Omnidirectional Integral Photography images compression using the 3D-DCT

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Abstract: Integral Photography images exhibit high intra-pixel as well as inter-elemental-image correlation. In this work, we present an efficient, omnidirectional Integral Photography compression scheme based on a Hilbert curve scan and a three dimensional transform technique.

OCIS codes: (999.9999) Image compression; (100.6890) Three-dimensional image processing; (110.3000) Image quality assessment.

1. Introduction

There are many compression schemes proposed for Integral Photography (IP) [1] image coding based on disparity estimation techniques [2,3] or higher order transforms [4]. However, disparity estimation encoders, based on the MPEG standard [5], are inefficient in cases of IP images that contain small sized elemental images, while the proposed higher order transform techniques are used in unidirectional IP compression.

In this work, we describe a three-dimensional discrete cosine transform (3D-DCT) [6] encoder for use in omnidirectional IP image compression. The encoder utilizes the 2D Hilbert curve [7], shown in Fig.1, to rearrange the two-dimensional (2D) elemental image lattice. The Hilbert space-filling curve has excellent locality preservation properties and is used in an effort to maximize the correlation of the elemental images contained within each transformation cube. The performance of the encoder is also evaluated for a number of different scanning topologies [3].

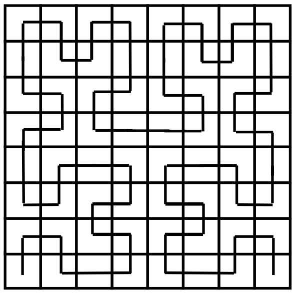

Fig. 1. Elemental images traversal scheme based on the Hilbert space filling curve.

2. Compression using the 3D-DCT and 2D scanning topologies

The 2D lattice of elemental images is initially transformed to a 1D series of elemental images, using the Hilbert curve or one of the scanning topologies described in [3]. Consecutive elemental images are grouped together to form volumes on which the 3D-DCT will be applied. In our approach, the 3D-DCT is applied on groups of eight elemental images as a compromise between good quality and computational efficiency. Improved quality can be pursued using adaptive schemes [4,6] on the expense of higher computational complexity. In detail each group of elemental images is further segmented in 8 x 8 x 8 pixel volumes and the 3D-DCT is applied on each of these volumes, producing 512 coefficients denoted as $F(u,v,w)$, with $u,v,w=1,\dots,8$. The 3D-DCT quantized coefficients are determined using Eq. 1.

$$F_q(u,v,w) = round\left[\frac{F(u,v,w)}{Q(u,v,w)}\right] \qquad (1)$$

In the last equation, *round*(·) denotes the round function and the quantizer volume values [8] *Q*(*u*,*v*,*w*) are derived using Eq. 2

$$Q(u,v,w) = qf \cdot \left(u^p + v^p + w^p\right) \qquad (2)$$

where *qf* is a quality scale factor used to produce the PSNR-Bitrate curve and *p* is a decay constant that denotes the decay rate of the coefficients with respect to the frequencies *u,v,w* and was experimentally determined for our InIm set in the range [0.8,1.2]. Finally the 3D-DCT coefficients are scanned using a 3D zig-zag pattern followed by run-length and Huffman encoding.

3. Experimental results

The performance of the method is evaluated using the peak-signal-to-noise (PSNR) measure, which is widely used for the assessment of the result in 2D image and video compression schemes. The PSNR is defined as:

$$PSNR = 10 \cdot \log_{10}\left(\frac{255^2}{MSE}\right) \qquad (3)$$

and the mean square error (MSE) is calculated as:

$$MSE = \frac{1}{N \cdot M}\sum_{i=1}^{N}\sum_{j=1}^{M}\left(I(i,j) - I_r(i,j)\right)^2 \qquad (4)$$

where *I(i,j)* are the intensity values of an 8-bit grayscale M x N pixels original uncompressed IP image, and $I_r(i,j)$ are the intensity values of the reconstructed image after decompression.

In our work, we evaluated the above measure for the 3D-DCT encoder using the parallel, perpendicular and spiral scanning topologies proposed in [3] and the proposed Hilbert curve scan. The results for a representative test image are presented in Fig. 2.

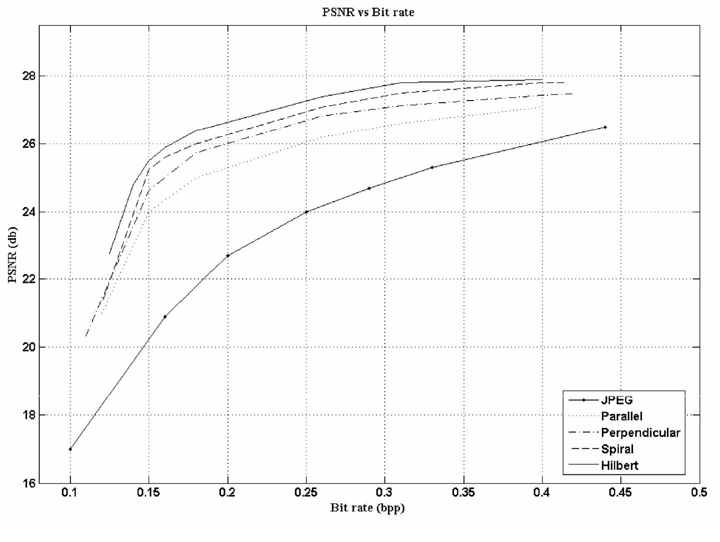

Fig. 2. Elemental images traversal scheme based on the Hilbert space filling curve.

It is clear that the 3D-DCT in conjunction with the Hilbert curve scan outperforms standard 2D compression algorithms like JPEG [9] as it manages to exploit the redundancy between consecutive images. It should also be noted that all traversal schemes oriented to omnidirectional IP images achieve higher performance than the parallel scan, which is used for unidirectional IP images. The encoder maximizes its performance for low and medium bit rates outperforming JPEG by 3 to 5 dB.

4. Conclusions

In this work, we demonstrated the use of the 3D-DCT for omnidirectional IP image compression in conjunction with different elemental image scanning topologies. A new type of scan is proposed for use with the encoder based on the 2D Hilbert curve. The results show that the proposed encoder outperforms the JPEG standard and that the use of the Hilbert curve maximizes its performance.

Acknowledgements

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