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Modulated Lapped Transforms in Image Coding

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Abstract

The class of modulated lapped transforms (MLT) with extended overlap is investigated in image coding. The finite-length-signals implementation using symmetric extensions is introduced and human visual sensitivity arrays are computed. Theoretical comparisons with other popular transforms are carried and simulations are made using intraframe coders. Emphasis is given in transmission over packet networks assuming high rate of data losses. The MLT with overlap factor 2 is shown to be superior in all our tests with bonus features such as greater robustness against block losses.

1 Introduction

While block transforms became very popular in the image coding field, the lapped orthogonal transform (LOT) [1, 2] arose as a promising competitor to transforms such as the discrete cosine transform (DCT) [3], which is the block transform used in most image and video coding algorithms [3]. The advantage of lapped transforms [4] resides on the length of their basis functions, providing improved spectral selection better filtering capabilities, and on the extreme reduction of the blocking artifacts commonly present in block transform coding at low bit-rates. Furthermore, the concept of lapped transforms was established and proven to be equivalent to the concept of paraunitary FIR uniform filter banks [4, 5]. Under this point of view, both the LOT and the DCT are considered as special choices of paraunitary filter banks [4, 5, 6]. Cosine modulated filter banks [5] allow perfect reconstruction (PR) in paraunitary analysis-synthesis systems, using a modulation of a low-pass prototype by a cosine train. By a proper choice of the phase of the modulating cosine, Malvar developed the modulated lapped transform (MLT) [7], which led to the so-called extended lapped transforms (ELT)[4, 8]. The ELT allows several overlapping factors, generating a family of PR cosine modulated filter banks. Both designations (MLT and ELT) are frequently applied to this class of filter banks[4]. Other cosine-modulation approaches have also been developed (see, for example, [5, 9] and references therein) and the most significant difference among them is the low-pass prototype choice and the phase of the cosine sequence.

As ELTs are maximally decimated FIR uniform filter banks, let M be the number of filters, which is the number of channels, the decimation factor of the subbands, and the block size. In the ELTs, the filters' length L is basicaly an even multiple of the block size M, as $L = 2KM$, where K is the overlap factor. The analysis filters ($f_m(n)$) are time-reversed versions of the synthesis filters ($g_m(n)$) as in any paraunitary filter bank (for $m = 0, 1 \ldots, M-1$ and $n = 0, 1, \ldots, L-1$). The MLT-ELT class is defined by [4, 8]

$$g_m(n) = f_m(L-1-n) = h(n)\sqrt{\frac{2}{M}}\cos\left[\left(m+\frac{1}{2}\right)\left(n+\frac{M+1}{2}\right)\frac{\pi}{M}\right] \quad (1)$$

for $m = 0, 1 \ldots, M-1$ and $n = 0, 1, \ldots, L-1$. $h(n)$ is a symmetric window modulating the cosine sequence and the impulse response of a low-pass prototype (with cutoff frequency at $\pi/2M$) which is translated in frequency to M different frequency slots in order to construct the uniform filter bank. We will mostly use ELT with $K = 2$, which will be designated as ELT-2, while ELT with other overlap factors will be referred as ELT-K. We assume row-column separable implementation of the transform. Therefore, one-dimensional analysis of the transform implementation is sufficient for two-dimensional applications.

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Fig. 6(c)