Special Issue on Printers: UDC 681.327.54' 22.04 : 519.728

Image Data Compression Techniques for Printers

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Abstract

Image data compression is becoming an indispensable technology to decrease memory capacity cost and to decrease transmission time, as printers begin to feature high resolution and color. This paper presents an overview of the bi-level image data compression system, Quic-Coder, that we developed. This is a non-reciprocal bi-level image data compression system aiming at improving compression performance, which is the first arithmetic coding system. Considering the relationship between high resolution and the visual characteristics of the printer, we designed the non-reciprocal characteristic such that the deterioration of images is hardly detected. Compared with the 2-level data compression system QM-Coder, which is the international standard, data volume can be decreased 20 ~ 30%.

1. Introduction

As high resolution and color become major issues, image data compression techniques are indispensable for decreasing storage cost and transfer time. For printers, a bi-level image data compression technique is especially important.

The well known and widely used bi-level image data compression techniques thus far are MH, MR and MMR based on Huffman coding. Recently, however, considerable research and development on arithmetic coding are in progress. The major difference between Huffman coding and arithmetic coding is that in Huffman coding, the encoding model related to probability modeling and a code component model that actually constitutes a code are not completly separated, while in arithmetic encoding, these models are completed separated. Because of this feature, arithmetic coding can dynamically adapt probability estimation to the local nature of a symbol string during the encoding process, and can encode images at an encoding rate (bit / pix) lower than the static entropy (bit / pix) of static codes based on MH, MR and MMR.

A well known arithmetic encoding system for bi-level images is QM-Coder[1] , which is an international standard. To improve the encoding performance of this system, we developed a bi-level image arithmetic coding system called "Quic-Coder"[2,3] (Quantization integrated compression Coder). Quic-Coder, which performs non-reversible encoding, a first in arithmetic coding, implemented an encoding performance that surpasses QM-Coder. The non-reversible characteristic was designed such that deterioration of images are almost undetectable, considering the relationship between the high resolution characteristics of printers and visual characteristics. Since the coding system of Quic-Coder is compatible with QM-Coder, Quic-Coder, which is a proprietary system, can be used in a standard international environment. As with QM-Coder, Quic-Coder gives the highest priority to compression rate. However, we also developed Quic-ACC (Quantization integrated compression by Arithmetic Copy Coding), based on the Quic-Coder concept, allowing Quic-ACC to be a system suitable when the critical focus is on processing time and encoding performance.

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This paper first presents an overview of Quic-Coder (Section 2), then an overview of Quic-ACC (Section 3), and a conclusion (Section 4).

2. Overview of Quic-Coder

2.1 Concept and processing system

Normally arithmetic coding involves reversible coding where original encoding symbols are completely restored. Quic-Coder does not change the code structure rules of arithmetic coding, but reversibly encodes bi-level images that are restructured within the frame of dynamic adaptation of arithmetic coding. With Quic-Coder, reconstructed images are adaptively generated during the encoding process based on reconstruction rules which have been set such that the encoding rate is decreased while minimizing the deterioration of visually detected image quality. Reconstruction rules depend on the adaptive encoding parameters of arithmetic coding, and are adaptively updated during the encoding process.

The configuration of Quic-Coder is described next in comparison with ordinary arithmetic coding models that include QM-Coder.

In the arithmetic coding of bi-level symbols, the partitioning of a number line [0, 1] block by symbol appearance probability and selecting the partitioned block are recursively repeated, and binary coordinate values in the final partitioned block are output as coded words. The ordinary arithmetic coded model for partitioning a number line [0, 1] block and selecting a partitioned block consists of an encoded model section and an arithmetic code construction section (Figure 1). The encoded model section estimates the symbol appearance probability using symbols which appeared before the target symbol to be encoded. The arithmetic code construction section maps a symbol string on coordinate values on the number line using symbol appearance probability as an encoding parameter, and constructs arithmetic codes.

Figure 2 shows the Quic-Coder model. The encoding model section and arithmetic code construction section are the same as those of QM-Coder. In the Quic encoding model, one pixel reconstruction processing section used to reconstruct pixel values is integrated into the above sections. One pixel reconstruction processing section generates bi-level images suitable for constructing arithmetic codes to be short length considering symbol appearance probability. This pixel reconstruction processing section is also controlled by rules to preserve image quality. Figure 3 shows the processing flow of one pixel encoding. Quic codes also can be decoded by QM-Decoder. Quick-Coder can be applied to both monochrome images and each color of color images.

2.2 Encoding performance of Quic-Coder

Table 1 shows the encoding performance of Quic-Coder in comparison with QM-Coder. Images used here are a part of SCID*1 No. 4 images and have been binarized by a systematic dither method. Figure 4 shows the original image binarized by a systematic dither method (4 x 4), which was output at 300 dpi to compare image quality. Figure 5 shows an image reconstruction by the Quic encoding process. Compared with Figure 4, no image quality deterioration is observed in the image shown in Figure 5, as confirmed in a subjective evaluation experiment. Black pixels in Figure 6 show the positions where pixel values are different between Figures 4 and 5. This difference of pixel values relates to the deterioration of image quality, however, the ratio of these points in an entire image is low, 1.1%, which is not detected as deterioration in a subjective evaluation. Although the reconstruction ratio is low, the encoding rate of QM-Coder in Figure 4 is 0.130 (bit / pix), while the encoding rate of Quic-Coder in Figure 5 is 0.094 (bit / pix), indicating that 27.6% of codes have been decreased. Figure 7 shows an enlarged view of the pixel arrangement before and after reconstruction.

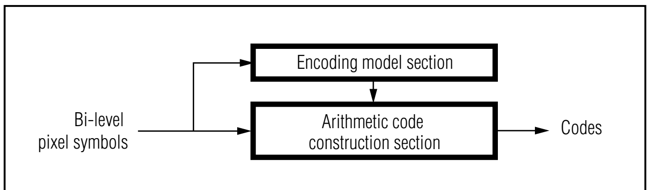

Figure 1: QM-Coder model

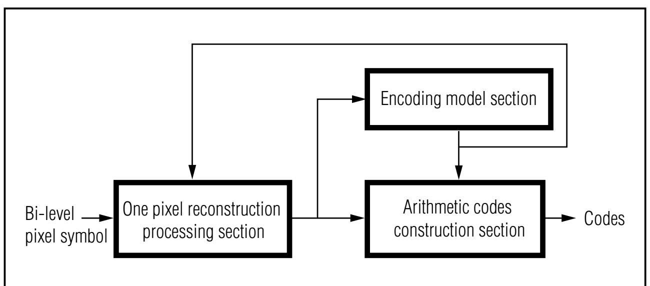

Figure 2: Quic-Coder model

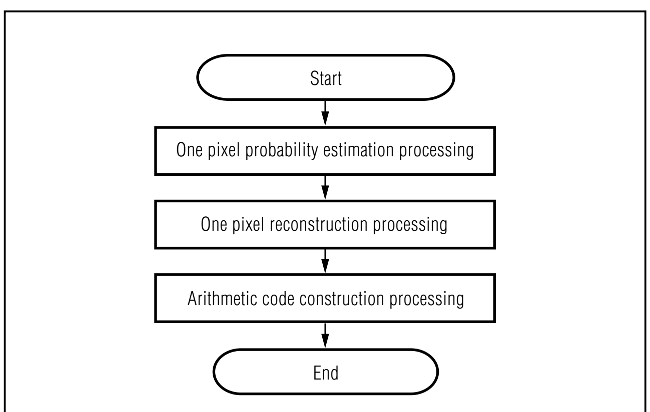

Figure 3: Processing flow of one pixel encoding

3. Overview of Quic-ACC

In the case of a printer which cannot stop printing once printing has begun, such as an electrophotographic printer, the data volume of an original image transferred per unit time is critical. This volume is higher as the encoding speed becomes faster and as the encoding performance becomes more advanced. We developed Quic-ACC based on the concept of Quic-Coder for such a case.

Quic-ACC is based on copy codes for creating copies of target n (1 < n) pixel strings to be encoded from a previous symbol series. Quic-ACC can follow up the change of image characteristics, just like arithmetic coding.

Figure 8 shows a Quic-ACC model. The basic model consists of an encoding model section and a copy code construction section, where a pixel reconstruction section similar to Quic-Code has been integrated. The pixel reconstruction section generates a bi-level n pixel string which is suitable for constructing shorter codes. This pixel reconstructing process-

Bi-level quantization method		QM-coder	Quic-coder	Data volume reduction rate (%)
		Encoding (bit/pix)	Performance (bit/pix)	
Systematic dither method	Bayer 4 × 4	0.130	0.094	27.6
	Bayer 8 × 8	0.156	0.113	27.4
	Screw 4 × 4	0.124	0.098	20.9
Error diffusion method	Floyd	0.455	0.352	22.6
	Jarvis	0.674	0.550	18.3

Table 1: Comparison of encoding performance (bit / pix)

*1 High resolution color digital standard image data. Supervised by Japanese Standard Association, image Processing Technology Standardization Committee

Figure 4: Bi-level original image

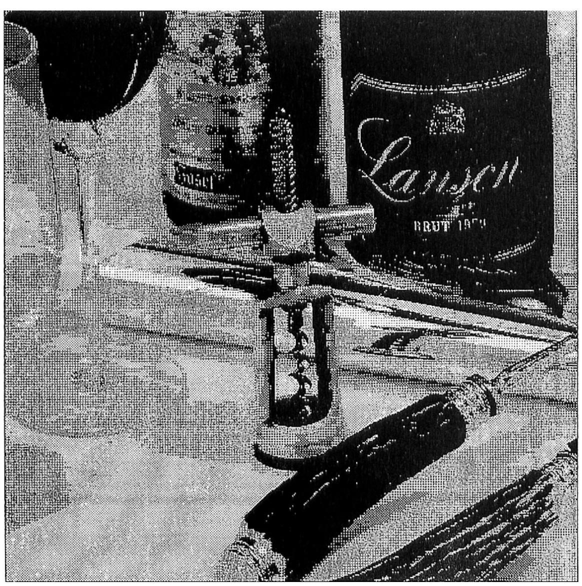

Figure 5: Reconstructed image

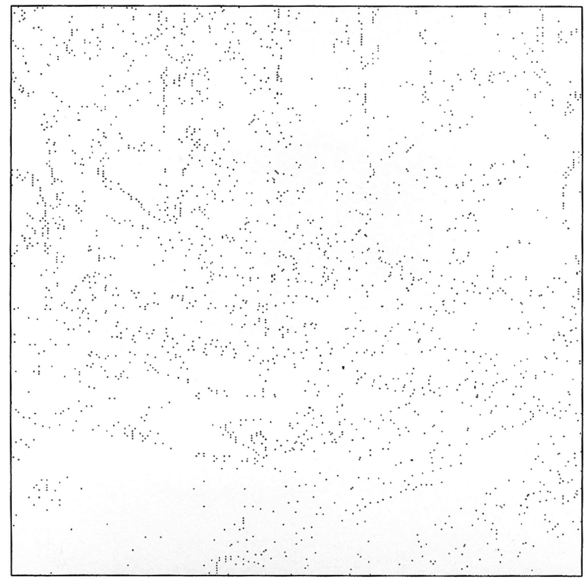

Figure 6: Image showing reconstructed position

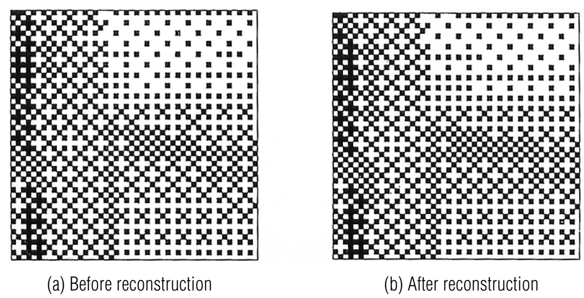

Figure 7: Pixel arrangement before and after reconstruction

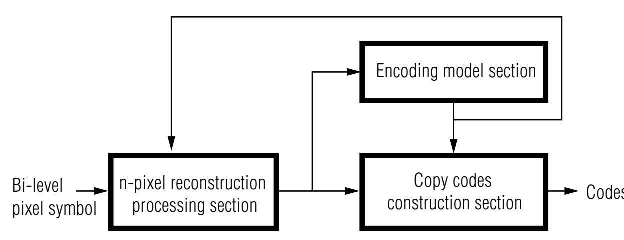

Figure 8: Quic-ACC model

ing is controlled by rules for preserving image quality. Figure 9 shows the processing flow of n pixel encoding. Decoding can be executed by a reverse operation that corresponds to the basic model of encoding.

Compared with QM-Coder, which is soft codec, the encoding rate (bit / pix) of Quic-ACC is 2 ~ 3 times more. Thus encoding performance is not as good as QM-Coder but processing time is 1 / 70. The above mentioned data processing volume per unit time is 23 ~ 35 times better than QM-Coder. Quic-ACC has also been released as an LSI, and has achieved the top level data processing capability per unit time world wide as a bi-level image encoding system for printers.

4. Conclusion

As high resolution and color printing becomes popular in printers, image data compression techniques are indispensable to decrease storage cost and transmission time. This paper described Quic-Coder and Quic-ACC, proprietary products that we developed.

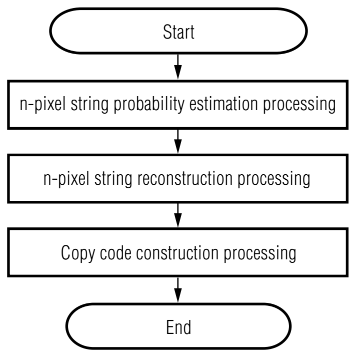

Figure 9: Processing flow of n pixel encoding

In the future, we will continuously pursue superb performance in data compression systems suitable for respective purposes.

5. References

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3. N. Matsushiro and O. Asada: "Highly efficient arithmetic coding for bi-level images," *Journal of Television Engineering of Japan,* 49, 1, (1995): 46 ~ 56.