# THPM 15.1

## Adaptive subsampling JPEG image coding

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**Abstract - We present a JPEG-based image coding system which preprocesses the image by adaptive subsampling based on the local activity levels. As a result, it yields good quality in both smooth and complex areas of the image at high compression ratios.**

### 1. Introduction

The JPEG standard of still image compression has been widely used since its announcement [1]. To exploit the economic advantages, it is desirable to develop JPEG compatible coding system which can use existing JPEG hardware/software. At a moderate compression ratio, JPEG gives satisfactory quality in most cases. However, at higher compression ratios (e.g. >20 for gray-level images), JPEG suffers from serious blocking effects which are very annoying to the human vision, and the resulting image quality is practically unacceptable.

There exist several pre-/post-processing approaches to reduce the blocking effect at high compression ratios, e.g., smoothing and decimation/ interpolation. In smoothing, some kind of low pass filters is applied across block boundaries. In decimation/interpolation, the image is first subsampled, and the resulting "smaller" image is fed into JPEG coder. At the decoder, the JPEG decoded image from the JPEG decoder is interpolated back to its original size. These approaches can eliminate much of the blocking effect by the low-pass filtering property. Unfortunately, they either result in blurred images or require complex computations [2] [3]. In addition, images could even be distorted by aliasing if it is not properly filtered before decimation.

A different approach is to redesign a better JPEG Q-table than the default one. A simple way to reduce the blocking effect is allocating more bits to low frequency components of DCT coefficients [4].

We propose an algorithm aiming at the improvement of the image quality at higher compression ratios than that JPEG can handle. This scheme combines decimation/interpolation and activity classification as the pre-/post-processing, and uses JPEG with optimal Q-tables as the compression engine. It yields better image quality than the original JPEG or the uniform subsampling JPEG. The increased complexity is only minor compared to JPEG itself.

### 2. Adaptive subsampling coding system

The block diagram of the system is depicted in Figure 1. The image is first fed into the classifier which clusters each 16 x 16 block into high/low activity classes based on their variance, or AC energy. For ease of implementation, we adopt the general approach - using the L1 norm as a measurement to avoid the square operations [4]. The block with L1 norm greater than a pre-determined threshold is classified as a high activity block. Otherwise, it is classified as a low activity block. It is observed that the statistical models of high activity blocks have significant differences from those of low activity blocks. Thus, designing codecs separately for each class generally yields an extra coding gain. The 16 x 16 block size is chosen for the reasons of the compatibility to JPEG after subsampling and the observation that the correlation beyond 16 pixels is relatively small. Image blocks are classified in the raster scan order, and the blocks of the same class are concatenated respectively.

Subsampling, or decimation, is only applied to low activity blocks which contains little energy in high frequencies. Both the high activity block stream and the subsampled low activity block stream are sent to JPEG coders, respectively. Both Q-tables of JPEG are designed optimally for their input streams based on the scheme proposed by Paik except that the step size of the DC component is fixed to 16 [6]. With buffered image, a single JPEG coder with different Q-tables is able to serve both streams.

At the decoding end, both streams are decoded by the corresponding JPEG decoders. The low activity blocks are interpolated into the original size. For simplicity, a linear interpolator which only needs

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an addition and a shift operations is employed. It is represented by

$$i[n]=(x[n-1]+x[n+1])/2,$$

where $i[n]$ denotes the pixel interpolated by $x[n+1]$ and $x[n-1]$, which are the two neighboring pixels in the horizontal direction or the vertical direction.

## 3. Experiment results

We have done a series of experiments on 8-bit gray-level images to evaluate the performances of the original JPEG, the uniform subsampling JPEG, and the adaptive subsampling JPEG codings. All the Q-tables are designed optimally for their input streams. In each scheme, the Q-factors of JPEG quantization tables are adjusted to reach the desired compression ratios or bitrates. In adaptive subsampling JPEG scheme, an additional parameter, the thresholds of the activity levels, can be tuned. Out experiments show that it does not provide any significant coding gain by having more than two classes other than the high and low activity classes.

Comparisons on the "Lenna" image at the same compression ratio, ranging from 20 to 30 are performed. The PSNRs of different coding schemes are listed in Table 1. Both JPEG and the adaptive subsampling schemes yield similar performance at the compression ratio near 20. The uniform subsampling scheme gets lower scores because of the high-frequency distortion. As the compression ratio starts to raise, the blocking effect in JPEG begins to deteriorate the image quality seriously. The adaptive subsampling scheme still provide acceptable quality subjectively by the fact that it has reduced the blocking effects both at edges and shade regions [3]. At the compression ratio near 30, both uniform subsampling and adaptive subsampling schemes get similar subjective scores, but with different distortions. The uniform subsampling scheme yields the lowest mean squared error. It, however, suffers from the phenomena of ringing around boundaries between the edge and the shade regions. On the other hand, the adaptive subsampling scheme generates a different boundary effect at the boundary between two activity classes.

## 4. Conclusion

We have presented a coding scheme which is built upon JPEG with a limited overhead in computational complexity and performs better than JPEG at high compression ratios. It allocates more bits to high activity blocks to reduce the blocking effect and retains satisfactory quality in low activity blocks by subsampling and interpolation. This scheme can utilize existing JPEG hardware/software. Thus, it provides a practical solution.

## References


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| CR (rate) | 21.99 (0.3637) | 24.25 (0.3299) | 26.30 (0.3042) | 27.88 (0.2870) |
|---|---|---|---|---|
| JPEG | 31.77 | 31.24 | 30.70 | 30.32 |
| US JPEG | 32.08 | 31.82 | 31.60 | 31.41 |
| AS JPEG | 32.05 | 31.57 | 31.03 | 30.75 |

**Table 1. PSNRs of original JPEG (JPEG), uniform sub-sampling JPEG (US JPEG), and adaptive sub-sampling JPEG (AS JPEG) at different compression ratios (CR)**

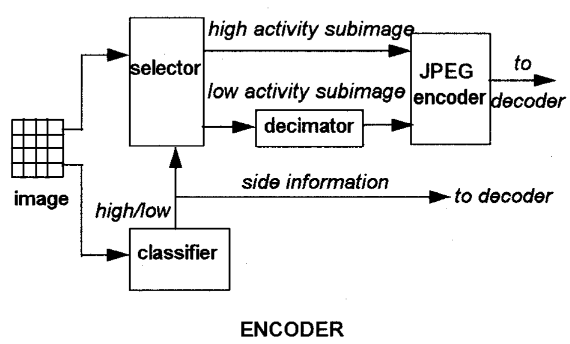


**Figure 1. The block diagram of an adaptive subsampling JPEG coding scheme**