the required overheads for storing pre-order lists are negligible when compared with sizes of compressed bit-streams.

Simulataion results and conclusion: Our simulation consists of two parts. The first part is the case where we exhaust all levels of the prepared quantisers for the given resolution scale with no local bit-streaming constraint. In the second part, we used the local constraint (ii) in generation of the bit-stream. We used the wavelet

Table 1: Comparison of localised PSNR and bit rate reduction between single bit-stream scheme with SPIHT compression engine and proposed dynamic multiple bit-stream scheme with [3] for Lena image

Display resolution	No local constraint			Constant distortion constraint			
	Received bits at decoders	Local PSNR		Local PSNR	Received bits		Reduction gain
		Static single	Dynamic multiple		Static single	Dynamic multiple	
		dB	dB	dB			%
64×64	23593	40.48	60.77		22282	11730	47.4
128×128	61866	41.98	53.41	40	47185	30310	35.8
256×256	139592	41.98	46.82		107479	81264	24.4
512×512	218890	39.58	40.62		241172	204210	15.3

compression engine of [3] which has a total of 44 quantisation levels over all the subbands. As a result, 44 different bit-stream fragments were generated and stored for each image. The left part of Table 1 compares the *localised PSNR* performance between the *static single* bit-stream scheme with the SPIHT coder [1] and the proposed *dynamic multiple* bit-stream scheme for each display resolution when the same number of bits are received. Here, the localised PSNR is defined as the PSNR localised to the requested image size of the reconstructed image over the unquantised approximate signal. We can see that the PSNR gain of the proposed scheme increases significantly as the resolution decreases. Consequently, we can see that the proposed scheme provides faster progression than the conventional scheme with the same number of bits. Similarily, the right part of Table 1, where the normalised PSNR was fixed as 40dB (i.e. 6.5in MSE) for each resolution, shows that the proposed scheme has significant bit rate reduction over the single bit-stream case when the constant image quality constraints are used. From this, we can conjecture that network load can be alleviated by using the proposed scheme.

The propsed bit-streaming scheme can be implemented by a look-up-table and thus can be operated in real-time for the individual image requests. The proposed scheme can be expected to be effectively employed for picture archival and communication systems (PACS), and also in video retrieval or multicast systems.

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Results on successive approximation vector quantisation

M. Craizer, E.A.B. da Silva and E.G. Ramos

Successive approximation vector quantisation is a new algorithm that has given very good results in coding wavelet coefficients of images. Results which had been previously obtained on an experimental basis are established analytically. After modifications derived from this analysis, the algorithm shows very good convergence properties, as well as an improved coding performance.

Introduction: Wavelet transforms have become very popular in image coding applications. Among wavelet image coding methods, the ones which use successive approximation of wavelet coefficients have performances comparable to the best ones in the literature [1]. In these methods, the wavelet coefficients are scanned in successive passes. In each pass, one bit of precision is added to the coefficients. In addition, similarities among bands of same spatial orientation are taken into account through the use of zero-trees. The symbols generated are, in general, coded with an adaptive arithmetic coder. In most cases, the coefficients are quantised individually, i.e. using successive approximation *scalar* quantisation.

It is natural to ask whether such methods could be extended to vectors in order to incorporate some of the advantages of vector over scalar quantisers. Residual vector quantisation addresses this issue [3]; however, most residual vector quantisation methods require an expensive joint optimisation of the codebooks of each stage in order to provide good coding efficiency.

Recently, da Silva *et al.* [4] have developed a method to perform successive approximation vector quantisation (SA-VQ) that does not need any codebook optimisation: each vector is approximated by a series of vectors of decreasing magnitudes and orientations drawn from a fixed *orientation codebook*. These orientation codebooks are, in general, based on regular lattices related to the solution of the sphere packing problem [5]. An embedded wavelet coder similar to that in [6], but replacing the successive approximation scalar quantisation by the successive approximation vector quantisation has been described in [4] (SA-W-VQ coder). Indeed, it performs consistently better than the scalar one, giving results comparable to state-of-the-art wavelet image coding.

More specifically, in successive approximation vector quantisation, the residuals in pass n are coded by vectors having magnitudes equal to $\alpha^n B$, where α and B are fixed. However, for a given orientation codebook, it is not guaranteed that for every value of α, any vector can be approximated with arbitrary precision. In [4], conditions to guarantee the convergence of this scheme have been derived in an experimental basis for the worst case, that is, when in every pass the orientation error is equal to θ_{max}; θ_{max} is a characteristic of the orientation codebook, and is the maximum possible angular distance between any vector and its nearest neighbour in the orientation codebook.

In this Letter, we first state a theorem which has been proved by relating the values of α and θ_{max} necessary for the convergence of SA-VQ. However, experimental results of coding wavelet transforms of images show that this value of α is very conservative, and the best performance of this algorithm is obtained for values of α which are much smaller than those given by the theorem [4]. It is thus very desirable to have more realistic results related to the performance of the algorithm. Therefore, we next state a theorem which establishes that, after small modifications, SA-VQ is guaranteed to converge for these smaller values of α. Then, the image coding results of an SA-W-VQ coder incorporating these modifications are presented and discussed, followed by conclusions and suggestions for further improvements.

SA-VQ convergence: More formally, the SA-VQ algorithm consists of approximating a vector $\mathbf{X}$, $\|\mathbf{X}\| < B$, by a series of vectors as follows: after n passes, $\mathbf{X}$ is approximated by $\mathbf{X}_n = \Sigma_{j=1}^{n} \alpha^j B \mathbf{u}_{m_j}$, where $\mathbf{u}_{m_j}$, $\|\mathbf{u}_{m_j}\| = 1$, is drawn from a fixed orientation codebook Y. Convergence of the scheme means that $\lim_{n\to\infty} \mathbf{r}_n = 0$, where $\mathbf{r}_n = \|\mathbf{X} - \mathbf{X}_n\|$. We then have the following theorem:

Theorem 1: The SA-VQ algorithm converges if

$$\alpha \geq \frac{1}{2\cos(\theta_{max})} \qquad \theta_{max} \leq 45° \qquad (1)$$

$$\alpha \geq \sin(\theta_{max}) \qquad \theta_{max} \geq 45° \qquad (2)$$

Modified version of SA-VQ with improved convergence: For an SA-W-VQ-like coder to converge for smaller values of α, the successive approximation vector quantisation algorithm has to be modified to guarantee that $\alpha^{n+1}B \leq \|\mathbf{r}_n\| \leq \alpha^n B$ at every step. This is carried out as follows: if the magnitude of $\mathbf{r}_n$ is smaller than $\alpha^{n+1}B$, the zero vector is transmitted, so that there is no refinement for that pass. If the magnitude of $\mathbf{r}_n$ is greater than $\alpha^n B$, an escape code is transmitted, so that both coder and decoder know that the exponent of α should not be incremented for that vector in that pass.

Theorem 2: Suppose that the orientation codebook used in SA-VQ has $\theta_{max} < 60°$. Then the modified version of the SA-VQ algorithm converges for every $0.5 \leq \alpha < 1$.

It is important to note that, as long as the value of $(\cos\theta)_{max} < 60°$, the modified SA-VQ algorithm will converge for $0.5 \leq \alpha < 1$, irrespective of the particular orientation codebook used. This result is then much stronger than that of Theorem 1.

Experimental results: The images Lena 256×256, Zelda and Boats have been coded at 0.5 bit/pixel using the 'conventional' SA-W-VQ algorithm [4], as well as the improved SA-W-VQ with the modifications proposed in the preceding Section. The PSNR of these images was plotted against values of α in the range [0.50, 0.99]. The results are shown in Fig. 1 for the first shell of the E_8 lattice [5] as the orientation codebook.

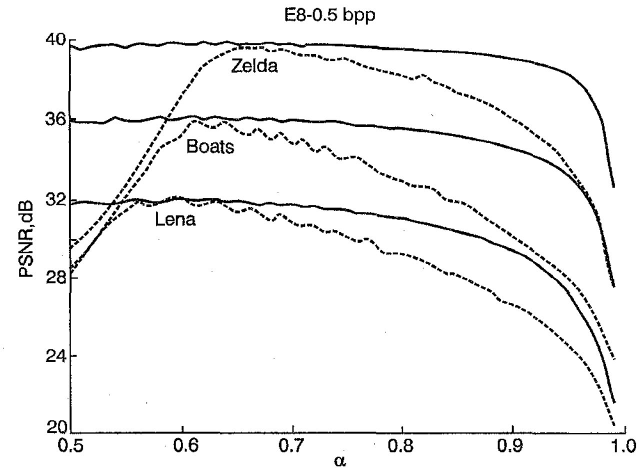

Fig. 1 *α against PSNR for the images Zelda, Boats and Lena, for 'conventional' and 'improved' SA-W-VQ algorithms*

– – – – conventional
——— improved

For this orientation codebook, $\cos(\theta_{max}) = 0.707$. According to Theorem 1, this requires that $\alpha \geq 0.707$ in order to guarantee convergence of the 'conventional' SA-W-VQ algorithm. From this graph, it can be clearly observed that the worst case value of α is very pessimistic. Besides, in the 'conventional' SA-W-VQ coder, the value of α which gives the peak performance varies reasonably from image to image. For Zelda, the peak performance is obtained with α in the range [0.65, 0.69]; for Boats, α is in the range [0.61, 0.64]; for Lena, α is in the range [0.59, 0.60]. Therefore, in the 'conventional' SA-W-VQ coder, there was no single value of α that could be universally used for all images.

In contrast, looking at the performance of the 'improved' SA-W-VQ coder, it can be seen that the PSNR performance is almost independent of the value of α chosen. This behaviour is in accordance with Theorem 2. In addition, in some cases it gives slightly higher peak PSNR performance than for the 'conventional' one. The same performance pattern repeats itself for the D_4 and Λ_{16} lattices. This is a very desirable result, for we now have an algorithm whose performance does not depend too much on α, and therefore is almost image independent. That is, we can safely chose α close to 0.5 and guarantee a performance very close to the optimal.

Conclusions: Summarising, it can be said that the proposed modifications to the SA-VQ algorithm have definitely improved the SA-W-VQ coder. The analytical tools developed and the good convergence behaviour shown open many new possibilities. Considering that the SA-W-VQ coder already gives rate × distortion performances comparable to the state-of-the-art, these are very promising results.

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Simple method for estimation of global motion parameters using sparse translational motion vector fields

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A simple method for the estimation of global motion parameters from sparse translational vector fields is presented. Differential operations on pairs of adjacent motion vectors are used to derive local estimates of rotation and change of scale. A majority vote is then applied to identify global trends corresponding to the required estimates. Key features of the proposed technique are its low complexity and its compatibility with standardised motion estimation tools.

Introduction: The estimation of global motion from sequences of images has important applications in video bit rate reduction [1], archive restoration [2], camera stabilisation [3] and many more. A common approximation is that global motion can be described by translation, rotation and change of scale. Typically four parameters are necessary to specify these operations; horizontal and vertical translation, angle of rotation and magnitude of scale change. To obtain estimates of such parameters a number of algorithms has been proposed in the literature [4, 5]. To optimise estimation algorithms like the above, make use of the available image information at full resolution. With regard to implementation,