United States Patent Application Publication 20250267297
Kind Code A1
Publication Date August 21, 2025
Inventor(s) Naser; Karam et al.

TEMPLATE BASED CCLM/MMLM SLOPE ADJUSTMENT

Abstract

Systems, methods, and instrumentalities are disclosed for template based cross component linear model/multimode linear model (CCLM/MMLM) adjustment. In an example, a device, such as a video decoding device, or a video encoding device, may obtain a prediction model for predicting a coding block. The device may select an adjustment model, from multiple adjustment models, for adjusting the prediction model. The device may adjust the prediction model based on the selected adjustment model. The device may process (e.g., encode and/or decode) the coding block based on the adjusted prediction model.

Inventors: **Naser; Karam (Mouazé, FR), Bordes; Philippe (Laille, FR), Poirier; Tangi (Thorigné-Fouillard, FR), Chen; Ya (Rennes, FR)**

Applicant: **InterDigital CE Patent Holdings, SAS** (Paris, FR)

Family ID: **1000008590599**

Assignee: **InterDigital CE Patent Holdings, SAS (Paris, FR)**

Appl. No.: **18/855186**

Filed (or PCT Filed): **April 07, 2023**

PCT No.: **PCT/EP2023/059312**

Foreign Application Priority Data

EP	22305499.0	Apr. 08, 2022

Publication Classification

Int. Cl.: **H04N19/196** (20140101); **H04N19/103** (20140101); **H04N19/176** (20140101)

U.S. Cl.:

CPC **H04N19/196** (20141101); **H04N19/103** (20141101); **H04N19/176** (20141101);

Background/Summary

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of European Provisional Patent Application No. 22305499.0, filed Apr. 8, 2022, the contents of which are hereby incorporated by reference herein.

BACKGROUND

[0002] Video coding systems may be used to compress digital video signals, e.g., to reduce the storage and/or transmission bandwidth needed for such signals. Video coding systems may include, for example, block-based, wavelet-based, and/or object-based systems.

SUMMARY

[0003] Systems, methods, and instrumentalities are disclosed for prediction model adjustment such as cross component linear model/multimode linear model (CCLM/MMLM) adjustment. In an example, a video decoder, may obtain a prediction model for predicting a coding block. Multiple adjustment models may be available for adjusting the prediction model. The video decoder may select an adjustment model, from multiple adjustment models, for adjusting the prediction model for the coding block. The video decoder may adjust the prediction model based on the selected adjustment model. The video decoder may decode the coding block based on the adjusted prediction model.

[0004] The video decoder may derive a slope and an offset of the prediction model based on reconstructed samples neighboring the coding block. Adjusting the prediction model may include adjusting the slope and/or the offset of the prediction model based on the selected adjustment model.

[0005] The prediction model may include a cross component prediction model. The video decoder may determine multiple parameters of the cross component prediction model for predicting a coding block based on neighboring chroma samples and luma samples of the coding block. Different adjustment models may be configured to adjust the parameters of the cross component prediction model differently.

[0006] Different adjustment models may be configured to adjust the prediction model differently. For example, an example adjustment model may adjust the slope of the prediction model around a minimum value. An example adjustment model may adjust the slope of the prediction model around a midpoint value. An example adjustment model may adjust the slope of the prediction model around a maximum value. An example adjustment model may adjust the prediction model by adjusting the offset of the prediction model and maintaining a same slope of the prediction model.

[0007] The selected adjustment model may be obtained based on an adjustment model indication in video data. For example, the device may, based on the adjustment model indication, determine a pivot point of the selected adjustment model. Adjusting the prediction model based on the selected adjustment model may include adjusting a slope of the prediction model via the determined pivot point. For example, the device may, based on the adjustment model indication, determine an offset adjustment of the selected adjustment model. The video decoder may adjust an offset of the prediction model based on the determined offset adjustment while maintaining a same slope of the prediction model.

[0008] The prediction model for predicting the coding block may include multiple prediction models. The selected adjustment model may include multiple adjustment models configured to independently adjust the prediction models. The video decoder may determine, based on the selected adjustment model, a first pivot point of adjusting a first prediction model and a second pivot point of adjusting a second prediction model. The video decoder may adjust a slope of the first prediction model via the determined first pivot point and adjust a slope of the second prediction model via the determined second pivot point. The coding block may be decoded based on the first and the second adjusted prediction models.

[0009] In an example, a video encoder may obtain a prediction model for predicting a coding block. The video encoder may select an adjustment model, from multiple adjustment models, for adjusting the prediction model. The video encoder may adjust the prediction model based on the selected adjustment model. The video encoder may encode the coding block based on the adjusted prediction model.

[0010] The video encoder may obtain the multiple adjustment models and select a suitable adjustment model for adjusting the prediction model. The video encoder may, for a first adjustment model of multiple adjustment models, compute a difference between sample values of the coding block and predicted sample values that are predicted using the prediction model adjusted based on the first adjustment model. The video encoder may, for a second adjustment model of multiple adjustment models, compute a difference between the sample values of the coding block and predicted sample values that are predicted using the prediction model adjusted based on the second adjustment model. The adjustment model may be selected based at least on comparing the differences. For example, the adjustment model associated with a smallest difference may be selected for the coding block.

[0011] The prediction model may include a cross component prediction model. The video encoder may determine multiple parameters of the cross component prediction model based on neighboring chroma samples and luma samples of the coding block. A first adjustment model and a second adjustment model of the multiple adjustment models may adjust the multiple parameters of the cross component prediction model differently.

[0012] A first adjustment model of the multiple adjustment models may adjust a slope of the prediction model around a minimum value. A second adjustment model of the multiple adjustment models may adjust a slope of the prediction model around a midpoint value, and a third adjustment model of the multiple adjustment models may adjust a slope of the prediction model around a maximum value. The video encoder may test the adjustment models and select a suitable adjustment model that yields a best prediction of the coding block.

[0013] The video encoder may adjust the prediction model based on the selected adjustment model by adjusting an offset of the prediction model and maintaining a same slope of the prediction model. The video encoder may determine a pivot point of the selected adjustment model, and adjusting the prediction model based on the selected adjustment model may include adjusting a slope of the prediction model via the determined pivot point. The video encoder may include, in video data, an adjustment model indicator indicating the selected adjustment model and/or the determined pivot point of the selected adjustment model.

[0014] The video encoder may determine an offset adjustment for adjusting the prediction model. The video encoder may adjust an offset of the prediction model based on the determined offset adjustment of the selected adjustment model while maintaining a same slope of the prediction model. The video encoder may include, in video data, an adjustment model indicator indicating the selected adjustment model and/or the determined offset adjustment of the selected adjustment model.

[0015] The prediction model for predicting the coding block may include multiple linear prediction models, and the selected adjustment model may include multiple adjustment models to independently adjust the prediction models. The video encoder may determine a pivot point for adjusting a first linear prediction model and a different pivot point of adjusting a second linear prediction model. Based on the determination, the video encoder may adjust the slopes of the linear prediction models via the different pivot points. The video encoder may indicate the chosen pivots points via an adjustment model indicator in video data.

[0016] Systems, methods, and instrumentalities described herein may involve a decoder. In examples, the systems, methods, and instrumentalities described herein may involve an encoder. In examples, the systems, methods, and instrumentalities described herein may involve a signal (e.g., from an encoder and/or received by a decoder). A computer-readable medium may include instructions for causing one or more processors to perform methods described herein. A computer program product may include instructions which, when the program is executed by one or more processors, may cause the one or more processors to carry out the methods described herein.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] FIG. **1**A is a system diagram illustrating an example communications system in which one or more disclosed embodiments may be implemented.

[0018] FIG. **1**B is a system diagram illustrating an example wireless transmit/receive unit (WTRU) that may be used within the communications system illustrated in FIG. **1**A according to an embodiment.

[0019] FIG. **1**C is a system diagram illustrating an example radio access network (RAN) and an example core network (CN) that may be used within the communications system illustrated in FIG. **1**A according to an embodiment.

[0020] FIG. **1**D is a system diagram illustrating a further example RAN and a further example CN that may be used within the communications system illustrated in FIG. **1**A according to an embodiment.

[0021] FIG. **2** illustrates an example video encoder.

[0022] FIG. **3** illustrates an example video decoder.

[0023] FIG. **4** illustrates an example of a system in which various aspects and examples may be implemented.

[0024] FIG. **5** illustrates an example of the location of the left and above samples and the sample of the current block involved in CCLM mode.

[0025] FIGS. **6**A and **6**B illustrate an example of the effect of the slope adjustment parameter.

[0026] FIG. **7** illustrates an example of computing an adjustment value using reconstructed luma and chroma samples.

[0027] FIG. **8** illustrates an example of using template samples to derive an adjustment value.

[0028] FIGS. **9**A-**9**B illustrate examples of slope modification around extreme values.

[0029] FIG. **10** illustrates an example of modifying the offset value.

DETAILED DESCRIPTION

[0030] A more detailed understanding may be had from the following description, given by way of example in conjunction with the accompanying drawings.

[0031] FIG. **1**A is a diagram illustrating an example communications system **100** in which one or more disclosed embodiments may be implemented. The communications system **100** may be a multiple access system that provides content, such as voice, data, video, messaging, broadcast, etc., to multiple wireless users. The communications system **100** may enable multiple wireless users to access such content through the sharing of system resources, including wireless bandwidth. For example, the communications systems **100** may employ one or more channel access methods, such as code division multiple access (CDMA), time division multiple access (TDMA), frequency division multiple access (FDMA), orthogonal FDMA (OFDMA), single-carrier FDMA (SC-FDMA), zero-tail unique-word DFT-Spread OFDM (ZT UW DTS-s OFDM), unique word OFDM (UW-OFDM), resource block-filtered OFDM, filter bank multicarrier (FBMC), and the like.

[0032] As shown in FIG. **1**A, the communications system **100** may include wireless transmit/receive units (WTRUs) **102***a*, **102***b*, **102***c*, **102***d*, a RAN **104**/**113**, a CN **106**/**115**, a public switched telephone network (PSTN) **108**, the Internet **110**, and other networks **112**, though it will be appreciated that the disclosed embodiments contemplate any number of WTRUs, base stations, networks, and/or network elements. Each of the WTRUs **102***a*, **102***b*, **102***c*, **102***d* may be any type of device configured to operate and/or communicate in a wireless environment. By way of example, the WTRUs **102***a*, **102***b*, **102***c*, **102***d*, any of which may be referred to as a “station” and/or a “STA”, may be configured to transmit and/or receive wireless signals and may include a user equipment (UE), a mobile station, a fixed or mobile subscriber unit, a subscription-based unit, a pager, a cellular telephone, a personal digital assistant (PDA), a smartphone, a laptop, a netbook, a personal computer, a wireless sensor, a hotspot or Mi-Fi device, an Internet of Things (IoT) device, a watch or other wearable, a head-mounted display (HMD), a vehicle, a drone, a medical device and applications (e.g., remote surgery), an industrial device and applications (e.g., a robot and/or other wireless devices operating in an industrial and/or an automated processing chain contexts), a consumer electronics device, a device operating on commercial and/or industrial wireless networks, and the like. Any of the WTRUs **102***a*, **102***b*, **102***c* and **102***d* may be interchangeably referred to as a UE.

[0033] The communications systems **100** may also include a base station **114***a* and/or a base station **114***b*. Each of the base stations **114***a*, **114***b* may be any type of device configured to wirelessly interface with at least one of the WTRUs **102***a*, **102***b*, **102***c*, **102***d* to facilitate access to one or more communication networks, such as the CN **106**/**115**, the Internet **110**, and/or the other networks **112**. By way of example, the base stations **114***a*, **114***b* may be a base transceiver station (BTS), a Node-B, an eNode B, a Home Node B, a Home eNode B, a gNB, a NR NodeB, a site controller, an access point (AP), a wireless router, and the like. While the base stations **114***a*, **114***b* are each depicted as a single element, it will be appreciated that the base stations **114***a*, **114***b* may include any number of interconnected base stations and/or network elements.

[0034] The base station **114***a* may be part of the RAN **104**/**113**, which may also include other base stations and/or network elements (not shown), such as a base station controller (BSC), a radio network controller (RNC), relay nodes, etc. The base station **114***a* and/or the base station **114***b* may be configured to transmit and/or receive wireless signals on one or more carrier frequencies, which may be referred to as a cell (not shown). These frequencies may be in licensed spectrum, unlicensed spectrum, or a combination of licensed and unlicensed spectrum. A cell may provide coverage for a wireless service to a specific geographical area that may be relatively fixed or that may change over time. The cell may further be divided into cell sectors. For example, the cell associated with the base station **114***a* may be divided into three sectors. Thus, in one embodiment, the base station **114***a* may include three transceivers, i.e., one for each sector of the cell. In an embodiment, the base station **114***a* may employ multiple-input multiple output (MIMO) technology and may utilize multiple transceivers for each sector of the cell. For example, beamforming may be used to transmit and/or receive signals in desired spatial directions.

[0035] The base stations **114***a*, **114***b* may communicate with one or more of the WTRUs **102***a*, **102***b*, **102***c*, **102***d* over an air interface **116**, which may be any suitable wireless communication link (e.g., radio frequency (RF), microwave, centimeter wave, micrometer wave, infrared (IR), ultraviolet (UV), visible light, etc.). The air interface **116** may be established using any suitable radio access technology (RAT).

[0036] More specifically, as noted above, the communications system **100** may be a multiple access system and may employ one or more channel access schemes, such as CDMA, TDMA, FDMA, OFDMA, SC-FDMA, and the like. For example, the base station **114***a* in the RAN **104**/**113** and the WTRUs **102***a*, **102***b*, **102***c* may implement a radio technology such as Universal Mobile Telecommunications System (UMTS) Terrestrial Radio Access (UTRA), which may establish the air interface **115**/**116**/**117** using wideband CDMA (WCDMA). WCDMA may include communication protocols such as High-Speed Packet Access (HSPA) and/or Evolved HSPA (HSPA+). HSPA may include High-Speed Downlink (DL) Packet Access (HSDPA) and/or High-Speed UL Packet Access (HSUPA).

[0037] In an embodiment, the base station **114***a* and the WTRUs **102***a*, **102***b*, **102***c* may implement a radio technology such as Evolved UMTS Terrestrial Radio Access (E-UTRA), which may establish the air interface **116** using Long Term Evolution (LTE) and/or LTE-Advanced (LTE-A) and/or LTE-Advanced Pro (LTE-A Pro).

[0038] In an embodiment, the base station **114***a* and the WTRUs **102***a*, **102***b*, **102***c* may implement a radio technology such as NR Radio Access, which may establish the air interface **116** using New Radio (NR).

[0039] In an embodiment, the base station **114***a* and the WTRUs **102***a*, **102***b*, **102***c* may implement multiple radio access technologies. For example, the base station **114***a* and the WTRUs **102***a*, **102***b*, **102***c* may implement LTE radio access and NR radio access together, for instance using dual connectivity (DC) principles. Thus, the air interface utilized by WTRUs **102***a*, **102***b*, **102***c* may be characterized by multiple types of radio access technologies and/or transmissions sent to/from multiple types of base stations (e.g., a eNB and a gNB).

[0040] In other embodiments, the base station **114***a* and the WTRUs **102***a*, **102***b*, **102***c* may implement radio technologies such as IEEE 802.11 (i.e., Wireless Fidelity (WiFi), IEEE 802.16 (i.e., Worldwide Interoperability for Microwave Access (WiMAX)), CDMA2000, CDMA2000 1×, CDMA2000 EV-DO, Interim Standard 2000 (IS-2000), Interim Standard 95 (IS-95), Interim Standard 856 (IS-856), Global System for Mobile communications (GSM), Enhanced Data rates for GSM Evolution (EDGE), GSM EDGE (GERAN), and the like.

[0041] The base station **114***b* in FIG. **1**A may be a wireless router, Home Node B, Home eNode B, or access point, for example, and may utilize any suitable RAT for facilitating wireless connectivity in a localized area, such as a place of business, a home, a vehicle, a campus, an industrial facility, an air corridor (e.g., for use by drones), a roadway, and the like. In one embodiment, the base station **114***b* and the WTRUs **102***c*, **102***d* may implement a radio technology such as IEEE 802.11 to establish a wireless local area network (WLAN). In an embodiment, the base station **114***b* and the WTRUs **102***c*, **102***d* may implement a radio technology such as IEEE 802.15 to establish a wireless personal area network (WPAN). In yet another embodiment, the base station **114***b* and the WTRUs **102***c*, **102***d* may utilize a cellular-based RAT (e.g., WCDMA, CDMA2000, GSM, LTE, LTE-A, LTE-A Pro, NR etc.) to establish a picocell or femtocell. As shown in FIG. **1**A, the base station **114***b* may have a direct connection to the Internet **110**. Thus, the base station **114***b* may not be required to access the Internet **110** via the CN **106**/**115**.

[0042] The RAN **104**/**113** may be in communication with the CN **106**/**115**, which may be any type of network configured to provide voice, data, applications, and/or voice over internet protocol (VoIP) services to one or more of the WTRUs **102***a*, **102***b*, **102***c*, **102***d*. The data may have varying quality of service (QoS) requirements, such as differing throughput requirements, latency requirements, error tolerance requirements, reliability requirements, data throughput requirements, mobility requirements, and the like. The CN **106**/**115** may provide call control, billing services, mobile location-based services, pre-paid calling, Internet connectivity, video distribution, etc., and/or perform high-level security functions, such as user authentication. Although not shown in FIG. **1**A, it will be appreciated that the RAN **104**/**113** and/or the CN **106**/**115** may be in director indirect communication with other RANs that employ the same RAT as the RAN **104**/**113** or a different RAT. For example, in addition to being connected to the RAN **104**/**113**, which may be utilizing a NR radio technology, the CN **106**/**115** may also be in communication with another RAN (not shown) employing a GSM, UMTS, CDMA 2000, WiMAX, E-UTRA, or WiFi radio technology.

[0043] The CN **106**/**115** may also serve as a gateway for the WTRUs **102***a*, **102***b*, **102***c*, **102***d* to access the PSTN **108**, the Internet **110**, and/or the other networks **112**. The PSTN **108** may include circuit-switched telephone networks that provide plain old telephone service (POTS). The Internet **110** may include a global system of interconnected computer networks and devices that use common communication protocols, such as the transmission control protocol (TCP), user datagram protocol (UDP) and/or the internet protocol (IP) in the TCP/IP internet protocol suite. The networks **112** may include wired and/or wireless communications networks owned and/or operated by other service providers. For example, the networks **112** may include another CN connected to one or more RANs, which may employ the same RAT as the RAN **104**/**113** or a different RAT.

[0044] Some or all of the WTRUs **102***a*, **102***b*, **102***c*, **102***d* in the communications system **100** may include multi-mode capabilities (e.g., the WTRUs **102***a*, **102***b*, **102***c*, **102***d* may include multiple transceivers for communicating with different wireless networks over different wireless links). For example, the WTRU **102***c* shown in FIG. **1**A may be configured to communicate with the base station **114***a*, which may employ a cellular-based radio technology, and with the base station **114***b*, which may employ an IEEE 802 radio technology.

[0045] FIG. **1**B is a system diagram illustrating an example WTRU **102**. As shown in FIG. **1**B, the WTRU **102** may include a processor **118**, a transceiver **120**, a transmit/receive element **122**, a speaker/microphone **124**, a keypad **126**, a display/touchpad **128**, non-removable memory **130**, removable memory **132**, a power source **134**, a global positioning system (GPS) chipset **136**, and/or other peripherals **138**, among others. It will be appreciated that the WTRU **102** may include any sub-combination of the foregoing elements while remaining consistent with an embodiment.

[0046] The processor **118** may be a general purpose processor, a special purpose processor, a conventional processor, a digital signal processor (DSP), a plurality of microprocessors, one or more microprocessors in association with a DSP core, a controller, a microcontroller, Application Specific Integrated Circuits (ASICs), Field Programmable Gate Arrays (FPGAs) circuits, any other type of integrated circuit (IC), a state machine, and the like. The processor **118** may perform signal coding, data processing, power control, input/output processing, and/or any other functionality that enables the WTRU **102** to operate in a wireless environment. The processor **118** may be coupled to the transceiver **120**, which may be coupled to the transmit/receive element **122**. While FIG. **1**B depicts the processor **118** and the transceiver **120** as separate components, it will be appreciated that the processor **118** and the transceiver **120** may be integrated together in an electronic package or chip.

[0047] The transmit/receive element **122** may be configured to transmit signals to, or receive signals from, a base station (e.g., the base station **114***a*) over the air interface **116**. For example, in one embodiment, the transmit/receive element **122** may be an antenna configured to transmit and/or receive RF signals. In an embodiment, the transmit/receive element **122** may be an emitter/detector configured to transmit and/or receive IR, UV, or visible light signals, for example. In yet another embodiment, the transmit/receive element **122** may be configured to transmit and/or receive both RF and light signals. It will be appreciated that the transmit/receive element **122** may be configured to transmit and/or receive any combination of wireless signals.

[0048] Although the transmit/receive element **122** is depicted in FIG. **1**B as a single element, the WTRU **102** may include any number of transmit/receive elements **122**. More specifically, the WTRU **102** may employ MIMO technology. Thus, in one embodiment, the WTRU **102** may include two or more transmit/receive elements **122** (e.g., multiple antennas) for transmitting and receiving wireless signals over the air interface **116**.

[0049] The transceiver **120** may be configured to modulate the signals that are to be transmitted by the transmit/receive element **122** and to demodulate the signals that are received by the transmit/receive element **122**. As noted above, the WTRU **102** may have multi-mode capabilities. Thus, the transceiver **120** may include multiple transceivers for enabling the WTRU **102** to communicate via multiple RATs, such as NR and IEEE 802.11, for example.

[0050] The processor **118** of the WTRU **102** may be coupled to, and may receive user input data from, the speaker/microphone **124**, the keypad **126**, and/or the display/touchpad **128** (e.g., a liquid crystal display (LCD) display unit or organic light-emitting diode (OLED) display unit). The processor **118** may also output user data to the speaker/microphone **124**, the keypad **126**, and/or the display/touchpad **128**. In addition, the processor **118** may access information from, and store data in, any type of suitable memory, such as the non-removable memory **130** and/or the removable memory **132**. The non-removable memory **130** may include random-access memory (RAM), read-only memory (ROM), a hard disk, or any other type of memory storage device. The removable memory **132** may include a subscriber identity module (SIM) card, a memory stick, a secure digital (SD) memory card, and the like. In other embodiments, the processor **118** may access information from, and store data in, memory that is not physically located on the WTRU **102**, such as on a server or a home computer (not shown).

[0051] The processor **118** may receive power from the power source **134**, and may be configured to distribute and/or control the power to the other components in the WTRU **102**. The power source **134** may be any suitable device for powering the WTRU **102**. For example, the power source **134** may include one or more dry cell batteries (e.g., nickel-cadmium (NiCd), nickel-zinc (NiZn), nickel metal hydride (NiMH), lithium-ion (Li-ion), etc.), solar cells, fuel cells, and the like.

[0052] The processor **118** may also be coupled to the GPS chipset **136**, which may be configured to provide location information (e.g., longitude and latitude) regarding the current location of the WTRU **102**. In addition to, or in lieu of, the information from the GPS chipset **136**, the WTRU **102** may receive location information over the air interface **116** from a base station (e.g., base stations **114***a*, **114***b*) and/or determine its location based on the timing of the signals being received from two or more nearby base stations. It will be appreciated that the WTRU **102** may acquire location information by way of any suitable location-determination method while remaining consistent with an embodiment.

[0053] The processor **118** may further be coupled to other peripherals **138**, which may include one or more software and/or hardware modules that provide additional features, functionality and/or wired or wireless connectivity. For example, the peripherals **138** may include an accelerometer, an e-compass, a satellite transceiver, a digital camera (for photographs and/or video), a universal serial bus (USB) port, a vibration device, a television transceiver, a hands free headset, a Bluetooth© module, a frequency modulated (FM) radio unit, a digital music player, a media player, a video game player module, an Internet browser, a Virtual Reality and/or Augmented Reality (VR/AR) device, an activity tracker, and the like. The peripherals **138** may include one or more sensors, the sensors may be one or more of a gyroscope, an accelerometer, a hall effect sensor, a magnetometer, an orientation sensor, a proximity sensor, a temperature sensor, a time sensor; a geolocation sensor; an altimeter, a light sensor, a touch sensor, a magnetometer, a barometer, a gesture sensor, a biometric sensor, and/or a humidity sensor.

[0054] The WTRU **102** may include a full duplex radio for which transmission and reception of some or all of the signals (e.g., associated with particular subframes for both the UL (e.g., for transmission) and downlink (e.g., for reception) may be concurrent and/or simultaneous. The full duplex radio may include an interference management unit to reduce and or substantially eliminate self-interference via either hardware (e.g., a choke) or signal processing via a processor (e.g., a separate processor (not shown) or via processor **118**). In an embodiment, the WRTU **102** may include a half-duplex radio for which transmission and reception of some or all of the signals (e.g., associated with particular subframes for either the UL (e.g., for transmission) or the downlink (e.g., for reception)).

[0055] FIG. **1**C is a system diagram illustrating the RAN **104** and the CN **106** according to an embodiment. As noted above, the RAN **104** may employ an E-UTRA radio technology to communicate with the WTRUs **102***a*, **102***b*, **102***c* over the air interface **116**. The RAN **104** may also be in communication with the CN **106**.

[0056] The RAN **104** may include eNode-Bs **160***a*, **160***b*, **160***c*, though it will be appreciated that the RAN **104** may include any number of eNode-Bs while remaining consistent with an embodiment. The eNode-Bs **160***a*, **160***b*, **160***c* may each include one or more transceivers for communicating with the WTRUs **102***a*, **102***b*, **102***c* over the air interface **116**. In one embodiment, the eNode-Bs **160***a*, **160***b*, **160***c* may implement MIMO technology. Thus, the eNode-B **160***a*, for example, may use multiple antennas to transmit wireless signals to, and/or receive wireless signals from, the WTRU **102***a*.
[0057] Each of the eNode-Bs **160***a*, **160***b*, **160***c* may be associated with a particular cell (not shown) and may be configured to handle radio resource management decisions, handover decisions, scheduling of users in the UL and/or DL, and the like. As shown in FIG. **1**C, the eNode-Bs **160***a*, **160***b*, **160***c* may communicate with one another over an X2 interface.
[0058] The CN **106** shown in FIG. **1**C may include a mobility management entity (MME) **162**, a serving gateway (SGW) **164**, and a packet data network (PDN) gateway (or PGW) **166**. While each of the foregoing elements are depicted as part of the CN **106**, it will be appreciated that any of these elements may be owned and/or operated by an entity other than the CN operator.
[0059] The MME **162** may be connected to each of the eNode-Bs **162***a*, **162***b*, **162***c* in the RAN **104** via an S1 interface and may serve as a control node. For example, the MME **162** may be responsible for authenticating users of the WTRUs **102***a*, **102***b*, **102***c*, bearer activation/deactivation, selecting a particular serving gateway during an initial attach of the WTRUs **102***a*, **102***b*, **102***c*, and the like. The MME **162** may provide a control plane function for switching between the RAN **104** and other RANs (not shown) that employ other radio technologies, such as GSM and/or WCDMA.
[0060] The SGW **164** may be connected to each of the eNode Bs **160***a*, **160***b*, **160***c* in the RAN **104** via the S1 interface. The SGW **164** may generally route and forward user data packets to/from the WTRUs **102***a*, **102***b*, **102***c*. The SGW **164** may perform other functions, such as anchoring user planes during inter-eNode B handovers, triggering paging when DL data is available for the WTRUs **102***a*, **102***b*, **102***c*, managing and storing contexts of the WTRUs **102***a*, **102***b*, **102***c*, and the like.
[0061] The SGW **164** may be connected to the PGW **166**, which may provide the WTRUs **102***a*, **102***b*, **102***c* with access to packet-switched networks, such as the Internet **110**, to facilitate communications between the WTRUs **102***a*, **102***b*, **102***c* and IP-enabled devices.
[0062] The CN **106** may facilitate communications with other networks. For example, the CN **106** may provide the WTRUs **102***a*, **102***b*, **102***c* with access to circuit-switched networks, such as the PSTN **108**, to facilitate communications between the WTRUs **102***a*, **102***b*, **102***c* and traditional land-line communications devices. For example, the CN **106** may include, or may communicate with, an IP gateway (e.g., an IP multimedia subsystem (IMS) server) that serves as an interface between the CN **106** and the PSTN **108**. In addition, the CN **106** may provide the WTRUs **102***a*, **102***b*, **102***c* with access to the other networks **112**, which may include other wired and/or wireless networks that are owned and/or operated by other service providers.
[0063] Although the WTRU is described in FIGS. **1**A-**1**D as a wireless terminal, it is contemplated that in certain representative embodiments that such a terminal may use (e.g., temporarily or permanently) wired communication interfaces with the communication network.
[0064] In representative embodiments, the other network **112** may be a WLAN.
[0065] A WLAN in Infrastructure Basic Service Set (BSS) mode may have an Access Point (AP) for the BSS and one or more stations (STAs) associated with the AP. The AP may have an access or an interface to a Distribution System (DS) or another type of wired/wireless network that carries traffic in to and/or out of the BSS. Traffic to STAs that originates from outside the BSS may arrive through the AP and may be delivered to the STAs. Traffic originating from STAs to destinations outside the BSS may be sent to the AP to be delivered to respective destinations. Traffic between STAs within the BSS may be sent through the AP, for example, where the source STA may send traffic to the AP and the AP may deliver the traffic to the destination STA. The traffic between STAs within a BSS may be considered and/or referred to as peer-to-peer traffic. The peer-to-peer traffic may be sent between (e.g., directly between) the source and destination STAs with a direct link setup (DLS). In certain representative embodiments, the DLS may use an 802.11e DLS or an 802.11z tunneled DLS (TDLS). A WLAN using an Independent BSS (IBSS) mode may not have an AP, and the STAs (e.g., all of the STAs) within or using the IBSS may communicate directly with each other. The IBSS mode of communication may sometimes be referred to herein as an “ad-hoc” mode of communication.
[0066] When using the 802.11ac infrastructure mode of operation or a similar mode of operations, the AP may transmit a beacon on a fixed channel, such as a primary channel. The primary channel may be a fixed width (e.g., 20 MHz wide bandwidth) or a dynamically set width via signaling. The primary channel may be the operating channel of the BSS and may be used by the STAs to establish a connection with the AP. In certain representative embodiments, Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) may be implemented, for example in in 802.11 systems. For CSMA/CA, the STAs (e.g., every STA), including the AP, may sense the primary channel. If the primary channel is sensed/detected and/or determined to be busy by a particular STA, the particular STA may back off. One STA (e.g., only one station) may transmit at any given time in a given BSS.
[0067] High Throughput (HT) STAs may use a 40 MHz wide channel for communication, for example, via a combination of the primary 20 MHz channel with an adjacent or nonadjacent 20 MHz channel to form a 40 MHz wide channel.
[0068] Very High Throughput (VHT) STAs may support 20 MHz, 40 MHz, 80 MHz, and/or 160 MHz wide channels. The 40 MHz, and/or 80 MHz, channels may be formed by combining contiguous 20 MHz channels. A 160 MHz channel may be formed by combining 8 contiguous 20 MHz channels, or by combining two non-contiguous 80 MHz channels, which may be referred to as an 80+80 configuration. For the 80+80 configuration, the data, after channel encoding, may be passed through a segment parser that may divide the data into two streams. Inverse Fast Fourier Transform (IFFT) processing, and time domain processing, may be done on each stream separately. The streams may be mapped on to the two 80 MHz channels, and the data may be transmitted by a transmitting STA. At the receiver of the receiving STA, the above described operation for the 80+80 configuration may be reversed, and the combined data may be sent to the Medium Access Control (MAC).
[0069] Sub 1 GHz modes of operation are supported by 802.11af and 802.11ah. The channel operating bandwidths, and carriers, are reduced in 802.11af and 802.11ah relative to those used in 802.11n, and 802.11ac. 802.11af supports 5 MHz, 10 MHz and 20 MHz bandwidths in the TV White Space (TVWS) spectrum, and 802.11ah supports 1 MHz, 2 MHz, 4 MHz, 8 MHz, and 16 MHz bandwidths using non-TVWS spectrum. According to a representative embodiment, 802.11ah may support Meter Type Control/Machine-Type Communications, such as MTC devices in a macro coverage area. MTC devices may have certain capabilities, for example, limited capabilities including support for (e.g., only support for) certain and/or limited bandwidths. The MTC devices may include a battery with a battery life above a threshold (e.g., to maintain a very long battery life).
[0070] WLAN systems, which may support multiple channels, and channel bandwidths, such as 802.11n, 802.11ac, 802.11af, and 802.11ah, include a channel which may be designated as the primary channel. The primary channel may have a bandwidth equal to the largest common operating bandwidth supported by all STAs in the BSS. The bandwidth of the primary channel may be set and/or limited by a STA, from among all STAs in operating in a BSS, which supports the smallest bandwidth operating mode. In the example of 802.11ah, the primary channel may be 1 MHz wide for STAs (e.g., MTC type devices) that support (e.g., only support) a 1 MHz mode, even if the AP, and other STAs in the BSS support 2 MHz, 4 MHz, 8 MHz, 16 MHz, and/or other channel bandwidth operating modes. Carrier sensing and/or Network Allocation Vector (NAV) settings may depend on the status of the primary channel. If the primary channel is busy, for example, due to a STA (which supports only a 1 MHz operating mode), transmitting to the AP, the entire available frequency bands may be considered busy even though a majority of the frequency bands remains idle and may be available.

[0071] In the United States, the available frequency bands, which may be used by 802.11ah, are from 902 MHz to 928 MHz. In Korea, the available frequency bands are from 917.5 MHz to 923.5 MHz. In Japan, the available frequency bands are from 916.5 MHz to 927.5 MHz. The total bandwidth available for 802.11ah is 6 MHz to 26 MHz depending on the country code.

[0072] FIG. **1**D is a system diagram illustrating the RAN **113** and the CN **115** according to an embodiment. As noted above, the RAN **113** may employ an NR radio technology to communicate with the WTRUs **102***a*, **102***b*, **102***c* over the air interface **116**. The RAN **113** may also be in communication with the CN **115**.

[0073] The RAN **113** may include gNBs **180***a*, **180***b*, **180***c*, though it will be appreciated that the RAN **113** may include any number of gNBs while remaining consistent with an embodiment. The gNBs **180***a*, **180***b*, **180***c* may each include one or more transceivers for communicating with the WTRUs **102***a*, **102***b*, **102***c* over the air interface **116**. In one embodiment, the gNBs **180***a*, **180***b*, **180***c* may implement MIMO technology. For example, gNBs **180***a*, **108***b* may utilize beamforming to transmit signals to and/or receive signals from the gNBs **180***a*, **180***b*, **180***c*. Thus, the gNB **180***a*, for example, may use multiple antennas to transmit wireless signals to, and/or receive wireless signals from, the WTRU **102***a*. In an embodiment, the gNBs **180***a*, **180***b*, **180***c* may implement carrier aggregation technology. For example, the gNB **180***a* may transmit multiple component carriers to the WTRU **102***a* (not shown). A subset of these component carriers may be on unlicensed spectrum while the remaining component carriers may be on licensed spectrum. In an embodiment, the gNBs **180***a*, **180***b*, **180***c* may implement Coordinated Multi-Point (CoMP) technology. For example, WTRU **102***a* may receive coordinated transmissions from gNB **180***a* and gNB **180***b* (and/or gNB **180***c*).

[0074] The WTRUs **102***a*, **102***b*, **102***c* may communicate with gNBs **180***a*, **180***b*, **180***c* using transmissions associated with a scalable numerology. For example, the OFDM symbol spacing and/or OFDM subcarrier spacing may vary for different transmissions, different cells, and/or different portions of the wireless transmission spectrum. The WTRUs **102***a*, **102***b*, **102***c* may communicate with gNBs **180***a*, **180***b*, **180***c* using subframe or transmission time intervals (TTIs) of various or scalable lengths (e.g., containing varying number of OFDM symbols and/or lasting varying lengths of absolute time).

[0075] The gNBs **180***a*, **180***b*, **180***c* may be configured to communicate with the WTRUs **102***a*, **102***b*, **102***c* in a standalone configuration and/or a non-standalone configuration. In the standalone configuration, WTRUs **102***a*, **102***b*, **102***c* may communicate with gNBs **180***a*, **180***b*, **180***c* without also accessing other RANs (e.g., such as eNode-Bs **160***a*, **160***b*, **160***c*). In the standalone configuration, WTRUs **102***a*, **102***b*, **102***c* may utilize one or more of gNBs **180***a*, **180***b*, **180***c* as a mobility anchor point. In the standalone configuration, WTRUs **102***a*, **102***b*, **102***c* may communicate with gNBs **180***a*, **180***b*, **180***c* using signals in an unlicensed band. In a non-standalone configuration WTRUs **102***a*, **102***b*, **102***c* may communicate with/connect to gNBs **180***a*, **180***b*, **180***c* while also communicating with/connecting to another RAN such as eNode-Bs **160***a*, **160***b*, **160***c*. For example, WTRUs **102***a*, **102***b*, **102***c* may implement DC principles to communicate with one or more gNBs **180***a*, **180***b*, **180***c* and one or more eNode-Bs **160***a*, **160***b*, **160***c* substantially simultaneously. In the non-standalone configuration, eNode-Bs **160***a*, **160***b*, **160***c* may serve as a mobility anchor for WTRUs **102***a*, **102***b*, **102***c* and gNBs **180***a*, **180***b*, **180***c* may provide additional coverage and/or throughput for servicing WTRUs **102***a*, **102***b*, **102***c*.

[0076] Each of the gNBs **180***a*, **180***b*, **180***c* may be associated with a particular cell (not shown) and may be configured to handle radio resource management decisions, handover decisions, scheduling of users in the UL and/or DL, support of network slicing, dual connectivity, interworking between NR and E-UTRA, routing of user plane data towards User Plane Function (UPF) **184***a*, **184***b*, routing of control plane information towards Access and Mobility Management Function (AMF) **182***a*, **182***b* and the like. As shown in FIG. **1**D, the gNBs **180***a*, **180***b*, **180***c* may communicate with one another over an Xn interface.

[0077] The CN **115** shown in FIG. **1**D may include at least one AMF **182***a*, **182***b*, at least one UPF **184***a*,**184***b*, at least one Session Management Function (SMF) **183***a*, **183***b*, and possibly a Data Network (DN) **185***a*, **185***b*. While each of the foregoing elements are depicted as part of the CN **115**, it will be appreciated that any of these elements may be owned and/or operated by an entity other than the CN operator.

[0078] The AMF **182***a*, **182***b* may be connected to one or more of the gNBs **180***a*, **180***b*, **180***c* in the RAN **113** via an N2 interface and may serve as a control node. For example, the AMF **182***a*, **182***b* may be responsible for authenticating users of the WTRUs **102***a*, **102***b*, **102***c*, support for network slicing (e.g., handling of different PDU sessions with different requirements), selecting a particular SMF **183***a*, **183***b*, management of the registration area, termination of NAS signaling, mobility management, and the like. Network slicing may be used by the AMF **182***a*, **182***b* in order to customize CN support for WTRUs **102***a*, **102***b*, **102***c* based on the types of services being utilized WTRUs **102***a*, **102***b*, **102***c*. For example, different network slices may be established for different use cases such as services relying on ultra-reliable low latency (URLLC) access, services relying on enhanced massive mobile broadband (eMBB) access, services for machine type communication (MTC) access, and/or the like. The AMF **162** may provide a control plane function for switching between the RAN **113** and other RANs (not shown) that employ other radio technologies, such as LTE, LTE-A, LTE-A Pro, and/or non-3GPP access technologies such as WiFi.

[0079] The SMF **183***a*, **183***b* may be connected to an AMF **182***a*, **182***b* in the CN **115** via an N11 interface. The SMF **183***a*, **183***b* may also be connected to a UPF **184***a*, **184***b* in the CN **115** via an N4 interface. The SMF **183***a*, **183***b* may select and control the UPF **184***a*, **184***b* and configure the routing of traffic through the UPF **184***a*, **184***b*. The SMF **183***a*, **183***b* may perform other functions, such as managing and allocating UE IP address, managing PDU sessions, controlling policy enforcement and QoS, providing downlink data notifications, and the like. A PDU session type may be IP-based, non-IP based, Ethernet-based, and the like.

[0080] The UPF **184***a*, **184***b* may be connected to one or more of the gNBs **180***a*, **180***b*, **180***c* in the RAN **113** via an N3 interface, which may provide the WTRUs **102***a*, **102***b*, **102***c* with access to packet-switched networks, such as the Internet **110**, to facilitate communications between the WTRUs **102***a*, **102***b*, **102***c* and IP-enabled devices. The UPF **184**, **184***b* may perform other functions, such as routing and forwarding packets, enforcing user plane policies, supporting multi-homed PDU sessions, handling user plane QoS, buffering downlink packets, providing mobility anchoring, and the like.

[0081] The CN **115** may facilitate communications with other networks. For example, the CN **115** may include, or may communicate with, an IP gateway (e.g., an IP multimedia subsystem (IMS) server) that serves as an interface between the CN **115** and the PSTN **108**. In addition, the CN **115** may provide the WTRUs **102***a*, **102***b*, **102***c* with access to the other networks **112**, which may include other wired and/or wireless networks that are owned and/or operated by other service providers. In one embodiment, the WTRUs **102***a*, **102***b*, **102***c* may be connected to a local Data Network (DN) **185***a*, **185***b* through the UPF **184***a*, **184***b* via the N3 interface to the UPF **184***a*, **184***b* and an N6 interface between the UPF **184***a*, **184***b* and the DN **185***a*, **185***b*.

[0082] In view of FIGS. **1**A-**1**D, and the corresponding description of FIGS. **1**A-**1**D, one or more, or all, of the functions described herein with regard to one or more of: WTRU **102***a-d*, Base Station **114***a-b*, eNode-B **160***a-c*, MME **162**, SGW **164**, PGW **166**, gNB **180***a-c*, AMF **182***a-b*, UPF **184***a-b*, SMF **183***a-b*, DN **185***a-b*, and/or any other device(s) described herein, may be performed by one or more emulation devices (not shown). The emulation devices may be one or more devices configured to emulate one or more, or all, of the functions described herein. For example, the emulation devices may be used to test other devices and/or to simulate network and/or WTRU functions.

[0083] The emulation devices may be designed to implement one or more tests of other devices in a lab environment and/or in an operator network environment. For example, the one or more emulation devices may perform the one or more, or all, functions while being fully or partially implemented and/or deployed as part of a wired and/or wireless communication network in order to test other devices within the communication network. The one or more emulation devices may perform the one or more, or all, functions while being temporarily implemented/deployed as part of a wired and/or wireless communication network. The emulation device may be directly coupled to another device for purposes of testing and/or may performing testing using over-the-air wireless communications.

[0084] The one or more emulation devices may perform the one or more, including all, functions while not being implemented/deployed as part of a wired and/or wireless communication network. For example, the emulation devices may be utilized in a testing scenario in a testing laboratory and/or a non-deployed (e.g., testing) wired and/or wireless communication network in order to implement testing of one or more components. The one or more emulation devices may be test equipment. Direct RF coupling and/or wireless communications via RF circuitry (e.g., which may include one or more antennas) may be used by the emulation devices to transmit and/or receive data.

[0085] This application describes a variety of aspects, including tools, features, examples, models, approaches, etc. Many of these aspects are described with specificity and, at least to show the individual characteristics, are often described in a manner that may sound limiting. However, this is for purposes of clarity in description, and does not limit the application or scope of those aspects. Indeed, all of the different aspects may be combined and interchanged to provide further aspects. Moreover, the aspects may be combined and interchanged with aspects described in earlier filings as well.

[0086] The aspects described and contemplated in this application may be implemented in many different forms. FIGS. **5-10** described herein may provide examples, but other examples are contemplated. The discussion of FIGS. **5-10** does not limit the breadth of the implementations. At least one of the aspects generally relates to video encoding and decoding, and at least one other aspect generally relates to transmitting a bitstream generated or encoded. These and other aspects may be implemented as a method, an apparatus, a computer readable storage medium having stored thereon instructions for encoding or decoding video data according to any of the methods described, and/or a computer readable storage medium having stored thereon a bitstream generated according to any of the methods described.

[0087] In the present application, the terms "reconstructed" and "decoded" may be used interchangeably, the terms "pixel" and "sample" may be used interchangeably, the terms "image," "picture" and "frame" may be used interchangeably.

[0088] Various methods are described herein, and each of the methods comprises one or more steps or actions for achieving the described method. Unless a specific order of steps or actions is required for proper operation of the method, the order and/or use of specific steps and/or actions may be modified or combined. Additionally, terms such as "first", "second", etc. may be used in various examples to modify an element, component, step, operation, etc., such as, for example, a "first decoding" and a "second decoding". Use of such terms does not imply an ordering to the modified operations unless specifically required. So, in this example, the first decoding need not be performed before the second decoding, and may occur, for example, before, during, or in an overlapping time period with the second decoding.

[0089] Various methods and other aspects described in this application may be used to modify modules, for example, decoding modules, of a video encoder **200** and decoder **300** as shown in FIG. **2** and FIG. **3**. Moreover, the subject matter disclosed herein may be applied, for example, to any type, format or version of video coding, whether described in a standard or a recommendation, whether pre-existing or future-developed, and extensions of any such standards and recommendations. Unless indicated otherwise, or technically precluded, the aspects described in this application may be used individually or in combination.

[0090] Various numeric values are used in examples described the present application, such as numeric values referenced in examples shown and discussed relative to FIGS. **9** and **10**, Eq. (5), Table 1, a number of intra modes, a down sampling ratio, a number of adjustment values, etc. These and other specific values are for purposes of describing examples and the aspects described are not limited to these specific values.

[0091] FIG. **2** is a diagram showing an example video encoder. Variations of example encoder **200** are contemplated, but the encoder **200** is described below for purposes of clarity without describing all expected variations.

[0092] Before being encoded, the video sequence may go through pre-encoding processing (**201**), for example, applying a color transform to the input color picture (e.g., conversion from RGB 4:4:4 to YCbCr 4:2:0), or performing a remapping of the input picture components in order to get a signal distribution more resilient to compression (for instance using a histogram equalization of one of the color components). Metadata may be associated with the pre-processing, and attached to the bitstream.

[0093] In the encoder **200**, a picture is encoded by the encoder elements as described below. The picture to be encoded is partitioned (**202**) and processed in units of, for example, coding units (CUs). Each unit is encoded using, for example, either an intra or inter mode. When a unit is encoded in an intra mode, it performs intra prediction (**260**). In an inter mode, motion estimation (**275**) and compensation (**270**) are performed. The encoder decides (**205**) which one of the intra mode or inter mode to use for encoding the unit, and indicates the intra/inter decision by, for example, a prediction mode flag. Prediction residuals are calculated, for example, by subtracting (**210**) the predicted block from the original image block.

[0094] The prediction residuals are then transformed (**225**) and quantized (**230**). The quantized transform coefficients, as well as motion vectors and other syntax elements, such as picture partitioning information, are entropy coded (**245**) to output a bitstream. The encoder can skip the transform and apply quantization directly to the non-transformed residual signal. The encoder can bypass both transform and quantization, i.e., the residual is coded directly without the application of the transform or quantization processes.

[0095] The encoder decodes an encoded block to provide a reference for further predictions. The quantized transform coefficients are de-quantized (**240**) and inverse transformed (**250**) to decode prediction residuals. Combining (**255**) the decoded prediction residuals and the predicted block, an image block is reconstructed. In-loop filters (**265**) are applied to the reconstructed picture to perform, for example, deblocking/SAO (Sample Adaptive Offset)/ALF (Adaptive Loop Filter) filtering to reduce encoding artifacts. The filtered image is stored at a reference picture buffer (**280**).

[0096] FIG. **3** is a diagram showing an example of a video decoder. In example decoder **300**, a bitstream is decoded by the decoder elements as described below. Video decoder **300** generally performs a decoding pass reciprocal to the encoding pass as described in FIG. **2**. The encoder **200** also generally performs video decoding as part of encoding video data.

[0097] In particular, the input of the decoder includes a video bitstream, which may be generated by video encoder **200**. The bitstream is first entropy decoded (**330**) to obtain transform coefficients, prediction modes, motion vectors, and other coded information. The picture partition information indicates how the picture is partitioned. The decoder may therefore divide (**335**) the picture according to the decoded picture partitioning information. The transform coefficients are de-quantized (**340**) and inverse transformed (**350**) to decode the prediction residuals. Combining (**355**) the decoded prediction residuals and the predicted block, an image block is reconstructed. The predicted block may be obtained (**370**) from intra prediction (**360**) or motion-compensated prediction (i.e., inter prediction) (**375**). In-loop filters (**365**) are applied to the reconstructed image. The filtered image is stored at a reference picture buffer (**380**). In examples, for a given picture, the contents of the reference picture buffer **380** on the decoder **300** side may be identical to the contents of the reference picture buffer **280** on the encoder **200** side (e.g., for the same picture).

[0098] The decoded picture can further go through post-decoding processing (**385**), for example, an inverse color transform (e.g. conversion from YCbCr 4:2:0 to RGB 4:4:4) or an inverse remapping performing the inverse of the remapping process performed in the pre-encoding processing (**201**). The post-decoding processing can use metadata derived in the pre-encoding processing and signaled in the bitstream. In examples, the decoded images (e.g., after application of the in-loop filters (**365**) and/or after post-decoding processing (**385**), if post-decoding processing is used) may be sent to a display device for rendering to a user.

[0099] FIG. **4** is a diagram showing an example of a system in which various aspects and examples described herein may be implemented.

System **400** may be embodied as a device including the various components described below and is configured to perform one or more of the aspects described in this document. Examples of such devices, include, but are not limited to, various electronic devices such as personal computers, laptop computers, smartphones, tablet computers, digital multimedia set top boxes, digital television receivers, personal video recording systems, connected home appliances, and servers. Elements of system **400**, singly or in combination, may be embodied in a single integrated circuit (IC), multiple ICs, and/or discrete components. For example, in at least one example, the processing and encoder/decoder elements of system **400** are distributed across multiple ICs and/or discrete components. In various examples, the system **400** is communicatively coupled to one or more other systems, or other electronic devices, via, for example, a communications bus or through dedicated input and/or output ports. In various examples, the system **400** is configured to implement one or more of the aspects described in this document.

[0100] The system **400** includes at least one processor **410** configured to execute instructions loaded therein for implementing, for example, the various aspects described in this document. Processor **410** can include embedded memory, input output interface, and various other circuitries as known in the art. The system **400** includes at least one memory **420** (e.g., a volatile memory device, and/or a non-volatile memory device). System **400** includes a storage device **440**, which can include non-volatile memory and/or volatile memory, including, but not limited to, Electrically Erasable Programmable Read-Only Memory (EEPROM), Read-Only Memory (ROM), Programmable Read-Only Memory (PROM), Random Access Memory (RAM), Dynamic Random Access Memory (DRAM), Static Random Access Memory (SRAM), flash, magnetic disk drive, and/or optical disk drive. The storage device **440** can include an internal storage device, an attached storage device (including detachable and non-detachable storage devices), and/or a network accessible storage device, as non-limiting examples.

[0101] System **400** includes an encoder/decoder module **430** configured, for example, to process data to provide an encoded video or decoded video, and the encoder/decoder module **430** can include its own processor and memory. The encoder/decoder module **430** represents module(s) that may be included in a device to perform the encoding and/or decoding functions. As is known, a device can include one or both of the encoding and decoding modules. Additionally, encoder/decoder module **430** may be implemented as a separate element of system **400** or may be incorporated within processor **410** as a combination of hardware and software as known to those skilled in the art.

[0102] Program code to be loaded onto processor **410** or encoder/decoder **430** to perform the various aspects described in this document may be stored in storage device **440** and subsequently loaded onto memory **420** for execution by processor **410**. In accordance with various examples, one or more of processor **410**, memory **420**, storage device **440**, and encoder/decoder module **430** can store one or more of various items during the performance of the processes described in this document. Such stored items can include, but are not limited to, the input video, the decoded video or portions of the decoded video, the bitstream, matrices, variables, and intermediate or final results from the processing of equations, formulas, operations, and operational logic.

[0103] In examples, memory inside of the processor **410** and/or the encoder/decoder module **430** is used to store instructions and to provide working memory for processing that is needed during encoding or decoding. In other examples, however, a memory external to the processing device (for example, the processing device may be either the processor **410** or the encoder/decoder module **430**) is used for one or more of these functions. The external memory may be the memory **420** and/or the storage device **440**, for example, a dynamic volatile memory and/or a non-volatile flash memory. In several examples, an external non-volatile flash memory is used to store the operating system of, for example, a television. In at least one example, a fast external dynamic volatile memory such as a RAM is used as working memory for video encoding and decoding operations.

[0104] The input to the elements of system **400** may be provided through various input devices as indicated in block **445**. Such input devices include, but are not limited to, (i) a radio frequency (RF) portion that receives an RF signal transmitted, for example, over the air by a broadcaster, (ii) a Component (COMP) input terminal (or a set of COMP input terminals), (iii) a Universal Serial Bus (USB) input terminal, and/or (iv) a High Definition Multimedia Interface (HDMI) input terminal. Other examples, not shown in FIG. **4**, include composite video.

[0105] In various examples, the input devices of block **445** have associated respective input processing elements as known in the art. For example, the RF portion may be associated with elements suitable for (i) selecting a desired frequency (also referred to as selecting a signal, or band-limiting a signal to a band of frequencies), (ii) downconverting the selected signal, (iii) band-limiting again to a narrower band of frequencies to select (for example) a signal frequency band which may be referred to as a channel in certain examples, (iv) demodulating the downconverted and band-limited signal, (v) performing error correction, and/or (vi) demultiplexing to select the desired stream of data packets. The RF portion of various examples includes one or more elements to perform these functions, for example, frequency selectors, signal selectors, band-limiters, channel selectors, filters, downconverters, demodulators, error correctors, and demultiplexers. The RF portion can include a tuner that performs various of these functions, including, for example, downconverting the received signal to a lower frequency (for example, an intermediate frequency or a near-baseband frequency) or to baseband. In one set-top box example, the RF portion and its associated input processing element receives an RF signal transmitted over a wired (for example, cable) medium, and performs frequency selection by filtering, downconverting, and filtering again to a desired frequency band. Various examples rearrange the order of the above-described (and other) elements, remove some of these elements, and/or add other elements performing similar or different functions. Adding elements can include inserting elements in between existing elements, such as, for example, inserting amplifiers and an analog-to-digital converter. In various examples, the RF portion includes an antenna.

[0106] The USB and/or HDMI terminals can include respective interface processors for connecting system **400** to other electronic devices across USB and/or HDMI connections. It is to be understood that various aspects of input processing, for example, Reed-Solomon error correction, may be implemented, for example, within a separate input processing IC or within processor **410** as necessary. Similarly, aspects of USB or HDMI interface processing may be implemented within separate interface ICs or within processor **410** as necessary. The demodulated, error corrected, and demultiplexed stream is provided to various processing elements, including, for example, processor **410**, and encoder/decoder **430** operating in combination with the memory and storage elements to process the datastream as necessary for presentation on an output device.

[0107] Various elements of system **400** may be provided within an integrated housing, Within the integrated housing, the various elements may be interconnected and transmit data therebetween using suitable connection arrangement **425**, for example, an internal bus as known in the art, including the Inter-IC (**12**C) bus, wiring, and printed circuit boards.

[0108] The system **400** includes communication interface **450** that enables communication with other devices via communication channel **460**. The communication interface **450** can include, but is not limited to, a transceiver configured to transmit and to receive data over communication channel **460**. The communication interface **450** can include, but is not limited to, a modem or network card and the communication channel **460** may be implemented, for example, within a wired and/or a wireless medium.

[0109] Data is streamed, or otherwise provided, to the system **400**, in various examples, using a wireless network such as a Wi-Fi network, for example IEEE 802.11 (IEEE refers to the Institute of Electrical and Electronics Engineers). The Wi-Fi signal of these examples is received over the communications channel **460** and the communications interface **450** which are adapted for Wi-Fi communications. The communications channel **460** of these examples is typically connected to an access point or router that provides access to external networks including the Internet for allowing streaming applications and other over-the-top communications. Other examples provide streamed data to the system **400** using a set-top box that delivers the data over the HDMI connection of the input block **445**. Still other examples provide streamed data to the system **400** using the RF connection of the input block **445**. As indicated above, various examples provide data in a non-streaming manner. Additionally, various examples use wireless networks other than Wi-Fi, for example a cellular network or a Bluetooth© network.

[0110] The system **400** can provide an output signal to various output devices, including a display **475**, speakers **485**, and other peripheral devices **495**. The display **475** of various examples includes one or more of, for example, a touchscreen display, an organic light-emitting diode (OLED) display, a curved display, and/or a foldable display. The display **475** may be for a television, a tablet, a laptop, a cell phone (mobile phone), or other device. The display **475** can also be integrated with other components (for example, as in a smart phone), or separate (for example, an external monitor for a laptop). The other peripheral devices **495** include, in various examples, one or more of a stand-alone digital video disc (or digital versatile disc) (DVD, for both terms), a disk player, a stereo system, and/or a lighting system. Various examples use one or more peripheral devices **495** that provide a function based on the output of the system **400**. For example, a disk player performs the function of playing the output of the system **400**.
[0111] In various examples, control signals are communicated between the system **400** and the display **475**, speakers **485**, or other peripheral devices **495** using signaling such as AV.Link, Consumer Electronics Control (CEC), or other communications protocols that enable device-to-device control with or without user intervention. The output devices may be communicatively coupled to system **400** via dedicated connections through respective interfaces **470**, **480**, and **490**. Alternatively, the output devices may be connected to system **400** using the communications channel **460** via the communications interface **450**. The display **475** and speakers **485** may be integrated in a single unit with the other components of system **400** in an electronic device such as, for example, a television. In various examples, the display interface **470** includes a display driver, such as, for example, a timing controller (T Con) chip.
[0112] The display **475** and speakers **485** can alternatively be separate from one or more of the other components, for example, if the RF portion of input **445** is part of a separate set-top box. In various examples in which the display **475** and speakers **485** are external components, the output signal may be provided via dedicated output connections, including, for example, HDMI ports, USB ports, or COMP outputs. The examples may be carried out by computer software implemented by the processor **410** or by hardware, or by a combination of hardware and software. As a non-limiting example, the examples may be implemented by one or more integrated circuits. The memory **420** may be of any type appropriate to the technical environment and may be implemented using any appropriate data storage technology, such as optical memory devices, magnetic memory devices, semiconductor-based memory devices, fixed memory, and removable memory, as non-limiting examples. The processor **410** may be of any type appropriate to the technical environment, and can encompass one or more of microprocessors, general purpose computers, special purpose computers, and processors based on a multi-core architecture, as non-limiting examples.
[0113] Various implementations involve decoding. “Decoding”, as used in this application, can encompass all or part of the processes performed, for example, on a received encoded sequence in order to produce a final output suitable for display. In various examples, such processes include one or more of the processes typically performed by a decoder, for example, entropy decoding, inverse quantization, inverse transformation, and differential decoding. In various examples, such processes also, or alternatively, include processes performed by a decoder of various implementations described in this application, for example, obtaining a prediction model for predicting a coding block; selecting an adjustment model, from a plurality of adjustment models, for adjusting the prediction model; adjusting the prediction model based on the selected adjustment model; and decoding the coding block based on the adjusted prediction model, etc.
[0114] As further examples, in one example “decoding” refers only to entropy decoding, in another example “decoding” refers only to differential decoding, and in another example “decoding” refers to a combination of entropy decoding and differential decoding. Whether the phrase “decoding process” is intended to refer specifically to a subset of operations or generally to the broader decoding process will be clear based on the context of the specific descriptions and is believed to be well understood by those skilled in the art.
[0115] Various implementations involve encoding. In an analogous way to the above discussion about “decoding”, “encoding” as used in this application can encompass all or part of the processes performed, for example, on an input video sequence in order to produce an encoded bitstream. In various examples, such processes include one or more of the processes typically performed by an encoder, for example, partitioning, differential encoding, transformation, quantization, and entropy encoding. In various examples, such processes also, or alternatively, include processes performed by an encoder of various implementations described in this application, for example, obtaining a prediction model for predicting a coding block; selecting an adjustment model, from a plurality of adjustment models, for adjusting the prediction model; adjusting the prediction model based on the selected adjustment model; and encoding the coding block based on the adjusted prediction model, etc.
[0116] As further examples, in one example “encoding” refers only to entropy encoding, in another example “encoding” refers only to differential encoding, and in another example “encoding” refers to a combination of differential encoding and entropy encoding. Whether the phrase “encoding process” is intended to refer specifically to a subset of operations or generally to the broader encoding process will be clear based on the context of the specific descriptions and is believed to be well understood by those skilled in the art.
[0117] Note that syntax elements as used herein, for example, coding syntax for an indication indicating that a pivot point is to be determined, an adjustment model indicator indicating that the adjustment model is to be used for adjusting a prediction model, and/or a first pivot point indicator and a second pivot point indicator indicating that a first pivot point and a second pivot point for adjusting prediction models associated with the coding block, respectively, are to be determined etc., are descriptive terms. As such, they do not preclude the use of other syntax element names or functions.
[0118] When a figure is presented as a flow diagram, it should be understood that it also provides a block diagram of a corresponding apparatus. Similarly, when a figure is presented as a block diagram, it should be understood that it also provides a flow diagram of a corresponding method/process.
[0119] The implementations and aspects described herein may be implemented in, for example, a method or a process, an apparatus, a software program, a data stream, or a signal. Even if only discussed in the context of a single form of implementation (for example, discussed only as a method), the implementation of features discussed can also be implemented in other forms (for example, an apparatus or program). An apparatus may be implemented in, for example, appropriate hardware, software, and firmware. The methods may be implemented in, for example, a processor, which refers to processing devices in general, including, for example, a computer, a microprocessor, an integrated circuit, or a programmable logic device. Processors also include communication devices, such as, for example, computers, cell phones, portable/personal digital assistants (“PDAs”), and other devices that facilitate communication of information between end-users.
[0120] Reference to “one example” or “an example” or “one implementation” or “an implementation”, as well as other variations thereof, means that a particular feature, structure, characteristic, and so forth described in connection with the example is included in at least one example. Thus, the appearances of the phrase “in one example” or “in an example” or “in one implementation” or “in an implementation”, as well any other variations, appearing in various places throughout this application are not necessarily all referring to the same example.
[0121] Additionally, this application may refer to “determining” various pieces of information. Determining the information can include one or more of, for example, estimating the information, calculating the information, predicting the information, or retrieving the information from memory. Obtaining may include receiving, retrieving, constructing, generating, and/or determining.
[0122] Further, this application may refer to “accessing” various pieces of information. Accessing the information can include one or more of, for example, receiving the information, retrieving the information (for example, from memory), storing the information, moving the information, copying the information, calculating the information, determining the information, predicting the information, or estimating the information.
[0123] Additionally, this application may refer to “receiving” various pieces of information. Receiving is, as with “accessing”, intended to be a

broad term. Receiving the information can include one or more of, for example, accessing the information, or retrieving the information (for example, from memory). Further, “receiving” is typically involved, in one way or another, during operations such as, for example, storing the information, processing the information, transmitting the information, moving the information, copying the information, erasing the information, calculating the information, determining the information, predicting the information, or estimating the information.

[0124] It is to be appreciated that the use of any of the following “/”, “and/or”, and “at least one of”, for example, in the cases of “A/B”, “A and/or B” and “at least one of A and B”, is intended to encompass the selection of the first listed option (A) only, or the selection of the second listed option (B) only, or the selection of both options (A and B). As a further example, in the cases of “A, B, and/or C” and “at least one of A, B, and C”, such phrasing is intended to encompass the selection of the first listed option (A) only, or the selection of the second listed option (B) only, or the selection of the third listed option (C) only, or the selection of the first and the second listed options (A and B) only, or the selection of the first and third listed options (A and C) only, or the selection of the second and third listed options (B and C) only, or the selection of all three options (A and B and C). This may be extended, as is clear to one of ordinary skill in this and related arts, for as many items as are listed.

[0125] Also, as used herein, the word “signal” refers to, among other things, indicating something to a corresponding decoder. Encoder signals may include, for example, a signal indicating whether an encoder selected implicit or explicit determination of one or more adjustment values, etc. In this way, in an example the same parameter is used at both the encoder side and the decoder side. Thus, for example, an encoder can transmit (explicit signaling) a particular parameter to the decoder so that the decoder can use the same particular parameter. Conversely, if the decoder already has the particular parameter as well as others, then signaling may be used without transmitting (implicit signaling) to simply allow the decoder to know and select the particular parameter. By avoiding transmission of any actual functions, a bit savings is realized in various examples. It is to be appreciated that signaling may be accomplished in a variety of ways. For example, one or more syntax elements, flags, and so forth are used to signal information to a corresponding decoder in various examples. While the preceding relates to the verb form of the word “signal”, the word “signal” can also be used herein as a noun.

[0126] As will be evident to one of ordinary skill in the art, implementations may produce a variety of signals formatted to carry information that may be, for example, stored or transmitted. The information can include, for example, instructions for performing a method, or data produced by one of the described implementations. For example, a signal may be formatted to carry the bitstream of a described example. Such a signal may be formatted, for example, as an electromagnetic wave (for example, using a radio frequency portion of spectrum) or as a baseband signal. The formatting may include, for example, encoding a data stream and modulating a carrier with the encoded data stream. The information that the signal carries may be, for example, analog or digital information. The signal may be transmitted over a variety of different wired or wireless links, as is known. The signal may be stored on, or accessed or received from, a processor-readable medium.

[0127] Many examples are described herein. Features of examples may be provided alone or in any combination, across various claim categories and types. Further, examples may include one or more of the features, devices, or aspects described herein, alone or in any combination, across various claim categories and types. For example, features described herein may be implemented in a bitstream or signal that includes information generated as described herein. The information may allow a decoder to decode a bitstream, the encoder, bitstream, and/or decoder according to any of the embodiments described. For example, features described herein may be implemented by creating and/or transmitting and/or receiving and/or decoding a bitstream or signal. For example, features described herein may be implemented a method, process, apparatus, medium storing instructions, medium storing data, or signal. For example, features described herein may be implemented by a TV, set-top box, cell phone, tablet, or other electronic device that performs decoding. The TV, set-top box, cell phone, tablet, or other electronic device may display (e.g., using a monitor, screen, or other type of display) a resulting image (e.g., an image from residual reconstruction of the video bitstream). The TV, set-top box, cell phone, tablet, or other electronic device may receive a signal including an encoded image and perform decoding.

[0128] Features described herein may be associated with adjusting a cross-component linear model (CCLM) and a multi-model linear model (MMLM). CCLM and MMLM may be chroma prediction modes with a prediction signal generated from luma components. CCLM and MMLM may be modified by a scale factor and a slope. The slope value may be modified. For example, the slope may be adjusted based on the reconstructed pixels (e.g., reconstructed luma and chroma samples) surrounding the current block.

[0129] Cross component prediction may be performed. For example, template based CCLM/MMLM with (e.g., implicit) slope adjustment may be performed (e.g., in the context of video coding). CCLM and MMLM may be chroma prediction modes. A prediction of chroma samples may be generated from luma samples in a coding block. The predication model may include a bias factor and a slope. The slope value may be adjusted, for example, based on the reconstructed pixels surrounding the current chroma block.

[0130] In cross component prediction, cross component redundancy may be reduced, for example, by modeling the relationship between the luma and chroma component. For example, in CCLM, linear model parameters may be derived from reconstructed luma and chroma samples surrounding the current block. Signaling may be reduced or avoided, for example, and the same model derivation process (e.g., CCLM) may be repeated at the decoder side.

[0131] CCLM may be extended to MMLM, for example, when utilizing multiple linear models. In examples, MMLM may include multiple CCLMs (e.g., two CCLMs). The parameters for multiple prediction models may be derived at the encoder side and the decoder side.

[0132] In examples, the slope may be adjusted by testing different values at the encoder side. The slope adjustment value may be signaled to the decoder (e.g., may be signaled to the decoder by the encoder).

[0133] Slope adjustment may be obtained, for example, by deriving the slope adjustment value at the encoder and decoder sides. In examples, multiple slopes may be determined for multiple adjustment models.

[0134] A prediction model may be adjusted based on a selected adjustment model. Signaling overhead may be reduced (e.g., removed) and/or the bitrate may be modified (e.g., by deriving the slope adjustment value at the encoder and decoder sides).

[0135] A CCLM prediction mode may be used in video coding. Chroma samples may be predicted based on reconstructed luma samples (e.g., for the same coding block), for example, by using a linear model. A linear model may be implemented, for example, in accordance with Eq. (1):

[00001] $\text{pred}_C(i,j) =$ .Math. $\text{rec}_L'(i,j) +$ (1)

As shown by example in Eq. (1), pred.sub.C(i, j) may represent predicted chroma samples in a CU. As shown by example in Eq. (1), rec.sub.L′(i, j) may represent downsampled reconstructed luma samples of the CU.

[0136] CCLM parameters (e.g., α and β) may be derived, for example, based on (e.g., at most four) neighboring chroma samples and corresponding downsampled luma samples. The current chroma block dimensions may be W×H. In examples, W″ and H′ may be set in accordance with the following logic: [0137] W′=W, H′=H, for example, if/when LM mode is applied; [0138] W′=W+H, for example, if/when LM-A mode is applied; and/or [0139] H′=H+W, for example, if/when LM-L mode is applied.

[0140] The above neighboring positions may be denoted as S[0, −1] . . . S[W′−1, −1] and the left neighbouring positions may be denoted as S[−1, 0] . . . S[−1, H′−1]. The four samples may be selected (e.g., in accordance with the example logic), as follows: [0141] S[W′/4, −1], S[3*W′/4, −1], S[−1, H′/4], S[−1, 3*H′/4], for example, if/when LM mode is applied and both above and left neighboring samples are available; [0142] S[W′/8, −1], S[3*W′/8, −1], S[5*W′/8, −1], S[7*W′/8, −1], for example, if/when LM-A mode is applied or only the above neighboring samples are available; and/or [0143] S[−1, H′/8], S[−1, 3*H′/8], S[−1, 5*H′/8], S[−1, 7*H′/8], for example, if/when LM-L mode is applied or only the left neighboring samples are available.

[0144] In examples, the four neighboring luma samples at the selected positions may be down-sampled and compared four times to find two larger values, denoted as x.sup.0.sub.A and x.sup.1.sub.A, and two smaller values, denoted as x.sup.0.sub.B and x.sup.1.sub.B. Corresponding chroma sample values may be denoted as y.sup.0.sub.A, y.sup.1.sub.A, y.sup.0.sub.B and y.sup.1.sub.B. In examples, x.sub.A, x.sub.B, y.sub.A and y.sub.B may be derived, for example, in accordance with Eq. (2a-2d):

[00002] $X_a = (x_A^0 + x_A^1 + 1) \quad 1 \quad (2a) \quad X_b = (x_B^0 + x_B^1 + 1) \quad 1 \quad (2b) \quad Y_a = (y_A^0 + y_A^1 + 1) \quad 1 \quad (2c) \quad Y_b = (y_B^0 + y_B^1 + 1) \quad 1 \quad (2d)$

Linear model parameters α and β may be determined, for example, in accordance with Eq. (3) and Eq. (4):

[00003] $= \frac{Y_a - Y_b}{X_a - X_b} \quad (3) \qquad = Y_b - \text{ .Math. } X_b \quad (4)$

[0145] FIG. **5** illustrates an example of the location of the left and above samples and the sample of the current block involved in CCLM mode. FIG. **5** shows an example of locations of the samples used for the derivation of linear model parameters α and β.
[0146] A division operation to calculate parameter α (e.g., as shown in Eq. (3)) may be implemented, for example, with a look-up table. The difference between maximum and minimum values (e.g., the diff value) and/or the parameter α may be expressed by an exponential notation, for example, to reduce the amount of memory used to store the table. In examples, diff may be approximated with a 4-bit significant part and an exponent. A table for 1/diff may be reduced to 16 elements for 16 values of the significand, for example, in accordance with Eq. (5):

[00004] $\text{DivTable}[\,] = \{0, 7, 6, 5, 5, 4, 4, 3, 3, 2, 2, 1, 1, 1, 1, 0\} \quad (5)$

The difference, diff (e.g., as shown by the example), may be approximated.
[0147] The above template and left template may be used in conjunction to calculate linear model coefficients. The above template and left template may be used (e.g., alternatively, independently) in one or more (e.g., other) LM modes (e.g., LM_T, and LM_L modes).
[0148] In examples (e.g., in LM_T mode), the above template (e.g., only the above template) may be used to calculate the linear model coefficients. The above template may be extended to (W+H) samples, for example, to obtain more samples. In examples (e.g., in LM_L mode), the left template (e.g., only the left template) may be used to calculate the linear model coefficients. The left template may be extended to (H+W) samples, for example, to obtain more samples. In examples (e.g., in LM_LT mode), left and above templates may be used in conjunction to calculate linear model coefficients.
[0149] Chroma sample locations may be matched for video sequences (e.g., for 4:2:0 video sequences). Multiple (e.g., two) types of downsampling filters may be applied to luma samples to achieve a downsampling ratio (e.g., a 2 to 1 downsampling ratio) in horizontal and/or vertical directions. A selection of a downsampling filter may be specified, for example, by a sequence parameter set (SPS) level flag. Downsampling filters may correspond to “type-0” and “type-2” content, respectively, for example, in accordance with Eq. (6) and Eq. (7):
[00005]

$$\text{Rec}_L'(i,j) = [\text{rec}_L(2i-1, 2j-1) + 2 \text{ .Math. } \text{rec}_L(2i-1, 2j-1) + \text{rec}_L(2i+1, 2j-1) + \text{rec}_L(2i-1, 2j) + 2 \text{ .Math. } \text{rec}_L(2i, 2j) + \text{rec}_L(2i+1, 2j) + 4] \quad 3 \quad (6$$

$$\text{rec}_L'(i,j) = [\text{rec}_L(2i, 2j-1) + \text{rec}_L(2i-1, 2j) + 4 \text{ .Math. } \text{rec}_L(2i, 2j) + \text{rec}_L(2i+1, 2j) + \text{rec}_L(2i, 2j+1) + 4] \quad 3 \quad (7)$$

[0150] A luma line (e.g., general line buffer in intra prediction) may be used to determine or generate the downsampled luma samples, for example, if/when the upper reference line is at the CTU boundary.
[0151] The prediction model parameters are computed as part of the decoding process, and signaling of the parameters may be bypassed or skipped.
[0152] In examples (e.g., for chroma intra mode coding), multiple intra modes (e.g., a total of 8 intra modes) may be allowed (e.g., and utilized) for chroma intra mode coding. Intra modes may include one or more (e.g., five traditional) intra modes and one or more (e.g., three) cross-component linear model modes (e.g., CCLM, LM_A, and LM_L).
[0153] Table 1 shows examples of chroma mode signaling and a derivation process. Chroma mode coding may depend on the intra prediction mode of the corresponding luma block. A chroma block may correspond to multiple luma blocks, for example, if/when a separate block partitioning structure for luma and chroma components is enabled in I slices. In examples (e.g., for Chroma DM mode), the intra prediction mode of the corresponding luma block covering the center position of the current chroma block may be inherited.
TABLE-US-00001 TABLE 1 Example derivation of chroma prediction mode from luma mode when CCLM is enabled Corresponding luma intra prediction mode Chroma prediction mode 0 50 18 1 X (0 <= X <= 66) 0 66 0 0 0 0 1 50 66 50 50 50 2 18 18 66 18 18 3 1 1 1 66 1 4 0 50 18 1 X 5 81 81 81 81 81 6 82 82 82 82 82 7 83 83 83 83 83
[0154] A binarization table (e.g., a single binarization table) may be used, for example, regardless of the value of an sps_cclm_enabled_flag.
[0155] MMLM may be used to predict a coding block. CCLM may be implemented with, for example, one or more (e.g., three) multi-model LM (MMLM) modes. In an (e.g., each) MMLM mode, reconstructed neighboring samples may be classified into multiple (e.g., two) classes, for example, using a threshold. In examples, a threshold may be the average of luma reconstructed neighboring samples. The linear model of a (e.g., each) class may be derived, for example, using a Least-Mean-Square (LMS) method. The LMS method may be used to derive the linear model for a CCLM mode.
[0156] A slope of a prediction model may be adjusted. CCLM may use a prediction model with one or more (e.g., two) parameters to map luma values to chroma values. A slope parameter “a” and a bias parameter “b” may define a mapping, for example, in accordance with Eq. (8):

[00006] $\text{chromaVal} = a * \text{lumaVal} + b \quad (8)$

[0157] An adjustment “u” to the slope parameter may be signaled to update the model, for example, in accordance with Eq. (9):

[00007] $\text{chromaVal} = a' * \text{lumaVal} + b' \quad (9)$

Updated slope parameters may be determined, for example, in accordance with Eq. (10a-10b):

[00008] $a' = a + u \quad (10a) \quad b' = b - u * y_r \quad (10b)$

[0158] The mapping function may be tilted or rotated around a point with luminance value y.sub.r, for example, based on the selection. An average of the reference luma samples used in the model creation may be used as y.sub.r, for example, to provide a (e.g., meaningful) modification to the model. FIG. **6** illustrates an example of the process.
[0159] FIGS. **6**A and **6**B illustrate an example effect of the slope adjustment parameter “u”. FIG. **6**A shows a model for CCLM without updated slope parameters. FIG. **6**B shows a model for CCLM with updated slope parameters.
[0160] In examples, a slope adjustment parameter may be an integer between −4 and 4, inclusive. A slope adjustment parameter may be signaled in video data (e.g., the bitstream). The unit of a slope adjustment parameter may be, for example, ⅛th of a chroma sample value per one luma sample value (e.g., for 10-bit content).
[0161] In examples, adjustment may be available for CCLM model(s) that use reference samples above and left of the block (e.g., “LM_CHROMA_IDX” and “MMLM_CHROMA_IDX”), but not for “single side” modes. For example, availability of adjustment for CCLM models may be based on coding efficiency vs. complexity trade-off considerations.
[0162] For coding block using a multimode CCLM model, multiple prediction models may be adjusted. For example, slope adjustment may be applied for each of the prediction models associated with the multimode CCLM model. One or more slope updates may be signaled for a chroma

block.
[0163] In examples, an encoder may determine a slope adjustment. For example, the encoder may perform a sum of absolute transformed differences (SATD) based search for the best value of the slope update for Cr. An encoder may perform a similar SATD based search for Cb. A combined slope adjustment pair (e.g., SATD based update for Cr, SATD based update for Cb) may be included in a list of rate distortion (RD) checks for a transform unit (TU), for example, if there is a non-zero slope adjustment parameter for Cr or Cb.
[0164] FIG. **7** illustrates an example of deriving an adjustment model based on reconstructed luma and chroma samples. For example, an adjustment value may be computed using reconstructed luma and chroma samples neighboring the current block. The adjustment value may be computed at the decoder side and the encoder side. As shown by example in FIG. **7**, the slope adjustment value may be derived at the decoder side (e.g., and the encoder side), for example, using a template made of available reconstructed luma and chroma samples. The luma and chroma samples may include the same samples used to derive the CCLM/MMLM parameters (e.g., the CCLM and MMLM parameters may be based on the obtained reconstructed luma and chroma samples). The adjustment value may be derived using CCLM or MMLM. The adjustment value may be computed, for example, by testing possible values on the reconstructed samples. The adjustment value selected may be the possible value that minimizes the distance.
[0165] A slope adjustment may be implicit (e.g., explicit signaling of the slope adjustment may be bypassed). The adjustment value (u) may be derived at the decoder side. The value may be deduced at the decoder side, for example, rather than signaling the adjustment value (u) from the encoder to the decoder.
[0166] In examples, the chroma samples available to the decoder may be used to derive the adjustment value (u).
[0167] FIG. **8** illustrates an example of using chroma samples to derive an adjustment value.
[0168] A template may include W*N samples above the current block and H*M left of the current block. Parameters W and H may represent width and height, respectively. The different values of the adjustment value “u” may be tested at the encoder and decoder. CCLM/MMLM may be performed on the template at the encoder and decoder. For example, a cross component prediction model may be applied with potential adjustment values to predict chroma samples in a template using their respective collocated reconstructed luma samples. The chroma samples predicted using the various adjustment values may be compared to the actual reconstructed chroma samples in the template. The adjustment value that leads to the most accurate prediction may be selected as the adjustment value for the model for the current block. In examples, operations may be performed for adjustment value “u” from −4 to 4. The selected (e.g., best) value of u may be the value that provides the most accurate (e.g., best) prediction on the template. The value of u may be determined without signaling. In examples, N and M may be equal. In examples, N and M may depend on dimensions of the current block.
[0169] The above template (e.g., only the above template) may be considered for deriving the u value, for example, if/when the above samples (e.g., only the above samples) are considered for CCLM/MMLM (LM_A). The left template (e.g., only the left template) may be considered for deriving the u value, for example, if/when the left samples (e.g., only the left samples) are considered for CCLM/MMLM (LM_A). The above and left templates may be considered for deriving the u value, for example, if/when the above and left samples are considered for CCLM/MMLM (LM_A).
[0170] An adjustment determination indication may indicate implicit or explicit signaling of an adjustment value. An encoder may determine whether the adjustment value is to be explicitly signaled in the bitstream or derived/deduced by the decoder, and indicate the determination via an implicit or explicit adjustment flag. A flag may be signaled to indicate (e.g., to the decoder) whether the adjustment value (u) is signaled to or deduced by the decoder. For example, implicit slope adjustment may be indicated by a flag equal to zero and explicit slope adjustment may be indicated by a flag not equal to zero (e.g., flag equal to one).
[0171] The number of adjustment values may vary. In examples, there may be eight (8) adjustment values (e.g., −4 −3 −2 −1 1 2 3 4). Eight adjustment values may provide a reasonable compromise between good predictions and signaling overhead. Limitations on the number of adjustment values may be alleviated for implicit slope adjustment without signaling. In examples, non-integer values between −4 and 4 may be used as adjustment values. In examples, a range (e.g., a wide range) of integer and/or non-integer adjustment values may be used (e.g., −10 to 10). A wide (e.g., high) range of numbers to test may correspond to encoder and decoder computational complexity (e.g., an additional computational complexity). In examples, a reasonable trade off to select the range of adjustment values may be implemented.
[0172] Different adjustment models may be available for adjusting the prediction model(s) for a coding block. A slope adjustment to the prediction model may be based on modifying the slope around the midpoint of the luma (y.sub.r as shown by example in FIG. **6**B). A slope adjustment may be based on pivoting the prediction model around extreme points, such as maximum and/or minimum luma values. FIGS. **9**A-**9**B show examples of slope modification. In some examples, the slope adjustment may be based on modifying the slope around a pivot point indicated in video data.
[0173] FIGS. **9**A-**9**B illustrate examples of slope modification around extreme values. FIG. **9**A shows an example of slope modification around a minimum luma value. FIG. **9**B shows an example of slope modification around a maximum luma value. For example, example adjustment models may include slope modifications around extreme luma values.
[0174] Slope modification around extreme luma values may provide flexibility to select a suitable slope for a particular coding block. Slope modification around extreme luma values may not require additional (e.g., further) signaling.
[0175] For example, the prediction model for the coding block may include a linear prediction model. The linear function may be modified, for example, by pivoting around a minimum value and/or around a maximum value. For example, the minimum value of the linear prediction model may be the pivot point for slope modification. The maximum value of the linear prediction model may be the pivot point for slope modification.
[0176] Multiple adjustment models may be obtained for adjusting the prediction model of the coding block. For example, in an example adjustment model, the slope of the prediction model may be adjusted around a pivot point, and the pivot point may be a minimum value of the prediction model. In an example adjustment model, the slope of the prediction model may be adjusted around a pivot point, and the pivot point may be a maximum value of the prediction model. In an example adjustment model, the slope of the prediction model may be adjusted around a pivot point, and the pivot point may be a midpoint of the prediction model.
[0177] In an example of modification around a minimum value, assuming Ymin is the minimum value of the collocated luma samples, a and b values may be modified, for example, in accordance with Eq. (11a) and Eq. (11b):
[00009] $a = * u \quad (11a) \quad b = b - u * Y\mathrm{min} \quad (11b)$
[0178] In an example of modification around a maximum value, assuming Ymax is the minimum value of the collocated luma samples, a and b values may be modified, for example, in accordance with Eq. (12a) and Eq. (12b):
[00010] $a = a * u \quad (12a) \quad b = b - u * Y\mathrm{max} \quad (12b)$
[0179] In example adjustment models, the offset value (e.g., the constant value b) may be modified with or without modifying the slope. In examples, the prediction model may be adjusted based on the selected adjustment model by adjusting the offset of the prediction model and maintaining (e.g., not adjusting) the slope (e.g., of the prediction model). FIG. **10** shows an example of changing the constant value (e.g., only the constant value).
[0180] FIG. **10** illustrates an example of modifying linear slope value b. Modification of the slope value b may be implemented, for example, in

accordance with Eq. (13):

[00011] $b = b + u$ (13)

[0181] Multiple parameters of a prediction model (e.g., a slope and an offset) may be derived (e.g., by a video decoder) based on reconstructed samples neighboring the coding block. The decoder may adjust the prediction model based on the selected adjustment model. The selected adjustment model may be configured to adjust the slope and/or the offset of the prediction model.

[0182] Example adjustment models described herein may be implemented alone or in any combination. For example, different u values may be tested at encoder and decoder sides, the slope may be changed around mid and extreme points at encoder and decoder sides, and/or the constant value may be changed at encoder and decoder sides. A (e.g., the best) model may be selected, for example, according to the measured distance with or without signaling. While examples provided herein relate to predicting chroma samples based on collocated luma samples, those skilled in the art can appreciate that the examples may apply to predicting luma samples based on collocated chroma samples.

[0183] In examples, an encoder may select an adjustment model from multiple adjustment models for adjusting the prediction model for a coding block. For example, the encoder may perform a sum of absolute transformed differences (SATD) based search for the best adjustment model for Cr. The SATD distance (e.g., the distance associated with each adjustment model) may be computed for the available adjustment models by calculating the SATD between the sample (e.g., chroma and luma) values of the current block and the predicted sample values. The computed SATD distances for the different adjustment models may be used to select the adjustment model suitable for the current block. The prediction model may be adjusted based on the adjustment model chosen.

[0184] Multiple adjustment models may be obtained (e.g., by a video encoder) for adjusting the prediction model. A first difference (e.g., an SATD) for a first adjustment model between sample values of the coding block and predicted sample values that are predicted based on the first adjustment model may be computed (e.g., by the video encoder). A second difference for a second adjustment model between sample values of the coding block and predicted sample values that are predicted based on a second adjustment model may be computed (e.g., by the video encoder). An adjustment model may be selected based on comparing the first difference and the second difference. The selected adjustment model may be indicated in video data.

[0185] A selected adjustment model may be obtained based on indication(s) in video data, as shown in the following tables. For example, in Table 2, the selected adjustment model may be obtained based on an adjustment model indication (e.g., in video data). For example, the adjustment model indication may be or may include the AdjustModel indication shown in Table 2. Based on the adjustment model indication, one or more pivot point of the selected adjustment model may be determined. For example, the pivot points may be signaled by Pivotpoint_M1 and Pivotpoint_M2.

TABLE-US-00002 TABLE 2 Example for signaling pivot points including syntaxes of the adjustment model and the pivot points. Decode_Coding_Unit_Data { ... ... cclmFlag = decode_cclm_flag( ) If (cclmFlag) { AdjustModel = decode_adjust_model( ) If (AdjustModel) { Pivotpoint = Decode_Pivot_Points( ) } ... ... mmlmFlag = decode_mmlm_flag( ) If (cclmFlag) { AdjustModel = decode_adjust_model( ) If (AdjustModel) { Pivotpoint_M1 = Decode_Pivot_Points( ) Pivotpoint_M2 = Decode_Pivot_Points( ) } ... }

[0186] As shown in Table 2, the selected adjustment model may be obtained based on an adjustment model indication (e.g., in video data) indicating a first pivot point of the selected adjustment model (e.g., Pivotpoint_M1) and a second pivot point of the adjustment model (e.g., Pivotpoint_M2). For example, the prediction model for a block may include multiple prediction models. When MMLM is used for a coding block, multiple linear prediction models are used to predict the coding block. Adjusting the prediction model for the coding block may be based on multiple pivot points, for example, a first pivot point of the selected adjustment model and a second pivot point of the selected adjustment model. It may be determined, based on the selected adjustment model, that a first prediction model for the coding block pivots around the first pivot point of the first prediction model, and that a second prediction model for the coding block pivots around the second pivot point of the selected adjustment model.

[0187] The first pivot point may be based on a first adjustment model, and a second pivot point may be based on a second adjustment model. The first pivot point may be used to adjust a first prediction model of the multiple prediction models. The second pivot point may be used to adjust a second prediction model of the multiple linear prediction models. The video decoder may adjust a slope of the first linear prediction model via the determined first pivot point and adjust a slope of the second linear prediction model via the determined second pivot point.

[0188] For example, in Table 3, the selected adjustment model may be obtained based on an adjustment model indication (e.g., in video data) indicating a pivot point of the selected adjustment model. For example, based on indication isMidPoint, whether the pivot point of the selected adjustment model is a midpoint of the prediction model may be determined. Based on indication PivotPoint, whether to use a start point or an end point of the prediction model as the pivot point may be determined. For example, PivotPoint=1 may indicate a beginning of the prediction model as the pivot point, and PivotPoint=2 may indicate an end of the prediction model as the pivot point.

TABLE-US-00003 TABLE 3 Example for determining a start point and an end point (e.g., for pivoting a prediction model) including syntaxes of the midpoint and the pivot points. Decode_Pivot_Points( ) { isMidPoint = decode_is_mid_point( ) If (isMidPoint) { Return 0 } PivotPoint = decode_start_or_end_pivot_point( ) Return PivotPoint + 1 }

[0189] For example, in Table 4, the selected adjustment model may be obtained based on an adjustment model indication (e.g., in video data) indicating a pivot point. As shown in Table 4, the pivot point may be selected from multiple predefined points, such as **2**N+1 potential pivot points. The predefined points may include a midpoint and N points on each side of the midpoint (e.g., N predefined potential pivot points above the midpoint and a predefined potential pivot point below the midpoint). The adjustment model indication may be configured to indicate around which predefined points the prediction model is to be adjusted.

TABLE-US-00004 TABLE 4 Example for determining 2N + 1 pivot points (e.g., for pivoting a prediction model) including syntaxes of the midpoints and pivot points. Decode_Coding_Unit_Data { ... ...x cclmFlag = decode_cclm_flag( ) If (cclmFlag) { AdjustModel = decode_adjust_model( ) If (AdjustModel) { IsMidPoint = decode_is_mid_point( ) If (IsMidPoint == 0) { Pivotpoint = Decode_Pivot_Points( ) } } ... ... mmlmFlag = decode_mmlm_flag( ) If (cclmFlag) { AdjustModel = decode_adjust_model( ) If (AdjustModel) { IsMidPoint1 = decode_is_mid_point( ) If (IsMidPoint1 == 0) { Pivotpoint1 = Decode_Pivot_Points( ) } IsMidPoint2 = decode_is_mid_point( ) If (IsMidPoint2 == 0) { Pivotpoint2 = Decode_Pivot_Points( ) } ... }

[0190] As shown in Table 5, Log 2(N) bits may be processed (e.g., encoded and/or decoded). For example, 4 points (e.g., pivot points) may use 2 bits for processing (e.g., to encode and/or decode).

TABLE-US-00005 TABLE 5 Example of 2N + 1 pivot points (e.g., for pivoting a prediction model) including syntaxes of pivot points. Decode_Pivot_Points( ) { PivotPoint = decode_pivot_point (log2(N)) Return PivotPoint }

[0191] While the examples provided herein may assume that media content is streamed to a display device, there is no specific restriction on the type of display device that may benefit from the example techniques described herein. For example, the display device may be a television, a projector, a mobile phone, a tablet, etc. Further, the example techniques described herein may apply to not only streaming use cases, but also teleconferencing settings. In addition, a decoder and a display as described herein may be separate devices or may be parts of a same device. For example, a set-top box may decode an incoming video stream and provide (e.g., subsequently) the decoded stream to a display device (e.g., via

HDMI), and information regarding viewing conditions such as a viewing distance may be transmitted from the display device to the set-top box (e.g., via HDMI).
[0192] Although features and elements are described above in particular combinations, one of ordinary skill in the art will appreciate that each feature or element can be used alone or in any combination with the other features and elements. In addition, the methods described herein may be implemented in a computer program, software, or firmware incorporated in a computer-readable medium for execution by a computer or processor. Examples of computer-readable media include electronic signals (transmitted over wired or wireless connections) and computer-readable storage media. Examples of computer-readable storage media include, but are not limited to, a read only memory (ROM), a random access memory (RAM), a register, cache memory, semiconductor memory devices, magnetic media such as internal hard disks and removable disks, magneto-optical media, and optical media such as CD-ROM disks, and digital versatile disks (DVDs). A processor in association with software may be used to implement a radio frequency transceiver for use in a WTRU, UE, terminal, base station, RNC, or any host computer.

Claims

1-40. (canceled)
41. A video decoding device, comprising: a processor configured to: obtain a prediction model for predicting a coding block; select an adjustment model, from a plurality of adjustment models, for adjusting the prediction model; adjust the prediction model based on the selected adjustment model; and decode the coding block based on the adjusted prediction model.
42. The device of claim 41, wherein the processor is further configured to: derive a slope and an offset of the prediction model based on reconstructed samples neighboring the coding block, wherein adjusting the prediction model based on the selected adjustment model comprises adjusting at least one of the slope or the offset of the prediction model based on the selected adjustment model.
43. The device of claim 41, wherein the prediction model comprises a cross component prediction model, and the processor is further configured to: determine a plurality of parameters of the cross component prediction model based on neighboring chroma samples and luma samples of the coding block, wherein a first adjustment model and a second adjustment model of the plurality of adjustment models are configured to adjust the plurality of parameters of the cross component prediction model differently.
44. The device of claim 41, wherein a first adjustment model of the plurality of adjustment models is configured to adjust a slope of the prediction model around a minimum value, a second adjustment model of the plurality of adjustment models is configured to adjust the slope of the prediction model around a midpoint value, and a third adjustment model of the plurality of adjustment models is configured to adjust the slope of the prediction model around a maximum value.
45. The device of claim 41, wherein the processor is further configured to: adjust the prediction model based on the selected adjustment model by adjusting an offset of the prediction model and maintaining a same slope of the prediction model.
46. The device of claim 41, wherein the selected adjustment model is obtained based on an adjustment model indication in video data, and wherein the processor is further configured to: based on the adjustment model indication, determine a pivot point of the selected adjustment model, wherein adjusting the prediction model based on the selected adjustment model comprises adjusting a slope of the prediction model via the determined pivot point.
47. A method for a video decoder, method comprising: obtaining a prediction model for predicting a coding block; selecting an adjustment model, from a plurality of adjustment models, for adjusting the prediction model; adjusting the prediction model based on the selected adjustment model; and decoding the coding block based on the adjusted prediction model.
48. The method of claim 47, wherein the method further comprises: deriving a slope and an offset of the prediction model based on reconstructed samples neighboring the coding block, wherein adjusting the prediction model based on the selected adjustment model comprises adjusting at least one of the slope or the offset of the prediction model based on the selected adjustment model.
49. The method of claim 47, wherein the prediction model comprises a cross component prediction model, and the method further comprises: determining a plurality of parameters of the cross component prediction model based on neighboring chroma samples and luma samples of the coding block, wherein a first adjustment model and a second adjustment model of the plurality of adjustment models are configured to adjust the plurality of parameters of the cross component prediction model differently.
50. The method of claim 47, wherein a first adjustment model of the plurality of adjustment models is configured to adjust a slope of the prediction model around a minimum value, a second adjustment model of the plurality of adjustment models is configured to adjust the slope of the prediction model around a midpoint value, and a third adjustment model of the plurality of adjustment models is configured to adjust the slope of the prediction model around a maximum value.
51. The method of claim 47, wherein the method further comprises: adjusting the prediction model based on the selected adjustment model by adjusting an offset of the prediction model and maintaining a same slope of the prediction model.
52. The method of claim 47, wherein the selected adjustment model is obtained based on an adjustment model indication in video data, and wherein the method further comprises: based on the adjustment model indication, determining a pivot point of the selected adjustment model, wherein adjusting the prediction model based on the selected adjustment model comprises adjusting a slope of the prediction model via the determined pivot point.
53. A video encoding device, comprising: a processor configured to: obtain a prediction model for predicting a coding block; select an adjustment model, from a plurality of adjustment models, for adjusting the prediction model; adjust the prediction model based on the selected adjustment model; and encode the coding block based on the adjusted prediction model.
54. The device of claim 53, wherein the processor is further configured to: obtain the plurality of adjustment models configured to adjust the prediction model; for a first adjustment model of the plurality of adjustment models, compute a first difference between sample values of the coding block and predicted sample values that are predicted based on the first adjustment model; and for a second adjustment model of the plurality of adjustment models, compute a second difference between the sample values of the coding block and predicted sample values that are predicted based on the second adjustment model, wherein the adjustment model is selected based at least on comparing the first difference and the second difference.
55. The device of claim 53, wherein the prediction model comprises a cross component prediction model, and the processor is further configured to: determine a plurality of parameters of the cross component prediction model based on neighboring chroma samples and luma samples of the coding block, wherein a first adjustment model and a second adjustment model of the plurality of adjustment models are configured to adjust the plurality of parameters of the cross component prediction model differently.
56. The device of claim 53, wherein a first adjustment model of the plurality of adjustment models is configured to adjust a slope of the prediction model around a minimum value, a second adjustment model of the plurality of adjustment models is configured to adjust the slope of the prediction model around a midpoint value, and a third adjustment model of the plurality of adjustment models is configured to adjust the slope of the prediction model around a maximum value.
57. A method for a video encoder, the method comprising: obtaining a prediction model for predicting a coding block; selecting an adjustment

model, from a plurality of adjustment models, for adjusting the prediction model; adjusting the prediction model based on the selected adjustment model; and encoding the coding block based on the adjusted prediction model.

58. The method of claim 57, wherein the method further comprises: obtaining the plurality of adjustment models configured to adjust the prediction model; for a first adjustment model of the plurality of adjustment models, computing a first difference between sample values of the coding block and predicted sample values that are predicted based on the first adjustment model; and for a second adjustment model of the plurality of adjustment models, computing a second difference between the sample values of the coding block and predicted sample values that are predicted based on the second adjustment model, wherein the adjustment model is selected based at least on comparing the first difference and the second difference.

59. The method of claim 57, wherein the prediction model comprises a cross component prediction model, and the method further comprises: determining a plurality of parameters of the cross component prediction model based on neighboring chroma samples and luma samples of the coding block, wherein a first adjustment model and a second adjustment model of the plurality of adjustment models are configured to adjust the plurality of parameters of the cross component prediction model differently.

60. The method of claim 57, wherein a first adjustment model of the plurality of adjustment models is configured to adjust a slope of the prediction model around a minimum value, a second adjustment model of the plurality of adjustment models is configured to adjust the slope of the prediction model around a midpoint value, and a third adjustment model of the plurality of adjustment models is configured to adjust the slope of the prediction model around a maximum value.