Huffman Modeling for DCT Based Coding

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ABSTRACT

In this paper we present a statistical modeling for DCT events frequency distribution for three images classes: landscape, portrait and document. We show that it is possible to fit a mathematical model capturing the underlying statistical distribution. This modeling allows us to automatically generate optimized Huffman tables for each quality factor involved in the compression engine.

INTRODUCTION

The wide diffusion of imaging consumer devices (Digital Still Cameras, Imaging Phones, etc.) coupled with the increased overall performances capabilities, makes necessary an increasing reduction in the bitstream size of compressed digital images.
The final step of the JPEG baseline algorithm ([5]) is a lossless compression obtained by an entropy encoding. The normalized DCT coefficients, properly grouped according to some simple heuristics techniques, are encoded by classical Huffman coding ([3], [10]) making use of a set of coding tables. Usually, the standard coding tables are used, as suggested in ([5], [8]) and included in the final bit-stream for every image to be compressed. This approach presents two main disadvantages:

1) the JPEG Huffman encoder writes all codes of the corresponding tables in the final bitstream even if only some of them were used to encode the associated events of the particular input image. An overhead (mainly for high compression rate) is clearly present because the header of the JPEG file will contain complete tables where unused codes are stored.
2) besides the JPEG standard encoder doesn't make use of any statistic about the distribution of the events of the current image.

To overcome these problems the JPEG encoder can be modified so that it can compute the frequencies of the events in each image to encode as described in [5]. The implementation of these algorithms allows obtaining an Huffman optimizer that, as a black box, takes as input the frequencies collected for a single image and generates optimal coding tables for it.
As shown in Fig. 1, the optimizer requires a pre-processing phase in which the statistics of the current image are collected. It's not always possible implementing such computation in embedded systems for low-cost imaging devices, where limited resources are available. On the other hand, static Huffman coding can be properly managed collecting statistics for a class of data having relatively stable characteristics. This approach is also used in [7] where experiments with a previous phase of collection of statistics for source programs in four programming languages are successfully applied.
In [1] we presented an algorithm to generate Huffman coding tables for classes of images conceived using the Huffman optimizer. Applying the new generated tables instead of the standard ones, it's possible to obtain a further reduction in the final size of the bitstream without loss of quality.
In [6] a technique to achieve an improved version of the JPEG encoder modifying the Huffman algorithm is presented; nevertheless using multiple tables to have better compression generates a bitstream not fully compliant with the standard version of the JPEG. Similar drawbacks can be found in ([2], [9]). Our proposed approach allows obtaining a standard compliant bitstream.
During the experiments performed in [1] an interesting regularity between quality factor and events frequency has emerged. We show that it is possible to fit some mathematical model for these curves capturing the underlying statistical distribution ([4]). Results reported in this paper confirm our conjecture.

Fig. 1. The Huffman Optimizer

THE ALGORITHM

The final step of the JPEG encoding is the Huffman coding. The JPEG standard specification ([5]) suggests some Huffman tables providing good results on average, taking into account typical compression performances on different kinds of images. The encoder can use these tables or can optimize them for a given image with an initial statistics-gathering phase ([8], [10]). The Huffman optimizer is an automatic generator of dynamic optimal Huffman tables for each single image to encode by JPEG compression algorithm. If the statistics, taken as input by the optimizer block, refer to a dataset of images rather than to a single image, the optimizer generates new Huffman coding tables for the global input dataset (as shown in Fig. 2). Major details and experimental results can be found in [1].

Fig. 2. A block description of the steps performed by the algorithm for automatic generation of Huffman coding tables for classes of images.

MODELING

We have chosen linear spline, in order to model the events frequencies distributions curves (related to DCT coefficients, after ordering) with a suitable mathematical function. In this way, just through a homotopyc function between linear spline curves it is possible to adapt the corresponding tables coding for each event frequency distribution for an arbitrary QF (Quality Factor), without using the statistical classification step. It has been proven [1] that it is possible to obtain effective improvement in terms of overall bitsize. In Fig. 3 are reported three different plots, corresponding to the measured bpp (bit-per-pixel), obtained coding images from a dataset, with the corresponding optimized table for portrait class. Similar results have been measured for the other two classes under investigation.

In order to proof our idea we collected DCT events frequencies (DC luminance coding) for some key QFs (0, 25, 50, 75, and 100). Then, we tried to extrapolate the events frequencies for other, randomly chosen, QFs (12, 33 and 62), by homotopyc interpolation and compared them with the real evaluated events frequencies (as described in [1]). Table 1 reports the obtained results.

The final paper will include also the coding performances of the generated Huffman tables. Preliminary results show how the proposed strategy seems to well fit the real statistical distribution especially for low-mid QFs.

Further analysis is needed to limit the overall error actually present for high QF values. Experiments are on going to evaluate other mathematical models.

Events Class	QF=12 Interp.	QF=12 Real	QF=33 Interp.	QF=33 Real	QF=62 Interp.	QF=62 Real
0	568645	570110	564519	559664	558823	66523
1	110003	109530	111648	111320	113919	89608
2	20068	19305	21720	24123	24002	126858
3	1793	1635	2347	4477	3111	101898
4	113	80	309	859	579	86065
5	42	6	115	184	214	76840
6	3	1	8	39	13	67078
7	1	1	1	1	1	50260
8	1	1	1	1	1	26519
9	1	1	1	1	1	8356
10	1	1	1	1	1	661
11	1	1	1	1	1	1

Table 1. Real and interpolated events frequencies for DC luminance events referred to landscape class.

REFERENCES

[1] Battiato S., Bosco C., Bruna A., Di Blasi G., Gallo G.: "Statistical Modeling of Huffman Tables Coding", to appear in Proceedings of ICIAP2005, Cagliari, Italy, 2005

[2] Bauermann I., Steinbach E.: "Further lossless compression of Jpeg Images". In Proceedings of PCS 2004 – Picture Coding Symposium, CA - USA, 2004

[3] Bookstein A., Klein S.T., Raita T.: "Is Huffman Coding Dead?", Computing, Vol.50, 1993, pp.279-296

[4] Epperson J.F.: "An Introduction to Numerical Methods and Analysis", Wiley, 2001

[5] ITU-CCITT Recommendation T.81: "Information technology – Digital compression and coding of continuous-tone still images – Requirements and Guidelines", ISO/IEC 10918-1, 1992

[6] Lakhani G.: "Modified JPEG Huffman Coding". In IEEE Transactions on Image Processing, Vol.12, No.2, 2003, pp. 159-169

[7] McIntyre D. R., Pechura M.A.: "Data Compression Using Static Huffman Code-Decode Tables", Commun. ACM, Vol.28, 1985, pp. 612-616

[8] Pennebaker W.B., Mitchell J.L.: "JPEG - Still Image Compression Standard", Van Nostrand Reinhold, NY, 1993

[9] Skretting K., Husøy J.H., Aase S.O.: "Improved Huffman Coding Using Recursive Splitting", In Proceedings of Norwegian Signal Processing, NORSIG 1999, Symp., Asker, Norway, 1999

[10] Wallace G.K.: "The JPEG still picture compression standard", Commun. ACM, vol.34, 1991, pp. 30-44

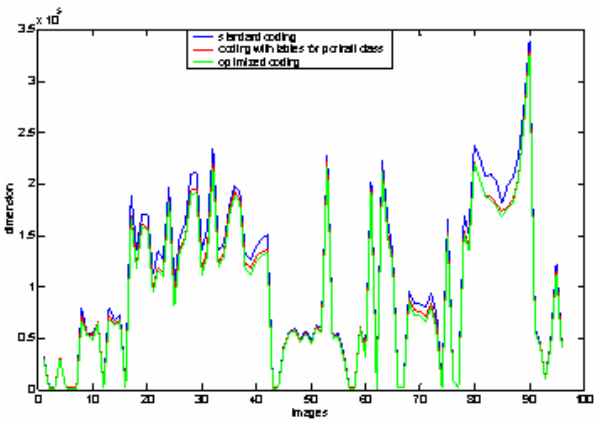

Fig. 3. Three types of coding applied to a new datasets for portrait images. In all graphics the standard coding is represented by a blue line, the optimized coding for class is represented by a red line while the optimized coding is represented by a green line. In the Y axis of each graphic the dimension is reported in byte.