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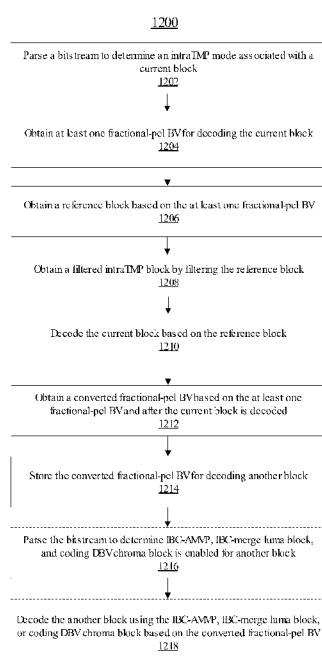


FIG. 12

(57) Abstract: According to one aspect of the present disclosure, a method of decoding by a decoder is provided. The method may include parsing, by a processor, a bitstream to determine an intra template matching prediction (TMP) mode associated with a current block. The method may include obtaining, by the processor, at least one fractional-pel block vector (BV) for decoding the current block. The method may include obtaining, by the processor, a reference block based on the at least one fractional-pel BV. The method may include decoding, by the processor, the current block based on the reference block. The method may include obtaining, by the processor, a converted fractional-pel BV based on the at least one fractional-pel BV and after the current block is decoded. The method may include storing, by the processor, the converted fractional-pel BV for decoding another block.



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# SYSTEM AND METHOD FOR INTRA PREDICTION USING FRACTIONAL-PEL BLOCK VECTOR

## CROSS-REFERENCE TO RELATED APPLICATIONS

5 [0001] This application claims the benefit of priority to U.S. Provisional Application No. 63/521,071, entitled "FRACTIONAL-PEL INTRA TEMPLATE MATCHING" and filed on June 14, 2023, which is incorporated by reference herein in its entirety.

## BACKGROUND

[0002] Embodiments of the present disclosure relate to video coding.

10 [0003] Digital video has become mainstream and is being used in a wide range of applications including digital television, video telephony, and teleconferencing. These digital video applications are feasible because of the advances in computing and communication technologies as well as efficient video coding techniques. Various video coding techniques may be used to compress video data, such that coding on the video data can be performed using one or more video coding standards. Exemplary video coding standards may include, but not limited to, 15 versatile video coding (H.266/VVC), high-efficiency video coding (H.265/HEVC), advanced video coding (H.264/AVC), moving picture expert group (MPEG) coding, enhanced video coding model (ECM), to name a few.

## SUMMARY

20 [0004] According to one aspect of the present disclosure, a method of decoding by a decoder is provided. The method may include parsing, by a processor, a bitstream to determine an intra template matching prediction (intraTMP) mode associated with a current block. The method may include obtaining, by the processor, at least one fractional-pel block vector (BV) for decoding the current block. The method may include obtaining, by the processor, a reference block based on the at least one fractional-pel BV. The method may include decoding, by the 25 processor, the current block based on the reference block. The method may include obtaining, by the processor, a converted fractional-pel BV based on the at least one fractional-pel BV and after the current block is decoded. The method may include storing, by the processor, the converted fractional-pel BV for decoding another block.

30 [0005] According to another aspect of the present disclosure, an apparatus for decoding is provided. The apparatus may include a processor and memory storing instructions. The memory storing instructions, which when executed by the processor, may cause the processor to parse a bitstream to determine an intraTMP mode associated with a current block. The memory storing instructions, which when executed by the processor, may cause the processor to obtain at least one fractional-pel BV for decoding the current block. The memory storing instructions, which when 35 executed by the processor, may cause the processor to obtain a reference block based on the at least one fractional-pel BV. The memory storing instructions, which when executed by the processor, may cause the processor to decode the current block based on the reference block. The memory storing instructions, which when executed by the processor, may cause the processor to obtain a converted fractional-pel BV based on the at least one fractional-pel BV and after the 40 current block is decoded. The memory storing instructions, which when executed by the processor, may cause the processor to store the converted fractional-pel BV for decoding another block.

[0006] According to a further aspect of the present disclosure, a non-transitory computer-readable medium storing instructions is provided. The instructions, which when executed by the

processor, may cause the processor to parse a bitstream to determine an intraTMP mode associated with a current block. The instructions, which when executed by the processor, may cause the processor to obtain at least one fractional-pel BV for decoding the current block. The instructions, which when executed by the processor, may cause the processor to obtain a reference block based on the at least one fractional-pel BV. The instructions, which when executed by the processor, may cause the processor to decode the current block based on the reference block. The instructions, which when executed by the processor, may cause the processor to obtain a converted fractional-pel BV based on the at least one fractional-pel BV and after the current block is decoded. The instructions, which when executed by the processor, may cause the processor to store the converted fractional-pel BV for decoding another block.

[0007] According to yet another aspect of the present disclosure, a method of encoding by an encoder is provided. The method may include obtaining, by the processor, at least one fractional-pel BV for encoding a current block. The method may include obtaining, by the processor, a reference block based on the at least one fractional-pel BV. The method may include encoding, by the processor, the current block based on the reference block. The method may include obtaining, by the processor, a converted fractional-pel BV based on the at least one fractional-pel BV and after the current block is encoded. The method may include storing, by the processor, the converted fractional-pel BV for decoding another block. The method may include encoding, by the processor, an intraTMP mode associated with the current block to a bitstream.

[0008] According to yet a further aspect of the present disclosure, an apparatus for encoding is provided. The apparatus may include a processor and memory storing instructions. The memory storing instructions, which when executed by the processor, may cause the processor to obtain at least one fractional-pel BV for encoding a current block. The memory storing instructions, which when executed by the processor, may cause the processor to obtain a reference block based on the at least one fractional-pel BV. The memory storing instructions, which when executed by the processor, may cause the processor to encode the current block based on the reference block. The memory storing instructions, which when executed by the processor, may cause the processor to obtain a converted fractional-pel BV based on the at least one fractional-pel BV and after the current block is encoded. The memory storing instructions, which when executed by the processor, may cause the processor to store the converted fractional-pel BV for encoding another block. The memory storing instructions, which when executed by the processor, may cause the processor to encode an intraTMP mode associated with the current block to a bitstream.

[0009] According to still a further aspect of the present disclosure, a non-transitory computer-readable medium storing instructions for an encoder is provided. The instructions, which when executed by a processor, may cause the processor to obtain at least one fractional-pel BV for encoding a current block. The instructions, which when executed by a processor, may cause the processor to obtain a reference block based on the at least one fractional-pel BV. The instructions, which when executed by a processor, may cause the processor to encode the current block based on the reference block. The instructions, which when executed by a processor, may cause the processor to obtain a converted fractional-pel BV based on the at least one fractional-pel BV and after the current block is encoded. The instructions, which when executed by a processor, may cause the processor to store the converted fractional-pel BV for encoding another block. The instructions, which when executed by a processor, may cause the processor to encode an intraTMP mode associated with the current block to a bitstream.

[0010] These illustrative embodiments are mentioned not to limit or define the present disclosure, but to provide examples to aid understanding thereof. Additional embodiments are described in the Detailed Description, and further description is provided there.

## BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The accompanying drawings, which are incorporated herein and form a part of the

specification, illustrate embodiments of the present disclosure and, together with the description, further serve to explain the principles of the present disclosure and to enable a person skilled in the pertinent art to make and use the present disclosure.

[0012] FIG. 1 illustrates a block diagram of an exemplary encoding system, according to some embodiments of the present disclosure.

[0013] FIG. 2 illustrates a block diagram of an exemplary decoding system, according to some embodiments of the present disclosure.

[0014] FIG. 3 illustrates a detailed block diagram of an exemplary encoder in the encoding system in FIG. 1, according to some embodiments of the present disclosure.

[0015] FIG. 4 illustrates a detailed block diagram of an exemplary decoder in the decoding system in FIG. 2, according to some embodiments of the present disclosure.

[0016] FIG. 5 illustrates an exemplary picture divided into coding tree units (CTUs), according to some embodiments of the present disclosure.

[0017] FIG. 6 illustrates an exemplary CTU divided into coding units (CUs), according to some embodiments of the present disclosure.

[0018] FIG. 7 illustrates a schematic visualization of a current CU block and spatially adjacent and non-adjacent reconstructed samples to the current block, according to some embodiments of the present disclosure.

[0019] FIG. 8 illustrates a schematic visualization of the angular modes of VVC, according to some embodiments of the present disclosure.

[0020] FIG. 9A illustrates a diagram of slice partitioning for intra prediction, according to some embodiments of the present disclosure.

[0021] FIG. 9B illustrates a diagram of tile partitioning for intra prediction, according to some embodiments of the present disclosure.

[0022] FIG. 9C illustrates a diagram of wavefront-parallel processing for intra prediction, according to some embodiments of the present disclosure.

[0023] FIG. 10A illustrates a diagram of intra block copy (IBC), according to some embodiments of the present disclosure.

[0024] FIG. 10B illustrates a diagram of intra template matching prediction (intraTMP), according to some embodiments of the present disclosure.

[0025] FIG. 10C illustrates a diagram of an extended search region for intraTMP, according to some embodiments of the present disclosure.

[0026] FIG. 11 illustrates a diagram of fractional-pel positions for intraTMP, according to some embodiments of the present disclosure.

[0027] FIG. 12 illustrates a flowchart of a method of decoding, according to some embodiments of the present disclosure.

[0028] FIG. 13 illustrates a flowchart of a method of video encoding, according to some embodiments of the present disclosure.

[0029] Embodiments of the present disclosure will be described with reference to the accompanying drawings.

## DETAILED DESCRIPTION

[0030] Although some configurations and arrangements are discussed, it should be understood that this is done for illustrative purposes only. A person skilled in the pertinent art will recognize that other configurations and arrangements can be used without departing from the spirit and scope of the present disclosure. It will be apparent to a person skilled in the pertinent art that the present disclosure can also be employed in a variety of other applications.

[0031] It is noted that references in the specification to “one embodiment,” “an embodiment,” “an example embodiment,” “some embodiments,” “certain embodiments,” etc.,

indicate that the embodiment described may include a particular feature, structure, or characteristic, but every embodiment may not necessarily include the particular feature, structure, or characteristic. Moreover, such phrases do not necessarily refer to the same embodiment. Further, when a particular feature, structure, or characteristic is described in connection with an embodiment, it would be within the knowledge of a person skilled in the pertinent art to effect such feature, structure, or characteristic in connection with other embodiments whether or not explicitly described.

[0032] In general, terminology may be understood at least in part from usage in context. For example, the term “one or more” as used herein, depending at least in part upon context, may be used to describe any feature, structure, or characteristic in a singular sense or may be used to describe combinations of features, structures or characteristics in a plural sense. Similarly, terms, such as “a,” “an,” or “the,” again, may be understood to convey a singular usage or to convey a plural usage, depending at least in part upon context. In addition, the term “based on” may be understood as not necessarily intended to convey an exclusive set of factors and may, instead, allow for existence of additional factors not necessarily expressly described, again, depending at least in part on context.

[0033] Various aspects of video coding systems will now be described with reference to various apparatus and methods. These apparatus and methods will be described in the following detailed description and illustrated in the accompanying drawings by various modules, components, circuits, steps, operations, processes, algorithms, etc. (collectively referred to as “elements”). These elements may be implemented using electronic hardware, firmware, computer software, or any combination thereof. Whether such elements are implemented as hardware, firmware, or software depends upon the particular application and design constraints imposed on the overall system.

[0034] The techniques described herein may be used for various video coding applications. As described herein, video coding includes both encoding and decoding a video. Encoding and decoding of a video can be performed by the unit of block. For example, an encoding/decoding process such as transform, quantization, prediction, in-loop filtering, reconstruction, or the like may be performed on a coding block, a transform block, or a prediction block. As described herein, a block to be encoded/decoded will be referred to as a “current block.” For example, the current block may represent a coding block, a transform block, or a prediction block according to a current encoding/decoding process. In addition, it is understood that the term “unit” used in the present disclosure indicates a basic unit for performing a specific encoding/decoding process, and the term “block” indicates a sample array of a predetermined size. Unless otherwise stated, the “block” and “unit” may be used interchangeably.

[0035] FIG. 1 illustrates a block diagram of an exemplary encoding system 100, according to some embodiments of the present disclosure. FIG. 2 illustrates a block diagram of an exemplary decoding system 200, according to some embodiments of the present disclosure. Each system 100 or 200 may be applied or integrated into various systems and apparatus capable of data processing, such as computers and wireless communication devices. For example, system 100 or 200 may be the entirety or part of a mobile phone, a desktop computer, a laptop computer, a tablet, a vehicle computer, a gaming console, a printer, a positioning device, a wearable electronic device, a smart sensor, a virtual reality (VR) device, an augmented reality (AR) device, or any other suitable electronic devices having data processing capability. As shown in FIGs. 7 and 8, system 100 or 200 may include a processor 102, a memory 104, and an interface 106. These components are shown as connected to one another by a bus, but other connection types are also permitted. It is understood that system 100 or 200 may include any other suitable components for performing functions described here.

[0036] Processor 102 may include microprocessors, such as a graphic processing unit (GPU), image signal processor (ISP), central processing unit (CPU), digital signal processor (DSP), tensor processing unit (TPU), vision processing unit (VPU), neural processing unit (NPU), synergistic processing unit (SPU), or physics processing unit (PPU), microcontroller units (MCUs),

application-specific integrated circuits (ASICs), field-programmable gate arrays (FPGAs), programmable logic devices (PLDs), state machines, gated logic, discrete hardware circuits, and other suitable hardware configured to perform the various functions described throughout the present disclosure. Although only one processor is shown in FIGs. 7 and 8, it is understood that multiple processors can be included. Processor 102 may be a hardware device having one or more processing cores. Processor 102 may execute software. Software shall be construed broadly to mean instructions, instruction sets, code, code segments, program code, programs, subprograms, software modules, applications, software applications, software packages, routines, subroutines, objects, executables, threads of execution, procedures, functions, etc., whether referred to as software, firmware, middleware, microcode, hardware description language, or otherwise. Software can include computer instructions written in an interpreted language, a compiled language, or machine code. Other techniques for instructing hardware are also permitted under the broad category of software.

[0037] Memory 104 can broadly include both memory (a.k.a. primary/system memory) and storage (a.k.a. secondary memory). For example, memory 104 may include random-access memory (RAM), read-only memory (ROM), static RAM (SRAM), dynamic RAM (DRAM), ferro-electric RAM (FRAM), electrically erasable programmable ROM (EEPROM), compact disc read-only memory (CD-ROM) or other optical disk storage, hard disk drive (HDD), such as magnetic disk storage or other magnetic storage devices, Flash drive, solid-state drive (SSD), or any other medium that can be used to carry or store desired program code in the form of instructions that can be accessed and executed by processor 102. Broadly, memory 104 may be embodied by any computer-readable medium, such as a non-transitory computer-readable medium. Although only one memory is shown in FIGs. 7 and 8, it is understood that multiple memories can be included.

[0038] Interface 106 can broadly include a data interface and a communication interface that is configured to receive and transmit a signal in a process of receiving and transmitting information with other external network elements. For example, interface 106 may include input/output (I/O) devices and wired or wireless transceivers. Although only one memory is shown in FIGs. 7 and 8, it is understood that multiple interfaces can be included.

[0039] Processor 102, memory 104, and interface 106 may be implemented in various forms in system 100 or 200 for performing video coding functions. In some embodiments, processor 102, memory 104, and interface 106 of system 100 or 200 are implemented (e.g., integrated) on one or more system-on-chips (SoCs). In one example, processor 102, memory 104, and interface 106 may be integrated on an application processor (AP) SoC that handles application processing in an operating system (OS) environment, including running video encoding and decoding applications. In another example, processor 102, memory 104, and interface 106 may be integrated on a specialized processor chip for video coding, such as a GPU or ISP chip dedicated to image and video processing in a real-time operating system (RTOS).

[0040] As shown in FIG. 1, in encoding system 100, processor 102 may include one or more modules, such as an encoder 101. Although FIG. 1 shows that encoder 101 is within one processor 102, it is understood that encoder 101 may include one or more sub-modules that can be implemented on different processors located closely or remotely with each other. Encoder 101 (and any corresponding sub-modules or sub-units) can be hardware units (e.g., portions of an integrated circuit) of processor 102 designed for use with other components or software units implemented by processor 102 through executing at least part of a program, e.g., instructions. The instructions of the program may be stored on a computer-readable medium, such as memory 104, and when executed by processor 102, it may perform a process having one or more functions related to video encoding, such as picture partitioning, inter prediction, intra prediction, transformation, quantization, filtering, entropy encoding, etc., as described below in detail.

[0041] Similarly, as shown in FIG. 2, in decoding system 200, processor 102 may include one or more modules, such as a decoder 201. Although FIG. 2 shows that decoder 201 is within one processor 102, it is understood that decoder 201 may include one or more sub-modules that

can be implemented on different processors located closely or remotely with each other. Decoder 201 (and any corresponding sub-modules or sub-units) can be hardware units (e.g., portions of an integrated circuit) of processor 102 designed for use with other components or software units implemented by processor 102 through executing at least part of a program, e.g., instructions. The instructions of the program may be stored on a computer-readable medium, such as memory 104, and when executed by processor 102, it may perform a process having one or more functions related to video decoding, such as entropy decoding, inverse quantization, inverse transformation, inter prediction, intra prediction, filtering, as described below in detail.

[0042] FIG. 3 illustrates a detailed block diagram of exemplary encoder 101 in encoding system 100 in FIG. 1, according to some embodiments of the present disclosure. As shown in FIG. 3, encoder 101 may include a partitioning module 302, an inter prediction module 304, an intra prediction module 306, a transform module 308, a quantization module 310, a dequantization module 312, an inverse transform module 314, a filter module 316, a buffer module 318, and an encoding module 320. It is understood that each of the elements shown in FIG. 3 is independently shown to represent characteristic functions different from each other in a video encoder, and it does not mean that each component is formed by the configuration unit of separate hardware or single software. That is, each element is included to be listed as an element for convenience of explanation, and at least two of the elements may be combined to form a single element, or one element may be divided into a plurality of elements to perform a function. It is also understood that some of the elements are not necessary elements that perform functions described in the present disclosure but instead may be optional elements for improving performance. It is further understood that these elements may be implemented using electronic hardware, firmware, computer software, or any combination thereof. Whether such elements are implemented as hardware, firmware, or software depends upon the particular application and design constraints imposed on encoder 101.

[0043] Partitioning module 302 may be configured to partition an input picture of a video into at least one processing unit. A picture can be a frame of the video or a field of the video. In some embodiments, a picture includes an array of luma samples in monochrome format, or an array of luma samples and two corresponding arrays of chroma samples. At this point, the processing unit may be a prediction unit (PU), a transform unit (TU), or a coding unit (CU). Partitioning module 302 may partition a picture into a combination of a plurality of coding units, prediction units, and transform units, and encode a picture by selecting a combination of a coding unit, a prediction unit, and a transform unit based on a predetermined criterion (e.g., a cost function).

[0044] Similar to H.265/HEVC, H.266/VVC is a block-based hybrid spatial and temporal predictive coding scheme. As shown in FIG. 5, during encoding, an input picture 500 is first divided into square blocks – CTUs 502, by partitioning module 302. For example, CTUs 502 can be blocks of 128×128 pixels. As shown in FIG. 6, each CTU 502 in input picture 500 can be partitioned by partitioning module 302 into one or more CUs 602, which can be used for prediction and transformation. Unlike H.265/HEVC, in H.266/VVC, CUs 602 can be rectangular or square, and can be coded without further partitioning into prediction units or transform units. For example, as shown in FIG. 6, the partition of CTU 502 into CUs 602 may include quadtree splitting (indicated in solid lines), binary tree splitting (indicated in dashed lines), and ternary splitting (indicated in dash-dotted lines). Each CU 602 can be as large as its root CTU or be subdivisions of root CTU 502 as small as 4×4 blocks, according to some embodiments.

[0045] Referring to FIG. 4, inter prediction module 304 may be configured to perform inter prediction on a prediction unit, and intra prediction module 306 may be configured to perform intra prediction on the prediction unit. It may be determined whether to use inter prediction or to perform intra prediction for the prediction unit, and determine specific information (e.g., intra prediction mode, motion vector, reference picture, etc.) according to each prediction method. At this point, a processing unit for performing prediction may be different from a processing unit for determining a prediction method and specific content. For example, a prediction method and a

prediction mode may be determined in a prediction unit, and prediction may be performed in a transform unit. Residual coefficients in a residual block between the generated prediction block and the original block may be input into transform module 308. In addition, prediction mode information, motion vector information, and the like used for prediction may be encoded by encoding module 320 together with the residual coefficients or quantization levels into the bitstream. It is understood that in certain encoding modes, an original block may be encoded as it is without generating a prediction block through prediction module 304 or 306. It is also understood that in certain encoding modes, prediction, transform, and/or quantization may be skipped as well.

[0046] In some embodiments, inter prediction module 304 may predict a prediction unit based on information on at least one picture among pictures before or after the current picture, and in some cases, it may predict a prediction unit based on information on a partial area that has been encoded in the current picture. Inter prediction module 304 may include sub-modules, such as a reference picture interpolation module, a motion prediction module, and a motion compensation module (not shown). For example, the reference picture interpolation module may receive reference picture information from buffer module 318 and generate pixel information of an integer number of pixels or less from the reference picture. In the case of a luminance pixel, a discrete cosine transform (DCT)-based 8-tap interpolation filter with a varying filter coefficient may be used to generate pixel information of an integer number of pixels or less by the unit of 1/4 pixels. In the case of a color difference signal, a DCT-based 4-tap interpolation filter with a varying filter coefficient may be used to generate pixel information of an integer number of pixels or less by the unit of 1/8 pixels. The motion prediction module may perform motion prediction based on the reference picture interpolated by the reference picture interpolation part. Various methods, such as a full search-based block matching algorithm (FBMA), a three-step search (TSS), and a new three-step search algorithm (NTS) may be used as a method of calculating a motion vector. The motion vector may have a motion vector value of a unit of 1/2, 1/4, or 1/16 pixels or integer pel based on interpolated pixels. The motion prediction module may predict a current prediction unit by varying the motion prediction method. Various methods, such as a skip method, a merge method, an advanced motion vector prediction (AMVP) method, an intra-block copy method, and the like, may be used as the motion prediction method.

[0047] Still referring to FIG. 3, in some embodiments, intra prediction module 306 may generate a prediction unit based on the information on reference pixels around the current block, which is pixel information in the current picture. The reference pixels may be located in reference lines non-adjacent to the current block. When a block in the neighborhood of the current prediction unit is a block on which inter prediction has been performed and thus, the reference pixel is a pixel on which inter prediction has been performed, the reference pixel included in the block on which inter prediction has been performed may be used in place of reference pixel information of a block in the neighborhood on which intra prediction has been performed. That is, when a reference pixel is unavailable, at least one reference pixel among available reference pixels may be used in place of unavailable reference pixel information. In the intra prediction, the prediction mode may have an angular prediction mode that uses reference pixel information according to a prediction direction, and a non-angular prediction mode that does not use directional information when performing prediction. A mode for predicting luminance information may be different from a mode for predicting color difference information, and intra prediction mode information used to predict luminance information or predicted luminance signal information may be used to predict the color difference information. If the size of the prediction unit is the same as the size of the transform unit when intra prediction is performed, the intra prediction may be performed for the prediction unit based on pixels on the left side, pixels on the top-left side, and pixels on the top of the prediction unit. However, if the size of the prediction unit is different from the size of the transform unit when the intra prediction is performed, the intra prediction may be performed using a reference pixel based on the transform unit.

[0048] The intra prediction method may generate a prediction block after applying an adaptive intra smoothing (AIS) filter to the reference pixel according to a prediction mode. The type of the AIS filter applied to the reference pixel may vary. In order to perform the intra prediction method, the intra prediction mode of the current prediction unit may be predicted from the intra prediction mode of the prediction unit existing in the neighborhood of the current prediction unit. When a prediction mode of the current prediction unit is predicted using the mode information predicted from the neighboring prediction unit, if the intra prediction modes of the current prediction unit are the same as the prediction unit in the neighborhood, information indicating that the prediction modes of the current prediction unit are the same as the prediction unit in the neighborhood may be transmitted using predetermined flag information, and if the prediction modes of the current prediction unit and the prediction unit in the neighborhood are different from each other, prediction mode information of the current block may be encoded by extra flags information.

[0049] As shown in FIG. 3, a residual block including a prediction unit that has performed prediction based on the prediction unit generated by prediction module 304 or 306 and residual coefficient information (also referred to herein as the “residual”), which is a difference value of the prediction unit with the original block, may be generated. The generated residual block may be input into transform module 308. Additional details of residuals and transforms for video coding will now be provided.

[0050] In hybrid video coding systems, redundancy in the video signal is first exploited by applying inter or intra prediction tools for each CU. The difference between the original samples of a CU and the prediction block for that CU is commonly referred to as the residual. Even after prediction, the residual may still be highly spatially correlated. Although conditional entropy coding can capture some spatial dependency between adjacent samples, it is computationally impractical to form entropy coding statistical models that can fully exploit spatial correlation in the residual. In contrast, transform coding is a practical and effective method for spatially decorrelating the residual.

[0051] For example, transform module 308 may transform the residual using an integerized version of the two-dimensional discrete cosine transform (DCT), which may be applied separably in the horizontal and vertical directions. For an  $M \times N$  block of residual samples (where  $M$  is the width of the block and  $N$  is the height of the block), transform module 308 may obtain transform coefficients by applying an  $M \times M$  DCT to each row, resulting in intermediate transform coefficients, and then applying an  $N \times N$  DCT to each column of intermediate transform coefficients.

[0052] For intra-coded CUs (also referred to herein as “intra CUs”), spatial neighboring reconstructed samples are used to predict the current block, and the intra prediction mode is signaled once for the entire CU. Each CU consists of one or more collocated coding blocks (CBs) corresponding to the color components of the video sequence. For example, consumer video typically takes the 4:2:0 chroma format, in which case each CU consists of a luma CB and two chroma CBs with one-quarter of the samples of the luma CB. Intra prediction and transform coding are performed at the prediction block (PB) and transform block (TB) levels, respectively. Each CB consists of a single TB, except in the cases of Intra Subpartition (ISP) mode and implicit splitting. For luma CBs, the maximum side length of a TB is 64, and the minimum side length is 4. In addition, luma TBs are further specified as  $W \times H$  rectangular blocks of width  $W$  and height  $H$ , where  $W, H \in \{4, 8, 16, 32, 64\}$ . For chroma CBs, the maximum TB side length is 32, and chroma TBs are rectangular  $W \times H$  blocks of width  $W$  and height  $H$ . Here,  $W, H \in \{2, 4, 8, 16, 32\}$ , but blocks of shapes  $2 \times H$  and  $4 \times 2$  are excluded in order to address memory architecture and throughput requirements.

[0053] FIG. 7 illustrates a schematic visualization 700 of a current CU block 702 and spatially adjacent and non-adjacent reconstructed samples to the current block, according to some aspects of the present disclosure. In FIG. 7, the number 0, 1, 2, ... indicates the pixel-line index in relation to current CU block 702.

[0054] In VVC, the intra prediction samples for the current block are generated using reference samples that are obtained from reconstructed samples of neighboring blocks. For a  $W \times H$  block, the reference samples are spatially adjacent to the current block, consisting of the vertical line of  $2 \cdot H$  reconstructed samples to the left of the block and extending downwards, the top left reconstructed sample, and the horizontal line of  $2 \cdot W$  reconstructed samples above the current block and extending to the right. This “L” shaped set of samples may be referred to in this disclosure as a “reference line.” The reference line directly adjacent to current CU block 702 is shown as the line with index 0 in FIG. 7.

[0055] Similar to AVC and HEVC, VVC also supports angular intra prediction modes. Angular intra prediction is a directional intra prediction method. In comparison to HEVC, the angular intra prediction of VVC was modified by increasing the prediction accuracy and by an adaptation to the new partitioning framework. The former was realized by enlarging the number of angular prediction directions and by more accurate interpolation filters, while the latter was achieved by introducing wide-angular intra prediction modes. In VVC, the number of directional modes available for a given block is increased to 65 directions from the 33 HEVC directions. The angular modes 800 of VVC are depicted in FIG. 8.

[0056] The directions having even indices between 2 and 66 are equivalent to the directions of the angular modes supported in HEVC. For blocks of square shape, an equal number of angular modes is assigned to the top and left side of a block. On the other hand, intra blocks of rectangular shape, which are not present in HEVC, are a central part of VVC’s partitioning scheme with additional intra prediction directions assigned to the longer side of a block. The additional modes allocated along a longer side are called Wide-Angle Intra Prediction (WAIP) modes, since they correspond to prediction directions with angles greater than  $45^\circ$  relative to the horizontal or vertical mode. A WAIP mode for a given mode index is defined by mapping the original directional mode to a mode that has the opposite direction with an index offset equal to one, as shown in FIG. 8. For a given rectangular block, the aspect ratio, e.g., the ratio of width to height, is used to determine which angular modes are to be replaced by the corresponding wide-angular modes.

[0057] For square-shaped blocks in VVC, each pair of predicted samples that are horizontally or vertically adjacent are predicted from a pair of adjacent reference samples. To the contrary, WAIP extends the angular range of directional prediction beyond  $45^\circ$ , and therefore, for a coding block predicted with a WAIP mode, adjacent predicted samples may be predicted from non-adjacent reference samples.

[0058] In addition to the directly adjacent line of neighboring samples, one of the two non-adjacent reference lines (line 1 and line 2) that are depicted in FIG. 7 may include the input samples for intra prediction in VVC. For ECM, more non-adjacent reference lines may be used. The use of adjacent and non-adjacent reference samples is referred to as multiple reference line (MRL) prediction.

[0059] The intra modes that can be used for MRL are the DC mode and the angular prediction modes. However, for a given block, not all of these modes can be combined with MRL. The MRL mode is always coupled with a mode in the Most Probable Mode (MPM) list in VVC. This coupling means that if non-adjacent reference lines are used, the intra prediction mode is one of the MPMs. Such a design of an MPM-based MRL prediction mode is motivated by the observation that non-adjacent reference lines are mainly beneficial for texture patterns with sharp and strongly directed edges. In these cases, MPMs are much more frequently selected since there is typically a strong correlation between the texture patterns of the neighboring and the current blocks. On the other hand, choosing a non-MPM for intra prediction is an indication that edges are not consistently distributed in neighboring blocks, and thus, the MRL prediction mode is expected to be less useful in this case. In addition, it has been observed that MRL does not provide additional coding gain when the intra prediction mode is the Planar mode, since this mode is typically used for smooth areas. Consequently, MRL excludes the Planar mode, which is always one of the MPMs. The angular or DC prediction process in MRL is very similar to the case of a directly adjacent reference line. However, for angular modes with a non-integer slope, a DCT-based

interpolation filter (DCTIF) is always used. This design choice is both evidenced by experimental results and aligned with the empirical observation that MRL is mostly beneficial for sharp and strongly directed edges where the DCTIF is more appropriate since it retains more high frequencies than some other filters.

[0060] From a hardware design perspective, applying multiple reference lines as proposed in the initial methods requires extra cost of line buffers that are used for holding the additional reference lines. In typical hardware designs, line buffers are part of the on-chip memory architecture for image and video coding, and it is of great importance to minimize their on-chip area. To address this issue, MRL is disabled and not signaled for the coding units that are attached to the top boundary of the CTU. In this way, the extra buffers for holding non-adjacent reference lines are bounded by 128, which is the width of the largest unit size.

[0061] In some known approaches, an intra prediction fusion method was proposed to improve the accuracy of intra prediction. More specifically, if the current block is a luma block, and it is coded with a non-integer slope angular mode and not in the ISP mode, and the block size (width \* height) is greater than 16, two prediction blocks generated from two different reference lines will be “fused”, where the prediction fusion is calculated as a weighted summation of the two prediction blocks. More specifically, a first reference line at index  $i$  ( $line_i$ ) is specified with the current methods of signaling in the bitstream, and the prediction block generated from this reference line using the selected intra prediction mode is denoted as  $p(line_i)$ , where  $p(\cdot)$  represents the operation of generating a prediction block from a reference line with a given intra prediction mode. In the known approach, the reference line  $line_{i+1}$  is implicitly selected as the second reference line. That is, the second reference line is one index position further away from the current block relative to the first reference line. Similarly, the prediction block generated from the second reference line is denoted as  $p(line_{i+1})$ . The weighted sum of the two prediction blocks is obtained as follows and serves as the predictor for the current block according to equation (1).

$$p_{fusion} = w_0 * p(line_i) + w_1 * p(line_{i+1}) \quad (1),$$

where  $p_{fusion}$  represents the fused prediction,  $w_0$  and  $w_1$  are two weighting factors, and they are set as  $\frac{3}{4}$  and  $\frac{1}{4}$  in the experiment, respectively.

[0062] In the intra prediction methods described above, a predictor is derived dependent on neighboring reference samples. However, this is itself dependent on the reference samples being available to the current CU. Availability of samples depends on two factors: 1) whether the samples have already been reconstructed, and 2) whether the samples belong to a logical unit that the current CU is permitted to use.

[0063] To determine whether samples have already been reconstructed, we consider the partitioning structure of VVC. Referring to FIG. 5, each picture is divided into a tiling of square CTUs, which are processed in raster scan order. When an intra prediction method is performed on a current CU 602 in a current CTU 502, samples belonging to other CTUs preceding current CTU 502 in raster scan order are reconstructed and may be available for prediction. Samples belonging to CTUs following the current CTU 502 in raster scan order are not reconstructed and, therefore, are not available.

[0064] Each CTU 502 itself is partitioned into CUs by a hierarchical structure consisting of quadtree, binary tree, and ternary tree splits, with an example of such splits shown in FIG. 6. The scan order of CUs within a CTU 502 is determined by the partitioning structure. For a single level of partitioning split, the partitions are scanned in the following order: 1) left to right for the cases of horizontal binary tree split or horizontal ternary tree split, 2) top to bottom for the cases of vertical binary tree split or vertical ternary tree split, and 3) top-left, top-right, bottom-left, bottom-right for the case of quadtree split.

[0065] If a partition contains further hierarchical splits, then all CUs within that partition are scanned before continuing to the CUs in the next partition. FIG. 6 shows an example of partitioning of a CTU 502 into 15 CUs. Each CU 602 in FIG. 6 is numbered from 1 to 15 to indicate their scan order. When an intra prediction method is performed on a current CU in a

current CTU, samples belonging to other CUs in the current CTU that precede the current CU in the current CTU's partitioning scan order are reconstructed and may be available for prediction. Samples belonging to the current CU, or CUs following the current CU in the current CTU's partitioning scan order are not reconstructed and, therefore, not available.

[0066] Samples belonging to a CTU preceding the current CTU in raster scan order are considered reconstructed by the definition above. However, they are not necessarily available for intra prediction. To be considered available for prediction, they must also belong to a logical unit that the current CU is permitted to use. Pictures may be divided into sub-picture partitions, each of which contains a whole number of CTUs. FIG. 9A illustrates a diagram of slice partitioning 900 of a picture for intra prediction, according to some embodiments of the present disclosure. Samples belonging to a slice partition 904 other than the slice containing the current CU (of CTU 902) are not available for intra prediction. Imposing this restriction allows slices to be decoded independently.

[0067] FIG. 9B illustrates a diagram of tile partitioning 901 of a picture for intra prediction, according to some embodiments of the present disclosure. Samples belonging to a tile partition 906 other than the tile containing the current CU (of CTU 902) are not available for intra prediction. Imposing this restriction allows tiles to be decoded independently.

[0068] FIG. 9C illustrates a diagram of wavefront-parallel processing 903 of a picture for intra prediction, according to some embodiments of the present disclosure.

[0069] The manner in which an intra prediction method (e.g., slice partitioning, tile partitioning, or wavefront-parallel processing) deals with unavailability of reference samples needed for prediction varies depending on the method. The method may simply be disabled when such samples are not available. Alternatively, some extrapolation of the unavailable samples may be performed, such as by boundary extension.

[0070] In the intra prediction methods described above with reference to FIGs. 9A-9C, the predictor is derived only from spatially neighboring reference samples. However, greater coding gain can be achieved by expanding the region of reconstructed samples that may be used to derive a predictor. One example of this is with the intra block copy (IBC) mode.

[0071] FIG. 10A illustrates a diagram of IBC 1000, according to some embodiments of the present disclosure.

[0072] Referring to FIG. 10A, when a current CU 1004 is predicted by intra block copy mode, a block vector (BV) 1010 is signalled to indicate which block within the same picture will be copied to serve as a predictor 1012 for the current block. Signalling of this block vector may be performed by signalling a block vector difference (BVD) in the bitstream, such that the block vector can be determined by adding the BVD to a block vector predictor. Alternatively, if a block vector from a previous CU is an exact match for the current block vector, it may be signalled by a merge flag. Regardless of the signalling mechanism, the block vector points at a location within the same picture to indicate a block of samples equal in size to the current CU 1004 that is used as a predictor block for the current CU 1004. Some restrictions may apply to the block vector. In a first restriction, the block vector 1010 may point at a block of samples in the current picture that are available for intra prediction. In a second restriction, the block vector 1010 may be restricted to a search region defined for the IBC tool, which may be smaller than the current picture. For example, in VVC the IBC search region is current CTU 1002 and the previous CTU. In ECM the IBC search region is the current CTU row 1006 and the above CTU row 1014 when the CTU size is 256x256, or the current CTU row 1006 and the above 2 CTU rows when the current CTU size is 128x128 or smaller.

[0073] To further improve coding performance, a fractional-pel IBC method was proposed in ECM-9.0. More specifically, a 1/16-pel resolution is supported in addition to the existing full-pel IBC. The 8-tap luma filter as well as the chroma filter used in VVC for fractional motion compensation are used to interpolate the fractional-pel values. After an IBC block is coded, the 1/16-pel resolution is stored for coding future blocks.

[0074] FIG. 10B illustrates a diagram of intraTMP 1001, according to some embodiments

of the present disclosure.

[0075] Referring to FIG. 10B, intraTMP is an intra prediction mode similar to IBC in that the current CU 1022 is also predicted by a block of samples from the current picture. intraTMP may only be selected as a prediction mode for CUs with size 64x64 or smaller. Unlike IBC, however, a block vector 1024 is not signalled in the bitstream in intraTMP. Instead, decoder 201 compares a pre-defined L-shaped or other shaped templates of reconstructed samples neighbouring the current CU 1022 against the same shaped templates of candidate predictors within a pre-determined search region. For the case where the template is L-shaped, both neighbouring samples to the left and above of the current CU 1022 or intraTMP predictor 1026 are used. Let the width of the template area to the left be TmpW, and let the width of the template area above be TmpH. Other template shapes include a left template, which only includes the template area to the left, and an above template, which only consists of the template area above.

[0076] The intraTMP predictor block is determined by finding the best candidate template that matches the current CU template. The best match may be determined by finding the template that minimises the sum of absolute differences (SAD), or the sum of absolute transformed differences (SATD), or by comparing hashes between templates. The search algorithm through the search region may be exhaustive (for example, by scanning the template over the search region with sample-resolution shifts), or fast (for example, by performing a coarse search first, then performing a local refinement search around the best match from the coarse search). Regardless, the search algorithm is performed identically by both the encoder and decoder so that the intraTMP predictor is implicitly known by both encoder 101 and decoder 201 without requiring signalling in the bitstream. An example of intraTMP is shown in FIG. 10B with the current CU template and the best matching template indicated by hatched shading.

[0077] Still referring to FIG. 10B, for an intraTMP predictor 1026 to be selected, the block of samples corresponding to intraTMP predictor 1026 must be fully contained within the search region. The search region is shown in FIG. 10B by dashed shading. Within the current CTU 1020, the search region is restricted to a rectangular block of samples, bounded at one corner by the top-left corner of the current CTU 1020, and bounded at the other corner by the top-left corner of the current CU 1022.

[0078] Outside of the current CTU 1020, the search region is limited by imposing maximum lengths on the intraTMP block vector of (searchRangeWidth 1028, searchRangeHeight 1030), where searchRangeWidth 1028 and searchRangeHeight 1030 are set proportional to the dimensions of the current CU 1022. That is, the searchRangeWidth =  $a * \text{BlkW}$  and searchRangeHeight =  $a * \text{BlkH}$ , where ' $a$ ' is a constant that controls the gain/complexity trade-off, and BlkW and BlkH are the width and height of the current CU 1022, respectively. Here, ' $a$ ' is set to 5 in the ECM-7.0 test software. searchRangeHeight 1030 only limits the length of the block vectors in the negative vertical direction (that is, in the direction to the top of the picture). For block vectors with a positive vertical component, the search region is limited by the bottom boundary of the current CTU row. For example, in FIG. 10B, the search region extends to the bottom boundary of the left CTU 1032, regardless of the value of searchRangeHeight 1030. In addition, these limits to the search range do not apply to the current CTU 1020. For example, for small CUs where searchRangeWidth 1028 and searchRangeHeight 1030 may be small compared to the dimensions of current CTU 1020, the search region still extends as far as the top-left corner of the current CTU 1020.

[0079] Beyond the restriction imposed by the search region, the intraTMP predictor 1026 and its template must consist of samples that are available for intra prediction. For example, the boundaries of the search region are still overridden by picture, slice, or tile boundaries. Let the coordinates of the top-left corner of the currentCU relative to the current picture be (currCuX, currCuY). Then, the left boundary of the intraTMP search region is initially intraTmpLeftBound = currCuX - searchRangeWidth. To account for the picture boundary, the left boundary is clipped to allow TmpW sample width for the predictor's template. intraTmpLeftBound = max(intraTmpLeftBound, TmpW)

[0080] To speed up the template matching process, the search region is initially traversed horizontally or vertically in increments of 2 pixels at a time. This is also referred to as a search sub-sampling factor of 2. This leads to a 4-fold reduction in the template matching search complexity. After finding the best match from the initial search, a refinement process is performed.

5 The refinement is done via a second template matching search around the best match with a reduced range. In ECM-7.0, the reduced range is set to  $\text{BlkH}/2$ .

[0081] FIG. 10C illustrates a diagram of an extended search region for intraTMP 1003, according to some embodiments of the present disclosure.

[0082] Referring to FIG. 10C, for small CUs, the search range may be overly limiting so that a good predictor becomes difficult to obtain. For example, a 4x4 CU would only be allowed a maximum search range of (20, 20). To improve this situation for small CUs, some implementations place a minimum limit on the intraTMP search range. For example,  $\text{searchRangeWidth} = \max(a * \text{BlkW}, \text{minSearchRange})$  and  $\text{searchRangeHeight} = \max(a * \text{BlkH}, \text{minSearchRange})$ , where  $\text{minSearchRange}$  is set as 128.

15 [0083] This implementation excludes some regions in the current CTU 1020 that are available for prediction. Here, it is proposed to extend the search region in the current CTU 1020 to include areas directly above and directly left of the current CU 1022. The proposed modified search region is FIG. 10C, with the areas added to the search region relative to that of FIG. 10B marked with crosshatch shading.

20 [0084] FIG. 11 illustrates a diagram of fractional-pel positions 1100 for intraTMP, according to some embodiments of the present disclosure.

[0085] Referring to FIG. 11, ECM-9.0 employs a multi-candidate intraTMP. A candidate list is constructed with the candidate BVs ranked in ascending order of their template matching costs, and the index of the selected candidate is signaled in the bitstream.

25 [0086] Fractional-pel precision is enabled for intraTMP in the ECM-9.0. More specifically, intraTMP block may have quarter-pel fractional resolution BV. Three fractional-pel offsets, e.g., half-pel, quarter-pel, and three quarter-pel, in eight directions around the integer-pel position are supported, resulting in fractional-pel positions as shown in FIG. 11. If a non-zero fractional-pel offset is signaled, a direction index is signaled to indicate which direction is used. Four-tap DCT-IF interpolation filters in ECM are used for sub-pel interpolation in intraTMP.

30 [0087] ECM-9.0 also employs a model-derived intraTMP prediction block. The model parameters are derived using a template of the current block and a corresponding matching template. The prediction block is obtained by applying the model to filter the reference block.

[0088] ECM-9.0 employs a fusion method that blends multiple reference blocks to derive the final prediction block, with a Wiener-filter-based weight derivation method. The Block Vectors (BVs) of these reference blocks are obtained via a template matching search process.

35 [0089] Three additional intraTMP modes, e.g., left template, above template and L-shape fusion modes, are used in ECM-9.0. The left and above template modes use only the left side or above side to derive the template matching candidates, whereas the L-shape fusion mode uses both left and above templates. The fusion mode fuses the best two or the best five L-shape candidates by a template matching cost based or mean-square error (MSE) minimization based linear combination formula.

40 [0090] In the current ECM-9.0, the syntax related to intraTMP is shown in Table 1.

|                              |
|------------------------------|
| ...                          |
| intra_tmp_flag               |
| if(intra_tmp_flag) {         |
| intra_tmp_fusion_flag        |
| if(intra_tmp_fusion_flag) {  |
| intra_tmp_fusion_weight_type |
| intra_tmp_fusion_idx         |
| } else {                     |

|                                            |
|--------------------------------------------|
| intra_tmp_idx                              |
| intra_tmp_filter_flag                      |
| if(!intra_tmp_filter_flag) {               |
| intra_tmp_sub_pel_precision_idx            |
| if(intra_tmp_sub_pel_precision_idx != 0) { |
| intra_tmp_sub_pel_direction_idx            |
| } // if(intra_tmp_sub...)                  |
| } // if(!intra_tmp_filter_flag)            |
| } // else                                  |
| } // intra_tmp_flag                        |
| ...                                        |

Table 1: intraTMP syntax elements in ECM-9.0

[0091] Referring to Table 1, intra\_tmp\_flag indicates whether the intra prediction type for the current block is intraTMP or not, intra\_tmp\_fusion\_flag indicates whether fusion is used or not for the current block, and intra\_tmp\_fusion\_idx specifies the candidate set used for intraTMP fusion. The range of intra\_tmp\_fusion\_idx is 0 to 2, and intra\_tmp\_fusion\_idx is used to indicate one of the three candidate sets {BV0 to BV4}, {BV5 to BV9}, {BV10 to BV14}. intra\_tmp\_fusion\_weight\_type indicates whether the SAD-based weight derivation method or the Wiener-filter-based weight derivation method is used. intra\_tmp\_idx specifies the index of BV in the candidate list used for the current block. The range of intra\_tmp\_idx is 0 to 18. Candidates from the L-shape template, top template and left template are included in the same candidate list. intra\_tmp\_sub\_pel\_precision\_idx specifies the precision index for the current block. The range of intra\_tmp\_sub\_pel\_precision\_idx is 0 to 3, used to indicate integer-pel precision, 1/2-pel precision, 1/4-pel precision, and 3/4-pel precision, respectively. intra\_tmp\_sub\_pel\_direction\_idx specifies the sub-pel direction index for the current block. The range of intra\_tmp\_sub\_pel\_phase\_idx is 0 to 7.

[0092] An intraTMP block may be coded with a fractional-pel BV resolution only if the current block is coded as neither fused intraTMP (e.g., intra\_tmp\_fusion\_flag as 1) nor filtered intraTMP (e.g., intra\_tmp\_filter\_flag as 1) in the current ECM-9.0. If a block is coded as either fused intraTMP or filtered intraTMP, the intraTMP block only has a BV in full-pel (integer-pel) resolution.

[0093] After an intraTMP block is coded, regardless of whether the current intraTMP coded block has an integer-pel or a quarter-pel fractional resolution BV, only integer-pel BV information for the current intraTMP block is stored for coding future blocks. More specifically, if the current intraTMP has a quarter-pel fractional BV, this quarter-pel fractional BV is rounded into the integer-pel resolution first. The integer-pel BV is then converted into 1/16-pel resolution (the current integer-pel BV left shift by 4). The converted 1/16-pel resolution BV is stored for coding future blocks in the ECM-9.0.

[0094] Referring again to FIG. 3, transform module 308 can transform the video signals in the residual block from the pixel domain to a transform domain (e.g., a frequency domain depending on the transform method). It is understood that in some examples, transform module 308 may be skipped, and the video signals may not be transformed to the transform domain.

[0095] Quantization module 310 may be configured to quantize the coefficient of each position in the coding block to generate quantization levels of the positions. The current block may be the residual block. That is, quantization module 310 can perform a quantization process on each residual block. The residual block may include  $N \times M$  positions (samples), each associated with a transformed or non-transformed video signal/data, such as luma and/or chroma information, where  $N$  and  $M$  are positive integers. In the present disclosure, before quantization, the transformed or non-transformed video signal at a specific position is referred to herein as a “coefficient.” After quantization, the quantized value of the coefficient is referred to herein as a “quantization level” or “level.”

[0096] Quantization can be used to reduce the dynamic range of transformed or non-transformed video signals so that fewer bits will be used to represent video signals. Quantization typically involves division by a quantization step size and subsequent rounding, while dequantization (a.k.a. inverse quantization) involves multiplication by the quantization step size.

5 The quantization step size can be indicated by a quantization parameter (QP). Such a quantization process is referred to as scalar quantization. The quantization of all coefficients within a coding block can be done independently, and this kind of quantization method is used in some existing video compression standards, such as H.264/AVC and H.265/HEVC. The QP in quantization can affect the bit rate used for encoding/decoding the pictures of the video. For example, a higher QP can result in a lower bit rate, and a lower QP can result in a higher bit rate.

10 [0097] For an  $N \times M$  coding block, a specific coding scan order may be used to convert the two-dimensional (2D) coefficients of a block into a one-dimensional (1D) order for coefficient quantization and coding. Typically, the coding scan starts from the left-top corner and stops at the right-bottom corner of a coding block or the last non-zero coefficient/level in a right-bottom direction. It is understood that the coding scan order may include any suitable order, such as a zig-zag scan order, a vertical (column) scan order, a horizontal (row) scan order, a diagonal scan order, or any combinations thereof. Quantization of a coefficient within a coding block may make use of the coding scan order information. For example, it may depend on the status of the previous quantization level along the coding scan order. In order to further improve the coding efficiency, more than one quantizer, e.g., two scalar quantizers, can be used by quantization module 310. Which quantizer will be used for quantizing the current coefficient may depend on the information preceding the current coefficient in coding scan order. Such a quantization process is referred to as dependent quantization.

25 [0098] Referring to FIG. 3, encoding module 320 may be configured to encode the quantization level of each position in the coding block into the bitstream. In some embodiments, encoding module 320 may perform entropy encoding on the coding block. Entropy encoding may use various binarization methods, such as Golomb-Rice binarization, to convert each quantization level into a respective binary representation, such as binary bins. Then, the binary representation can be further compressed using entropy encoding algorithms. The compressed data may be added to the bitstream. Besides the quantization levels, encoding module 320 may encode various other information, such as block type information of a coding unit, prediction mode information, partitioning unit information, prediction unit information, transmission unit information, motion vector information, reference frame information, block interpolation information, and filtering information input from, for example, prediction modules 304 and 306. In some embodiments, encoding module 320 may perform residual coding on a coding block to convert the quantization level into the bitstream. For example, after quantization, there may be  $N \times M$  quantization levels for an  $N \times M$  block. These  $N \times M$  levels may be zero or non-zero values. The non-zero levels may be further binarized to binary bins if the levels are not binary, for example, using combined Truncated Rice (TR) and limited EGk binarization.

40 [0099] Non-binary syntax elements may be mapped to binary codewords. The bijective mapping between symbols and codewords, for which typically simple structured codes are used, is called binarization. The binary symbols, also called bins, of both binary syntax elements and codewords for non-binary data may be coded using binary arithmetic coding. The core coding engine of context-adaptive binary arithmetic coding (CABAC) can support two operating modes: a context coding mode, in which the bins are coded with adaptive probability models, and a less complex bypass mode that uses a fixed probability of 1/2. The adaptive probability models are also called contexts, and the assignment of probability models to individual bins is referred to as context modeling.

50 [0100] As shown in FIG. 3, dequantization module 312 may be configured to dequantize the quantization levels by dequantization module 312, and inverse transform module 314 may be configured to inversely transform the coefficients transformed by transform module 308. The reconstructed residual block generated by dequantization module 312 and inverse transform

module 314 may be combined with the prediction units predicted through prediction module 304 or 306 to generate a reconstructed block.

[0101] Filter module 316 may include at least one among a deblocking filter, a sample adaptive offset (SAO), and an adaptive loop filter (ALF). The deblocking filter may remove block distortion generated by the boundary between blocks in the reconstructed picture. The SAO module may correct an offset to the original video by the unit of pixel for a video on which the deblocking has been performed. ALF may be performed based on a value obtained by comparing the reconstructed and filtered video and the original video. Buffer module 318 may be configured to store the reconstructed block or picture calculated through filter module 316, and the reconstructed and stored block or picture may be provided to inter prediction module 304 when inter prediction is performed.

[0102] FIG. 4 illustrates a detailed block diagram of exemplary decoder 201 in decoding system 200 in FIG. 2, according to some embodiments of the present disclosure. As shown in FIG. 4, decoder 201 may include a decoding module 402, a dequantization module 404, an inverse transform module 406, an inter prediction module 408, an intra prediction module 410, a filter module 412, and a buffer module 414. It is understood that each of the elements shown in FIG. 4 is independently shown to represent characteristic functions different from each other in a video decoder, and it does not mean that each component is formed by the configuration unit of separate hardware or single software. That is, each element is included to be listed as an element for convenience of explanation, and at least two of the elements may be combined to form a single element, or one element may be divided into a plurality of elements to perform a function. It is also understood that some of the elements are not necessary elements that perform functions described in the present disclosure but instead may be optional elements for improving performance. It is further understood that these elements may be implemented using electronic hardware, firmware, computer software, or any combination thereof. Whether such elements are implemented as hardware, firmware, or software depends upon the particular application and design constraints imposed on decoder 201.

[0103] When a video bitstream is input from a video encoder (e.g., encoder 101), the input bitstream may be decoded by decoder 201 in a procedure opposite to that of the video encoder. Thus, some details of decoding that are described above with respect to encoding may be skipped for ease of description. Decoding module 402 may be configured to decode the bitstream to obtain various information encoded into the bitstream, such as the quantization level of each position in the coding block. In some embodiments, decoding module 402 may perform entropy decoding (decompressing) corresponding to the entropy encoding (compressing) performed by the encoder, such as, for example, video local-area network (VideoLAN) coding (VLC), context-adaptive variable-length coding (CAVLC), CABAC, syntax-based binary arithmetic coding (SBAC), PIPE coding, and the like to obtain the binary representation (e.g., binary bins). Decoding module 402 may further convert the binary representations to quantization levels using Golomb-Rice binarization, including, for example, EGk binarization and combined TR and limited EGk binarization. Besides the quantization levels of the positions in the transform units, decoding module 402 may decode various other information, such as the parameters used for Golomb-Rice binarization (e.g., the Rice parameter), block type information of a coding unit, prediction mode information, partitioning unit information, prediction unit information, transmission unit information, motion vector information, reference frame information, block interpolation information, and filtering information. During the decoding process, decoding module 402 may perform rearrangement on the bitstream to reconstruct and rearrange the data from a 1D order into a 2D rearranged block through a method of inverse-scanning based on the coding scan order used by the encoder.

[0104] Dequantization module 404 may be configured to dequantize the quantization level of each position of the coding block (e.g., the 2D reconstructed block) to obtain the coefficient of each position. In some embodiments, dequantization module 404 may perform dependent dequantization based on quantization parameters provided by the encoder as well, including the

information related to the quantizers used in dependent quantization, for example, the quantization step size used by each quantizer.

[0105] Inverse transform module 406 may be configured to perform inverse transformation, for example, inverse discrete cosine transform (DCT), inverse DST, and inverse Karhunen–Loève transform (KLT), for DCT, DST, and KLT performed by the encoder, respectively, to transform the data from the transform domain (e.g., coefficients) back to the pixel domain (e.g., luma and/or chroma information). In some embodiments, inverse transform module 406 may selectively perform a transform operation (e.g., DCT, DST, KLT) according to a plurality of pieces of information such as a prediction method, a size of the current block, a prediction direction, and the like.

[0106] Inter prediction module 408 and intra prediction module 410 may be configured to generate a prediction block based on information related to the generation of a prediction block provided by decoding module 402 and information of a previously decoded block or picture provided by buffer module 414. As described above, if the size of the prediction unit and the size of the transform unit are the same when intra prediction is performed in the same manner as the operation of the encoder, intra prediction may be performed on the prediction unit based on the pixel existing on the left side, the pixel on the top-left side, and the pixel on the top of the prediction unit. However, if the size of the prediction unit and the size of the transform unit are different when intra prediction is performed, intra prediction may be performed using a reference pixel based on a transform unit.

[0107] In existing intraTMP methods, an integer-pel BV is stored for a coded intraTMP block. This may result in a suboptimal coding performance.

[0108] Still referring to FIG. 4, to overcome these and other challenges, the present disclosure proposes intra prediction module 410 directly converts a quarter-pel fractional BV (instead of an integer-pel BV) into 1/16-pel resolution (the current quarter-pel BV left shift by 2). This converted intraTMP BV is called converted fractional-pel BV. Intra prediction module 410 then stores converted fractional-pel BV after coding a fractional-pel intraTMP block. When coding future blocks, the stored converted fractional-pel BV may be referenced by coding modes that re-use stored BVs by intra prediction module 410. Examples of such coding modes include IBC-advanced motion vector prediction (AMVP), IBC-merge luma block, and coding direct block vector (DBV) chroma block, etc.

[0109] More specifically, if a current block is predicted by intraTMP and is coded in neither the fused intraTMP nor filtered intraTMP mode, intra prediction module 410 may directly convert a resulting quarter-pel fractional resolution BV into 1/16-pel resolution directly (the current quarter-pel BV left shift by 2), which may be stored for the current block. If the current block is predicted by intraTMP and is coded as either fused intraTMP or filtered intraTMP mode, intra prediction module 410 may convert an integer-pel resolution BV into 1/16-pel resolution (the current quarter-pel BV left shift by 4), which may be stored for the current block.

[0110] In some implementations, intra prediction module 410 may obtain a fractional-pel BV by using the template of the current block and the template of the reference block for a coded fused or filtered intraTMP block, even when the current block is coded in either the fused or filtered intraTMP mode. More specifically, intra prediction module 410 may obtain a full-pel BV by using the template of the current block and the template of the reference block, which minimizes the difference between two templates within a pre-specified search range according to the current intraTMP process. Intra prediction module 410 may search a fractional-pel BV with a specified resolution, e.g., half-pel, quarter-pel, or 1/16-pel, etc., around the obtained full-pel BV for the template of the reference block to further minimize the difference between the template of the current block and the template of the reference block. As used here, such fractional-pel BV is called a template fractional-pel BV.

[0111] As one example, the template fractional-pel BV may have similar three fractional-pel offsets, e.g., half-pel, quarter-pel, and three quarter-pel, in eight directions around the integer-

pel position as shown in FIG. 11. As another example, the template fractional-pel BV may have IBC-like fractional-pel, which may occupy all fractional-pel, e.g., 1/16-pel positions.

[0112] In some implementations, intra prediction module 410 may still use the filtered intraTMP block full-pel BV to find the reference block. Then, the filtered reference block may be used as the prediction for coding the current block without any change. After coding this filtered intraTMP block, the template fractional-pel BV may be obtained and converted into pre-defined resolution, e.g., 1/16-pel. The converted template fractional-pel BV may be stored for the current block.

[0113] In some implementations, intra prediction module 410 may first obtain the template fractional-pel BV. The filtered intraTMP block uses the template fractional-pel BV to find the reference block. Then, intra prediction module 410 may apply the filtering to this fractional-pel interpolated reference block. After coding this filtered intraTMP block, intra prediction module 410 may convert the template fractional-pel BV into pre-defined resolution, e.g., 1/16-pel, before storing it for the current block.

[0114] Suppose that there are N intraTMP reference blocks used for a fused intraTMP mode. One intraTMP reference block with the least SAD is denoted as the first intraTMP reference block among these N intraTMP reference blocks. Here, intra prediction module 410 may obtain the template fractional-pel BV by using the template of the current block and the template of the first intraTMP reference block.

[0115] In some implementations, the fused intraTMP keeps no change. After coding this fused intraTMP block, intra prediction module 410 may obtain and convert the template fractional-pel BV into pre-defined resolution, e.g., 1/16-pel. The converted template fractional-pel BV is then stored for the current block.

[0116] In some implementations, intra prediction module 410 may interpolate the first intraTMP reference block using the obtained template fractional-pel BV. Here, the interpolated reference block replaces the first intraTMP reference block to generate the fused intraTMP block. After coding the current block, the template fractional-pel BV is converted into pre-defined resolution, e.g., 1/16-pel, and then stored for the current block.

[0117] In some implementations, intra prediction module 410 may further interpolate N intraTMP reference blocks using the obtained template fractional-pel BV for the first intraTMP reference block, and the interpolated reference blocks replace the N intraTMP reference blocks to generate the fused intraTMP block. After coding the current block, the template fractional-pel BV for the first intraTMP is converted into a pre-defined resolution, e.g., 1/16-pel, and then stored for the current block.

[0118] In some implementations, intra prediction module 410 may obtain N template fractional-pel BVs using the template of the current block and the templates of N intraTMP reference block. Intra prediction module 410 may further interpolate N intraTMP reference blocks using corresponding template fractional-pel BVs, and the interpolated N reference blocks replace the N intraTMP reference blocks to generate the fused intraTMP block. After coding the current block, the first (best) template fractional-pel BV is converted into pre-defined resolution, e.g., 1/16-pel, and then stored for the current block.

[0119] Using the fractional-pel techniques described above, the coding performance of intra prediction module 410 may be improved.

[0120] For example, inter prediction module 408 may be configured to receive a bitstream that includes a reference frame, a current frame, and an indication of a weighting factor associated with a multiple-hypothesis prediction (MHP) procedure from an encoder. Inter prediction module 408 may be configured to perform the MHP procedure for a CU located in the current frame based on a search block (e.g., reference frame and/or reference template) in the reference frame. In some embodiments, to perform the MHP procedure, the inter prediction module 408 may be configured to perform template matching for the CU located in the current frame based on a search block in the reference frame and the weighting factor to obtain motion information. In some embodiments, to perform the MHP procedures, inter prediction module 408 may be configured to identify a

weighting factor index associated with the weighting factor based on the template matching. Inter prediction module 408 may be configured to identify a weighting factor sign of the weighting factor based on an indication included in the bitstream. Inter prediction module performs an inter prediction procedure based on the current frame, the reference frame, the weighting factor index, and the weighting factor sign of the weighting factor to decode the bitstream.

[0121] The reconstructed block or reconstructed picture combined from the outputs of inverse transform module 406 and prediction module 408 or 410 may be provided to filter module 412. Filter module 412 may include a deblocking filter, an offset correction module, and an ALF. Buffer module 414 may store the reconstructed picture or block and use it as a reference picture or a reference block for inter prediction module 408 and may output the reconstructed picture.

[0122] Consistent with the scope of the present disclosure, encoding module 320 and decoding module 402 may be configured to adopt a scheme of quantization level binarization with Rice parameter adapted to the bit depth and/or the bit rate for encoding the picture of the video to improve the coding efficiency.

[0123] FIG. 12 illustrates a flowchart of an exemplary method 1200 of video decoding, according to some embodiments of the present disclosure. Method 1200 may be performed by a system, e.g., such as decoding system 200, decoder 201, or intra prediction module 410, just to name a few. Method 1200 may include operations 1202-1218, as described below. It is to be appreciated that some of the steps may be optional, and some of the steps may be performed simultaneously, or in a different order than shown in FIG. 12.

[0124] Referring to FIG. 12, at 1202, the system may parse a bitstream to determine an intraTMP mode associated with a current block. For example, referring to FIG. 2 and 4, decoder 201 may parse a bitstream encoded based on at least one flag by encoder 101. By parsing the bitstream, decoder 201 may determine an intraTMP mode enabled for the current block based on an intraTMP flag or syntax element.

[0125] At 1204, the system may obtain at least one fractional-pel BV for decoding the current block. For example, referring to FIG. 4, intra prediction module 410 obtains a quarter-pel fractional BV.

[0126] At 1206, the system may obtain a reference block based on the at least one fractional-pel BV. For example, referring to FIG. 4, intra prediction module 410 may obtain a reference block based on the at least one fractional-pel BV.

[0127] At 1208, the system may obtain a filtered intraTMP block by filtering the reference block. For example, referring to FIG. 4, intra prediction module 410 may first obtain the template fractional-pel BV. The filtered intraTMP block uses the template fractional-pel BV to find the reference block. Then, intra prediction module 410 may apply the filtering to this fractional-pel interpolated reference block.

[0128] At 1210, the system may decode the current block based on the reference block. For example, referring to FIG. 4, decoder 201 may decode the current block based on the reference block.

[0129] At 1212, the system may obtain a converted fractional-pel BV based on the at least one fractional-pel BV and after the current block is decoded. For example, referring to FIG. 4, a fractional-pel BV (instead of an integer-pel BV) may be converted into 1/16-pel resolution (the current quarter-pel BV left shift by 2). This converted intraTMP BV is called converted fractional-pel BV. Intra prediction module 410 then stores converted fractional-pel BV after coding a intraTMP block. When coding future blocks, the stored converted fractional-pel BV may be referenced by coding modes that re-use stored BVs by intra prediction module 410. Examples of such coding modes include IBC-AMVP, IBC-merge luma block, and coding DBV chroma block, intraTMP-merge mode, etc. More specifically, if a current block is predicted by intraTMP and is coded in neither the fused intraTMP nor filtered intraTMP mode, intra prediction module 410 may convert a resulting quarter-pel fractional resolution BV into 1/16-pel resolution directly (the current quarter-pel BV left shift by 2), which may be stored for the current block. If the current block is predicted by intraTMP and is coded as either fused intraTMP or filtered intraTMP mode,

intra prediction module 410 may convert an integer-pel resolution BV into 1/16-pel resolution (the current quarter-pel BV left shift by 4), which may be stored for the current block.

[0130] At 1214, the system may store the converted fractional-pel BV for decoding another block. For example, referring to FIG. 4, Intra prediction module 410 then stores converted fractional-pel BV after coding a fractional-pel intraTMP block. When coding future blocks, the stored converted fractional-pel BV may be referenced by coding modes that re-use stored BVs by intra prediction module 410. Examples of such coding modes include IBC-AMVP, IBC-merge luma block, and coding DBV chroma block, etc. More specifically, if a current block is predicted by intraTMP and is coded in neither the fused intraTMP nor filtered intraTMP mode, intra prediction module 410 may convert a resulting quarter-pel fractional resolution BV into 1/16-pel resolution directly (the current quarter-pel BV left shift by 2), which may be stored for the current block. If the current block is predicted by intraTMP and is coded as either fused intraTMP or filtered intraTMP mode, intra prediction module 410 may convert an integer-pel resolution BV into 1/16-pel resolution (the current quarter-pel BV left shift by 4), which may be stored for the current block.

[0131] At 1216, the system may parse the bitstream to determine IBC-AMVP, IBC-merge luma block, and coding DBV chroma block is enabled for another block. For example, referring to FIG. 2, decoder 201 may parse the bitstream to determine IBC-AMVP, IBC-merge luma block, and coding DBV chroma block is enabled for another block. By parsing the bitstream, decoder 201 may determine an intraTMP mode enabled for the current block based on an intraTMP flag or syntax element.

[0132] At 1218, the system may decode the another block using the IBC-AMVP, IBC-merge luma block, or coding DBV chroma block based on the converted fractional-pel BV. For example, referring to FIG. 2, decoder 201 may decode another block using the converted fractional-pel BV.

[0133] FIG. 13 illustrates a flowchart of an exemplary method 1300 of video encoding, according to some embodiments of the present disclosure. Method 1300 may be performed by a system, e.g., such as encoding system 100, encoder 101, or intra prediction module 306, just to name a few. Method 1300 may include operations 1302-1318, as described below. It is to be appreciated that some of the steps may be optional, and some of the steps may be performed simultaneously, or in a different order than shown in FIG. 13.

[0134] Referring to FIG. 13, at 1302, the system may obtain at least one fractional-pel BV for encoding a current block. For example, referring to FIG. 3, intra prediction module 306 obtains a quarter-pel fractional BV.

[0135] At 1304, the system may obtain a reference block based on the at least one fractional-pel BV. For example, referring to FIG. 3, intra prediction module 306 may obtain a reference block based on the at least one fractional-pel BV.

[0136] At 1306, the system may obtain a filtered intraTMP block by filtering the reference block. For example, referring to FIG. 3, intra prediction module 306 may first obtain the template fractional-pel BV. The filtered intraTMP block uses the template fractional-pel BV to find the reference block. Then, intra prediction module 306 may apply the filtering to this fractional-pel interpolated reference block.

[0137] At 1308, the system may encode the current block based on the reference block. For example, referring to FIG. 3, encoder 101 may encode the current block based on the reference block.

[0138] At 1310, the system may obtain a converted fractional-pel BV based on the at least one fractional-pel BV and after the current block is encoded. For example, referring to FIG. 3, a fractional-pel BV (instead of an integer-pel BV) may be converted into 1/16-pel resolution (the current quarter-pel BV left shift by 2). This converted intraTMP BV is called converted fractional-pel BV. Intra prediction module 306 then stores converted fractional-pel BV after coding a intraTMP block. When coding future blocks, the stored converted fractional-pel BV may be referenced by coding modes that re-use stored BVs by intra prediction module 306. Examples of

such coding modes include IBC-AMVP, IBC-merge luma block, and coding DBV chroma block, intraTMP-merge mode, etc. More specifically, if a current block is predicted by intraTMP and is coded in neither the fused intraTMP nor filtered intraTMP mode, intra prediction module 306 may convert a resulting quarter-pel fractional resolution BV into 1/16-pel resolution directly (the current quarter-pel BV left shift by 2), which may be stored for the current block. If the current block is predicted by intraTMP and is coded as either fused intraTMP or filtered intraTMP mode, intra prediction module 306 may convert an integer-pel resolution BV into 1/16-pel resolution (the current quarter-pel BV left shift by 4), which may be stored for the current block.

[0139] At 1312, the system may store the converted fractional-pel BV for encoding another block. For example, referring to FIG. 3, Intra prediction module 306 then stores converted fractional-pel BV after coding a fractional-pel intraTMP block. When coding future blocks, the stored converted fractional-pel BV may be referenced by coding modes that re-use stored BVs by intra prediction module 306. Examples of such coding modes include IBC-AMVP, IBC-merge luma block, and coding DBV chroma block, etc. More specifically, if a current block is predicted by intraTMP and is coded in neither the fused intraTMP nor filtered intraTMP mode, intra prediction module 306 may convert a resulting quarter-pel fractional resolution BV into 1/16-pel resolution directly (the current quarter-pel BV left shift by 2), which may be stored for the current block. If the current block is predicted by intraTMP and is coded as either fused intraTMP or filtered intraTMP mode, intra prediction module 306 may convert an integer-pel resolution BV into 1/16-pel resolution (the current quarter-pel BV left shift by 4), which may be stored for the current block.

[0140] At 1314, the system may parse the bitstream to determine IBC-AMVP, IBC-merge luma block, and coding DBV chroma block is enabled for another block. For example, referring to FIG. 1, encoder 101 may parse the bitstream to determine IBC-AMVP, IBC-merge luma block, and coding DBV chroma block is enabled for another block. By parsing the bitstream, encoder 101 may determine an intraTMP mode enabled for the current block based on an intraTMP flag or syntax element.

[0141] At 1316, the system may encode the another block using the IBC-AMVP, IBC-merge luma block, or coding DBV chroma block based on the converted fractional-pel BV. For example, referring to FIG. 1, encoder 101 may encode another block using the converted fractional-pel BV.

[0142] At 1318, the system may encode an intraTMP mode associated with a current block into a bitstream. For example, referring to FIGs. 1 and 3, encoder 101 may encode an intraTMP mode enabled for the current block into a bitstream based on an intraTMP flag or syntax element.

[0143] In various aspects of the present disclosure, the functions described herein may be implemented in hardware, software, firmware, or any combination thereof. If implemented in software, the functions may be stored as instructions on a non-transitory computer-readable medium. Computer-readable media includes computer storage media. Storage media may be any available media that can be accessed by a processor, such as processor 102 in FIGs. 1 and 2. By way of example, and not limitation, such computer-readable media can include RAM, ROM, EEPROM, CD-ROM or other optical disk storage, HDD, such as magnetic disk storage or other magnetic storage devices, Flash drive, SSD, or any other medium that can be used to carry or store desired program code in the form of instructions or data structures and that can be accessed by a processing system, such as a mobile device or a computer. Disk and disc, as used herein, include CD, laser disc, optical disc, digital video disc (DVD), and floppy disk 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.

[0144] According to one aspect of the present disclosure, a method of decoding by a decoder is provided. The method may include parsing, by a processor, a bitstream to determine an intraTMP mode associated with a current block. The method may include obtaining, by the processor, at least one fractional-pel BV for decoding the current block. The method may include obtaining, by the processor, a reference block based on the at least one fractional-pel BV. The

method may include decoding, by the processor, the current block based on the reference block. The method may include obtaining, by the processor, a converted fractional-pel BV based on the at least one fractional-pel BV and after the current block is decoded. The method may include storing, by the processor, the converted fractional-pel BV for decoding another block.

5 [0145] In some implementations, the method may include parsing, by the processor, the bitstream to determine IBC- AMVP, IBC-merge luma block, and coding DBV chroma block is enabled for another block. In some implementations, the method may include decoding, by the processor, the another block using the IBC-AMVP, IBC-merge luma block, or coding DBV chroma block based on the converted fractional-pel BV.

10 [0146] In some implementations, the obtaining, by the processor, the at least one fractional-pel BV for decoding the current block may include obtaining, by the processor, a full-pel BV by minimizing a difference between a template of the current block and a template of a reference block within a pre-defined search range. In some implementations, the obtaining, by the processor, the at least one fractional-pel BV for decoding the current block may include searching, by the processor, the full-pel BV using a resolution associated with the at least one fractional-pel BV to obtain the at least one fractional-pel BV. In some implementations, the at least one fractional-pel BV may be a template fractional-pel BV.

15 [0147] In some implementations, the method may include obtaining, by the processor, a filtered intraTMP block by filtering the reference block. In some implementations, the current block may be decoded based on the filtered intraTMP block.

20 [0148] In some implementations, the intraTMP mode may include fused intraTMP mode. In some implementations, the fused intraTMP mode may be associated with N reference blocks. In some implementations, the obtaining, by the processor, the reference block based on the at least one fractional-pel BV may include obtaining, by the processor, a first reference block with a least SAD from among the N reference blocks. In some implementations, the template of the reference block used to obtain the template fractional-pel BV may be the template of the first reference block.

25 [0149] In some implementations, the obtaining, by the processor, the reference block based on the at least one fractional-pel BV may include interpolating, by the processor, the first reference block to obtain an interpolated reference block. In some implementations, the obtaining, by the processor, the reference block based on the at least one fractional-pel BV may include generating, by the processor, a fused intraTMP block based on the interpolated reference block. In some implementations, the current block may be decoded based on the fused intraTMP block.

30 [0150] In some implementations, the obtaining, by the processor, at least one fractional-pel BV for decoding the current block may include obtaining, by the processor, N template fractional-pel BVs using a template of the current block and respective templates of each of N intraTMP reference blocks. In some implementations, the the obtaining, by the processor, the reference block based on the at least one fractional-pel BV may include interpolating, by the processor, each of the N intraTMP reference blocks associated using corresponding one of the N template fractional-pel BVs to generate a fused intraTMP block, the fused intraTMP block being the reference block. In some implementations, the current block may be decoded based on the fused intraTMP block.

35 [0151] According to another aspect of the present disclosure, an apparatus for decoding is provided. The apparatus may include a processor and memory storing instructions. The memory storing instructions, which when executed by the processor, may cause the processor to parse a bitstream to determine an intraTMP mode associated with a current block. The memory storing instructions, which when executed by the processor, may cause the processor to obtain at least one fractional-pel BV for decoding the current block. The memory storing instructions, which when executed by the processor, may cause the processor to obtain a reference block based on the at least one fractional-pel BV. The memory storing instructions, which when executed by the processor, may cause the processor to decode the current block based on the reference block. The memory storing instructions, which when executed by the processor, may cause the processor to obtain a converted fractional-pel BV based on the at least one fractional-pel BV and after the

current block is decoded. The memory storing instructions, which when executed by the processor, may cause the processor to store the converted fractional-pel BV for decoding another block.

[0152] In some implementations, the memory storing instructions, which when executed by the processor, may cause the processor to parse the bitstream to determine IBC-AMVP, IBC-merge luma block, and coding DBV chroma block is enabled for another block. In some implementations, the memory storing instructions, which when executed by the processor, may cause the processor to decode the another block using the IBC-AMVP, IBC-merge luma block, or coding DBV chroma block based on the converted fractional-pel BV.

[0153] In some implementations, to obtain the at least one fractional-pel BV for decoding the current block, the memory storing instructions, which when executed by the processor, may cause the processor to obtain a full-pel BV by minimizing a difference between a template of the current block and a template of a reference block within a pre-defined search range. In some implementations, to obtain the at least one fractional-pel BV for decoding the current block, the memory storing instructions, which when executed by the processor, may cause the processor to search the full-pel BV using a resolution associated with the at least one fractional-pel BV to obtain the at least one fractional-pel BV, the at least one fractional-pel BV being a template fractional-pel BV.

[0154] In some implementations, the memory storing instructions, which when executed by the processor, may cause the processor to obtain a filtered intraTMP block by filtering the reference block. In some implementations, the current block may be decoded based on the filtered intraTMP block.

[0155] In some implementations, the intraTMP mode may include fused intraTMP mode. In some implementations, the fused intraTMP mode is associated with N reference blocks. In some implementations, to obtain the reference block based on the at least one fractional-pel BV, the memory storing instructions, which when executed by the processor, may cause the processor to obtain a first reference block with a least sum of absolute differences (SAD) from among the N reference blocks. In some implementations, the template of the reference block used to obtain the template fractional-pel BV may be the template of the first reference block.

[0156] In some implementations, to obtain the reference block based on the at least one fractional-pel BV, the memory storing instructions, which when executed by the processor, may cause the processor to interpolate the first reference block to obtain an interpolated reference block. In some implementations, to obtain the reference block based on the at least one fractional-pel BV, the memory storing instructions, which when executed by the processor, may cause the processor to generate a fused intraTMP block based on the interpolated reference block. In some implementations, the current block may be decoded based on the fused intraTMP block.

[0157] In some implementations, to obtain at least one fractional-pel BV for decoding the current block, the memory storing instructions, which when executed by the processor, may cause the processor to obtain N template fractional-pel BVs using a template of the current block and respective templates of each of N intraTMP reference blocks. In some implementations, to obtain the reference block based on the at least one fractional-pel BV, the memory storing instructions, which when executed by the processor, may cause the processor to interpolate each of the N intraTMP reference blocks associated using corresponding one of the N template fractional-pel BVs to generate a fused intraTMP block. In some implementations, the fused intraTMP block may be the reference block. In some implementations, the current block may be decoded based on the fused intraTMP block.

[0158] According to a further aspect of the present disclosure, a non-transitory computer-readable medium storing instructions is provided. The instructions, which when executed by the processor, may cause the processor to parse a bitstream to determine an intraTMP mode associated with a current block. The instructions, which when executed by the processor, may cause the processor to obtain at least one fractional-pel BV for decoding the current block. The instructions, which when executed by the processor, may cause the processor to obtain a reference block based on the at least one fractional-pel BV. The instructions, which when executed by the processor,

may cause the processor to decode the current block based on the reference block. The instructions, which when executed by the processor, may cause the processor to obtain a converted fractional-pel BV based on the at least one fractional-pel BV and after the current block is decoded. The instructions, which when executed by the processor, may cause the processor to store the converted fractional-pel BV for decoding another block.

[0159] In some implementations, the instructions, which when executed by the processor, may cause the processor to parse the bitstream to determine IBC-AMVP, IBC-merge luma block, and coding DBV chroma block is enabled for another block. In some implementations, the instructions, which when executed by the processor, may cause the processor to decode the another block using the IBC-AMVP, IBC-merge luma block, or coding DBV chroma block based on the converted fractional-pel BV.

[0160] In some implementations, to obtain the at least one fractional-pel BV for decoding the current block, the instructions, which when executed by the processor, may cause the processor to obtain a full-pel BV by minimizing a difference between a template of the current block and a template of a reference block within a pre-defined search range. In some implementations, to obtain the at least one fractional-pel BV for decoding the current block, the instructions, which when executed by the processor, may cause the processor to search the full-pel BV using a resolution associated with the at least one fractional-pel BV to obtain the at least one fractional-pel BV, the at least one fractional-pel BV being a template fractional-pel BV.

[0161] In some implementations, the instructions, which when executed by the processor, may cause the processor to obtain a filtered intraTMP block by filtering the reference block. In some implementations, the current block may be decoded based on the filtered intraTMP block.

[0162] In some implementations, the intraTMP mode may include fused intraTMP mode. In some implementations, the fused intraTMP mode is associated with N reference blocks. In some implementations, to obtain the reference block based on the at least one fractional-pel BV, the instructions, which when executed by the processor, may cause the processor to obtain a first reference block with a least sum of absolute differences (SAD) from among the N reference blocks. In some implementations, the template of the reference block used to obtain the template fractional-pel BV may be the template of the first reference block.

[0163] In some implementations, to obtain the reference block based on the at least one fractional-pel BV, the instructions, which when executed by the processor, may cause the processor to interpolate the first reference block to obtain an interpolated reference block. In some implementations, to obtain the reference block based on the at least one fractional-pel BV, the instructions, which when executed by the processor, may cause the processor to generate a fused intraTMP block based on the interpolated reference block. In some implementations, the current block may be decoded based on the fused intraTMP block.

[0164] In some implementations, to obtain at least one fractional-pel BV for decoding the current block, the instructions, which when executed by the processor, may cause the processor to obtain N template fractional-pel BVs using a template of the current block and respective templates of each of N intraTMP reference blocks. In some implementations, to obtain the reference block based on the at least one fractional-pel BV, the instructions, which when executed by the processor, may cause the processor to interpolate each of the N intraTMP reference blocks associated using corresponding one of the N template fractional-pel BVs to generate a fused intraTMP block. In some implementations, the fused intraTMP block may be the reference block. In some implementations, the current block may be decoded based on the fused intraTMP block.

[0165] According to yet another aspect of the present disclosure, a method of encoding by an encoder is provided. The method may include obtaining, by the processor, at least one fractional-pel BV for encoding a current block. The method may include obtaining, by the processor, a reference block based on the at least one fractional-pel BV. The method may include encoding, by the processor, the current block based on the reference block. The method may include obtaining, by the processor, a converted fractional-pel BV based on the at least one fractional-pel BV and after the current block is encoded. The method may include storing, by the

processor, the converted fractional-pel BV for decoding another block. The method may include encoding, by the processor, an intraTMP mode associated with the current block to a bitstream.

[0166] According to yet a further aspect of the present disclosure, an apparatus for encoding is provided. The apparatus may include a processor and memory storing instructions.

5 The memory storing instructions, which when executed by the processor, may cause the processor to obtain at least one fractional-pel BV for encoding a current block. The memory storing instructions, which when executed by the processor, may cause the processor to obtain a reference block based on the at least one fractional-pel BV. The memory storing instructions, which when executed by the processor, may cause the processor to encode the current block based on the  
10 reference block. The memory storing instructions, which when executed by the processor, may cause the processor to obtain a converted fractional-pel BV based on the at least one fractional-pel BV and after the current block is encoded. The memory storing instructions, which when executed by the processor, may cause the processor to store the converted fractional-pel BV for encoding another block. The memory storing instructions, which when executed by the processor, may cause the processor to encode an intraTMP mode associated with the current block to a bitstream.

[0167] According to still a further aspect of the present disclosure, a non-transitory computer-readable medium storing instructions for an encoder is provided. The instructions, which when executed by a processor, may cause the processor to obtain at least one fractional-pel BV for encoding a current block. The instructions, which when executed by a processor, may cause the processor to obtain a reference block based on the at least one fractional-pel BV. The instructions, which when executed by a processor, may cause the processor to encode the current block based on the reference block. The instructions, which when executed by a processor, may cause the processor to obtain a converted fractional-pel BV based on the at least one fractional-pel BV and after the current block is encoded. The instructions, which when executed by a processor, may cause the processor to store the converted fractional-pel BV for encoding another block. The instructions, which when executed by a processor, may cause the processor to encode an intraTMP mode associated with the current block to a bitstream.

[0168] The foregoing description of the embodiments will so reveal the general nature of the present disclosure that others can, by applying knowledge within the skill of the art, readily  
30 modify and/or adapt for various applications such embodiments, without undue experimentation, without departing from the general concept of the present disclosure. Therefore, such adaptations and modifications are intended to be within the meaning and range of equivalents of the disclosed embodiments, based on the teaching and guidance presented herein. It is to be understood that the phraseology or terminology herein is for the purpose of description and not of limitation, such that  
35 the terminology or phraseology of the present specification is to be interpreted by the skilled artisan in light of the teachings and guidance.

[0169] Embodiments of the present disclosure have been described above with the aid of functional building blocks illustrating the implementation of specified functions and relationships thereof. The boundaries of these functional building blocks have been arbitrarily defined herein  
40 for the convenience of the description. Alternate boundaries can be defined so long as the specified functions and relationships thereof are appropriately performed.

[0170] The Summary and Abstract sections may set forth one or more but not all exemplary embodiments of the present disclosure as contemplated by the inventor(s), and thus, are not intended to limit the present disclosure and the appended claims in any way.

45 [0171] Various functional blocks, modules, and steps are disclosed above. The arrangements provided are illustrative and without limitation. Accordingly, the functional blocks, modules, and steps may be reordered or combined in different ways than in the examples provided above. Likewise, some embodiments include only a subset of the functional blocks, modules, and steps, and any such subset is permitted.

50 [0172] The breadth and scope of the present disclosure should not be limited by any of the above-described exemplary embodiments, but should be defined only in accordance with the following claims and their equivalents.

## CLAIMS

1. A method of decoding by a decoder, comprising:  
parsing, by a processor, a bitstream to determine an intra template matching (intraTMP)  
mode associated with a current block;

5 obtaining, by the processor, at least one fractional-pel block vector (BV) for decoding the current block;

obtaining, by the processor, a reference block based on the at least one fractional-pel BV;

decoding, by the processor, the current block based on the reference block;

10 obtaining, by the processor, a converted fractional-pel BV based on the at least one fractional-pel BV and after the current block is decoded; and

storing, by the processor, the converted fractional-pel BV for decoding another block.

2. The method of claim 1, further comprising:

15 parsing, by the processor, the bitstream to determine intra block copy (IBC)-advanced motion vector prediction (AMVP), IBC-merge luma block, and coding direct block vector (DBV) chroma block is enabled for another block; and

decoding, by the processor, the another block using the IBC-AMVP, IBC-merge luma block, or coding DBV chroma block based on the converted fractional-pel BV.

20 3. The method of claim 1, wherein the obtaining, by the processor, the at least one fractional-pel block vector (BV) for decoding the current block comprises:

obtaining, by the processor, a full-pel BV by minimizing a difference between a template of the current block and a template of a reference block within a pre-defined search range; and

25 searching, by the processor, the full-pel BV using a resolution associated with the at least one fractional-pel BV to obtain the at least one fractional-pel BV, the at least one fractional-pel BV being a template fractional-pel BV.

4. The method of claim 3, further comprising:

30 obtaining, by the processor, a filtered intraTMP block by filtering the reference block, wherein the current block is decoded based on the filtered intraTMP block.

5. The method of claim 4, wherein:

the intraTMP mode includes fused intraTMP mode,

the fused intraTMP mode is associated with N reference blocks,

35 the obtaining, by the processor, the reference block based on the at least one fractional-pel BV comprises:

obtaining, by the processor, a first reference block with a least sum of absolute differences (SAD) from among the N reference blocks, and

40 the template of the reference block used to obtain the template fractional-pel BV is the template of the first reference block.

6. The method of claim 5, wherein:

45 the obtaining, by the processor, the reference block based on the at least one fractional-pel BV comprises:

interpolating, by the processor, the first reference block to obtain an interpolated reference block; and

generating, by the processor, a fused intraTMP block based on the interpolated reference block, and

50 the current block is decoded based on the fused intraTMP block.

7. The method of claim 5, wherein:

the obtaining, by the processor, at least one fractional-pel block vector (BV) for decoding the current block comprises:

obtaining, by the processor, N template fractional-pel BVs using a template of the current block and respective templates of each of N intraTMP reference blocks,

the obtaining, by the processor, the reference block based on the at least one fractional-pel BV comprises:

interpolating, by the processor, each of the N intraTMP reference blocks associated using corresponding one of the N template fractional-pel BVs to generate a fused intraTMP block, the fused intraTMP block being the reference block, and

the current block is decoded based on the fused intraTMP block.

8. An apparatus for decoding, comprising:

a processor; and

memory storing instructions, which when executed by the processor, cause the processor to: parse a bitstream to determine an intra template matching (intraTMP) mode associated with a current block;

obtain at least one fractional-pel block vector (BV) for decoding the current block;

obtain a reference block based on the at least one fractional-pel BV;

decode the current block based on the reference block;

obtain a converted fractional-pel BV based on the at least one fractional-pel BV and after the current block is decoded; and

store the converted fractional-pel BV for decoding another block.

9. The apparatus of claim 8, wherein the memory storing instructions, which when executed by the processor, cause the processor to:

parse the bitstream to determine intra block copy (IBC)-advanced motion vector prediction (AMVP), IBC-merge luma block, and coding direct block vector (DBV) chroma block is enabled for another block; and

decode the another block using the IBC-AMVP, IBC-merge luma block, or coding DBV chroma block based on the converted fractional-pel BV.

10. The apparatus of claim 8, wherein, to obtain the at least one fractional-pel block vector (BV) for decoding the current block, the memory storing instructions, which when executed by the processor, cause the processor to:

obtain a full-pel BV by minimizing a difference between a template of the current block and a template of a reference block within a pre-defined search range; and

search the full-pel BV using a resolution associated with the at least one fractional-pel BV to obtain the at least one fractional-pel BV, the at least one fractional-pel BV being a template fractional-pel BV.

11. The apparatus of claim 10, wherein the memory storing instructions, which when executed by the processor, cause the processor to:

obtain a filtered intraTMP block by filtering the reference block,

wherein the current block is decoded based on the filtered intraTMP block.

12. The apparatus of claim 11, wherein:

the intraTMP mode includes fused intraTMP mode,

the fused intraTMP mode is associated with N reference blocks,

to obtain the reference block based on the at least one fractional-pel BV, the memory storing instructions, which when executed by the processor, cause the processor to:

obtain a first reference block with a least sum of absolute differences (SAD) from among the N reference blocks, and

the template of the reference block used to obtain the template fractional-pel BV is the template of the first reference block.

13. The apparatus of claim 12, wherein:

to obtain the reference block based on the at least one fractional-pel BV, the memory storing instructions, which when executed by the processor, cause the processor to: interpolate the first reference block to obtain an interpolated reference block; and generate a fused intraTMP block based on the interpolated reference block, and the current block is decoded based on the fused intraTMP block.

14. The apparatus of claim 12, wherein:

to obtain at least one fractional-pel block vector (BV) for decoding the current block, the memory storing instructions, which when executed by the processor, cause the processor to: obtain N template fractional-pel BVs using a template of the current block and respective templates of each of N intraTMP reference blocks, to obtain the reference block based on the at least one fractional-pel BV, the memory storing instructions, which when executed by the processor, cause the processor to: interpolate each of the N intraTMP reference blocks associated using corresponding one of the N template fractional-pel BVs to generate a fused intraTMP block, the fused intraTMP block being the reference block, and the current block is decoded based on the fused intraTMP block.

15. A non-transitory computer-readable medium storing instructions, which when executed by a processor, cause the processor to:

parse a bitstream to determine an intra template matching (intraTMP) mode associated with a current block; obtain at least one fractional-pel block vector (BV) for decoding the current block; obtain a reference block based on the at least one fractional-pel BV; decode the current block based on the reference block; obtain a converted fractional-pel BV based on the at least one fractional-pel BV and after the current block is decoded; and store the converted fractional-pel BV for decoding another block.

16. The non-transitory computer-readable medium of claim 15, wherein the instructions, which when executed by the processor, cause the processor to:

parse the bitstream to determine intra block copy (IBC)-advanced motion vector prediction (AMVP), IBC-merge luma block, and coding direct block vector (DBV) chroma block is enabled for another block; and

decode the another block using the IBC-AMVP, IBC-merge luma block, or coding DBV chroma block based on the converted fractional-pel BV.

17. The non-transitory computer-readable medium of claim 15, wherein, to obtain the at least one fractional-pel block vector (BV) for decoding the current block, the instructions, which when executed by the processor, cause the processor to:

obtain a full-pel BV by minimizing a difference between a template of the current block and a template of a reference block within a pre-defined search range;

search the full-pel BV using a resolution associated with the at least one fractional-pel BV to obtain the at least one fractional-pel BV, the at least one fractional-pel BV being a template fractional-pel BV; and

obtain a filtered intraTMP block by filtering the reference block, wherein the current block is decoded based on the filtered intraTMP block.

18. The non-transitory computer-readable medium of claim 17, wherein:  
the intraTMP mode includes fused intraTMP mode,  
the fused intraTMP mode is associated with N reference blocks,  
to obtain the reference block based on the at least one fractional-pel BV, the instructions,  
5 which when executed by the processor, cause the processor to:  
obtain a first reference block with a least sum of absolute differences (SAD) from among  
the N reference blocks, and  
the template of the reference block used to obtain the template fractional-pel BV is the  
template of the first reference block.

19. The non-transitory computer-readable medium of claim 18, wherein:  
to obtain the reference block based on the at least one fractional-pel BV, the instructions,  
which when executed by the processor, cause the processor to:  
interpolate the first reference block to obtain an interpolated reference block; and  
15 generate a fused intraTMP block based on the interpolated reference block, and  
the current block is decoded based on the fused intraTMP block.

20. The non-transitory computer-readable medium of claim 18, wherein:  
to obtain at least one fractional-pel block vector (BV) for decoding the current block, the  
20 instructions, which when executed by the processor, cause the processor to:  
obtain N template fractional-pel BVs using a template of the current block and respective  
templates of each of N intraTMP reference blocks,  
to obtain the reference block based on the at least one fractional-pel BV, the instructions,  
which when executed by the processor, cause the processor to:  
25 interpolate each of the N intraTMP reference blocks associated using corresponding one of  
the N template fractional-pel BVs to generate a fused intraTMP block, the fused intraTMP block  
being the reference block, and  
the current block is decoded based on the fused intraTMP block.

21. A method of encoding by an encoder, comprising:  
obtaining, by the processor, at least one fractional-pel block vector (BV) for encoding a  
current block;  
obtaining, by the processor, a reference block based on the at least one fractional-pel BV;  
encoding, by the processor, the current block based on the reference block;  
35 obtaining, by the processor, a converted fractional-pel BV based on the at least one  
fractional-pel BV and after the current block is encoded;  
storing, by the processor, the converted fractional-pel BV for encoding another block; and  
encoding, by the processor, an intra template matching (intraTMP) mode associated with  
the current block to a bitstream.

22. An apparatus for encoding, comprising:  
a processor; and  
memory storing instructions, which when executed by the processor, cause the processor to:  
obtain at least one fractional-pel block vector (BV) for encoding a current block;  
45 obtain a reference block based on the at least one fractional-pel BV;  
encode the current block based on the reference block;  
obtain a converted fractional-pel BV based on the at least one fractional-pel BV and after  
the current block is encoded;  
store the converted fractional-pel BV for encoding another block; and  
50 encode an intra template matching (intraTMP) mode associated with the current block to a  
bitstream.

23. A non-transitory computer-readable medium storing instructions, which when executed by a processor, cause the processor to:
- obtain at least one fractional-pel block vector (BV) for encoding a current block;
  - obtain a reference block based on the at least one fractional-pel BV;
  - 5     encode the current block based on the reference block;
  - obtain a converted fractional-pel BV based on the at least one fractional-pel BV and after the current block is encoded;
  - store the converted fractional-pel BV for encoding another block; and
  - 10    encode an intra template matching (intraTMP) mode associated with the current block to a bitstream.

100

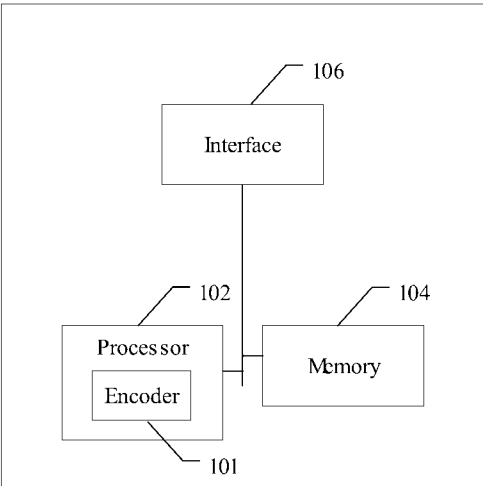


FIG. 1

200

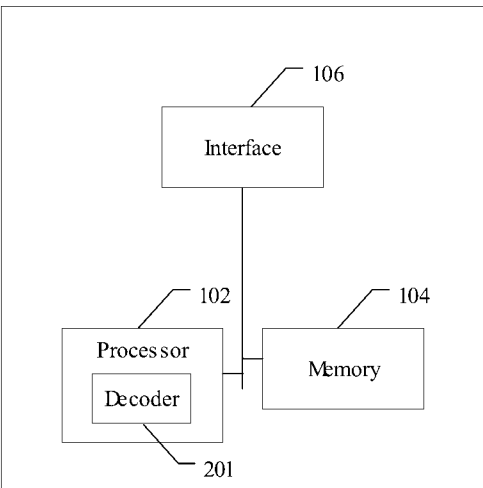


FIG. 2

101

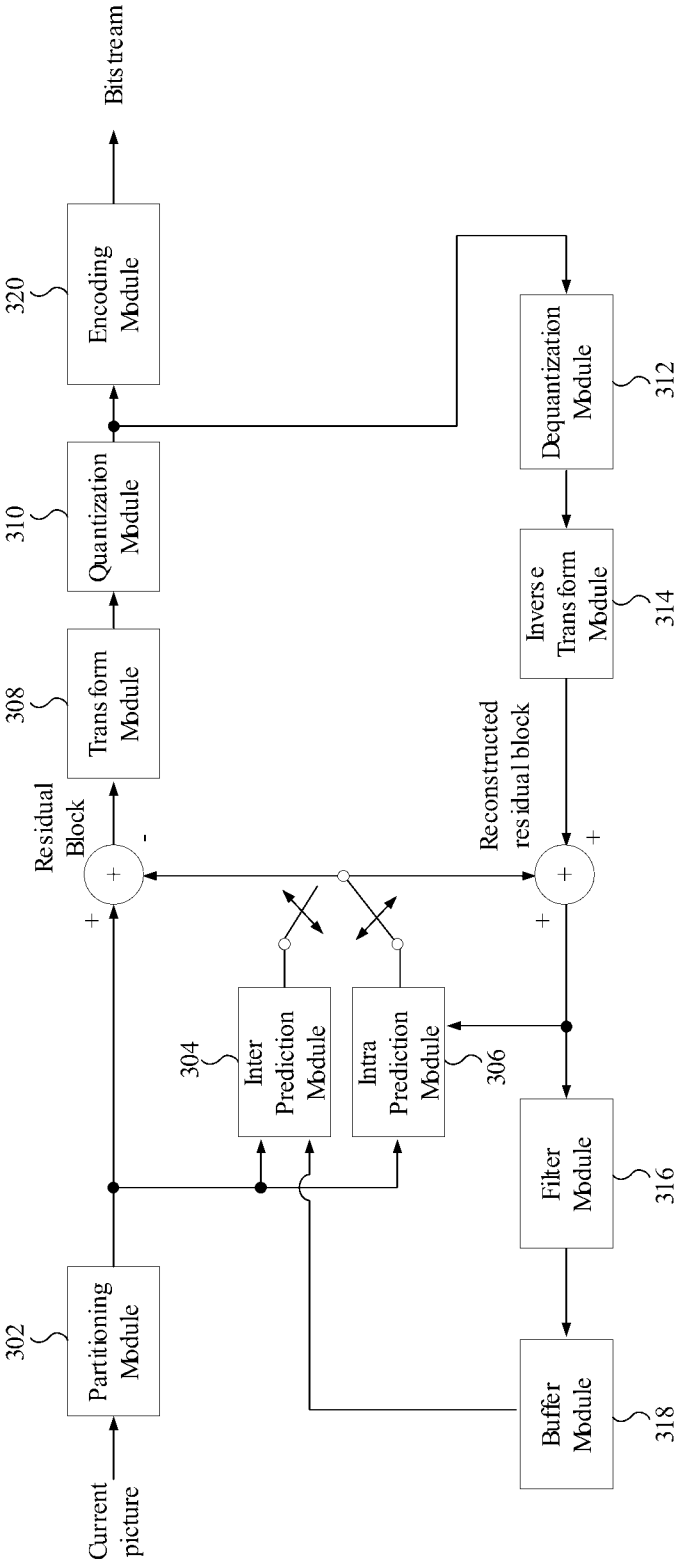


FIG. 3

201

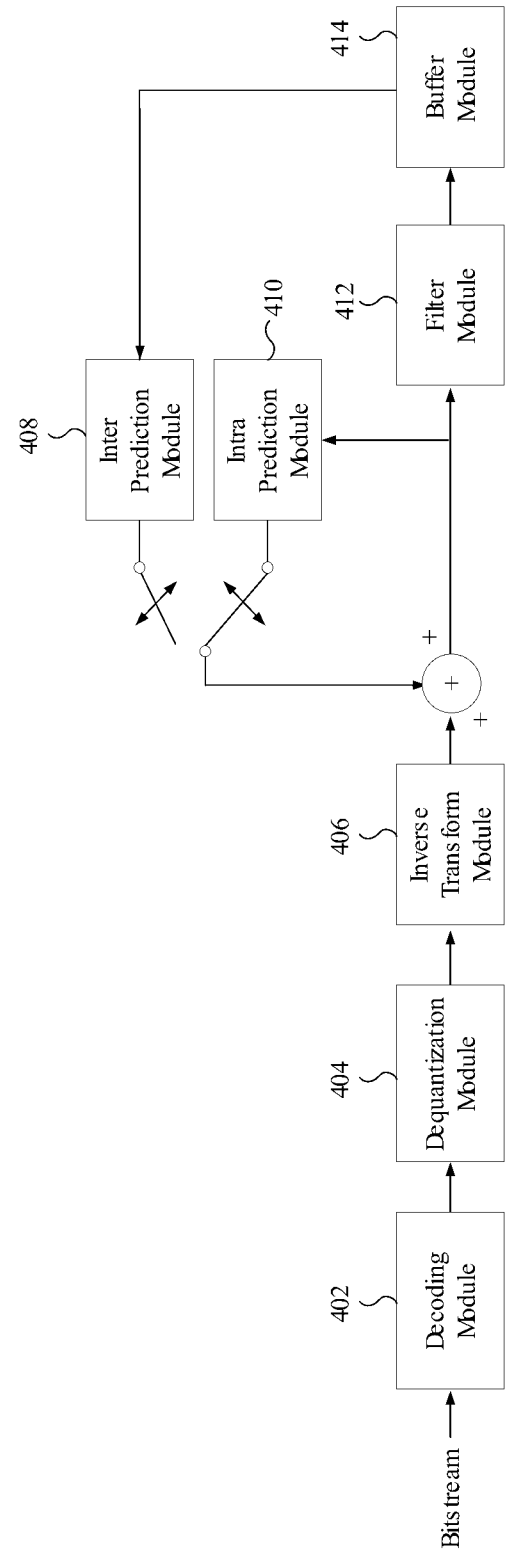


FIG. 4

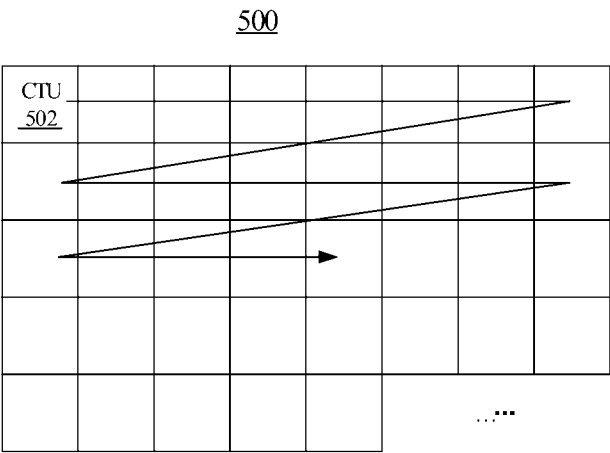


FIG. 5

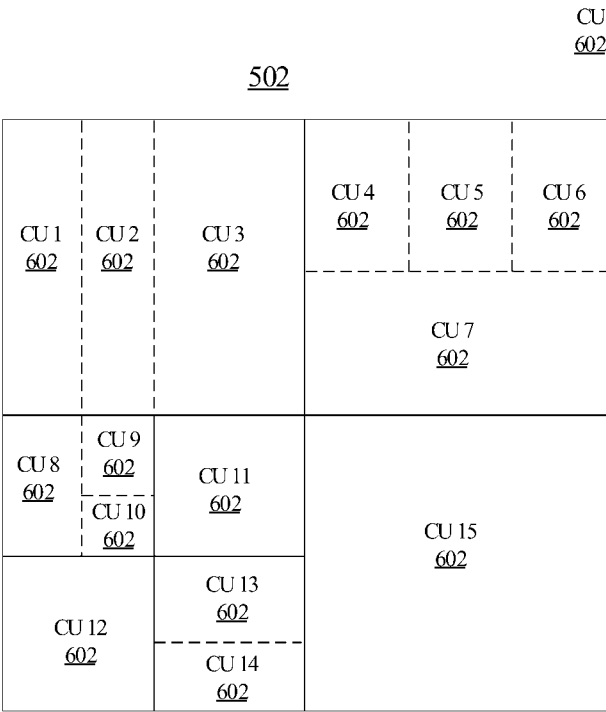


FIG. 6

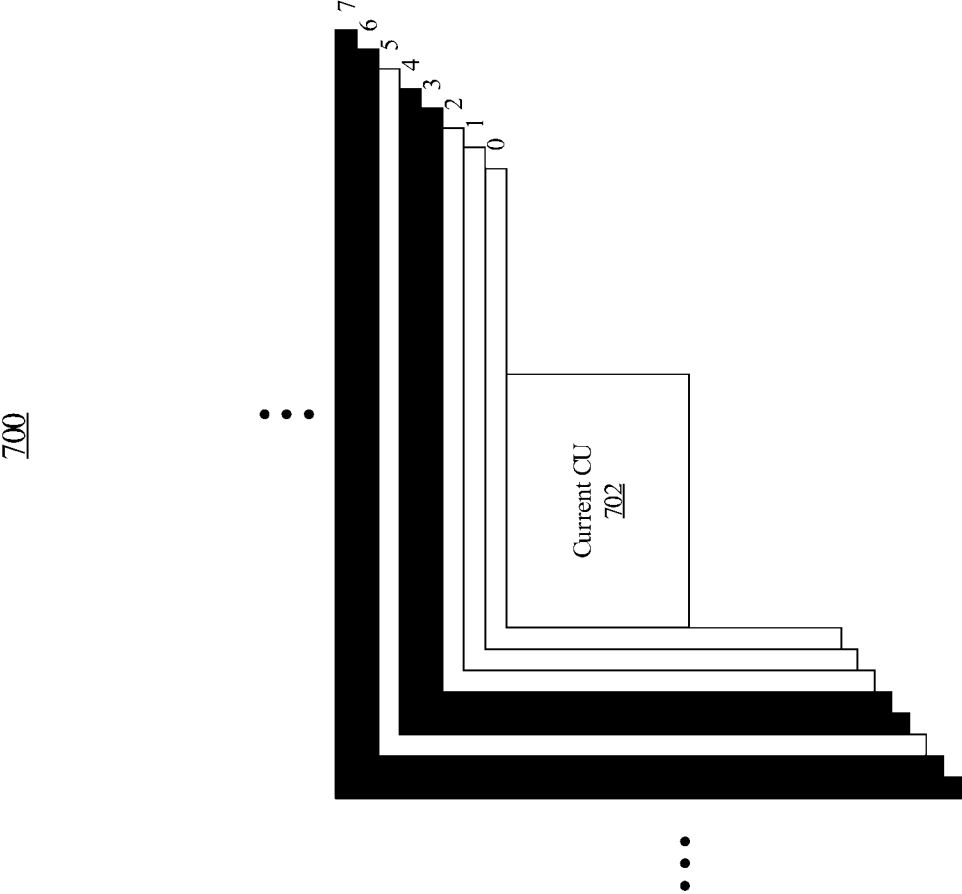


FIG. 7

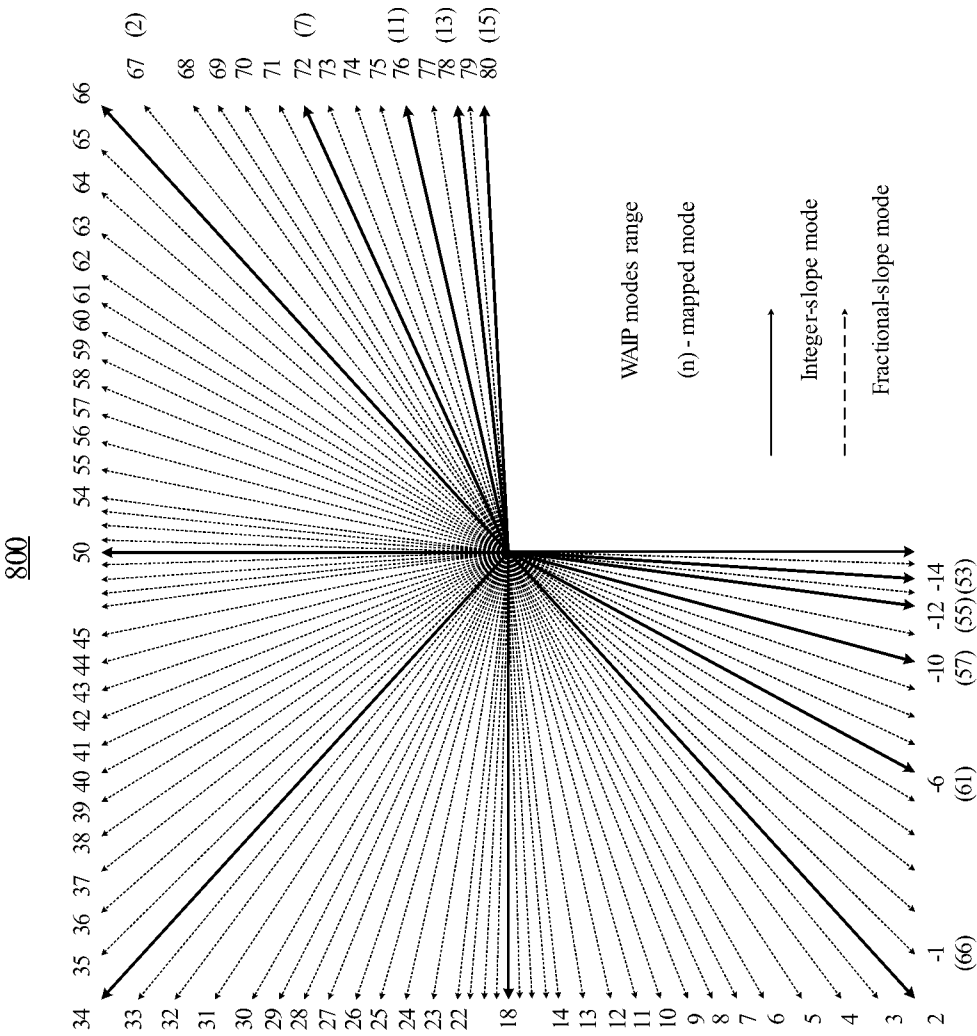


FIG. 8

900

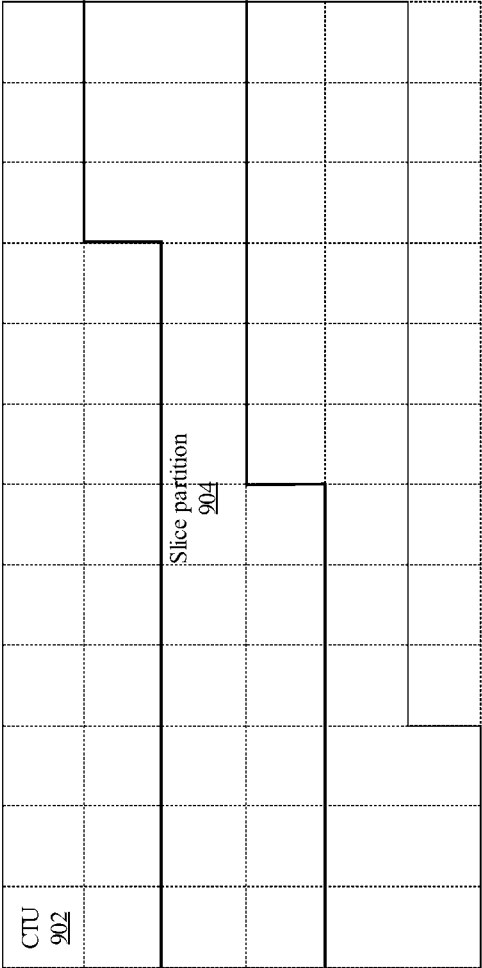


FIG. 9A

901

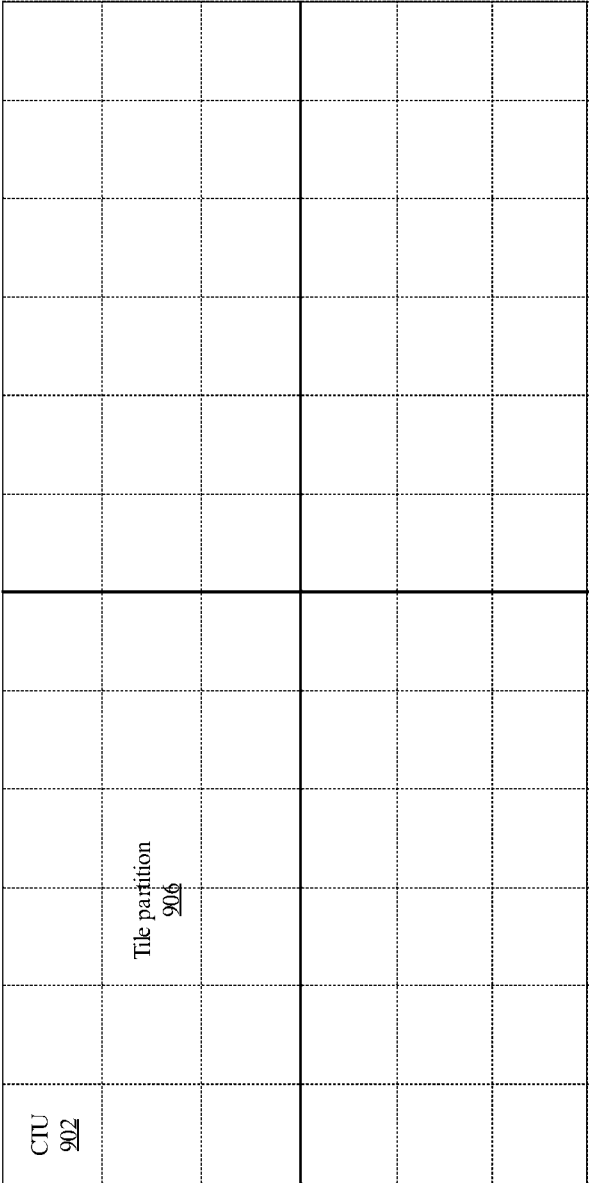


FIG. 9B

903

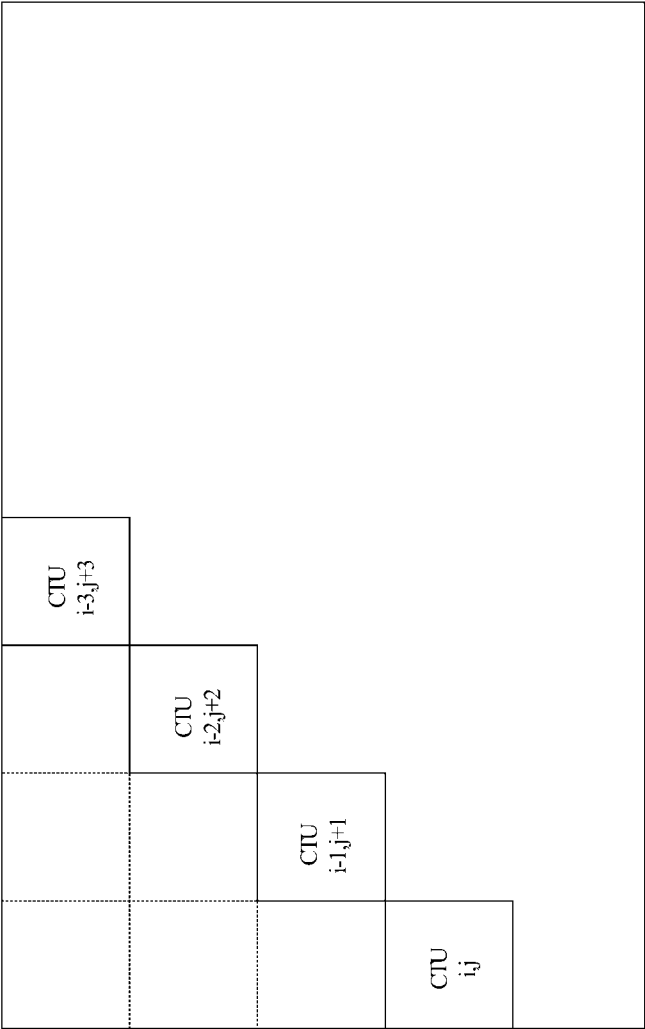


FIG. 9C

1000

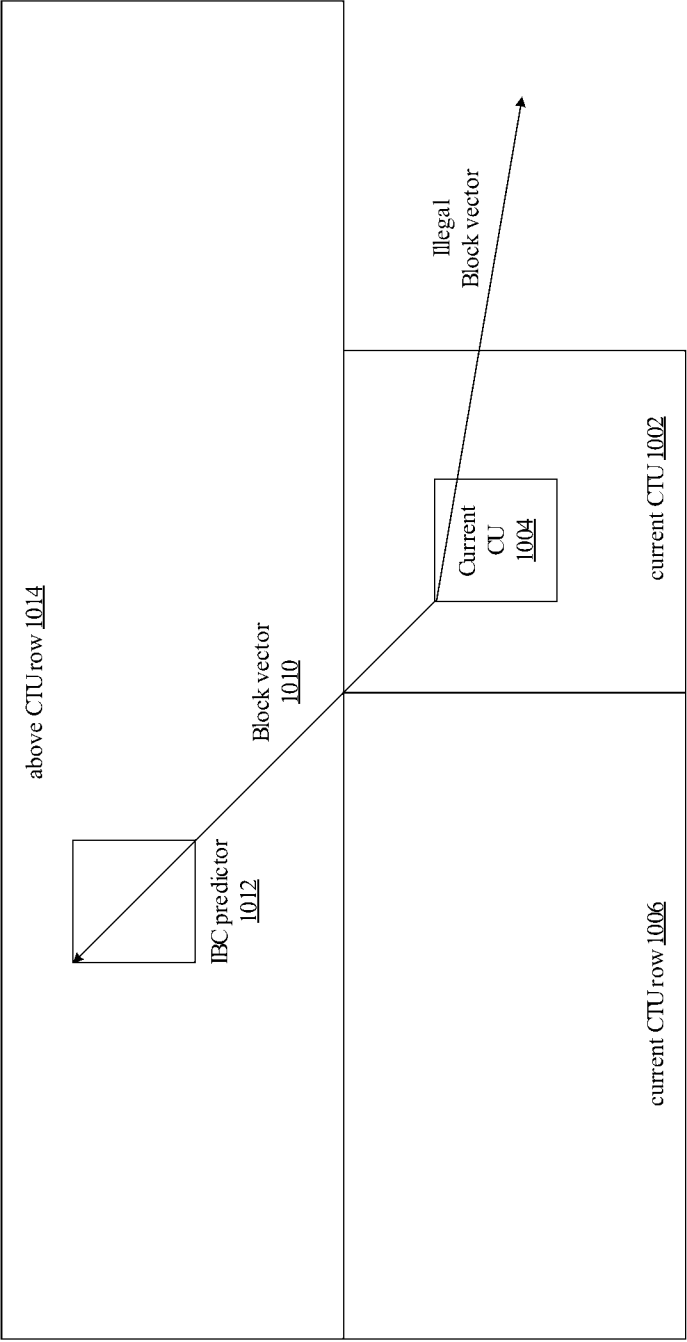


FIG. 10A

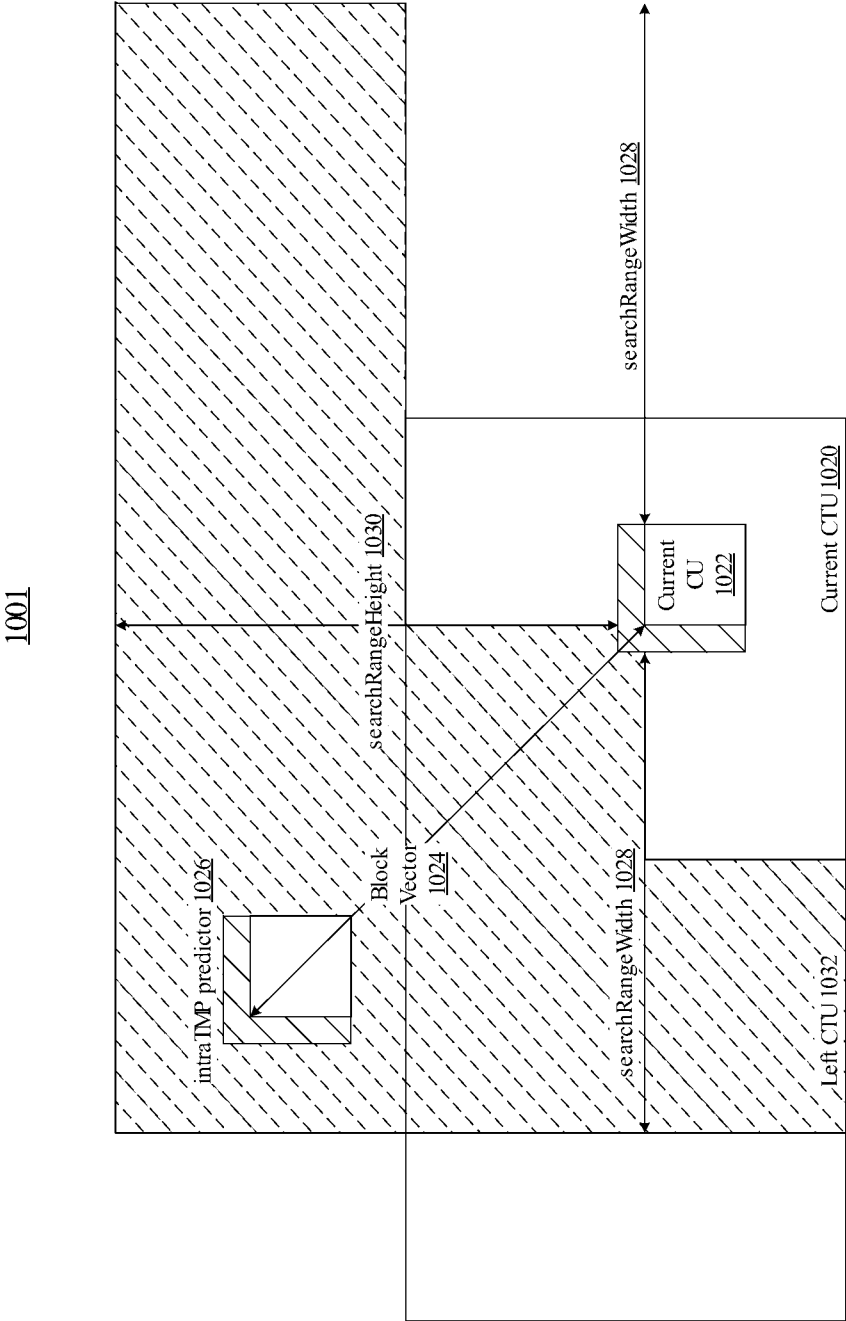


FIG. 10B

1003

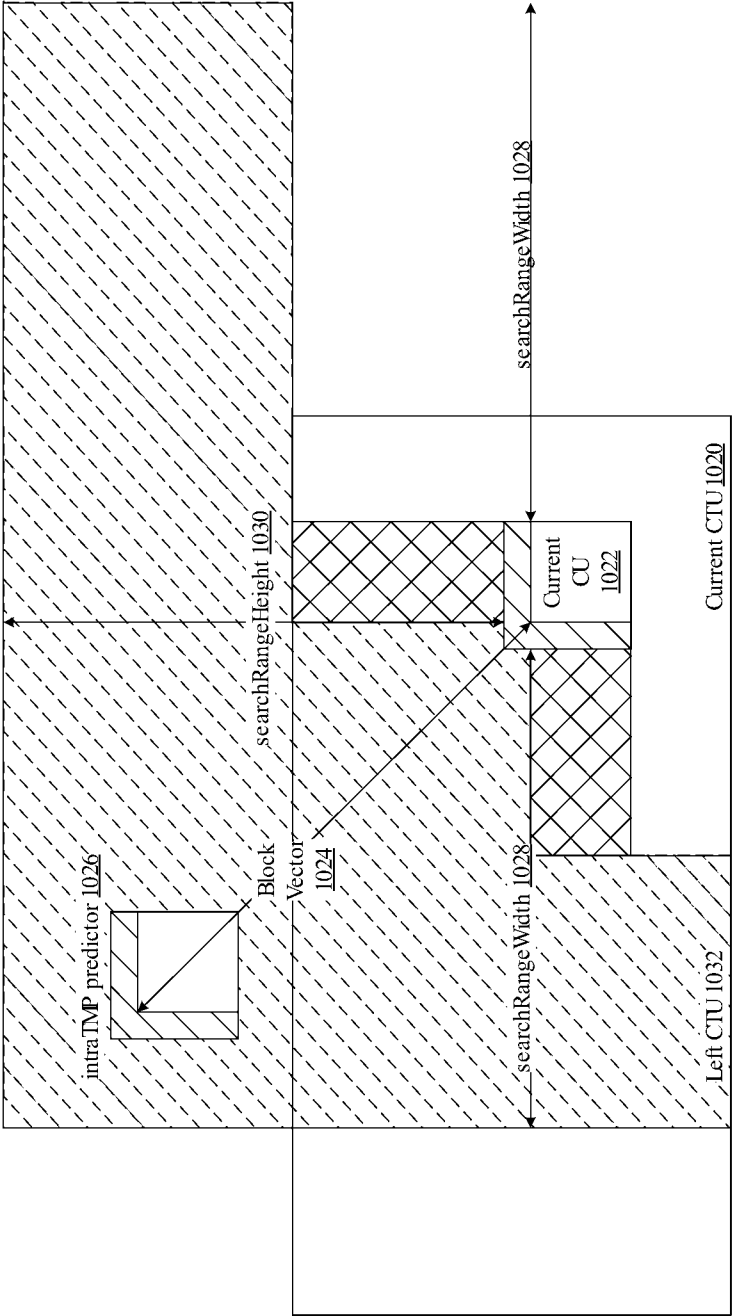
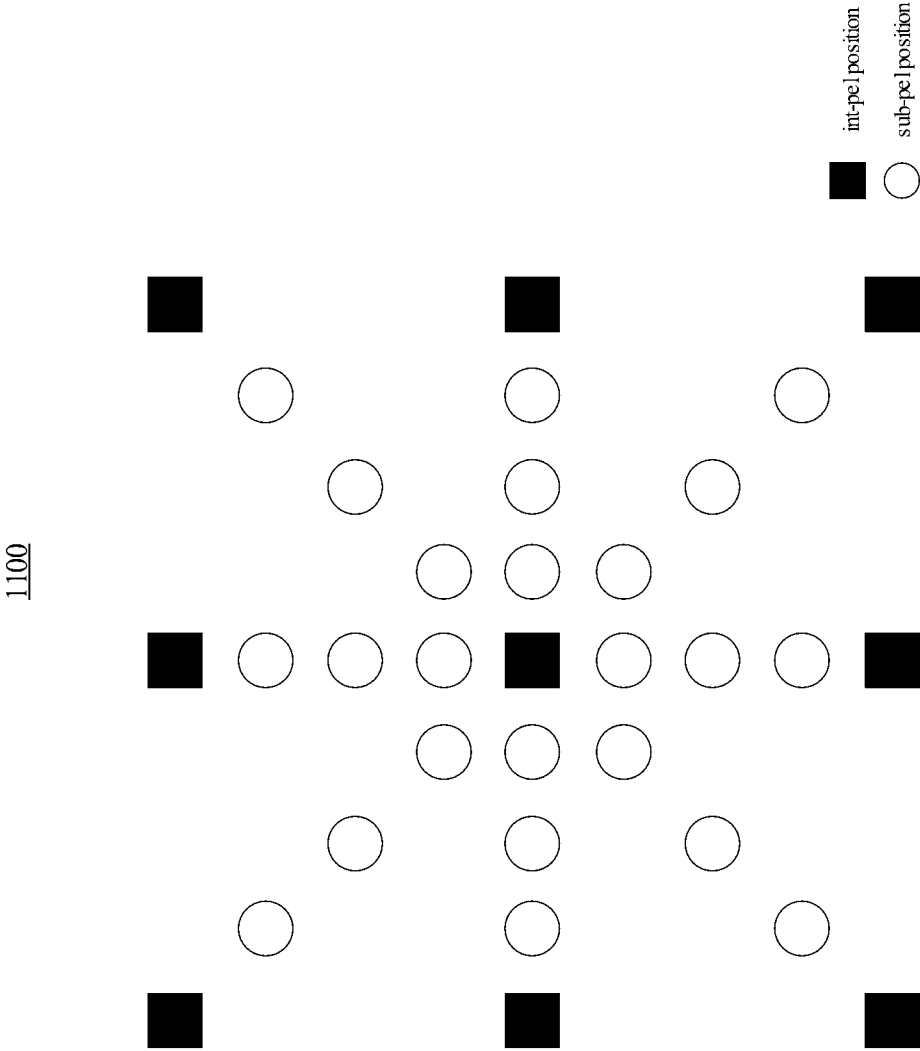


FIG. 10C



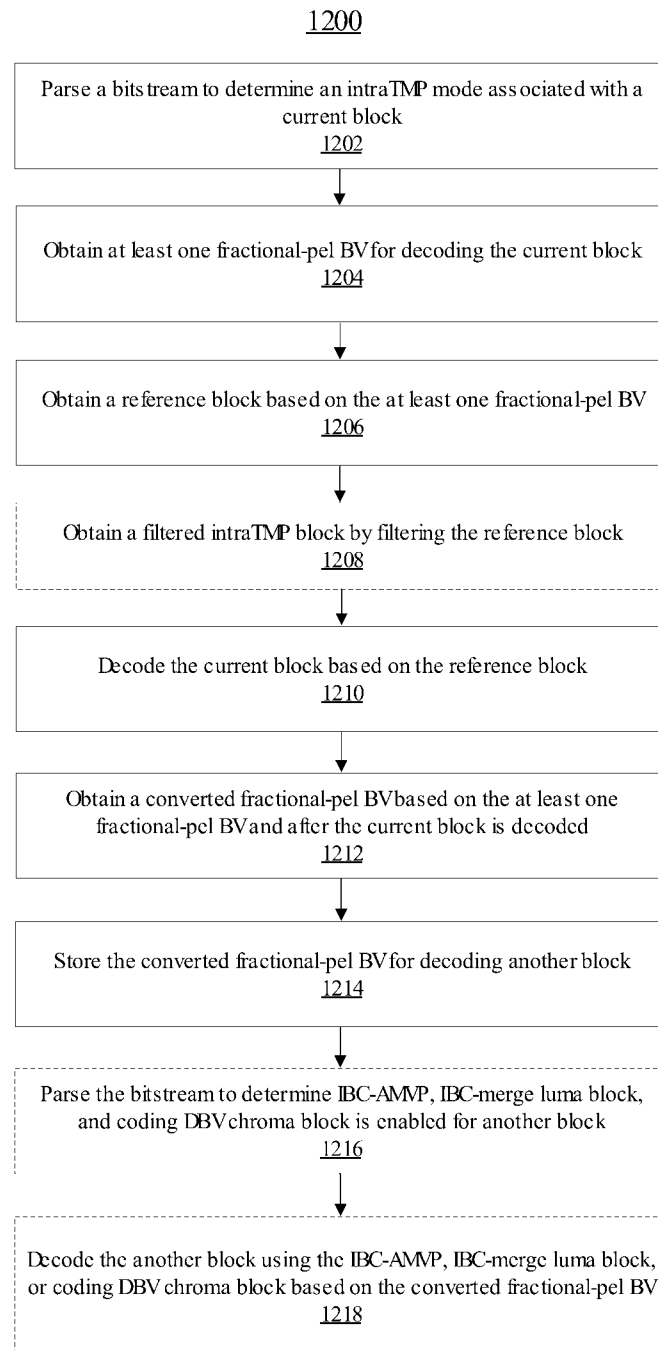


FIG. 12

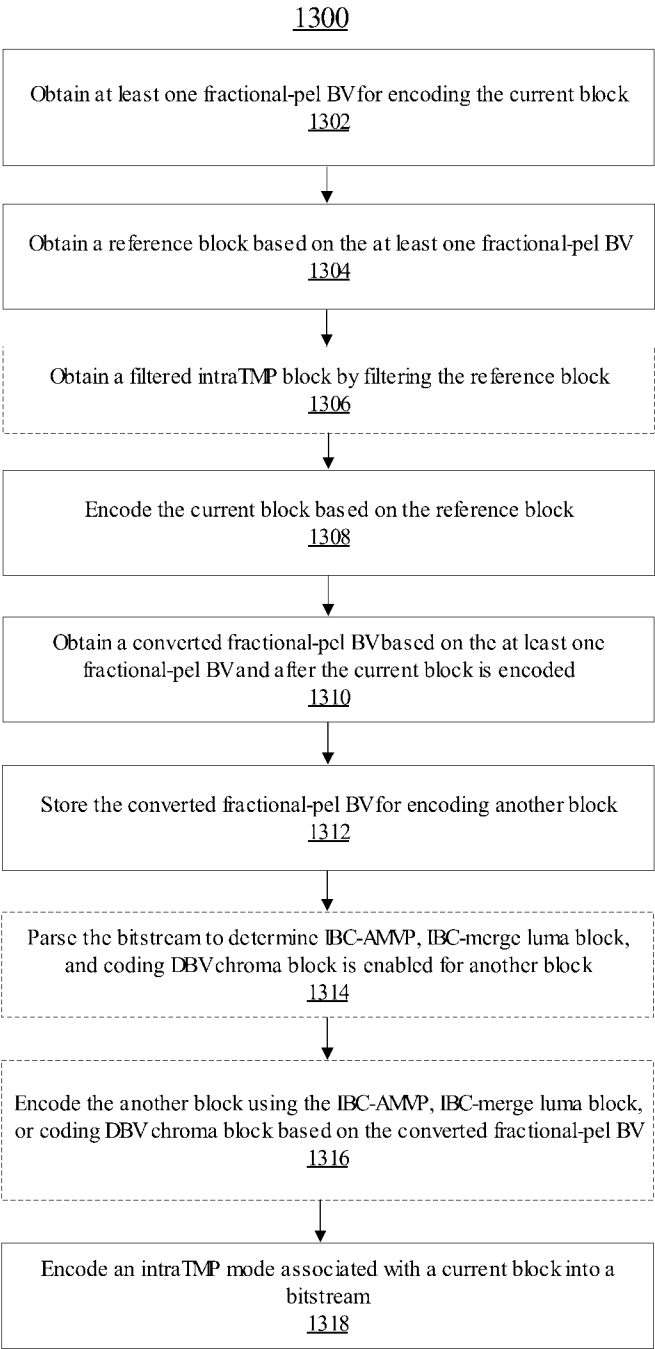


FIG. 13

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2024/099443

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                |                                                                                       |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
| <b>A. CLASSIFICATION OF SUBJECT MATTER</b><br>H04N19/105(2014.01)i<br><br>According to International Patent Classification (IPC) or to both national classification and IPC                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                |                                                                                       |
| <b>B. FIELDS SEARCHED</b><br><br>Minimum documentation searched (classification system followed by classification symbols)<br>IPC: H04N<br><br>Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched<br><br>Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)<br>CNTXT,ENTXTC,CNKI,ENTXT,JVET:IntraTMP,intra TMP, fractional pel, block vector, BV, convert+, stor???, sav???, decod +, encod+                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                                |                                                                                       |
| <b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                |                                                                                       |
| Category*                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Citation of document, with indication, where appropriate, of the relevant passages                                                                                                                             | Relevant to claim No.                                                                 |
| PX                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Yue Yu et al. "Non-EE2: On IntraTMP block vector"<br><i>Joint Video Experts Team (JVET) of ITU-T SG 16 WP 3 and ISO/IEC JTC 1/SC 29: JVET-AE0075-v3</i> , 19 July 2023 (2023-07-19),<br>pages 1-2              | 1-23                                                                                  |
| A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Xinwei Li et al. "EE2-1.12: Intra TMP with sub-pel precision"<br><i>Joint Video Experts Team (JVET) of ITU-T SG 16 WP 3 and ISO/IEC JTC 1/SC 29: JVET-AD0125-v1</i> , 28 April 2023 (2023-04-28),<br>pages 1-3 | 1-23                                                                                  |
| A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | CN 116074537 A (ZHEJIANG DAHUA TECHNOLOGY CO., LTD.) 05 May 2023<br>(2023-05-05)<br>the whole document                                                                                                         | 1-23                                                                                  |
| A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | CN 114424533 A (OPPO GUANGDONG MOBILE TELECOM CORP. LTD.) 29 April 2022<br>(2022-04-29)<br>the whole document                                                                                                  | 1-23                                                                                  |
| A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | US 2015103915 A1 (SONY CORP.) 16 April 2015 (2015-04-16)<br>the whole document                                                                                                                                 | 1-23                                                                                  |
| <input type="checkbox"/> Further documents are listed in the continuation of Box C. <input checked="" type="checkbox"/> See patent family annex.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                                                                                |                                                                                       |
| <p>* Special categories of cited documents:</p> <p>“A” document defining the general state of the art which is not considered to be of particular relevance</p> <p>“D” document cited by the applicant in the international application</p> <p>“E” earlier application or patent but published on or after the international filing date</p> <p>“L” document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>“O” document referring to an oral disclosure, use, exhibition or other means</p> <p>“P” document published prior to the international filing date but later than the priority date claimed</p> <p>“T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>“X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone</p> <p>“Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art</p> <p>“&amp;” document member of the same patent family</p> |                                                                                                                                                                                                                |                                                                                       |
| Date of the actual completion of the international search<br><b>13 September 2024</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                                                                                                                                                | Date of mailing of the international search report<br><b>19 September 2024</b>        |
| Name and mailing address of the ISA/CN<br><b>CHINA NATIONAL INTELLECTUAL PROPERTY ADMINISTRATION<br/>6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing<br/>100088, China</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                | Authorized officer<br><br><b>ZHANG,ZhiHua</b><br><br>Telephone No. (+86) 010-62089470 |

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Information on patent family members

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