# SEGMENTED IMAGE CODING OF PALETTIZED IMAGES

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## ABSTRACT

This paper adresses the efficient high-compression coding of palettized color images. The most common methods for the lossy compression of color images rely on independent block oriented transform coding of the three or four color components. These techniques do not make use of the high redundancy of the color components and introduce some very undesirable errors at high compression, in particular block distortion. We present an efficient and original technique to code color images with a small number of colors. This is an important class of images in multimedia applications. The technique codes the according luminance image using an existing segmented image coding method for monochrome images. The color information is independently represented in a bit map. The method does not rely on the commonly used color separation and shows a far better subjective image quality than JPEG at high compression.

## 1. INTRODUCTION

The most common methods for the lossy compression of color images rely on independent block oriented transform coding of the three or four color components. These techniques, e.g. the lossy compression standard JPEG [1], do not make use of the high redundancy of the color components. This reduces the possible compression ratio. Moreover, although they yield a good reconstructed image quality at modest compression ratios, they introduce some very undesirable errors at high compression, in particular block distortion and blurring. This explains the research on second-generation image compression techniques, which aim to code the more important visual information with smaller loss.

Segmented image coding (SIC) is such a technique, which segments the image into non-rectangular regions of similar texture. The region contours are coded using e.g. chain codes. The texture inside a certain region is approximated by a linear combination of orthonormal base functions [2]. In this method, edge blurring is avoided by coding the contours and the texture separately. Also the block effect is eliminated even though the texture approximation is discontinuous at the block boundaries. This is because the discontinuities coincide with the region boundaries and are therefore masked by the image edges. The gentle degradation of the image quality with decreasing bit rate is an important advantage of SIC in high-compression coding.

The paper describes an extension of an existing Segmented Image Coding (SIC) method for monochrome images to images containing a limited number of colors. This class of images is frequently used in multimedia applications. The new, original technique codes the according luminance image of the color image and stores the color information in a bit map, which is compressed using the lossless bi-level JBIG coding scheme. The experimental results show that the new method produces a much better subjective image quality than JPEG at high compression due to the absence of block distortion. Also it does not separate the image into her color components.

In our work, we evaluated the usefulness of the SIC approach for the coding of still color images. Results of the separate segmented image coding of the color components are shown in section 2. In section 3, we present a new extension of an existing segmented image coding method for monochrome images to images with a color map. In section 4, we investigate the use of a region-adapted color space, which is found by the Karhunen-Loève transformation of the RGB color values. Finally, conclusions of our research are drawn in section 5.

## 2. SEGMENTED IMAGE CODING OF 24-BIT COLOR IMAGES

As in the JPEG compression algorithm, we convert the RGB color space to the YCbCr color space because of the good correlation of the color components in this space. However, due to the remaining redundancy, segmentation of the luminance image will be satisfactory for the two chrominance components as well. In this way, the part of the contour data in the total amount of compressed data, which becomes very significant at high compression ratios, is kept under control. We made use of an improved version [3] of the "edgmentation" algorithm [4] for the gray-scale image segmentation. After segmentation, the region's texture is transformed using weakly-separable base functions. These are a special type of orthonormal base functions which can be computed 10 to 30 times faster than non-weakly-separable base functions [5, 6]. The resulting coefficients are uniformly quantized and coded with a Huffman entropy coder. In our implementation, the coding of the contours is not done explicitly. We supposed the amount of data needed to encode the contours equals 1.6 bit per edge pixel.

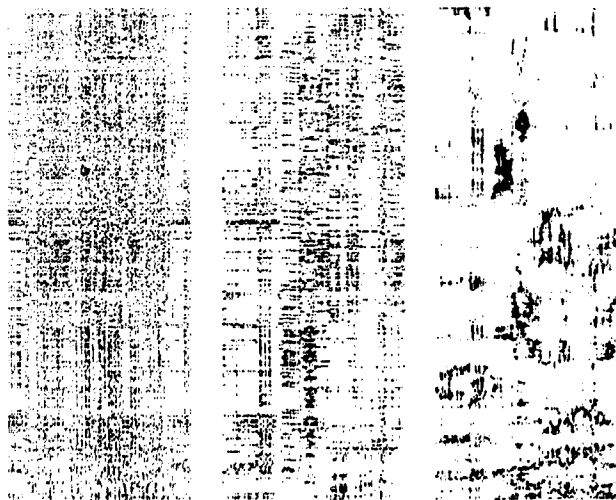The images compressed with JPEG at low to modest

Figure 1. Bit map representation of the color information, before (left) and after (center) sorting of the color map. At the right, the bit map after sorting of the bit vectors.

compression ratios (up to 50) show a slightly better visual quality[1]. However, in spite of a higher mean square error of the luminance component, the SIC algorithm outperforms JPEG at high compression due to the absence of the very annoying block effect.

## 3. SEGMENTED IMAGE CODING OF COLOR IMAGES WITH A COLOR MAP

### 3.1. Coding of the luminance image

Nowadays, most of the images used in multimedia applications contain up to 256 colors. Each pixel is asssigned an index of a well defined list of RGB-values. For the important class of 8-bit images, separation of the image into the color components which are then processed independently is not efficient due to the involved data expansion. Most of the compression methods developed for palettized images consider the index image as a gray-scale image and compress with JPEG [7] or other techniques [8, 9]. Our technique codes the according luminance image with the aid of an existing segmented image coding technique for monochrome images. At decompression, we try to reconstruct the original colors out of the luminance values. Therefore we include in the compressed image data some information on the presence of colors in each region of the segmented image. Indeed, the possibility of different colors having the same gray-value causes a problem at the decompression stage. Moreover, because SIC is lossy, gray-values in the reconstructed image are not always equal to the corresponding gray-values in the original image. A color derived from a slightly changed luminance value can differ thoroughly from the original color and lead to very annoying errors.

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[1] Results of the compression algorithms described in the paper on some test images, can be seen at http://www.elis.rug.ac.be/ELISgroups/mbv/overloop/icassp97/

|       | Y  | Cb | Cr  |
|-------|-----|-----|------|
| JPEG  | 46  | 27  | 43   |
| ROTC  | 56  | 82  | 119  |
| ROTC* | 59  | 72  | 103  |

|       | Y   | Cb  | Cr  |
|-------|------|------|------|
| JPEG  | 114  | 45   | 72   |
| ROTC  | 129  | 120  | 153  |
| ROTC* | 128  | 103  | 126  |

Table 1. Mean square error at compression ratio 8 (top) and compression ratio 21 (bottom).

### 3.2. Coding of the color information

We developed an efficient manner to code which colors are present in each region. For every region we construct a bit vector with length equal to the total number of colors in the image (thus a maximum of 256). The $i$-th bit of the string equals 1 if the color with index $i$ is present in the region. A bit map is constructed by combining the bit vectors for all segments, see figure 1.

To increase the possible compression ratio of this bit map and hence the global compression ratio, we increase the correlation of neighbouring "pixels" in the bit map. The correlation of the pixels in a row of the bit map can be improved by sorting of the color map. Neighbouring pixels in a region of the image have colors which resemble well. If we make sure that similar colors also have close indices in the color map, the 1-bits in every bit vector will be more grouped. The sorting is done with a heuristic algorithm to resolve the Traveling SalesPerson problem: the "farthest insertion sort" algorithm. In the same way, the bit rows are sorted. The resulting bit map is shown in figure 1. This bit map compresses well using the lossless bi-level JBIG (Joint Bilevel Image Group) scheme. JBIG is the CCITT lossless facsimile compression standard [10].

Finally, the compressed data consist of the Huffman compressed coefficient data, the data representing the contour information and a compressed bit map containing color information.

At decompression, the luminance image is reconstructed from the coefficient and contour data. For each pixel, the gray-value $g$ is translated into a color. Herefore we look at the proper bit vector of the bit map, which represents the color list of the pixel's region. We choose the color present in the region with gray-value closest to gray-value $g$.

Results of experiments done on some test images show that the technique can introduce in certain regions colors which differ strongly from the average color of the region. This is caused by shortcomings of the segmentation procedure. Some pixels, typically pixels near the edge of a region, are assigned to a wrong region by the segmentation algorithm. If the gray-value of the color of such a pixel is close to the gray-values of the colors of the other pixels of the region, the mapping of luminance onto color can introduce major errors. In this way, the color of the edge pixel is "translated" into the body of the region.

As a solution to this problem, we discard the colors of the edge pixel in the color list of the region. This is done by using a threshold. If the fraction of pixels with color $k$ is

smaller than a certain threshold, this color is rejected from the according color list. In addition, the amount of data needed to represent the color information decreases with typically 15 %. Indeed, colors are removed which differ most of the "average" color of the segment.

## 3.3. Results and comparison with JPEG

The improvements on the ROTC technique (denoted by ROTC* ) make the effect of the segmentation less visible. The outcome in terms of mean square error for the 256x256 toucan test image are presented in table 1. One can see a better performance of JPEG. However, in spite of a higher mean square error our technique outperforms JPEG at high compression due to the absence of the very annoying block effect. This makes it interesting for high-compression coding. Moreover, the computational complexity of the algorithm is very moderate [11].

## 4. CONVERSION TO REGION-ADAPTED COLOR SPACE

The mapping of the colors to the luminance values is a projection of points in the three-dimensional color space to the luminance vector. Since segmented image coding is lossy, it is possible that the reconstructed gray-values are mapped back to totally different colors. As we noticed, colors are in this way translated from the edge towards the center of the region. A possible improvement could be made by conversion to the optimal color space instead of the luminance space. The most compact color representation of the colors in an image is achieved when the dominant colors of the image are grouped round one coordinate axis of the color space. Due to the presence of very different colors in an image, only a small improvement in efficiency will be gained by conversion of the entire image. However, within one region, the color will be similar. As a consequence, it is more interesting to determine the optimal color space within each region of the image. This is done by a Karhunen-Loève transformation of the RGB color values [12].

We examined the performance of the ROTC algorithm with the use of these projections instead of the luminance values. Both in terms of subjective visual quality and root mean square error, the method seems to fail. Apparently, the loss of efficiency caused by imperfections in segmentation is too high for the Karhunen-Loève transform to yield a return.

## 5. CONCLUSION

The usefulness of segmented image coding for color images is examined. Special attention was paid to images with a color map. These are frequently used in multimedia applications.

The method for true color images codes the three color components separately. At high compression, the method performs better in terms of subjective image quality than the block-oriented transform techniques, due to the absence of block distortion.

For images with a color map containing up to 256 colors, a new and promising technique is developed. It codes the according luminance image, while the color information is compactly and independently stored in a bit map.

Some modifications using a region-adapted color space were investigated. Currently, we investigate the use of segmentation of the color image itself to make such an approach profitable.

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