Active Mesh Texture Coding Based on Warping and DCT

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Abstract

In this paper, we consider the texture coding of quadrangular cells which compose active meshes. Active mesh algorithms which have been developed for region based video coding mainly use interpolation techniques to quantize the cell texture. Here, we propose a new quantiztion scheme which associates image warping and an adaptive JPEG scheme. Our approach leads to an interesting trade-off between mesh complexity and image quality.

1. General context

By combining quadtree segmentation [3], multiresolution representation and active mesh [2][8], Wang et al. have proposed an efficient region-based video coder [7]. It starts with a multiresolution image pyramid built from the original image and then, generates a multiresolution active quadtree mesh through the pyramid using a top-down strategy.

Such an algorithm leads to an image segmentation into quadrangular cells of various sizes (See Figure 4.a). The image code contains the quadtree structure [2], the mesh description, i.e. the node positions [8][1], and the texture code describing the cell contents [8].

The image quality will depend on the mesh complexity and on the texture quantization algorithm. Wang et al. [8] have studied mean average interpolation (each pixel is simply replaced by the gray level of its cell), inversely mapped interpolation (each pixel are interpolated only from its cell nodal values) and least squares interpolation. More sophisticated interpolation techniques can also be found in [4].

Here, we propose a new approach which takes advantage of image warping [9] and DCT block coder [6].

2. Coding the cell texture

Figure 1 shows an overview of the proposed algorithm.

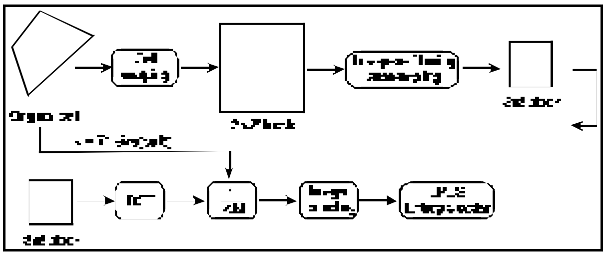

Figure 1: Overview of the texture quantization algorithm.

The first step transforms the original deformed cell into a 8x8 square block. We have noted that the direct mapping of the original cell into 8x8 blocks introduces high frequencies which penalize the quantization step. Thus, we propose to warp first the original cell into the closest 2^px2^p block. Indeed, since the sizes of the original cell and the square block are close, a good quality texture mapping is obtained. Then, we apply recursively a low-pass filter followed by a 2:1 decimation to get the final block of size 8x8. We use the perspective warping, which maps any pixel in the original cell with coordinates [u v] to an other pixel in a square cell with coordinates [x y] by :

$$x = \frac{x'}{w'} \qquad (1) \qquad\qquad y = \frac{y'}{w'} \qquad (2)$$

and

$$\begin{bmatrix} x' & y' & w' \end{bmatrix} = \begin{bmatrix} u & v & 1 \end{bmatrix} \times A \qquad (3)$$

where A is a 3x3 transformation matrix which coefficients are easily computed from both the source cell and the destination block coordinates. Inverse warping proceeds by the same way by switching the matrix A to its adjoint. For further details on the warping algorithm, one can see [9].

The second step consists in applying a JPEG quantizer on each 8x8 block which involves the DCT and the JPEG normalization matrix M. The quantization quality is driven by weighting the normalization matrix by a coefficient *k* which depends on the size of the original cell (n) as follows:

$$k = \left(\frac{64}{n}\right)^{a} \qquad (4)$$

where a is chosen experimentally.

Indeed, the mesh deformation algorithm segments the image into homogeneous cells, and after mapping on the 8x8 block, large cells contain more high frequencies (which should be preserved) than smaller cells. This adaptive weighting of the normalization matrix avoids any bit allocation procedure. Indeed once the coefficient a is chosen (see Section 3), the final image quality is adjusted only by the split criteria applied on cells during the mesh generation algorithm [2][7]. Note that cells containing less than 64 pixels are quantized using mean interpolation.

Finally, the last step in Figure 1 is the JPEG entropic coder which includes the zig-zag scan and the run-length coding [6] of the AC coefficients. Note that the DC value of each 8x8 block is PCM coded.

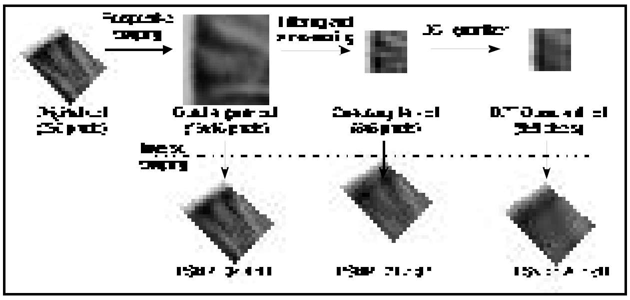

Figure 2: Illustration of the distortion introduced at the different levels of our quantizer.

Figure 2 illustrates the distortion introduced at the different levels of our quantizer : the warping distortion, the subsampling distortion and the JPEG distortion. The warping distortion is highly conditioned by the cell deformation, the subsampling distortion by the cell size while the JPEG distortion depends on the cell contents. Note that the cell in Figure 2 has been chosen for visual illustration but it is not representative (because not homogeneous) of the cells obtained with an active quadtree mesh.

3. Results

The results we present have been obtained using adaptive multiresolution quadtree meshes generated with a fast non iterative deformation algorithm which simply moves the nodes in the direction of the gradient gravity center of its four neighbor cells. Iterative and sophisticated deformation algorithms can be found in [7][5]. The mesh structure is coded using the algorithm proposed in [1].

The image quality of our coder depends on the split criteria (here we use the cell variance) and on the coefficient a used with the normalization matrix (see Figure 1 and Eq. 4). Figure 3 shows the influence of this coefficient on the PSNR versus bit rate performances. One can see that above 0.9 the performances go down and that 0.7 seems to be a good compromise. The following results have been obtained with a fixed to *0.7*.

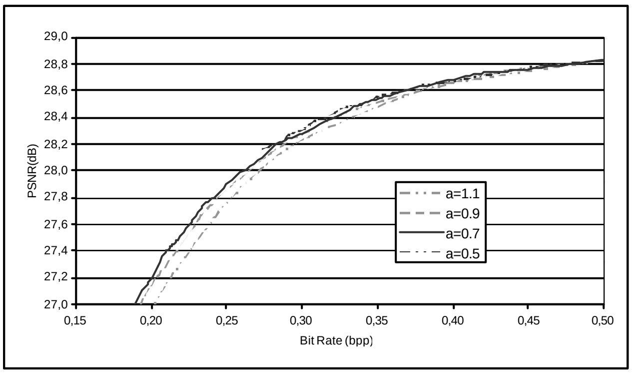

Figure 3: Influence of the normalization parameter a *on the PSNR versus bit rate performances of the proposed quantizer for Lena image.*

Figure 4 shows the gain in term of bit rate versus PSNR provided by the proposed approach on Lena 512x512 pixels. Figure 4-b is the result of the mean average interpolation quantizer (MAQ) on a mesh containing 769 cells. Using the warping DCT quantizer (WDQ) on the same mesh leads to a significant improvement of the PSNR (Figure 4-d) with consequently a decrease of the coding rate. But Figure 4-c shows that at the same rate, and thus with a more complex mesh (4489 cells), the PSNR is still lower using the MAQ.

Bit rate (bpp)	Number of cells	PSNR (dB)	Quantizer
0.1	2074	22.8	MAQ
0.1	256	23.9	WDQ
0.2	4489	23.7	MAQ
0.2	769	27.5	WDQ
0.4	9205	24.8	MAQ
0.4	3058	29.1	WDQ

Table 1: Comparison of the warping DCT quantizer (WDQ) and the mean average interpolation quantizer (MAQ) on Lena for a given bit rate.

Table 1 compares our quantizer and the mean average interpolation for different bit rates on Lena. Table 2 gives a comparison at 0.2 bpp on several images. These tables confirm the interest of our approach which leads to a good PSNR with a low complexity mesh. For the (512x512 pixels) peppers image, it gives a 4 dB improvement compared to the mean average interpolation with a number of cells divided by 6. On smaller and more homogeneous images such coastguard (352x240 pixels), the PSNR improvement is less than 2 dB.

Table 3 shows the evolution of the PSNR and the bit rate when changing the quantizer with a fixed mesh. Note we can gain 7.2 dB on the mean average with the same mesh but as a consequence the bit rate is multiplied by 5.

Image	Number of cells	PSNR (dB)	Quantizer
Lena	4489	23.7	MAQ
Lena	769	27.5	WDQ
Peppers	4273	21.56	MAQ
Peppers	688	25.7	WDQ
Coastguard 100	1531	19.9	MAQ
Coastguard 100	172	21.6	WDQ

Table 2: Comparison of the warping DCT quantizer (WDQ) and the mean average quantizer (MAQ) for a given bit rate of 0.2 bpp on different images.

Number of cells	Bit rate (bpp)	PSNR (dB)	Quantizer
502	0.027	19.5	MAQ
502	0.145	25.1	WDQ
997	0.05	20.8	MAQ
997	0.235	28.0	WDQ

Table 3: Comparison of the warping DCT quantizer (WDC) and the mean average quantizer (MAV) on Lena for a given mesh.

Compared with the JPEG algorithm, our approach leads to a significant improvement of the visual quality in homogeneous regions as illustrated on Figure 5 even if the global PSNR is lower. Note that such a quantizer is dedicated to mesh coding schemes which are techniques in infancy. In addition, active mesh coders are more effective for image sequence coding.

4. Conclusion

We have proposed a quantizer based on warping and JPEG to code the texture of quadrangular cells provided by active meshes. Such a quantizer represents an alternative to the pure interpolation techniques and offers good image quality even on low complexity adaptive meshes. It appears to be a good candidate to code the I-frame images of an image sequence to be coded using active meshes.

The performances of our quantizer should be improved by using different sizes of normalization matrix to avoid the subsampling step (Figure 2). Using iterative mesh deformation model driven by a quantizer error energy term such in [8], will also help to improve the texture quality.

Our approach may also be used in an adaptive active mesh coding scheme which will choose the texture quantizer as a function of the cell properties.

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References

[1] H. Benoit-Cattin, A. Planat-Chrétien, P. Joachimsmann, A. Baskurt, P. Clarysse, and I. E. Magnin, “On the coding of active mesh”, *In Proc. of ICIP-98* Chicago, Vol.2, pp. 895-898, Oct.1998.

[2] C.-L. Huang and C.-Y. Hsu, “A new motion compensation method for image sequence coding using hierarchical grid interpolation”, *IEEE Trans. on Circuits and Systems for Video Technology*, vol. 4, n° 1, pp. 42-52, Feb. 1994.

[3] G. M. Hunter and Stieglitz, “Operations on images using Quadtree”, *IEEE Trans. on Patern Analysis and Machine Intelligence*, vol. 1,2, pp. 145-153,1979.

[4] H. Le Floch, “Echantillonnage irrégulier et interpolation : application à la représentation d'images fixes et animées”, *Ph.D Thesis*, Rennes University, France, 1997, 183p.

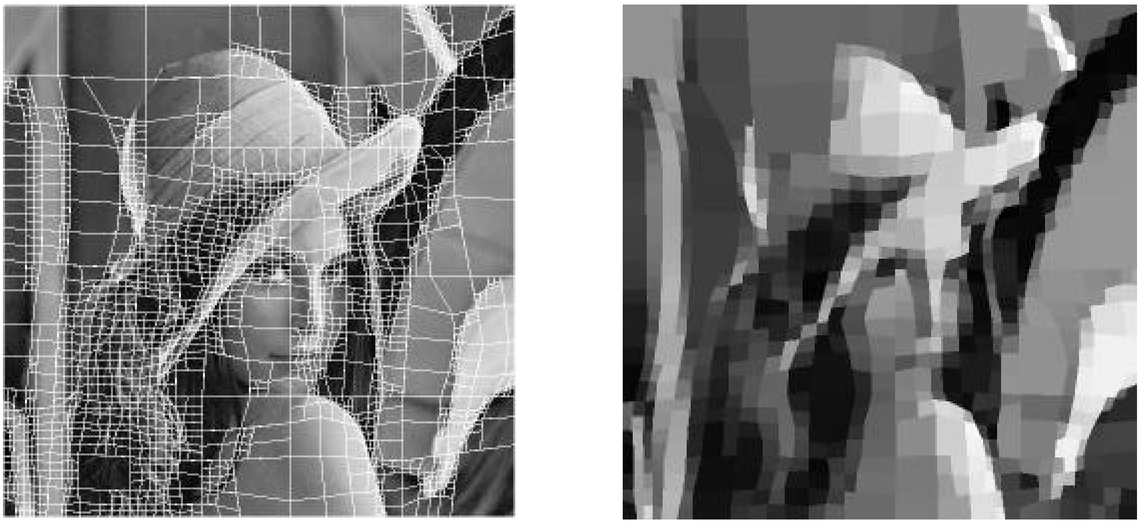
[5] A. Planat, I. E. Magnin, O. Ratib, D. Didier, and D. Revel, “An adaptive multiscale approach for movement estimation with discontinuities”, *In Proc. of RFIA'98*, Clermont-Ferrand, pp. 81-90, 1998.

[6] W.B. Pennebaker, J.L. Mitchell, “JPEG still image compression standard”,Van Nostrand Reinhold: New York, 1993.

[7] Y. Wang, O. Lee, and A. Vetro, “Use of two-dimensional deformable mesh structures for video coding. Part II: The analysis problem and a region-based coder employing an active mesh representation”, *IEEE Trans. on Circuits and Systems for Video Technology*, vol. 6, n° 6, pp. 647-659, Dec. 1996.

[8] Y. Wang and O. Lee, “Active Mesh - A feature seeking and tracking image sequence representation scheme”, *IEEE Trans. On Image Processing*, vol. 3, n° 5, pp. 610-624, Sept. 1994.

[9] G. Wolberg, *Digital image warping*: IEEE Computer Society Press, 1992.



a) *Example of mesh generated with an Active Quadtree Mesh Algorithm*

b) *Quantized image using mean average interpolation. 769 cells, 0.04 bpp, PSNR= 20.6 dB*

c) *Quantized image using mean average interpolation. 4489 cells, 0.2 bpp, PSNR= 23.7 dB*

d) *Quantized image using the proposed quantizer. 769 cells, 0.2 bpp, PSNR= 27.5 dB*

Figure 4: Examples of mesh and quantized images.

a)

b)

Figure 5: Visual comparison at 0.2 bpp (Lena shoulder). a) Our approach (27.5 dB). b) JPEG (28.9 dB).