Analysis Encoding and Synthesis Decoding for Image Compression

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***Abstract*—This paper presents a novel analysis and synthesis approach to image compression. In the encoding stage, an analysis scheme is used to selectively encode visually important features of an image to achieve computational and compression efficiencies, and in the decoding stage, a synthesis method is employed to reconstruct the full image from the selectively encoded image features. By integrating established image coding technologies and the latest development in computer graphics, especially texture synthesis and image inpainting, our method opens up a promising new direction for developing novel solutions to image compression and related problems. Preliminary experimental results are presented to demonstrate the practicability of this innovative image compression method.**

I. INTRODUCTION

Image compression is a very important and well-studied subject. It is also one of the most successful areas in computational visual information processing in the sense that many well-established image/video coding standards, such as JPEG and MPEG [1, 2], have now been extensively used in our daily life. It could be argued that the performances of state of the art image/video compression technologies have already met most of our daily requirements. With the rapid development in hardware (processing speed, memory capacity and network bandwidth) performances, it could also be argued that trying to improve the compression performances (in the rate distortion sense) would probably not be very productive.

However, our motivation for this work is not to develop image compression algorithms that can rival current state of the art in terms of rate distortion performances, rather, we are interested in novel approaches that may deepen our understanding of the field, and are potentially useful in guiding the development of new practical applications. We are also interested in applying the latest development in computer graphics, especially texture synthesis and image inpainting [3, 4], to new application domains.

Based on such a motivation, we have developed a novel analysis and synthesis based method for image compression. In this novel scheme, image features are selectively coded by a conventional image coding scheme. Specifically, only areas of high activities, such as edges, busy texture areas, are coded and stored (or transmitted), while low activity areas, such as smooth areas are discarded and not stored at all, thus incurring very little computation and coding overheads. At the decoding stage, those not coded low activity areas are synthesized or painted through a synthesis/inpainting procedure.

The organization of the paper is as follows. In section 2, we briefly review a previously developed feature selective image coding scheme developed by the first author [5, 6]. Section 3 presents an image inpainting method for the reconstruction of feature selectively coded image. Section 4 presents experimental results and section 5 concludes the paper.

II. VISUAL VECTOR QUANTIZATION AND GRADIENT SELECTIVE IMAGE CODING

A. *Visual Vector Quantization (VVQ)*

The visual vector quantization (VVQ) [5] was developed as a simple alternative to the original VQ for coding images to a moderate bit rate and satisfactory visual quality. Traditional VQ for image coding operates in 'pixel space'. The image to be coded is divided into small blocks, and the pixel values within this block form a multi-dimensional vector. It is well known that the encoding process for traditional VQ based image compression schemes is computationally intensive. In VVQ, perceptually important features of the block (horizontal and vertical edge information) are extracted and used to form a 'visual vector'. An image block is coded by quantizing each of these features individually. Thus coding consists of two sets of one-dimensional tests, reducing the computational load significantly. The codebook is created by training a neural network with the visual vectors as input, and the residual training blocks as the desired output. Block reconstruction is achieved by substituting the appropriate image block from the codebook.

The codebook is created in two stages, each using data from training image(s). Firstly, the training data is segmented into m x n blocks. The horizontal and vertical derivatives of the block, D_h and D_v, are then found. This results in a pair of values for each block, i.e. a data set in the two-dimensional 'visual vector' space. A competitive learning algorithm is used to cluster the D_h values for the training blocks into several classes. For the results presented in this paper, three classes were used corresponding to the directional derivative being negative large (NL), small (S) or positive large (PL). This process was repeated for the vertical derivative D_v. Since three classes were defined in each direction, an image block may fall into one of nine different classes. The three co-ordinates for each direction are then stored and used during the coding stage to classify a block into one of the nine classes.

The codebook entry for each block class is found by training a backpropagation neural network to reproduce the residual block (m x n pixel values) at its output, when the, D_h and D_v, co-ordinates for the appropriate class are presented at its input. After the network has been trained to reproduce all nine classes of block, the network outputs for each of the nine classes are taken as the codebook entries. Thus the codebook needed to reconstruct the blocks consists of nine entries, each of which comprises m x n pixel values. Figure 1 shows the VVQ image coding system operation and Figure 2 shows the VVQ codebook used in this paper.

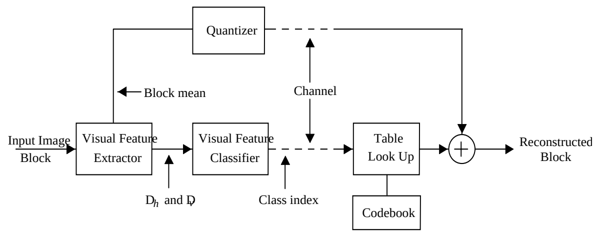

Figure 1 Block diagram of VVQ image coding system

Dh \ Dv	NL	S	PL
NL	Class 1	Class 2	Class 3
S	Class 4	Class 5	Class 6
PL	Class 7	Class 8	Class 9

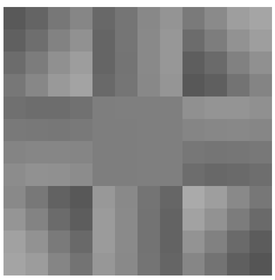

Figure 2 Directional derivative classes and their corresponding codewords

B. *Gradient Selective Coding*

Image coding by VVQ is based on classifying the directional derivatives of the image blocks. The magnitudes of the directional derivatives give indications of whether or not the block contains edges. A large magnitude value of the directional derivative indicates the block contains edge information, conversely, a small value of the directional derivative indicates the block contains no significant edge. From Figure 2, it can be seen that when both D_h and D_v are small, the codewords pattern (class 5) contains no significant edge. It is well known that edges, although consist of a small part of the image, are the most important visual information contents. It has been shown in [6] that it is possible to just encode and store blocks containing significant gradient values and throw away those block containing no significant edges. However, the method used in [6] for reconstructing the original image from those blocks containing significant edges are too simplistic and results showed visually annoying artifacts. An example is shown in Figure 3.

Figure 3 Top: original image, Middle: VVQ coded image with 59% of the image disarded (areas shown in whilte pixels), Bottom: Image reconstructed from the image in the middle using a simple interpolation method [6]. It is seen that visual artefacts are clearly visible.

III. SYNTHESIS OF PARTIALLY ENCODED IMAGE

In the field of computer graphics, there has been much recent interest in image synthesis, including texture synthesis and image inpainting. In [4], a non-texture inpainting method was proposed, which can be applied to edge coding for image compression. Since the gradient selective coding effectively only codes edges, the inpainting method of [4] could be used to fill the empty pixels. At the time of writing, we are refining our implementation of the algorithm of [4] to "inpaint" the gradient selectively coded images. We present some preliminary results in the next section and will be able to report comprehensive results to the conference.

IV. EXPERIMENTAL RESULTS

Here are examples of the gradient selectively coded images and reconstructed images. It is seen that these results look very promising.

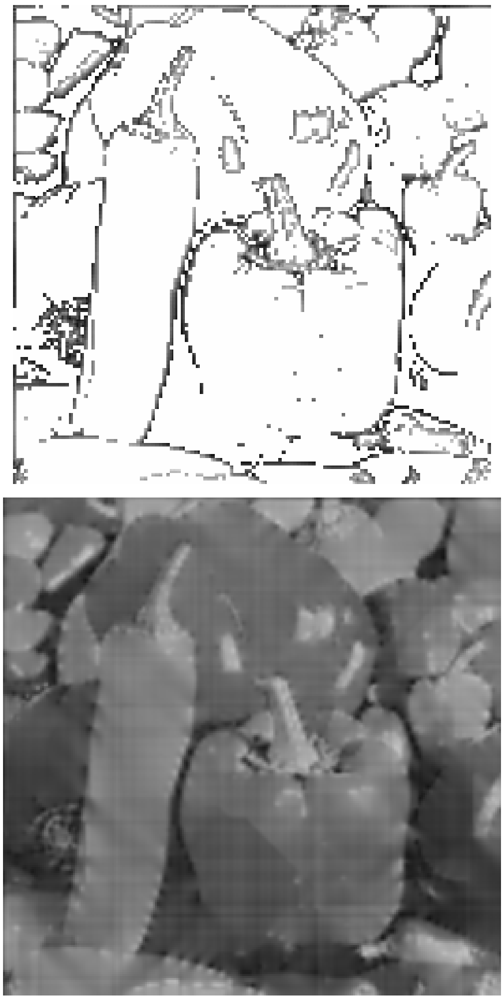

Figure 4 Top: VVQ coded image with 84% of the image disarded. Bottom: reconstructed image through synthsis.

Figure 5 Top: VVQ coded image with 88% of the image disarded. Bottom: reconstructed image through synthsis.

V. CONCLUDING REMARKS

In this paper, we have presented a novel approach to image compression. The method combines a previously developed feature selective image coding method with the latest technology in computer graphics. Based on this scheme, it is only necessary to store information around the edge areas, and the areas not stored can be painted through by a synthesis method. We are currently refining our implementation of the algorithm and also investigating the use of texture synthesis approach [3] to fill the empty areas. It is expected results will be available for reporting to the conference.

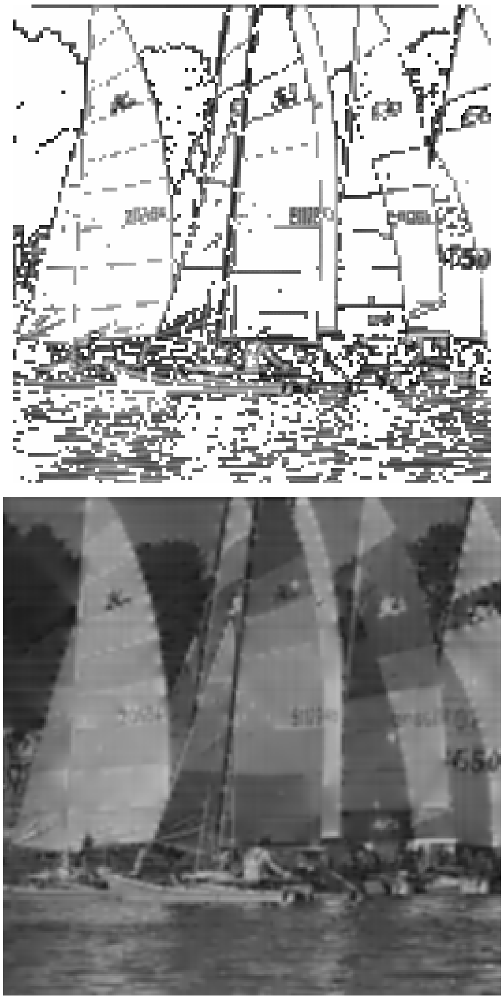

Figure 6 Top: VVQ coded image with 69% of the image disarded. Bottom: reconstructed image through synthsis.

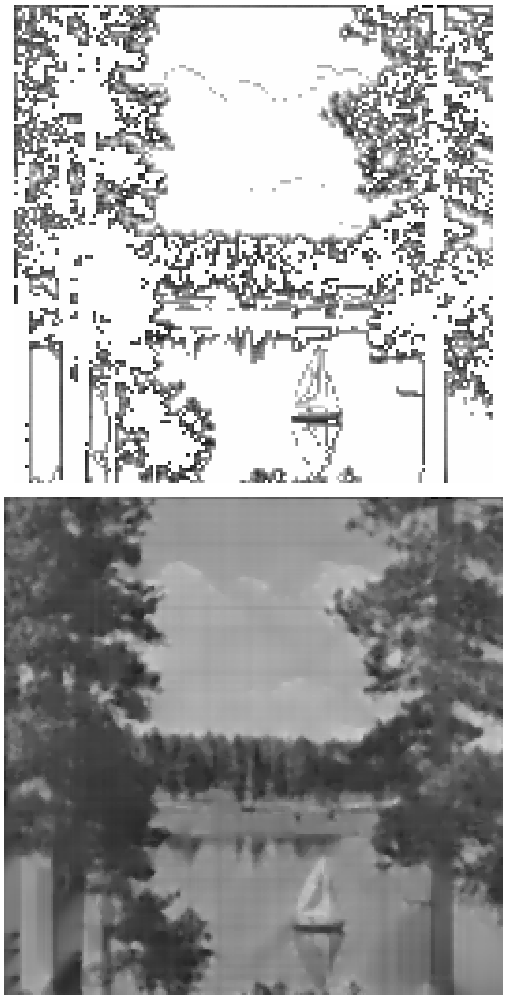

Figure 7 Top: VVQ coded image with 70% of the image disarded. Bottom: reconstructed image through synthsis.

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