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(54) **MULTI-PASS VIDEO ENCODER AND METHODS FOR USE THEREWITH**

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(51) **Int. Cl.**

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H04N 19/192	(2014.01)
H04N 19/115	(2014.01)
H04N 19/61	(2014.01)
H04N 19/56	(2014.01)
H04N 19/523	(2014.01)
H04N 19/40	(2014.01)

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CPC ***H04N 19/192*** (2014.11); ***H04N 19/115*** (2014.11); ***H04N 19/61*** (2014.11); *H04N 19/40* (2014.11); *H04N 19/523* (2014.11); *H04N 19/56* (2014.11)

(58) **Field of Classification Search**

CPC H04N 7/26031; H04N 7/26164

USPC 375/240.15, E7.088, E7.103, E7.148, 375/E7.153, E7.155, E7.16, E7.165, 375/E7.211, E7.224; 348/409, 394, 403, 348/411

See application file for complete search history.

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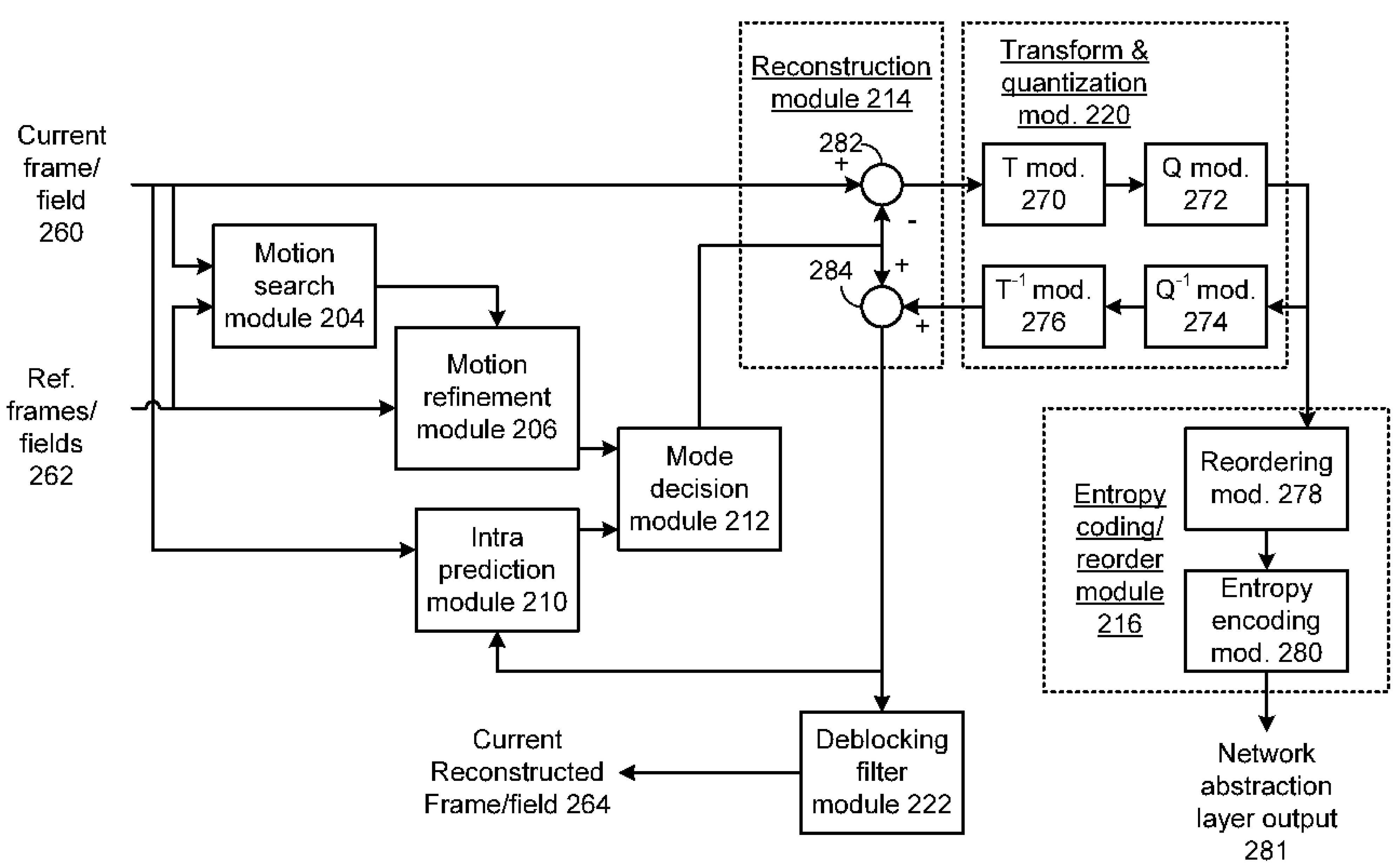
(57) **ABSTRACT**

A multi-pass video encoder includes a video encoding module that encodes a video signal based on an initial configuration data set to generate an initial processed video signal and an initial output data set. An application coding control module generates the initial configuration data set and generates a first updated configuration data set based on both the initial processed video signal and the initial output data set. The video encoding module further encodes the video signal based on the first updated configuration data set to generate a first updated processed video signal and a first updated output data set.

10 Claims, 10 Drawing Sheets



Video encoding operation

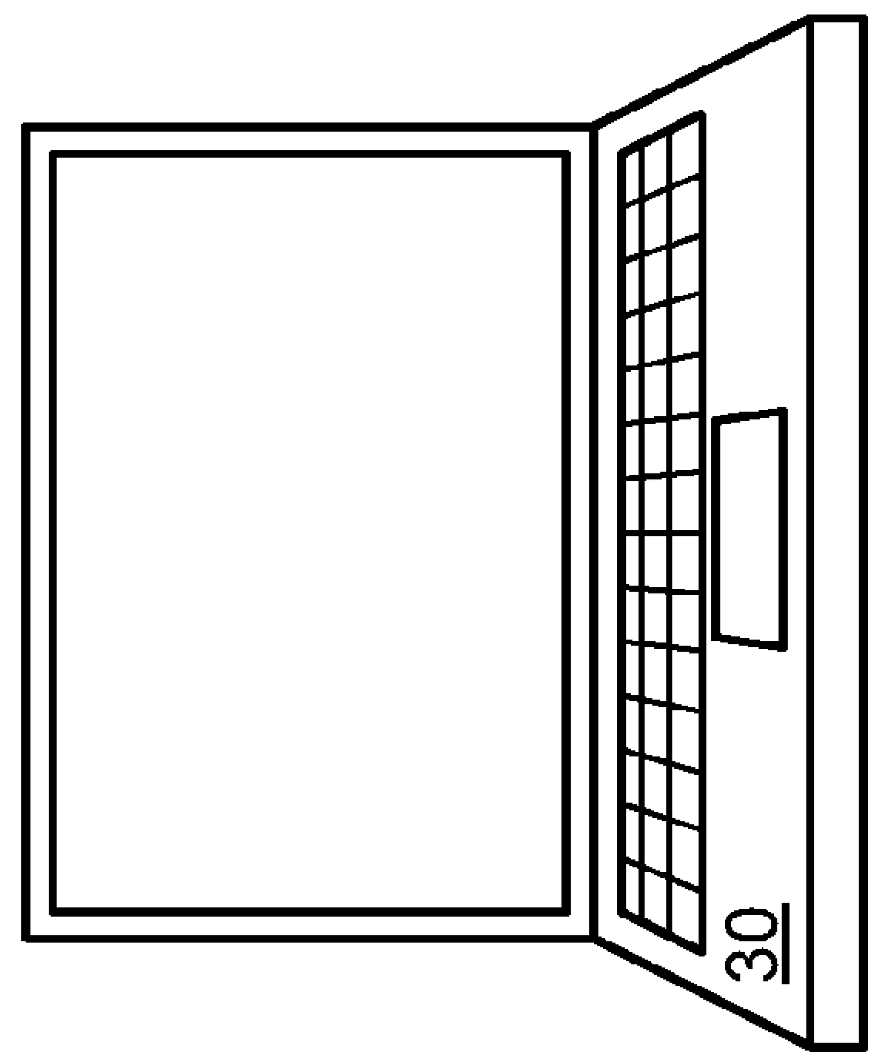


FIG. 3

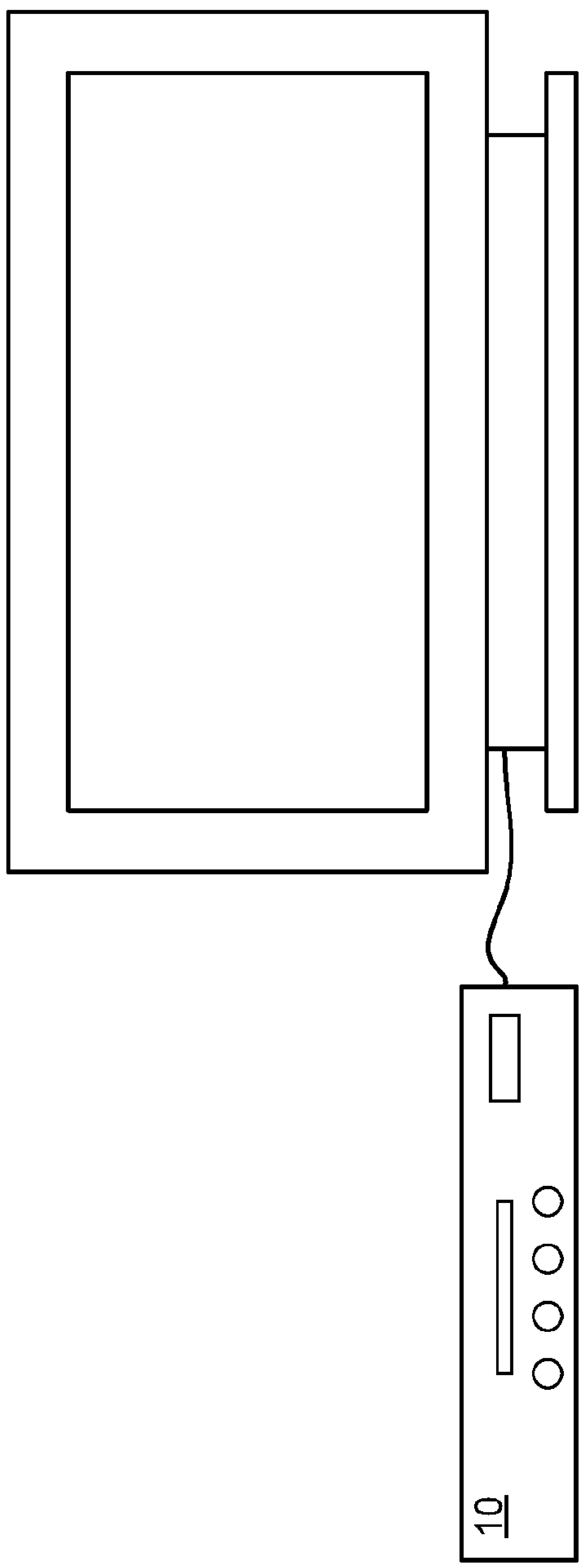


FIG. 1

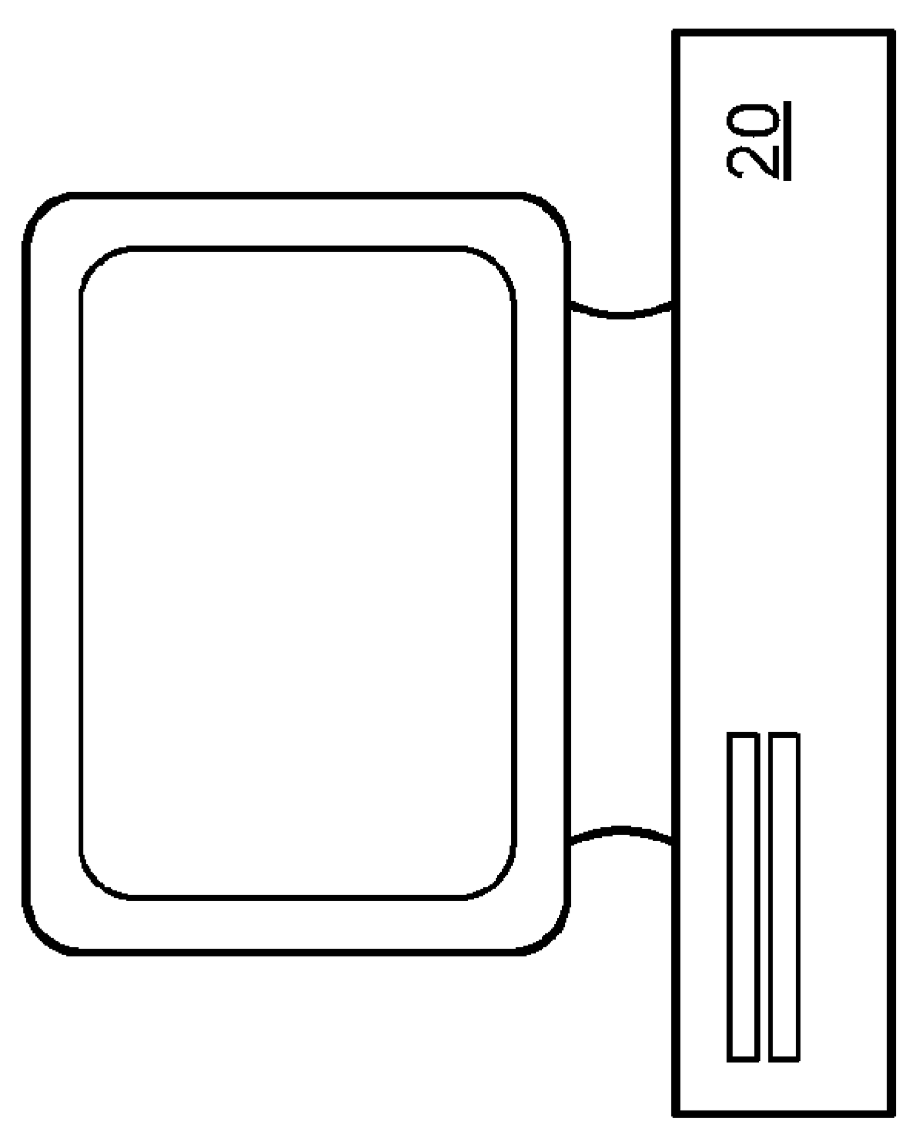


FIG. 2

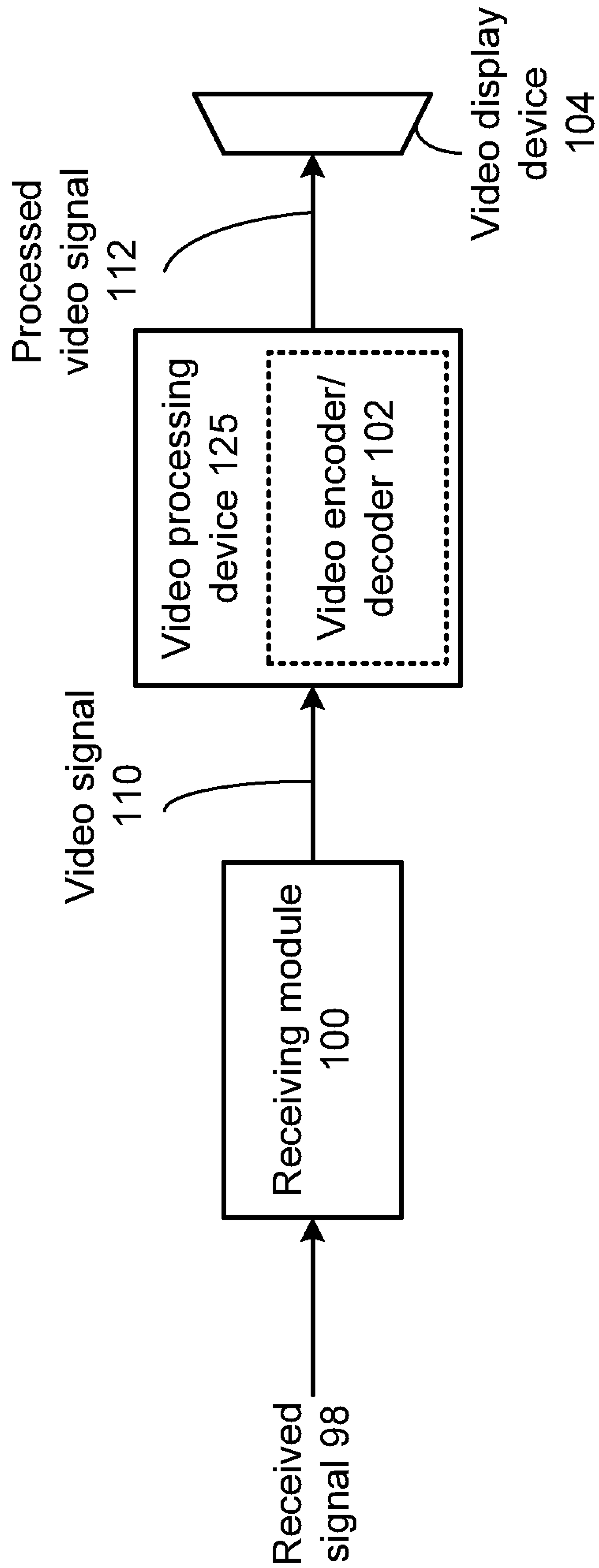

Received signal 98
Receiving module 100
Video signal 110
Video processing device 125
Video encoder/ decoder 102
Processed video signal 112
Video display device 104

FIG. 4

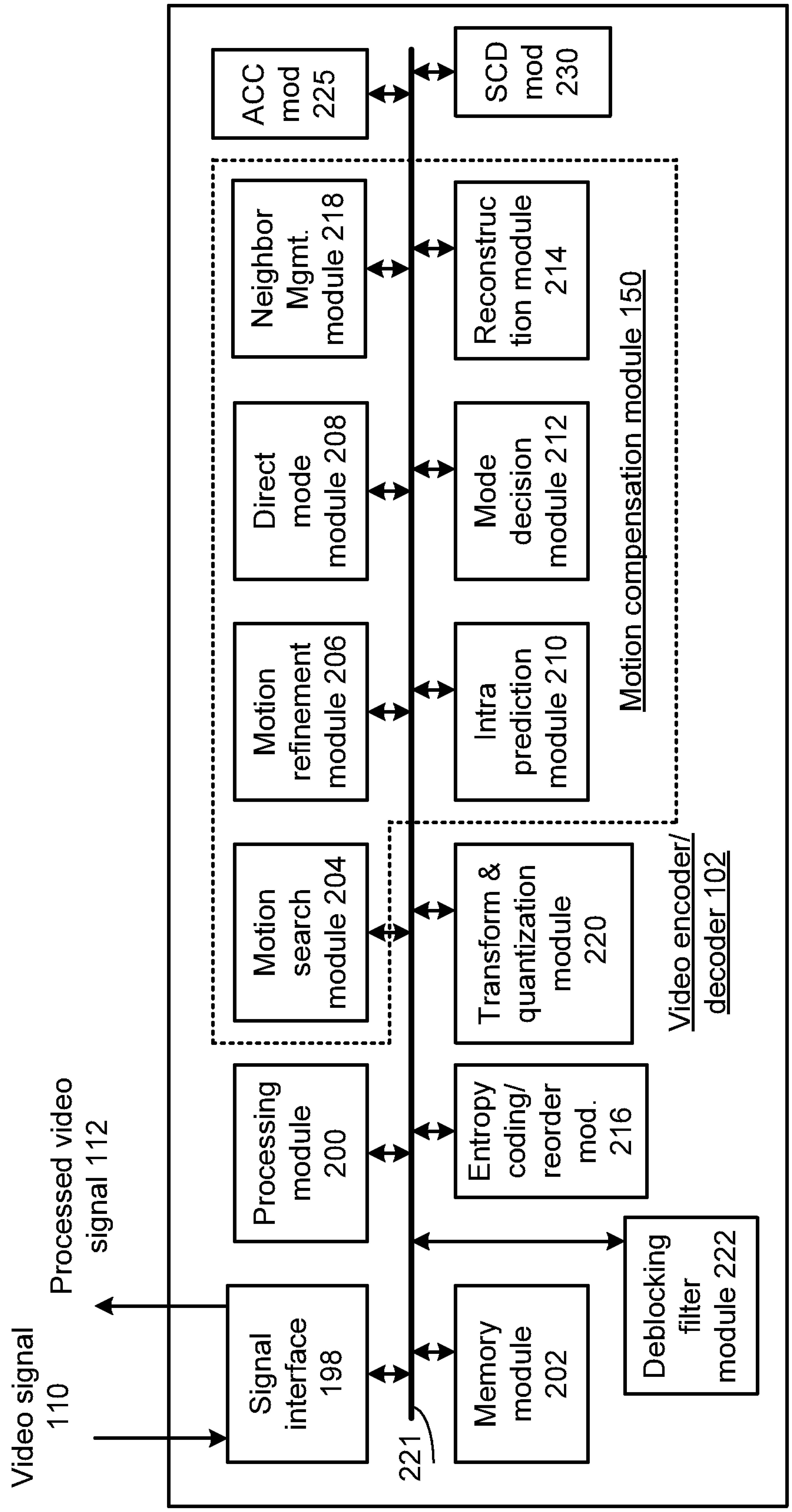

Video signal 110
Processed video signal 112
Signal interface 198
Processing module 200
Memory module 202
Motion search module 204
Motion refinement module 206
Direct mode module 208
Intra prediction module 210
Mode decision module 212
Reconstruction module 214
Entropy coding/reorder mod. 216
Neighbor Mgmt. module 218
Transform & quantization module 220
221
Deblocking filter module 222
ACC mod 225
SCD mod 230
Motion compensation module 150
Video encoder/decoder 102

FIG. 5

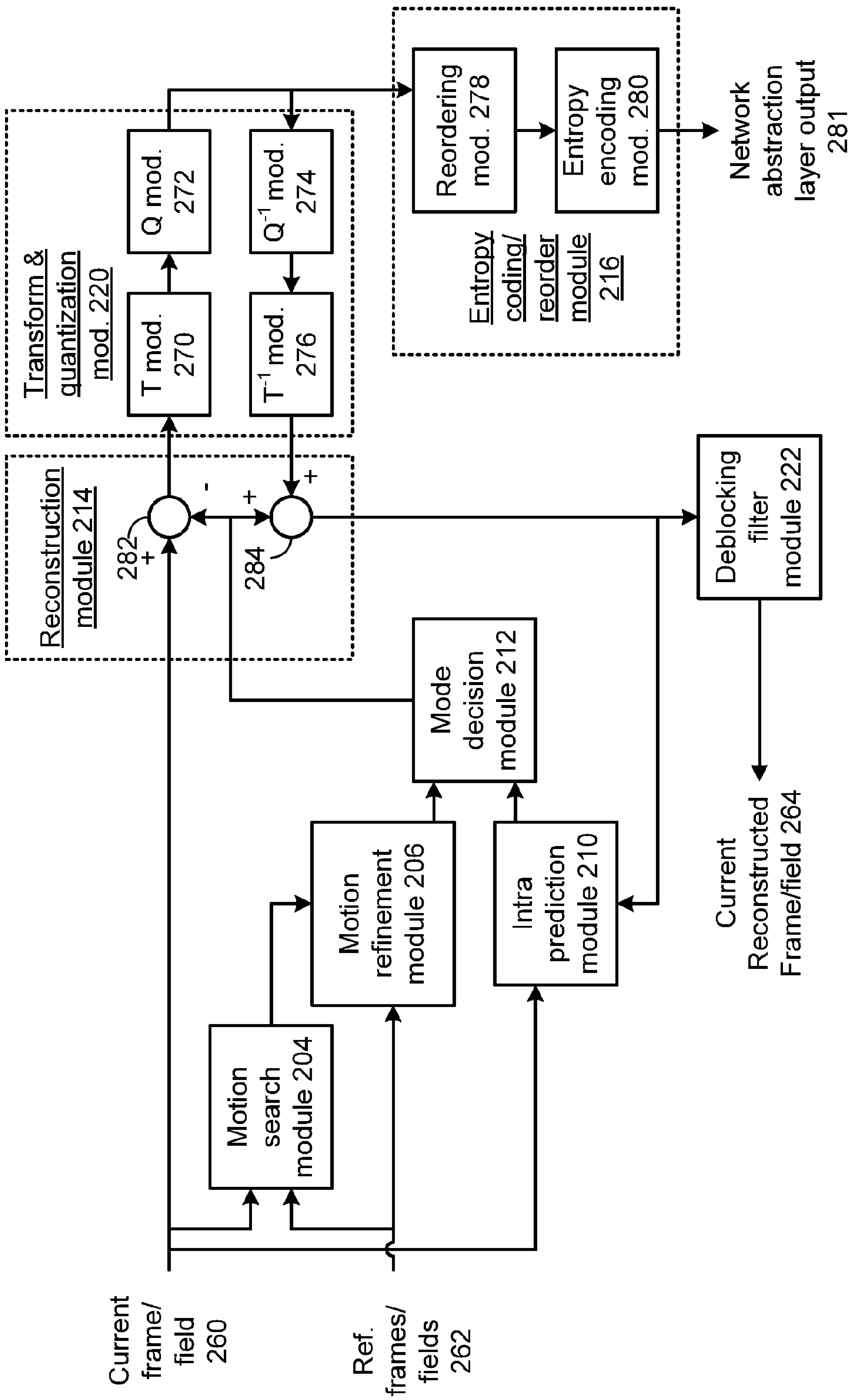


FIG. 6

Video encoding operation

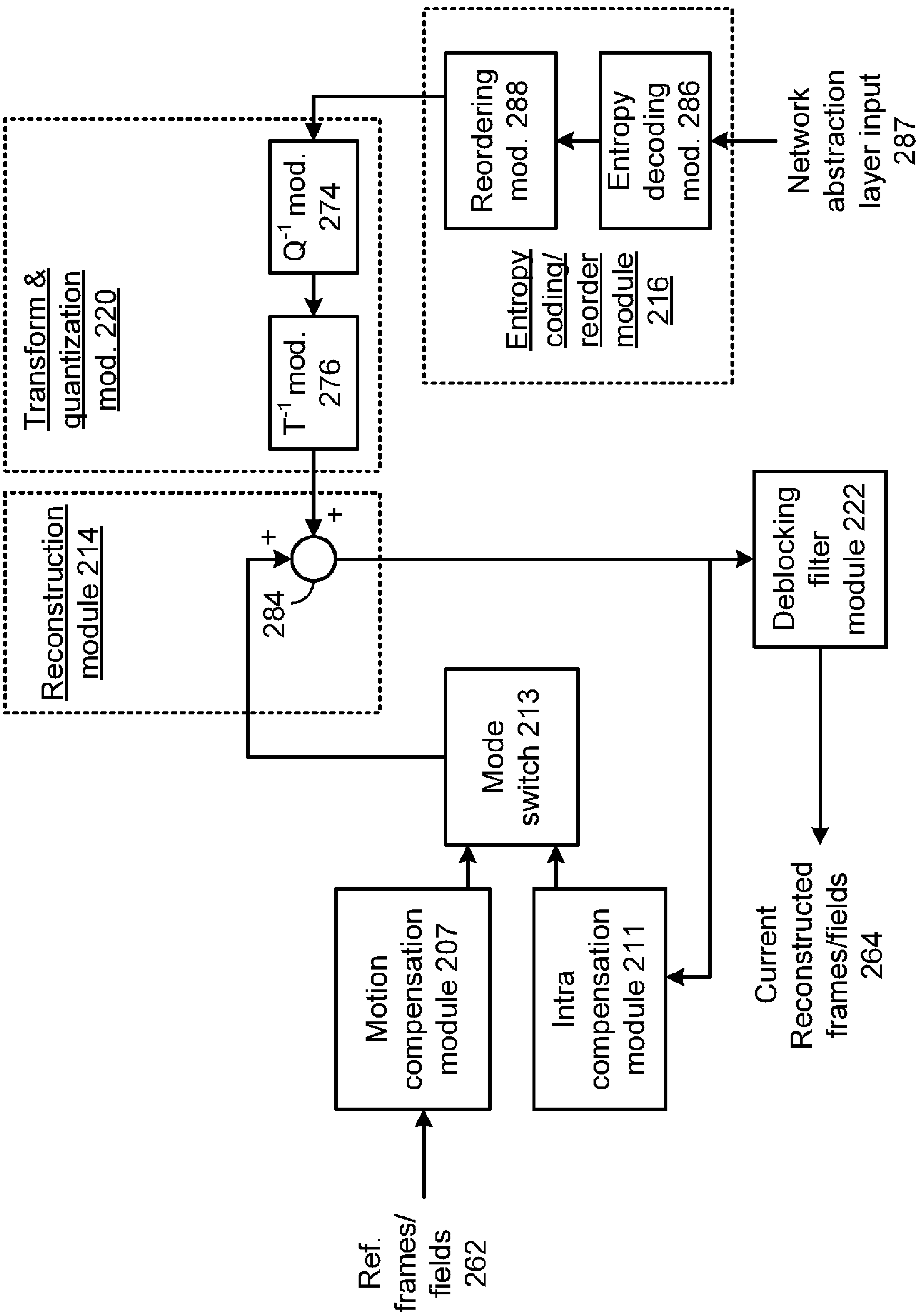
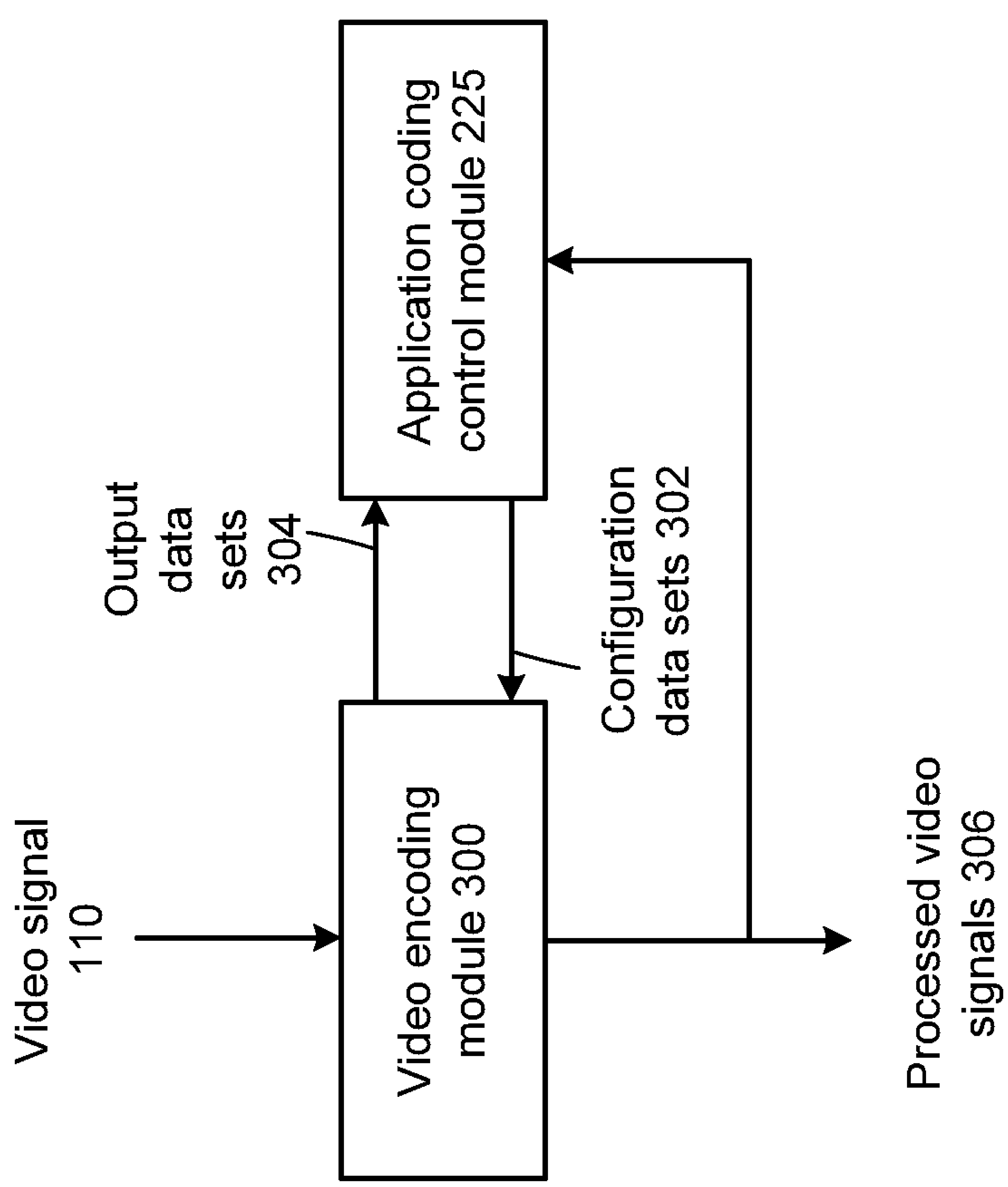


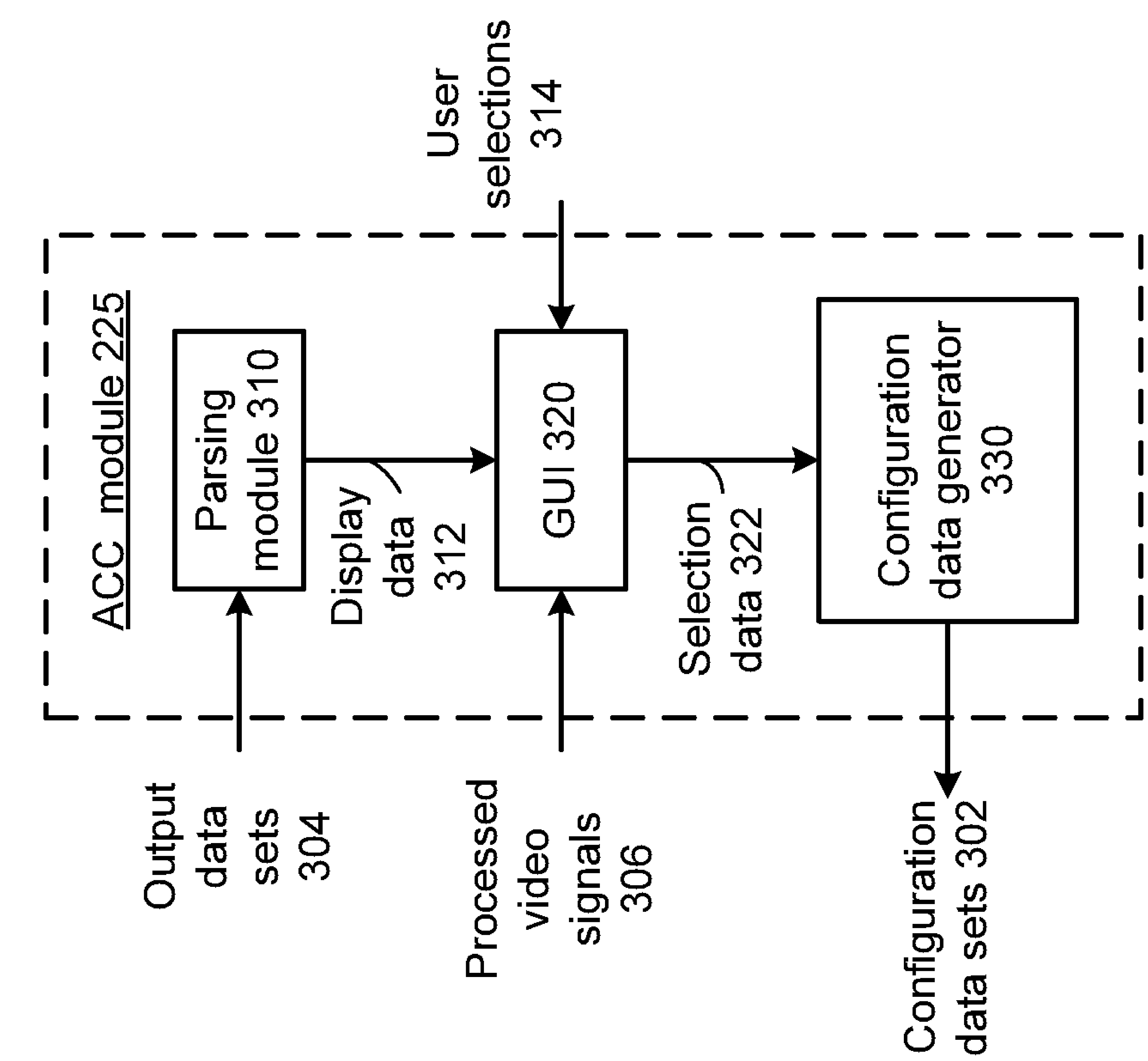
FIG. 7

Video decoding operation



Video signal 110
Video encoding module 300
Output data sets 304
Configuration data sets 302
Application coding control module 225
Processed video signals 306

FIG. 8



ACC module 225
Parsing module 310
Display data 312
GUI 320
User selections 314
Selection data 322
Configuration data generator 330
Output data sets 304
Processed video signals 306
Configuration data sets 302

FIG. 9

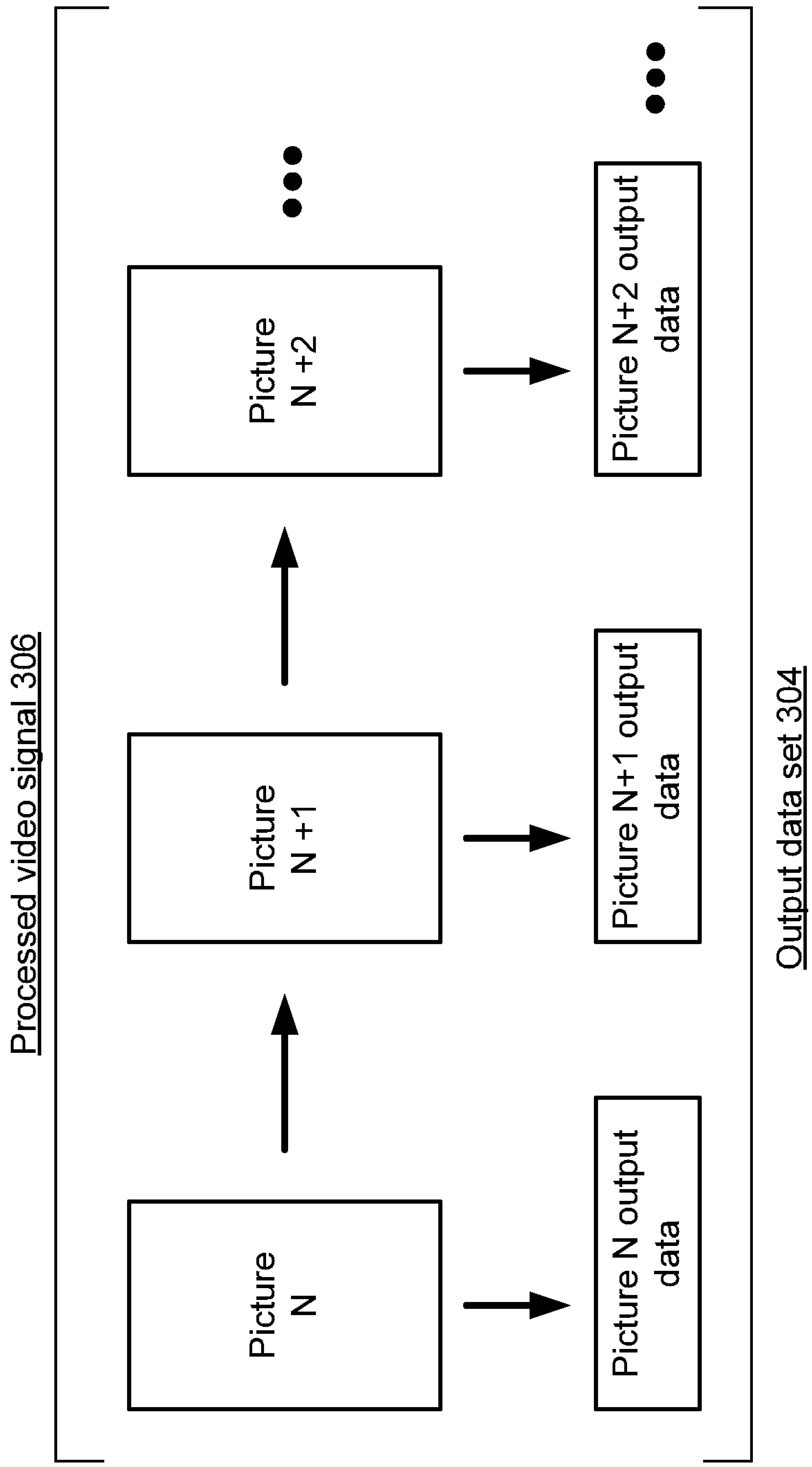

Processed video signal 306
Picture N
Picture N +1
Picture N +2
Picture N output data
Picture N+1 output data
Picture N+2 output data
Output data set 304

FIG. 10

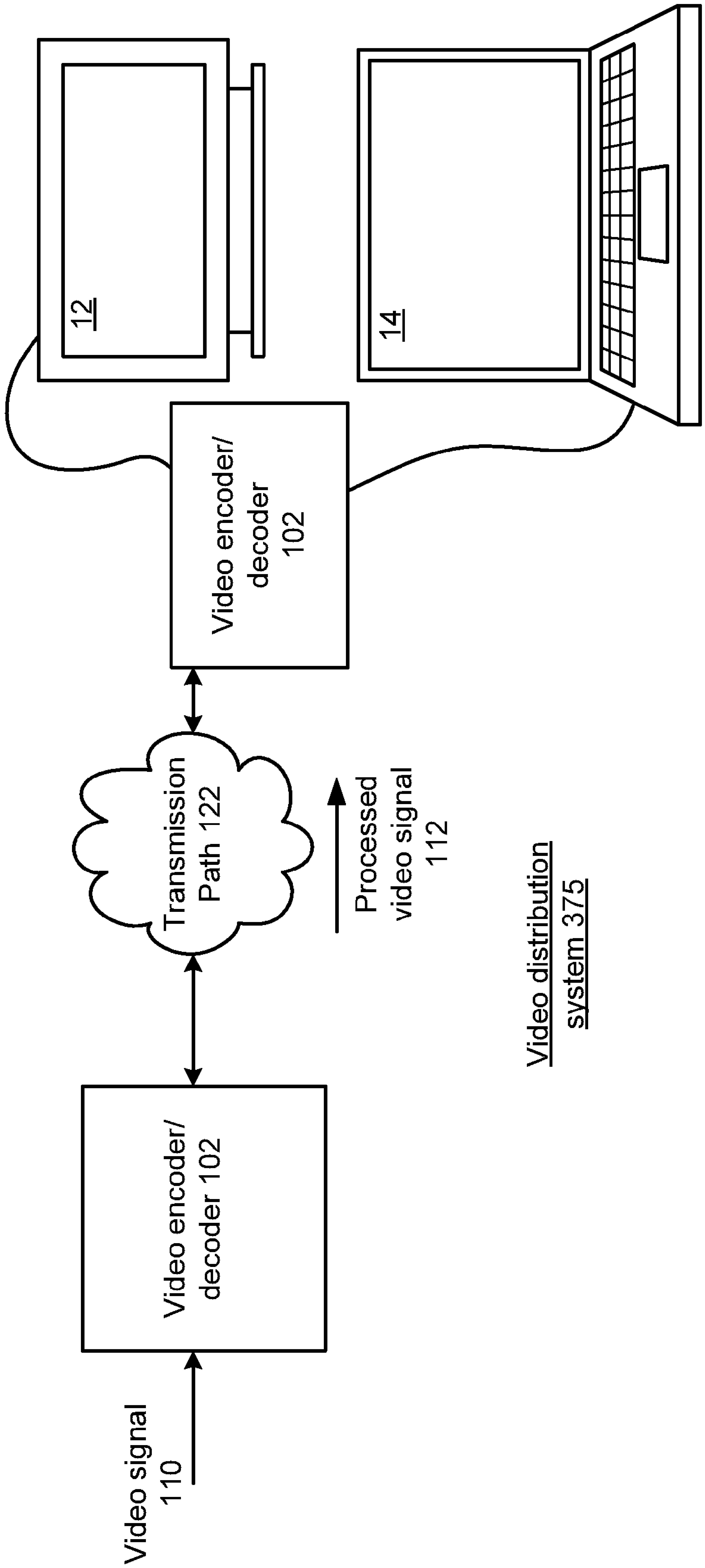

12
14
Video encoder/
decoder
102
Transmission
Path 122
Processed
video signal
112
Video distribution
system 375
Video encoder/
decoder 102
Video signal
110

FIG. 11

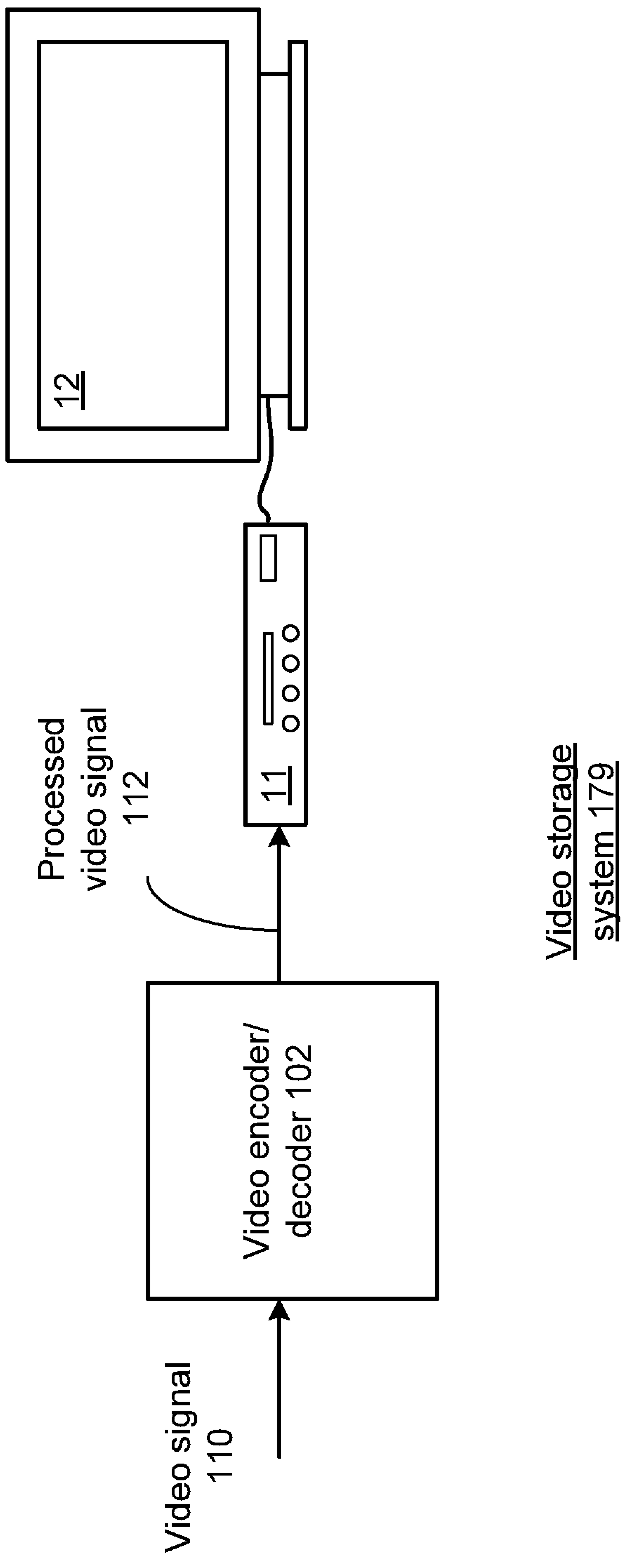

12
11
Processed video signal 112
Video encoder/ decoder 102
Video signal 110
Video storage system 179

FIG. 12

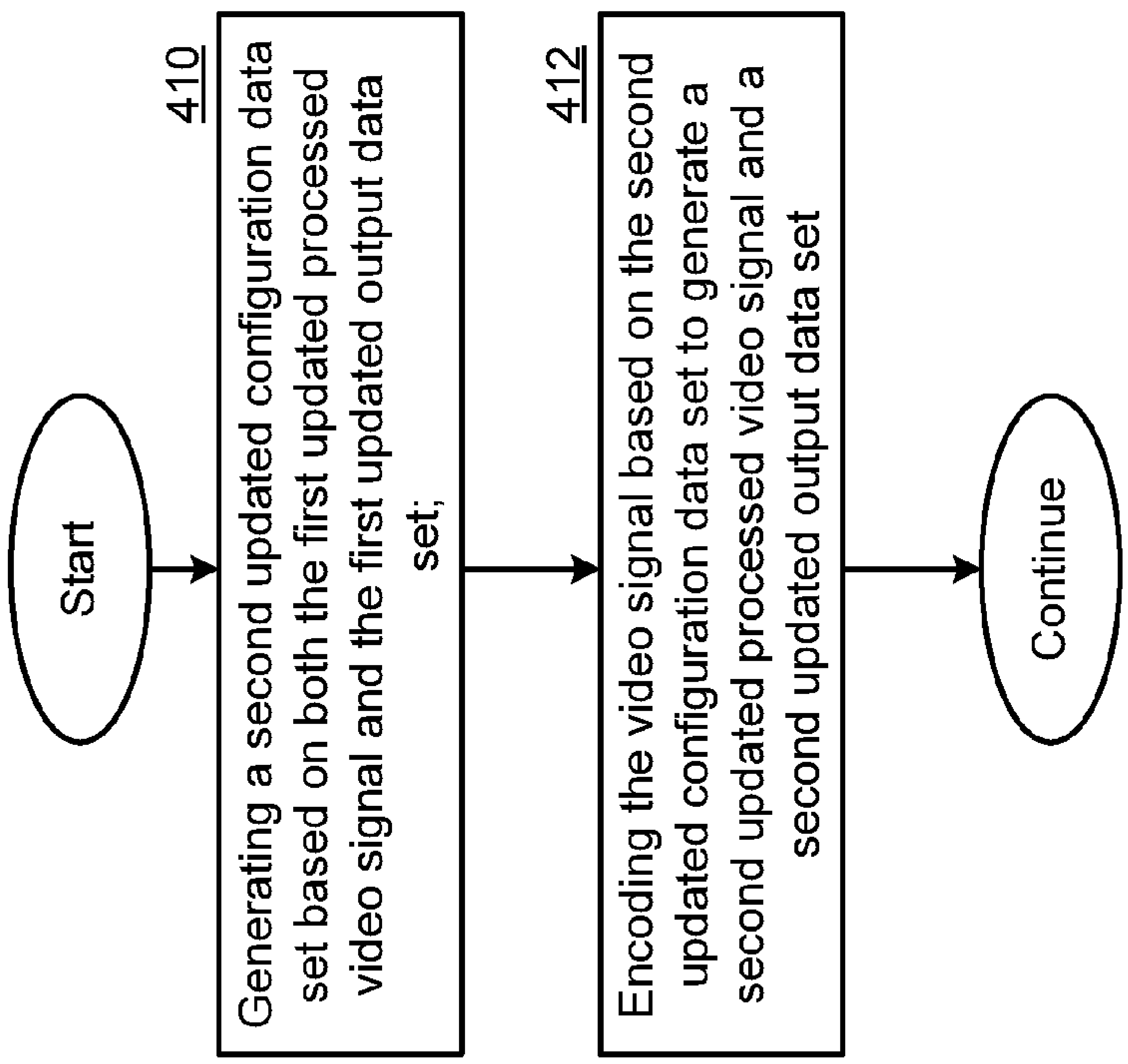

Start
410
Generating a second updated configuration data set based on both the first updated processed video signal and the first updated output data set;
412
Encoding the video signal based on the second updated configuration data set to generate a second updated processed video signal and a second updated output data set
Continue

FIG. 14

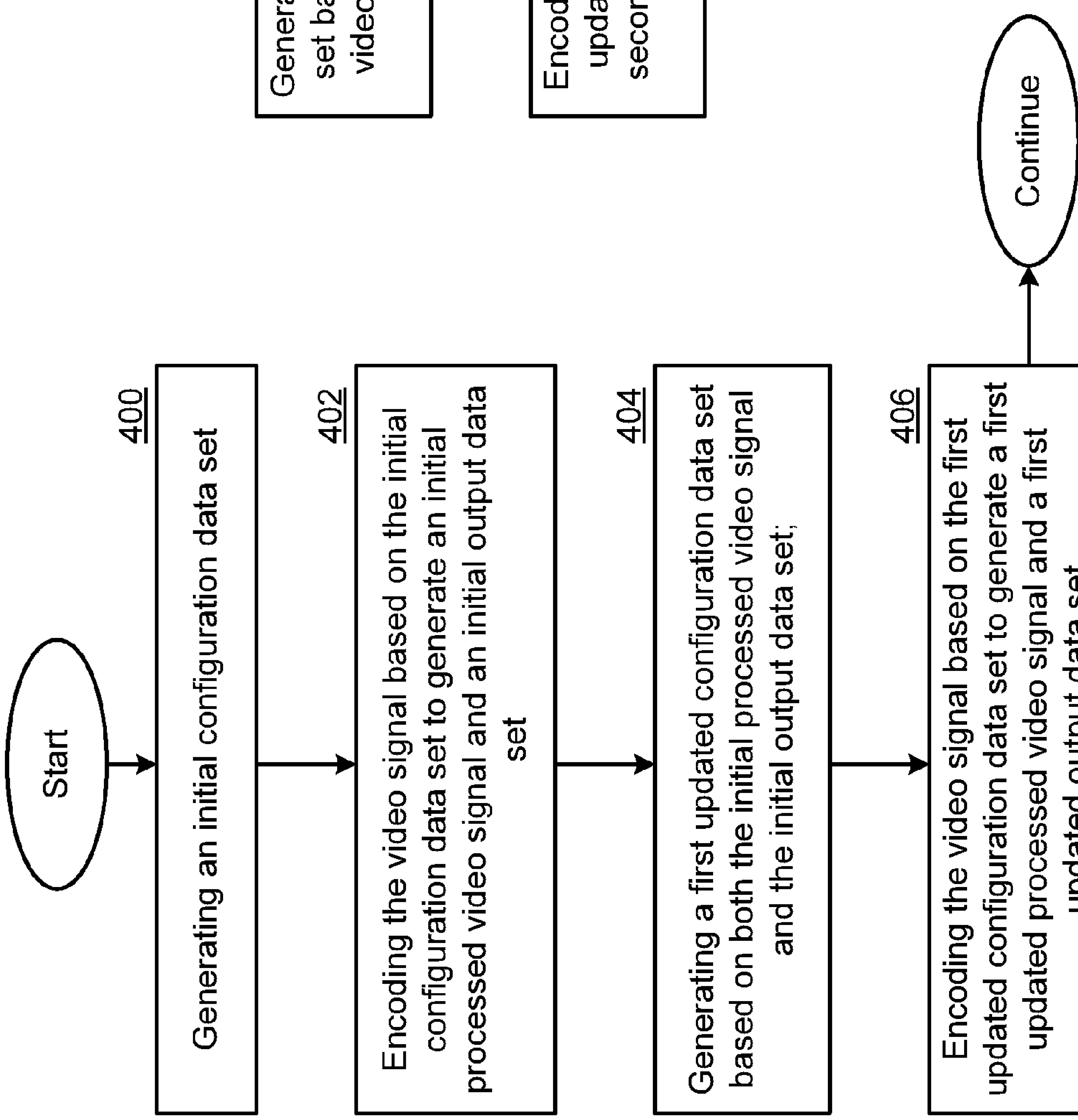

Start
400
Generating an initial configuration data set
402
Encoding the video signal based on the initial configuration data set to generate an initial processed video signal and an initial output data set
404
Generating a first updated configuration data set based on both the initial processed video signal and the initial output data set;
406
Encoding the video signal based on the first updated configuration data set to generate a first updated processed video signal and a first updated output data set
Continue

FIG. 13

MULTI-PASS VIDEO ENCODER AND METHODS FOR USE THEREWITH

CROSS REFERENCE TO RELATED PATENTS

Not Applicable

TECHNICAL FIELD OF THE INVENTION

The present invention relates to encoding used in devices such as video encoders/decoders.

DESCRIPTION OF RELATED ART

Video encoding has become an important issue for modern video processing devices. Robust encoding algorithms allow video signals to be transmitted with reduced bandwidth and stored in less memory. However, the accuracy of these encoding methods face the scrutiny of users that are becoming accustomed to greater resolution and higher picture quality. Standards have been promulgated for many encoding methods including the H.264 standard that is also referred to as MPEG-4, part 10 or Advanced Video Coding, (AVC). While this standard sets forth many powerful techniques, further improvements are possible to improve the performance and speed of implementation of such methods. The video signal encoded by these encoding methods must be similarly decoded for playback on most video display devices.

Efficient and fast encoding and decoding of video signals is important to the implementation of many video devices, particularly video devices that are destined for home use. Further limitations and disadvantages of conventional and traditional approaches will become apparent to one of ordinary skill in the art through comparison of such systems with the present invention.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

FIGS. **1-3** present pictorial diagram representations of various video devices in accordance with embodiments of the present invention.

FIG. **4** presents a block diagram representation of a video device in accordance with an embodiment of the present invention.

FIG. **5** presents a block diagram representation of a video encoder/decoder **102** in accordance with an embodiment of the present invention.

FIG. **6** presents a block flow diagram of a video encoding operation in accordance with an embodiment of the present invention.

FIG. **7** presents a block flow diagram of a video decoding operation in accordance with an embodiment of the present invention.

FIG. **8** presents a block diagram representation of a video encoder in accordance with an embodiment of the present invention.

FIG. **9** presents a block diagram representation of an application coding control module **225** in accordance with an embodiment of the present invention.

FIG. **10** presents a graphical representation of processed video signal **306** in accordance with an embodiment of the present invention.

FIG. **11** presents a block diagram representation of a video distribution system **375** in accordance with an embodiment of the present invention.

FIG. **12** presents a block diagram representation of a video storage system **179** in accordance with an embodiment of the present invention.

FIG. **13** presents a flowchart representation of a method in accordance with an embodiment of the present invention.

FIG. **14** presents a flowchart representation of a method in accordance with an embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION INCLUDING THE PRESENTLY PREFERRED EMBODIMENTS

FIGS. **1-3** present pictorial diagram representations of various video devices in accordance with embodiments of the present invention. In particular, set top box **10** with built-in digital video recorder functionality or a stand alone digital video recorder, computer **20** and portable computer **30** illustrate electronic devices that incorporate a video device **125** that includes one or more features or functions of the present invention. While these particular devices are illustrated, video processing device **125** includes any device that is capable of encoding, decoding and/or transcoding video content in accordance with the methods and systems described in conjunction with FIGS. **4-14** and the appended claims.

FIG. **4** presents a block diagram representation of a video device in accordance with an embodiment of the present invention. In particular, this video device includes a receiving module **100**, such as a television receiver, cable television receiver, satellite broadcast receiver, broadband modem, 3G transceiver or other information receiver or transceiver that is capable of receiving a received signal **98** and extracting one or more video signals **110** via time division demultiplexing, frequency division demultiplexing or other demultiplexing technique. Video processing device **125** includes video encoder/decoder **102** and is coupled to the receiving module **100** to encode, decode or transcode the video signal for storage, editing, and/or playback in a format corresponding to video display device **104**.

In an embodiment of the present invention, the received signal **98** is a broadcast video signal, such as a television signal, high definition television signal, enhanced definition television signal or other broadcast video signal that has been transmitted over a wireless medium, either directly or through one or more satellites or other relay stations or through a cable network, optical network or other transmission network. In addition, received signal **98** can be generated from a stored video file, played back from a recording medium such as a magnetic tape, magnetic disk or optical disk, and can include a streaming video signal that is transmitted over a public or private network such as a local area network, wide area network, metropolitan area network or the Internet.

Video signal **110** can include an analog video signal that is formatted in any of a number of video formats including National Television Systems Committee (NTSC), Phase Alternating Line (PAL) or Sequentiel Couleur Avec Memoire (SECAM). Processed video signal **112** can include a digital video signal complying with a digital video codec standard such as H.264, MPEG-4 Part 10 Advanced Video Coding (AVC) or another digital format such as a Motion Picture Experts Group (MPEG) format (such as MPEG1, MPEG2 or MPEG4), QuickTime format, Real Media format, Windows Media Video (WMV) or Audio Video Interleave (AVI), etc.

Video display devices **104** can include a television, monitor, computer, handheld device or other video display device that creates an optical image stream either directly or indirectly, such as by projection, based on decoding the processed video signal **112** either as a streaming video signal or by playback of a stored digital video file.

FIG. **5** presents a block diagram representation of a video encoder/decoder **102** in accordance with an embodiment of the present invention. In particular, video encoder/decoder **102** can be a video codec that operates in accordance with many of the functions and features of the H.264 standard, the MPEG-4 standard, VC-1 (SMPTE standard 421M) or other standard, to generate processed video signal **112** by encoding, decoding or transcoding video signal **110**. Video signal **110** is optionally formatted by signal interface **198** for encoding, decoding or transcoding.

The video encoder/decoder **102** includes a processing module **200** that can be implemented using a single processing device or a plurality of processing devices. Such a processing device may be a microprocessor, co-processors, a micro-controller, digital signal processor, microcomputer, central processing unit, field programmable gate array, programmable logic device, state machine, logic circuitry, analog circuitry, digital circuitry, and/or any device that manipulates signals (analog and/or digital) based on operational instructions that are stored in a memory, such as memory module **202**. Memory module **202** may be a single memory device or a plurality of memory devices. Such a memory device can include a hard disk drive or other disk drive, read-only memory, random access memory, volatile memory, non-volatile memory, static memory, dynamic memory, flash memory, cache memory, and/or any device that stores digital information. Note that when the processing module implements one or more of its functions via a state machine, analog circuitry, digital circuitry, and/or logic circuitry, the memory storing the corresponding operational instructions may be embedded within, or external to, the circuitry comprising the state machine, analog circuitry, digital circuitry, and/or logic circuitry.

Processing module **200**, and memory module **202** are coupled, via bus **221**, to the signal interface **198** and a plurality of other modules, such as motion search module **204**, motion refinement module **206**, direct mode module **208**, intra-prediction module **210**, mode decision module **212**, reconstruction module **214**, entropy coding/reorder module **216**, neighbor management module **218**, forward transform and quantization module **220**, deblocking filter module **222**, application coding and control module **225** and scene detection module **230**. In an embodiment of the present invention, the modules of video encoder/decoder **102** can be implemented via an XCODE processing device sold by VIXS Systems, Inc along with software or firmware. Alternatively, one or more of these modules can be implemented using other hardware, such as another processor or a hardware engine that includes a state machine, analog circuitry, digital circuitry, and/or logic circuitry, and that operates either independently or under the control and/or direction of processing module **200** or one or more of the other modules, depending on the particular implementation. It should also be noted that the software implementations of the present invention can be stored on a tangible storage medium such as a magnetic or optical disk, read-only memory or random access memory and also be produced as an article of manufacture. While a particular bus architecture is shown, alternative architectures using direct connectivity between one or more modules and/or additional busses can likewise be implemented in accordance with the present invention.

Video encoder/decoder **102** can operate in various modes of operation that include an encoding mode and a decoding mode that is set by the value of a mode selection signal that may be a user defined parameter, user input, register value, memory value or other signal. In addition, in video encoder/decoder **102**, the particular standard used by the encoding or decoding mode to encode or decode the input signal can be determined by a standard selection signal that also may be a user defined parameter, user input, register value, memory value or other signal. In an embodiment of the present invention, the operation of the encoding mode utilizes a plurality of modules that each perform a specific encoding function. The operation of decoding also utilizes at least one of these plurality of modules to perform a similar function in decoding. In this fashion, modules such as the motion refinement module **206** and more particularly an interpolation filter used therein, and intra-prediction module **210**, can be used in both the encoding and decoding process to save on architectural real estate when video encoder/decoder **102** is implemented on an integrated circuit or to achieve other efficiencies. In addition, some or all of the components of the direct mode module **208**, mode decision module **212**, reconstruction module **214**, transformation and quantization module **220**, deblocking filter module **222** or other function specific modules can be used in both the encoding and decoding process for similar purposes.

Motion compensation module **150** includes a motion search module **204** that processes pictures from the video signal **110** based on a segmentation into macroblocks of pixel values, such as of 16 pixels by 16 pixels size, from the columns and rows of a frame and/or field of the video signal **110**. In an embodiment of the present invention, the motion search module determines, for each macroblock or macroblock pair of a field and/or frame of the video signal one or more motion vectors that represents the displacement of the macroblock (or subblock) from a reference frame or reference field of the video signal to a current frame or field. In operation, the motion search module operates within a search range to locate a macroblock (or subblock) in the current frame or field to an integer pixel level accuracy such as to a resolution of 1-pixel. Candidate locations are evaluated based on a cost formulation to determine the location and corresponding motion vector that have a most favorable (such as lowest) cost.

In an embodiment of the present invention, a cost formulation is based on the Sum of Absolute Difference (SAD) between the reference macroblock and candidate macroblock pixel values and a weighted rate term that represents the number of bits required to be spent on coding the difference between the candidate motion vector and either a predicted motion vector (PMV) that is based on the neighboring macroblock to the right of the current macroblock and on motion vectors from neighboring current macroblocks of a prior row of the video signal or an estimated predicted motion vector that is determined based on motion vectors from neighboring current macroblocks of a prior row of the video signal. In an embodiment of the present invention, the cost calculation avoids the use of neighboring subblocks within the current macroblock. In this fashion, motion search module **204** is able to operate on a macroblock to contemporaneously determine the motion search motion vector for each subblock of the macroblock.

A motion refinement module **206** generates a refined motion vector for each macroblock of the plurality of macroblocks, based on the motion search motion vector. In an embodiment of the present invention, the motion refinement module determines, for each macroblock or macroblock pair of a field and/or frame of the video signal **110**, a refined motion vector that represents the displacement of the macroblock from a reference frame or reference field of the video signal to a current frame or field.

Based on the pixels and interpolated pixels, the motion refinement module **206** refines the location of the macroblock in the current frame or field to a greater pixel level accuracy such as to a resolution of ¼-pixel or other sub-pixel resolution. Candidate locations are also evaluated based on a cost formulation to determine the location and refined motion vector that have a most favorable (such as lowest) cost. As in the case with the motion search module, a cost formulation can be based on the Sum of Absolute Difference (SAD) between the reference macroblock and candidate macroblock pixel values and a weighted rate term that represents the number of bits required to be spent on coding the difference between the candidate motion vector and either a predicted motion vector (PMV) that is based on the neighboring macroblock to the right of the current macroblock and on motion vectors from neighboring current macroblocks of a prior row of the video signal or an estimated predicted motion vector that is determined based on motion vectors from neighboring current macroblocks of a prior row of the video signal. In an embodiment of the present invention, the cost calculation avoids the use of neighboring subblocks within the current macroblock. In this fashion, motion refinement module **206** is able to operate on a macroblock to contemporaneously determine the motion search motion vector for each subblock of the macroblock.

When estimated predicted motion vectors are used, the cost formulation avoids the use of motion vectors from the current row and both the motion search module **204** and the motion refinement module **206** can operate in parallel on an entire row of video signal **110**, to contemporaneously determine the refined motion vector for each macroblock in the row.

A direct mode module **208** generates a direct mode motion vector for each macroblock, based on macroblocks that neighbor the macroblock. In an embodiment of the present invention, the direct mode module **208** operates to determine the direct mode motion vector and the cost associated with the direct mode motion vector based on the cost for candidate direct mode motion vectors for the B slices of video signal **110**, such as in a fashion defined by the H.264 standard.

While the prior modules have focused on inter-prediction of the motion vector, intra-prediction module **210** generates a best intra prediction mode for each macroblock of the plurality of macroblocks. In an embodiment of the present invention, intra-prediction module **210** operates as defined by the H.264 standard, however, other intra-prediction techniques can likewise be employed. In particular, intra-prediction module **210** operates to evaluate a plurality of intra prediction modes such as a Intra-4×4 or Intra-16×16, which are luma prediction modes, chroma prediction (8×8) or other intra coding, based on motion vectors determined from neighboring macroblocks to determine the best intra prediction mode and the associated cost.

A mode decision module **212** determines a final macroblock cost for each macroblock of the plurality of macroblocks based on costs associated with the refined motion vector, the direct mode motion vector, and the best intra prediction mode, and in particular, the method that yields the most favorable (lowest) cost, or an otherwise acceptable cost. A reconstruction module **214** completes the motion compensation by generating residual luma and/or chroma pixel values for each macroblock of the plurality of macroblocks.

A forward transform and quantization module **220** of video encoder/decoder **102** generates processed video signal **112** by transforming coding and quantizing the residual pixel values into quantized transformed coefficients that can be further coded, such as by entropy coding in entropy coding module **216**, filtered by de-blocking filter module **222**. In an embodiment of the present invention, further formatting and/or buffering can optionally be performed by signal interface **198** and the processed video signal **112** can be represented as being output therefrom.

As discussed above, many of the modules of motion compensation module **150** operate based on motion vectors determined for neighboring macroblocks. Neighbor management module **218** generates and stores neighbor data for at least one macroblock of the plurality of macroblocks for retrieval by at least one of the motion search module **204**, the motion refinement module **206**, the direct mode module **208**, intra-prediction module **210**, entropy coding module **216** and deblocking filter module **222**, when operating on at least one neighboring macroblock of the plurality of macroblocks. In an embodiment of the present invention, a data structure, such as a linked list, array or one or more registers are used to associate and store neighbor data for each macroblock in a buffer, cache, shared memory or other memory structure. Neighbor data includes motion vectors, reference indices, quantization parameters, coded-block patterns, macroblock types, intra/inter prediction module types neighboring pixel values and or other data from neighboring macroblocks and/or subblocks used to by one or more of the modules or procedures of the present invention to calculate results for a current macroblock. For example, in order to determine the predicated motion vector for the motion search module **204** and motion refinement module **206**, both the motion vectors and reference index of neighbors are required. In addition to these data, the direct mode module **208** requires the motion vectors of the co-located macroblock of previous reference pictures. The deblocking filter module **222** operates according to a set of filtering strengths determined by using the neighbors' motion vectors, quantization parameters, reference index, and coded-block-patterns, etc. For entropy coding in entropy coding module **216**, the motion vector differences (MVD), macroblock types, quantization parameter delta, inter predication type, etc. are required.

Consider the example where a particular macroblock MB (x, y) requires neighbor data from macroblocks MB (x−1, y−1), MB (x, y−1), MB (x+1, y−1) and MB (x−1, y). In prior art codecs, the preparation of the neighbor data needs to calculate the location of the relevant neighbor sub-blocks. However, the calculation is not as straightforward as it was in conventional video coding standards. For example, in H.264 coding, the support of multiple partition types make the size and shape for the subblocks vary significantly. Furthermore, the support of the macroblock adaptive frame and field (MBAFF) coding allows the macroblocks to be either in frame or in field mode. For each mode, one neighbor derivation method is defined in H.264. So the calculation needs to consider each mode accordingly. In addition, in order to get all of the neighbor data required, the derivation needs to be invoked four times since there are four neighbors involved—MB (x−1, y−1), MB (x, y−1), MB (x+1, y−1), and MB (x−1, y). So the encoding of the current macroblock MB (x, y) cannot start not until the location of the four neighbors has been determined and their data have been fetched from memory.

In an embodiment of the present invention, when each macroblock is processed and final motion vectors and encoded data are determined, neighbor data is stored in data structures for each neighboring macroblock that will need this data. Since the neighbor data is prepared in advance, the current macroblock MB (x, y) can start right away when it is ready to be processed. The burden of pinpointing neighbors is virtually re-allocated to its preceding macroblocks. The encoding of macroblocks can be therefore be more streamline and faster. In other words, when the final motion vectors are determined for MB (x−1, y−1), neighbor data is stored for each neighboring macroblock that is yet to be processed, including MB (x, y) and also other neighboring macroblocks such as MB (x, y−1), MB (x−2, y) MB (x−1, y). Similarly, when the final motion vectors are determined for MB (x, y−1), MB (x+1, y−1) and MB (x−1, y) neighbor data is stored for each neighboring macroblock corresponding to each of these macroblocks that are yet to be processed, including MB (x, y). In this fashion, when MB (x, y) is ready to be processed, the neighbor data is already stored in a data structure that corresponds to this macroblock for fast retrieval.

The motion compensation can then proceed using the retrieved data. In particular, the motion search module **204** and/or the motion refinement module, can generate at least one predicted motion vector (such as a standard PMV or estimated predicted motion vector) for each macroblock of the plurality of macroblocks using retrieved neighbor data. Further, the direct mode module **208** can generate at least one direct mode motion vector for each macroblock of the plurality of macroblocks using retrieved neighbor data and the intra-prediction module **210** can generate the best intra prediction mode for each macroblock of the plurality of macroblocks using retrieved neighbor data, and the coding module **216** can use retrieved neighbor data in entropy coding, each as set forth in the H.264 standard, the MPEG-4 standard, VC-1 (SMPTE standard 421M) or by other standard or other means.

Scene detection module **230** detects scene changes in the video signal **110** based, for example on motion detection in the video signal **110**. In an embodiment of the present invention, scene detection module **230** generates a motion identification signal for each picture video signal **110**. The motion in each picture, such as a video field (or frame if it is progressive-scan video source), can be represented by a parameter called Global Motion (GM). The value of GM quantifies the change of the field compared to the previous same-parity field. In terms of each macroblock pair, the top field is compared to the top field, bottom field compared to bottom field, etc. The value of GM can be computed as the sum of Pixel Motion (PM) over all pixels in the field or frame, where the value of PM is calculated for each pixel in the field or frame.

The parameter GM, can be used to detect a scene change in the video signal **110**. When scene happens on a field, the field will generate considerably higher GM value compared to "normal" fields. A scene change can be detected by analyzing the GM pattern along consecutive fields, for example by detecting an increase or decrease in GM in consecutive fields that exceeds a scene detection threshold. Once a scene change is detected that corresponds to a particular image, encoding parameters of encoder/decoder **102** can be adjusted to achieve better results. For example, the detection of a scene change can be used to trigger the start of a new group of pictures (GOP). In another example, the encoder/decoder **102** responds to a scene change detection by adjusting the values of QP to compensate for the scene change, by enabling or disabling video filters or by adjusting or adapting other parameters of the encoding, decoding, transcoding or other processing by encoder/decoder **102**.

While not expressly shown, video encoder/decoder **102** can include a memory cache, shared memory, a memory management module, a comb filter or other video filter, and/or other module to support the encoding of video signal **110** into processed video signal **112**.

Further details of general encoding and decoding processes will be described in greater detail in conjunction with FIGS. **6** and **7**. In addition, video encoder/decoder **102** includes application coding control module **225** that operates in conjunction with a multi-pass encoding process that will be described in greater detail in conjunction with FIGS. **8-14**.

FIG. **6** presents a block flow diagram of a video encoding operation in accordance with an embodiment of the present invention. In particular, an example video encoding operation is shown that uses many of the function specific modules described in conjunction with FIG. **5** to implement a similar encoding operation. Motion search module **204** generates a motion search motion vector for each macroblock of a plurality of macroblocks based on a current frame/field **260** and one or more reference frames/fields **262**. Motion refinement module **206** generates a refined motion vector for each macroblock of the plurality of macroblocks, based on the motion search motion vector. Intra-prediction module **210** evaluates and chooses a best intra prediction mode for each macroblock of the plurality of macroblocks. Mode decision module **212** determines a final motion vector for each macroblock of the plurality of macroblocks based on costs associated with the refined motion vector, and the best intra prediction mode.

Reconstruction module **214** generates residual pixel values corresponding to the final motion vector for each macroblock of the plurality of macroblocks by subtraction from the pixel values of the current frame/field **260** by difference circuit **282** and generates unfiltered reconstructed frames/fields by re-adding residual pixel values (processed through transform and quantization module **220**) using adding circuit **284**. The transform and quantization module **220** transforms and quantizes the residual pixel values in transform module **270** and quantization module **272** and re-forms residual pixel values by inverse transforming and dequantization in inverse transform module **276** and dequantization module **274**. In addition, the quantized and transformed residual pixel values are reordered by reordering module **278** and entropy encoded by entropy encoding module **280** of entropy coding/reordering module **216** to form network abstraction layer output **281**.

Deblocking filter module **222** forms the current reconstructed frames/fields **264** from the unfiltered reconstructed frames/fields. It should also be noted that current reconstructed frames/fields **264** can be buffered to generate reference frames/fields **262** for future current frames/fields **260**.

As discussed in conjunction with FIG. **5**, one or more of the modules of video encoder/decoder **102** can also be used in the decoding process as will be described further in conjunction with FIG. **7**.

FIG. **7** presents a block flow diagram of a video decoding operation in accordance with an embodiment of the present invention. In particular, this video decoding operation contains many common elements described in conjunction with FIG. **6** that are referred to by common reference numerals. In this case, the motion compensation module **207**, the intra-compensation module **211**, the mode switch **213**, process reference frames/fields **262** to generate current reconstructed frames/fields **264**. In addition, the reconstruction module **214** reuses the adding circuit **284** and the transform and quantization module reuses the inverse transform module **276** and the inverse quantization module **274**. It should be noted that while entropy coding/reorder module **216** is reused, instead of reordering module **278** and entropy encoding module **280** producing the network abstraction layer output **281**, network abstraction layer input **287** is processed by entropy decoding module **286** and reordering module **288**.

While the reuse of modules, such as particular function specific hardware engines, has been described in conjunction with the specific encoding and decoding operations of FIGS. **6** and **7**, the present invention can likewise be similarly employed to the other embodiments of the present invention described in conjunction with FIGS. **1-5** and **8-14** and/or with other function specific modules used in conjunction with video encoding and decoding. In particular, while FIG. **6** describes a single pass encoding process, FIGS. **8-14** describe the use of the encoding portion of encoder/decoder **102** in conjunction with a multi-pass encoding of video signal **110** controlled by application coding control module **225**.

FIG. **8** presents a block diagram representation of a video encoder in accordance with an embodiment of the present invention. In particular a multi-pass video encoder is shown that includes a single pass video encoding module **300** that can be implemented via the encoding components of video encoder/decoder **102**, an XCODE processing device made available from VIXS Systems, Inc. or other single pass video encoder. The single pass video encoding module is controlled by application coding control module **225** to iteratively encode video signal **110** into processed video signals **306** through multiple passes. In general, application coding control module **225** generates successive configuration data sets **302** to specify one or more encoding parameters to be used by the video encoding module **300** in each iterative encoding of the video signal **110**. In an embodiment of the present invention, the application coding control module **225** can be implemented using a single processing device or a plurality of processing devices that, at each iteration, analyze the output data set **304** and the processed video signal **306** in order to automatically generate the next configuration data set **302**. In the alternative, as will be discussed further in conjunction with FIG. **9**, the application coding control module **225** operates based on user selections to select successive configuration data sets **302**.

In a first pass, the video encoding module **300** encodes the video signal **110** based on an initial configuration data set **302** generated by application control module **225**. The video encoding module **300** generates the encoded video signal as an initial processed video signal **306**. In addition, the video encoding module generates an initial output data set **304** that includes data that indicates parameters of the actual video encoding. The application coding control module **225** analyzes both the initial processed video signal **306** and the initial output data set **304** and, in response, generates a first updated configuration data set **302**.

In a second pass, the video encoding module **300** encodes the video signal **110** again based on the first updated configuration data set **302** to generate a first updated processed video signal **306** and a first updated output data set **304**. The process can continue by the application coding control module **225** generating a second updated configuration data set **302** based on both the first updated processed video signal **306** and the first updated output data set **304**. A third pass can be performed by the video encoding module **300** encoding the video signal **110** based on the second updated configuration data set **302** to generate a second updated processed video signal **306** and a second updated output data set **304**.

In this fashion, the video encoding module **300** and application coding control module **225** cooperate to iteratively refine the encoding of video signal **110** into a processed video signal **306** over 2, 3, 4, 5 or a greater number of iterations. It should be noted that previous versions of the processed video signals **306**, configuration data sets **302**, and output data sets **304** can be buffered in memory such as memory module **202**, and discarded either after each new iteration or after the final iteration. In particular, the processed video signal **306** generated by the final iteration or selected from the previous processed video signals after the final iteration can be output as the processed video signal **112**.

The operation of video encoding module **300** and application coding control module **225** can be described in conjunction with the following examples. The initial configuration data set **302** can, for instance, control the first pass encoding/transcoding of video signal **110** to collect stream information. Assuming the details of the video signal **110** (picture numbers, resolution, etc.) may not be available, the initial configuration data set **302** may only specify stream level coding control parameters. In one example, the application coding control module **225** specifies a GOP structure, and a picture level Qp for I, P and B picture. In this case, the video encoding module **300** may start a new GOP based on scene change detection result from scene change detection module **230** while following the GOP size restriction specified by the initial configuration data set **302**. The video encoding module **300** can assign individual MB Qp (offset to the picture level Qp), based on MB statistical information such as variance and/or motion.

In another example, the application coding control module **225** can give the video encoding module **300** more freedom to control the encoding process. Instead of specifying picture level Qp for each picture type (I, P or B), the application coding control module **225** may only specify a baseline Qp for the stream. In response, the video encoding module **300** can adaptively assign picture level Qp to different picture types based on characteristics of the stream to be coded.

As discussed above, the video encoding module **300** generates successive output data sets **304** in conjunction with each encoding of the video signal **110**. For example, the video encoding module **300** can stream output data at the same time that it is outputting the processed video signal **306**. The output data set can be provided through a data structure for each picture of the processed video signal **306**. All pictures in the stream will have a corresponding data structure in the output information data file that indicate parameters used in the encoding of each picture, along with optionally other statistics and metrics. For example, an output data set **304** can include picture level Qp, picture level motion information, picture level variance information, etc. Based on the desired size of the output data set **304**, MB level information may or may not be included.

After the first iteration, an analysis of the initial output data set **304** and the initial processed video signal **306** can provide the application coding control module **225** with greater information that can be used to refine later pass codings. Later-pass configuration data sets **302** can be provided by the application coding control module **225** to specify coding parameters for each picture of the stream, such as AVC coding parameters or condign parameters associated with other encoding methodologies. For example, the configuration data sets can include picture level coding control parameters such as picture level Qp, picture type (I, P and B), and other coding parameters. In an embodiment of the present invention, the configuration data sets **302** and the output data sets **304** can have similar data structures and include similar information.

While described above primarily in terms of an encoding of a video signal **110**, these techniques can similarly be applied to a transcoding of the a video signal **110** into a processed video signal **112** having a different video compression format, scale, resolution, frame rate or other format. It should be noted that the multi-pass operation of this encoding system allows the non-realtime encoding/transcoding application to achieve, offline, better rate control and picture quality. Rate control functionality can be solely performed by application coding control module **225**, based on appropriate selection of the configuration data sets **302**.

FIG. **9** presents a block diagram representation of an application coding control module **225** in accordance with an embodiment of the present invention. In this embodiment, the application coding control module **225** operates based on user selections **314** to select successive configuration data set **302**. In particular, the application coding control module **225** includes a parsing module **310** that generates display data **312** from the initial and subsequent output data sets **304** for display. A graphical user interface **320** displays the display data **312** and at least a portion of the initial processed video signal **306**, in a split screen format, for example, to allow a user to gage the quality of the encoded video, spot encoding artifacts and the potential problems. The graphical user interface **320** allows the user to input user selections **314** such as updated coding parameters, etc, that are to be transferred as selection data **322** and used by configuration data generator **330** to generate updated configuration data sets **302**.

In operation, the application coding control module **225** generates configuration data **302** to configure the video encoding module **300** for the first-pass (e.g. best effort) encoding. The application coding control module **225** allows the user to analyze the processed video signal **306** and the output data sets **304**. The application coding control module can provide an easy interface for the user to change the coding parameters and automatically generate configuration data sets **302** for the configuration of later-pass encoding via the video encoding module **300**.

FIG. **10** presents a graphical representation of processed video signal **306** in accordance with an embodiment of the present invention. As shown, each processed video signal **306** (initial or later-pass) includes a plurality of pictures [N, N+1, N+2, . . .] such as frames or fields of the video stream. The output data sets **304** generated in conjunction with the processed video signal **306** (initial or later-pass) includes separate output data for each picture [picture N output data, picture N+1 output data, picture N+2 output data, . . .]. All pictures in the stream will have a corresponding data structure in the output information data file that indicate, for instance, parameters used in the encoding of each picture, along with optionally other statistics and metrics. In the example discussed in conjunction with FIG. **8**, the output data set **304** can include picture level Qp, picture level motion information, picture level variance information, etc. Based on the desired size of the output data set **304**, MB level information may or may not be included.

FIG. **11** presents a block diagram representation of a video distribution system **375** in accordance with an embodiment of the present invention. In particular, processed video signal **112** is transmitted from a first video encoder/decoder **102** via a transmission path **122** to a second video encoder/decoder **102** that operates as a decoder. The second video encoder/decoder **102** operates to decode the processed video signal **112** for display on a display device such as television **12**, computer **14** or other display device.

The transmission path **122** can include a wireless path that operates in accordance with a wireless local area network protocol such as an 802.11 protocol, a WIMAX protocol, a Bluetooth protocol, etc. Further, the transmission path can include a wired path that operates in accordance with a wired protocol such as a Universal Serial Bus protocol, an Ethernet protocol or other high speed protocol.

FIG. **12** presents a block diagram representation of a video storage system **179** in accordance with an embodiment of the present invention. In particular, device **11** is a set top box with built-in digital video recorder functionality, a stand alone digital video recorder, a DVD recorder/player or other device that stores the processed video signal **112** for display on video display device such as television **12**. While video encoder/decoder **102** is shown as a separate device, it can further be incorporated into device **11**. In this configuration, video encoder/decoder **102** can further operate to decode the processed video signal **112** when retrieved from storage to generate a video signal in a format that is suitable for display by video display device **12**. While these particular devices are illustrated, video storage system **179** can include a hard drive, flash memory device, computer, DVD burner, or any other device that is capable of generating, storing, decoding and/or displaying the video content of processed video signal **112** in accordance with the methods and systems described in conjunction with the features and functions of the present invention as described herein.

FIG. **13** presents a flowchart representation of a method in accordance with an embodiment of the present invention. In particular, a method is presented for use in conjunction with a video processing device having one or more of the features and functions described in association with FIGS. **1-12**. In step **400** an initial configuration data set is generated. In step **402**, a video signal is encoded based on the initial configuration data set to generate an initial processed video signal and an initial output data set. In step **404**, a first updated configuration data set is generated based on both the initial processed video signal and the initial output data set. In step **406**, the video signal is encoded based on the first updated configuration data set to generate a first updated processed video signal and a first updated output data set.

The initial configuration data set can indicate: a group of picture structure for a plurality of pictures of the initial processed video signal; a picture level quantization parameter for I, P and B pictures in the plurality of pictures of the initial processed video signal; and/or a baseline quantization parameter. The initial output data set can include separate initial output data for each of an initial plurality of pictures of the initial processed video signal. Likewise, the first updated output data set can include separate first updated output data for each of a first updated plurality of pictures of the first updated processed video signal. The initial output data set can include: at least one picture level quantization parameter for a plurality of pictures of the initial processed video signal; at least one picture level motion parameter for a plurality of pictures of the initial processed video signal; and at least one picture level variance for a plurality of pictures of the initial processed video signal.

Step **404** can include: generating display data from the initial output data set; displaying the display data and at least a portion of the initial processed video signal; generating selection data in response to user selections; and/or generating the first updated configuration data, based on the selection data.

FIG. **14** presents a flowchart representation of a method in accordance with an embodiment of the present invention. In particular, a method is presented for use in conjunction with a video processing device having one or more of the features and functions described in association with FIGS. **1-13**. In step **410** a second updated configuration data set is generated based on both the first updated processed video signal and the first updated output data set. In step **412**, the video signal is encoded based on the second updated configuration data set to generate a second updated processed video signal and a second updated output data set.

While particular combinations of various functions and features of the present invention have been expressly described herein, other combinations of these features and functions are possible that are not limited by the particular examples disclosed herein are expressly incorporated in within the scope of the present invention.

As one of ordinary skill in the art will appreciate, the term "substantially" or "approximately", as may be used herein, provides an industry-accepted tolerance to its corresponding term and/or relativity between items. Such an industry-accepted tolerance ranges from less than one percent to twenty percent and corresponds to, but is not limited to, component values, integrated circuit process variations, temperature variations, rise and fall times, and/or thermal noise. Such relativity between items ranges from a difference of a few percent to magnitude differences. As one of ordinary skill in the art will further appreciate, the term "coupled", as may be used herein, includes direct coupling and indirect coupling via another component, element, circuit, or module where, for indirect coupling, the intervening component, element, circuit, or module does not modify the information of a signal but may adjust its current level, voltage level, and/or power level. As one of ordinary skill in the art will also appreciate, inferred coupling (i.e., where one element is coupled to another element by inference) includes direct and indirect coupling between two elements in the same manner as "coupled". As one of ordinary skill in the art will further appreciate, the term "compares favorably", as may be used herein, indicates that a comparison between two or more elements, items, signals, etc., provides a desired relationship. For example, when the desired relationship is that signal **1** has a greater magnitude than signal **2**, a favorable comparison may be achieved when the magnitude of signal **1** is greater than that of signal **2** or when the magnitude of signal **2** is less than that of signal **1**.

As the term module is used in the description of the various embodiments of the present invention, a module includes a functional block that is implemented in hardware, software, and/or firmware that performs one or module functions such as the processing of an input signal to produce an output signal. As used herein, a module may contain submodules that themselves are modules.

Thus, there has been described herein an apparatus and method, as well as several embodiments including a preferred embodiment, for implementing a video processing device, a video encoder/decoder and multi-pass encoder for use therewith. Various embodiments of the present invention herein-described have features that distinguish the present invention from the prior art.

It will be apparent to those skilled in the art that the disclosed invention may be modified in numerous ways and may assume many embodiments other than the preferred forms specifically set out and described above. Accordingly, it is intended by the appended claims to cover all modifications of the invention which fall within the true spirit and scope of the invention.

What is claimed is:

1. A multi-pass video encoder for use in a video processing device that processes a video signal, the multi-pass video encoder comprising:

a video encoding module, that encodes the video signal based on an initial configuration data set to generate an initial processed video signal and an initial output data set; and

an application coding control module, coupled to the video encoding module, that generates the initial configuration data set and that generates a first updated configuration data set based on both display of the initial processed video signal and the initial output data set;

wherein the video encoding module further is operable to encode the video signal based on the first updated configuration data set to generate a first updated processed video signal and a first updated output data set; and

wherein the initial configuration data set, the first updated configuration data set, the initial output data set and the first updated output data set are storable simultaneously in a buffer and a final encoding of the video signal is selectable in response to user input based on a comparison of the display of a video stream generated from the initial output data set and a contemporaneous display of a video stream generated from the first updated output data set;

wherein the application coding control module generates a second updated configuration data set based on both the first updated processed video signal and the first updated output data set;

wherein the video encoding module further encodes the video signal based on the second updated configuration data set to generate a second updated processed video signal and a second updated output data set; and

wherein the initial configuration data set, the first updated configuration data set, the second updated configuration data set, the initial output data set, the first updated output data set and the second updated output data set are stored simultaneously in the buffer, wherein the final encoding of the video signal is selected further in response to the user input based on a comparison of a display of the second updated output data set with the display of the initial output data set, and the display of the first updated output data set.

2. The multi-pass video encoder of claim **1** wherein the initial configuration data set indicates at least one of:

a group of picture structure for a plurality of pictures of the initial processed video signal;

a picture level quantization parameter for I, P and B pictures in the plurality of pictures of the initial processed video signal; and

a baseline quantization parameter.

3. The multi-pass video encoder of claim **1** wherein the initial output data set includes separate initial output data for each of an initial plurality of pictures of the initial processed video signal, and wherein the first updated output data set includes separate first updated output data for each of a first updated plurality of pictures of the first updated processed video signal.

4. The multi-pass video encoder of claim **1** wherein the initial output data set includes at least one of:

at least one picture level quantization parameter for a plurality of pictures of the initial processed video signal;

at least one picture level motion parameter for the plurality of pictures of the initial processed video signal; and

at least one picture level variance for the plurality of pictures of the initial processed video signal.

5. The multi-pass video encoder of claim **1** wherein the application coding control module includes:

a parsing module that generates display data from the initial output data set;

a graphical user interface, coupled to the parsing module, that:

displays the display data and at least a portion of the initial processed video signal to a user for review; and

generates selection data in response to user selections based on the user's review of the display data; and

a configuration data generation module, coupled to the graphical user interface, that generates the first updated configuration data set, based on the selection data.

6. A method for use in a video processing device that processes a video signal, the method comprising:

generating an initial configuration data set;

encoding the video signal based on the initial configuration data set to generate an initial processed video signal and an initial output data set;

generating a first updated configuration data set based on both display of the initial processed video signal and the initial output data set;

encoding the video signal based on the first updated configuration data set to generate a first updated processed video signal and a first updated output data set;

simultaneously storing the initial configuration data set, the first updated configuration data set, the initial output data set and the first updated output data set in a buffer;

generating a second updated configuration data set based on both the first updated processed video signal and the first updated output data set;

encoding the video signal based on the second updated configuration data set to generate a second updated processed video signal and a second updated output data set; and

simultaneously storing the initial configuration data set, the first updated configuration data set, the second updated configuration data set, the initial output data set, the first updated output data set and the second updated output data set in the buffer;

wherein a final encoding of the video signal is selected in response to user input based on a comparison of the display of a video stream of the initial output data set and a contemporaneous display of a video stream of the first updated output data set and further in response to the user input based on a comparison of a display of the second updated output data set with the display of the initial output data set, and the display of the first updated output data set.

7. The method of claim **6** wherein the initial configuration data set indicates at least one of:

a group of picture structure for a plurality of pictures of the initial processed video signal;

a picture level quantization parameter for I, P and B pictures in the plurality of pictures of the initial processed video signal; and

a baseline quantization parameter.

8. The method of claim **6** wherein the initial output data set includes separate initial output data for each of an initial plurality of pictures of the initial processed video signal, and wherein the first updated output data set includes separate first updated output data for each of a first updated plurality of pictures of the first updated processed video signal.

9. The method of claim **6** wherein the initial output data set includes at least one of:

at least one picture level quantization parameter for a plurality of pictures of the initial processed video signal;

at least one picture level motion parameter for the plurality of pictures of the initial processed video signal; and

at least one picture level variance for the plurality of pictures of the initial processed video signal.

10. The method of claim **6** wherein generating the first updated configuration data set includes:

generating display data from the initial output data set;

displaying the display data and at least a portion of the initial processed video signal to a user for review;

generating selection data in response to user selections based on the user's review of the display data; and

generating the first updated configuration data set, based on the selection data.

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