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Filippov et al.

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(54) **METHOD AND APPARATUS FOR CHROMA INTRA PREDICTION IN VIDEO CODING**

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(Continued)

(51) **Int. Cl.**

H04N 19/593 (2014.01)
H04N 19/11 (2014.01)

(Continued)

(52) **U.S. Cl.**

CPC ***H04N 19/593*** (2014.11); ***H04N 19/11*** (2014.11); ***H04N 19/159*** (2014.11); ***H04N 19/172*** (2014.11); ***H04N 19/186*** (2014.11)

(58) **Field of Classification Search**

CPC H04N 19/593; H04N 19/11; H04N 19/159; H04N 19/172; H04N 19/186; H04N 19/70

(Continued)

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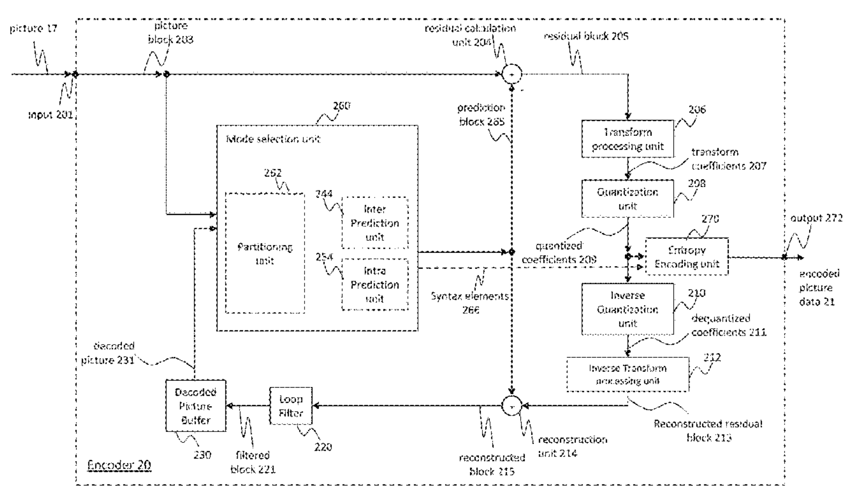
(57) **ABSTRACT**

Devices and methods of directional intra prediction for chroma component of a picture are provided. The method includes obtaining an initial intra prediction mode of the chroma component based on a value of a luma intra prediction mode (intraPredModeY) by using a first look up table (LUT), deriving a chroma intra prediction mode (intraPredModeC) from a second LUT by using the initial intra prediction mode of the chroma component. The chroma component has different subsampling ratios in horizontal and vertical directions. The second LUT has 67 entries, indices for the second LUT are 0-66, and each index is associated with an angle of an intra prediction direction. The method further includes obtaining an angle parameter for the chroma component based on the chroma intra prediction

(Continued)



mode intraPredModeC; and obtaining predicted samples of the chroma component based on the angle parameter.

19 Claims, 18 Drawing Sheets

Related U.S. Application Data

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(51) **Int. Cl.**
H04N 19/159 (2014.01)
H04N 19/172 (2014.01)
H04N 19/186 (2014.01)

(58) **Field of Classification Search**
USPC 375/240.12
See application file for complete search history.

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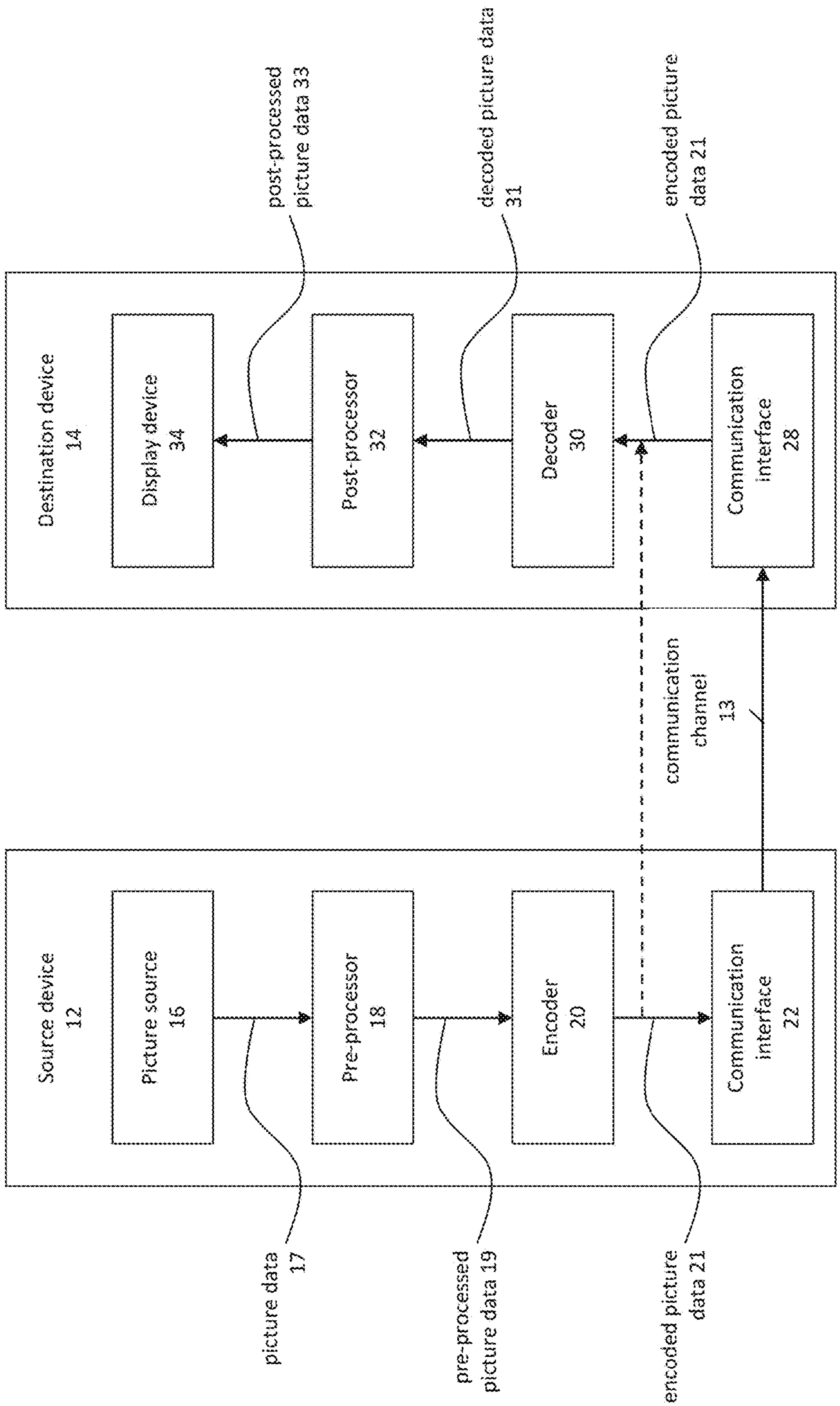


Source device 12
Picture source 16
Pre-processor 18
Encoder 20
Communication interface 22
picture data 17
pre-processed picture data 19
encoded picture data 21
communication channel 13
Destination device 14
Display device 34
Post-processor 32
Decoder 30
Communication interface 28
post-processed picture data 33
decoded picture data 31
encoded picture data 21

10

FIG. 1A

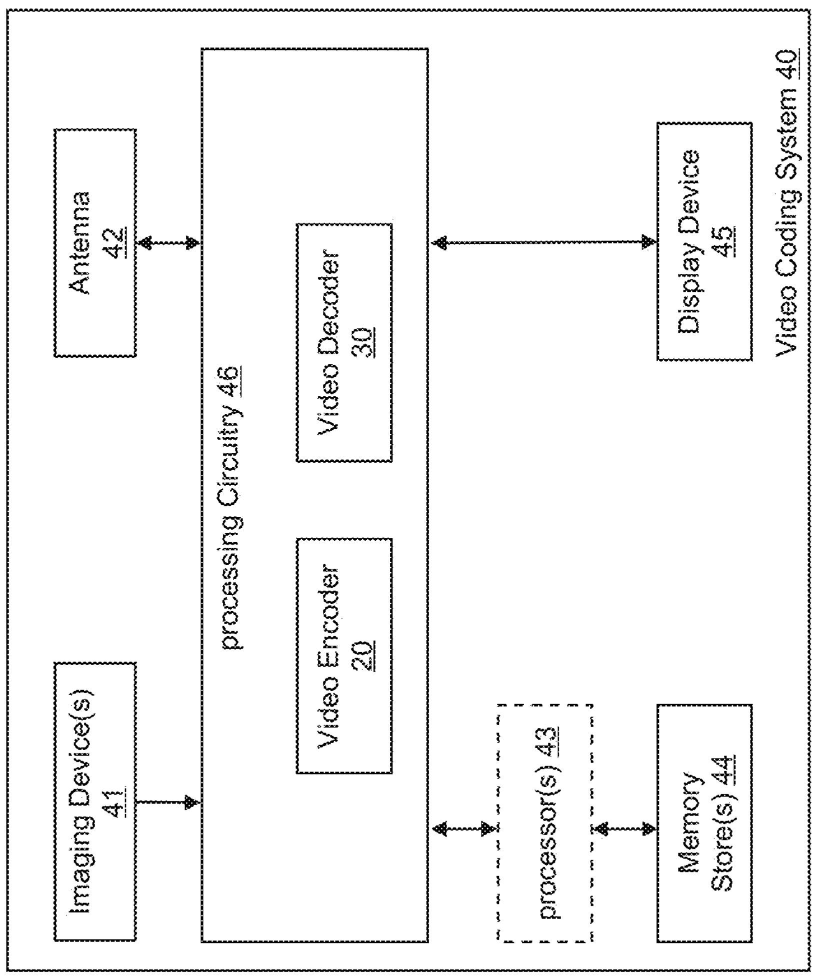
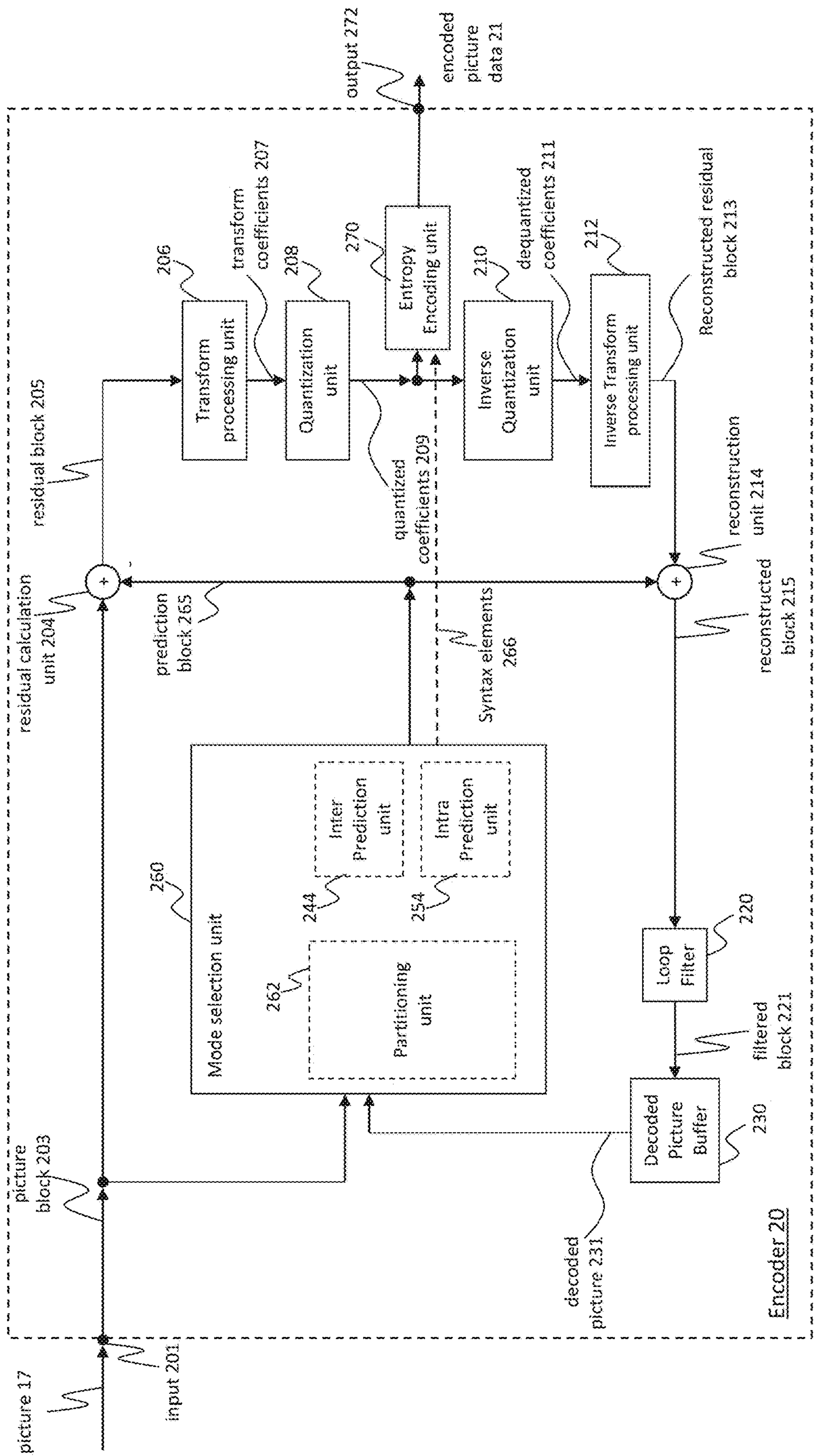
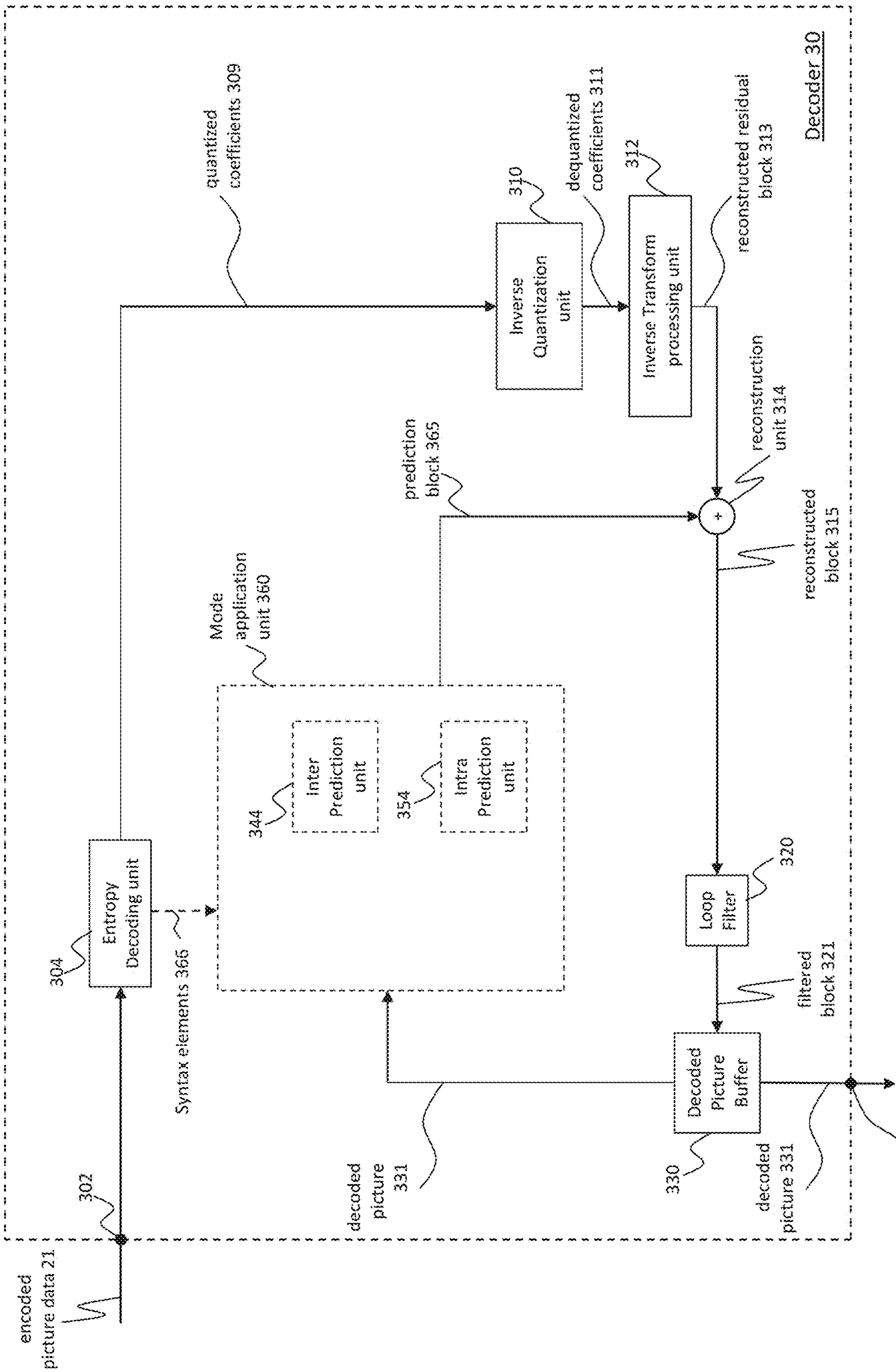

Imaging Device(s) 41
Antenna 42
processing Circuitry 46
Video Encoder 20
Video Decoder 30
processor(s) 43
Memory Store(s) 44
Display Device 45
Video Coding System 40

FIG. 1B



output 272
encoded picture data 21
transform coefficients 207
206
208
270
Entropy Encoding unit
210
dequantized coefficients 211
212
Reconstructed residual block 213
residual block 205
Transform processing unit
Quantization unit
Inverse Quantization unit
Inverse Transform processing unit
quantized coefficients 209
reconstruction unit 214
residual calculation unit 204
prediction block 265
Syntax elements 266
reconstructed block 215
260
Inter Prediction unit
Intra Prediction unit
244
254
Mode selection unit
262
Partitioning unit
Loop Filter
220
filtered block 221
picture block 203
Decoded Picture Buffer
230
decoded picture 231
picture 17
input 201
Encoder 20

FIG. 2



Decoder 30
encoded picture data 21
302
304
Entropy Decoding unit
Syntax elements 365
quantized coefficients 309
310
Inverse Quantization unit
dequantized coefficients 311
312
Inverse Transform processing unit
reconstructed residual block 313
reconstruction unit 314
prediction block 365
reconstructed block 315
Mode application unit 360
344
Inter Prediction unit
354
Intra Prediction unit
320
Loop Filter
filtered block 321
330
Decoded Picture Buffer
decoded picture 331
decoded picture 331
output 332

FIG. 3

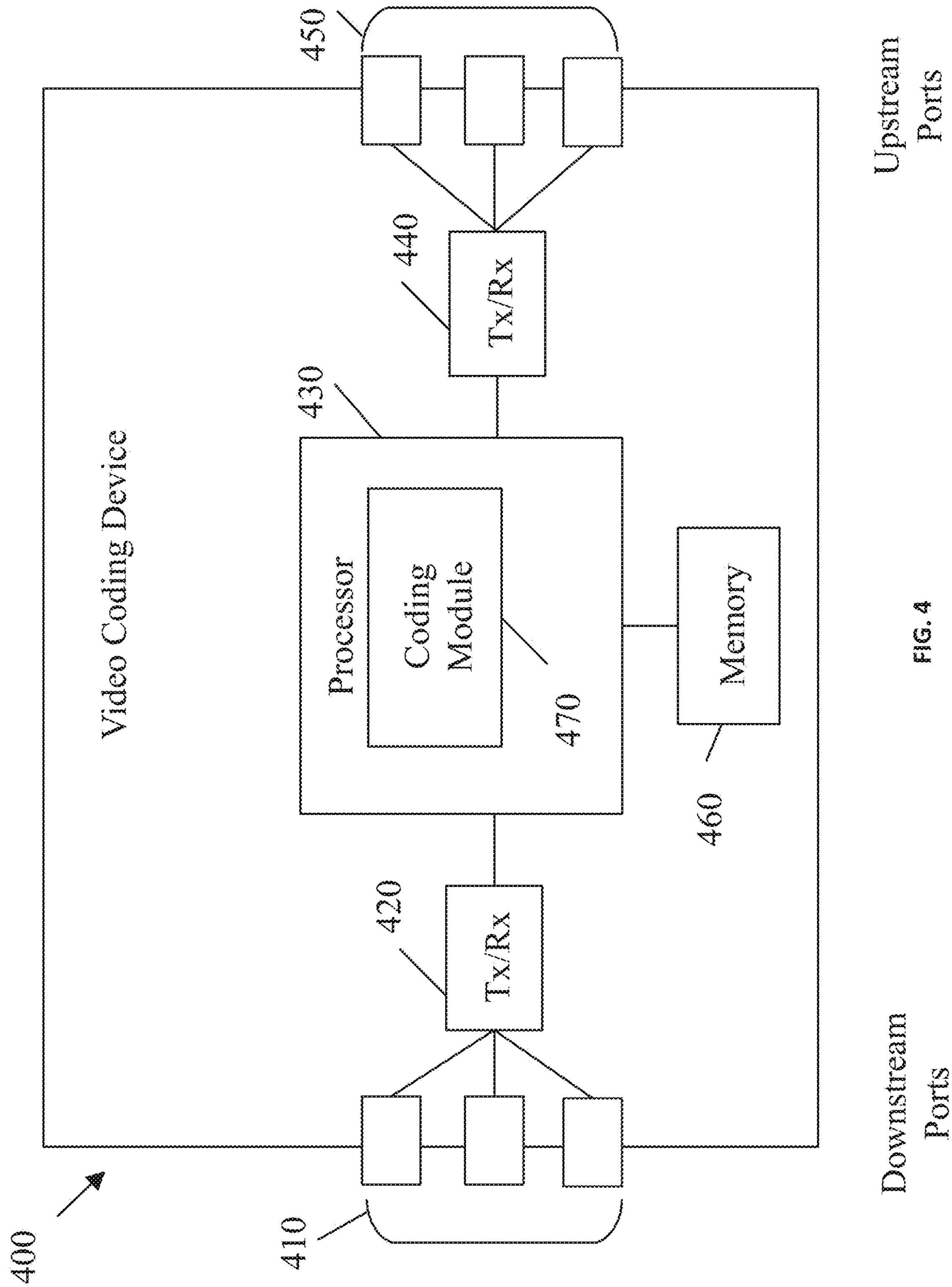

400
Video Coding Device
410
Downstream Ports
420
Tx/Rx
430
Processor
Coding Module
470
440
Tx/Rx
450
Upstream Ports
Memory
460

FIG. 4

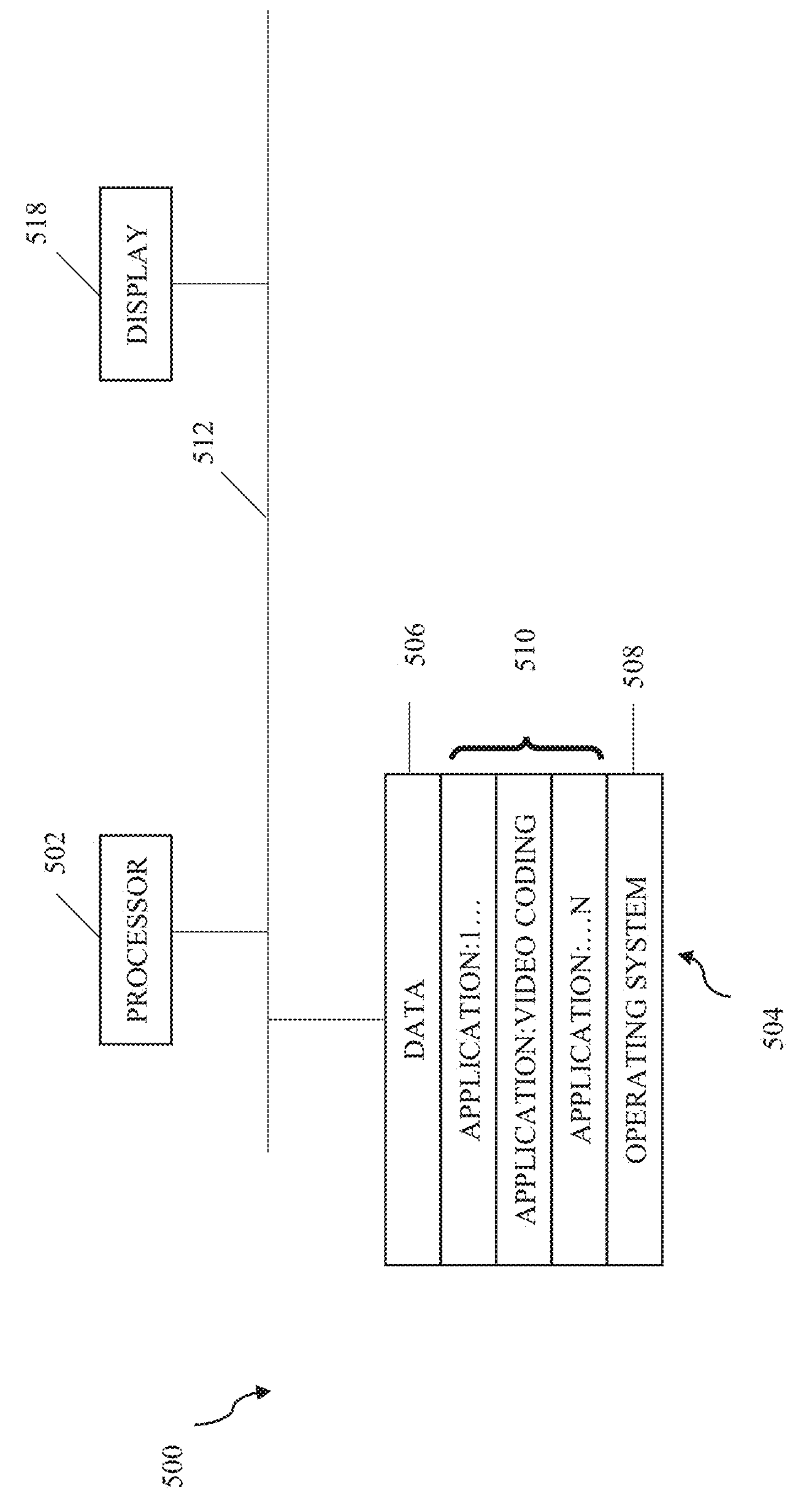
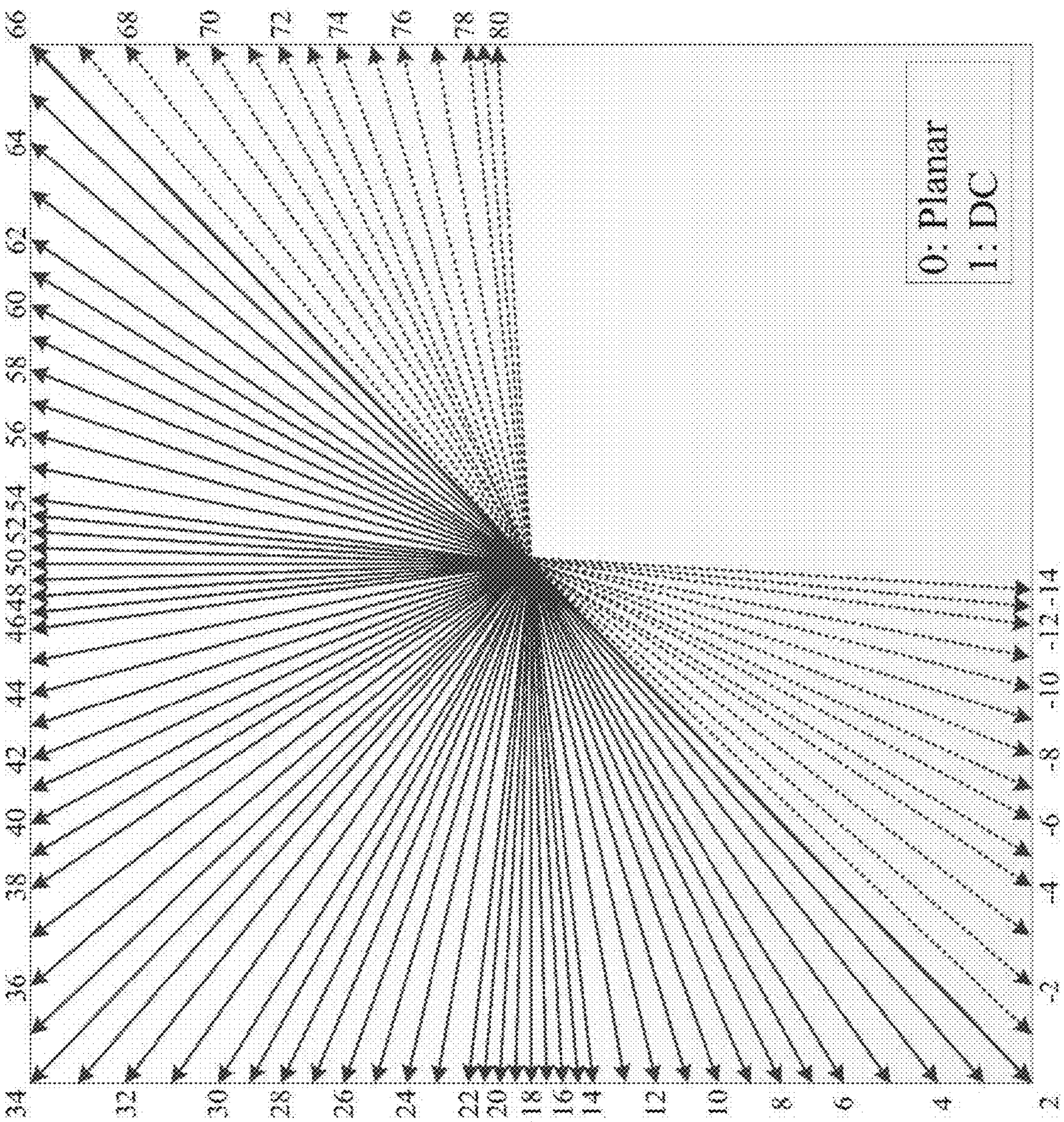

518
DISPLAY
512
502
PROCESSOR
506
510
508
DATA
APPLICATION:1…
APPLICATION:VIDEO CODING
APPLICATION:…N
OPERATING SYSTEM
504
500

FIG. 5


0: Planar
1: DC
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
48
50
52
54
56
58
60
62
64
66
68
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72
74
76
78
80
-2
-4
-6
-8
-10
-12
-14

FIG. 6

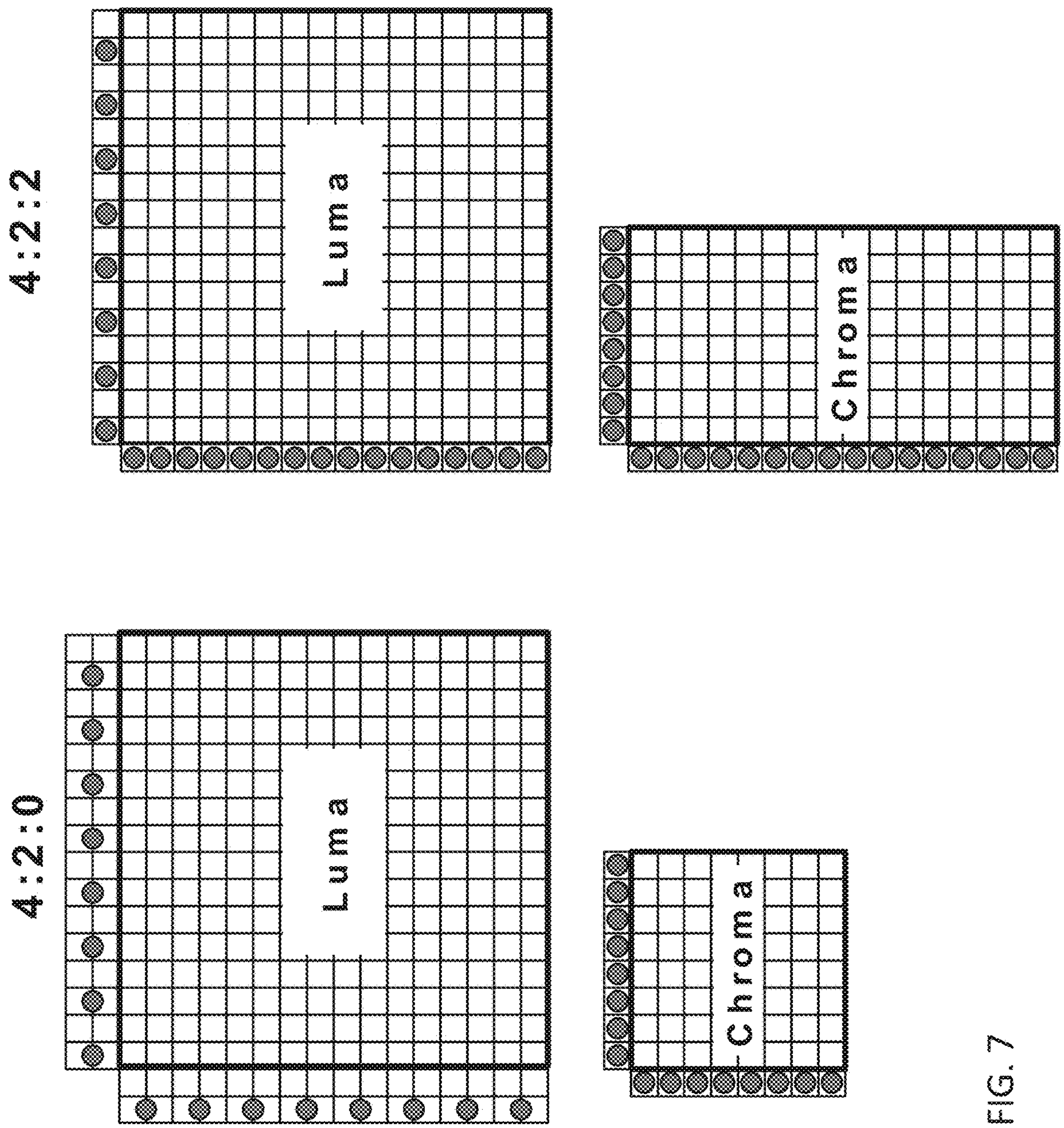

FIG. 7

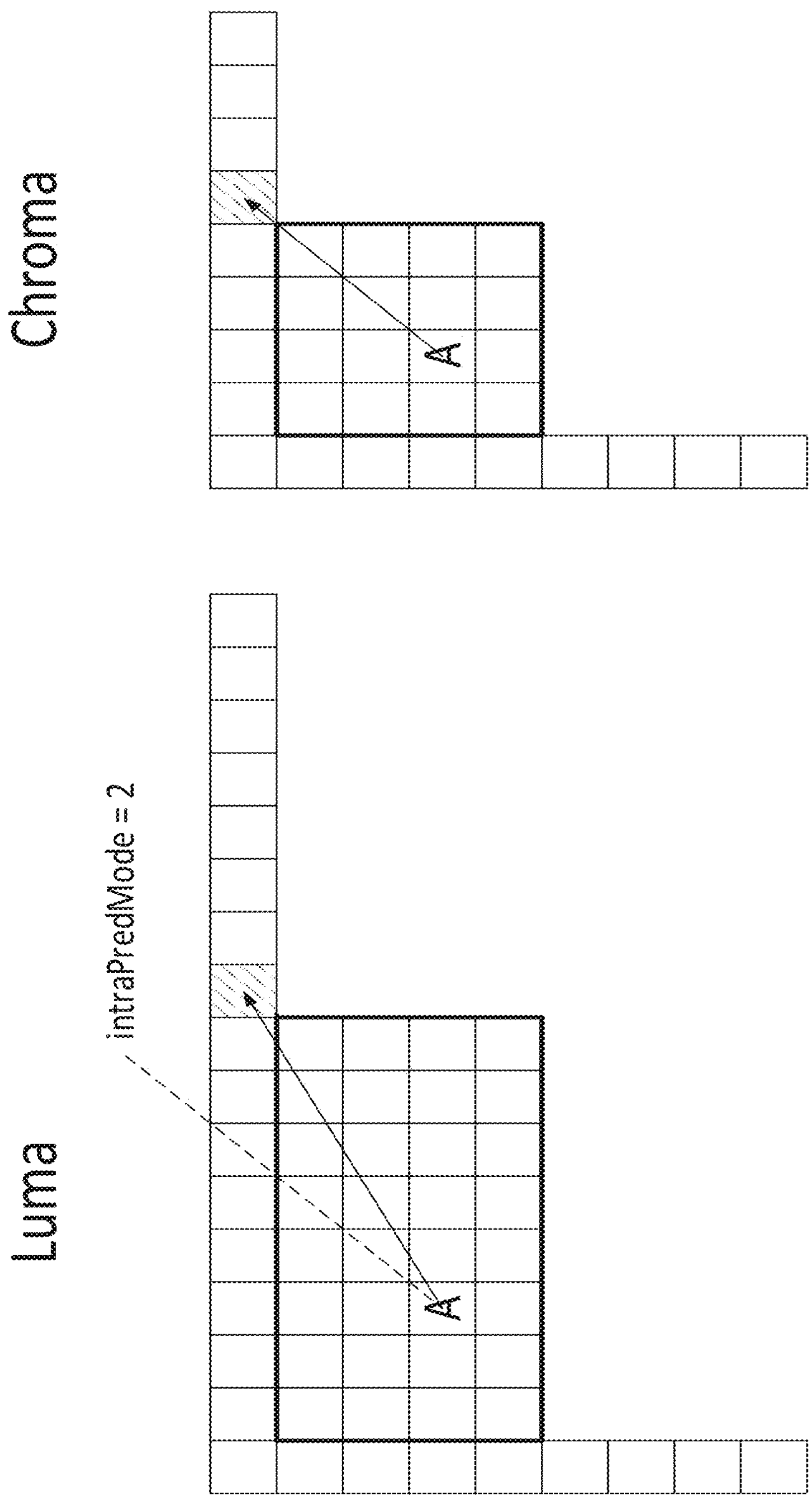

FIG. 8

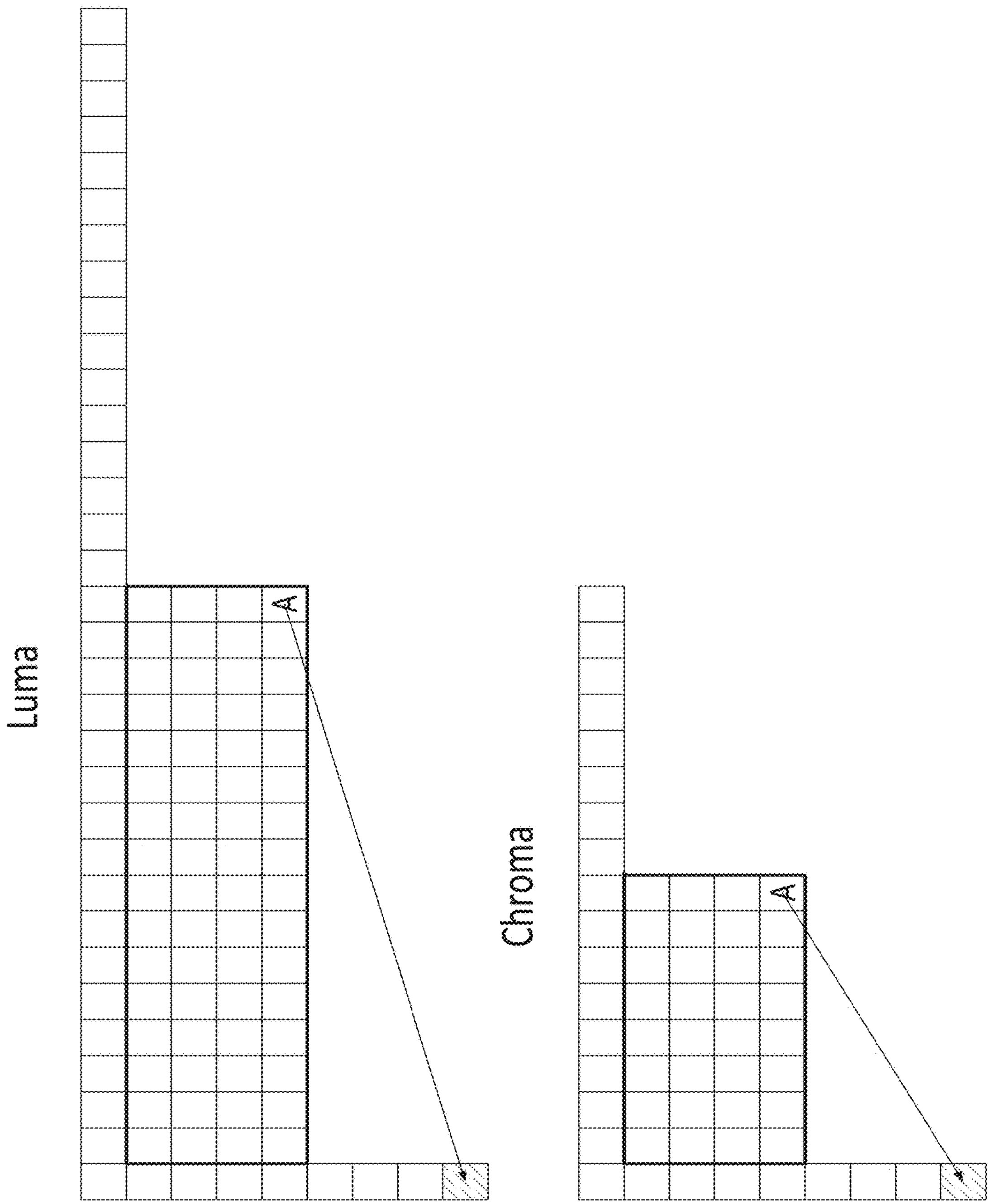

FIG. 9

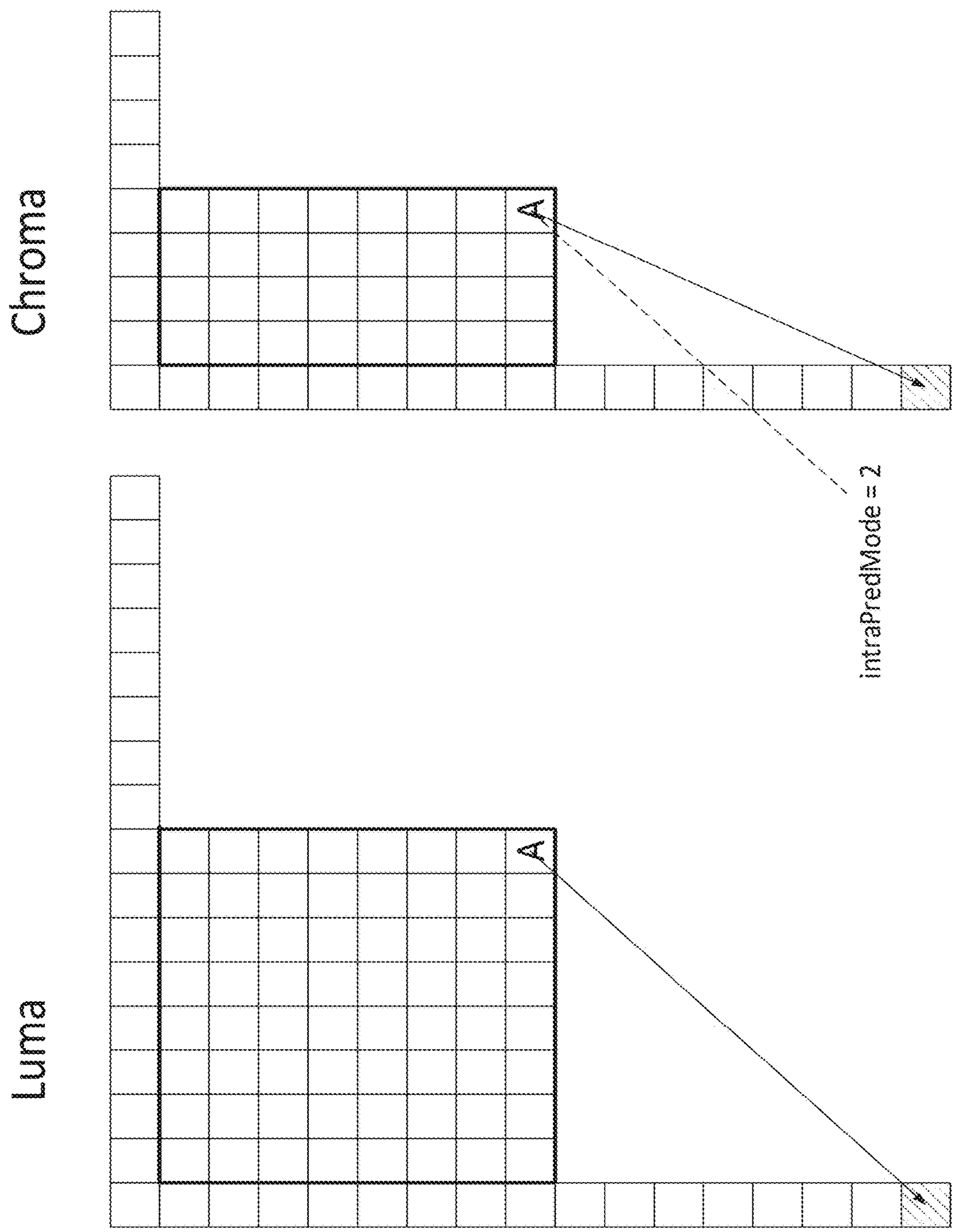

FIG. 10

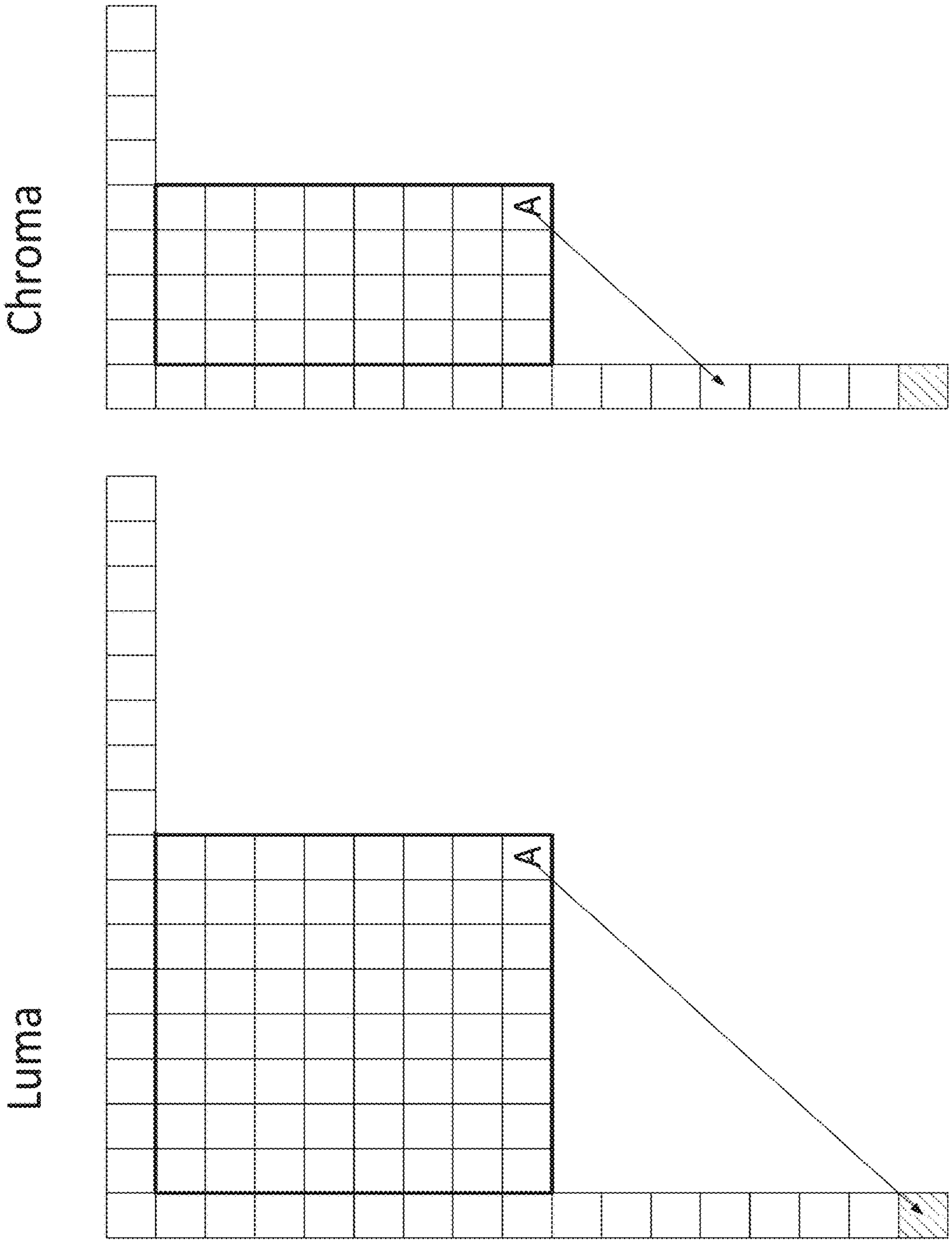

FIG. 11

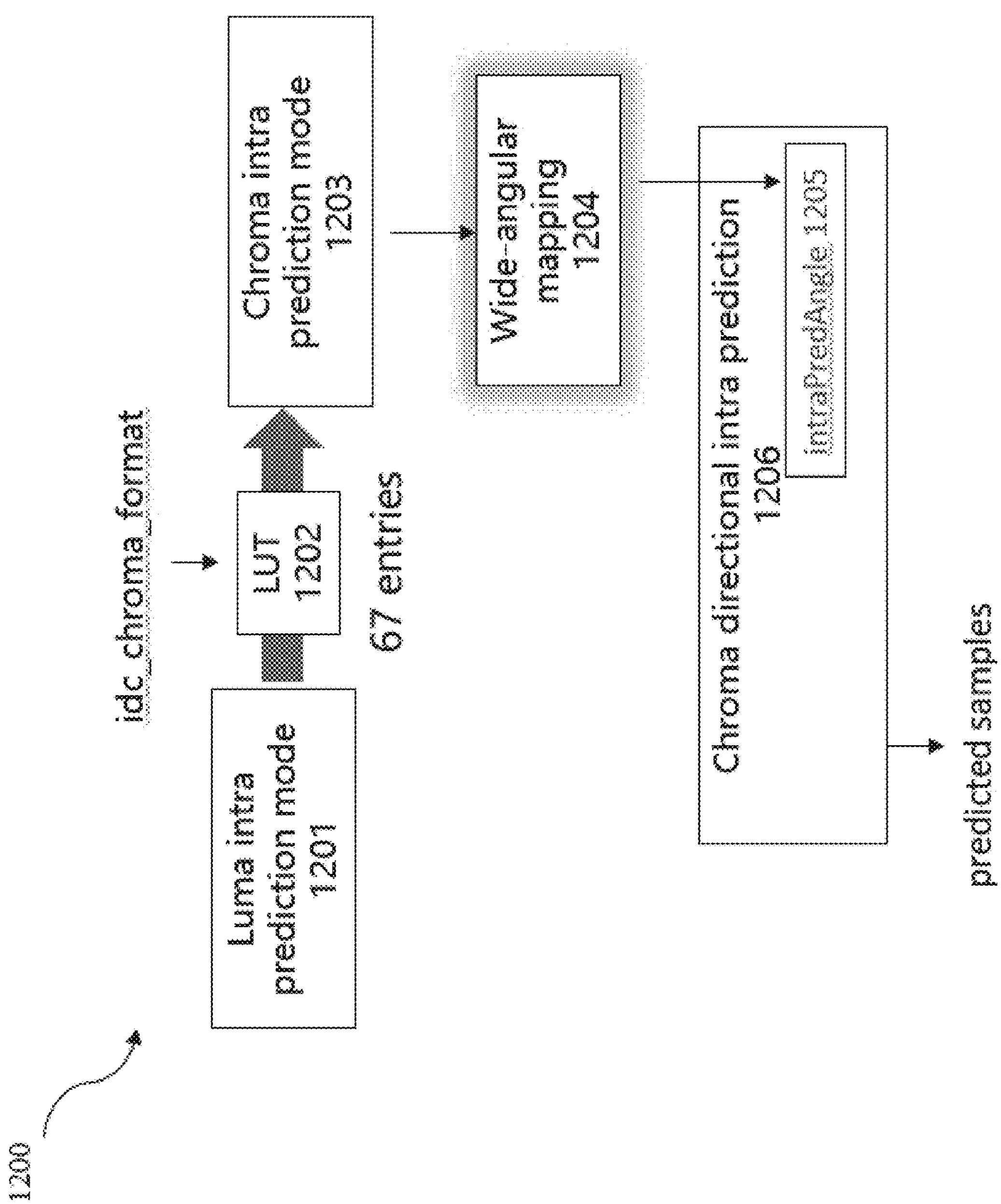
1200
Luma intra prediction mode 1201
idc_chroma_format
LUT 1202
67 entries
Chroma intra prediction mode 1203
Wide-angular mapping 1204
Chroma directional intra prediction 1206
intraPredAngle 1205
predicted samples

FIG. 12A

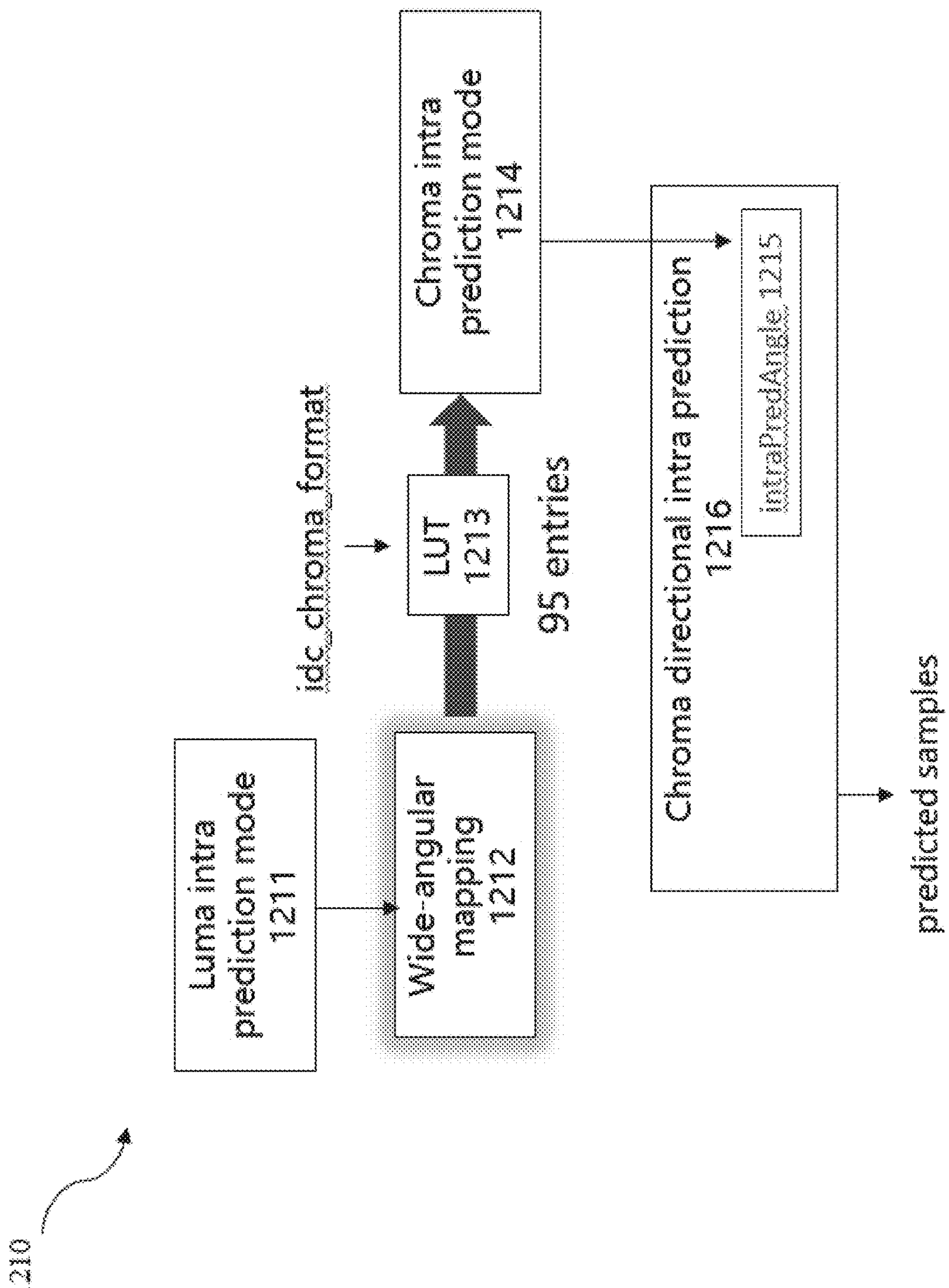
1210
Luma intra prediction mode 1211
Wide-angular mapping 1212
idc_chroma_format
LUT 1213
95 entries
Chroma intra prediction mode 1214
intraPredAngle 1215
Chroma directional intra prediction 1216
predicted samples

FIG. 12B

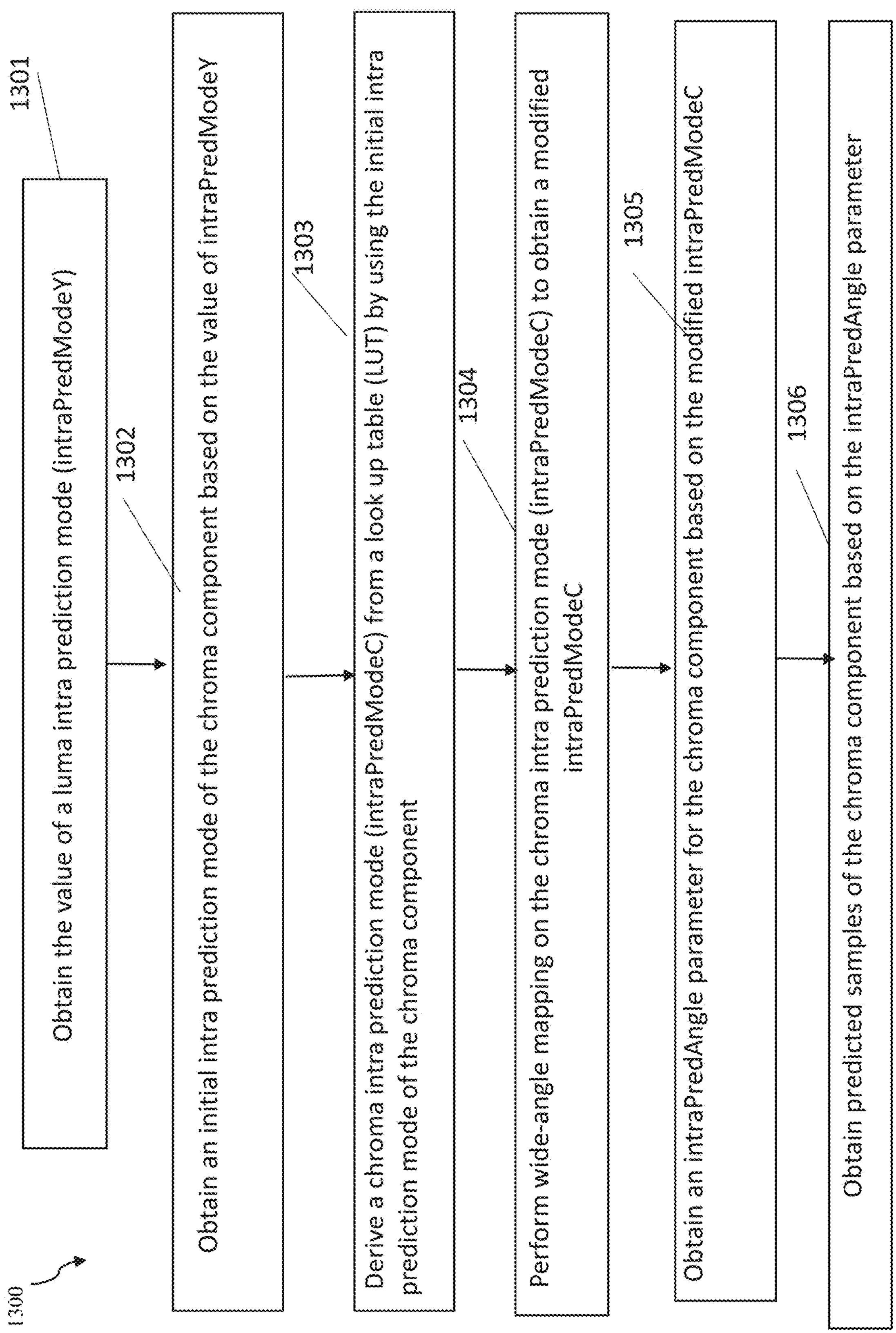
1300
1301
Obtain the value of a luma intra prediction mode (intraPredModeY)
1302
Obtain an initial intra prediction mode of the chroma component based on the value of intraPredModeY
1303
Derive a chroma intra prediction mode (intraPredModeC) from a look up table (LUT) by using the initial intra prediction mode of the chroma component
1304
Perform wide-angle mapping on the chroma intra prediction mode (intraPredModeC) to obtain a modified intraPredModeC
1305
Obtain an intraPredAngle parameter for the chroma component based on the modified intraPredModeC
1306
Obtain predicted samples of the chroma component based on the intraPredAngle parameter

FIG. 13

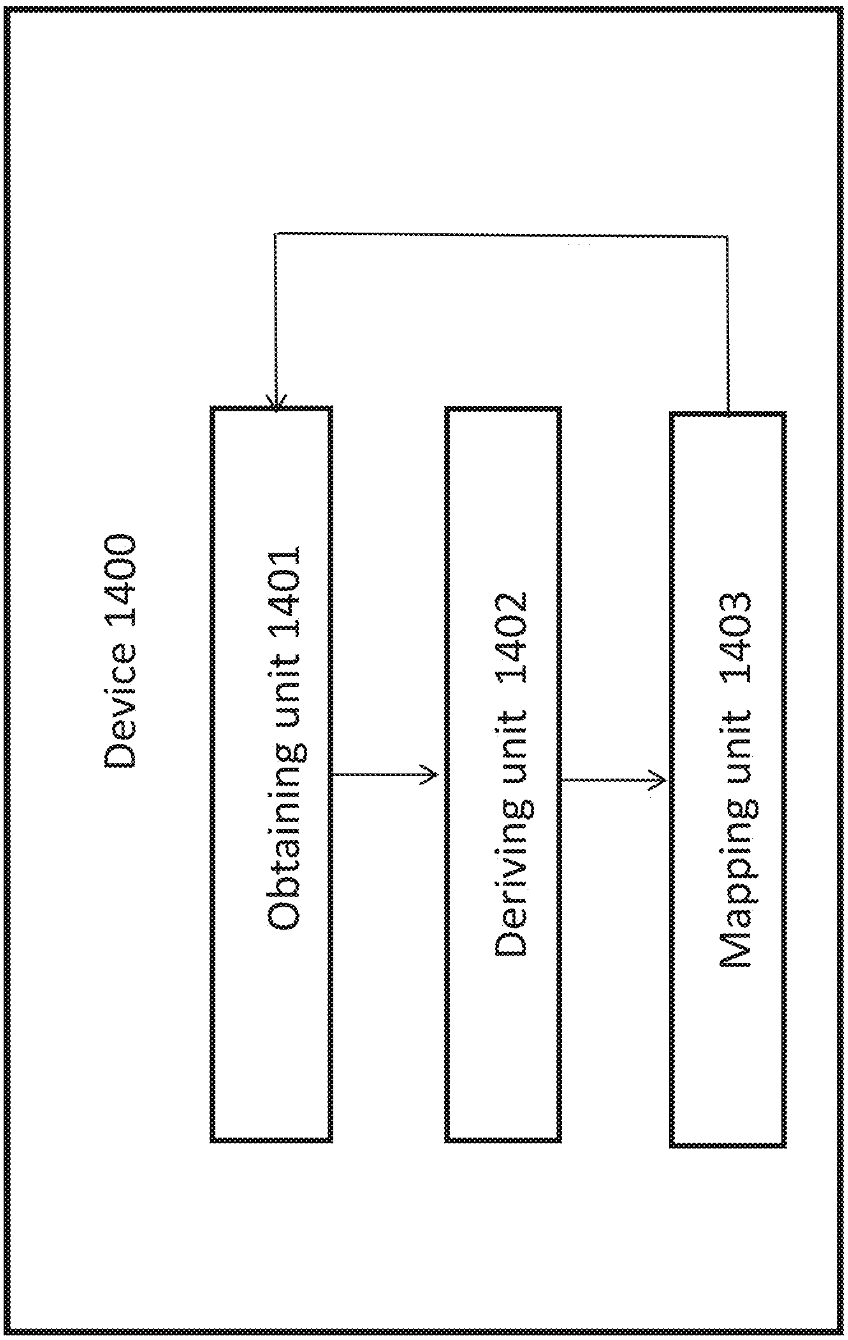
Device 1400
Obtaining unit 1401
Deriving unit 1402
Mapping unit 1403

FIG. 14

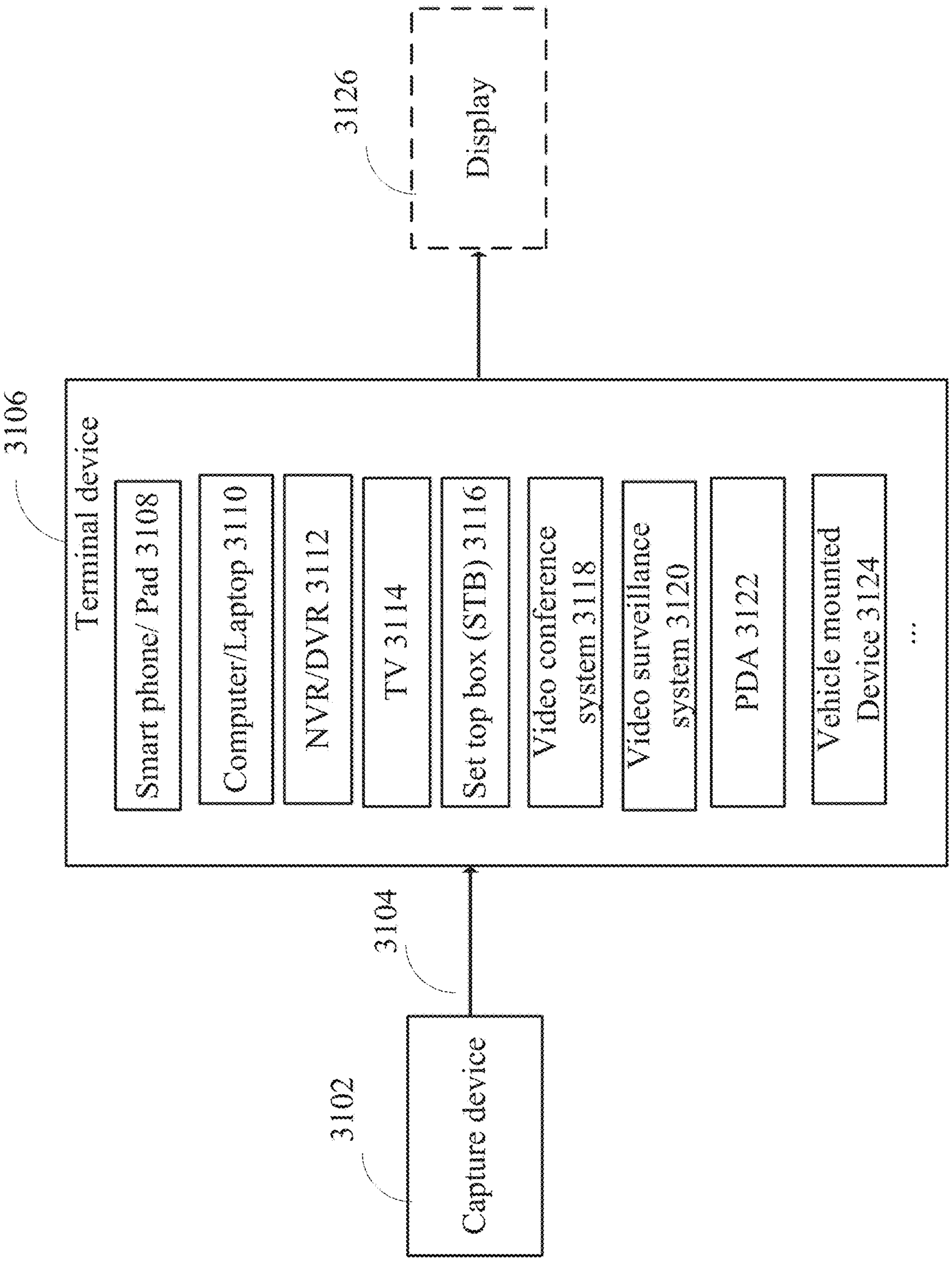
3126
Display
3106
Terminal device
Smart phone/ Pad 3108
Computer/Laptop 3110
NVR/DVR 3112
TV 3114
Set top box (STB) 3116
Video conference system 3118
Video surveillance system 3120
PDA 3122
Vehicle mounted Device 3124
...
3104
3102
Capture device

FIG. 15

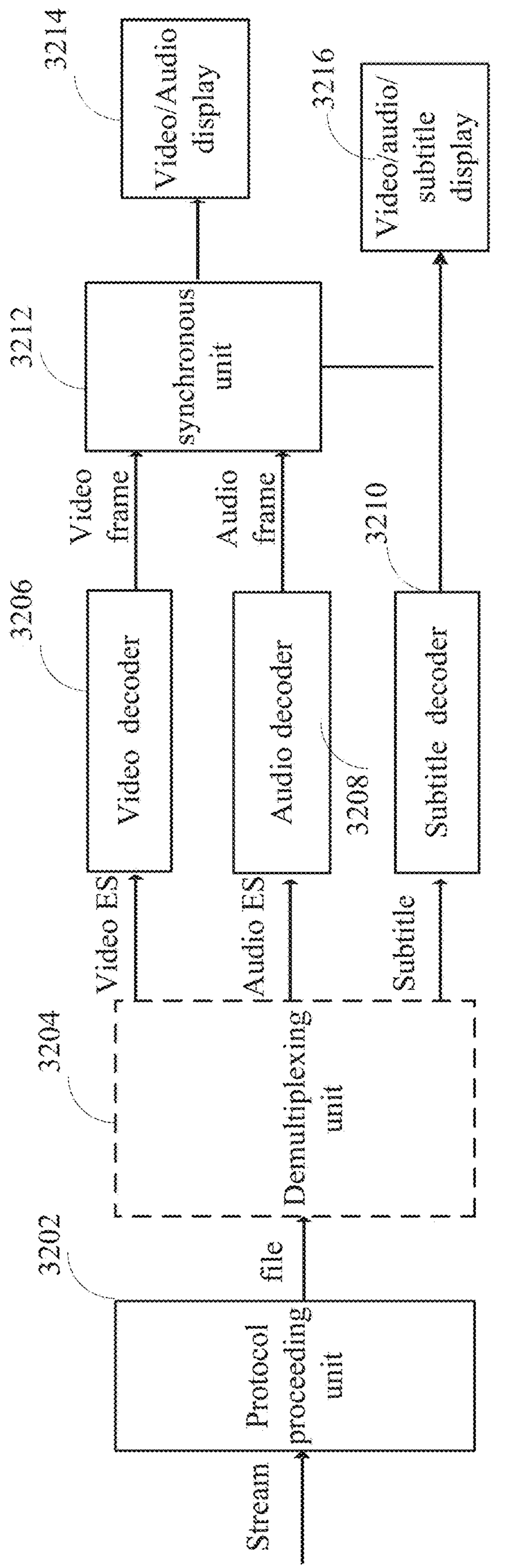
Stream
Protocol proceeding unit
3202
file
Demultiplexing unit
3204
Video ES
Audio ES
Subtitle
Video decoder
3206
Audio decoder
3208
Subtitle decoder
3210
Video frame
Audio frame
synchronous unit
3212
Video/Audio display
3214
Video/audio/ subtitle display
3216

FIG. 16

METHOD AND APPARATUS FOR CHROMA INTRA PREDICTION IN VIDEO CODING

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. patent application Ser. No. 17/373,347, filed on Jul. 12, 2021, which is a continuation of International Application No. PCT/RU2020/050059, filed on Mar. 24, 2020, which claims priority to U.S. Provisional Application No. 62/822,981, filed on Mar. 24, 2019. All of the afore-mentioned patent applications are hereby incorporated by reference in their entireties.

TECHNICAL FIELD

Embodiments of the present application generally relate to the field of picture processing and more particularly to methods of chroma intra prediction in video coding.

BACKGROUND

Video coding (video encoding and decoding) is used in a wide range of digital video applications, for example broadcast digital TV, video transmission over internet and mobile networks, real-time conversational applications such as video chat, video conferencing, DVD and Blu-ray discs, video content acquisition and editing systems, and camcorders of security applications.

The amount of video data needed to depict even a relatively short video can be substantial, which may result in difficulties when the data is to be streamed or otherwise communicated across a communications network with limited bandwidth capacity. Thus, video data is generally compressed before being communicated across modern day telecommunications networks. The size of a video could also be an issue when the video is stored on a storage device because memory resources may be limited. Video compression devices often use software and/or hardware at the source to code the video data prior to transmission or storage, thereby decreasing the quantity of data needed to represent digital video images. The compressed data is then received at the destination by a video decompression device that decodes the video data. With limited network resources and ever increasing demands of higher video quality, improved compression and decompression techniques that improve compression ratio with little to no sacrifice in picture quality are desirable.

SUMMARY

Embodiments of the present application provide apparatuses and methods for encoding and decoding according to the independent claims.

The foregoing and other objects are achieved by the subject matter of the independent claims. Further embodiments are apparent from the dependent claims, the description and the figures.

According to a first aspect, a method of directional intra prediction for chroma component of a picture is provided. The method includes obtaining an initial intra prediction mode of the chroma component (for example, mode X in process map422), and deriving a chroma intra prediction mode (intraPredModeC) (for example, mode Y in process map422) from a look up table (LUT) by using the initial intra prediction mode of the chroma component, where the chroma component has different subsampling ratios in horizontal and vertical directions. The method further includes performing wide-angle mapping on the chroma intra prediction mode (intraPredModeC) to obtain a modified intraPredModeC; obtaining an intraPredAngle parameter for the chroma component based on the modified intraPredModeC; and obtaining predicted samples of the chroma component based on the intraPredAngle parameter.

In an embodiment, the method further comprises: obtaining the value of a luma intra prediction mode (intraPredModeY) from a bitstream; wherein the obtaining the initial intra prediction mode of the chroma component comprises: obtaining the initial intra prediction mode of the chroma component based on the value of the luma intra prediction mode (intraPredModeY).

In an embodiment, the performing wide-angle mapping on the chroma intra prediction mode (intraPredModeC) to obtain the modified intraPredModeC comprises:

- performing wide-angle mapping on an original intra prediction mode (predModeIntra) to obtain a modified predModeIntra, wherein the value of the original predModeIntra is equal to the value of the chroma intra prediction mode (intraPredModeC).

In an embodiment, the LUT (for example, table 8-4) has 67 entries, the index for the LUT is 0-66.

The method according to the first aspect can be performed by the device according to a second aspect of the disclosure. The device of directional intra prediction for chroma component of a picture, comprising an obtaining unit, a deriving unit, and the mapping unit. The obtaining unit, configured to obtain an initial intra prediction mode of the chroma component. The deriving unit, configured to derive a chroma intra prediction mode (intraPredModeC) from a look up table (LUT) by using the initial intra prediction mode of the chroma component, the chroma component having different sub sampling ratios in horizontal and vertical directions. The mapping unit, configured to perform wide-angle mapping on the chroma intra prediction mode (intraPredModeC) to obtain a modified intraPredModeC; and the obtaining unit, further configured to obtain an intraPredAngle parameter for the chroma component based on the modified intraPredModeC; and obtain predicted samples of the chroma component based on the intraPredAngle parameter.

Further features and embodiments of the method according to the second aspect correspond to the features and embodiments of the apparatus according to the first aspect.

According to a third aspect, an apparatus for decoding a video stream that includes a processor and a memory is provided. The memory is storing instructions that cause the processor to perform the method according to the first aspect.

According to a fourth aspect, an apparatus for encoding a video stream that includes a processor and a memory is provided. The memory is storing instructions that cause the processor to perform the method according to the first aspect.

According to a fifth aspect, a computer-readable storage medium having stored thereon instructions, which when executed, cause one or more processors configured to code video data is proposed. The instructions cause the one or more processors to perform a method according to the first aspect or any embodiment of the first aspect.

According to a sixth aspect, a computer program is provided, where the computer program comprises program code for performing the method according to the first aspect or any embodiment of the first aspect when executed on a computer.

According to a seventh aspect, the present disclosure further provides an encoder, comprising processing circuitry for carrying out the method as described above.

According to an eighth aspect, the present disclosure further provides a decoder comprising processing circuitry for carrying out the method as described above.

The embodiments of the present disclosure provide the minimum number of entries in the LUT that is used to determine chroma intra prediction mode from the initial chroma intra prediction mode. The initial chroma intra prediction mode may be equal to the initial luma intra prediction mode. This is achieved by the order of operations performed, i.e., by chrominance intra prediction mode mapping to luminance mode being performed prior to wide-angular mapping.

Details of one or more embodiments are set forth in the accompanying drawings and the description below. Other features, objects, and advantages will be apparent from the description, drawings, and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

In the following embodiments of the disclosure are described in more detail with reference to the attached figures and drawings, in which:

FIG. **1**A is a block diagram showing an example of a video coding system according to an embodiment;

FIG. **1**B is a block diagram showing another example of a video coding system according to an embodiment;

FIG. **2** is a block diagram showing an example of a video encoder according to an embodiment;

FIG. **3** is a block diagram showing an example structure of a video decoder according to an embodiment;

FIG. **4** is a block diagram illustrating an example of an encoding apparatus or a decoding apparatus;

FIG. **5** is a block diagram illustrating another example of an encoding apparatus or a decoding apparatus;

FIG. **6** is a drawing showing angular intra prediction directions and the associated intra-prediction modes in VTM-4.0 and VVC specification draft v.4;

FIG. **7** is a drawing showing luma and chroma color planes for YUV 4:2:0 and YUV 4:2:2 chroma formats;

FIG. **8** shows an example of the case when IntraPredModeC is derived from IntraPredModeY where IntraPredModeY is wide-angle intra prediction mode and IntraPredModeC is a non-wide-angle angle intra prediction mode;

FIG. **9** shows an example of the case when IntraPredModeC is derived from IntraPredModeY where IntraPredModeY is non-wide-angle intra prediction mode and IntraPredModeC is a non-wide-angle angle intra prediction mode;

FIG. **10** shows an example of the case when IntraPredModeC is derived from IntraPredModeY where IntraPredModeY is non-wide-angle intra prediction mode and IntraPredModeC is a wide-angle angle intra prediction mode;

FIG. **11** shows an example of the case when IntraPredModeC is derived from IntraPredModeY using prediction mode clipping and where IntraPredModeY is non-wide-angle intra prediction mode and IntraPredModeC is a non-wide-angle angle intra prediction mode;

FIG. **12**A is a block diagram illustrating a system for intra prediction of a chroma component according to an embodiment;

FIG. **12**B is another block diagram illustrating a system for intra prediction of a chroma component according to an embodiment;

FIG. **13** is a flow diagram illustrating a process of intra prediction of a chroma component according to an embodiment;

FIG. **14** is a block diagram illustrating a device of intra prediction of a chroma component according to an embodiment;

FIG. **15** is a block diagram showing an example structure of a content supply system which realizes a content delivery service; and

FIG. **16** is a block diagram showing a structure of an example of a terminal device.

In the following identical reference signs refer to identical or at least functionally equivalent features if not explicitly specified otherwise.

DETAILED DESCRIPTION OF THE EMBODIMENTS

In the following description, reference is made to the accompanying figures, which form part of the disclosure, and which show, by way of illustration, specific aspects of embodiments of the disclosure or specific aspects in which embodiments of the present disclosure may be used. It is understood that embodiments of the disclosure may be used in other aspects and comprise structural or logical changes not depicted in the figures. The following detailed description, therefore, is not to be taken in a limiting sense, and the scope of the present disclosure is defined by the appended claims.

For instance, it is understood that a disclosure in connection with a described method may also hold true for a corresponding device or system configured to perform the method and vice versa. For example, if one or a plurality of specific method steps are described, a corresponding device may include one or a plurality of units, e.g. functional units, to perform the described one or plurality of method steps (e.g. one unit performing the one or plurality of steps, or a plurality of units each performing one or more of the plurality of steps), even if such one or more units are not explicitly described or illustrated in the figures. On the other hand, for example, if a specific apparatus is described based on one or a plurality of units, e.g. functional units, a corresponding method may include one step to perform the functionality of the one or plurality of units (e.g. one step performing the functionality of the one or plurality of units, or a plurality of steps each performing the functionality of one or more of the plurality of units), even if such one or plurality of steps are not explicitly described or illustrated in the figures. Further, it is understood that the features of the various exemplary embodiments and/or aspects described herein may be combined with each other, unless specifically noted otherwise.

Video coding typically refers to the processing of a sequence of pictures, which form the video or video sequence. Instead of the term “picture” the term “frame” or “image” may be used as synonyms in the field of video coding. Video coding (or coding in general) comprises two parts video encoding and video decoding. Video encoding is performed at the source side, typically comprising processing (e.g. by compression) the original video pictures to reduce the amount of data required for representing the video pictures (for more efficient storage and/or transmission). Video decoding is performed at the destination side and typically comprises the inverse processing compared to the encoder to reconstruct the video pictures. Embodiments referring to “coding” of video pictures (or pictures in general) shall be understood to relate to “encoding” or "decoding" of video pictures or respective video sequences. The combination of the encoding part and the decoding part is also referred to as coding and decoding (CODEC).

In case of lossless video coding, the original video pictures can be reconstructed, i.e. the reconstructed video pictures have the same quality as the original video pictures (assuming no transmission loss or other data loss during storage or transmission). In case of lossy video coding, further compression, e.g. by quantization, is performed, to reduce the amount of data representing the video pictures, which cannot be completely reconstructed at the decoder, i.e. the quality of the reconstructed video pictures is lower or worse compared to the quality of the original video pictures.

Several video coding standards belong to the group of "lossy hybrid video codecs" (i.e. combine spatial and temporal prediction in the sample domain and 2D transform coding for applying quantization in the transform domain). Each picture of a video sequence is typically partitioned into a set of non-overlapping blocks and the coding is typically performed on a block level. In other words, at the encoder the video is typically processed, i.e. encoded, on a block (video block) level, e.g. by using spatial (intra picture) prediction and/or temporal (inter picture) prediction to generate a prediction block, subtracting the prediction block from the current block (block currently processed/to be processed) to obtain a residual block, transforming the residual block and quantizing the residual block in the transform domain to reduce the amount of data to be transmitted (compression), whereas at the decoder the inverse processing compared to the encoder is applied to the encoded or compressed block to reconstruct the current block for representation. Furthermore, the encoder duplicates the decoder processing loop such that both will generate identical predictions (e.g. intra- and inter predictions) and/or re-constructions for processing, i.e. coding, the subsequent blocks.

In the following embodiments of a video coding system **10**, a video encoder **20** and a video decoder **30** are described based on FIGS. **1** to **3**.

FIG. **1**A is a schematic block diagram illustrating an example coding system **10**, e.g., a video coding system, that may utilize techniques of this present application. Video encoder (or encoder) **20** and video decoder (or decoder) **30** of coding system **10** represent examples of devices that may be configured to perform techniques in accordance with various examples described in the present application.

As shown in FIG. **1**A, the coding system **10** comprises a source device **12** configured to provide encoded picture data **21**, e.g., to a destination device **14**, for decoding the encoded picture data **13**.

The source device **12** comprises an encoder **20**, and may additionally comprise a picture source **16**, a pre-processor (or pre-processing unit) **18**, e.g., a picture pre-processor, and a communication interface or communication unit **22**.

The picture source **16** may comprise or be any kind of picture capturing device, for example a camera for capturing a real-world picture, and/or any kind of a picture generating device, for example a computer-graphics processor for generating a computer animated picture, or any kind of other device for obtaining and/or providing a real-world picture, a computer generated picture (e.g. a screen content, a virtual reality (VR) picture) and/or any combination thereof (e.g. an augmented reality (AR) picture). The picture source may be any kind of memory or storage storing any of the aforementioned pictures.

In distinction to the pre-processor **18** and the processing performed by the pre-processing unit **18**, the picture or picture data **17** may also be referred to as raw picture or raw picture data.

Pre-processor **18** is configured to receive the picture data **17** and to perform pre-processing on the picture data **17** to obtain a pre-processed picture **19** or pre-processed picture data **19**. Pre-processing performed by the pre-processor **18** may, e.g., comprise trimming, color format conversion (e.g. from RGB to YCbCr), color correction, or de-noising. It can be understood that the pre-processing unit **18** may be optional component.

The video encoder **20** is configured to receive the pre-processed picture data **19** and provide encoded picture data **21** (further details will be described below, e.g., based on FIG. **2**). Communication interface **22** of the source device **12** may be configured to receive the encoded picture data **21** and to transmit the encoded picture data **21** (or any further processed version thereof) over communication channel **13** to another device, e.g. the destination device **14** or any other device, for storage or direct reconstruction.

The destination device **14** comprises a decoder **30** (e.g. a video decoder), and may additionally comprise a communication interface or communication unit **28**, a post-processor (or post-processing unit) **32** and a display device **34**.

The communication interface **28** of the destination device **14** is configured receive the encoded picture data **21** (or any further processed version thereof), e.g., directly from the source device **12** or from any other source, e.g., a storage device, such as an encoded picture data storage device, and provide the encoded picture data **21** to the decoder **30**.

The communication interface **22** and the communication interface **28** may be configured to transmit or receive the encoded picture data **21** or encoded data **13** via a direct communication link between the source device **12** and the destination device **14**, e.g. a direct wired or wireless connection, or via any kind of network, e.g. a wired or wireless network or any combination thereof, or any kind of private and public network, or any kind of combination thereof.

The communication interface **22** may be, e.g., configured to package the encoded picture data **21** into an appropriate format, e.g. packets, and/or process the encoded picture data using any kind of transmission encoding or processing for transmission over a communication link or communication network.

The communication interface **28**, forming the counterpart of the communication interface **22**, may be, e.g., configured to receive the transmitted data and process the transmission data using any kind of corresponding transmission decoding or processing and/or de-packaging to obtain the encoded picture data **21**.

Both, communication interface **22** and communication interface **28** may be configured as unidirectional communication interfaces as indicated by the arrow for the communication channel **13** in FIG. **1**A pointing from the source device **12** to the destination device **14**, or bi-directional communication interfaces, and may be configured, e.g. to send and receive messages, e.g. to set up a connection, to acknowledge and exchange any other information related to the communication link and/or data transmission, e.g. encoded picture data transmission.

The decoder **30** is configured to receive the encoded picture data **21** and provide decoded picture data **31** or a decoded picture **31** (further details will be described below, e.g., based on FIG. **3** or FIG. **5**).

The post-processor **32** of destination device **14** is configured to post-process the decoded picture data **31** (also called reconstructed picture data), e.g. the decoded picture **31**, to obtain post-processed picture data **33**, e.g. a post-processed picture **33**. The post-processing performed by the post-processing unit **32** may comprise, e.g. color format conversion (e.g. from YCbCr to RGB), color correction, trimming, or re-sampling, or any other processing, e.g. for preparing the decoded picture data **31** for display, e.g. by display device **34**.

The display device **34** of the destination device **14** is configured to receive the post-processed picture data **33** for displaying the picture, e.g. to a user or viewer. The display device **34** may be or comprise any kind of display for representing the reconstructed picture, e.g. an integrated or external display or monitor. The displays may, e.g. comprise liquid crystal displays (LCD), organic light emitting diodes (OLED) displays, plasma displays, projectors, micro LED displays, liquid crystal on silicon (LCoS), digital light processor (DLP) or any kind of other display.

Although FIG. **1A** depicts the source device **12** and the destination device **14** as separate devices, embodiments of devices may also comprise both or both functionalities, the source device **12** or corresponding functionality and the destination device **14** or corresponding functionality. In such embodiments the source device **12** or corresponding functionality and the destination device **14** or corresponding functionality may be implemented using the same hardware and/or software or by separate hardware and/or software or any combination thereof.

As will be apparent for the skilled person based on the description, the existence and (exact) split of functionalities of the different units or functionalities within the source device **12** and/or destination device **14** as shown in FIG. **1A** may vary depending on the actual device and application.

The encoder **20** (e.g. a video encoder) or the decoder **30** (e.g. a video decoder) or both encoder **20** and decoder **30** may be implemented via processing circuitry as shown in FIG. **1B**, such as one or more microprocessors, digital signal processors (DSPs), application-specific integrated circuits (ASICs), field-programmable gate arrays (FPGAs), discrete logic, hardware, video coding dedicated or any combinations thereof. The encoder **20** may be implemented via processing circuitry **46** to embody the various modules as discussed with respect to encoder **20** of FIG. **2** and/or any other encoder system or subsystem described herein. The decoder **30** may be implemented via processing circuitry **46** to embody the various modules as discussed with respect to decoder **30** of FIG. **3** and/or any other decoder system or subsystem described herein. The processing circuitry may be configured to perform the various operations as discussed later. As shown in FIG. **5**, if the techniques are implemented partially in software, a device may store instructions for the software in a suitable, non-transitory computer-readable storage medium and may execute the instructions in hardware using one or more processors to perform the techniques of this disclosure. Either of video encoder **20** and video decoder **30** may be integrated as part of a combined encoder/decoder (CODEC) in a single device, for example, as shown in FIG. **1B**.

Source device **12** and destination device **14** may comprise any of a wide range of devices, including any kind of handheld or stationary devices, e.g. notebook or laptop computers, mobile phones, smart phones, tablets or tablet computers, cameras, desktop computers, set-top boxes, televisions, display devices, digital media players, video gaming consoles, video streaming devices (such as content services servers or content delivery servers), broadcast receiver device, broadcast transmitter device, or the like and may use no or any kind of operating system. In some cases, the source device **12** and the destination device **14** may be equipped for wireless communication. Thus, the source device **12** and the destination device **14** may be wireless communication devices.

In some embodiments, video coding system **10** illustrated in FIG. **1A** is merely an example and the techniques of the present application may apply to video coding settings (e.g., video encoding or video decoding) that do not necessarily include any data communication between the encoding and decoding devices. In other examples, data is retrieved from a local memory, streamed over a network, or the like. A video encoding device may encode and store data to memory, and/or a video decoding device may retrieve and decode data from memory. In some examples, the encoding and decoding is performed by devices that do not communicate with one another, but simply encode data to memory and/or retrieve and decode data from memory.

For convenience of description, embodiments of the disclosure are described herein, for example, by reference to High-Efficiency Video Coding (HEVC) or to the reference software of Versatile Video coding (VVC), the next generation video coding standard developed by the Joint Collaboration Team on Video Coding (JCT-VC) of ITU-T Video Coding Experts Group (VCEG) and ISO/IEC Motion Picture Experts Group (MPEG). One of ordinary skill in the art will understand that embodiments of the disclosure are not limited to HEVC or VVC.

Encoder and Encoding Method

FIG. **2** shows a schematic block diagram of an example video encoder according to an embodiment. In the example of FIG. **2**, video encoder **20** comprises an input (or input interface) **201**, a residual calculation unit **204**, a transform processing unit **206**, a quantization unit **208**, an inverse quantization unit **210**, and inverse transform processing unit **212**, a reconstruction unit **214**, a loop filter unit **220**, a decoded picture buffer (DPB) **230**, a mode selection unit **260**, an entropy encoding unit **270** and an output (or output interface) **272**. The mode selection unit **260** may include an inter prediction unit **244**, an intra prediction unit **254** and a partitioning unit **262**. Inter prediction unit **244** may include a motion estimation unit and a motion compensation unit (not shown). A video encoder **20** as shown in FIG. **2** may also be referred to as hybrid video encoder or a video encoder according to a hybrid video codec.

The residual calculation unit **204**, the transform processing unit **206**, the quantization unit **208**, the mode selection unit **260** may be referred to as forming a forward signal path of the encoder **20**, whereas the inverse quantization unit **210**, the inverse transform processing unit **212**, the reconstruction unit **214**, the buffer **216**, the loop filter **220**, the decoded picture buffer (DPB) **230**, the inter prediction unit **244** and the intra-prediction unit **254** may be referred to as forming a backward signal path of the video encoder **20**, wherein the backward signal path of the video encoder **20** corresponds to the signal path of the decoder (see video decoder **30** in FIG. **3**). The inverse quantization unit **210**, the inverse transform processing unit **212**, the reconstruction unit **214**, the loop filter **220**, the decoded picture buffer (DPB) **230**, the inter prediction unit **244** and the intra-prediction unit **254** are also referred to forming the "built-in decoder" of video encoder **20**.

Pictures & Picture Partitioning (Pictures & Blocks)

The encoder **20** may be configured to receive, e.g. via input **201**, a picture (or picture data) **17**, e.g. picture of a sequence of pictures forming a video or video sequence. The received picture or picture data may also be a pre-processed picture (or pre-processed picture data) **19**. For sake of simplicity the following description refers to the picture **17**. The picture **17** may also be referred to as current picture or picture to be coded (in particular in video coding to distinguish the current picture from other pictures, e.g. previously encoded and/or decoded pictures of the same video sequence, i.e. the video sequence which also comprises the current picture).

A (digital) picture is or can be regarded as a two-dimensional array or matrix of samples with intensity values. A sample in the array may also be referred to as pixel (short form of picture element) or a pel. The number of samples in horizontal and vertical direction (or axis) of the array or picture define the size and/or resolution of the picture. For representation of color, typically three color components are employed, i.e. the picture may be represented or include three sample arrays. In RBG format or color space a picture comprises a corresponding red, green and blue sample array. However, in video coding each pixel is typically represented in a luminance and chrominance format or color space, e.g. YCbCr, which comprises a luminance component indicated by Y (sometimes also L is used instead) and two chrominance components indicated by Cb and Cr. The luminance (or short luma) component Y represents the brightness or grey level intensity (e.g. like in a grey-scale picture), while the two chrominance (or short chroma) components Cb and Cr represent the chromaticity or color information components. Accordingly, a picture in YCbCr format comprises a luminance sample array of luminance sample values (Y), and two chrominance sample arrays of chrominance values (Cb and Cr). Pictures in RGB format may be converted or transformed into YCbCr format and vice versa, the process is also known as color transformation or conversion. If a picture is monochrome, the picture may comprise only a luminance sample array. Accordingly, a picture may be, for example, an array of luma samples in monochrome format or an array of luma samples and two corresponding arrays of chroma samples in 4:2:0, 4:2:2, and 4:4:4 colour format.

Embodiments of the video encoder **20** may comprise a picture partitioning unit (not depicted in FIG. **2**) configured to partition the picture **17** into a plurality of (typically non-overlapping) picture blocks **203**. These blocks may also be referred to as root blocks, macro blocks (H.264/AVC) or coding tree blocks (CTB) or coding tree units (CTU) (H.265/HEVC and VVC). The picture partitioning unit may be configured to use the same block size for all pictures of a video sequence and the corresponding grid defining the block size, or to change the block size between pictures or subsets or groups of pictures, and partition each picture into the corresponding blocks.

In some embodiments, the video encoder may be configured to receive directly a block **203** of the picture **17**, e.g. one, several or all blocks forming the picture **17**. The picture block **203** may also be referred to as current picture block or picture block to be coded.

Like the picture **17**, the picture block **203** again is or can be regarded as a two-dimensional array or matrix of samples with intensity values (sample values), although of smaller dimension than the picture **17**. In other words, the block **203** may comprise, e.g., one sample array (e.g. a luma array in case of a monochrome picture **17**, or a luma or chroma array in case of a color picture) or three sample arrays (e.g. a luma and two chroma arrays in case of a color picture **17**) or any other number and/or kind of arrays depending on the color format applied. The number of samples in horizontal and vertical direction (or axis) of the block **203** define the size of block **203**. Accordingly, a block may, for example, an M×N (M-column by N-row) array of samples, or an MxN array of transform coefficients.

Embodiments of the video encoder **20** as shown in FIG. **2** may be configured to encode the picture **17** block by block, e.g. the encoding and prediction is performed per block **203**.

Embodiments of the video encoder **20** as shown in FIG. **2** may be further configured to partition and/or encode the picture by using slices (also referred to as video slices), wherein a picture may be partitioned into or encoded using one or more slices (typically non-overlapping), and each slice may comprise one or more blocks (e.g. CTUs).

Embodiments of the video encoder **20** as shown in FIG. **2** may be further configured to partition and/or encode the picture by using tile groups (also referred to as video tile groups) and/or tiles (also referred to as video tiles), wherein a picture may be partitioned into or encoded using one or more tile groups (typically non-overlapping), and each tile group may comprise, e.g. one or more blocks (e.g. CTUs) or one or more tiles, wherein each tile, e.g. may be of rectangular shape and may comprise one or more blocks (e.g. CTUs), e.g. complete or fractional blocks.

Residual Calculation

The residual calculation unit **204** may be configured to calculate a residual block **205** (also referred to as residual **205**) based on the picture block **203** and a prediction block **265** (further details about the prediction block **265** are provided later), e.g. by subtracting sample values of the prediction block **265** from sample values of the picture block **203**, sample by sample (pixel by pixel) to obtain the residual block **205** in the sample domain.

Transform

The transform processing unit **206** may be configured to apply a transform, e.g. a discrete cosine transform (DCT) or discrete sine transform (DST), on the sample values of the residual block **205** to obtain transform coefficients **207** in a transform domain. The transform coefficients **207** may also be referred to as transform residual coefficients and represent the residual block **205** in the transform domain.

The transform processing unit **206** may be configured to apply integer approximations of DCT/DST, such as the transforms specified for H.265/HEVC. Compared to an orthogonal DCT transform, such integer approximations are typically scaled by a certain factor. In order to preserve the norm of the residual block which is processed by forward and inverse transforms, additional scaling factors are applied as part of the transform process. The scaling factors are typically chosen based on certain constraints like scaling factors being a power of two for shift operations, bit depth of the transform coefficients, tradeoff between accuracy and implementation costs, etc. Specific scaling factors are, for example, specified for the inverse transform, e.g. by inverse transform processing unit **212** (and the corresponding inverse transform, e.g. by inverse transform processing unit **312** at video decoder **30**) and corresponding scaling factors for the forward transform, e.g. by transform processing unit **206**, at an encoder **20** may be specified accordingly.

Embodiments of the video encoder **20** (respectively transform processing unit **206**) may be configured to output transform parameters, e.g. a type of transform or transforms, e.g. directly or encoded or compressed via the entropy encoding unit **270**, so that, e.g., the video decoder **30** may receive and use the transform parameters for decoding.

Quantization

The quantization unit **208** may be configured to quantize the transform coefficients **207** to obtain quantized coefficients **209**, e.g. by applying scalar quantization or vector quantization. The quantized coefficients **209** may also be referred to as quantized transform coefficients **209** or quantized residual coefficients **209**.

The quantization process may reduce the bit depth associated with some or all of the transform coefficients **207**. For example, an n-bit transform coefficient may be rounded down to an m-bit Transform coefficient during quantization, where n is greater than m. The degree of quantization may be modified by adjusting a quantization parameter (QP). For example, for scalar quantization, different scaling may be applied to achieve finer or coarser quantization. Smaller quantization step sizes correspond to finer quantization, whereas larger quantization step sizes correspond to coarser quantization. The applicable quantization step size may be indicated by a quantization parameter (QP). The quantization parameter may for example be an index to a predefined set of applicable quantization step sizes. For example, small quantization parameters may correspond to fine quantization (small quantization step sizes) and large quantization parameters may correspond to coarse quantization (large quantization step sizes) or vice versa. The quantization may include division by a quantization step size and a corresponding and/or the inverse dequantization, e.g. by inverse quantization unit **210**, may include multiplication by the quantization step size. Embodiments according to some standards, e.g. HEVC, may be configured to use a quantization parameter to determine the quantization step size. Generally, the quantization step size may be calculated based on a quantization parameter using a fixed point approximation of an equation including division. Additional scaling factors may be introduced for quantization and dequantization to restore the norm of the residual block, which might get modified because of the scaling used in the fixed point approximation of the equation for quantization step size and quantization parameter. In an embodiment, the scaling of the inverse transform and dequantization might be combined. Alternatively, customized quantization tables may be used and signaled from an encoder to a decoder, e.g. in a bitstream. The quantization is a lossy operation, wherein the loss increases with increasing quantization step sizes.

Embodiments of the video encoder **20** (respectively quantization unit **208**) may be configured to output quantization parameters (QP), e.g. directly or encoded via the entropy encoding unit **270**, so that, e.g., the video decoder **30** may receive and apply the quantization parameters for decoding.

Inverse Quantization

The inverse quantization unit **210** is configured to apply the inverse quantization of the quantization unit **208** on the quantized coefficients to obtain dequantized coefficients **211**, e.g. by applying the inverse of the quantization scheme applied by the quantization unit **208** based on or using the same quantization step size as the quantization unit **208**. The dequantized coefficients **211** may also be referred to as dequantized residual coefficients **211** and correspond—although typically not identical to the transform coefficients due to the loss by quantization—to the transform coefficients **207**.

Inverse Transform

The inverse transform processing unit **212** is configured to apply the inverse transform of the transform applied by the transform processing unit **206**, e.g. an inverse discrete cosine transform (DCT) or inverse discrete sine transform (DST) or other inverse transforms, to obtain a reconstructed residual block **213** (or corresponding dequantized coefficients **213**) in the sample domain. The reconstructed residual block **213** may also be referred to as transform block **213**.

Reconstruction

The reconstruction unit **214** (e.g. adder or summer **214**) is configured to add the transform block **213** (i.e. reconstructed residual block **213**) to the prediction block **265** to obtain a reconstructed block **215** in the sample domain, e.g. by adding—sample by sample—the sample values of the reconstructed residual block **213** and the sample values of the prediction block **265**.

Filtering

The loop filter unit (or loop filter) **220** is configured to filter the reconstructed block **215** to obtain a filtered block **221**, or in general, to filter reconstructed samples to obtain filtered samples. The loop filter unit is, e.g., configured to smooth pixel transitions, or otherwise improve the video quality. The loop filter unit **220** may comprise one or more loop filters such as a de-blocking filter, a sample-adaptive offset (SAO) filter or one or more other filters, e.g. a bilateral filter, an adaptive loop filter (ALF), a sharpening, a smoothing filter or a collaborative filter, or any combination thereof. Although the loop filter unit **220** is shown in FIG. **2** as being an in loop filter, in other configurations, the loop filter unit **220** may be implemented as a post loop filter. The filtered block **221** may also be referred to as filtered reconstructed block.

Embodiments of the video encoder **20** (respectively loop filter unit **220**) may be configured to output loop filter parameters (such as sample adaptive offset information), e.g. directly or encoded via the entropy encoding unit **270**, so that, e.g., a decoder **30** may receive and apply the same loop filter parameters or respective loop filters for decoding.

Decoded Picture Buffer

The decoded picture buffer (DPB) **230** may be a memory that stores reference pictures, or in general reference picture data, for encoding video data by video encoder **20**. The DPB **230** may be formed by any of a variety of memory devices, such as dynamic random access memory (DRAM), including synchronous DRAM (SDRAM), magnetoresistive RAM (MRAM), resistive RAM (RRAM), or other types of memory devices. The decoded picture buffer (DPB) **230** may be configured to store one or more filtered blocks **221**. The decoded picture buffer **230** may be further configured to store other previously filtered blocks, e.g. previously reconstructed and filtered blocks **221**, of the same current picture or of different pictures, e.g. previously reconstructed pictures, and may provide complete previously reconstructed, i.e. decoded, pictures (and corresponding reference blocks and samples) and/or a partially reconstructed current picture (and corresponding reference blocks and samples), for example for inter prediction. The decoded picture buffer (DPB) **230** may be also configured to store one or more unfiltered reconstructed blocks **215**, or in general unfiltered reconstructed samples, e.g. if the reconstructed block **215** is not filtered by loop filter unit **220**, or any other further processed version of the reconstructed blocks or samples.

Mode Selection (Partitioning & Prediction)

The mode selection unit **260** comprises partitioning unit **262**, inter-prediction unit **244** and intra-prediction unit **254**, and is configured to receive or obtain original picture data, e.g. an original block **203** (current block **203** of the current picture **17**), and reconstructed picture data, e.g. filtered and/or unfiltered reconstructed samples or blocks of the same (current) picture and/or from one or a plurality of previously decoded pictures, e.g. from decoded picture buffer **230** or other buffers (e.g. line buffer, not shown). The reconstructed picture data is used as reference picture data for prediction, e.g. inter-prediction or intra-prediction, to obtain a prediction block (or predictor) **265**.

Mode selection unit **260** may be configured to determine or select a partitioning for a current block prediction mode (including no partitioning) and a prediction mode (e.g. an intra or inter prediction mode) and generate a corresponding prediction block **265**, which is used for the calculation of the residual block **205** and for the reconstruction of the reconstructed block **215**.

Embodiments of the mode selection unit **260** may be configured to select the partitioning and the prediction mode (e.g. from those supported by or available for mode selection unit **260**), which provide the best match or in other words the minimum residual (minimum residual means better compression for transmission or storage), or a minimum signaling overhead (minimum signaling overhead means better compression for transmission or storage), or which considers or balances both. The mode selection unit **260** may be configured to determine the partitioning and prediction mode based on rate distortion optimization (RDO), i.e. select the prediction mode which provides a minimum rate distortion. Terms like "best", "minimum", "optimum" etc. in this context do not necessarily refer to an overall "best", "minimum", "optimum", etc. but may also refer to the fulfillment of a termination or selection criterion like a value exceeding or falling below a threshold or other constraints leading potentially to a "sub-optimum selection" but reducing complexity and processing time.

In other words, the partitioning unit **262** may be configured to partition the block **203** into smaller block partitions or sub-blocks (which form again blocks), e.g. iteratively using quad-tree-partitioning (QT), binary partitioning (BT) or triple-tree-partitioning (TT) or any combination thereof, and to perform, e.g., the prediction for each of the block partitions or sub-blocks, wherein the mode selection comprises the selection of the tree-structure of the partitioned block **203** and the prediction modes are applied to each of the block partitions or sub-blocks.

In the following the partitioning (e.g. by partitioning unit **260**) and prediction processing (by inter-prediction unit **244** and intra-prediction unit **254**) performed by an example video encoder **20** will be explained in more detail.

Partitioning

The partitioning unit **262** may partition (or split) a current block **203** into smaller partitions, e.g. smaller blocks of square or rectangular size. These smaller blocks (which may also be referred to as sub-blocks) may be further partitioned into even smaller partitions. This is also referred to tree-partitioning or hierarchical tree-partitioning, wherein a root block, e.g. at root tree-level 0 (hierarchy-level 0, depth 0), may be recursively partitioned, e.g. partitioned into two or more blocks of a next lower tree-level, e.g. nodes at tree-level 1 (hierarchy-level 1, depth 1), wherein these blocks may be again partitioned into two or more blocks of a next lower level, e.g. tree-level 2 (hierarchy-level 2, depth 2), etc. until the partitioning is terminated, e.g. because a termination criterion is fulfilled, e.g. a maximum tree depth or minimum block size is reached. Blocks which are not further partitioned are also referred to as leaf-blocks or leaf nodes of the tree. A tree using partitioning into two partitions is referred to as binary-tree (BT), a tree using partitioning into three partitions is referred to as ternary-tree (TT), and a tree using partitioning into four partitions is referred to as quad-tree (QT).

As mentioned before, the term "block" as used herein may be a portion, in particular a square or rectangular portion, of a picture. With reference, for example, to HEVC and VVC, the block may be or correspond to a coding tree unit (CTU), a coding unit (CU), prediction unit (PU), and transform unit (TU) and/or to the corresponding blocks, e.g. a coding tree block (CTB), a coding block (CB), a transform block (TB) or prediction block (PB).

For example, a coding tree unit (CTU) may be or comprise a CTB of luma samples, two corresponding CTBs of chroma samples of a picture that has three sample arrays, or a CTB of samples of a monochrome picture or a picture that is coded using three separate colour planes and syntax structures used to code the samples. Correspondingly, a coding tree block (CTB) may be an NxN block of samples for some value of N such that the division of a component into CTBs is a partitioning. A coding unit (CU) may be or comprise a coding block of luma samples, two corresponding coding blocks of chroma samples of a picture that has three sample arrays, or a coding block of samples of a monochrome picture or a picture that is coded using three separate colour planes and syntax structures used to code the samples. Correspondingly a coding block (CB) may be an M×N block of samples for some values of M and N such that the division of a CTB into coding blocks is a partitioning.

In some embodiments, e.g., according to HEVC, a coding tree unit (CTU) may be split into CUs by using a quad-tree structure denoted as coding tree. The decision whether to code a picture area using inter-picture (temporal) or intra-picture (spatial) prediction is made at the CU level. Each CU can be further split into one, two or four PUs according to the PU splitting type. Inside one PU, the same prediction process is applied and the relevant information is transmitted to the decoder on a PU basis. After obtaining the residual block by applying the prediction process based on the PU splitting type, a CU can be partitioned into transform units (TUs) according to another quadtree structure similar to the coding tree for the CU.

In some embodiments, e.g., according to the latest video coding standard currently in development, which is referred to as Versatile Video Coding (VVC), a combined Quad-tree and binary tree (QTBT) partitioning is for example used to partition a coding block. In the QTBT block structure, a CU can have either a square or rectangular shape. For example, a coding tree unit (CTU) is first partitioned by a quadtree structure. The quadtree leaf nodes are further partitioned by a binary tree or ternary (or triple) tree structure. The partitioning tree leaf nodes are called coding units (CUs), and that segmentation is used for prediction and transform processing without any further partitioning. This means that the CU, PU and TU have the same block size in the QTBT coding block structure. In parallel, multiple partition, for example, triple tree partition may be used together with the QTBT block structure.

In one example, the mode selection unit **260** of video encoder **20** may be configured to perform any combination of the partitioning techniques described herein.

As described above, the video encoder **20** is configured to determine or select the best or an optimum prediction mode from a set of (e.g. pre-determined) prediction modes. The set of prediction modes may comprise, e.g., intra-prediction modes and/or inter-prediction modes.

Intra-Prediction

The set of intra-prediction modes may comprise **35** different intra-prediction modes, e.g. non-directional modes like DC (or mean) mode and planar mode, or directional modes, e.g. as defined in HEVC, or may comprise **67** different intra-prediction modes, e.g. non-directional modes like DC (or mean) mode and planar mode, or directional modes, e.g. as defined for VVC.

The intra-prediction unit **254** is configured to use reconstructed samples of neighboring blocks of the same current picture to generate an intra-prediction block **265** according to an intra-prediction mode of the set of intra-prediction modes.

The intra prediction unit **254** (or in general the mode selection unit **260**) is further configured to output intra-prediction parameters (or in general information indicative of the selected intra prediction mode for the block) to the entropy encoding unit **270** in form of syntax elements **266** for inclusion into the encoded picture data **21**, so that, e.g., the video decoder **30** may receive and use the prediction parameters for decoding.

Inter-Prediction

The set of (or possible) inter-prediction modes depends on the available reference pictures (i.e. previous at least partially decoded pictures, e.g. stored in DBP **230**) and other inter-prediction parameters, e.g. whether the whole reference picture or only a part, e.g. a search window area around the area of the current block, of the reference picture is used for searching for a best matching reference block, and/or e.g. whether pixel interpolation is applied, e.g. half/semi-pel and/or quarter-pel interpolation, or not.

Additional to the above prediction modes, skip mode and/or direct mode may be applied.

The inter prediction unit **244** may include a motion estimation (ME) unit and a motion compensation (MC) unit (both not shown in FIG. **2**). The motion estimation unit may be configured to receive or obtain the picture block **203** (current picture block **203** of the current picture **17**) and a decoded picture **231**, or at least one or a plurality of previously reconstructed blocks, e.g. reconstructed blocks of one or a plurality of other/different previously decoded pictures **231**, for motion estimation. E.g., a video sequence may comprise the current picture and the previously decoded pictures **231**, or in other words, the current picture and the previously decoded pictures **231** may be part of or form a sequence of pictures forming a video sequence.

The encoder **20**, for example, may be configured to select a reference block from a plurality of reference blocks of the same or different pictures of the plurality of other pictures and provide a reference picture (or reference picture index) and/or an offset (spatial offset) between the position (x, y coordinates) of the reference block and the position of the current block as inter prediction parameters to the motion estimation unit. This offset is also called motion vector (MV).

The motion compensation unit is configured to obtain, e.g. receive, an inter prediction parameter and to perform inter prediction based on or using the inter prediction parameter to obtain an inter prediction block **265**. Motion compensation, performed by the motion compensation unit, may involve fetching or generating the prediction block based on the motion/block vector determined by motion estimation, possibly performing interpolations to sub-pixel precision. Interpolation filtering may generate additional pixel samples from known pixel samples, thus potentially increasing the number of candidate prediction blocks that may be used to code a picture block. Upon receiving the motion vector for the PU of the current picture block, the motion compensation unit may locate the prediction block to which the motion vector points in one of the reference picture lists.

The motion compensation unit may also generate syntax elements associated with the blocks and video slices for use by video decoder **30** in decoding the picture blocks of the video slice. In addition or as an alternative to slices and respective syntax elements, tile groups and/or tiles and respective syntax elements may be generated or used.

Entropy Coding

The entropy encoding unit **270** is configured to apply, for example, an entropy encoding algorithm or scheme (e.g. a variable length coding (VLC) scheme, an context adaptive VLC scheme (CAVLC), an arithmetic coding scheme, a binarization, a context adaptive binary arithmetic coding (CABAC), syntax-based context-adaptive binary arithmetic coding (SBAC), probability interval partitioning entropy (PIPE) coding or another entropy encoding methodology or technique) or bypass (no compression) on the quantized coefficients **209**, inter prediction parameters, intra prediction parameters, loop filter parameters and/or other syntax elements to obtain encoded picture data **21** which can be output via the output **272**, e.g. in the form of an encoded bitstream **21**, so that, e.g., the video decoder **30** may receive and use the parameters for decoding. The encoded bitstream **21** may be transmitted to video decoder **30**, or stored in a memory for later transmission or retrieval by video decoder **30**.

Other structural variations of the video encoder **20** can be used to encode the video stream. For example, a non-transform based encoder **20** can quantize the residual signal directly without the transform processing unit **206** for certain blocks or frames. In another embodiment, an encoder **20** can have the quantization unit **208** and the inverse quantization unit **210** combined into a single unit.

Decoder and Decoding Method

FIG. **3** shows an example of a video decoder according to an embodiment. Video decoder **30** is configured to receive encoded picture data **21** (e.g. encoded bitstream), e.g. encoded by encoder **20**, to obtain a decoded picture **331**. The encoded picture data or bitstream comprises information for decoding the encoded picture data, e.g. data that represents picture blocks of an encoded video slice (and/or tile groups or tiles) and associated syntax elements.

In the example of FIG. **3**, the decoder **30** comprises an entropy decoding unit **304**, an inverse quantization unit **310**, an inverse transform processing unit **312**, a reconstruction unit **314** (e.g. a summer), a loop filter **320**, a decoded picture buffer (DBP) **330**, a mode application unit **360**, an inter prediction unit **344** and an intra prediction unit **354**. Inter prediction unit **344** may be or include a motion compensation unit. Video decoder **30** may, in some examples, perform a decoding pass generally reciprocal to the encoding pass described with respect to video encoder **100** from FIG. **2**.

As explained with regard to the encoder **20**, the inverse quantization unit **210**, the inverse transform processing unit **212**, the reconstruction unit **214** the loop filter **220**, the decoded picture buffer (DPB) **230**, the inter prediction unit **344** and the intra prediction unit **354** are also referred to as forming the "built-in decoder" of video encoder **20**. Accordingly, the inverse quantization unit **310** may be identical in function to the inverse quantization unit **110**, the inverse transform processing unit **312** may be identical in function to the inverse transform processing unit **212**, the reconstruction unit **314** may be identical in function to reconstruction unit **214**, the loop filter **320** may be identical in function to the loop filter **220**, and the decoded picture buffer **330** may be identical in function to the decoded picture buffer **230**. Therefore, the explanations provided for the respective units and functions of the video **20** encoder apply correspondingly to the respective units and functions of the video decoder **30**.

Entropy Decoding

The entropy decoding unit **304** is configured to parse the bitstream **21** (or in general encoded picture data) and perform, for example, entropy decoding to the encoded picture data **21** to obtain, e.g., quantized coefficients **309** and/or decoded coding parameters (not shown in FIG. **3**), e.g. any or all of inter prediction parameters (e.g. reference picture index and motion vector), intra prediction parameter (e.g. intra prediction mode or index), transform parameters, quantization parameters, loop filter parameters, and/or other syntax elements. Entropy decoding unit **304** maybe configured to apply the decoding algorithms or schemes corresponding to the encoding schemes as described with regard to the entropy encoding unit **270** of the encoder **20**. Entropy decoding unit **304** may be further configured to provide inter prediction parameters, intra prediction parameter and/or other syntax elements to the mode application unit **360** and other parameters to other units of the decoder **30**. Video decoder **30** may receive the syntax elements at the video slice level and/or the video block level. In addition or as an alternative to slices and respective syntax elements, tile groups and/or tiles and respective syntax elements may be received and/or used.

Inverse Quantization

The inverse quantization unit **310** may be configured to receive quantization parameters (QP) (or in general information related to the inverse quantization) and quantized coefficients from the encoded picture data **21** (e.g. by parsing and/or decoding, e.g. by entropy decoding unit **304**) and to apply based on the quantization parameters an inverse quantization on the decoded quantized coefficients **309** to obtain dequantized coefficients **311**, which may also be referred to as transform coefficients **311**. The inverse quantization process may include use of a quantization parameter determined by video encoder **20** for each video block in the video slice (or tile or tile group) to determine a degree of quantization and, likewise, a degree of inverse quantization that should be applied.

Inverse Transform

Inverse transform processing unit **312** may be configured to receive dequantized coefficients **311**, also referred to as transform coefficients **311**, and to apply a transform to the dequantized coefficients **311** in order to obtain reconstructed residual blocks **213** in the sample domain. The reconstructed residual blocks **213** may also be referred to as transform blocks **313**. The transform may be an inverse transform, e.g., an inverse DCT, an inverse DST, an inverse integer transform, or a conceptually similar inverse transform process. The inverse transform processing unit **312** may be further configured to receive transform parameters or corresponding information from the encoded picture data **21** (e.g. by parsing and/or decoding, e.g. by entropy decoding unit **304**) to determine the transform to be applied to the dequantized coefficients **311**.

Reconstruction

The reconstruction unit **314** (e.g. adder or summer **314**) may be configured to add the reconstructed residual block **313**, to the prediction block **365** to obtain a reconstructed block **315** in the sample domain, e.g. by adding the sample values of the reconstructed residual block **313** and the sample values of the prediction block **365**.

Filtering

The loop filter unit **320** (either in the coding loop or after the coding loop) is configured to filter the reconstructed block **315** to obtain a filtered block **321**, e.g. to smooth pixel transitions, or otherwise improve the video quality. The loop filter unit **320** may comprise one or more loop filters such as a de-blocking filter, a sample-adaptive offset (SAO) filter or one or more other filters, e.g. a bilateral filter, an adaptive loop filter (ALF), a sharpening, a smoothing filter or a collaborative filter, or any combination thereof. Although the loop filter unit **320** is shown in FIG. **3** as being an in loop filter, in other configurations, the loop filter unit **320** may be implemented as a post loop filter.

Decoded Picture Buffer

The decoded video blocks **321** of a picture are then stored in decoded picture buffer **330**, which stores the decoded pictures **331** as reference pictures for subsequent motion compensation for other pictures and/or for output respectively display.

The decoder **30** is configured to output the decoded picture **331**, e.g. via output **332**, for presentation or viewing to a user.

Prediction

The inter prediction unit **344** may be identical to the inter prediction unit **244** (in particular to the motion compensation unit) and the intra prediction unit **354** may be identical to the inter prediction unit **254** in function, and performs split or partitioning decisions and prediction based on the partitioning and/or prediction parameters or respective information received from the encoded picture data **21** (e.g. by parsing and/or decoding, e.g. by entropy decoding unit **304**). Mode application unit **360** may be configured to perform the prediction (intra or inter prediction) per block based on reconstructed pictures, blocks or respective samples (filtered or unfiltered) to obtain the prediction block **365**.

When the video slice is coded as an intra coded (I) slice, intra prediction unit **354** of mode application unit **360** is configured to generate prediction block **365** for a picture block of the current video slice based on a signaled intra prediction mode and data from previously decoded blocks of the current picture. When the video picture is coded as an inter coded (i.e., B, or P) slice, inter prediction unit **344** (e.g. motion compensation unit) of mode application unit **360** is configured to produce prediction blocks **365** for a video block of the current video slice based on the motion vectors and other syntax elements received from entropy decoding unit **304**. For inter prediction, the prediction blocks may be produced from one of the reference pictures within one of the reference picture lists. Video decoder **30** may construct the reference frame lists, List 0 and List 1, using default construction techniques based on reference pictures stored in DPB **330**. The same or similar may be applied for or by embodiments using tile groups (e.g. video tile groups) and/or tiles (e.g. video tiles) in addition or alternatively to slices (e.g. video slices), e.g. a video may be coded using I, P or B tile groups and/or tiles.

Mode application unit **360** is configured to determine the prediction information for a video block of the current video slice by parsing the motion vectors or related information and other syntax elements, and uses the prediction information to produce the prediction blocks for the current video block being decoded. For example, the mode application unit **360** uses some of the received syntax elements to determine a prediction mode (e.g., intra or inter prediction) used to code the video blocks of the video slice, an inter prediction slice type (e.g., B slice, P slice, or GPB slice), construction information for one or more of the reference picture lists for the slice, motion vectors for each inter encoded video block of the slice, inter prediction status for each inter coded video block of the slice, and other information to decode the video blocks in the current video slice. The same or similar may be applied for or by embodiments using tile groups (e.g. video tile groups) and/or tiles (e.g. video tiles) in addition or alternatively to slices (e.g. video slices), e.g. a video may be coded using I, P or B tile groups and/or tiles.

Embodiments of the video decoder **30** as shown in FIG. **3** may be configured to partition and/or decode the picture by using slices (also referred to as video slices), wherein a picture may be partitioned into or decoded using one or more slices (typically non-overlapping), and each slice may comprise one or more blocks (e.g. CTUs).

Embodiments of the video decoder **30** as shown in FIG. **3** may be configured to partition and/or decode the picture by using tile groups (also referred to as video tile groups) and/or tiles (also referred to as video tiles), wherein a picture may be partitioned into or decoded using one or more tile groups (typically non-overlapping), and each tile group may comprise, e.g. one or more blocks (e.g. CTUs) or one or more tiles, wherein each tile, e.g. may be of rectangular shape and may comprise one or more blocks (e.g. CTUs), e.g. complete or fractional blocks.

Other variations of the video decoder **30** can be used to decode the encoded picture data **21**. For example, the decoder **30** can produce the output video stream without the loop filtering unit **320**. For example, a non-transform based decoder **30** can inverse-quantize the residual signal directly without the inverse-transform processing unit **312** for certain blocks or frames. In another embodiment, the video decoder **30** can have the inverse-quantization unit **310** and the inverse-transform processing unit **312** combined into a single unit.

It should be understood that, in the encoder **20** and the decoder **30**, a processing result of a current step may be further processed and then output to the next step. For example, after interpolation filtering, motion vector derivation or loop filtering, a further operation, such as Clip or shift, may be performed on the processing result of the interpolation filtering, motion vector derivation or loop filtering.

It should be noted that further operations may be applied to the derived motion vectors of current block (including but not limit to control point motion vectors of affine mode, sub-blockmotion vectors in affine, planar, advanced temporal motion vector prediction (ATMVP) modes, temporal motion vectors, and so on). For example, the value of motion vector is constrained to a predefined range according to its representing bit. If the representing bit of motion vector is bitDepth, then the range is −2^(bitDepth−1)~2^(bitDepth−1)−1, where "^" means exponentiation. For example, if bitDepth is set equal to 16, the range is −32768~32767; if bitDepth is set equal to 18, the range is −131072~131071. For example, the value of the derived motion vector (e.g. the MVs of four 4×4 sub-blocks within one 8×8 block) is constrained such that the max difference between integer parts of the four 4×4 sub-block MVs is no more than N pixels, such as no more than 1 pixel. Here provides two methods for constraining the motion vector according to the bitDepth.

Method 1: remove the overflow MSB (most significant bit) by flowing operations

$$ux=(mvx+2^{bitDepth})\%2^{bitDepth} \tag{1}$$

$$mvx=(ux>=2^{bitDepth-1})?(ux-2^{bitDepth}):ux \tag{2}$$

$$uy=(mvy+2^{bitDepth})\%2^{bitDepth} \tag{3}$$

$$mvy=(uy>=2^{bitDepth-1})?(uy-2^{bitDepth}):uy \tag{4}$$

where mvx is a horizontal component of a motion vector of an image block or a sub-block, mvy is a vertical component of a motion vector of an image block or a sub-block, and ux and uy indicates an intermediate value;

For example, if the value of mvx is −32769, after applying formula (1) and (2), the resulting value is 32767. In computer system, decimal numbers are stored as two's complement. The two's complement of −2769 is 1,0111,1111,1111,1111 (17 bits), then the MSB is discarded, so the resulting two's complement is 0111,1111,1111,1111 (decimal number is 32767), which is same as the output by applying formula (1) and (2).

$$ux=(mvpx+mvdx+2^{bitDepth})\%2^{bitDepth} \tag{5}$$

$$mvx=(ux>=2^{bitDepth-1})?(ux-2^{bitDepth}):ux \tag{6}$$

$$ux=(mvpy+mvdy+2^{bitDepth})\%2^{bitDepth} \tag{7}$$

$$mvx=(uy>=2^{bitDepth-1})?(uy-2^{bitDepth}):uy \tag{8}$$

The operations may be applied during the sum of mvp and mvd, as shown in formula (5) to (8).

Method 2: remove the overflow MSB by clipping the value

$$vx=\text{Clip3}(-2^{bitDepth-1},2^{bitDepth-1}-1,vx)$$

$$vy=\text{Clip3}(-2^{bitDepth-1},2^{bitDepth-1}-1,vy)$$

where vx is a horizontal component of a motion vector of an image block or a sub-block, vy is a vertical component of a motion vector of an image block or a sub-block; x, y and z respectively correspond to three input value of the MV clipping process, and the definition of function Clip3 is as follow:

$$Clip3(x, y, z) = \begin{cases} x \; ; & z < x \\ y \; ; & z > y \\ z \; ; & \text{otherwise} \end{cases}$$

FIG. **4** is a schematic diagram of a video coding device **400** according to an embodiment of the disclosure. The video coding device **400** is suitable for implementing the disclosed embodiments as described herein. In an embodiment, the video coding device **400** may be a decoder such as video decoder **30** of FIG. **1**A or an encoder such as video encoder **20** of FIG. **1**A.

The video coding device **400** comprises ingress ports (or input ports) **410** and receiver units (Rx) **420** for receiving data; a processor, logic unit, or central processing unit (CPU) **430** to process the data; transmitter units (Tx) **440** and egress ports (or output ports) **450** for transmitting the data; and a memory **460** for storing the data. The video coding device **400** may also comprise optical-to-electrical (OE) components and electrical-to-optical (EO) components coupled to the ingress ports **410**, the receiver units **420**, the transmitter units **440**, and the egress ports **450** for egress or ingress of optical or electrical signals.

The processor **430** is implemented by hardware and software. The processor **430** may be implemented as one or more CPU chips, cores (e.g., as a multi-core processor), FPGAs, ASICs, and DSPs. The processor **430** is in communication with the ingress ports **410**, receiver units **420**, transmitter units **440**, egress ports **450**, and memory **460**. The processor **430** comprises a coding module **470**. The coding module **470** implements the disclosed embodiments described above. For instance, the coding module **470** implements, processes, prepares, or provides the various coding operations. The inclusion of the coding module **470** therefore provides a substantial improvement to the functionality of the video coding device **400** and effects a transformation of the video coding device **400** to a different state. Alternatively, the coding module **470** is implemented as instructions stored in the memory **460** and executed by the processor **430**.

The memory **460** may comprise one or more disks, tape drives, and solid-state drives and may be used as an over-flow data storage device, to store programs when such programs are selected for execution, and to store instructions and data that are read during program execution. The memory **460** may be, for example, volatile and/or non-volatile and may be a read-only memory (ROM), random access memory (RAM), ternary content-addressable memory (TCAM), and/or static random-access memory (SRAM).

FIG. **5** is a block diagram of an apparatus that may be used as either or both of the source device **12** and the destination device **14** from FIG. **1** according to an embodiment.

A processor **502** in the apparatus **500** can be a central processing unit. Alternatively, the processor **502** can be any other type of device, or multiple devices, capable of manipulating or processing information now-existing or hereafter developed. Although the disclosed embodiments can be practiced with a single processor as shown, e.g., the processor **502**, advantages in speed and efficiency can be achieved using more than one processor.

A memory **504** in the apparatus **500** can be a read only memory (ROM) device or a random access memory (RAM) device in an embodiment. Any other suitable type of storage device can be used as the memory **504**. The memory **504** can include code and data **506** that is accessed by the processor **502** using a bus **512**. The memory **504** can further include an operating system **508** and application programs **510**, the application programs **510** including at least one program that permits the processor **502** to perform the methods described here. For example, the application programs **510** can include applications 1 through N, which further include a video coding application that performs the methods described here. The apparatus **500** can also include one or more output devices, such as a display **518**. The display **518** may be, in one example, a touch sensitive display that combines a display with a touch sensitive element that is operable to sense touch inputs. The display **518** can be coupled to the processor **502** via the bus **512**.

Although depicted here as a single bus, the bus **512** of the apparatus **500** can be composed of multiple buses. Further, the secondary storage **514** can be directly coupled to the other components of the apparatus **500** or can be accessed via a network and can comprise a single integrated unit such as a memory card or multiple units such as multiple memory cards. The apparatus **500** can thus be implemented in a wide variety of configurations.

Directional intra prediction is a well-known technique that includes propagating the values of the neighboring samples into the predicted block as specified by the prediction direction. FIG. **6** illustrates the 93 prediction directions, where the dashed directions are associated with the wide-angle modes that are only applied to non-square blocks.

Direction could be specified by the increase of an offset between position of predicted and reference sample. The larger magnitude of this increase corresponds to a greater skew of the prediction direction. Table 1 specifies the mapping table between predModeIntra and the angle parameter intraPredAngle. This parameter is in fact the increase of this offset per row (or per column) specified in the 1/32 sample resolution.

TABLE 1

Specification of intraPredAngle

predModeIntra	−14	−13	−12	−11	−10	−9	−8	−7	−6	−5	−4	−3	−2	−1	2	3	4
intraPredAngle	512	341	256	171	128	102	86	73	64	57	51	45	39	35	32	29	26
predModeIntra	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
intraPredAngle	23	20	18	16	14	12	10	8	6	4	3	2	1	0	−1	−2	−3
predModeIntra	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
intraPredAngle	−4	−6	−8	−10	−12	−14	−16	−18	−20	−23	−26	−29	−32	−29	−26	−23	−20
predModeIntra	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55
intraPredAngle	−18	−16	−14	−12	−10	−8	−6	−4	−3	−2	−1	0	1	2	3	4	6
predModeIntra	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72
intraPredAngle	8	10	12	14	16	18	20	23	26	29	32	35	39	45	51	57	64
predModeIntra	73	74	75	76	77	78	79	80									
intraPredAngle	73	86	102	128	171	256	341	512									

Wide-angle modes could be identified by the absolute value of intraPredAngle greater than 32 (1 sample), that corresponds to the slope of prediction direction greater than 45 degrees.

Predicted samples ("predSamples") could be obtained from the neighbouring samples "p" as described below:

The values of the prediction samples predSamples[x][y], with x=0 . . . nTbW−1, y=0 . . . nTbH−1 are derived as follows:

If predModeIntra is greater than or equal to 34, the following ordered operations apply:

1. The reference sample array ref[x] is specified as follows:

The following applies:

$$\text{ref}[x]=p[-1-\text{refIdx}+x][-1-\text{refIdx}],\ \text{with } x=0\ \ldots\ \text{nTbW}+\text{refIdx}$$

If intraPredAngle is less than 0, the main reference sample array is extended as follows:

When (nTbH*intraPredAngle)>>5 is less than −1,

$$\text{ref}[x]=p[-1-\text{refIdx}][-1-\text{refIdx}+((x*\text{invAngle}+128)\gg 8)],\ \text{with } x=-1\ \ldots\ (\text{nTbH}*\text{intraPredAngle})\gg 5$$

$$\text{ref}[((\text{nTbH}*\text{intraPredAngle})\gg 5)-1]=\text{ref}[(\text{nTbH}*\text{intraPredAngle})\gg 5]$$

$$\text{ref}[\text{nTbW}+1+\text{refIdx}]=\text{ref}[\text{nTbW}+\text{refIdx}]$$

Otherwise,

$$\text{ref}[x]=p[-1-\text{refIdx}+x][-1-\text{refIdx}],\ \text{with } x=\text{nTbW}+1+\text{refIdx}\ \ldots\ \text{refW}+\text{refIdx}$$

$$\text{ref}[-1]=\text{ref}[0]$$

The additional samples ref[refW+refIdx+x] with x=1 . . . (Max(1, nTbW/nTbH)*refIdx+1) are derived as follows:

$$\text{ref}[\text{refH}+\text{refIdx}+x]=p[-1+\text{refW}][-1-\text{refIdx}]$$

2. The values of the prediction samples predSamples [x][y], with x=0 . . . nTbW−1, y=0 . . . nTbH−1 are derived as follows:

The index variable iIdx and the multiplication factor iFact are derived as follows:

$$\text{iIdx}=((y+1+\text{refIdx})*\text{intraPredAngle})\gg 5+\text{refIdx}$$

$$\text{iFact}=((y+1+\text{refIdx})*\text{intraPredAngle})\&31$$

If cIdx is equal to 0, the following applies:

The interpolation filter coefficients fT[j] with j=0 . . . 3 are derived as follows:

$$fT[j]=\text{filterFlag}\,?\,fG[\text{iFact}][j]:fC[\text{iFact}][j]$$

The value of the prediction samples predSamples [x][y] is derived as follows:

$$\text{predSamples}[x][y]=\text{Clip1}Y(((\Sigma_{i=0}^{3}fT[i]*\text{ref}[x+\text{iIdx}+i])+32)\gg 6)$$

Otherwise (cIdx is not equal to 0), depending on the value of iFact, the following applies:

If iFact is not equal to 0, the value of the prediction samples predSamples[x][y] is derived as follows:

$$\text{predSamples}[x][y]=((32-\text{iFact})*\text{ref}[x+\text{iIdx}+1]+\text{iFact}*\text{ref}[x+\text{iIdx}+2]+16)\gg 5$$

Otherwise, the value of the prediction samples predSamples[x][y] is derived as follows:

$$\text{predSamples}[x][y]=\text{ref}[x+\text{iIdx}+1]$$

Otherwise (predModeIntra is less than 34), the following ordered operations apply:

1. The reference sample array ref[x] is specified as follows:

The following applies:

$$\text{ref}[x]=p[-1-\text{refIdx}][-1-\text{refIdx}+x],\ \text{with } x=0\ \ldots\ \text{nTbH}+\text{refIdx}$$

If intraPredAngle is less than 0, the main reference sample array is extended as follows:

When (nTbW*intraPredAngle)>>5 is less than −1,

$$\text{ref}[x]=p[-1-\text{refIdx}+((x*\text{invAngle}+128)\gg 8)][-1-\text{refIdx}],\ \text{with } x=-1\ \ldots\ (\text{nTbW}*\text{intraPredAngle})\gg 5$$

$$\text{ref}[((\text{nTbW}*\text{intraPredAngle})\gg 5)-1]=\text{ref}[(\text{nTbW}*\text{intraPredAngle})\gg 5]$$

$$\text{ref}[\text{nTbG}+1+\text{refIdx}]=\text{ref}[\text{nTbH}+\text{refIdx}] \qquad (8\text{-}145)$$

Otherwise,

$$\text{ref}[x]=p[-1-\text{refIdx}][-1-\text{refIdx}+x],\ \text{with } x=\text{nTbH}+1+\text{refIdx}\ \ldots\ \text{refH}+\text{refIdx}$$

$$\text{ref}[-1]=\text{ref}[0]$$

The additional samples ref[refH+refIdx+x] with x=1 . . . (Max(1, nTbW/nTbH)*refIdx+1) are derived as follows:

$$\text{ref}[\text{refH}+\text{refIdx}+x]=p[-1+\text{refH}][-1-\text{refIdx}]$$

2. The values of the prediction samples predSamples [x][y], with x=0 . . . nTbW−1, y=0 . . . nTbH−1 are derived as follows:

The index variable iIdx and the multiplication factor iFact are derived as follows:

$$\text{iIdx}=((x+1+\text{refIdx})*\text{intraPredAngle})\gg 5$$

$$\text{iFact}=((x+1+\text{refIdx})*\text{intraPredAngle})\&31$$

If cIdx is equal to 0, the following applies:

The interpolation filter coefficients fT[j] with j=0 . . . 3 are derived as follows:

$$fT[j]=\text{filterFlag}\,?\,fG[\text{iFact}][j]:fC[\text{iFact}][j]$$

The value of the prediction samples predSamples [x][y] is derived as follows:

$$\text{predSamples}[x][y]=\text{Clip1}Y(((\sigma_{i=0}^{3}fT[i]*\text{ref}[y+\text{iIdx}+i])+32)\gg 6)$$

Otherwise (cIdx is not equal to 0), depending on the value of iFact, the following applies:

If iFact is not equal to 0, the value of the prediction samples predSamples[x][y] is derived as follows:

$$\text{predSamples}[x][y]=((32-\text{iFact})*\text{ref}[y+\text{iIdx}+1]+\text{iFact}*\text{ref}[y+\text{iIdx}+2]+16)\gg 5$$

Otherwise, the value of the prediction samples predSamples[x][y] is derived as follows:

$$\text{predSamples}[x][y]=\text{ref}[y+\text{iIdx}+1]$$

Signaling of intra prediction modes for luma and chroma components could be performed in such a way, that chroma intra prediction mode is derived from luma intra prediction mode:

The chroma intra prediction mode IntraPredModeC[xCb] [yCb] is derived using intra_chroma_pred_mode[xCb][yCb] and IntraPredModeY[xCb+cbWidth/2][yCb+cbHeight/2] as specified in Table 2 and Table 3.

TABLE 2

Specification of IntraPredModeC[xCb][yCb] depending on intra_chroma_pred_mode[xCb][yCb] and IntraPredModeY[xCb + cbWidth/2][yCb + cbHeight/2] when sps_cclm_enabled_flag is equal to 0					
intra_chroma_pred_	IntraPredModeY[xCb + cbWidth/2][yCb + cbHeight/2]				
mode[xCb][yCb]	0	50	18	1	X (0 <= X <= 66)
0	66	0	0	0	0
1	50	66	50	50	50
2	18	18	66	18	18
3	1	1	1	66	1
4	0	50	18	1	X

TABLE 3

Specification of IntraPredModeC[xCb][yCb] depending on intra_chroma_pred_mode[xCb][yCb] and IntraPredModeY[xCb + cbWidth/2][yCb + cbHeight/2] when sps_cclm_enabled_flag is equal to 1					
intra_chroma_pred_	IntraPredModeY[xCb + cbWidth/2][yCb + cbHeight/2]				
mode[xCb][yCb]	0	50	18	1	X (0 <= X <= 66)
0	66	0	0	0	0
1	50	66	50	50	50
2	18	18	66	18	18
3	1	1	1	66	1
4	81	81	81	81	81
5	82	82	82	82	82
6	83	83	83	83	83
7	0	50	18	1	X

Parameter "intra_chroma_pred_mode" is signaled within a bitstream. From Table 2 and Table 3 it could be noticed, that in certain cases (denoted by "X"), intra prediction mode for chroma component (IntraPredModeC) is set equal to the intra prediction mode specified for the co-located luma block.

Chroma format determines precedence and subsampling of chroma arrays, as shown in FIG. 7. In monochrome sampling there is only one sample array, which is nominally considered the luma array.

In 4:2:0 sampling, each of the two chroma arrays has half the height and half the width of the luma array.

In 4:2:2 sampling, each of the two chroma arrays has the same height and half the width of the luma array.

This solution provides the same intra prediction direction for predicting chroma samples as it is specified for luma samples. However, when chroma subsampling ratio in horizontal direction is not equal to chroma subsampling ratio in vertical direction, intra prediction directions for chroma will be affected by subsampling, resulting in different mapping of intra prediction mode to the angle of intra prediction direction. To compensate for this effect, in the range extensions of HM it was proposed to perform a mode mapping operation, i.e. to perform a fetch from the dedicated lookup table (LUT) for the corresponding luma intra prediction mode (IntraPredModeY) and to use the fetched value for chroma intra prediction mode (IntraPredModeC). Table 4 gives this LUT for the set of modes specified in the HEVC standard.

TABLE 4

Specification of the LUT for intra prediction mode mapping for 4:2:2 chroma format																		
IntraPredModeY	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
IntraPredModeC	0	1	2	2	2	2	2	4	6	8	10	12	14	16	18	18	18	18
IntraPredModeY		18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
IntraPredModeC		22	22	23	23	24	24	25	25	26	27	27	28	28	29	29	30	30

In VVC specification draft 4 in the intra prediction process, the index of intra prediction mode (intraPredMode) is modified in accordance with aspect ratio as follows:

The variables nW and nH are derived as follows:

If IntraSubPartitionsSplitType is equal to ISP_NO_SPLIT or cIdx is not equal to 0, the following applies:

$$nW=\mathrm{nTbW}$$

$$nH=\mathrm{nTbH}$$

Otherwise (IntraSubPartitionsSplitType is not equal to ISP_NO_SPLIT and cIdx is equal to 0), the following applies:

$$nW=\mathrm{nCbW}$$

$$nH=\mathrm{nCbH}$$

The variable whRatio is set equal to Abs(Log 2(nW/nH)).

The variable wideAngle is set equal to 0.

For non-square blocks (nW is not equal to nH), the intra prediction mode predModeIntra is modified as follows:

If all of the following conditions are true, wideAngle is set equal to 1 and predModeIntra is set equal to (predModeIntra+65).
- nW is greater than nH
- predModeIntra is greater than or equal to 2
- predModeIntra is less than (whRatio>1)?(8+2*whRatio):8

Otherwise, if all of the following conditions are true, wideAngle is set equal to 1 and predModeIntra is set equal to (predModeIntra−67).
- nH is greater than nW
- predModeIntra is less than or equal to 66
- predModeIntra is greater than (whRatio>1)?(60−2*whRatio):60

The process of modifying intra prediction mode (predModeIntra) with respect to the aspect ratio (whRatio) described above would be further referred to as "wide-angle mapping".

If to apply the state of the art approach, intra prediction direction for chroma samples may be opposite to the direction specified for collocated luma samples, because conditions for luma and chroma blocks would be different due to horizontal chroma subsampling as specified for YUV 4:2:2 chroma format.

The embodiments of the disclosure proposes to jointly consider block aspect ratio and chroma subsampling format when using luma intra prediction mode for chroma intra prediction.

The disclosure provides several methods/embodiments to solve this problem. One method introduces clipping operation in order to guarantee that luma and chroma directional intra prediction uses the same side of the block.

Another method includes modification of the wide-angle mapping process in order to guarantee that resulting chroma prediction mode has the same angle of the mapped direction. As follows from the description above, these directions do not coincide. ("(predModeIntra−67)" and "(predModeIntra+65)").

The third method includes adjustment of input parameters for wide-angle mapping process. Specifically, it is proposed to use luma aspect ratio instead of chroma one. In addition, the intraPredAngle parameter is left or right shifted to compensate for the effect of chroma subsampling.

Alternatively, for the set of signaled luma intra prediction modes given in VVC specification draft (which are in the range of 0 . . . 66), the following lookup table could be used (Table 5)

TABLE 5

Specification of the LUT for intra prediction mode mapping for 4:2:2 chroma format in case of 66 signaled intra prediction directions

IntraPredModeY	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
IntraPredModeC	0	1	2	2	2	2	2	2	2	3	4	6	8	10	12	13	14	16
IntraPredModeY	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
IntraPredModeC	18	20	22	23	24	26	28	30	32	33	34	35	36	37	38	39	40	41
IntraPredModeY	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53
IntraPredModeC	42	43	44	44	44	45	46	46	46	47	48	48	48	49	50	51	52	52
IntraPredModeY	54	55	56	57	58	59	60	61	62	63	64	65	66					
IntraPredModeC	52	53	54	54	54	55	56	56	56	57	58	59	60					

One of the possible solution includes applying LUT specified in table 5 to the value of luma intra prediction mode (IntraPredModeY) and to use the obtained mode as an input intra prediction mode (IntraPredModeC) of directional intra prediction process for chroma block, that comprises:

- wide-angle mapping of intraPredModeC
- derivation of reference sample array ("ref") and intraPredAngle parameter
- obtaining the values of predicted chroma samples using above-determined reference samples ("ref") and intraPredAngle parameter.

This approach works well if when luma intra prediction mode (intrapredmodey) is not a wide-angle mode. As shown in FIG. **9**, predicted chroma and luma samples on the same spatial positions "A" would use reference samples that are also located on the same spatial positions.

This method also works in the case shown in FIG. **11**, because it specifies clipping of output chroma intra prediction direction to the angle of 45 degrees (mode 2). This clipping is implemented by the means of specifying the same value for a set of entries in the LUT (please, notice entries IntraPredModeY=2 . . . 8).

Another embodiment of the disclosure includes modification of wide-angle mapping process for the case when operation "wide-angle mapping of IntraPredModeC" is performed.

The following description specifies the additional dependency of wide-angle mapping process on whether the mapped direction is performed for chroma intra prediction for chroma format specifying different subsampling ratios in horizontal and vertical directions (denoted further as "SubWidthC" and "SubHeightC", respectively):

The variables nW and nH are derived as follows:

If IntraSubPartitionsSplitType is equal to ISP_NO_SPLIT or cIdx is not equal to 0, the following applies:

$$nW = \mathrm{nTbW}$$

$$nH = \mathrm{nTbH}$$

Otherwise (IntraSubPartitionsSplitType is not equal to ISP_NO_SPLIT and cIdx is equal to 0), the following applies:

$$nW = \mathrm{nCbW}$$

$$nH = \mathrm{nCbH}$$

If SubWidthC is not equal to SubHeightC, the value of variable modeDelta is set to (cIdx==0?0:1), otherwise modeDelta is set to 0.

The variable whRatio is set equal to Abs(Log 2(nW/nH)).

The variable wideAngle is set equal to 0.

For non-square blocks (nW is not equal to nH), the intra prediction mode predModeIntra is modified as follows:

If all of the following conditions are true, wideAngle is set equal to 1 and predModeIntra is set equal to (predModeIntra+65+modeDelta).

- nW is greater than nH
- predModeIntra is greater than or equal to 2
- predModeIntra is less than (whRatio>1)?(8+2*whRatio):8

Otherwise, if all of the following conditions are true, wideAngle is set equal to 1 and predModeIntra is set equal to (predModeIntra−67+modeDelta).

- nH is greater than nW
- predModeIntra is less than or equal to 66
- predModeIntra is greater than (whRatio>1)?(60−2*whRatio):60

However, approaches described above may result in an opposite direction of luma and chroma intra prediction modes in case when luma intra prediction mode (IntraPredModeY) corresponds to wide-angle direction. FIG. **8** shows an example of the case when IntraPredModeC is derived from IntraPredModeY where IntraPredModeY is wide-angle intra prediction mode and IntraPredModeC is a non-wide-angle angle intra prediction mode. The example of the case when expected intra prediction mode (as shown in FIG. **8**) is not produced by the method disclosed above. FIG. **9** shows an example of the case when IntraPredModeC is derived from IntraPredModeY where IntraPredModeY is non-wide-angle intra prediction mode and IntraPredModeC is a non-wide-angle angle intra prediction mode. FIG. **10** shows an example of the case when IntraPredModeC is derived from IntraPredModeY where IntraPredModeY is non-wide-angle intra prediction mode and IntraPredModeC is a wide-angle angle intra prediction mode. The example of the case (as shown in FIG. **10**) when non-wide angle input luma intra prediction mode (IntraPredModeY) produces wide-angle chroma intra prediction mode (IntraPredModeC). FIG. **11** shows an example of the case when IntraPredModeC is derived from IntraPredModeY using prediction mode clipping and where IntraPredModeY is non-wide-angle intra prediction mode and IntraPredModeC is a non-wide-angle angle intra prediction mode.

An embodiment specifying the method ("Method 3") shown in FIG. **8** and FIG. **10** could be disclosed in a form of the following operations when chroma format is defined as YUV 4:2:2 and input luma intra prediction mode (IntraPredModeY) is directional (i.e not equal to DC and not equal to PLANAR):wide-angle mapping of (IntraPredModeY) using aspect ratio of a luma block resulting in IntraPredModeFinalY;

derivation of reference sample array ("ref") and intraPredAngle parameter for chroma block using input prediction mode IntraPredModeFinalY, copmprising the following operations:

in case when IntraPredModeFinalY is not less than 34, intraPredAngle parameter is redefined as follows:

intraPredAngle=intraPredAngle>>1

otherwise, intraPredAngle parameter is redefined as follows

intraPredAngle=intraPredAngle<<1

obtaining the values of predicted chroma samples using above-determined reference samples ("ref") and intraPredAngle parameter.

Alternatively, instead of "intraPredAngle=intraPredAngle>>1" operation other division by 2 implementation may be used, such as: "intraPredAngle=sign(intraPredAngle)*((Abs(intraPredAngle)+1)>>1)" or "intraPredAngle=intraPredAngle/2".

A combination of the both methods cold be also applied. An embodiment would comprise the following operations for an input luma intra prediction mode (IntraPredModeY) that is directional (i.e not equal to DC and not equal to PLANAR):

if IntraPredModeY is not less than 18 and not greater than 50, the following operations apply

fetch from the LUT (e.g. as specified in table 5) using the key value of luma intra prediction mode (IntraPredModeY) resulting in chroma input intra prediction mode (IntraPredModeC)

wide-angle mapping of IntraPredModeC

derivation of reference sample array ("ref") and intraPredAngle parameter

obtaining the values of predicted chroma samples using above-determined reference samples ("ref") and intraPredAngle parameter.

Otherwise, perform operations specified in "Method 3" description.

An embodiment of the disclosure could be also represented in the following form:

8.4.3 Derivation Process for Chroma Intra Prediction Mode

Input to this process are:

a luma location (xCb, yCb) specifying the top-left sample of the current chroma coding block relative to the top-left luma sample of the current picture,

a variable cbWidth specifying the width of the current coding block in luma samples,

a variable cbHeight specifying the height of the current coding block in luma samples.

In this process, the chroma intra prediction mode IntraPredModeC[xCb][yCb] is derived.

The chroma intra prediction mode IntraPredModeC[xCb][yCb] is derived using intra_chroma_pred_mode[xCb][yCb] and IntraPredModeY[xCb+cbWidth/2][yCb+cbHeight/2] as specified in Table 8-2 and Table 8-3.

The chroma intra prediction mode IntraPredModeC[xCb][yCb] is derived using process map422.

TABLE 8-2

Specification of IntraPredModeC[xCb][yCb] depending on intra_chroma_pred_mode[xCb][yCb] and IntraPredModeY[xCb + cbWidth/2][yCb + cbHeight/2] when sps_cclm_enabled_flag is equal to 0

intra_chroma_pred_	IntraPredModeY[xCb + cbWidth/2][yCb + cbHeight/2]				
mode[xCb][yCb]	0	50	18	1	X (0 <= X <= 66)
0	66	0	0	0	0
1	50	66	50	50	50
2	18	18	66	18	18
3	1	1	1	66	1
4	0	50	18	1	X

TABLE 8-3

Specification of IntraPredModeC[xCb][yCb] depending on intra_chroma_pred_mode[xCb][yCb] and IntraPredModeY[xCb + cbWidth/2][yCb + cbHeight/2] when sps_cclm_enabled_flag is equal to 1

intra_chroma_pred_	IntraPredModeY[xCb + cbWidth/2][yCb + cbHeight/2]				
mode[xCb][yCb]	0	50	18	1	X (0 <= X <= 66)
0	66	0	0	0	0
1	50	66	50	50	50
2	18	18	66	18	18
3	1	1	1	66	1
4	81	81	81	81	81
5	82	82	82	82	82
6	83	83	83	83	83
7	0	50	18	1	X

In the mapping process map422( ) output intra prediction mode Y is derived from the input intra prediction mode X as follows:

Output intra prediction mode Y is set equal to input intra prediction mode X if one of the following is true:

SubWidthC is equal to SubHeightC,

X is smaller than 2,

X is larger than 66

Otherwise, intra prediction mode Y is set equal to the value acording to the lookup table defined in Table 8-4.

TABLE 8-4

Specification of the lookup table for the map422( ) mapping process																		
X	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Y	0	1	2	2	2	2	2	2	2	3	4	6	8	10	12	13	14	16
X	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
Y	18	20	22	23	24	26	28	30	32	33	34	35	36	37	38	39	40	41
X	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53
Y	42	43	44	44	44	45	46	46	46	47	48	48	48	49	50	51	52	52
X	54	55	56	57	58	59	60	61	62	63	64	65	66					
Y	52	53	54	54	54	55	56	56	56	57	58	59	60					

Another embodiment of the disclosure could also be represented in the following form:

8.4.3 Derivation Process for Chroma Intra Prediction Mode

Input to this process are:

- a luma location (xCb, yCb) specifying the top-left sample of the current chroma coding block relative to the top-left luma sample of the current picture,
- a variable cbWidth specifying the width of the current coding block in luma samples,
- a variable cbHeight specifying the height of the current coding block in luma samples.

In this process, the chroma intra prediction mode IntraPredModeC[xCb][yCb] is derived.

The chroma intra prediction mode IntraPredModeC[xCb][yCb] is derived using intra_chroma_pred_mode[xCb][yCb] and IntraPredModeY[xCb+cbWidth/2][yCb+cbHeight/2] as specified in Table 8-2 and Table 8-3.

The chroma intra prediction mode IntraPredModeC[xCb][yCb] is derived using process map422.

TABLE 8-2

Specification of IntraPredModeC[xCb][yCb] depending on intra_chroma_pred_mode[xCb][yCb] and IntraPredModeY[xCb + cbWidth / 2][yCb + cbHeight / 2] when sps_cclm_enabled_flag is equal to 0

intra_chroma_pred_	IntraPredModeY[xCb + cbWidth / 2][yCb + cbHeight / 2]				
mode[xCb][yCb]	0	50	18	1	X (0 <= X <= 66)
0	66	0	0	0	0
1	50	66	50	50	50
2	18	18	66	18	18
3	1	1	1	66	1
4	0	50	18	1	X

TABLE 8-3

Specification of IntraPredModeC[xCb][yCb] depending on intra_chroma_pred_mode[xCb][yCb] and IntraPredModeY[xCb + cbWidth / 2][yCb + cbHeight / 2] when sps_cclm_enabled_flag is equal to 1

intra_chroma_pred_	IntraPredModeY[xCb + cbWidth / 2][yCb + cbHeight / 2]				
mode[xCb][yCb]	0	50	18	1	X (0 <= X <= 66)
0	66	0	0	0	0
1	50	66	50	50	50
2	18	18	66	18	18
3	1	1	1	66	1
4	81	81	81	81	81
5	82	82	82	82	82
6	83	83	83	83	83
7	0	50	18	1	X

In the mapping process map422( ) output intra prediction mode Y is derived from the input intra prediction mode X as follows:

Output intra prediction mode Y is set equal to input intra prediction mode X if one of the following is true:

SubWidthC is equal to SubHeightC,

X is smaller than 2,

X is larger than 66

Otherwise, intra prediction mode Y is set equal to the value acording to the lookup table defined in Table 8-4.

Variable nW is set equal cbWidth, variable nH is set equal cbHeight. The variable whRatio is set equal to Abs(Log 2(nW/nH)).

For non-square blocks (nW is not equal to nH), clipping of the output intra prediction mode Y is performed as follows:

If all of the following conditions are true, Y is set equal to ((whRatio>1)?(8+2*whRatio):8):

nW is greater than nH

Y is greater than or equal to 2

Y is less than (whRatio>1)?(8+2*whRatio):8

Otherwise, if all of the following conditions are true, Y is set equal to ((whRatio>1)?(60−2*whRatio):60):

nH is greater than nW

Y is less than or equal to 66

Y is greater than (whRatio>1)?(60−2*whRatio):60

TABLE 8-4

Specification of the lookup table for the map422( ) mapping process																		
X	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Y	0	1	2	2	2	2	2	2	2	3	4	6	8	10	12	13	14	16
X	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
Y	18	20	22	23	24	26	28	30	32	33	34	35	36	37	38	39	40	41
X	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53
Y	42	43	44	44	44	45	46	46	46	47	48	48	48	49	50	51	52	52
X	54	55	56	57	58	59	60	61	62	63	64	65	66					
Y	52	53	54	54	54	55	56	56	56	57	58	59	60					

A method of intraPredAngle parameter adjustment could also be implemented in the following form:

8.4.4.2.7 Specification of INTRA_ANGULAR2 . . . INTRA_ANGULAR66 Intra Prediction Modes

Inputs to this process are:

the intra prediction mode predModeIntra,

a variable refIdx specifying the intra prediction reference line index,

a variable nTbW specifying the transform block width,

a variable nTbH specifying the transform block height,

a variable refW specifying the reference samples width,

a variable refH specifying the reference samples height,

a variable nCbW specifying the coding block width,

a variable nCbH specifying the coding block height,

a variable cIdx specifying the colour component of the current block,

the neighbouring samples p[x][y], with x=−1−refIdx, y=−1−refIdx . . . refH−1 and x=−refIdx . . . refW−1, y=−1−refIdx.

Outputs of this process are the modified intra prediction mode predModeIntra and the predicted samples predSamples[x][y], with x=0 . . . nTbW−1, y=0 . . . nTbH−1.

The variable nTbS is set equal to (Log 2(nTbW)+Log 2(nTbH))>>1.

The variables nW and nH are derived as follows:

IntraSubPartitionsSplitType is equal to ISP_NO_SPLIT or cIdx is not equal to 0, the following applies:

$$nW=\mathrm{nTbW}$$

$$nH=\mathrm{nTbH}$$

Otherwise (IntraSubPartitionsSplitType is not equal to ISP_NO_SPLIT and cIdx is equal to 0), the following applies:

$$nW=\mathrm{nCbW}$$

$$nH=\mathrm{nCbH}$$

The variable whRatio is set equal to Abs(Log 2(nW/nH)).

If cIdx is not equal to 0 and subWidthC is greater than subHeightC, whRatio is incremented by 1.

The variable wideAngle is set equal to 0.

For non-square blocks (nW is not equal to nH), the intra prediction mode predModeIntra is modified as follows:

If all of the following conditions are true, wideAngle is set equal to 1 and predModeIntra is set equal to (predModeIntra+65).

nW is greater than nH

predModeIntra is greater than or equal to 2

predModeIntra is less than (whRatio>1)?(8+2*whRatio):8

Otherwise, if all of the following conditions are true, wideAngle is set equal to 1 and predModeIntra is set equal to (predModeIntra−67).

nH is greater than nW

predModeIntra is less than or equal to 66

predModeIntra is greater than (whRatio>1)?(60−2*whRatio):60

The variable filterFlag is derived as follows:

If one or more of the following conditions is true, filterFlag is set equal to 0.

predModeIntra is equal to INTRA_ANGULAR2, INTRA_ANGULAR34 or INTRA_ANGULAR66

refIdx is not equal to 0

IntraSubPartitionsSplitType is not equal to ISP_NO_SPLIT and cIdx is equal to 0 and predModeIntra is greater than or equal to INTRA_ANGULAR34 and nW is greater than 8

IntraSubPartitionsSplitType is not equal to ISP_NO_SPLIT and cIdx is equal to 0 and predModeIntra is less than INTRA_ANGULAR34 and nH is greater than 8.

Otherwise, the following applies:

The variable minDistVerHor is set equal to Min(Abs (predModeIntra−50), Abs(predModeIntra−18)).

The variable intraHorVerDistThres[nTbS] is specified in Table 6.

The variable filterFlag is derived as follows:

If minDistVerHor is greater than intraHorVerDistThres[nTbS] or wideAngle is equal to 1, filterFlag is set equal to 1.

Otherwise, filterFlag is set equal to 0.

TABLE 6

Specification of intraHorVerDistThres[nTbS] for various transform block sizes nTbS

	nTbS = 2	nTbS = 3	nTbS = 4	nTbS = 5	nTbS = 6	nTbS = 7
intraHorVerDistThres[nTbS]	16	14	2	0	0	0

FIG. **6** illustrates the 93 prediction directions, where the dashed directions are associated with the wide-angle modes that are only applied to non-square blocks.

Table 8-5 specifies the mapping table between predModeIntra and the angle parameter intraPredAngle.

TABLE 8-5

Specification of intraPredAngle

predModeIntra	−14	−13	−12	−11	−10	−9	−8	−7	−6	−5	−4	−3	−2	−1	2	3	4
intraPredAngle	512	341	256	171	128	102	86	73	64	57	51	45	39	35	32	29	26
predModeIntra	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
intraPredAngle	23	20	18	16	14	12	10	8	6	4	3	2	1	0	−1	−2	−3
predModeIntra	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
intraPredAngle	−4	−6	−8	−10	−12	−14	−16	−18	−20	−23	−26	−29	−32	−29	−26	−23	−20
predModeIntra	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55
intraPredAngle	−18	−16	−14	−12	−10	−8	−6	−4	−3	−2	−1	0	1	2	3	4	6
predModeIntra	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72
intraPredAngle	8	10	12	14	16	18	20	23	26	29	32	35	39	45	51	57	64

TABLE 8-5-continued

Specification of intraPredAngle								
predModeIntra	73	74	75	76	77	78	79	80
intraPredAngle	73	86	102	128	171	256	341	512

If cIdx is not equal to 0, and subWidthC is greater than subHeightC the following apply:

If predModeIntra is greater than or equal to 34, intraPredAngle is set equal to intraPredAngle>>1

Otherwise, intraPredAngle is set equal to intra Pred Angle<<1

The inverse angle parameter invAngle is derived based on intraPredAngle as follows:

$$invAngle = \text{Round}\left(\frac{256*32}{intraPredAngle}\right)$$

The interpolation filter coefficients fC[phase][j] and fG[phase][j] with phase=0 . . . 31 and j=0 . . . 3 are specified in Table 8-6.

TABLE 8-6

Specification of interpolation filter coefficients fC and fG

Fractional sample	fC interpolation filter coefficients				fG interpolation filter coefficients			
position p	f_c[p][0]	f_c[p][1]	f_c[p][2]	f_c[p][3]	fG[p][0]	fG[p][1]	fG[p][2]	fG[p][3]
0	0	64	0	0	16	32	16	0
1	−1	63	2	0	15	29	17	3
2	−2	62	4	0	15	29	17	3
3	−2	60	7	−1	14	29	18	3
4	−2	58	10	−2	13	29	18	4
5	−3	57	12	−2	13	28	19	4
6	−4	56	14	−2	13	28	19	4
7	−4	55	15	−2	12	28	20	4
8	−4	54	16	−2	11	28	20	5
9	−5	53	18	−2	11	27	21	5
10	−6	52	20	−2	10	27	22	5
11	−6	49	24	−3	9	27	22	6
12	−6	46	28	−4	9	26	23	6
13	−5	44	29	−4	9	26	23	6
14	−4	42	30	−4	8	25	24	7
15	−4	39	33	−4	8	25	24	7
16	−4	36	36	−4	8	24	24	8
17	−4	33	39	−4	7	24	25	8
18	−4	30	42	−4	7	24	25	8
19	−4	29	44	−5	6	23	26	9
20	−4	28	46	−6	6	23	26	9
21	−3	24	49	−6	6	22	27	9
22	−2	20	52	−6	5	22	27	10
23	−2	18	53	−5	5	21	27	11
24	−2	16	54	−4	5	20	28	11
25	−2	15	55	−4	4	20	28	12
26	−2	14	56	−4	4	19	28	13
27	−2	12	57	−3	4	19	28	13
28	−2	10	58	−2	4	18	29	13
29	−1	7	60	−2	3	18	29	14
30	0	4	62	−2	3	17	29	15
31	0	2	63	−1	3	17	29	15

The values of the prediction samples predSamples[x][y], with x=0 . . . nTbW−1, y=0 . . . nTbH−1 are derived as follows:

If predModeIntra is greater than or equal to 34, the following ordered operations apply:

3. The reference sample array ref[x] is specified as follows:

The following applies:

$ref[x]=p[-1-refIdx+x][-1-refIdx]$, with $x=0$ . . . nTbW+refIdx

If intraPredAngle is less than 0, the main reference sample array is extended as follows:

When (nTbH*intraPredAngle)>>5 is less than −1, ref[x]=p[−1−refIdx][−1−refIdx+((x*invAngle+128)>>8)], with x=−1 . . . (nTbH*intraPredAngle)>>5

ref[((nTbH*intraPredAngle)>>5)−1]=ref[(nTbH*intraPredAngle)>>5]

ref[nTbW+1+refIdx]=ref[nTbW+refIdx]

Otherwise,

ref[x]=p[−1−refIdx+x][−1−refIdx], with x=nTbW+1+refIdx . . . refW+refIdx

ref[−1]=ref[0]

The additional samples ref[refW+refIdx+x] with x=1 . . . (Max(1, nTbW/nTbH)*refIdx+1) are derived as follows:

ref[refW+refIdx+x]=p[−1+refW][−1−refIdx]

4. The values of the prediction samples predSamples[x][y], with x=0 . . . nTbW−1, y=0 . . . nTbH−1 are derived as follows:
The index variable iIdx and the multiplication factor iFact are derived as follows:

iIdx=((y+1+refIdx)*intraPredAngle)>>5+refIdx

iFact=((y+1+refIdx)*intraPredAngle)&31

If cIdx is equal to 0, the following applies:
The interpolation filter coefficients fT[j] with j=0 . . . 3 are derived as follows:

fT[j]=filterFlag?fG[iFact][j]:fC[iFact][j]

The value of the prediction samples predSamples[x][y] is derived as follows:

predSamples[x][y]=Clip1Y(((Σ$_{i=0}^{3}$fT[i]*ref[x+iIdx+i])+32)>>6)

Otherwise (cIdx is not equal to 0), depending on the value of iFact, the following applies:
If iFact is not equal to 0, the value of the prediction samples predSamples[x][y] is derived as follows:

predSamples[x][y]=((32−iFact)*ref[x+iIdx+1]+iFact*ref[x+iIdx+2]+16)>>5

Otherwise, the value of the prediction samples predSamples[x][y] is derived as follows:

predSamples[x][y]=ref[x+iIdx+1]

Otherwise (predModeIntra is less than 34), the following ordered operations apply:
3. The reference sample array ref[x] is specified as follows:
The following applies:

ref[x]=p[−1−refIdx][−1−refIdx+x], with x=0 . . . nTbH+refIdx

If intraPredAngle is less than 0, the main reference sample array is extended as follows:
When (nTbW*intraPredAngle)>>5 is less than −1,

ref[x]=p[−1−refIdx+((x*invAngle+128)>>8)][−1−refIdx], with x=−1 . . . (nTbW*intraPredAngle)>>5

ref[((nTbW*intraPredAngle)>>5)−1]=ref[(nTbW*intraPredAngle)>>5]

ref[nTbG+1+refIdx]=ref[nTbH+refIdx] (8-145)

Otherwise,

ref[x]=p[−1−refIdx][−1−refIdx+x], with x=nTbH+1+refIdx . . . refH+refIdx

ref[−1]=ref[0]

The additional samples ref[refH+refIdx+x] with x=1 . . . (Max(1, nTbW/nTbH)*refIdx+1) are derived as follows:

ref[refH+refIdx+x]=p[−1+refH][−1−refIdx]

4. The values of the prediction samples predSamples[x][y], with x=0 . . . nTbW−1, y=0 . . . nTbH−1 are derived as follows:
The index variable iIdx and the multiplication factor iFact are derived as follows:

iIdx=((x+1+refIdx)*intraPredAngle)>>5

iFact=((x+1+refIdx)*intraPredAngle)&31

If cIdx is equal to 0, the following applies:
The interpolation filter coefficients fT[j] with j=0 . . . 3 are derived as follows:

fT[j]=filterFlag?fG[iFact][j]:fC[iFact][j]

The value of the prediction samples predSamples[x][y] is derived as follows:

predSamples[x][y]=Clip1Y(((Σ$_{i=0}^{3}$fT[i]*ref[y+iIdx+i])+32)>>6)

Otherwise (cIdx is not equal to 0), depending on the value of iFact, the following applies:
If iFact is not equal to 0, the value of the prediction samples predSamples[x][y] is derived as follows:

predSamples[x][y]=((32=iFact)*ref[y+iIdx+1]+iFact*ref[y+iIdx+2]+16)>>5

Otherwise, the value of the prediction samples predSamples[x][y] is derived as follows:

predSamples[x][y]=ref[y+iIdx+1]

In particular, the following methods and embodiments of prediction coding of a current block implemented by a decoding or encoding device. The decoding device may be video decoder **30** of FIG. **1**A, or decoder **30** of FIG. **3**. The encoding device may be video encoder **20** of FIG. **1**A, or encoder **20** of FIG. **2**.

According to system **1200** (see FIG. **12**A), when the value of idc chrom format indicates 4:2:2 chroma format, a chroma intra prediction mode (intraPredModeC) **1203** is derived from a look up table (LUT) **1202** by using an initial intra prediction mode of the chroma component. The value of initial intra prediction mode of the chroma component may equal to the value of Luma intra prediction mode intraPredModeY **1201**. Table 2, table 3, table 8-2, or table 8-3 gives an example between the value of initial intra prediction mode of the chroma component intra_chroma_pred_mode[xCb][yCb] and the value of Luma intra prediction mode intraPredModeY IntraPredModeY[xCb+cbWidth/2][yCb+cbHeight/2].

The example for the look up table **1202** is table 5, or table 8-4. The look up table includes 67 entries, with index 0-66.

After performing wide-angle mapping **1204** on the Chroma intra prediction mode **1203**, a modified Chroma intra prediction mode is obtained. A parameter intraPredAngle **1205** is obtained based on the modified Chroma intra prediction mode. For example, by using the modified Chroma intra prediction mode as the predModeIntra, intraPredAngle **1205** is obtained from the table 1. Predicted samples of the chroma component are obtained by performing Chroma directional intra prediction **1206** based on the intraPredAngle parameter.

According to an embodiment **1210** (see FIG. **12**B), wide-angular mapping **1212** is performed on luma intra prediction mode intraPredModeY **1211** to obtain a modified intraPredModeY. When the value of idc chrom format indicates 4:2:2 chroma format, a chroma intra prediction mode (intraPredModeC) **1214** is derived from a look up table (LUT) **1213** by using the modified intraPredModeY. The look up table **1213** may have 95 entries, with index 0-94.

A parameter intraPredAngle **1215** is obtained based on the Chroma intra prediction mode **1214**. For example, by using the Chroma intra prediction mode as the predModeIntra, intraPredAngle **1215** is obtained from the table 1. Predicted samples of the chroma component are obtained by performing Chroma directional intra prediction **1216** based on the intraPredAngle parameter.

Referring to FIG. **13**, process **1300** includes the following operations: block **1301**, the device obtains the value of a luma intra prediction mode (intraPredModeY). For example, the device obtains the value of intraPredModeY by parsing a bitstream. Block **1302**, the device obtains the initial intra prediction mode of the chroma component (IntraPredModeC) based on the value of the luma intra prediction mode (intraPredModeY), for example, based on Table 2, table 3, table 8-2, or table 8-3. Block **1303**, the device derives a chroma intra prediction mode (intraPredModeC) from a look up table (LUT) by using the initial intra prediction mode of the chroma component (intraPredModeC) when the chroma format is 4:2:2. At the example of table 8-4, the initial intra prediction mode of the chroma component is mode X, a chroma intra prediction mode (intraPredModeC) is mode Y. That means the original intraPredModeC is adjusted to obtain the intraPredModeC.

Block **1304** includes performing wide-angle mapping on the chroma intra prediction mode (intraPredModeC) to obtain a modified intraPredModeC. As disclosed above, the wide-angle mapping includes for non-square blocks (nW is not equal to nH):

If all of the following conditions are true, wideAngle is set equal to 1 and predModeIntra is set equal to (predModeIntra+65):

- nW is greater than nH
- predModeIntra is greater than or equal to 2
- predModeIntra is less than (whRatio>1)?(8+2*whRatio):8

Otherwise, if all of the following conditions are true, wideAngle is set equal to 1 and predModeIntra is set equal to (predModeIntra−67):

- nH is greater than nW
- predModeIntra is less than or equal to 66
- predModeIntra is greater than (whRatio>1)?(60−2*whRatio):60

Block **1305** includes obtaining an intraPredAngle parameter for the chroma component based on the modified intraPredModeC. For example, by using the modified intraPredModeC as the predModeIntra, intraPredAngle **1215** is obtained from the table 1. Block **1306** includes obtaining predicted samples of the chroma component based on the intraPredAngle parameter.

Detailed information of this embodiment **1300** is shown in the above-mentioned embodiments.

FIG. **14** is a block diagram illustrating a device of intra prediction of a chroma component according to an embodiment. Device **1400** may be video decoder **30** of FIG. **1**A, or decoder **30** of FIG. **3**, or may be video encoder **20** of FIG. **1**A, or encoder **20** of FIG. **2**. The device **1400** can be used to implement the embodiment **1200**, **1210**, **1300** and the other embodiments described above.

The device of directional intra prediction for chroma component of a picture, includes an obtaining unit **1401**, a deriving unit **1402**, and a mapping unit **1403**.

The obtaining unit **1401**, configured to obtain an initial intra prediction mode of the chroma component. The deriving unit **1402**, configured to derive a chroma intra prediction mode (intraPredModeC) from a look up table (LUT) by using the initial intra prediction mode of the chroma component, the chroma component having different subsampling ratios in horizontal and vertical directions. The deriving unit **1402** can be used to derive the chroma intra prediction mode IntraPredModeC[xCb][yCb] by using intra_chroma_pred_mode[xCb][yCb] and IntraPredModeY[xCb+cbWidth/2][yCb+cbHeight/2] as specified in Table 8-2 and Table 8-3.

The mapping unit **1403**, configured to perform wide-angle mapping on the chroma intra prediction mode (intraPredModeC) to obtain a modified intraPredModeC. As an example, the mapping unit **1403** performs the wide-angle mapping on an original intra prediction mode (predModeIntra) to obtain a modified predModeIntra, where the value of the original predModeIntra is equal to the value of the chroma intra prediction mode (intraPredModeC).

The obtaining unit **1401**, further configured to obtain an intraPredAngle parameter for the chroma component, for example, from a mapping table, based on the modified intraPredModeC; and obtain predicted samples of the chroma component based on the intraPredAngle parameter.

The obtaining unit **1401** may also be configured to obtain the value of a luma intra prediction mode (intraPredModeY) from a bitstream, and then obtain the initial intra prediction mode of the chroma component based on the value of the luma intra prediction mode (intraPredModeY).

The present disclosure provides the following set of aspects:

Embodiment 1. A method of directional intra prediction for chroma component of a picture having different subsampling ratios in horizontal and vertical directions, comprising:

- obtaining the array of reference samples ("ref") and intraPredAngle parameter for chroma component, wherein intraPredAngle parameter derivation is adjusted according to the difference of chroma component subsampling ratios in horizontal and vertical directions
- obtain predicted samples of chroma component using the array of reference samples ("ref") and intraPredAngle parameter for chroma component.

Embodiment 2. The method of embodiment 1, wherein the method further comprising:

- obtaining the value of luma intra prediction mode (intraPredModeY) from the bitstream.

Embodiment 3. The method of embodiment 2, wherein intraPredAngle parameter for chroma component is obtained from chroma intra prediction mode (intraPredModeC) which is derived from the value of luma intra prediction mode (intraPredModeY).

Embodiment 4. Method of embodiment 3, wherein derivation of chroma intra prediction mode (intraPredModeC) is performed by the means of a fetch from a LUT.

Embodiment 5. The method of embodiment 3 or 4, wherein a clipping operation is performed if the obtained chroma intra prediction mode (intraPredModeC) is wide-angular.

Embodiment 6. The method of embodiment 5, wherein the chroma intra prediction mode is set to the closest non-wide angle mode in case of intraPredModeC satisfies mapping conditions of the wide-angle mapping process.

Embodiment 7. The method of any one of embodiments 1-6, wherein wide-angle mapping is performed for luma intra prediction mode (intraPredModeY) and resulting intra prediction mode is used to get the value of intraPredAngle parameter.

Embodiment 8. The method of embodiment 7, wherein the value of intraPredAngle parameter is adjusted in accordance with chroma format and is used to obtain predicted samples of chroma component.

Embodiment 9. The method of embodiment 7 or 8, wherein the chroma format is defined as YUV 4:2:2.

Embodiment 10. The method of any one of embodiment 7-9, wherein wide-angle mapping of (IntraPredModeY) using aspect ratio of a luma block resulting in IntraPredModeFinalY.

Embodiment 11. The method of embodiment 10, wherein when IntraPredModeFinalY is not less than 34, intraPredAngle parameter is defined as follows:

intraPredAngle=intraPredAngle>>1

otherwise, intraPredAngle parameter is redefined as follows

intraPredAngle=intraPredAngle<<1.

Embodiment 12. The method of any one of embodiments 1-11, wherein the intraPredAngle parameter is left or right shifted to compensate for the effect of chroma subsampling.

Embodiment 13. The method of any of embodiments 1-12, wherein the chroma intra prediction mode IntraPredModeC[xCb][yCb] is derived using intra_chroma_pred_mode[xCb][yCb] and IntraPredModeY[xCb+cbWidth/2][yCb+cbHeight/2] as specified in Table 8-2 and Table 8-3.

Embodiment 14. The method of any of embodiments 1-12, wherein the chroma intra prediction mode IntraPredModeC[xCb][yCb] is derived using process map422.

Embodiment 15. The method of any one of embodiments 1-14, wherein for non-square blocks (nW is not equal to nH), the intra prediction mode predModeIntra is obtained as follows:

If all of the following conditions are true, wideAngle is set equal to 1 and predModeIntra is set equal to (predModeIntra+65).
  nW is greater than nH
  predModeIntra is greater than or equal to 2
  predModeIntra is less than (whRatio>1)?(8+2*whRatio):8

Otherwise, if all of the following conditions are true, wideAngle is set equal to 1 and predModeIntra is set equal to (predModeIntra−67).
  nH is greater than nW
  predModeIntra is less than or equal to 66
  predModeIntra is greater than (whRatio>1)?(60−2*whRatio):60

Chroma mode derivation process in accordance with the method proposed is endowed with beneficial effects as compared with the conventional approaches. One of these effects is that the embodiments of the disclosure provide the minimum number of entries in the LUT that is used to determine chroma intra prediction mode from the initial luma intra prediction mode. This is achieved by the order of operations performed, i.e., by chrominance intra prediction mode mapping to luminance mode being performed prior to wide-angular mapping. When applying chroma-to-luma LUT without wide-angular mapping, it is required to specify mapping just for square block shape thus limiting required LUT entries to 67.

Besides, in the suggested embodiments, chrominance mode derivation does not require to obtain the shape of the collocated luminance block. In the conventional method, mapping of luminance intra prediction directions which is the result of wide-angular mapping process would require to consider the aspect ratio of luminance block as well. The reason of this dependency is that wide-angular mapping process requires information about the aspect ratio of the block to determine the value of mapped intra prediction mode. In embodiments of this disclosure, wide angular mapping is not performed for the input luminance intra prediction mode, and hence, the input luminance intra prediction mode could be obtained by bitstream parsing. Since it is not required to handle partitioning structure of luminance component, decoding latency is improved if the suggested order of operations is used.

Following is an explanation of the applications of the encoding method as well as the decoding method as shown in the above-mentioned embodiments, and a system using them.

FIG. **15** is a block diagram showing a content supply system for realizing content distribution service. Content supply system **3100** includes capture device **3102**, terminal device **3106**, and optionally includes display **3126**. The capture device **3102** communicates with the terminal device **3106** over communication link **3104**. The communication link may include the communication channel **13** described above. The communication link **3104** includes but not limited to WIFI, Ethernet, Cable, wireless (3G/4G/5G), USB, or any kind of combination thereof, or the like.

The capture device **3102** generates data, and may encode the data by the encoding method as shown in the above embodiments. Alternatively, the capture device **3102** may distribute the data to a streaming server (not shown in the Figures), and the server encodes the data and transmits the encoded data to the terminal device **3106**. The capture device **3102** includes but not limited to camera, smart phone or Pad, computer or laptop, video conference system, PDA, vehicle mounted device, or a combination of any of them, or the like. For example, the capture device **3102** may include the source device **12** as described above. When the data includes video, the video encoder **20** included in the capture device **3102** may actually perform video encoding processing. When the data includes audio (i.e., voice), an audio encoder included in the capture device **3102** may actually perform audio encoding processing. For some practical scenarios, the capture device **3102** distributes the encoded video and audio data by multiplexing them together. For other practical scenarios, for example in the video conference system, the encoded audio data and the encoded video data are not multiplexed. Capture device **3102** distributes the encoded audio data and the encoded video data to the terminal device **3106** separately.

In the content supply system **3100**, the terminal device **310** receives and reproduces the encoded data. The terminal device **3106** could be a device with data receiving and recovering capability, such as smart phone or Pad **3108**, computer or laptop **3110**, network video recorder (NVR)/digital video recorder (DVR) **3112**, TV **3114**, set top box (STB) **3116**, video conference system **3118**, video surveillance system **3120**, personal digital assistant (PDA) **3122**, vehicle mounted device **3124**, or a combination of any of them, or the like capable of decoding the above-mentioned encoded data. For example, the terminal device **3106** may include the destination device **14** as described above. When the encoded data includes video, the video decoder **30** included in the terminal device is prioritized to perform video decoding. When the encoded data includes audio, an audio decoder included in the terminal device is prioritized to perform audio decoding processing.

For a terminal device with its display, for example, smart phone or Pad **3108**, computer or laptop **3110**, network video recorder (NVR)/digital video recorder (DVR) **3112**, TV **3114**, personal digital assistant (PDA) **3122**, or vehicle mounted device **3124**, the terminal device can feed the decoded data to its display. For a terminal device equipped with no display, for example, STB **3116**, video conference system **3118**, or video surveillance system **3120**, an external display **3126** is contacted therein to receive and show the decoded data.

When each device in this system performs encoding or decoding, the picture encoding device or the picture decoding device, as shown in the above-mentioned embodiments, can be used.

FIG. **16** is a diagram showing a structure of an example terminal device. After terminal device **3106** receives stream from the capture device **3102**, the protocol proceeding unit **3202** analyzes the transmission protocol of the stream. The protocol includes but not limited to Real Time Streaming Protocol (RTSP), Hyper Text Transfer Protocol (HTTP), HTTP Live streaming protocol (HLS), MPEG-DASH, Real-time Transport protocol (RTP), Real Time Messaging Protocol (RTMP), or any kind of combination thereof, or the like.

After the protocol proceeding unit **3202** processes the stream, stream file is generated. The file is outputted to a demultiplexing unit **3204**. The demultiplexing unit **3204** can separate the multiplexed data into the encoded audio data and the encoded video data. As described above, for some practical scenarios, for example in the video conference system, the encoded audio data and the encoded video data are not multiplexed. In this situation, the encoded data is transmitted to video decoder **3206** and audio decoder **3208** without through the demultiplexing unit **3204**.

Via the demultiplexing processing, video elementary stream (ES), audio ES, and optionally subtitle are generated. The video decoder **3206**, which includes the video decoder **30** as explained in the above mentioned embodiments, decodes the video ES by the decoding method as shown in the above-mentioned embodiments to generate video frame, and feeds this data to the synchronous unit **3212**. The audio decoder **3208**, decodes the audio ES to generate audio frame, and feeds this data to the synchronous unit **3212**. Alternatively, the video frame may store in a buffer (not shown in FIG. Y) before feeding it to the synchronous unit **3212**. Similarly, the audio frame may store in a buffer (not shown in FIG. Y) before feeding it to the synchronous unit **3212**.

The synchronous unit **3212** synchronizes the video frame and the audio frame, and supplies the video/audio to a video/audio display **3214**. For example, the synchronous unit **3212** synchronizes the presentation of the video and audio information. Information may code in the syntax using time stamps concerning the presentation of coded audio and visual data and time stamps concerning the delivery of the data stream itself.

If subtitle is included in the stream, the subtitle decoder **3210** decodes the subtitle, and synchronizes it with the video frame and the audio frame, and supplies the video/audio/subtitle to a video/audio/subtitle display **3216**.

The present disclosure is not limited to the above-mentioned system, and either the picture encoding device or the picture decoding device in the above-mentioned embodiments can be incorporated into other system, for example, a car system.

Mathematical Operators

The mathematical operators used in this application are similar to those used in the C programming language. However, the results of integer division and arithmetic shift operations are defined more precisely, and additional operations are defined, such as exponentiation and real-valued division. Numbering and counting conventions generally begin from 0, e.g., "the first" is equivalent to the 0-th, "the second" is equivalent to the 1-th, etc.

Arithmetic Operators

The following arithmetic operators are defined as follows:

+Addition

−Subtraction (as a two-argument operator) or negation (as a unary prefix operator)

* Multiplication, including matrix multiplication

x^y Exponentiation. Specifies x to the power of y. In other contexts, such notation is used for superscripting not intended for interpretation as exponentiation.

/ Integer division with truncation of the result toward zero. For example, 7/4 and −7/−4 are truncated to 1 and −7/4 and 7/−4 are truncated to −1.

÷ Used to denote division in mathematical equations where no truncation or rounding is intended.

$$\frac{x}{y}$$

Used to denote division inmathematical equations where no truncation or rounding is intended.

$$\sum_{i=x}^{y} f(i)$$

The summation of f(i) with i taking all integer values from x up to and including y.

x % y Modulus. Remainder of x divided by y, defined only for integers x and y with x>=0 and y>0.

Logical Operators

The following logical operators are defined as follows:

x && y Boolean logical "and" of x and y

x||y Boolean logical "or" of x and y

! Boolean logical "not"

x?y:z If x is TRUE or not equal to 0, evaluates to the value of y; otherwise, evaluates to the value of z.

Relational Operators

The following relational operators are defined as follows:

> Greater than

>= Greater than or equal to

< Less than

<= Less than or equal to

== Equal to

!= Not equal to

When a relational operator is applied to a syntax element or variable that has been assigned the value "na" (not applicable), the value "na" is treated as a distinct value for the syntax element or variable. The value "na" is considered not to be equal to any other value.

Bit-Wise Operators

The following bit-wise operators are defined as follows:

& Bit-wise "and". When operating on integer arguments, operates on a two's complement representation of the integer value. When operating on a binary argument that contains fewer bits than another argument, the shorter argument is extended by adding more significant bits equal to 0.

| Bit-wise "or". When operating on integer arguments, operates on a two's complement representation of the integer value. When operating on a binary argument that contains fewer bits than another argument, the shorter argument is extended by adding more significant bits equal to 0.

^ Bit-wise "exclusive or". When operating on integer arguments, operates on a two's complement representation of the integer value. When operating on a binary argument that contains fewer bits than another argument, the shorter argument is extended by adding more significant bits equal to 0.

x>>y Arithmetic right shift of a two's complement integer representation of x by y binary digits. This function is defined only for non-negative integer values of y. Bits shifted into the most significant bits (MSBs) as a result of the right shift have a value equal to the MSB of x prior to the shift operation.

x<<y Arithmetic left shift of a two's complement integer representation of x by y binary digits. This function is defined only for non-negative integer values of y. Bits shifted into the least significant bits (LSBs) as a result of the left shift have a value equal to 0.

Assignment Operators

The following arithmetic operators are defined as follows:

= Assignment operator

++ Increment, i.e., x++ is equivalent to x=x+1; when used in an array index, evaluates to the value of the variable prior to the increment operation.

— Decrement, i.e., x— is equivalent to x=x−1; when used in an array index, evaluates to the value of the variable prior to the decrement operation.

+= Increment by amount specified, i.e., x+=3 is equivalent to x=x+3, and x+=(−3) is equivalent to x=x+(−3).

−= Decrement by amount specified, i.e., x−=3 is equivalent to x=x−3, and x−=(−3) is equivalent to x=x−(−3).

Range Notation

The following notation is used to specify a range of values:

x=y . . . z x takes on integer values starting from y to z, inclusive, with x, y, and z being integer numbers and z being greater than y.

Mathematical Functions

The following mathematical functions are defined:

$$\text{Abs} = \begin{cases} x & ; \quad x >= 0 \\ -x & ; \quad x < 0 \end{cases}$$

Asin(x) the trigonometric inverse sine function, operating on an argument x that is in the range of −1.0 to 1.0, inclusive, with an output value in the range of −π÷2 to π÷2, inclusive, in units of radians

Atan(x) the trigonometric inverse tangent function, operating on an argument x, with an output value in the range of −π÷2 to π÷2, inclusive, in units of radians

$$Atan2(y, x) = \begin{cases} Atan\left(\frac{y}{x}\right) & ; \quad x > 0 \\ Atan\left(\frac{y}{x}\right) + \pi & ; \quad x < 0 \ \&\ \&\ y >= 0 \\ Atan\left(\frac{y}{x}\right) - \pi & ; \quad x < 0 \ \&\&\ y < 0 \\ +\frac{\pi}{2} & ; \quad x == 0 \ \&\ \&\ y >= 0 \\ -\frac{\pi}{2} & ; \quad \text{otherwise} \end{cases}$$

Ceil(x) the smallest integer greater than or equal to x.

$Clip1_Y(x)=Clip3(0, (1<<BitDepth_Y)-1, x)$

$Clip1_C(x)=Clip3(0, (1<<BitDepth_C)-1, x)$

$$Clip3(x, y, z) = \begin{cases} x & ; \quad z < x \\ y & ; \quad z > y \\ z & ; \quad \text{otherwise} \end{cases}$$

Cos(x) the trigonometric cosine function operating on an argument x in units of radians

Floor(x) the largest integer less than or equal to x.

$$GetCurrMsb(a, b, c, d) = \begin{cases} c + d & ; \quad b - a >= d/2 \\ c - d & ; \quad a - b > d/2 \\ c & ; \quad \text{otherwise} \end{cases}$$

Ln(x) the natural logarithm of x (the base-e logarithm, where e is the natural logarithm base constant 2.718 281 828 . . .).

Log 2(x) the base-2 logarithm of x.

Log 10(x) the base-10 logarithm of x.

$$\text{Min}(x, y) = \begin{cases} x & ; \quad x <= y \\ y & ; \quad x > y \end{cases}$$

$$\text{Max}(x, y) = \begin{cases} x & ; \quad x >= y \\ y & ; \quad x < y \end{cases}$$

Round(x)=Sign(x)*Floor(Abs(x)+0.5)

$$\text{Sign}\ (x) = \begin{cases} 1 & ; \quad x > 0 \\ 0 & ; \quad x == 0 \\ -1 & ; \quad x < 0 \end{cases}$$

Sin(x) the trigonometric sine function operating on an argument x in units of radians

Sqrt(x)=$\sqrt{x}$

Swap(x, y)=(y, x)

Tan(x) the trigonometric tangent function operating on an argument x in units of radians

Order of Operation Precedence

When an order of precedence in an expression is not indicated explicitly by use of parentheses, the following rules apply:

Operations of a higher precedence are evaluated before any operation of a lower precedence.

Operations of the same precedence are evaluated sequentially from left to right.

The table below specifies the precedence of operations from highest to lowest; a higher position in the table indicates a higher precedence.

For those operators that are also used in the C programming language, the order of precedence used in this Specification is the same as used in the C programming language.

TABLE

Operation precedence from highest (at top of table) to lowest (at bottom of table)
operations (with operands x, y, and z)
"x++", "x− −"
"!x", "−x" (as a unary prefix operator)
x^y
$"x*y", "x/y", "x\div y", \frac{"x"}{y}, "x \% y"$
$"x+y", "x-y"$, (as a two−argument operator), $"\sum_{i=x}^{y} f(i)"$
"x << y", "x >> y"
"x < y", "x <= y", "x > y", "x >= y"
"x = = y", "x != y"
"x & y"
"x | y"
"x && y"
"x | | y"
"x ? y : z"
"x .. y"
"x = y", "x += y", "x −= y"

Text Description of Logical Operations

In the text, a statement of logical operations as would be described mathematically in the following form:

if(condition 0)
  statement 0
else if(condition 1)
  statement 1
. . .
else /*informative remark on remaining condition*/
  statement n

may be described in the following manner:

. . . as follows / . . . the following applies:
  If condition 0, statement 0
  Otherwise, if condition 1, statement 1
  . . .
  Otherwise (informative remark on remaining condition), statement n

Each "If . . . Otherwise, if . . . Otherwise, . . . " statement in the text is introduced with " . . . as follows" or " . . . the following applies" immediately followed by "If . . . ". The last condition of the "If . . . Otherwise, if . . . Otherwise, . . . " is always an "Otherwise, . . . ". Interleaved "If . . . Otherwise, if . . . Otherwise, . . . " statements can be identified by matching " . . . as follows" or " . . . the following applies" with the ending "Otherwise, . . . ".

In the text, a statement of logical operations as would be described mathematically in the following form:

if(condition 0a && condition 0b)
  statement 0
else if(condition 1a condition 1b)
  statement 1
. . .
else
  statement n

may be described in the following manner:

. . . as follows / . . . the following applies:
If all of the following conditions are true, statement 0:
  condition 0a
  condition 0b
Otherwise, if one or more of the following conditions are true, statement 1:
  condition 1a
  condition 1b
  . . .
Otherwise, statement n

In the text, a statement of logical operations as would be described mathematically in the following form:

if(condition 0)
  statement 0
if(condition 1)
  statement 1

may be described in the following manner:

When condition 0, statement 0
When condition 1, statement 1

Although embodiments of the disclosure have been primarily described based on video coding, it should be noted that embodiments of the coding system **10**, encoder **20** and decoder **30** (and correspondingly the system **10**) and the other embodiments described herein may also be configured for still picture processing or coding, i.e. the processing or coding of an individual picture independent of any preceding or consecutive picture as in video coding. In general only inter-prediction units **244** (encoder) and **344** (decoder) may not be available in case the picture processing coding is limited to a single picture **17**. All other functionalities (also referred to as tools or technologies) of the video encoder **20** and video decoder **30** may equally be used for still picture processing, e.g. residual calculation **204/304**, transform **206**, quantization **208**, inverse quantization **210/310**, (inverse) transform **212/312**, partitioning **262/362**, intra-prediction **254/354**, and/or loop filtering **220**, **320**, and entropy coding **270** and entropy decoding **304**.

Embodiments, e.g. of the encoder **20** and the decoder **30**, and functions described herein, e.g. with reference to the encoder **20** and the decoder **30**, may be implemented in hardware, software, firmware, or any combination thereof. If implemented in software, the functions may be stored on a computer-readable medium or transmitted over communication media as one or more instructions or code and executed by a hardware-based processing unit. Computer-readable media may include computer-readable storage media, which corresponds to a tangible medium such as data storage media, or communication media including any medium that facilitates transfer of a computer program from one place to another, e.g., according to a communication protocol. In this manner, computer-readable media generally may correspond to (1) tangible computer-readable storage media which is non-transitory or (2) a communication medium such as a signal or carrier wave. Data storage media may be any available media that can be accessed by one or more computers or one or more processors to retrieve instructions, code and/or data structures for implementation of the techniques described in this disclosure. A computer program product may include a computer-readable medium.

By way of example, and not limiting, such computer-readable storage media can comprise RAM, ROM, EEPROM, CD-ROM or other optical disk storage, magnetic disk storage, or other magnetic storage devices, flash memory, or any other medium that can be used to store desired program code in the form of instructions or data structures and that can be accessed by a computer. Also, any connection is properly termed a computer-readable medium. For example, if instructions are transmitted from a website, server, or other remote source using a coaxial cable, fiber optic cable, twisted pair, digital subscriber line (DSL), or wireless technologies such as infrared, radio, and microwave, then the coaxial cable, fiber optic cable, twisted pair, DSL, or wireless technologies such as infrared, radio, and microwave are included in the definition of medium. It should be understood, however, that computer-readable storage media and data storage media do not include connections, carrier waves, signals, or other transitory media, but are instead directed to non-transitory, tangible storage media. Disk and disc, as used herein, includes compact disc (CD), laser disc, optical disc, digital versatile disc (DVD), floppy disk and Blu-ray disc, where disks usually reproduce data magnetically, while discs reproduce data optically with lasers. Combinations of the above should also be included within the scope of computer-readable media.

Instructions may be executed by one or more processors, such as one or more digital signal processors (DSPs), general purpose microprocessors, application specific integrated circuits (ASICs), field programmable logic arrays (FPGAs), or other equivalent integrated or discrete logic circuitry. Accordingly, the term "processor," as used herein may refer to any of the foregoing structure or any other structure suitable for implementation of the techniques described herein. In addition, in some aspects, the functionality described herein may be provided within dedicated hardware and/or software modules configured for encoding and decoding, or incorporated in a combined codec. Also, the techniques could be fully implemented in one or more circuits or logic elements.

The techniques of this disclosure may be implemented in a wide variety of devices or apparatuses, including a wireless handset, an integrated circuit (IC) or a set of ICs (e.g., a chip set). Various components, modules, or units are described in this disclosure to emphasize functional aspects of devices configured to perform the disclosed techniques, but do not necessarily require realization by different hardware units. Rather, as described above, various units may be combined in a codec hardware unit or provided by a collection of interoperative hardware units, including one or more processors as described above, in conjunction with suitable software and/or firmware.

What is claimed is:

1. A method of directional intra prediction for chroma component of a picture, the method comprising:

obtaining an intra prediction mode of the chroma component based on a value of a luma intra prediction mode (intraPredModeY) by using a first look up table (LUT);

deriving a chroma intra prediction mode (intraPredModeC) from a second LUT by using the intra prediction mode of the chroma component, the chroma component having different subsampling ratios in horizontal and vertical directions, wherein the second LUT has 67 entries, indices for the second LUT are 0-66, and each index is associated with an angle of an intra prediction direction;

obtaining an angle parameter for the chroma component based on the chroma intra prediction mode (intraPredModeC); and

obtaining predicted samples of the chroma component based on the angle parameter.

2. The method of claim **1**, further comprising:

performing wide-angle mapping on the chroma intra prediction mode (intraPredModeC) to obtain a modified intraPredModeC;

wherein the obtaining the angle parameter for the chroma component based on the chroma intra prediction mode (intraPredModeC) comprises:

obtaining the angle parameter (intraPredAngle) for the chroma component based on the modified intraPredModeC.

3. The method of claim **2**, wherein performing the wide-angle mapping on the chroma intra prediction mode (intraPredModeC) to obtain the modified intraPredModeC comprises:

performing wide-angle mapping on an original intra prediction mode (predModeIntra) to obtain a modified predModeIntra, wherein a value of the original predModeIntra is equal to a value of the chroma intra prediction mode (intraPredModeC).

4. The method of claim **3**, wherein obtaining the angle parameter for the chroma component comprises:

obtaining the angle parameter for the chroma component from a mapping table by using the modified predModeIntra.

5. The method of claim **1**, further comprising: performing wide-angle mapping for the luma intra prediction mode (intraPredModeY) to derive a resulting intra prediction mode and using the resulting intra prediction mode to obtain a value of the angle parameter.

6. The method of claim **1**, wherein the chroma intra prediction mode IntraPredModeC[xCb][yCb] is obtained by using intra_chroma_pred_mode[xCb][yCb] and IntraPredModeY[xCb+cbWidth/2][yCb+cbHeight/2] as specified in the first LUT, wherein when sps_cclm_enabled_flag is equal to 0, the first LUT includes:

intra_chroma_pred_	IntraPredModeY[xCb + cbWidth / 2] [yCb + cbHeight / 2]				
mode[xCb][yCb]	0	50	18	1	X (0 <= X <= 66)
0	66	0	0	0	0
1	50	66	50	50	50
2	18	18	66	18	18
3	1	1	1	66	1
4	0	50	18	1	X

wherein when sps_cclm_enabled_flag is equal to 1, the first LUT includes:

intra_chroma_pred_	IntraPredModeY[xCb + cb Width / 2] [yCb + cbHeight / 2]				
mode[xCb][yCb]	0	50	18	1	X (0 <= X <= 66)
0	66	0	0	0	0
1	50	66	50	50	50
2	18	18	66	18	18
3	1	1	1	66	1
4	81	81	81	81	81
5	82	82	82	82	82
6	83	83	83	83	83
7	0	50	18	1	X.

7. The method of claim 1, wherein a mapping between an index and a corresponding angle parameter is:

predModeIntra	−14	−13	−12	−11	−10	−9	−8	−7	−6	−5	−4	−3	−2	−1	2	3	4
intraPredAngle	512	341	256	171	128	102	86	73	64	57	51	45	39	35	32	29	26
predModeIntra	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
intraPredAngle	23	20	18	16	14	12	10	8	6	4	3	2	1	0	−1	−2	−3
predModeIntra	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
intraPred Angle	−4	−6	−8	−10	−12	−14	−16	−18	−20	−23	−26	−29	−32	−29	−26	−23	−20
predModeIntra	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55
intraPredAngle	−18	−16	−14	−12	−10	−8	−6	−4	−3	−2	−1	0	1	2	3	4	6
predModeIntra	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72
intraPredAngle	8	10	12	14	16	18	20	23	26	29	32	35	39	45	51	57	64
predModeIntra	73	74	75	76	77	78	79	80									
intraPredAngle	73	86	102	128	171	256	341	512,									

wherein predModeIntra represents the index, and intraPredAngle represents the angle parameter of the corresponding index.

8. The method of claim 1, wherein the second LUT includes:

X	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Y	6	8	10	12	13	14	16	18	20	22	23	24	26	28	30

wherein mode X is the intra prediction mode of the chroma component, mode Y is the chroma intra prediction mode (intraPredModeC) derived from the second LUT.

9. The method of claim 1, wherein a chroma format of the chroma component is defined as YUV 4:2:2.

10. A device, comprising:

one or more processors; and

a computer-readable storage medium coupled to the one or more processors and storing programming instructions, which when executed by the one or more processors, cause the device to:

obtain an intra prediction mode of a chroma component based on a value of a luma intra prediction mode (intraPredModeY) by using a first look up table (LUT);

derive a chroma intra prediction mode (intraPredModeC) from a second LUT by using the intra prediction mode of the chroma component, the chroma component having different subsampling ratios in horizontal and vertical directions, wherein the second LUT has 67 entries, indices for the second LUT are 0-66, and each index is associated with an angle of an intra prediction direction;

obtain an angle parameter for the chroma component based on the chroma intra prediction mode (intraPredModeC); and

obtain predicted samples of the chroma component based on the angle parameter.

11. The device of claim 10, wherein the programming instructions, which when executed by the one or more processors, further cause the device to:

perform wide-angle mapping on the chroma intra prediction mode (intraPredModeC) to obtain a modified intraPredModeC;

wherein the angle parameter (intraPredAngle) for the chroma component is obtained based on the modified intraPredModeC.

12. The device of claim 11, wherein to perform the wide-angle mapping on the chroma intra prediction mode (intraPredModeC) to obtain the modified intraPredModeC, the programming instructions, which when executed by the one or more processors, cause the device to:

perform wide-angle mapping on an original intra prediction mode (predModeIntra) to obtain a modified predModeIntra, wherein a value of the original predModeIntra is equal to a value of the chroma intra prediction mode (intraPredModeC).

13. The device of claim 12, wherein to obtain the angle parameter for the chroma component, the programming instructions, which when executed by the one or more processors, cause the device to:

obtain the angle parameter for the chroma component from a mapping table by using the modified predModeIntra.

14. The device of claim 10, the chroma intra prediction mode IntraPredModeC[xCb][yCb] is obtained by using intra_chroma_pred_mode[xCb][yCb] and IntraPredModeY [xCb+cbWidth/2][yCb+cbHeight/2] as specified in the first LUT, wherein when sps_cclm_enabled_flag is equal to 0, the first LUT includes:

intra_chroma_pred_	IntraPredModeY[xCb + cbWidth / 2] [yCb + cbHeight / 2]				
mode[xCb][yCb]	0	50	18	1	X (0 <= X <= 66)
0	66	0	0	0	0
1	50	66	50	50	50
2	18	18	66	18	18
3	1	1	1	66	1
4	0	50	18	1	X

wherein when sps_cclm_enabled_flag is equal to 1, the first LUT includes:

intra_chroma_pred_	IntraPredModeY[xCb + cb Width / 2] [yCb + cbHeight / 2]				
mode[xCb][yCb]	0	50	18	1	X (0 <= X <= 66)
0	66	0	0	0	0
1	50	66	50	50	50
2	18	18	66	18	18
3	1	1	1	66	1
4	81	81	81	81	81
5	82	82	82	82	82
6	83	83	83	83	83
7	0	50	18	1	X.

15. The device of claim 10, wherein the second LUT includes:

X	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Y	6	8	10	12	13	14	16	18	20	22	23	24	26	28	30

wherein mode X is the intra prediction mode of the chroma component, mode Y is the chroma intra prediction mode (intraPredModeC) derived from the second LUT.

16. The device of claim **10**, wherein a mapping between an index and a corresponding angle parameter is:

predModeIntra	−14	−13	−12	−11	−10	−9	−8	−7	−6	−5	−4	−3	−2	−1	2	3	4
intraPredAngle	512	341	256	171	128	102	86	73	64	57	51	45	39	35	32	29	26
predModeIntra	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
intraPredAngle	23	20	18	16	14	12	10	8	6	4	3	2	1	0	−1	−2	−3
predModeIntra	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
intraPredAngle	−4	−6	−8	−10	−12	−14	−16	−18	−20	−23	−26	−29	−32	−29	−26	−23	−20
predModeIntra	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55
intraPredAngle	−18	−16	−14	−12	−10	−8	−6	−4	−3	−2	−1	0	1	2	3	4	6
predModeIntra	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72
intraPredAngle	8	10	12	14	16	18	20	23	26	29	32	35	39	45	51	57	64
predModeIntra	73	74	75	76	77	78	79	80									
intraPredAngle	73	86	102	128	171	256	341	512,									

wherein predModeIntra represents the index, and intraPredAngle represents the angle parameter of the corresponding index.

17. The device of claim **10**, wherein a chroma format of the chroma component is defined as YUV 4:2:2.

18. The device of claim **10**, wherein the device is an encoder or a decoder.

19. A non-transitory computer-readable storage medium storing a bitstream and instructions, wherein the instructions when executed by one or more processors of a device, causes the device to generate the bitstream by:

obtaining an intra prediction mode of a chroma component based on a value of a luma intra prediction mode (intraPredModeY) by using a first look up table (LUT);

deriving a chroma intra prediction mode (intraPredModeC) from a second LUT by using the intra prediction mode of the chroma component, the chroma component having different subsampling ratios in horizontal and vertical directions, wherein the second LUT has 67 entries, indices for the second LUT are 0-66, and each index is associated with an angle of an intra prediction direction;

obtaining an angle parameter for the chroma component based on the chroma intra prediction mode (intraPredModeC); and

obtaining predicted samples of the chroma component based on the angle parameter.

* * * * *