CHAPTER 10
HIGH-EFFICIENCY VIDEO CODING TRANSFORM HARDWARE ARCHITECTURES

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10.1 INTRODUCTION

High-Efficiency Video Coding (HEVC) is the latest video coding standard for the compression and decompression of video data. It was first published in 2013 and is widely used today in conjunction with the previous AVC/H.264 video coding standard. One of the core components of HEVC is its lossy transform unit which is based on both the Discrete Cosine Transform (DCT) for sizes of 4×4 to 32×32 and the Discrete Sine Transform (DST) for size 4×4.

The transform operation in HEVC is typically performed in the order of billions for a typical video stream. Consider a 4K video frame with a resolution of 3840×2160 with a total pixel of around 8.3 million. Assume, for example, half of the pixels in the video frame needs to be transformed into the frequency domain to remove redundancy and achieve compression; for a 30 frames per second (fps) video, one second of video stream thus requires around 120 million transform operations. To speed up video compression, the operation must be as fast as possible and with good energy efficiency. For this, a custom hardware design of the transform units is necessary to achieve this goal.

In this chapter, we review the custom hardware architectures of the HEVC transform. First, an overview of HEVC is given, followed by a brief theory on its transform unit. This is followed by the discussion on the existing unified architecture and the difference with our proposed split architecture. For each of these architectures, the folded and parallel structures are described next for the implementation of the individual transformations. Next, performance comparison, discussion, and analysis are provided for all the presented HEVC transform architectures and structures. The chapter finally concludes with an overall summary.

10.2 HIGH-EFFICIENCY VIDEO CODING OVERVIEW

HEVC was developed by the Joint Collaborative Team on Video Coding (JCT-VC), a collaboration between the ITU-T Video Coding Experts Group (VCEG) and the ISO/IEC Moving Picture Experts Group (MPEG) standardization organizations (Sze et al., 2014). HEVC is the international video compression standard, and it is a replacement for AVC/H.264 standard. HEVC, which is also known as H.265, supports resolutions up to 8192×4320, including 8K UHD.

Figure 10.1 shows a block diagram of an HEVC H.265 encoder and decoder. The grey area illustrates the decoder part in HEVC, while the outer side is the encoder part of HEVC. The architecture of HEVC H.265 is based on the block-based hybrid video coding inherited from AVC standard (Budagavi et al., 2013; Sullivan et al., 2012; Sze et al., 2014). First, each input picture will be partitioned into a regular grid of equal size Coding Tree Units (CTUs). The CTU is the basic processing unit, and it is the combination of two chromas Coding Tree Blocks (CTB) and a luma CTB.

Next, the CTBs can be further subdivided into multiple Coding Blocks (CBs) using a quadtree structure. The existence of quadtree syntax in CTU allows CB to be divided into appropriate sizes based on the regional signal characteristics, it is protected by CTB. The quadtree separation process can be repeated until the size for the luma CB reaches the minimum allowable CB dimension size selected by the encoder.

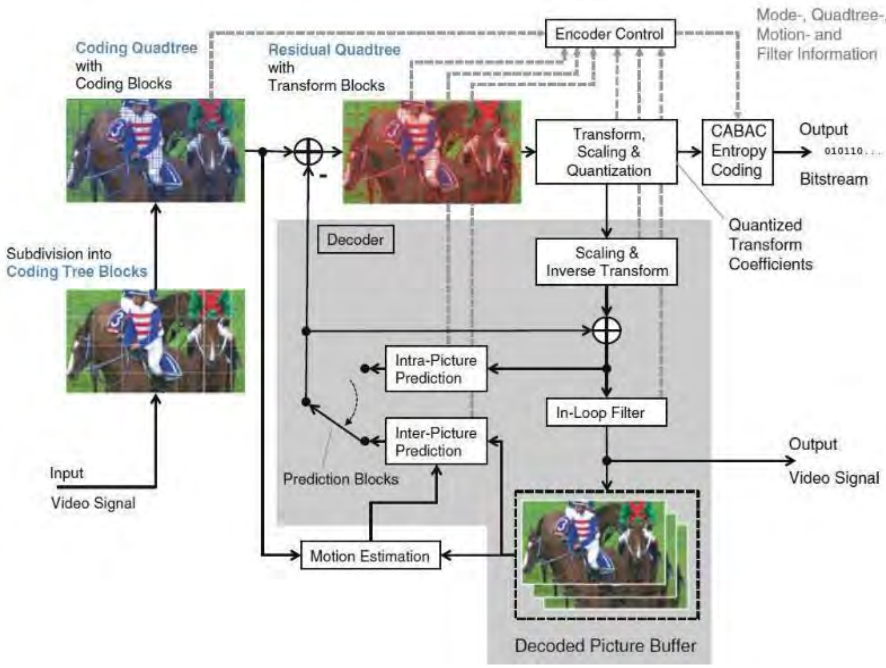

Figure 10.1 Block diagram of the high-efficiency video coding encoder and decoder (Sze et al., 2014)

Then, the encoder decides whether to code a video using inter-picture or intra-picture prediction. When the intra-picture is marked in prediction mode, the Prediction Block (PB) size is set equal to CB for all block sizes except for the smallest CB size. Conversely, when the inter-picture is turned and marked in prediction mode, the CB determines whether the chroma and luma are divided into one, two, or four PBs. For the prediction residual, the CB will be coded using Transform Blocks (TB) by the Residual Quadtree (RQT). The TB will go through transformation, scaling, and quantization.

The structure of CTBs is partitioned into CBs and TBs is shown in Figure 10.2. A CTB can only contain one CTU or can be divided to form several CTUs. The size of TB for DCT is from 4×4 to 32×32 and 4×4 for DST.