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Signaling of maximum transform size and residual coding method

Abstract

The present disclosure provides systems and methods for signaling a maximum transform size and a residual coding method. According to certain disclosed embodiments, the methods include: receiving a bitstream comprising a set of pictures, determining, according to the received bitstream, a value of a coded tree block size; and determining, based on the value of the coded tree block size, whether to signal a flag indicating a maximum transform size for luma samples.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS (1) The present disclosure claims priority to U.S. provisional application No. 62/980,117, filed on Feb. 21, 2020, which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

(1) The present disclosure generally relates to video processing, and more particularly, to methods and apparatuses for signaling a maximum transform size and a residual coding method.

BACKGROUND

(2) A video is a set of static pictures (or “frames”) capturing the visual information. To reduce the storage memory and the transmission bandwidth, a video can be compressed before storage or transmission and decompressed before display. The compression process is usually referred to as encoding and the decompression process is usually referred to as decoding. There are various video coding formats which use standardized video coding technologies, most commonly based on prediction, transform, quantization, entropy coding and in-loop filtering. The video coding standards, such as the High Efficiency Video Coding (HEVC/H.265) standard, the Versatile Video Coding (VVC/H.266) standard, and AVS standards, specifying the specific video coding formats, are developed by standardization organizations. With more and more advanced video coding technologies being adopted in the video standards, the coding efficiency of the new video coding standards get higher and higher.

SUMMARY OF THE DISCLOSURE

(3) The embodiments of the present disclosure provide a method and apparatus for signaling a maximum transform size. In some exemplary embodiments, the method includes: receiving a bitstream comprising a set of pictures, determining, according to the received bitstream, a value of a coded tree block size; and determining, based on the value of the coded tree block size, whether to signal a flag indicating a maximum transform size for luma samples.

(4) The apparatus can include a memory storing a set of instructions; and one or more processors configured to execute the set of instructions to cause the apparatus to perform: receiving a bitstream comprising a set of pictures, determining, according to the received bitstream, a value of a coded tree block size; and determining, based on the value of the coded tree block size, whether to signal a flag indicating a maximum transform size for luma samples.

(5) The embodiments of the present disclosure further provide a non-transitory computer readable

medium that stores a set of instructions that is executable by at least one processor of a computer to cause the computer to perform a method for signaling a maximum transform size, the method comprising: receiving a bitstream comprising a set of pictures, determining, according to the received bitstream, a value of a coded tree block size; and determining, based on the value of the coded tree block size, whether to signal a flag indicating a maximum transform size for luma samples.

(6) The embodiments of the present disclosure also provide a method and apparatus for signaling a residual coding method. In some exemplary embodiments, the method includes: receiving a bitstream comprising a set of pictures, determining, according to the received bitstream, a value of a first flag indicating whether a transform skip mode is enabled; and determining, based on the value of the first flag, whether to signal a second flag indicating a residual coding method.

(7) The apparatus can include a memory storing a set of instructions; and one or more processors configured to execute the set of instructions to cause the apparatus to perform: receiving a bitstream comprising a set of pictures, determining, according to the received bitstream, a value of a first flag indicating whether a transform skip mode is enabled; and determining, based on the value of the first flag, whether to signal a second flag indicating a residual coding method.

(8) The embodiments of the present disclosure further provide a non-transitory computer readable medium that stores a set of instructions that is executable by at least one processor of a computer to cause the computer to perform a method for signaling a residual coding method, the method comprising: receiving a bitstream comprising a set of pictures, determining, according to the received bitstream, a value of a first flag indicating whether a transform skip mode is enabled; and determining, based on the value of the first flag, whether to signal a second flag indicating a residual coding method.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) Embodiments and various aspects of the present disclosure are illustrated in the following detailed description and the accompanying figures. Various features shown in the figures are not drawn to scale.

(2) FIG. 1 is a schematic diagram illustrating structures of an example video sequence, consistent with some embodiments of the present disclosure.

(3) FIG. 2A is a schematic diagram illustrating an exemplary encoding process of a hybrid video coding system, consistent with some embodiments of the present disclosure.

(4) FIG. 2B is a schematic diagram illustrating another exemplary encoding process of a hybrid video coding system, consistent with some embodiments of the present disclosure.

(5) FIG. 3A is a schematic diagram illustrating an exemplary decoding process of a hybrid video coding system, consistent with some embodiments of the present disclosure.

(6) FIG. 3B is a schematic diagram illustrating another exemplary decoding process of a hybrid video coding system, consistent with some embodiments of the present disclosure.

(7) FIG. 4 is a block diagram of an exemplary apparatus for encoding or decoding a video, consistent with some embodiments of the present disclosure.

(8) FIG. 5A is an exemplary method for signaling a maximum transform size, consistent with some embodiments of the present disclosure.

(9) FIG. 5B is an exemplary method for signaling a maximum transform size, consistent with some embodiments of the present disclosure.

(10) FIG. 6A is an exemplary method for signaling a residual coding method, consistent with some embodiments of the present disclosure.

(11) FIG. 6B is an exemplary method for signaling a residual coding method, consistent with some

embodiments of the present disclosure.

DETAILED DESCRIPTION

(12) Reference will now be made in detail to exemplary embodiments, examples of which are illustrated in the accompanying drawings. The following description refers to the accompanying drawings in which the same numbers in different drawings represent the same or similar elements unless otherwise represented. The implementations set forth in the following description of exemplary embodiments do not represent all implementations consistent with the invention. Instead, they are merely examples of apparatuses and methods consistent with aspects related to the invention as recited in the appended claims. Particular aspects of the present disclosure are described in greater detail below. The terms and definitions provided herein control, if in conflict with terms and/or definitions incorporated by reference.

(13) The Joint Video Experts Team (JVET) of the ITU-T Video Coding Expert Group (ITU-T VCEG) and the ISO/IEC Moving Picture Expert Group (ISO/IEC MPEG) is currently developing the Versatile Video Coding (VVC/H.266) standard. The VVC standard is aimed at doubling the compression efficiency of its predecessor, the High Efficiency Video Coding (HEVC/H.265) standard. In other words, VVC's goal is to achieve the same subjective quality as HEVC/H.265 using half the bandwidth.

(14) To achieve the same subjective quality as HEVC/H.265 using half the bandwidth, the JVET has been developing technologies beyond HEVC using the joint exploration model (JEM) reference software. As coding technologies were incorporated into the JEM, the JEM achieved substantially higher coding performance than HEVC.

(15) The VVC standard has been developed recent, and continues to include more coding technologies that provide better compression performance. VVC is based on the same hybrid video coding system that has been used in modern video compression standards such as HEVC, H.264/AVC, MPEG2, H.263, etc.

(16) A video is a set of static pictures (or “frames”) arranged in a temporal sequence to store visual information. A video capture device (e.g., a camera) can be used to capture and store those pictures in a temporal sequence, and a video playback device (e.g., a television, a computer, a smartphone, a tablet computer, a video player, or any end-user terminal with a function of display) can be used to display such pictures in the temporal sequence. Also, in some applications, a video capturing device can transmit the captured video to the video playback device (e.g., a computer with a monitor) in real-time, such as for surveillance, conferencing, or live broadcasting.

(17) For reducing the storage space and the transmission bandwidth needed by such applications, the video can be compressed before storage and transmission and decompressed before the display. The compression and decompression can be implemented by software executed by a processor (e.g., a processor of a generic computer) or specialized hardware. The module for compression is generally referred to as an “encoder,” and the module for decompression is generally referred to as a “decoder.” The encoder and decoder can be collectively referred to as a “codec.” The encoder and decoder can be implemented as any of a variety of suitable hardware, software, or a combination thereof. For example, the hardware implementation of the encoder and decoder can include circuitry, such as one or more microprocessors, digital signal processors (DSPs), application-specific integrated circuits (ASICs), field-programmable gate arrays (FPGAs), discrete logic, or any combinations thereof. The software implementation of the encoder and decoder can include program codes, computer-executable instructions, firmware, or any suitable computer-implemented algorithm or process fixed in a computer-readable medium. Video compression and decompression can be implemented by various algorithms or standards, such as MPEG-1, MPEG-2, MPEG-4, H.26x series, or the like. In some applications, the codec can decompress the video from a first coding standard and re-compress the decompressed video using a second coding standard, in which case the codec can be referred to as a “transcoder.”

(18) The video encoding process can identify and keep useful information that can be used to

reconstruct a picture and disregard unimportant information for the reconstruction. If the disregarded, unimportant information cannot be fully reconstructed, such an encoding process can be referred to as “lossy.” Otherwise, it can be referred to as “lossless.” Most encoding processes are lossy, which is a tradeoff to reduce the needed storage space and the transmission bandwidth.

(19) The useful information of a picture being encoded (referred to as a “current picture”) include changes with respect to a reference picture (e.g., a picture previously encoded and reconstructed). Such changes can include position changes, luminosity changes, or color changes of the pixels, among which the position changes are mostly concerned. Position changes of a group of pixels that represent an object can reflect the motion of the object between the reference picture and the current picture.

(20) A picture coded without referencing another picture (i.e., it is its own reference picture) is referred to as an “I-picture.” A picture coded using a previous picture as a reference picture is referred to as a “P-picture.” A picture coded using both a previous picture and a future picture as reference pictures (i.e., the reference is “bi-directional”) is referred to as a “B-picture.”

(21) FIG. 1 illustrates structures of an example video sequence **100**, according to some embodiments of the present disclosure. Video sequence **100** can be a live video or a video having been captured and archived. Video **100** can be a real-life video, a computer-generated video (e.g., computer game video), or a combination thereof (e.g., a real-life video with augmented-reality effects). Video sequence **100** can be inputted from a video capture device (e.g., a camera), a video archive (e.g., a video file stored in a storage device) containing previously captured video, or a video feed interface (e.g., a video broadcast transceiver) to receive video from a video content provider.

(22) As shown in FIG. 1, video sequence **100** can include a series of pictures arranged temporally along a timeline, including pictures **102**, **104**, **106**, and **108**. Pictures **102-106** are continuous, and there are more pictures between pictures **106** and **108**. In FIG. 1, picture **102** is an I-picture, the reference picture of which is picture **102** itself. Picture **104** is a P-picture, the reference picture of which is picture **102**, as indicated by the arrow. Picture **106** is a B-picture, the reference pictures of which are pictures **104** and **108**, as indicated by the arrows. In some embodiments, the reference picture of a picture (e.g., picture **104**) can be not immediately preceding or following the picture. For example, the reference picture of picture **104** can be a picture preceding picture **102**. It should be noted that the reference pictures of pictures **102-106** are only examples, and the present disclosure does not limit embodiments of the reference pictures as the examples shown in FIG. 1.

(23) Typically, video codecs do not encode or decode an entire picture at one time due to the computing complexity of such tasks. Rather, they can split the picture into basic segments, and encode or decode the picture segment by segment. Such basic segments are referred to as basic processing units (“BPUs”) in the present disclosure. For example, structure **110** in FIG. 1 shows an example structure of a picture of video sequence **100** (e.g., any of pictures **102-108**). In structure **110**, a picture is divided into 4×4 basic processing units, the boundaries of which are shown as dash lines. In some embodiments, the basic processing units can be referred to as “macroblocks” in some video coding standards (e.g., MPEG family, H.261, H.263, or H.264/AVC), or as “coding tree units” (“CTUs”) in some other video coding standards (e.g., H.265/HEVC or H.266/VVC). The basic processing units can have variable sizes in a picture, such as 128×128, 64×64, 32×32, 16×16, 4×8, 16×32, or any arbitrary shape and size of pixels. The sizes and shapes of the basic processing units can be selected for a picture based on the balance of coding efficiency and levels of details to be kept in the basic processing unit. A CTU is the largest block unit and can include as many as 128×128 luma samples (plus the corresponding chroma samples depending on the chroma format). A CTU may be further partitioned into coding units (CUs) using quad-tree, binary tree, ternary tree, or a combination thereof.

(24) The basic processing units can be logical units, which can include a group of different types of video data stored in a computer memory (e.g., in a video frame buffer). For example, a basic

processing unit of a color picture can include a luma component (Y) representing achromatic brightness information, one or more chroma components (e.g., Cb and Cr) representing color information, and associated syntax elements, in which the luma and chroma components can have the same size of the basic processing unit. The luma and chroma components can be referred to as “coding tree blocks” (“CTBs”) in some video coding standards (e.g., H.265/HEVC or H.266/VVC). Any operation performed to a basic processing unit can be repeatedly performed to each of its luma and chroma components.

(25) Video coding has multiple stages of operations, examples of which are shown in FIGS. 2A-2B and FIGS. 3A-3B. For each stage, the size of the basic processing units can still be too large for processing, and thus can be further divided into segments referred to as “basic processing sub-units” in the present disclosure. In some embodiments, the basic processing sub-units can be referred to as “blocks” in some video coding standards (e.g., MPEG family, H.261, H.263, or H.264/AVC), or as “coding units” (“CUs”) in some other video coding standards (e.g., H.265/HEVC or H.266/VVC). A basic processing sub-unit can have the same or smaller size than the basic processing unit. Similar to the basic processing units, basic processing sub-units are also logical units, which can include a group of different types of video data (e.g., Y, Cb, Cr, and associated syntax elements) stored in a computer memory (e.g., in a video frame buffer). Any operation performed to a basic processing sub-unit can be repeatedly performed to each of its luma and chroma components. It should be noted that such division can be performed to further levels depending on processing needs. It should also be noted that different stages can divide the basic processing units using different schemes.

(26) For example, at a mode decision stage (an example of which is shown in FIG. 2B), the encoder can decide what prediction mode (e.g., intra-picture prediction or inter-picture prediction) to use for a basic processing unit, which can be too large to make such a decision. The encoder can split the basic processing unit into multiple basic processing sub-units (e.g., CUs as in H.265/HEVC or H.266/VVC), and decide a prediction type for each individual basic processing sub-unit.

(27) For another example, at a prediction stage (an example of which is shown in FIGS. 2A-2B), the encoder can perform prediction operation at the level of basic processing sub-units (e.g., CUs). However, in some cases, a basic processing sub-unit can still be too large to process. The encoder can further split the basic processing sub-unit into smaller segments (e.g., referred to as “prediction blocks” or “PBs” in H.265/HEVC or H.266/VVC), at the level of which the prediction operation can be performed.

(28) For another example, at a transform stage (an example of which is shown in FIGS. 2A-2B), the encoder can perform a transform operation for residual basic processing sub-units (e.g., CUs). However, in some cases, a basic processing sub-unit can still be too large to process. The encoder can further split the basic processing sub-unit into smaller segments (e.g., referred to as “transform blocks” or “TBs” in H.265/HEVC or H.266/VVC), at the level of which the transform operation can be performed. It should be noted that the division schemes of the same basic processing sub-unit can be different at the prediction stage and the transform stage. For example, in H.265/HEVC or H.266/VVC, the prediction blocks and transform blocks of the same CU can have different sizes and numbers.

(29) In structure **110** of FIG. **1**, basic processing unit **112** is further divided into 3×3 basic processing sub-units, the boundaries of which are shown as dotted lines. Different basic processing units of the same picture can be divided into basic processing sub-units in different schemes.

(30) In some implementations, to provide the capability of parallel processing and error resilience to video encoding and decoding, a picture can be divided into regions for processing, such that, for a region of the picture, the encoding or decoding process can depend on no information from any other region of the picture. In other words, each region of the picture can be processed independently. By doing so, the codec can process different regions of a picture in parallel, thus

increasing the coding efficiency. Also, when data of a region is corrupted in the processing or lost in network transmission, the codec can correctly encode or decode other regions of the same picture without reliance on the corrupted or lost data, thus providing the capability of error resilience. In some video coding standards, a picture can be divided into different types of regions. For example, H.265/HEVC and H.266/VVC provide two types of regions: “slices” and “tiles.” It should also be noted that different pictures of video sequence **100** can have different partition schemes for dividing a picture into regions.

(31) For example, in FIG. **1**, structure **110** is divided into three regions **114**, **116**, and **118**, the boundaries of which are shown as solid lines inside structure **110**. Region **114** includes four basic processing units. Each of regions **116** and **118** includes six basic processing units. It should be noted that the basic processing units, basic processing sub-units, and regions of structure **110** in FIG. **1** are only examples, and the present disclosure does not limit embodiments thereof.

(32) FIG. **2A** illustrates a schematic diagram of an example encoding process **200A**, consistent with embodiments of the disclosure. For example, the encoding process **200A** can be performed by an encoder. As shown in FIG. **2A**, the encoder can encode video sequence **202** into video bitstream **228** according to process **200A**. Similar to video sequence **100** in FIG. **1**, video sequence **202** can include a set of pictures (referred to as “original pictures”) arranged in a temporal order. Similar to structure **110** in FIG. **1**, each original picture of video sequence **202** can be divided by the encoder into basic processing units, basic processing sub-units, or regions for processing. In some embodiments, the encoder can perform process **200A** at the level of basic processing units for each original picture of video sequence **202**. For example, the encoder can perform process **200A** in an iterative manner, in which the encoder can encode a basic processing unit in one iteration of process **200A**. In some embodiments, the encoder can perform process **200A** in parallel for regions (e.g., regions **114-118**) of each original picture of video sequence **202**.

(33) In FIG. **2A**, the encoder can feed a basic processing unit (referred to as an “original BPU”) of an original picture of video sequence **202** to prediction stage **204** to generate prediction data **206** and predicted BPU **208**. The encoder can subtract predicted BPU **208** from the original BPU to generate residual BPU **210**. The encoder can feed residual BPU **210** to transform stage **212** and quantization stage **214** to generate quantized transform coefficients **216**. The encoder can feed prediction data **206** and quantized transform coefficients **216** to binary coding stage **226** to generate video bitstream **228**. Components **202**, **204**, **206**, **208**, **210**, **212**, **214**, **216**, **226**, and **228** can be referred to as a “forward path.” During process **200A**, after quantization stage **214**, the encoder can feed quantized transform coefficients **216** to inverse quantization stage **218** and inverse transform stage **220** to generate reconstructed residual BPU **222**. The encoder can add reconstructed residual BPU **222** to predicted BPU **208** to generate prediction reference **224**, which is used in prediction stage **204** for the next iteration of process **200A**. Components **218**, **220**, **222**, and **224** of process **200A** can be referred to as a “reconstruction path.” The reconstruction path can be used to ensure that both the encoder and the decoder use the same reference data for prediction.

(34) The encoder can perform process **200A** iteratively to encode each original BPU of the original picture (in the forward path) and generate predicted reference **224** for encoding the next original BPU of the original picture (in the reconstruction path). After encoding all original BPUs of the original picture, the encoder can proceed to encode the next picture in video sequence **202**.

(35) Referring to process **200A**, the encoder can receive video sequence **202** generated by a video capturing device (e.g., a camera). The term “receive” used herein can refer to receiving, inputting, acquiring, retrieving, obtaining, reading, accessing, or any action in any manner for inputting data.

(36) At prediction stage **204**, at a current iteration, the encoder can receive an original BPU and prediction reference **224**, and perform a prediction operation to generate prediction data **206** and predicted BPU **208**. Prediction reference **224** can be generated from the reconstruction path of the previous iteration of process **200A**. The purpose of prediction stage **204** is to reduce information redundancy by extracting prediction data **206** that can be used to reconstruct the original BPU as

predicted BPU **208** from prediction data **206** and prediction reference **224**.

(37) Ideally, predicted BPU **208** can be identical to the original BPU. However, due to non-ideal prediction and reconstruction operations, predicted BPU **208** is generally slightly different from the original BPU. For recording such differences, after generating predicted BPU **208**, the encoder can subtract it from the original BPU to generate residual BPU **210**. For example, the encoder can subtract values (e.g., greyscale values or RGB values) of pixels of predicted BPU **208** from values of corresponding pixels of the original BPU. Each pixel of residual BPU **210** can have a residual value as a result of such subtraction between the corresponding pixels of the original BPU and predicted BPU **208**. Compared with the original BPU, prediction data **206** and residual BPU **210** can have fewer bits, but they can be used to reconstruct the original BPU without significant quality deterioration. Thus, the original BPU is compressed.

(38) To further compress residual BPU **210**, at transform stage **212**, the encoder can reduce spatial redundancy of residual BPU **210** by decomposing it into a set of two-dimensional “base patterns,” each base pattern being associated with a “transform coefficient.” The base patterns can have the same size (e.g., the size of residual BPU **210**). Each base pattern can represent a variation frequency (e.g., frequency of brightness variation) component of residual BPU **210**. None of the base patterns can be reproduced from any combinations (e.g., linear combinations) of any other base patterns. In other words, the decomposition can decompose variations of residual BPU **210** into a frequency domain. Such a decomposition is analogous to a discrete Fourier transform of a function, in which the base patterns are analogous to the base functions (e.g., trigonometry functions) of the discrete Fourier transform, and the transform coefficients are analogous to the coefficients associated with the base functions.

(39) Different transform algorithms can use different base patterns. Various transform algorithms can be used at transform stage **212**, such as, for example, a discrete cosine transform, a discrete sine transform, or the like. The transform at transform stage **212** is invertible. That is, the encoder can restore residual BPU **210** by an inverse operation of the transform (referred to as an “inverse transform”). For example, to restore a pixel of residual BPU **210**, the inverse transform can be multiplying values of corresponding pixels of the base patterns by respective associated coefficients and adding the products to produce a weighted sum. For a video coding standard, both the encoder and decoder can use the same transform algorithm (thus the same base patterns). Thus, the encoder can record only the transform coefficients, from which the decoder can reconstruct residual BPU **210** without receiving the base patterns from the encoder. Compared with residual BPU **210**, the transform coefficients can have fewer bits, but they can be used to reconstruct residual BPU **210** without significant quality deterioration. Thus, residual BPU **210** is further compressed.

(40) The encoder can further compress the transform coefficients at quantization stage **214**. In the transform process, different base patterns can represent different variation frequencies (e.g., brightness variation frequencies). Because human eyes are generally better at recognizing low-frequency variation, the encoder can disregard information of high-frequency variation without causing significant quality deterioration in decoding. For example, at quantization stage **214**, the encoder can generate quantized transform coefficients **216** by dividing each transform coefficient by an integer value (referred to as a “quantization parameter”) and rounding the quotient to its nearest integer. After such an operation, some transform coefficients of the high-frequency base patterns can be converted to zero, and the transform coefficients of the low-frequency base patterns can be converted to smaller integers. The encoder can disregard the zero-value quantized transform coefficients **216**, by which the transform coefficients are further compressed. The quantization process is also invertible, in which quantized transform coefficients **216** can be reconstructed to the transform coefficients in an inverse operation of the quantization (referred to as “inverse quantization”).

(41) Because the encoder disregards the remainders of such divisions in the rounding operation,

quantization stage **214** can be lossy. Typically, quantization stage **214** can contribute the most information loss in process **200A**. The larger the information loss is, the fewer bits the quantized transform coefficients **216** can need. For obtaining different levels of information loss, the encoder can use different values of the quantization parameter or any other parameter of the quantization process.

(42) At binary coding stage **226**, the encoder can encode prediction data **206** and quantized transform coefficients **216** using a binary coding technique, such as, for example, entropy coding, variable length coding, arithmetic coding, Huffman coding, context-adaptive binary arithmetic coding, or any other lossless or lossy compression algorithm. In some embodiments, besides prediction data **206** and quantized transform coefficients **216**, the encoder can encode other information at binary coding stage **226**, such as, for example, a prediction mode used at prediction stage **204**, parameters of the prediction operation, a transform type at transform stage **212**, parameters of the quantization process (e.g., quantization parameters), an encoder control parameter (e.g., a bitrate control parameter), or the like. The encoder can use the output data of binary coding stage **226** to generate video bitstream **228**. In some embodiments, video bitstream **228** can be further packetized for network transmission.

(43) Referring to the reconstruction path of process **200A**, at inverse quantization stage **218**, the encoder can perform inverse quantization on quantized transform coefficients **216** to generate reconstructed transform coefficients. At inverse transform stage **220**, the encoder can generate reconstructed residual BPU **222** based on the reconstructed transform coefficients. The encoder can add reconstructed residual BPU **222** to predicted BPU **208** to generate prediction reference **224** that is to be used in the next iteration of process **200A**.

(44) It should be noted that other variations of the process **200A** can be used to encode video sequence **202**. In some embodiments, stages of process **200A** can be performed by the encoder in different orders. In some embodiments, one or more stages of process **200A** can be combined into a single stage. In some embodiments, a single stage of process **200A** can be divided into multiple stages. For example, transform stage **212** and quantization stage **214** can be combined into a single stage. In some embodiments, process **200A** can include additional stages. In some embodiments, process **200A** can omit one or more stages in FIG. 2A.

(45) FIG. 2B illustrates a schematic diagram of another example encoding process **200B**, consistent with embodiments of the disclosure. Process **200B** can be modified from process **200A**. For example, process **200B** can be used by an encoder conforming to a hybrid video coding standard (e.g., H.26x series). Compared with process **200A**, the forward path of process **200B** additionally includes mode decision stage **230** and divides prediction stage **204** into spatial prediction stage **2042** and temporal prediction stage **2044**. The reconstruction path of process **200B** additionally includes loop filter stage **232** and buffer **234**.

(46) Generally, prediction techniques can be categorized into two types: spatial prediction and temporal prediction. Spatial prediction (e.g., an intra-picture prediction or “intra prediction”) can use pixels from one or more already coded neighboring BPUs in the same picture to predict the current BPU. That is, prediction reference **224** in the spatial prediction can include the neighboring BPUs. The spatial prediction can reduce the inherent spatial redundancy of the picture. Temporal prediction (e.g., an inter-picture prediction or “inter prediction”) can use regions from one or more already coded pictures to predict the current BPU. That is, prediction reference **224** in the temporal prediction can include the coded pictures. The temporal prediction can reduce the inherent temporal redundancy of the pictures.

(47) Referring to process **200B**, in the forward path, the encoder performs the prediction operation at spatial prediction stage **2042** and temporal prediction stage **2044**. For example, at spatial prediction stage **2042**, the encoder can perform the intra prediction. For an original BPU of a picture being encoded, prediction reference **224** can include one or more neighboring BPUs that have been encoded (in the forward path) and reconstructed (in the reconstructed path) in the same

picture. The encoder can generate predicted BPU **208** by extrapolating the neighboring BPUs. The extrapolation technique can include, for example, a linear extrapolation or interpolation, a polynomial extrapolation or interpolation, or the like. In some embodiments, the encoder can perform the extrapolation at the pixel level, such as by extrapolating values of corresponding pixels for each pixel of predicted BPU **208**. The neighboring BPUs used for extrapolation can be located with respect to the original BPU from various directions, such as in a vertical direction (e.g., on top of the original BPU), a horizontal direction (e.g., to the left of the original BPU), a diagonal direction (e.g., to the down-left, down-right, up-left, or up-right of the original BPU), or any direction defined in the used video coding standard. For the intra prediction, prediction data **206** can include, for example, locations (e.g., coordinates) of the used neighboring BPUs, sizes of the used neighboring BPUs, parameters of the extrapolation, a direction of the used neighboring BPUs with respect to the original BPU, or the like.

(48) For another example, at temporal prediction stage **2044**, the encoder can perform the inter prediction. For an original BPU of a current picture, prediction reference **224** can include one or more pictures (referred to as “reference pictures”) that have been encoded (in the forward path) and reconstructed (in the reconstructed path). In some embodiments, a reference picture can be encoded and reconstructed BPU by BPU. For example, the encoder can add reconstructed residual BPU **222** to predicted BPU **208** to generate a reconstructed BPU. When all reconstructed BPUs of the same picture are generated, the encoder can generate a reconstructed picture as a reference picture. The encoder can perform an operation of “motion estimation” to search for a matching region in a scope (referred to as a “search window”) of the reference picture. The location of the search window in the reference picture can be determined based on the location of the original BPU in the current picture. For example, the search window can be centered at a location having the same coordinates in the reference picture as the original BPU in the current picture and can be extended out for a predetermined distance. When the encoder identifies (e.g., by using a pel-recursive algorithm, a block-matching algorithm, or the like) a region similar to the original BPU in the search window, the encoder can determine such a region as the matching region. The matching region can have different dimensions (e.g., being smaller than, equal to, larger than, or in a different shape) from the original BPU. Because the reference picture and the current picture are temporally separated in the timeline (e.g., as shown in FIG. **1**), it can be deemed that the matching region “moves” to the location of the original BPU as time goes by. The encoder can record the direction and distance of such a motion as a “motion vector.” When multiple reference pictures are used (e.g., as picture **106** in FIG. **1**), the encoder can search for a matching region and determine its associated motion vector for each reference picture. In some embodiments, the encoder can assign weights to pixel values of the matching regions of respective matching reference pictures.

(49) The motion estimation can be used to identify various types of motions, such as, for example, translations, rotations, zooming, or the like. For inter prediction, prediction data **206** can include, for example, locations (e.g., coordinates) of the matching region, the motion vectors associated with the matching region, the number of reference pictures, weights associated with the reference pictures, or the like.

(50) For generating predicted BPU **208**, the encoder can perform an operation of “motion compensation.” The motion compensation can be used to reconstruct predicted BPU **208** based on prediction data **206** (e.g., the motion vector) and prediction reference **224**. For example, the encoder can move the matching region of the reference picture according to the motion vector, in which the encoder can predict the original BPU of the current picture. When multiple reference pictures are used (e.g., as picture **106** in FIG. **1**), the encoder can move the matching regions of the reference pictures according to the respective motion vectors and average pixel values of the matching regions. In some embodiments, if the encoder has assigned weights to pixel values of the matching regions of respective matching reference pictures, the encoder can add a weighted sum of the pixel values of the moved matching regions.

(51) In some embodiments, the inter prediction can be unidirectional or bidirectional.

Unidirectional inter predictions can use one or more reference pictures in the same temporal direction with respect to the current picture. For example, picture **104** in FIG. **1** is a unidirectional inter-predicted picture, in which the reference picture (e.g., picture **102**) precedes picture **104**. Bidirectional inter predictions can use one or more reference pictures at both temporal directions with respect to the current picture. For example, picture **106** in FIG. **1** is a bidirectional inter-predicted picture, in which the reference pictures (e.g., pictures **104** and **108**) are at both temporal directions with respect to picture **104**.

(52) Still referring to the forward path of process **200B**, after spatial prediction **2042** and temporal prediction stage **2044**, at mode decision stage **230**, the encoder can select a prediction mode (e.g., one of the intra prediction or the inter prediction) for the current iteration of process **200B**. For example, the encoder can perform a rate-distortion optimization technique, in which the encoder can select a prediction mode to minimize a value of a cost function depending on a bit rate of a candidate prediction mode and distortion of the reconstructed reference picture under the candidate prediction mode. Depending on the selected prediction mode, the encoder can generate the corresponding predicted BPU **208** and predicted data **206**.

(53) In the reconstruction path of process **200B**, if intra prediction mode has been selected in the forward path, after generating prediction reference **224** (e.g., the current BPU that has been encoded and reconstructed in the current picture), the encoder can directly feed prediction reference **224** to spatial prediction stage **2042** for later usage (e.g., for extrapolation of a next BPU of the current picture). If the inter prediction mode has been selected in the forward path, after generating prediction reference **224** (e.g., the current picture in which all BPUs have been encoded and reconstructed), the encoder can feed prediction reference **224** to loop filter stage **232**, at which the encoder can apply a loop filter to prediction reference **224** to reduce or eliminate distortion (e.g., blocking artifacts) introduced by the inter prediction. The encoder can apply various loop filter techniques at loop filter stage **232**, such as, for example, deblocking, sample adaptive offsets, adaptive loop filters, or the like. The loop-filtered reference picture can be stored in buffer **234** (or “decoded picture buffer”) for later use (e.g., to be used as an inter-prediction reference picture for a future picture of video sequence **202**). The encoder can store one or more reference pictures in buffer **234** to be used at temporal prediction stage **2044**. In some embodiments, the encoder can encode parameters of the loop filter (e.g., a loop filter strength) at binary coding stage **226**, along with quantized transform coefficients **216**, prediction data **206**, and other information.

(54) FIG. **3A** illustrates a schematic diagram of an example decoding process **300A**, consistent with embodiments of the disclosure. Process **300A** can be a decompression process corresponding to the compression process **200A** in FIG. **2A**. In some embodiments, process **300A** can be similar to the reconstruction path of process **200A**. A decoder can decode video bitstream **228** into video stream **304** according to process **300A**. Video stream **304** can be very similar to video sequence **202**. However, due to the information loss in the compression and decompression process (e.g., quantization stage **214** in FIGS. **2A-2B**), generally, video stream **304** is not identical to video sequence **202**. Similar to processes **200A** and **200B** in FIGS. **2A-2B**, the decoder can perform process **300A** at the level of basic processing units (BPUs) for each picture encoded in video bitstream **228**. For example, the decoder can perform process **300A** in an iterative manner, in which the decoder can decode a basic processing unit in one iteration of process **300A**. In some embodiments, the decoder can perform process **300A** in parallel for regions (e.g., regions **114-118**) of each picture encoded in video bitstream **228**.

(55) In FIG. **3A**, the decoder can feed a portion of video bitstream **228** associated with a basic processing unit (referred to as an “encoded BPU”) of an encoded picture to binary decoding stage **302**. At binary decoding stage **302**, the decoder can decode the portion into prediction data **206** and quantized transform coefficients **216**. The decoder can feed quantized transform coefficients **216** to inverse quantization stage **218** and inverse transform stage **220** to generate reconstructed residual

BPU **222**. The decoder can feed prediction data **206** to prediction stage **204** to generate predicted BPU **208**. The decoder can add reconstructed residual BPU **222** to predicted BPU **208** to generate predicted reference **224**. In some embodiments, predicted reference **224** can be stored in a buffer (e.g., a decoded picture buffer in a computer memory). The decoder can feed predicted reference **224** to prediction stage **204** for performing a prediction operation in the next iteration of process **300A**.

(56) The decoder can perform process **300A** iteratively to decode each encoded BPU of the encoded picture and generate predicted reference **224** for encoding the next encoded BPU of the encoded picture. After decoding all encoded BPUs of the encoded picture, the decoder can output the picture to video stream **304** for display and proceed to decode the next encoded picture in video bitstream **228**.

(57) At binary decoding stage **302**, the decoder can perform an inverse operation of the binary coding technique used by the encoder (e.g., entropy coding, variable length coding, arithmetic coding, Huffman coding, context-adaptive binary arithmetic coding, or any other lossless compression algorithm). In some embodiments, besides prediction data **206** and quantized transform coefficients **216**, the decoder can decode other information at binary decoding stage **302**, such as, for example, a prediction mode, parameters of the prediction operation, a transform type, parameters of the quantization process (e.g., quantization parameters), an encoder control parameter (e.g., a bitrate control parameter), or the like. In some embodiments, if video bitstream **228** is transmitted over a network in packets, the decoder can depacketize video bitstream **228** before feeding it to binary decoding stage **302**.

(58) FIG. **3B** illustrates a schematic diagram of another example decoding process **300B**, consistent with embodiments of the disclosure. Process **300B** can be modified from process **300A**. For example, process **300B** can be used by a decoder conforming to a hybrid video coding standard (e.g., H.26x series). Compared with process **300A**, process **300B** additionally divides prediction stage **204** into spatial prediction stage **2042** and temporal prediction stage **2044**, and additionally includes loop filter stage **232** and buffer **234**.

(59) In process **300B**, for an encoded basic processing unit (referred to as a “current BPU”) of an encoded picture (referred to as a “current picture”) that is being decoded, prediction data **206** decoded from binary decoding stage **302** by the decoder can include various types of data, depending on what prediction mode was used to encode the current BPU by the encoder. For example, if intra prediction was used by the encoder to encode the current BPU, prediction data **206** can include a prediction mode indicator (e.g., a flag value) indicative of the intra prediction, parameters of the intra prediction operation, or the like. The parameters of the intra prediction operation can include, for example, locations (e.g., coordinates) of one or more neighboring BPUs used as a reference, sizes of the neighboring BPUs, parameters of extrapolation, a direction of the neighboring BPUs with respect to the original BPU, or the like. For another example, if inter prediction was used by the encoder to encode the current BPU, prediction data **206** can include a prediction mode indicator (e.g., a flag value) indicative of the inter prediction, parameters of the inter prediction operation, or the like. The parameters of the inter prediction operation can include, for example, the number of reference pictures associated with the current BPU, weights respectively associated with the reference pictures, locations (e.g., coordinates) of one or more matching regions in the respective reference pictures, one or more motion vectors respectively associated with the matching regions, or the like.

(60) Based on the prediction mode indicator, the decoder can decide whether to perform a spatial prediction (e.g., the intra prediction) at spatial prediction stage **2042** or a temporal prediction (e.g., the inter prediction) at temporal prediction stage **2044**. The details of performing such spatial prediction or temporal prediction are described in FIG. **2B** and will not be repeated hereinafter. After performing such spatial prediction or temporal prediction, the decoder can generate predicted BPU **208**. The decoder can add predicted BPU **208** and reconstructed residual BPU **222** to generate

prediction reference **224**, as described in FIG. **3A**.

(61) In process **300B**, the decoder can feed predicted reference **224** to spatial prediction stage **2042** or temporal prediction stage **2044** for performing a prediction operation in the next iteration of process **300B**. For example, if the current BPU is decoded using the intra prediction at spatial prediction stage **2042**, after generating prediction reference **224** (e.g., the decoded current BPU), the decoder can directly feed prediction reference **224** to spatial prediction stage **2042** for later usage (e.g., for extrapolation of a next BPU of the current picture). If the current BPU is decoded using the inter prediction at temporal prediction stage **2044**, after generating prediction reference **224** (e.g., a reference picture in which all BPUs have been decoded), the encoder can feed prediction reference **224** to loop filter stage **232** to reduce or eliminate distortion (e.g., blocking artifacts). The decoder can apply a loop filter to prediction reference **224**, in a way as described in FIG. **2B**. The loop-filtered reference picture can be stored in buffer **234** (e.g., a decoded picture buffer in a computer memory) for later use (e.g., to be used as an inter-prediction reference picture for a future encoded picture of video bitstream **228**). The decoder can store one or more reference pictures in buffer **234** to be used at temporal prediction stage **2044**. In some embodiments, when the prediction mode indicator of prediction data **206** indicates that inter prediction was used to encode the current BPU, prediction data can further include parameters of the loop filter (e.g., a loop filter strength).

(62) FIG. **4** is a block diagram of an example apparatus **400** for encoding or decoding a video, consistent with embodiments of the disclosure. As shown in FIG. **4**, apparatus **400** can include processor **402**. When processor **402** executes instructions described herein, apparatus **400** can become a specialized machine for video encoding or decoding. Processor **402** can be any type of circuitry capable of manipulating or processing information. For example, processor **402** can include any combination of any number of a central processing unit (or “CPU”), a graphics processing unit (or “GPU”), a neural processing unit (“NPU”), a microcontroller unit (“MCU”), an optical processor, a programmable logic controller, a microcontroller, a microprocessor, a digital signal processor, an intellectual property (IP) core, a Programmable Logic Array (PLA), a Programmable Array Logic (PAL), a Generic Array Logic (GAL), a Complex Programmable Logic Device (CPLD), a Field-Programmable Gate Array (FPGA), a System On Chip (SoC), an Application-Specific Integrated Circuit (ASIC), or the like. In some embodiments, processor **402** can also be a set of processors grouped as a single logical component. For example, as shown in FIG. **4**, processor **402** can include multiple processors, including processor **402a**, processor **402b**, and processor **402n**.

(63) Apparatus **400** can also include memory **404** configured to store data (e.g., a set of instructions, computer codes, intermediate data, or the like). For example, as shown in FIG. **4**, the stored data can include program instructions (e.g., program instructions for implementing the stages in processes **200A**, **200B**, **300A**, or **300B**) and data for processing (e.g., video sequence **202**, video bitstream **228**, or video stream **304**). Processor **402** can access the program instructions and data for processing (e.g., via bus **410**), and execute the program instructions to perform an operation or manipulation on the data for processing. Memory **404** can include a high-speed random-access storage device or a non-volatile storage device. In some embodiments, memory **404** can include any combination of any number of a random-access memory (RAM), a read-only memory (ROM), an optical disc, a magnetic disk, a hard drive, a solid-state drive, a flash drive, a security digital (SD) card, a memory stick, a compact flash (CF) card, or the like. Memory **404** can also be a group of memories (not shown in FIG. **4**) grouped as a single logical component.

(64) Bus **410** can be a communication device that transfers data between components inside apparatus **400**, such as an internal bus (e.g., a CPU-memory bus), an external bus (e.g., a universal serial bus port, a peripheral component interconnect express port), or the like.

(65) For ease of explanation without causing ambiguity, processor **402** and other data processing circuits are collectively referred to as a “data processing circuit” in this disclosure. The data

processing circuit can be implemented entirely as hardware, or as a combination of software, hardware, or firmware. In addition, the data processing circuit can be a single independent module or can be combined entirely or partially into any other component of apparatus **400**.

(66) Apparatus **400** can further include network interface **406** to provide wired or wireless communication with a network (e.g., the Internet, an intranet, a local area network, a mobile communications network, or the like). In some embodiments, network interface **406** can include any combination of any number of a network interface controller (NIC), a radio frequency (RF) module, a transponder, a transceiver, a modem, a router, a gateway, a wired network adapter, a wireless network adapter, a Bluetooth adapter, an infrared adapter, an near-field communication (“NFC”) adapter, a cellular network chip, or the like.

(67) In some embodiments, optionally, apparatus **400** can further include peripheral interface **408** to provide a connection to one or more peripheral devices. As shown in FIG. **4**, the peripheral device can include, but is not limited to, a cursor control device (e.g., a mouse, a touchpad, or a touchscreen), a keyboard, a display (e.g., a cathode-ray tube display, a liquid crystal display, or a light-emitting diode display), a video input device (e.g., a camera or an input interface coupled to a video archive), or the like.

(68) It should be noted that video codecs (e.g., a codec performing process **200A**, **200B**, **300A**, or **300B**) can be implemented as any combination of any software or hardware modules in apparatus **400**. For example, some or all stages of process **200A**, **200B**, **300A**, or **300B** can be implemented as one or more software modules of apparatus **400**, such as program instructions that can be loaded into memory **404**. For another example, some or all stages of process **200A**, **200B**, **300A**, or **300B** can be implemented as one or more hardware modules of apparatus **400**, such as a specialized data processing circuit (e.g., an FPGA, an ASIC, an NPU, or the like).

(69) In a first reference embodiment, a sequence parameter set (SPS) syntax element `sps_max_luma_transform_size_64_flag` is signaled to specify the maximum transform size. `sps_max_luma_transform_size_64_flag` equal to 1 specifies that the maximum transform size in luma samples is equal to 64. `sps_max_luma_transform_size_64_flag` equal to 0 specifies that the maximum transform size in luma samples is equal to 32. In the first reference embodiment, the `sps_max_luma_transform_size_64_flag` is always signaled regardless of the value of the coded tree block size (`CtbSizeY`). However, `sps_max_luma_transform_size_64_flag` is not required to be signaled and can be inferred to be 0 if `CtbSizeY` is less than 64.

(70) Moreover, in a second reference embodiment, a slice level residual coding selection method can be used. The following are exemplary semantics of the `slice_ts_residual_coding_disabled_flag`:

(71) `slice_ts_residual_coding_disabled_flag` equal to 1 specifies that the `residual_coding ()` syntax structure is used to parse the residual samples of a transform skip block for the current slice.

`slice_ts_residual_coding_disabled_flag` equal to 0 specifies that the `residual_ts_coding ()` syntax structure is used to parse the residual samples of a transform skip block for the current slice. When `slice_ts_residual_coding_disabled_flag` is not present, it is inferred to be equal to 0.

(72) In the second reference embodiment, the `slice_ts_residual_coding_disabled_flag` is always signaled. However, because the `slice_ts_residual_coding_disabled_flag` specifies the residual coding method of transform skip mode, if the transform skip mode is disabled at the SPS level, it is not required to signal `slice_ts_residual_coding_disabled_flag` in the slice header and can be inferred to be 0.

(73) The present disclosure provides methods and apparatus to reduce the above-described coding redundancy.

(74) FIG. **5A** is an exemplary method for signaling a maximum transform size, consistent with some embodiments of the present disclosure. In some embodiments, method **500A** can be performed by an encoder, a decoder, and one or more software or hardware components of an apparatus (e.g., apparatus **400** of FIG. **4**). For example, a processor (e.g., processor **402** of FIG. **4**) can perform method **500A**. In some embodiments, method **500A** can be implemented by a

computer program product, embodied in a computer-readable medium, including computer-executable instructions, such as program code, executed by computers (e.g., apparatus **400** of FIG. **4**). The method can include the following steps.

(75) In step **501**, a bitstream comprising a set of pictures is received. As described, a basic processing unit of a color picture can include a luma component (Y) representing achromatic brightness information, one or more chroma components (e.g., Cb and Cr) representing color information, and associated syntax elements, in which the luma and chroma components can have the same size of the basic processing unit. The luma and chroma components can be referred to as “coding tree blocks” (“CTBs”) in some video coding standards (e.g., H.265/HEVC or H.266/VVC). Any operation performed to a basic processing unit can be repeatedly performed to each of its luma and chroma components.

(76) In step **503**, a value of a coded tree block size is determined according to the received bitstream. The value of the coded tree block size is signaled in the received bitstream. For example, a value of CtbSizeY in exemplary semantics is determined.

(77) In step **505**, whether to signal a flag indicating a maximum transform size for luma samples is determined based on the value of the coded tree block size. For example, a sequence parameter set (SPS) syntax element `sps_max_luma_transform_size_64_flag` can be used for specifying the maximum transform size. `sps_max_luma_transform_size_64_flag` equal to 1 specifies that the maximum transform size in luma samples is equal to 64. `sps_max_luma_transform_size_64_flag` equal to 0 specifies that the maximum transform size in luma samples is equal to 32.

(78) In some embodiments, step **505** can include steps **505-1**, **505-3**, and **505-5** as shown in FIG. **5B**.

(79) In step **505-1**, whether the value of the coded tree block size satisfying a first condition or satisfying a second condition is determined according to the received bitstream.

(80) In some embodiments, the first condition can be the value being greater than 32, and the second condition can be the value being less than or equal to 32. Satisfying the first condition can lead to signaling the flag indicating the maximum transform size. Otherwise, satisfying the second condition can lead to a determination that the flag is not signaled.

(81) In step **505-3**, in response to the value of the coded tree block size being greater than 32, the flag is signaled.

(82) An exemplary SPS syntax is described below in Table 1. In some exemplary embodiments for signaling the maximum transform size, `sps_max_luma_transform_size_64_flag` is signaled only when CtbSizeY is greater than 32. Table 1 shows a part of an exemplary SPS syntax table for signaling a maximum transform size, according to some disclosed embodiments. In Table 1, the line with “if (CtbSizeY>32)” shows changes to the syntax used for the first reference embodiment. As described, in the first reference embodiment, the `sps_max_luma_transform_size_64_flag` is always signaled regardless of the value of the coded tree block size (CtbSizeY). In contrast, according to some embodiments of the present disclosure, the `sps_max_luma_transform_size_64_flag` is not always signaled. As shown in Table 1, signaling of the `sps_max_luma_transform_size_64_flag` is conditioned to CtbSizeY.

(83) TABLE-US-00001 TABLE 1 Exemplary SPS syntax table of disclosed method for signaling maximum transform size

if(qtbtt_dual_tree_intra_flag) {	
sps_log2_diff_min_qt_min_cb_intra_slice_chroma ue(v)	
sps_max_mtt_hierarchy_depth_intra_slice_chroma ue(v)	if(
sps_max_mtt_hierarchy_depth_intra_slice_chroma != 0) {	sps_log2
diff_max_bt_min_qt_intra_slice_chroma ue(v)	
sps_log2_diff_max_tt_min_qt_intra_slice_chroma ue(v)	} }
if (CtbSizeY > 32)	
sps_max_luma_transform_size_64_flag u(1)	if(ChromaArrayType != 0) {
sps_joint_cbr_enabled_flag u(1)	same_qp_table_for_chroma u(1)
same_qp_table_for_chroma ? 1 : (sps_joint_cbr_enabled_flag ? 3 : 2)	numQpTables =
	for(i = 0; i <


```

numQpTables; i++) {          qp_table_start_minus26[ i ] se(v)
num_points_in_qp_table_minus1[ i ] ue(v)          for( j = 0; j <=
num_points_in_qp_table_minus1[ i ]; j++) {          delta_qp_in_val_minus1[ i ][ j ] ue(v)
          delta_qp_diff_val[ i ][ j ] ue(v)          }          }          }

```

(84) In step 505-5, in response to the value of the coded tree block size being less than or equal to 32, it is determined that the flag is not signaled.

(85) In the signaling method consistent with Table 1, if the CtbSize Y is not greater than 32, the value of sps_max_luma_transform_size_64_flag is inferred to be 0. The semantics for deriving CtbSizeY are shown below.

(86) TABLE-US-00002 sps_log2_ctu_size_minus plus 5 specifies the luma coding tree block size of each CTU. The value of sps_log2_ctu_size_minus5 shall be in the range of 0 to 2, inclusive. The value 3 for sps_log2_ctu_size_minus5 is reserved for future use by ITU-T | ISO/IEC. The variables CtbLog2SizeY and CtbSizeY are derived as follows: $CtbLog2SizeY = sps_log2_ctu_size_minus5 + 5$ $CtbSizeY = 1 \ll CtbLog2SizeY$

(87) In some embodiments, the first condition and the second condition can be different from what is described above. In the example below, the first condition can be the value being not equal to 32, and the second condition can be the value being equal to 32.

(88) In an alternative step of step 505-3, in response to the value of the coded tree block size being not equal to 32, the flag is signaled.

(89) In an alternative step of step 505-5, in response to the value of the coded tree block size being equal to 32, it is determined that the flag is not signaled.

(90) An exemplary syntax is described as follows. The proposed syntax change shown in Table 1 can also be implemented using the condition “CtbSizeY!=32” instead of “CtbSizeY>32”. In this case: sps_max_luma_transform_size_64_flag is signaled if CtbSizeY is not equal to 32; and sps_max_luma_transform_size_64_flag is inferred to be 0 if CtbSizeY is equal to 32.

(91) An exemplary syntax is described as follows. The proposed syntax change shown in Table 1 can also be implemented using the condition “CtbSizeY>64” instead of “CtbSizeY>32”. In this case: sps_max_luma_transform_size_64_flag is signaled if CtbSizeY is greater or equal to 64; and sps_max_luma_transform_size_64_flag is inferred to be 0 if CtbSizeY is less than 64. In other words, the sps_max_luma_transform_size_64_flag is only required to signal if CtbSizeY is larger than 32. If CtbSizeY is not larger than 32, sps_max_luma_transform_size_64 flag is not signaled and inferred to be equal to 0. alternatively, sps_max_luma_transform_size_64_flag is only signaled if CtbSizeY is greater or equal to 64. If CtbSizeY is less than 64, sps_max_luma_transform_size_64_flag is not signaled and inferred to be equal to 0.

(92) In some exemplary embodiments for signaling the maximum transform size, instead of using CtbSizeY, signaling of the sps_max_luma_transform_size_64_flag is conditioned to sps_log2_ctu_size_minus5. As described above, sps_log2_ctu_size_minus5 plus 5 specifies the luma coding tree block size of each Coded Tree Unit (CTU). A CTU can be as large as 128×128 luma samples (plus the corresponding chroma samples depending on the chroma format). Table 2 below shows a part of an exemplary SPS syntax table for signaling a maximum transform size, according to some disclosed embodiments. In Table 2, the line with “if

(sps_log2_ctu_size_minus5>0)” shows changes to the syntax used for the first reference embodiment. As described, in the first reference embodiment, the

sps_max_luma_transform_size_64 flag is always signaled regardless of the value of the coded tree block size (e.g., CtbSizeY). In contrast, according to some embodiments of the present disclosure, the sps_max_luma_transform_size_64_flag is not always signaled. As shown in Table 2, in some embodiments, signaling of the sps_max_luma_transform_size_64_flag is conditioned to sps_log2_ctu_size_minus5. As Table 2 shows, sps_max_luma_transform_size_64 flag is signaled if sps_log2_ctu_size_minus5 is greater than 0; and the value of sps_max_luma_transform_size_64_flag is inferred to be 0 if sps_log2_ctu_size_minus5 is 0.

(93) In some embodiments, the value of the coded tree block size in step **501** can further comprise a value associated with a luma coding tree block size of each coded tree unit. The value (e.g., `sps_log2_ctu_size_minus5`) can be determined according to the received bitstream.

(94) In some embodiments, in an alternative step of step **505-1**, whether the value associated with the luma coding tree block size of each coded tree unit satisfying a first condition (e.g., being greater than 0) or a second condition (e.g., being equal to 0) can be determined.

(95) In some embodiments, in an alternative step of step **505-3**, in response to the value associated with the luma coding tree block size of each coded tree unit satisfying the first condition (e.g., being greater than 0), the flag (e.g., `sps_max_luma_transform_size_64_flag`) is signaled.

(96) In some embodiments, in an alternative step of step **505-5**, in response to the value associated with the luma coding tree block size of each coded tree unit satisfying the second condition (e.g., being equal to 0), it is determined that the flag (e.g., `sps_max_luma_transform_size_64_flag`) is not signaled.

(97) TABLE-US-00003 TABLE 2 Exemplary SPS syntax table of disclosed method for signaling

```
maximum transform size    if( qtbtt_dual_tree_intra_flag ) {
sps_log2_diff_min_qt_min_cb_intra_slice_chroma ue(v)
sps_max_mtt_hierarchy_depth_intra_slice_chroma ue(v)      if(
sps_max_mtt_hierarchy_depth_intra_slice_chroma != 0 ) {
sps_log2_diff_max_bt_min_qt_intra_slice_chroma ue(v)
sps_log2_diff_max_tt_min_qt_intra_slice_chroma ue(v)      } } if
(sps_log2_ctu_size_minus5 > 0)      sps_max_luma_transform_size_64_flag u(1)  if(
ChromaArrayType != 0 ) {      sps_joint_cbr_enabled_flag u(1)      same_qp_table_for_chroma
u(1)      numQpTables = same_qp_table_for_chroma ? 1 : ( sps_joint_cbr_enabled_flag ? 3 : 2 )
      for( i = 0; i < numQpTables; i++ ) {      qp_table_start_minus26[ i ] se(v)
num_points_in_qp_table_minus1[ i ] ue(v)      for( j = 0; j <=
num_points_in_qp_table_minus1[ i ]; j++ ) {      delta_qp_in_val_minus1[ i ][ j ] ue(v)
      delta_qp_diff_val[ i ][ j ] ue(v)      }      } }
```

(98) The above syntax changes shown in Table 2 can also be implemented using the condition “`sps_log2_ctu_size_minus5!=0`”. In this case:

(99) `sps_max_luma_transform_size_64_flag` is signaled if `sps_log2_ctu_size_minus5` is not equal to 0; and `sps_max_luma_transform_size_64_flag` is inferred to be 0 if `sps_log2_ctu_size_minus5` is equal to 0.

(100) In some embodiments, the first condition can also be the value (e.g., `sps_log2_ctu_size_minus5`) being not equal to 0 as shown in the example above. In an alternative step of step **505-3**, in response to the value associated with the luma coding tree block size of each coded tree unit satisfying the first condition (e.g., `sps_log2_ctu_size_minus5!=0`), the flag (e.g., `sps_max_luma_transform_size_64_flag`) is signaled.

(101) FIG. 6 is an exemplary method for signaling a residue coding method, consistent with some embodiments of the present disclosure. In some embodiments, method **600A** can be performed by an encoder, a decoder, and one or more software or hardware components of an apparatus (e.g., apparatus **400** of FIG. 4). For example, a processor (e.g., processor **402** of FIG. 4) can perform method **600A**. In some embodiments, method **600A** can be implemented by a computer program product, embodied in a computer-readable medium, including computer-executable instructions, such as program code, executed by computers (e.g., apparatus **400** of FIG. 4). The method can include the following steps.

(102) In step **601**, a bitstream comprising a set of pictures is received. As described, a basic processing unit of a color picture can include a luma component (Y) representing achromatic brightness information, one or more chroma components (e.g., Cb and Cr) representing color information, and associated syntax elements, in which the luma and chroma components can have the same size of the basic processing unit. The luma and chroma components can be referred to as

“coding tree blocks” (“CTBs”) in some video coding standards (e.g., H.265/HEVC or H.266/VVC). Any operation performed to a basic processing unit can be repeatedly performed to each of its luma and chroma components.

(103) In step **603**, a value of a first flag indicating whether a transform skip mode is enabled is determined according to the received bitstream. The value of the first flag can be signaled in the received bitstream. For example, a value of `sps_transform_skip_enabled_flag` can be determined.

(104) In step **605**, whether to signal a second flag indicating a residual coding method is determined based on the value of the first flag. For example, the second flag can be a slice level residual coding flag. The slice level residual coding flag `slice_ts_residual_coding_disabled_flag` specifies the residual coding method of transform skip mode. If the transform skip mode is disabled at a SPS level, it is not required to signal `slice_ts_residual_coding_disabled_flag` in the slice header and can be inferred to be 0.

(105) In some embodiments, step **605** can include steps **605-1**, **605-3**, and **605-5** as shown in FIG. 6B.

(106) In step **605-1**, whether the value of the first flag satisfying a first condition or satisfying a second condition is determined according to the received bitstream.

(107) In some embodiments, the first condition can be the value of the first flag being 1, and the second condition can be the value of the first flag being 0. Satisfying the first condition can lead to signaling the second flag. Otherwise, satisfying the second condition can lead to a determination that the second flag is not signaled.

(108) In step **605-3**, in response to the value of the first flag (e.g., `sps_transform_skip_enabled_flag`) being 1, the second flag (e.g., `slice_ts_residual_coding_disabled_flag`) is signaled.

(109) In step **605-5**, in response to the value of the first flag (e.g., `sps_transform_skip_enabled_flag`) being 0, it is determined that the second flag (e.g., `slice_ts_residual_coding_disabled_flag`) is not signaled.

(110) An exemplary SPS syntax is described below in Table 3. In some exemplary embodiments for signaling the residual coding method, the slice level residual coding flag `slice_ts_residual_coding_disabled_flag` is signaled if `sps_transform_skip_enabled_flag` is equal to 1. If `sps_transform_skip_enabled_flag` is equal to 0, the value of `slice_ts_residual_coding_disabled_flag` is inferred to be 0. The semantics of the `sps_transform_skip_enabled_flag` are shown below.

(111) TABLE-US-00004 `sps_transform_skip_enabled_flag` equal to 1 specifies that `transform_skip_flag` may be present in the transform unit syntax. `sps_transform_skip_enabled_flag` equal to 0 specifies that `transform_skip_flag` is not present in the transform unit syntax.

(112) Table 3 shows a part of an exemplary slice header syntax table for signaling a residual coding method, according to some disclosed embodiments. In Table 3, the line with “if (`sps_transform_skip_enabled_flag`)” shows changes to the syntax used for the second reference embodiment. As described, in the second reference embodiment, the `slice_ts_residual_coding_disabled_flag` is always signaled. In contrast, according to some embodiments of the present disclosure, the `slice_ts_residual_coding_disabled_flag` is not always signaled. The `slice_ts_residual_coding_disabled_flag` is only signaled if `sps_transform_skip_enabled_flag` is equal to 1. If `sps_transform_skip_enabled_flag` is equal to 0, `slice_ts_residual_coding_disabled_flag` is not signaled and inferred to be equal to 0. The proposed changes can reduce the signaling overhead at the slice header level.

(113) TABLE-US-00005 TABLE 3 Exemplary slice header syntax table of disclosed method for signaling residual coding method if (`sps_transform_skip_enabled_flag`)
`slice_ts_residual_coding_disabled_flag` u(1) if(`ph_lmcs_enabled_flag`) `slice_lmcs_enabled_flag` u(1) if(`pic_scaling_list_enabled_flag`) `slice_scaling_list_present_flag` u(1)

(114) In some embodiments, a non-transitory computer-readable storage medium including

instructions is also provided, and the instructions may be executed by a device (such as the disclosed encoder and decoder), for performing the above-described methods. Common forms of non-transitory media include, for example, a floppy disk, a flexible disk, hard disk, solid state drive, magnetic tape, or any other magnetic data storage medium, a CD-ROM, any other optical data storage medium, any physical medium with patterns of holes, a RAM, a PROM, and EPROM, a FLASH-EPROM or any other flash memory, NVRAM, a cache, a register, any other memory chip or cartridge, and networked versions of the same. The device may include one or more processors (CPUs), an input/output interface, a network interface, and/or a memory.

(115) The disclosed embodiments may further be described using the following clauses:

(116) 1. A video data signaling method, comprising: receiving a bitstream comprising a set of pictures; determining, according to the received bitstream, a value of a coded tree block size; and determining, based on the value of the coded tree block size, whether to signal a flag indicating a maximum transform size for luma samples.

(117) 2. The method of clause 1, wherein determining whether to signal the flag comprises: in response to the value of the coded tree block size being greater than 32, signaling the flag; or in response to the value of the coded tree block size being less than or equal to 32, determining that the flag is not signaled.

(118) 3. The method of clause 1, wherein determining whether to signal the flag comprises: in response to the value of the coded tree block size being not equal to 32, signaling the flag; or in response to the value of the coded tree block size being equal to 32, determining that the flag is not signaled.

(119) 4. The method of clause 1, wherein the value of the coded tree block size further comprises a value associated with a luma coding tree block size of a coded tree unit.

(120) 5. The method of clause 4, wherein determining whether to signal the flag comprises: in response to the value associated with the luma coding tree block size being greater than 0, signaling the flag; or in response to the value associated with the luma coding tree block size being equal to 0, determining that the flag is not signaled.

(121) 6. The method of clause 4, wherein determining whether to signal the flag comprises: in response to the value associated with the luma coding tree block size being not equal to 0, signaling the flag; or in response to the value associated with the luma coding tree block size being equal to 0, determining that the flag is not signaled.

(122) 7. The method of any of clauses 1-6, wherein the flag indicates that the maximum transform size is 64.

(123) 8. A video data signaling method, comprising: receiving a bitstream comprising a set of pictures; determining, according to the received bitstream, a value of a first flag indicating whether a transform skip mode is enabled; and determining, based on the value of the first flag, whether to signal a second flag indicating a residual coding method.

(124) 9. The method of clause 8, wherein determining whether to signal the second flag comprises: in response to the value of the first flag being 1, signaling the second flag; or in response to the value of the first flag being 0, determining that the second flag is not signaled.

(125) 10. The method of any of clauses 8 and 9, wherein: the first flag is signaled in a sequence parameter set, and the second flag is signaled in a slice header.

(126) 11. A video data signaling apparatus comprising: a memory storing a set of instructions; and one or more processors configured to execute the set of instructions to cause the apparatus to perform: receiving a bitstream comprising a set of pictures, determining, according to the received bitstream, a value of a coded tree block size; and determining, based on the value of the coded tree block size, whether to signal a flag indicating a maximum transform size for luma samples.

(127) 12. The apparatus of clause 11, wherein in determining whether to signal the flag, the one or more processors are configured to execute the set of instructions to cause the apparatus to further perform: in response to the value of the coded tree block size being greater than 32, signaling the

flag, or in response to the value of the coded tree block size being less than or equal to 32, determining that the flag is not signaled.

(128) 13. The apparatus of clause 11, wherein in determining whether to signal the flag, the one or more processors are configured to execute the set of instructions to cause the apparatus to further perform: in response to the value of the coded tree block size being not equal to 32, signaling the flag; or in response to the value of the coded tree block size being equal to 32, determining that the flag is not signaled.

(129) 14. The apparatus of clause 11, wherein the value of the coded tree block size further comprises a value associated with a luma coding tree block size of a coded tree unit.

(130) 15. The apparatus of clause 14, wherein in determining whether to signal the flag, the one or more processors are configured to execute the set of instructions to cause the apparatus to further perform: in response to the value associated with the luma coding tree block size being greater than 0, signaling the flag; or in response to the value associated with the luma coding tree block size being equal to 0, determining that the flag is not signaled.

(131) 16. The apparatus of clause 14, wherein in determining whether to signal the flag, the one or more processors are configured to execute the set of instructions to cause the apparatus to further perform: in response to the value associated with the luma coding tree block size being not equal to 0, signaling the flag; or in response to the value associated with the luma coding tree block size being equal to 0, determining that the flag is not signaled.

(132) 17. The apparatus of any of clauses 11-16, wherein the flag indicates that the maximum transform size is 64.

(133) 18. A video data signaling apparatus comprising: a memory storing a set of instructions; and one or more processors configured to execute the set of instructions to cause the apparatus to perform: receiving a bitstream comprising a set of pictures, determining, according to the received bitstream, a value of a first flag indicating whether a transform skip mode is enabled; and determining, based on the value of the first flag, whether to signal a second flag indicating a residual coding method.

(134) 19. The apparatus of clause 18, wherein in determining whether to signal the second flag, the one or more processors are configured to execute the set of instructions to cause the apparatus to further perform: in response to the value of the first flag being 1, signaling the second flag; or in response to the value of the first flag being 0, determining that the second flag is not signaled.

(135) 20. The apparatus of any of clauses 18 and 19, wherein: the first flag is signaled in a sequence parameter set, and the second flag is signaled in a slice header.

(136) 21. A non-transitory computer readable medium that stores a set of instructions that is executable by at least one processor of a computer to cause the computer to perform a video data signaling method, the method comprising: receiving a bitstream comprising a set of pictures; determining, according to the received bitstream, a value of a coded tree block size; and determining, based on the value of the coded tree block size, whether to signal a flag indicating a maximum transform size for luma samples.

(137) 22. The non-transitory computer readable medium of clause 21, wherein determining whether to signal the flag comprises: in response to the value of the coded tree block size being greater than 32, signaling the flag; or in response to the value of the coded tree block size being less than or equal to 32, determining that the flag is not signaled.

(138) 23. The non-transitory computer readable medium of clause 21, wherein determining whether to signal the flag comprises: in response to the value of the coded tree block size being not equal to 32, signaling the flag; or in response to the value of the coded tree block size being equal to 32, determining that the flag is not signaled.

(139) 24. The non-transitory computer readable medium of clause 21, the value of the coded tree block size further comprises a value associated with a luma coding tree block size of a coded tree unit.

(140) 25. The non-transitory computer readable medium of clause 24, wherein determining whether to signal the flag comprises: in response to the value associated with the luma coding tree block size being greater than 0, signaling the flag; or in response to the value associated with the luma coding tree block size being equal to 0, determining that the flag is not signaled.

(141) 26. The non-transitory computer readable medium of clause 24, wherein determining whether to signal the flag comprises: in response to the value associated with the luma coding tree block size being not equal to 0, signaling the flag; or in response to the value associated with the luma coding tree block size being equal to 0, determining that the flag is not signaled.

(142) 27. The non-transitory computer readable medium of any of clauses 21-26, wherein the flag indicates that the maximum transform size is 64.

(143) 28. A non-transitory computer readable medium that stores a set of instructions that is executable by at least one processor of a computer to cause the computer to perform a video data signaling method, the method comprising: receiving a bitstream comprising a set of pictures, determining, according to the received bitstream, a value of a first flag indicating whether a transform skip mode is enabled; and determining, based on the value of the first flag, whether to signal a second flag indicating a residual coding method.

(144) 29. The non-transitory computer readable medium of clause 28, wherein determining whether to signal the second flag comprises: in response to the value of the first flag being 1, signaling the second flag; or in response to the value of the first flag being 0, determining that the second flag is not signaled.

(145) 30. The non-transitory computer readable medium of any of clauses 28 and 29, wherein: the first flag is signaled in a sequence parameter set, and the second flag is signaled in a slice header.

(146) It should be noted that, the relational terms herein such as “first” and “second” are used only to differentiate an entity or operation from another entity or operation, and do not require or imply any actual relationship or sequence between these entities or operations. Moreover, the words “comprising,” “having,” “containing,” and “including,” and other similar forms are intended to be equivalent in meaning and be open ended in that an item or items following any one of these words is not meant to be an exhaustive listing of such item or items, or meant to be limited to only the listed item or items.

(147) As used herein, unless specifically stated otherwise, the term “or” encompasses all possible combinations, except where infeasible. For example, if it is stated that a database may include A or B, then, unless specifically stated otherwise or infeasible, the database may include A, or B, or A and B. As a second example, if it is stated that a database may include A, B, or C, then, unless specifically stated otherwise or infeasible, the database may include A, or B, or C, or A and B, or A and C, or B and C, or A and B and C.

(148) It is appreciated that the above described embodiments can be implemented by hardware, or software (program codes), or a combination of hardware and software. If implemented by software, it may be stored in the above-described computer-readable media. The software, when executed by the processor can perform the disclosed methods. The computing units and other functional units described in this disclosure can be implemented by hardware, or software, or a combination of hardware and software. One of ordinary skill in the art will also understand that multiple ones of the above described modules/units may be combined as one module/unit, and each of the above described modules/units may be further divided into a plurality of sub-modules/sub-units.

(149) In the foregoing specification, embodiments have been described with reference to numerous specific details that can vary from implementation to implementation. Certain adaptations and modifications of the described embodiments can be made. Other embodiments can be apparent to those skilled in the art from consideration of the specification and practice of the invention disclosed herein. It is intended that the specification and examples be considered as exemplary only, with a true scope and spirit of the invention being indicated by the following claims. It is also intended that the sequence of steps shown in figures are only for illustrative purposes and are not

intended to be limited to any particular sequence of steps. As such, those skilled in the art can appreciate that these steps can be performed in a different order while implementing the same method.

(150) In the drawings and specification, there have been disclosed exemplary embodiments. However, many variations and modifications can be made to these embodiments. Accordingly, although specific terms are employed, they are used in a generic and descriptive sense only and not for purposes of limitation.

Claims

1. A method of encoding a video sequence into a bitstream, the method comprising: determining a value of a size of a coding tree block; determining, based on the value of the coding tree block size, whether to encode a flag indicating a maximum transform size for luma samples; and based on the value of the coding tree block size being equal to or less than 32, skipping encoding the flag into a sequence parameter set (SPS) of the bitstream and determining the skipped encoded flag to have a value indicating that the maximum transform size for luma samples is equal to 32.
2. The method according to claim 1, wherein the flag comprises an `sps_max_luma_transform_size_64_flag`.
3. The method according to claim 1, further comprising encoding the bitstream according to Versatile Video Coding (VVC/H.266) standard.
4. The method according to claim 1, wherein the value of the flag is inferred to be equal to 0 if the value of the coding tree block size is equal to or less than 32.
5. The method according to claim 1, wherein the value of the coding tree block size is determined based on a parameter specifying a luma coding tree block size of each coding tree unit.
6. A video data decoding method, comprising: receiving a bitstream associated with a coding tree block; determining, based on a value of a size of the coding tree block, whether to decode a flag associated with a maximum transform size for luma samples, the flag being signaled in a sequence parameter set (SPS) of the bitstream; and based on the value of the coding tree block size being equal to or less than 32, skipping decoding the flag and inferring the skipped decoded flag to have a value indicating that the maximum transform size for luma samples is equal to 32.
7. The method according to claim 6, wherein the value of the coding tree block size is determined based on a parameter specifying a luma coding tree block size of each coding tree unit.
8. The method according to claim 6, wherein the flag comprises an `sps_max_luma_transform_size_64_flag`.
9. The method according to claim 6, wherein the flag is comprised in a sequence parameter set.
10. The method according to claim 6, further comprising decoding the bitstream according to Versatile Video Coding (VVC/H.266) standard.
11. The method according to claim 6, further comprising: in response to the value of the coding tree block size being equal to or less than 32, inferring the value of the flag to be equal to 0.
12. A method of storing a bitstream of a video sequence, the method comprising: generating a bitstream comprising: a sequence parameter set (SPS) associated with the video sequence, and a syntax element indicating a value of a size of a coding tree block; and storing the bitstream in a non-transitory computer readable medium, wherein the generating of the bitstream comprises: when the value of the coding tree block size is greater than 32, encoding, in the SPS, a flag indicating a maximum transform size for luma samples, a value of the flag being equal to 1 when the maximum transform size for luma samples is equal to 64, or the value of the flag being equal to 0 when the maximum transform size for luma samples is equal to 32; or when the value of the coding tree block size is equal to or less than 32, skipping encoding the flag in the SPS and inferring the value of the flag is inferred to be equal to 0.
13. The method according to claim 12, wherein the flag comprises an

sps_max_luma_transform_size_64_flag.

14. The method according to claim 12, wherein the bitstream is encoded according to Versatile Video Coding (VVC/H.266) standard.

15. The method according to claim 12, wherein the syntax element comprises an sps_log2_ctu_size_minus5.
