# A NOVEL CODING SCHEME FOR FULL PARALLAX 3D-TV PICTURES

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**ABSTRACT**

A unique integral imaging system is employed as part of a three dimensional television system, allowing display of full colour 3D images with continuous parallax within a wide viewing zone. A significant quantity of data is required to represent captured integral 3D images with adequate resolution. In this paper a lossy compression scheme is described, based on the use of a three dimensional discrete cosine transform (3D-DCT), which makes possible efficient storage and transmission of such images while maintaining all information necessary to produce a high quality 3D display. The results of simulations performed using the 3D-DCT algorithm are presented and it is shown that rate-distortion performance is vastly improved compared with that achieved using baseline JPEG, with captured integral 3D image data.

## 1. INTRODUCTION

Many applications exist for fully three dimensional video communication systems. One much discussed application is three dimensional television, which possesses several advantages over standard and high definition two dimensional systems. It has been reported that viewers experience an increase in total picture quality and sensation of depth and naturalness which leads them to prefer 3D presentation [1].

A unique three dimensional imaging arrangement based on Lippmann's integral photography method [2] has been reported [3] which is capable of producing a truly spatial display with continuous parallax in all directions. A single 'camera' is used to encode a true optical model of the scene in the form of a single flat intensity distribution suitable for electronic capture using, for example, commercially available CCDs. A flat panel display system, such as one using LCD technology, is used to reproduce the captured intensity modulated image, and with a microlens array placed over the display, the original scene is replayed in full colour and with continuous parallax in all directions. This technique has a number of advantages over 3D imaging systems presently used in 3D-TV system development, chiefly that an image with continuous parallax rather than multiple stereo viewpoints is produced and that only a single static camera is required for capture of a scene.

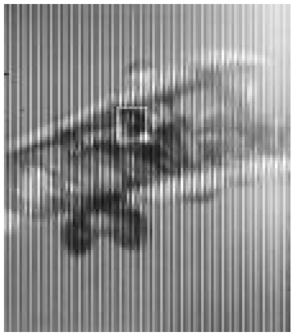
Previously it was thought that the bandwidth necessary for communication of an integral image would prohibit its use in 3D-TV systems [4]. However, experiments using specially developed lossy compression schemes for integral images have proved this incorrect. It has been shown that a full colour 3D display is possible and with present display geometry requires a transmission data rate approximately 1.5 times that required for high definition television (HDTV) broadcast. Hence there is a need for compression of the captured intensity distribution to allow transmission across conventional broadcast channels.

## 2. THE CAPTURED LENTICULAR-INTEGRAL IMAGE

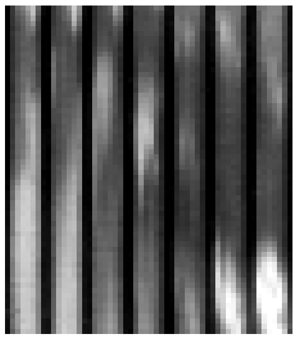
A lenticular-integral 3D image is an integral 3D image containing parallax information in only one direction, in this case horizontally. Aside from this difference, the principles of recording and replay are identical to those applying in the full integral (omnidirectional parallax) case. A lenticular sheet (a screen containing integrated horizontally-running cylindrical lenses) is used in recording to encode an optical model of the object scene, producing a planar intensity distribution with a regular vertical band structure. A captured lenticular-integral image is shown in figure 1a and a magnified section of that image, indicated by the white box in the full image, in figure 1b. A significant cross correlation exists in the captured image data between adjacent bands. This is exploited in the compression scheme described to provide a greater reduction in data than is possible using established algorithms for planar 2D image compression.

## 3. LENTICULAR-INTEGRAL IMAGE COMPRESSION

Many lossy compression schemes used in two dimensional video applications achieve data rate reduction by decorrelating in the spatial (inter-pixel) and temporal (inter-frame)



a)



b)

Figure 1: A reduced captured lenticular-integral image: a) Full; b) 10x magnification.

domains, quantising and finally lossless entropy encoding to exploit the resulting statistical redundancy [5]. The structure of the recorded planar intensity distribution in a frame of integral video is such that a high cross correlation in a third domain, between the subimages produced by the lenticular array used in the capture process, is present. This provides an opportunity for further improved compression performance by including a method to exploit this extra correlation.

A compression scheme has previously been presented by the authors for use with still integral 3D images [6] using a hybrid DPCM/DCT codec. In this scheme a given microlens or lenticular subimage is linearly predicted from the previous horizontal subimage. The difference between the prediction and actual block values is then passed to a DCT unit for intra-subimage spatial decorrelation. This scheme possesses several disadvantages, chiefly that no account is taken of vertical inter-subimage correlation and that decoding errors are propagated along a line of subimages giving rise to noticeable ringing effects at low bit rates.

A new approach which alleviates the problems associated with the previous hybrid DPCM/DCT scheme is now proposed. Several neighbouring subimages are placed together to form a volume of input data for a three dimensional DCT (see figure 2). When the transform is complete,

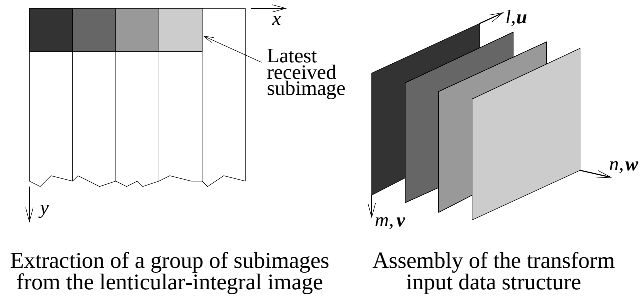



Figure 2: Assembly of 3D-DCT input data structure

integral image data in the relevant portion of the intensity distribution have been decorrelated in both intra-subimage ($u$ and $v$ axes) and inter-subimage ($w$ axis) spatial domains. A three-dimensional scalar quantisation array is then applied. Transform coefficients representing specific intra- and inter-subimage spatial frequencies are divided by corresponding quantiser scale values derived from the relative significance of coefficients at those frequencies in conveying the information representing the original scene without noticeable degradation. Finally an entropy encoding algorithm is used to exploit the statistical redundancy resulting from the quantisation operation. This algorithm uses a combination of run-length and Huffman techniques and is similar to that used in the JPEG and MPEG lossy 2D image compression systems[7, 5].

## 4. 3D-DCT SCHEME SIMULATIONS USING STILL LENTICULAR-INTEGRAL IMAGES

Simulations were performed with the 3D-DCT scheme being used to encode and decode a sample still lenticular-integral image. The key parameter in the algorithm is the volumetric quantisation array since it is in this stage which loss of information occurs. Hence the choice of quantisation step sizes for the individual 3D-DCT coefficient positions varies the degree of reduction in bit cost in the final encoded data, as a compromise with the fidelity of the reconstructed decoded 3D image.

For the purposes of these simulations, groups of 8 contiguous subimages were taken from the lenticular-integral image data (an 8-bit/pixel greyscale image) to form input data for an $8\times8\times8$ 3D-DCT. The transform coefficients were uniformly quantised in the intra-subimage spatial dimension (for all $u$ and $v$ in figure 2) and scaled along the inter-subimage dimension ($w$) using various functions of $w$, listed in table 1. The quantisation arrays used in the simulations can be described by the following relation:

$$Q_{(u,v,w)} = \lfloor qM_{(w)} \rfloor \qquad for\; u,v,w = 0..7.$$

Here $M_{(w)}$ represents the $w$ modulation function and $q$ represents a positive constant used to determine the overall

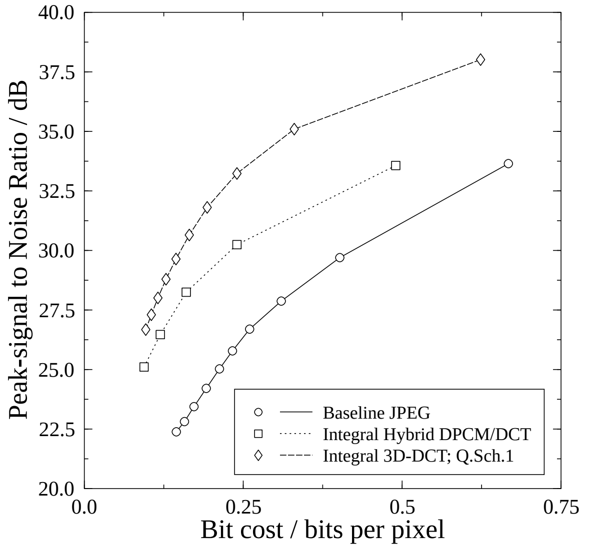



Figure 3: Performance of the 3D-DCT lenticular-integral image coding scheme, the hybrid DPCM/DCT scheme and baseline JPEG for compression of a greyscale integral 3D image.

coarseness of quantisation, thereby controlling the output bit rate and image fidelity. The quantisation schemes listed

| *Quant. scheme* | *$w$ modulation, $M_{(w)}$ ($w = 0..7$)* |
|---|---|
| 1 | $1$ |
| 2 | $\frac{w}{4} + 1$ |
| 3 | $\frac{w}{2} + 1$ |
| 4 | $w + 1$ |

Table 1: Quantisation schemes used in the simulations

correspond to increasingly coarse quantisation of the transformed information representing correlations between the neighbouring subimages.

## 5. SIMULATION RESULTS AND CONCLUSIONS

Simulations were executed using each of the quantisation schemes 1–4 above, with the parameter $q$ being varied to produce a spread of results at different bit rates and objective fidelity values. Figure 3 shows plots of output peak-signal to noise ratio (PSNR) versus bit cost per pixel for the image for 3D-DCT with Quantiser 1 in addition to Integral Hybrid DPCM/DCT and Baseline JPEG for comparison[6, 7]. It can be seen that the 3D-DCT scheme provides far improved rate-distortion performance compared with both baseline JPEG and the hybrid DPCM/DCT scheme according to the PSNR distortion measure used. Similar plots for the performance of the 3D-DCT scheme with quantisation schemes 1–4 are shown in figure 4. From these plots it can

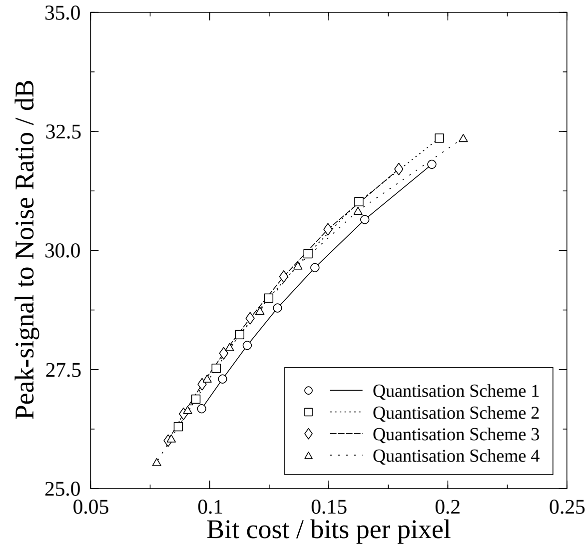



Figure 4: Performance of the 3D-DCT lenticular-integral image coding scheme for several quantisation strategies.

be seen that at very low bit rates rate-distortion performance is improved when the quantisation method includes modulation for the inter-subimage spatial dimension.

## 6. REFERENCES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