Applications of Reversible Integer Wavelet Transforms to Lossless Compression of Medical Image Volumes

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Abstract — **A method is proposed for embedded compression of medical image volumes. The method uses reversible integer wavelet transforms, and allows both lossy and lossless compression.**

I. Introduction

Although wavelet transforms have been widely used for lossy compression of images, their use has not been as widespread in lossless image coding applications. This is mostly due to the fact that wavelet transforms, in general, generate floating-point coefficients that are not well suited for lossless compression.

Recently, there has been some interest in developing wavelets that map integers to integers [1,2,3,4]. In [4], the authors introduced a general framework for generating such transforms using the lifting scheme. In this scheme, the input x[n] is first split into even and odd indexed samples, $s^{(0)}[n] = x[2n]$ and $d^{(0)}[n] = x[2n+1]$. Next, M pairs of alternating dual lifting and lifting steps are applied using

$$d^{(i)}[n] = d^{(i-1)}[n] - \lfloor(\sum_k p^{(i)}[k]s^{(i-1)}[n-k]) + \frac{1}{2}\rfloor$$

and

$$s^{(i)}[n] = s^{(i-1)}[n] - \lfloor(\sum_k u^{(i)}[k]d^{(i)}[n-k]) + \frac{1}{2}\rfloor,$$

for $i = 1, \cdots, M$, to obtain the highpass and lowpass coefficients, $d^{(M)}[n]$ and $s^{(M)}[n]$, respectively. Since these transforms generate integer coefficients, they are attractive for lossless coding applications. Furthermore, it is also possible to use these transforms in lossy coding applications. Thus, these transforms promise to unify lossy and lossless compression.

In this work, we introduce a method for compressing medical image volumes using reversible integer wavelet transforms. The presented method exploits dependencies in all three dimensions of the image volume.

II. Embedded Compression of Medical Image Volumes

Several of today's diagnostic medical imaging techniques generate a three-dimensional volume of the object being imaged. There has been recent interest in coding three dimensional data using three-dimensional wavelet transforms [5,6,7,8]. The work of [6,7,8] is zerotree based, while [5] is based on binary arithmetic coding, and is more similar to the work presented here.

In this work, the volume is first decomposed into subbands using three-dimensional integer wavelet transforms. The resulting integer coefficients are scanned to form bit-cubes. The bit-cubes are encoded starting from the most significant bit-cube to the least significant bit-cube. Inside each bit-cube the coefficients in lower frequency subbands are scanned before the coefficients in higher frequency subbands. The most significant bit in each subband is recorded in the file header, so that the subbands are skipped entirely until they contain a significant coefficient. Context-based arithmetic coding is used to encode the subbands. Contexts are generated to exploit dependencies in all three dimensions, and they use bits from the same bit-cube, as well as more significant bit-cubes.

The algorithm produces an embedded bitstream that allows both lossy and lossless representations. In other words, the initial portion of the bitstream can be decoded to reconstruct a lossy version of the image volume. If further decoding is performed, the quality of the reconstructed image volume is improved, until the volume is reconstructed perfectly. We discuss how to improve the lossy performance of the presented scheme with only a minor compromise of the lossless performance. Since the integer transforms used in this work are biorthogonal, they do not preserve the L_2 norm. We discuss an approach that computes scaling factors for each subband for a given integer wavelet transform. Experiments show that scaling the subbands with these factors improves the lossy performance of the transforms dramatically.

We compare the lossless and lossy performances of several integer wavelet transforms in our method using sets of CT and MR images. We also investigate the effects of using a different number of slices in a single coding unit. Comparisons with other 2-D and 3-D compression methods, such as the one presented in [8], are provided as well.

References

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