CONTENT ADAPTIVE WAVELET LIFTING FOR SCALABLE LOSSLESS VIDEO CODING

Daniela Lanz, Christian Herbert, and André Kaup

Multimedia Communications and Signal Processing
Friedrich-Alexander-University Erlangen-Nürnberg (FAU)
Cauerstr. 7, 91058 Erlangen, Germany
Email: {Daniela.Lanz,Christian.Herbert,Andre.Kaup}@FAU.de

ABSTRACT

Scalable lossless video coding is an important aspect for many professional applications. Wavelet-based video coding decomposes an input sequence into a lowpass and a highpass subband by filtering along the temporal axis. The lowpass subband can be used for previewing purposes, while the highpass subband provides the residual content for lossless reconstruction of the original sequence. The recursive application of the wavelet transform to the lowpass subband of the previous stage yields coarser temporal resolutions of the input sequence. This allows for lower bit rates, but also affects the visual quality of the lowpass subband. So far, the number of total decomposition levels is determined for the entire input sequence in advance. However, if the motion in the video sequence is strong or if abrupt scene changes occur, a further decomposition leads to a low-quality lowpass subband. Therefore, we propose a content adaptive wavelet transform, which locally adapts the depth of the decomposition to the content of the input sequence. Thereby, the visual quality of the lowpass subband is increased by up to 10.28 dB compared to a uniform wavelet transform with the same number of total decomposition levels, while the required rate is reduced by 1.06% additionally.

***Index Terms*—** Lossless Coding, Scalability, Discrete Wavelet Transform, Motion Compensation

1. INTRODUCTION

Many professional tasks like surveillance systems and telemedicine applications require lossless compression due to their sensitive content. However, lossless compression naturally leads to high bit rates. Considering any wireless network with limited channel capacity, a fast transmission of the entire data is challenging. Therefore, scalable lossless video coding is desirable, which allows for transmitting a base layer (BL) with coarser quality in the first instance and afterwards one or more enhancement layers (ELs), comprising the residual video data, to reconstruct the original sequence without any loss. Basically, three different types of video scalability can be distinguished. Temporal scalability affects the frame rate, spatial scalability controls the spatial resolution, and quality scalability manipulates the fidelity of the video. Beside DCT-based coding schemes like Scalable High Efficiency Video Coding (SHVC) [1] and Sample-Based Weighted Prediction for Enhancement Layer Coding (SELC) [2], also 3-D subband coding (SBC) [3] can be applied. 3-D SBC is based on Wavelet Transforms (WT), which naturally provide scalability features without additional overhead [4]. As shown in Fig. 1, by a transformation in temporal direction, the signal is decomposed into a lowpass (LP) and a highpass (HP) subband. Both subbands offer only half the frame rate compared to the original sequence. While the LP subband is very similar to the original signal, the HP subband contains the structural information of the video sequence. Afterwards, every frame of each subband is coded by the wavelet-based coder JPEG 2000 [5], resulting in a fully scalable BL-EL-representation.

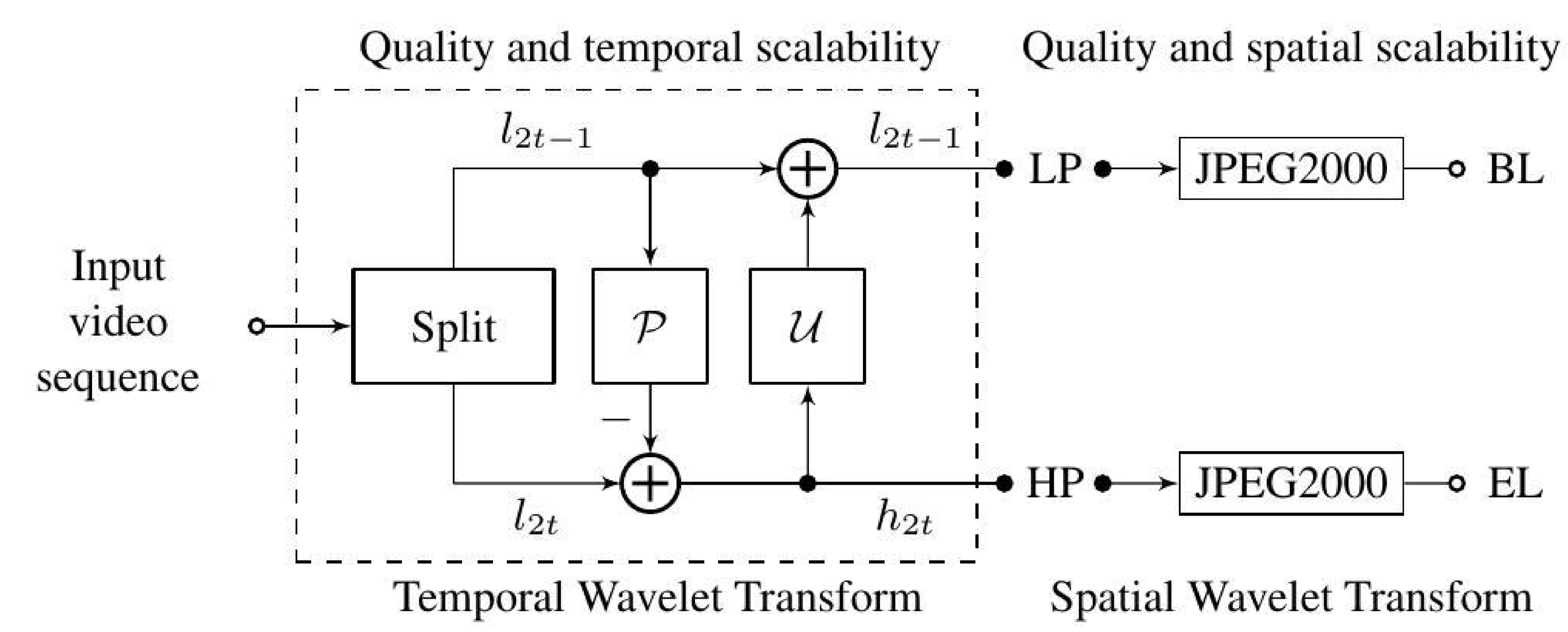

Fig. 1: Considered scenario to achieve a fully scalable representation of a video sequence. The dashed box shows the lifting structure of the wavelet transform for one decomposition level.

In this work, we focus on the optimization of the temporal scalability, which is controlled by the temporal WT highlighted by the dashed box in Fig. 1. The recursive application of the WT to the LP subband of the previous stage halves the frame rate for every decomposition level. This is advantageous for similar frames of the video sequence. In contrast, if huge changes occur among subsequent frames, the visual quality suffers significantly from multiple decomposition levels. This is why motion compensation (MC) should be included into the WT. However, MC always leads to a higher entire rate, mainly caused by the motion information, which has to be transmitted as additional overhead [6]. Further, there exists no practical approach for perfect MC. Hence, the error propagation will increase for a higher number of decomposition levels, leading to an inferior visual quality of the LP subband. Therefore, the temporal scaling should be adapted to the video sequence. This can be reached by our proposed content adaptive wavelet lifting (CA-WL), which provides fine temporal resolution for high dynamic parts of a video sequence, while parts with few changes among subsequent frames are resolved coarser. After a brief overview of 3-D SBC, the proposed CA-WL is described in detail. Simulation results are given in the next section, followed by a short conclusion and outlook at the end of the paper.

2. 3-D SUBBAND CODING

An efficient implementation of the discrete WT was proposed by Sweldens [7]. The so-called lifting structure consists of three steps: split, predict, and update. The block diagram of the lifting structure for a decomposition in temporal direction is depicted in the dashed