Conditional Post-Processing of JPEG Compressed Images

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Abstract

JPEG compressed images exhibit artifacts on decompression which are caused by the lossy nature of the JPEG compression. These artifacts can be considerably disturbing in document images, because of the high likelihood of high contrast edges in those images. In this paper we present a conditional post-processing of JPEG compressed images that reduces compression artifacts.

1. Introduction

The JPEG (Joint Photographic Experts Group) coding algorithm[1,2] has been established as an industry standard for still-frame, continuous-tone image compression. In JPEG compression, the source image is divided into 8×8 non-overlapping blocks and each block is transformed using Discrete Cosine Transform (DCT) and the coefficients are subsequently quantized, using a quantization table. The resultant terms are then further compressed using a lossless encoding scheme. In the decompression process, the steps are repeated in reverse order.

The DCT and the statistical encoding are reversible steps that do not include any loss into the system (except for rounding error). The inverse operation to the quantization step will, in general, give a DCT coefficient that is only an approximation of the original DCT coefficient. This discrepancy is the source of loss in the JPEG compression method.

The major artifacts of the JPEG images are blocking and ringing, which are mainly due to the coarse quantization of low frequency and high frequency DCT components, respectively. At a very low bit rate, these artifacts might be rather disturbing to human eyes. While research for reduction of blocking effects has been relatively extensively conducted,[3-6] little has been done for improving ringing.[7] The latter is particularly dominant in document images, where high contrast edges are likely encountered. In this paper we present an efficient algorithm for the reduction of high contrast edge artifacts.[8] The efficiency of the algorithm is achieved by first developing a likelihood measure for the artifact in the block, and by consequently processing the block in response to that measure.

2. Decompression Algorithm

Lossy compression is an M to one mapping, i.e., the same code can be generated by many different source images, and therefor it is impossible to guarantee the retrieval of the original input. The best thing we can achieve during the decompression, is to find one image, among the many possible candidates, that is close to our expectation, or more specifically, close to an idealized image. A good assumption for such an idealized image is image smoothness, since most of the input images will not contain elements that look like ringing or blocking artifacts. Based on this assumption, a better decompression can be achieved that is nevertheless a "valid" decompression, i.e.: the resultant image will have the identical compressed form as the original image.

In a previous paper, an iterative algorithm was described that guaranteed data integrity, while at the same time improving the visual quality of the decompressed images. One disadvantage of the algorithm was the reduced throughput due to the algorithms iterative character. In that algorithm, the image was modeled as having smooth areas and edges separating those areas. Figure 1 shows a comparison of the standard decompression of an image (in (a)) and the iterative decompression (in (b)). As can be seen from Figure 1, the image quality can be improved with the iterative method.

In order to obtain the result of Figure 1b, three iterations were performed for each 8×8 image block. From Figure 1, however, it is obvious that the iteration only needs to be performed on some image regions, whereas other image regions already fulfill the smoothness requirements. It would therefor be advantageous to define an algorithm that only processes those image blocks that would benefit from an iterative decompression while leaving the other image blocks unprocessed.

2.1 Defining an Iteration Criterion

In order to identify blocks that would benefit from processing, we have to use a criterion that correlates well with the likelihood of JPEG artifacts. Several criteria have been proposed in the literature, as for example the AC-energy,[9] and the modified AC-energy,[10] but we will be using a simpler criterion, namely the Encoding-Cost-Map[11] (ECM) which is a representation of length of Huffman codes for each coded block. The ECM correlates strongly with the AC-energy, but is easier to compute. Fig. 2 shows the relation between ECM and AC-energy (taken from Ref. 11).

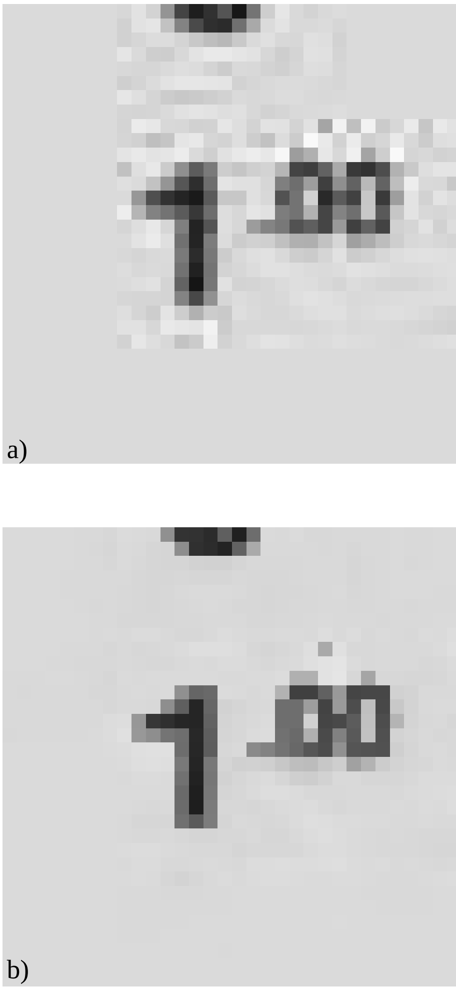

Figure 1. Comparison of standard JPEG decompression (in (a)) with the iterative decompression (in (b)). A total of 3 iterations is used for each 8x8 block.

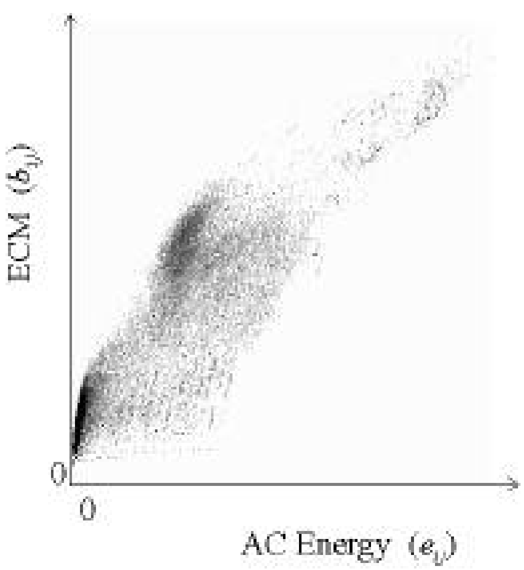

Figure 2. Comparison of AC-energy and encoding cost map. Both measures can be used to estimate the block activity, with ECM being a simpler method.

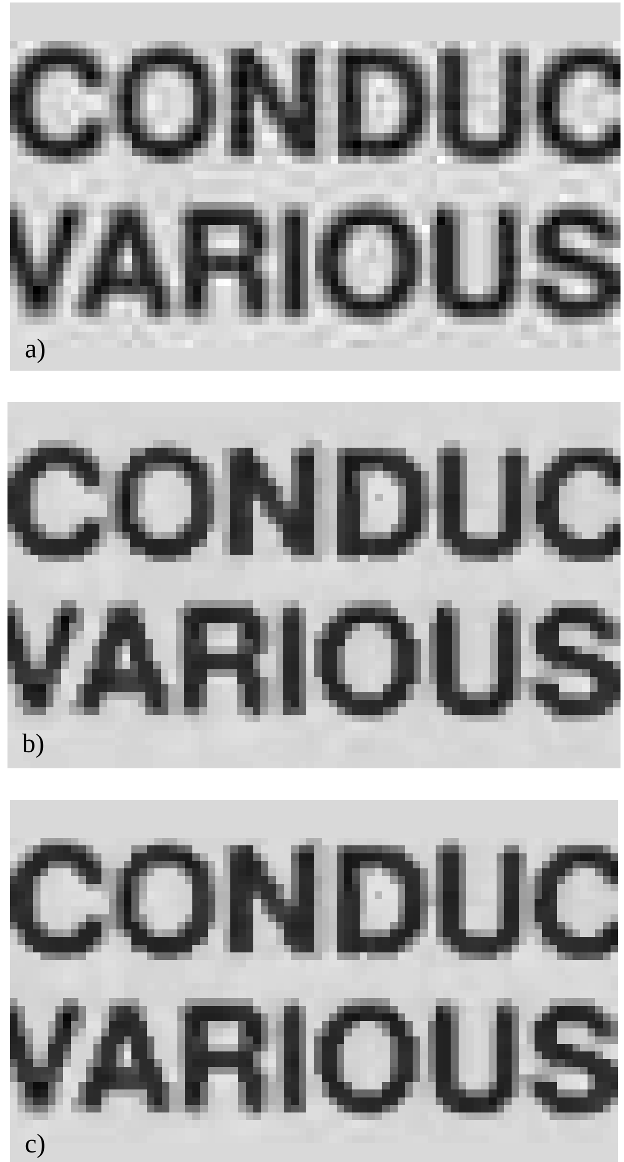

Figure 3. Comparison of standard reconstruction (a), iterative reconstruction using 3 iterations per block (b), and conditional iteration using an average of 0.45 iterations per block (c).

From Figure 2, it is obvious that a large ECM value corresponds to a block with high activity, and consequently to a block that has a high likelihood of exhibiting edge-ringing. We can use the ECM value to decide on the block processing, by using a larger number of iterations for blocks that have a high ECM and fewer iterations for blocks that have a low ECM.

3. Experimental Results

Figure 3 shows a small section of a test document used in the experiments. All numbers given relate to the entire document. In Figure 3a the standard JPEG reconstruction is shown, Fig. 3b shows the reconstruction using 3 iterations per block, and Figure 3c shows the reconstruction using an average of 0.45 iterations per block*. As can be seen from Figure 3, the image reconstruction of in the iterative decompressions is “visually preferred” over the standard reconstruction. At the same time, the processing speed can be noticeably improved over the fixed iteration algorithm without apparent loss in image quality.

4. Summary

We have described a JPEG decompression algorithm with reduced ringing and blocking noises. The proposed algorithm is compatible to the standard JPEG in the sense that if the decompressed image is to be compressed again the code generated would be the same as if it were compressed from the original image. An edge-preserving filter is used to smooth out artifacts while retaining important details. We showed simulation results which demonstrate that the proposed algorithm provides subjectively superior reconstruction to the standard JPEG decompression algorithm.

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* The numbers refer to the entire document, where the proposed algorithm takes advantage of “white-space” and slowly varying areas.