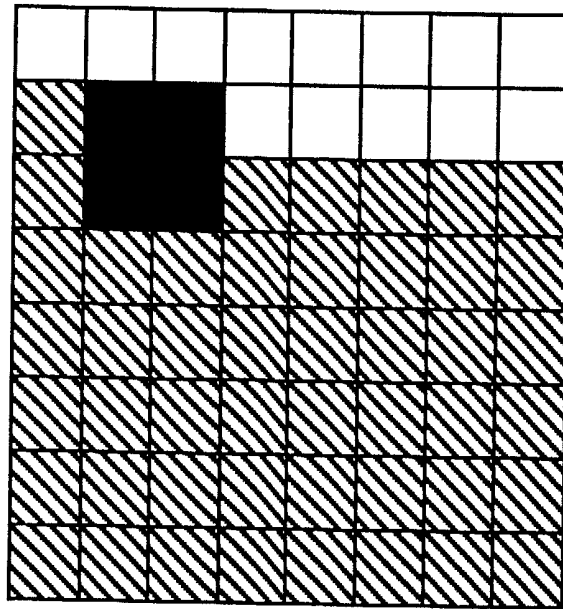
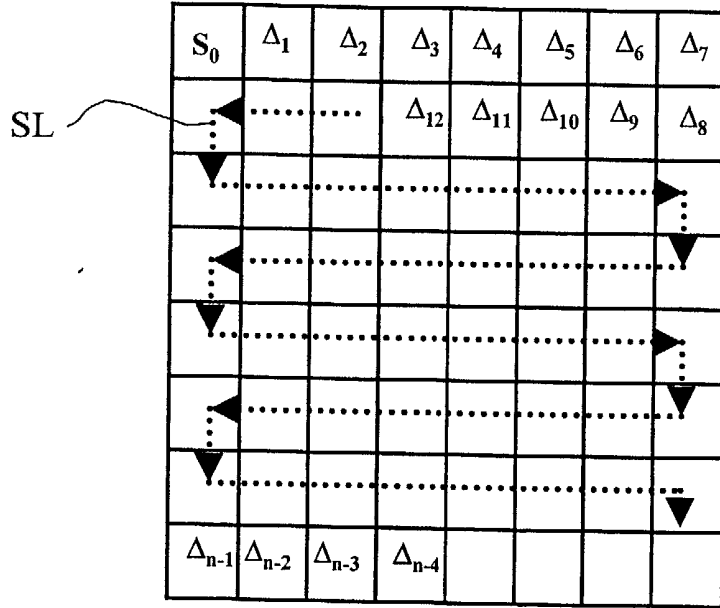


FIGURE 1






-  DECODED PIXELS
-  MISSING PIXEL DATA
-  UNSUCCESSFULLY DECODED PIXELS

FIG. 2

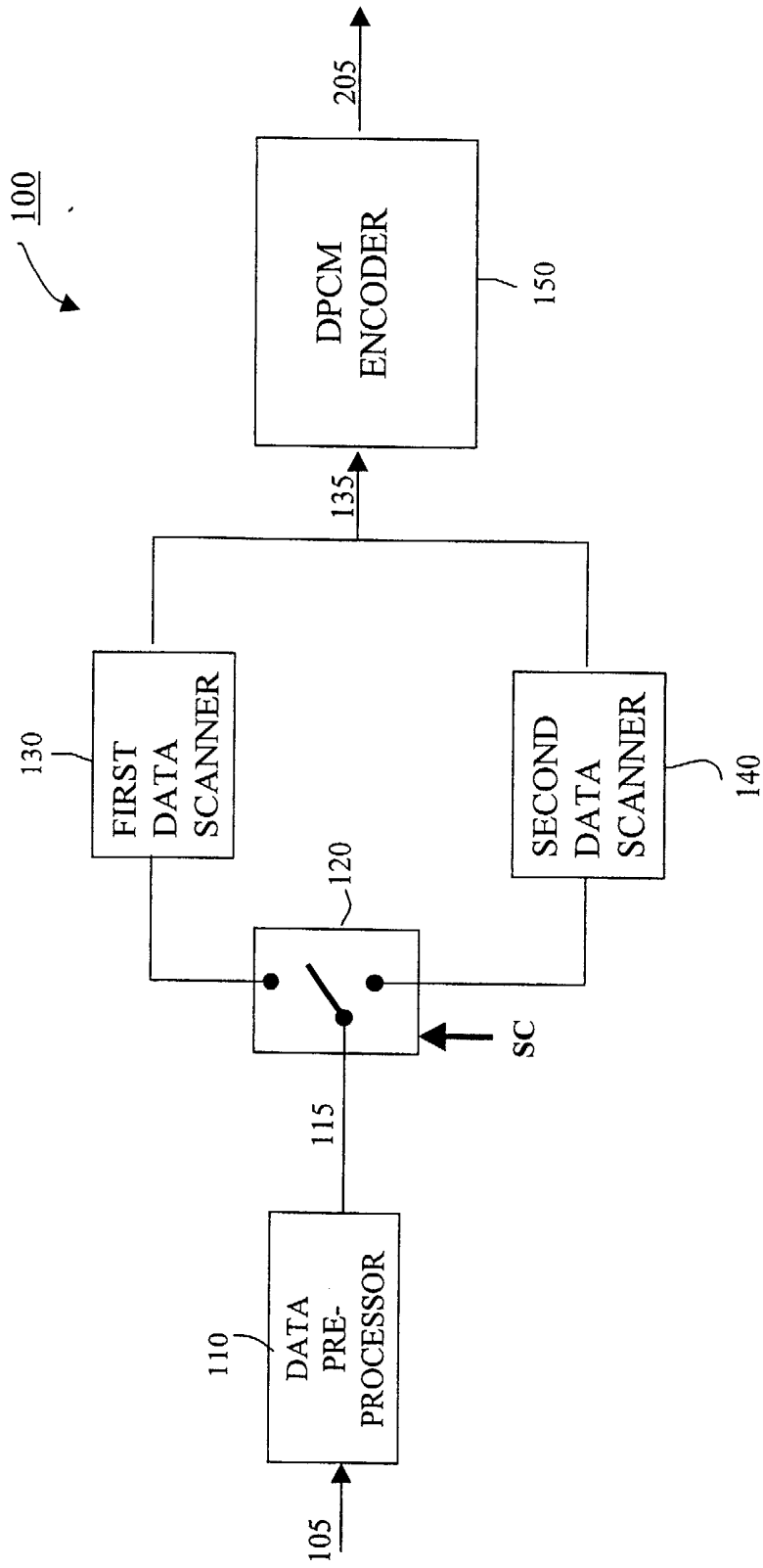


FIG. 3

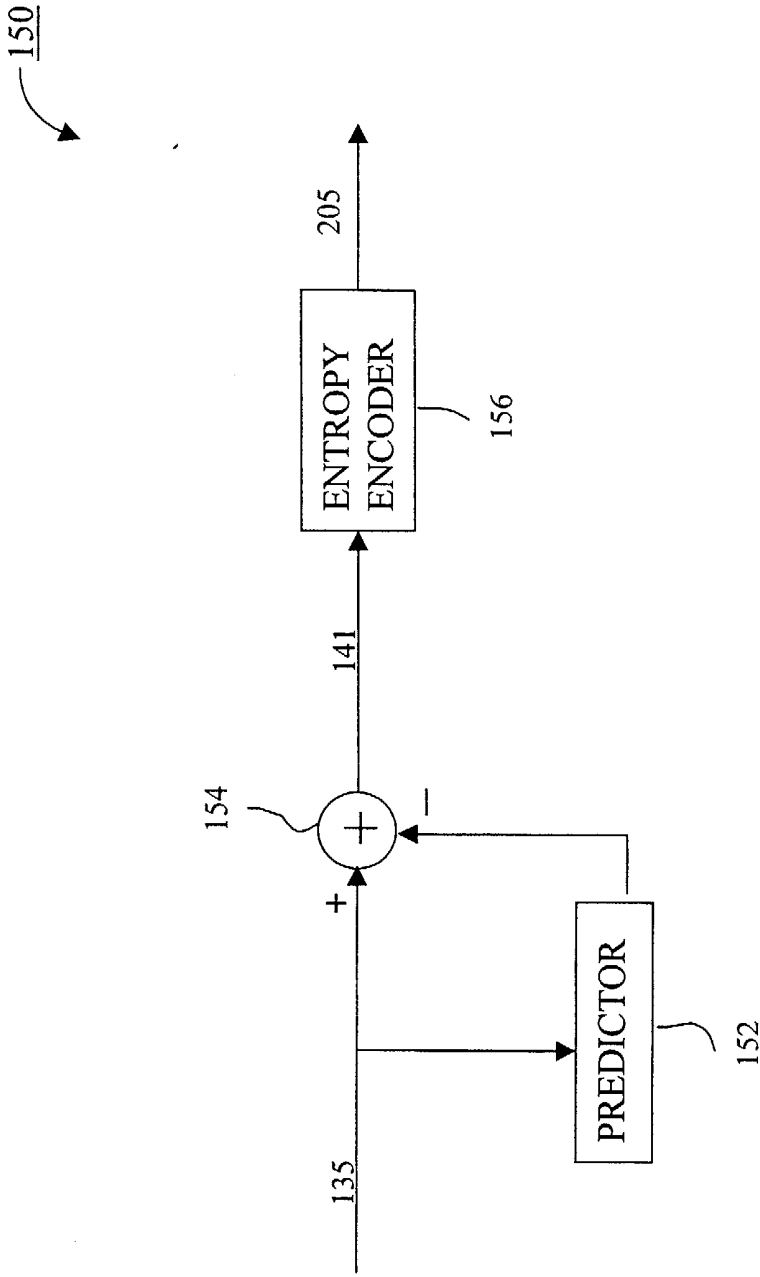


FIG. 4

FIELD 1

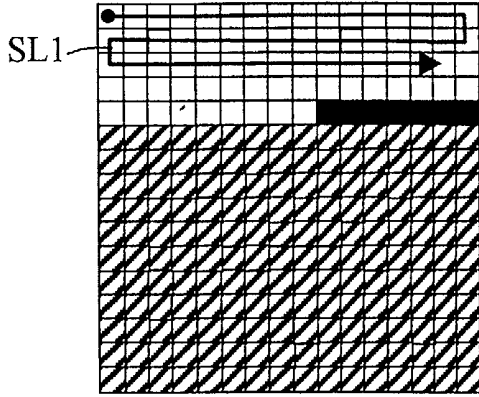


FIG. 5A

FIELD 2

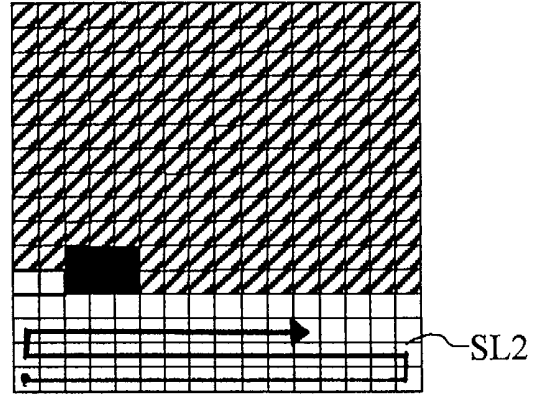


FIG. 5B

FIELD 1

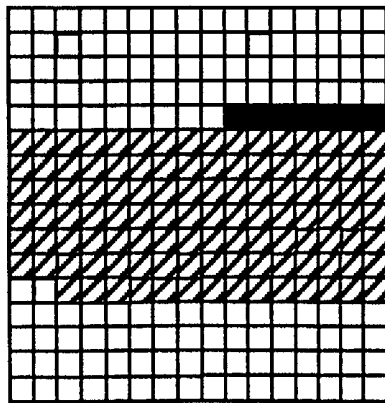


FIG. 5C

FIELD 2

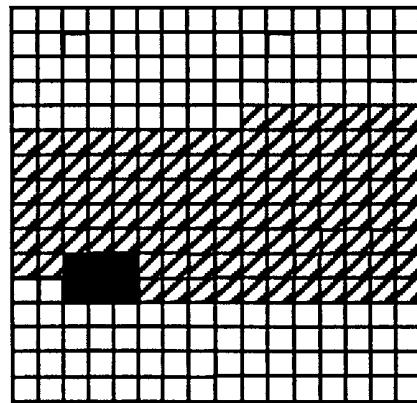
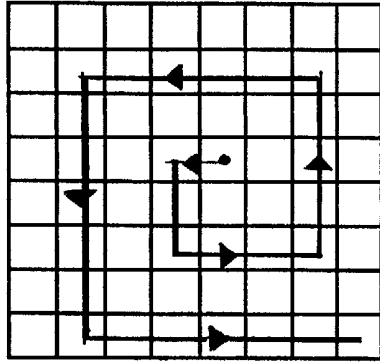


FIG. 5D

SECOND SCAN SEQUENCE



FIRST SCAN SEQUENCE

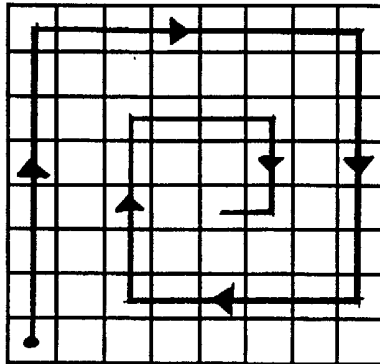


FIG. 6

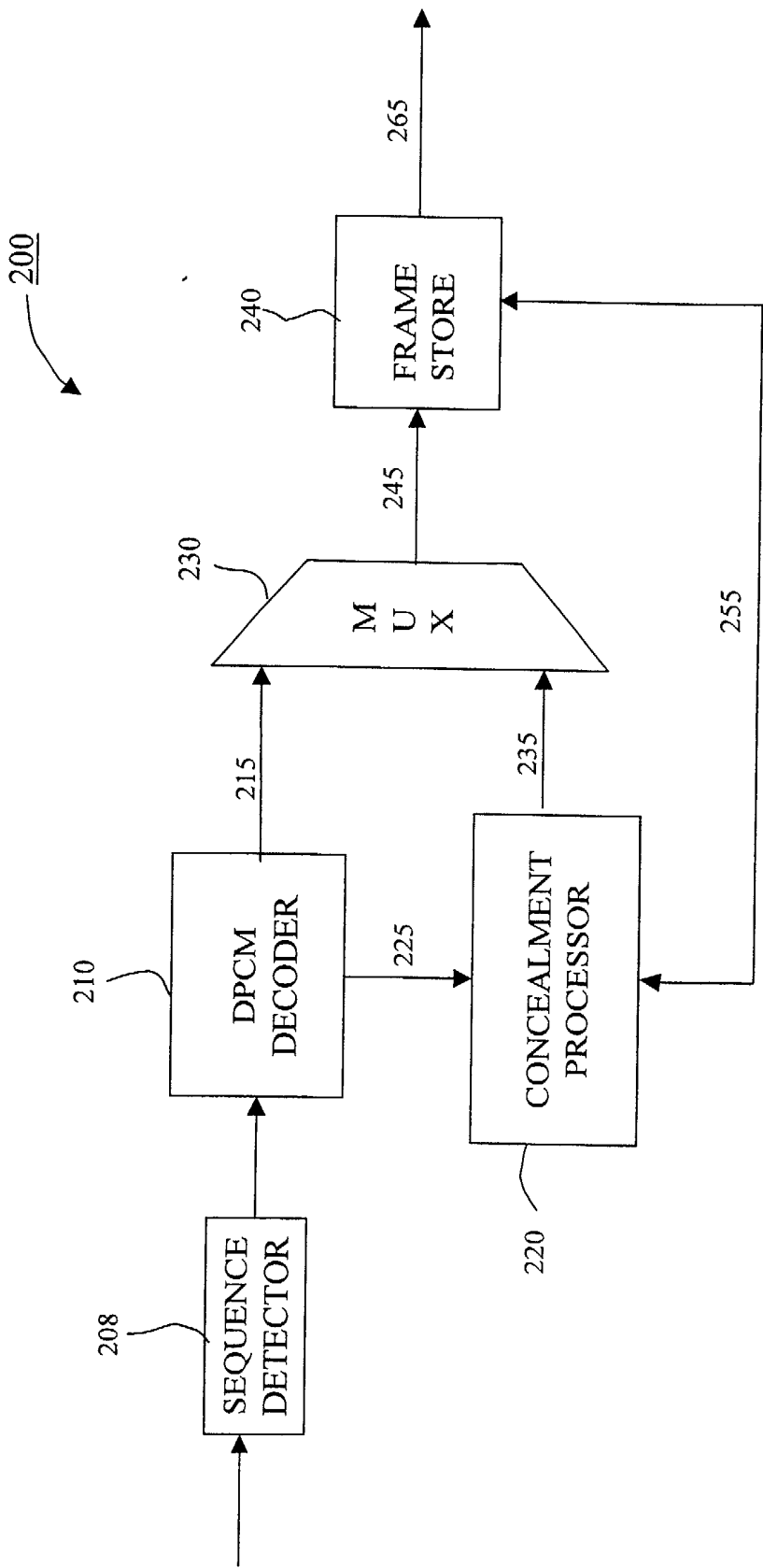


FIG. 7

210

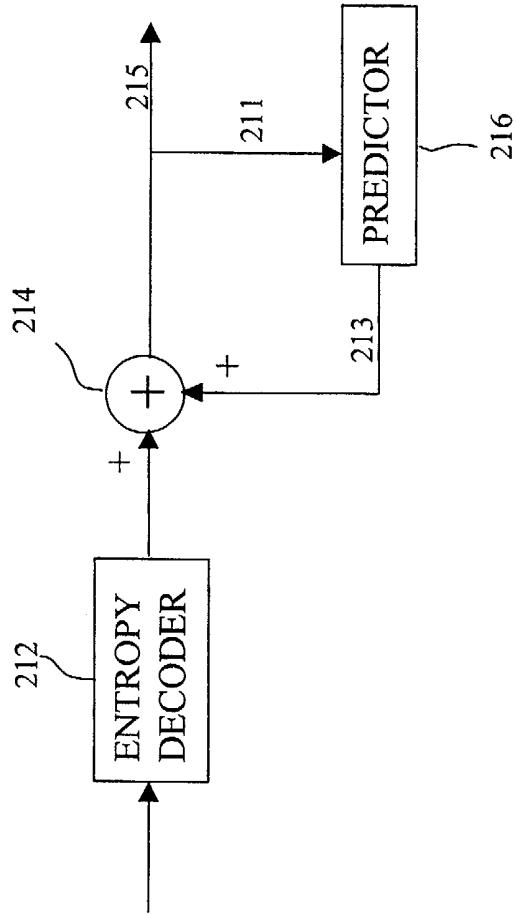


FIG. 8

DIFFERENTIAL ENCODING

This invention relates to differential encoding.

Differential encoding processes for encoding data such as Differential Pulse Code Modulation (DPCM) are well known and described for example in M.J. Riley and I.E.G. Richardson, "Digital Video Communications", Artech House Inc., 1997. Differential encoding processes are often used to encode image data but are applicable to any type of electronic data.

In one form of DPCM, a current pixel may be encoded either as a reference pixel value which is a direct representation of the pixel value, or as a differential pixel value. An image region may be represented by a reference pixel value and a group of one or more difference values. A difference value is determined from the reference pixel value and intermediate difference values, following an order of encoding dependency. Thus, an image region might have, for example, its top-left pixel encoded as a reference pixel value, and subsequent pixels as differential pixel values representing the difference between that pixel and a preceding pixel in an order of encoding dependency such as a raster scan pattern through the region.

DPCM can be improved by averaging the values of a neighbourhood of pixels in proximity to a current pixel. This may be further improved by using a weighting system, the weighting being dependent upon the proximity of a neighbouring pixel to the current pixel. The size of the neighbourhood can also be varied. Adaptive differential coding can also be implemented by modifying the algorithm used to calculate difference values. Such an algorithm can include calculations based on image statistics of a current image region or of a current image made up of image regions. DPCM can be operated in lossless mode as described above or in a lossy mode by quantising the DPCM encoded image regions.

In all of the above arrangements, it is a feature of DCPM that the decoding of difference values requires successful decoding of a reference pixel value and of other difference values. Generally, there is an order of encoding dependency associated with the difference values so that the operation to decode a difference value Δ_n requires the successful decoding of the reference pixel value and the intervening difference values $\Delta_1 \rightarrow \Delta_{n-1}$. In view of this, to avoid a small data error causing a large loss of decoded data, small image regions are generally encoded, for example an $8_H \times 8_V$ block.

Encoded image data is often stored on a storage medium such as magnetic tape or magnetic, optical or magneto-optical disc for off-line decoding and playback. In order for a user to gain an appreciation of the content of the image data, a useful function of playback devices is a shuttle mode in which the playback device is operable in such a way as to vary the speed and/or direction of playback.

A typical operation of shuttle mode would be to playback the video data at a multiple of the normal playback speed. In the case of a tape-based system, for example, such a shuttle operation may result in only data representing a subset of the image regions being successfully recovered from the tape. This results in lower quality playback in shuttle mode. However, full resolution playback is not strictly required for the user to gain an appreciation of the content of the image data stored on a tape.

Those image regions successfully recovered from the tape in shuttle mode may themselves lack a proportion of pixel representations. In an encoding process where data is represented spatially, those spatial locations lacking pixel representations are presented to an image output upon decoding as omitted pixel values for which no data is present. Thus shuttle mode playback quality is reduced as to the proportion of omitted pixel representations in identified image regions increases. Concealment techniques have been proposed, for example, by replacing omitted pixel representations with values approximated from pixel representations in spatial proximity to the omitted pixel representation or with values approximated from those in adjacent images. However, such concealment techniques themselves rely on having other pixels nearby which have been successfully decoded. In particular, temporal concealment processes require pixels at substantially the same spatial position as an unsuccessfully decoded pixel to be present in temporally adjacent images.

In summary, when an image region is encoded according to a differential encoding process such as DPCM, image regions identified on a storage medium may lack a proportion of pixel representations. Since a current difference value is determined from a reference pixel value and intermediate difference values in an order of encoding dependency, an unsuccessfully decoded pixel prevents subsequent differential pixel values from being successfully decoded.

This invention provides an encoding apparatus operable to encode video data representing successive images, each image comprising a plurality of pixels, the apparatus comprising:

a differential encoder arranged to encode each image as one or more predetermined image regions, each image region being encoded as a reference value and at least one differential pixel value, the differential pixel value(s) being derived in dependence on the reference value and/or other differential pixel value(s) in accordance with an order of encoding dependency;

in which, for each image region, the differential encoder is operable in a first encoding mode for a first subset of the images to encode the image region using a first order of encoding dependency and in a second encoding mode for a second, different, subset of the images to encode the image region using a second, different, order of encoding dependency, and in which the first and second subsets of images are arranged with respect to one another so that, from

image to image, each image region is encoded in accordance with a predetermined sequence of orders of encoding dependency.

The invention recognises that a limitation on techniques such as temporal concealment in previous DPCM-based systems is the use of the same order of encoding dependency from image to image. For example, in a block based encoding system the order of encoding dependency might have been a raster scan arrangement from top-left to bottom-right, and always the same from image to image. This would mean that if data errors were encountered in such previous systems, it would always be the same part of the image region (in the example, the bottom-right portion) which would be unsuccessfully decoded. This would prevent the use of temporal concealment for that part of the region.

The invention addresses this problem by providing at least two different orders of encoding dependency, each applicable to a subset of images. In this way, the pixels which are most likely to suffer in the event of data loss are varied from image to image. This can mean that pixels at various positions in an image region can be successfully decoded in different images, so allowing temporal concealment to be used more effectively.

The feature that the first and second subsets of images are arranged with respect to one another so that, from image to image, each image region is encoded in accordance with a predetermined sequence (e.g. a repeating sequence) of orders of encoding dependency can simplify the arrangements needed at decoding to detect which order of encoding dependency has been used.

Preferably the predetermined sequence is such that, for each pair of consecutive images, an image region is encoded using different orders of encoding dependency. This gives a more robust system in difficult decoding conditions, such as during shuttle replay in a tape-based system, in that it allows different parts of an image region to be decoded in successive images. This in turn can improve the concealment of unsuccessfully decoded pixels.

For elegant simplicity and ease of decoding, preferably the first and second subsets comprise complementary sets of alternate images, such as alternate fields of an interlaced video signal.

To give a greater difference between encoding modes in order to reduce the effects of missing pixels, it is preferred that the reference values in the first encoding mode and the reference values in the second encoding mode respectively represent pixels at different spatial positions within the image regions. Indeed, it is preferred that the reference values in the first encoding mode and the reference values in the second encoding mode respectively represent pixels at substantially opposite peripheral positions within the image regions.

This invention also provides a decoding apparatus operable to decode video data representing successive images, each image comprising a plurality of pixels, the apparatus comprising:

a differential decoder arranged to decode each image as one or more predetermined
5 image regions, each image region being encoded as a reference value and at least one differential pixel value, the differential pixel value(s) being derived in dependence on the reference value and/or other differential pixel value(s) in accordance with an order of encoding dependency, in which, for each image region, the differential decoder is operable in a first decoding mode for a first subset of the images to decode the image region in accordance with a first order of encoding
10 dependency and in a second decoding mode for a second, different, subset of the images to decode the image region in accordance with a second, different, order of encoding dependency;
and

means for detecting the decoding mode to use for each image region.

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

Embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings, throughout which like parts are defined by like references, and in which:

Figure 1 is a schematic diagram of a compression encoder and a corresponding decoder
20 for use with a data recording/reproducing device or a data transmission/reception system;

Figure 2A is a schematic diagram illustrating how processing of a block of image data is conventionally performed during DPCM compression;

Figure 2B is a schematic diagram illustrating how missing pixel data affects the ability of the decoder to reconstruct pixel values that have been encoded using a conventional DPCM
25 compression process;

Figure 3 schematically illustrates a bit rate reducing encoder according to an embodiment of the invention;

Figure 4 is a schematic diagram of the DPCM encoder of Figure 3;

Figures 5A and 5B schematically illustrate how processing of a 16 by 16 block of image
30 data is performed during DPCM compression according to embodiments of the invention;

Figures 5C and 5D schematically illustrates the reduced effects of missing pixel data on the reconstructed image block of Figures 5A and 5B respectively according to embodiments of the invention;

Figure 6 schematically illustrates alternative spiral scanning sequences;

35 Figure 7 schematically illustrates a decoder according to an embodiment of the invention;

Figure 8 is a schematic diagram of the DPCM decoder of Figure 7.

Figure 1 is a schematic diagram of a data compression system. This system comprises an encoder 100, a data transfer link 300 and a decoder 200. The encoder 100 receives an input video signal 5. The encoder 100 models the video image data to remove redundancy and to exploit its statistical properties. It produces encoded data symbols that represent the information in the input video signal 5 in a compressed format. The encoder 100 outputs a compressed data signal 15A that is supplied to the data transfer link 300 where it is either transmitted across a communication channel or stored on a recording medium. A compressed data signal 15B having been either read from the recording medium or received across a communication network is supplied to the decoder 200 which decodes the compressed data signal 15B and outputs a reconstructed image signal 35. Loss of some encoded data symbols is likely to occur between the output 15A of the encoder and the input 15B to the decoder. Such data loss may arise due to a noisy data link in a computer communication system or as a result of data being read from the recording medium at high speed during a video shuttle operation of a playback device.

The impact of the data loss on the reconstructed image signal 35 will vary depending on the encoding technique employed. In DPCM type modelling techniques that encode data in the spatial domain and predict original data symbols from the other reconstructed data symbols, the playback quality is particularly adversely affected when a proportion of the encoded data of an encoded image region is lost. For data encoded in the spatial domain the effects of missing data in the reproduced image tend to be spatially localised. By way of contrast for data transformed to the frequency domain prior to encoding, the effects of missing data will typically be to reduce the overall resolution of the reproduced image region rather than to produce localised effects.

Conventionally, when DPCM encoding is applied to an image field (or frame), the field is divided into blocks such as the 8×8 block of pixels illustrated in Figure 2A. The pixels of each image block are scanned in a predetermined order and this scanning order determines the encoding sequence of the image block data. In Figure 2A an "S-type" scan line SL is shown whereby adjacent pixels values are read along each row of the block and the scan direction alternates from row to row. The starting point of the scan, in this case the top left-hand pixel value S_0 , is the reference pixel value. It is only for the reference pixel that the original sample value itself is encoded. For the remainder of the pixels in the block, the differences Δ_j between successive image pixel values are encoded rather than the pixel sample values S_k themselves.

In an alternative method, the first pixel is predicted from the mean (i.e. DC value) of the block such that the mean value is used as the reference value. In this case every pixel is coded as a prediction and only the mean value is encoded. In a further alternative method the first pixel

can be predicted from the mid-point of a range of possible values, for example the value 128 for 8-bit values.

Data compression is achieved in lossless DPCM because the differences Δ_j between pixel values are typically smaller than the pixel sample values themselves hence fewer bits are required to encode the differential pixel values Δ_j . In the example of Figure 2A the transmitted image values correspond to the reference value S_0 and differential pixel values $\Delta_j = S_j - S_{j-1}$, where $1 \leq j \leq (n-1)$. The differential image data typically has a greatly reduced variance compared to the original image data and is significantly less correlated.

The decoder produces reconstructed image sample values S^R from the differential pixel values and the reference value according to the equation: $S^R_j = S^R_{j-1} + \Delta_j$ where $1 \leq j \leq (n-1)$. It can be seen from this equation that a current pixel is reconstructed by adding the current differential pixel value to the most recently reconstructed pixel value. Note that the sequence of pixel reconstruction is determined by the sequence of pixel encoding. If the differential pixel value Δ_m is missing from the data stream arriving at the decoder then the reconstructed pixel value S^R_m will be an omitted pixel value for which no data is present. Furthermore, pixel values S^R_j (where $m < j \leq n-1$) subsequent to the omitted pixel in the encoding sequence cannot be successfully decoded. This is illustrated by Figure 2B where the missing pixel data is shown as a black shaded area. The missing pixel data corresponds to difference values Δ_{13} , Δ_{14} , Δ_{17} and Δ_{18} . In this case the decoder cannot successfully decode pixel values that are beyond the pixel associated with Δ_{13} in the scanning order. The unsuccessfully decoded pixels correspond to the area shaded by diagonal lines in Figure 2B.

For a conventional DPCM modelling process in which the scanning sequence is fixed from block to block and from field to field (or frame to frame), the likelihood of successfully decoding pixel values of an image region corresponding to the latter portion of the scanning sequence is low in comparison to the likelihood of successfully decoding pixel values in the first portion of the scanning sequence. A standard concealment technique replaces unsuccessfully decoded pixel values by copying the decoded pixel values from substantially the same spatial position in a temporally adjacent image. However if the likelihood of the decoder encountering missing data is high it follows that the likelihood successfully decoding pixels in the latter portion of the image region in temporally adjacent fields is low. This makes concealment of missing data in known DPCM modelling processes difficult. Although full resolution may not be required e.g. when viewing images in shuttle mode of a playback device, it will be appreciated that if a given portion of the image region is consistently unsuccessfully decoded this is likely to be noticeable to a viewer.

Figure 3 schematically illustrates a bit-rate reducing encoder according to an embodiment of the invention. The encoder 100 comprises a data pre-processor 110, a switch unit 120, a first data scanner 130, a second data scanner 140 and a DPCM encoder 150.

Data corresponding to original RGB sample values of successive video images are supplied as input to the data pre-processor 110. The data could alternatively be supplied in $Y_C_B C_R$ format. The images can be processed either in a progressive frame mode or in an interlaced field mode. The data pre-processor serves to divide the input data of each image into image blocks comprising 16 horizontal by 16 vertical ($16_H \times 16_V$) pixel sample values for each of the signal components R, G, B. The data pre-processor shuffles the image blocks according to a predetermined shuffle ordering that serves to interleave the image data so that blocks of pixels which are adjacent in the input image frame are not read out at adjacent positions in the shuffle ordering. This shuffling process alleviates the effect of data losses on the image reconstructed by the decoder apparatus. Pixel blocks that are adjacent to each other in the input video frame are separated in the shuffled bit stream. A short duration data loss in which a contiguous portion of the bit stream is corrupted may affect a number of data blocks, but due to the shuffling these blocks will not be contiguous blocks in the reconstructed image.

The image block data signal 115 is output by the data pre-processor 110 and supplied to the switch unit 120. The switch unit operates under the influence of a switch control signal SC to supply the image data signal 115 block by block to either the first data scanner 130 or the second data scanner. In interlaced field mode, image blocks comprising a first field are each fed to the first scanner 130 whereas the image blocks of a second, complementary field are supplied to the second scanner 140. Similarly, in frame mode the switch 120 alternates between the first scanner 130 and the second scanner from frame to frame.

As illustrated in Figure 5A, the first data scanner 130 scans each $16_H \times 16_V$ image block using an S-type scan line SL1, starting from a reference pixel value at the top left-hand corner of the block and proceeding throughout the block until it reaches the bottom left-hand pixel value. The first scanner 130 delivers the data to the DPCM encoder in an order determined by this first scanning sequence SL1. The second data scanner 140 also performs an S-type scan SL2 but it starts from a different reference pixel value at the bottom left hand corner of the $16_H \times 16_V$ image block and proceeds upwards throughout the block until it reaches the top left-hand pixel value. The second scanner 140 delivers the data to the DPCM encoder in an order determined by this second, different scanning sequence SL2. The ordering of scanning sequence SL2 relative to SL1 ensures that the forward and reverse scans meet in the middle when an S-type scan is used.

The DPCM encoder 150 encodes the data supplied to it from the first and second data scanners 130, 140 such that the order of encoding dependency is determined by the scanning

sequence SL1 SL2 respectively. Thus in interlaced field mode, the encoding dependency of the first field of a frame is arranged to be different from the encoding dependency of the complementary field of the frame. Similarly, in frame mode the encoding dependency of adjacent frames in a temporal sequence differs. As a consequence of the two different encoding dependencies of the sample values, it is possible to ameliorate the effects of missing pixel data in the reconstructed images. The way in which the effects of missing pixel data are overcome by embodiments of the invention will be explained in detail below with reference to Figure 5 C,D.

Figure 4 is a schematic diagram of the DPCM encoder of Figure 3. The scanner output signal 135 from either the first scanner 130 or the second scanner 140 is supplied as input to the DPCM encoder 150. The DPCM encoder comprises a prediction processor 152, an adder 154 and an entropy encoder 156.

In the DPCM encoder 150, the input signal 135 is fed both to the prediction processor 152 and as a first input to the adder 154. The prediction processor 152 performs a calculation to predict the current pixel value from one or more preceding pixel values in the scanning sequence. In this embodiment of the invention the current pixel is predicted from the immediately previous pixel in the scanning sequence and hence the prediction processor simply provides a one-sample time delay. The output of the prediction processor is supplied as a second input to the adder 154, where it is subtracted from the current sample value to produce a differential pixel value Δ_j . The output signal 141 from the adder 154 is supplied as input to the entropy encoder 156. The entropy encoder 156 applies entropy coding to the data. In this particular embodiment, Golomb coding is used. The output of the entropy encoder 205 comprises encoded image data that may subsequently be transmitted across a communications network or recorded on a recording medium such as a tape or a disc.

In an alternative embodiment of the DPCM encoder, the prediction processor 152 could predict the current pixel value by:- using an average of pixels in the spatial neighbourhood of the current pixel; using an appropriately weighted linear sum of a number of pixel values preceding the current pixel in the scanning sequence; or by adaptively predicting the current pixel value based on the statistics of the current image.

Further alternative embodiments of the invention may lower the overall data rate by adding a quantiser to the lossless DPCM encoder of Figure 4. In forming a prediction, the decoder only has access to the reconstructed pixel values and not to the original sample values. Since quantisation of the differential image introduces error (i.e. it is a lossy compression process) the quantiser in these alternative embodiments should preferably be located within the prediction loop in the DPCM encoder. This ensures that the encoder, like the decoder bases its

predictions on the reconstructed pixel values which improves the accuracy of the predicted values.

Figures 5A and 5B schematically illustrate how processing of a $16_H \times 16_V$ block of image data is performed during DPCM compression according to embodiments of the invention.

5 Figure 5A shows the first field of a frame that is scanned using an S-type scan SL 1 starting from a reference pixel the top left-hand corner of the image block as indicated by the arrow. This is in accordance with the operation of the first data scanner 130 of Figure 3. Missing pixel data is shaded in black whereas pixel values that cannot be successfully reconstructed by the decoder (as a consequence of the missing pixels) are shaded by diagonal lines.

10 Figure 5B shows the second field of a frame that is complementary to the first field of Figure 5A. This second field is scanned using an S-type scan SL2 starting from a reference pixel at the bottom left-hand corner of the image block as indicated by the arrow. This scanning sequence corresponds to the operation of the second data scanner 140 of Figure 3. In this second field the locations of missing pixel data are different from the locations of the missing pixels in
15 the first image field.

Figures 5C and 5D schematically illustrate how the effects of missing pixel data on the reconstructed image block of Figures 5A and 5B are reduced according to embodiments of the invention. The image block of field 1 and the corresponding image block of field 2 each have missing encoded pixel values as shown in Figures 5A and 5B respectively. For each block this
20 prevents successful decoding of pixels subsequent to the first missing pixel in the scanning sequence. However, since the scanning sequence of field 2 is different from the scanning sequence of field 1 and the two scanning sequences start at opposite sides of the image, the unsuccessfully decoded pixels in the lower portion of the first field data block can be concealed by copying the successfully decoded pixel values from the lower portion of the second field data
25 block. Similarly, the reconstructed data from the upper portion of the first field is used to substitute for the unsuccessfully decoded pixels of the upper portion of the data block of the second field. Note that in interlaced field mode the rows of the $16_H \times 16_V$ block of the second field are interlaced with the rows of the corresponding $16_H \times 16_V$ block of the first field thereby forming a $16_H \times 32_V$ region of the reproduced image frame. In frame mode the reconstructed
30 pixels from one frame can be copied from a $16_H \times 16_V$ image block to conceal the unsuccessfully decoded pixel data of a corresponding $16_H \times 16_V$ image block of an adjacent frame.

It will be appreciated that although in the above example two different S-type scans are used to provide different orders of encoding dependency according to the present invention, various other scan types could be performed such as a raster scan, a zig-zag scan or a spiral scan.

35 Figure 6 schematically illustrates two complementary spiral scanning sequences. The spiral

scans allow maximum space to be covered if only, for example, half of the pixels of a Macro-Block are recovered. The missing pixels in between the recovered pixels can then easily be interpolated from their neighbours. An advantage of the spiral scan and of the S-type scan is that each pixel in the scanning order is spatially adjacent to the previous pixel which potentially allows more efficient entropy encoding. This is not the case for a raster scan.

Figure 7 schematically illustrates a decoder according to an embodiment of the invention. The decoder 200 comprises a sequence detector 208, a DPCM decoder 210, a concealment processor 220, a multiplexer 230 and a frame store 240.

The decoder 200 receives an encoded signal that has been either read from a recording medium or transmitted across a communications network. The decoder 200 must take account of the scanning sequence that was used during DPCM encoding an image block in order to write the reconstructed pixel sample values to the appropriate memory address in the frame store 240. In this embodiment of the invention, for each pair of consecutive images an image region is encoded using different scanning sequences and hence have different orders of encoding dependency. The sequence detector 208 uses scanning sequence flags embedded in the encoded data stream to determine whether the first or second scanning sequence was used in the encoding of each field/frame. The output of the sequence detector 208 is supplied as input to the DPCM decoder 210. The DPCM decoder 210 performs a block by block decoding process to produce reconstructed pixel values from the encoded data symbols.

Figure 8 schematically illustrates the internal structure of the DPCM decoder 210. The DPCM decoder 210 effectively reverses the encoding process performed by the DPCM encoder 150 of Figure 4. The DPCM decoder comprises an entropy decoder 212, an adder 214 and a prediction processor 216.

The entropy decoder 212 processes the encoded signal to reverse the Golomb coding performed by the entropy encoder 156. The output from the entropy decoder 212 is supplied as a first input to the adder 214. An output from the adder 214 is supplied to the prediction processor 216 which uses the same method as the prediction processor 216 of the encoder 152 to reconstruct the current pixel. In this case the prediction processor 216 simply provides a one sample time delay. The adder 214 adds the differential value Δ_j of the current pixel to the value of the most recently reconstructed pixel. The direct output signal 215 of the adder comprises reconstructed pixel values.

Returning to Figure 7, the output signal 215 from the DPCM decoder 210 is supplied to the multiplexer 230. The DPCM decoder 210 further outputs a signal 225 to the concealment processor that gives an indication of which pixel values were unsuccessfully decoded. The concealment processor 220 is in two-way communication with the frame store 240. The frame

store 240 holds decoded image sample values for each field or each frame in memory. The concealment processor 220 is operable to copy successfully decoded data from a differently scanned image block in a complementary field or an adjacent frame in order to conceal unsuccessfully decoded pixels. This concealment technique was described in more detail above with reference to Figure 5. In alternative embodiments of the invention the concealment processor may additionally use known concealment methods such as spatial interpolation for certain image regions. The concealment processor 220 outputs concealment data to the multiplexer 230 which multiplexes it with the successfully decoded data and supplies the reconstructed pixel values to the frame store 240.

In an alternative embodiment of the invention the concealment processor 220 is also operable to conceal unsuccessfully decoded pixel values using the DC value which is simply the mean pixel value of the block. This method is particularly suitable where the prediction for the first pixel in the block is made from the mean value. In this case the mean value is transmitted separately and thus can easily be used to perform concealment. In Figure 5D the mean value would be used to conceal the missing pixels towards the middle of the frame.

An alternative concealment processor is operable to simply copy the last successfully decoded pixel or to copy the last successfully decoded pixel in each column to conceal the missing pixels.

In so far as the embodiments of the invention described above are implemented, at least in part, using software-controlled data processing apparatus, it will be appreciated that a computer program providing such software control and a transmission, storage or other medium by which such a computer program is provided are envisaged as aspects of the present invention.

CLAIMS

1. An encoding apparatus operable to encode video data representing successive images, each image comprising a plurality of pixels, the apparatus comprising:
 - 5 a differential encoder arranged to encode each image as one or more predetermined image regions, each image region being encoded as a reference value and at least one differential pixel value, the differential pixel value(s) being derived in dependence on the reference value and/or other differential pixel value(s) in accordance with an order of encoding dependency;
in which, for each image region, the differential encoder is operable in a first encoding
10 mode for a first subset of the images to encode the image region using a first order of encoding dependency and in a second encoding mode for a second, different, subset of the images to encode the image region using a second, different, order of encoding dependency, and in which the first and second subsets of images are arranged with respect to one another so that, from image to image, each image region is encoded in accordance with a predetermined sequence of
15 orders of encoding dependency.
2. Apparatus according to claim 1, in which the predetermined sequence is a repeating sequence.
- 20 3. Apparatus according to claim 1 or claim 2, in which the predetermined sequence is such that, for each pair of consecutive images, an image region is encoded using different orders of encoding dependency.
4. Apparatus according to claim 2 or claim 3, in which the first and second subsets comprise
25 complementary sets of alternate images.
5. Apparatus according to any one of the preceding claims, in which the images are respective fields of an interlaced video signal.
- 30 6. Apparatus according to any one of the preceding claims, in which the reference values in the first encoding mode and the reference values in the second encoding mode respectively represent pixels at different spatial positions within the image regions.

7. Apparatus according to claim 6, in which the reference values in the first encoding mode and the reference values in the second encoding mode respectively represent pixels at substantially opposite peripheral positions within the image regions.
- 5 8. Apparatus according to any one of claims 1 to 7, in which, within an image region, the order of encoding dependency is defined by a raster scan of the region.
9. Apparatus according to any one of claims 1 to 7, in which, within an image region, the order of encoding dependency is defined by an S-type scan of the region.
- 10 10. Apparatus according to any one of claims 1 to 7, in which, within an image region, the order of encoding dependency is defined by a spiral-type scan of the region.
11. A decoding apparatus operable to decode video data representing successive images, each image comprising a plurality of pixels, the apparatus comprising:
- 15 a differential decoder arranged to decode each image as one or more predetermined image regions, each image region being encoded as a reference value and at least one differential pixel value, the differential pixel value(s) being derived in dependence on the reference value and/or other differential pixel value(s) in accordance with an order of encoding dependency, in which, for each image region, the differential decoder is operable in a first decoding mode for a first subset of the images to decode the image region in accordance with a first order of encoding dependency and in a second decoding mode for a second, different, subset of the images to decode the image region in accordance with a second, different, order of encoding dependency; and
- 20 25 means for detecting the decoding mode to use for each image region.
12. Apparatus according to claim 11, comprising means for generating concealment pixel values in respect of any image regions or parts of regions not successfully decoded.
- 30 13. Apparatus according to claim 12, wherein said concealment pixel values are mean pixel values.
14. Apparatus according to claim 12, wherein said concealment pixel values are previous successfully decoded pixel values.

15. An encoding method for encoding video data representing successive images, each image comprising a plurality of pixels, the method comprising the steps of:

5 differentially encoding each image as one or more predetermined image regions, each image region being encoded as a reference value and at least one differential pixel value, the differential pixel value(s) being derived in dependence on the reference value and/or other differential pixel value(s) in accordance with an order of encoding dependency;

10 in which, for each image region, a first encoding mode is used for a first subset of the images to encode the image region using a first order of encoding dependency and a second encoding mode is used for a second, different, subset of the images to encode the image region using a second, different, order of encoding dependency, and in which the first and second subsets of images are arranged with respect to one another so that, from image to image, each image region is encoded in accordance with a predetermined sequence of orders of encoding dependency.

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16. A decoding method for decoding video data representing successive images, each image comprising a plurality of pixels, the method comprising the steps of:

20 differentially decoding each image as one or more predetermined image regions, each image region being encoded as a reference value and at least one differential pixel value, the differential pixel value(s) being derived in dependence on the reference value and/or other differential pixel value(s) in accordance with an order of encoding dependency, in which, for each image region, a first decoding mode is used for a first subset of the images to decode the image region in accordance with a first order of encoding dependency and a second decoding mode is used for a second, different, subset of the images to decode the image region in accordance with a second, different, order of encoding dependency; and

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detecting the decoding mode to use for each image region.

17. An encoding method substantially as hereinbefore described with reference to the accompanying drawings.

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18. A decoding method substantially as hereinbefore described with reference to the accompanying drawings.

19. Computer software comprising program code for carrying out a method according to any one of claims 15 to 18.

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20. A data providing medium by which computer software according to claim 19 is provided.

21. A medium according to claim 20, the medium being a storage medium.

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22. A medium according to claim 20, the medium being a transmission medium.

23. Encoding apparatus substantially as hereinbefore described with reference to the accompanying drawings.

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24. Decoding apparatus substantially as hereinbefore described with reference to the accompanying drawings.



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Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:
UK CI (Ed.T): H4F (FRC FRP)
Int CI (Ed.7): H04N (7/26)
Other: Online: WPI, EPODOC, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
A	EP 0644697 A2 DAEWOO ELECTRONICS See column 4 lines 6-45.	

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
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