MRC FOR COMPRESSION OF COLORED ENGRAVINGS

Vladimir Misic [†], *Kevin J. Parker* [‡]
Department of Electrical and Computer Engineering, University of Rochester,
Rochester, NY 14627, USA
E-mail: [†] misicv@ece.rochester.edu
E-mail: [‡] parker@seas.rochester.edu

Robert R. Buckley
Xerox Corporation, 800 Phillips Rd., MS128-30E,
Webster, NY 14580, USA
E-mail: rbuckley@crt.xerox.com

ABSTRACT

The *William Blake Archive* is a multimedia digital archive that provides structured access to high-quality electronic reproductions of work authored by the great eighteenth-century poet and painter William Blake. Due to the specific nature of a large group of Blake's paintings (extensive high frequency content as the result of the under-lying engraved image), they are not suitable for very efficient compression that meets both rate and distortion criteria at the same time. This paper presents original modification of Mixed Raster Content (MRC) compression scheme --initially developed for the compression of compound documents-- for the compression of non-compound documents (color engravings). The results, as demonstrated, were digital facsimiles that showed exceptional fidelity to their prototypes at low bit-rates, especially when compared to alternate compression methods such as JPEG and JPEG2000.

1 INTRODUCTION

The *William Blake Archive (WBA)* [1] is part of an emerging class of electronic projects in the humanities that may be described as hypermedia archives. It provides structured access to high-quality electronic reproductions of rare and often unique primary source materials, in this case the work of poet and painter William Blake. Due to the extensive high frequency content of his colored engravings, their electronic representations are not suitable for very efficient compression that meets both rate and distortion criteria at the same time. Therefore, the *WBA* struggles to maintain the high quality of its reproductions and the small size of download files. The current solution deals with the problem by introducing multiple copies at different resolutions, and consequently at different levels of quality.

Resolving the "compression problem", the authors successfully utilized modified Mixed Raster Content (MRC) compression scheme [2, 3], originally developed for compression of compound documents, for the compression of non-compound documents. We interpreted digital reproductions of Blake's hand-colored engravings as a special form of compound documents by drawing an analogy between etched lines and text on the one hand, and colored layers and continuous-tone images on the other in modern electronic documents. This paper demonstrates successful use of that approach.

2 MIXED RASTER CONTENT

2.1 MRC for Document Compression

Compound documents are a very common form of document representation. They contain both text and continuous-tone images, and thus they are not suitable for very efficient compression in a rate/distortion sense. The most efficient compression algorithms, which are developed specifically for text or for continuous-tone images, exploit the fact that the human visual system (HVS) works differently for text and for pictures; consequently these algorithms are not equally successful for all image types.

When compressing text documents, it is important to preserve the edges and shapes of characters accurately (i.e. the high frequency content), since any such distortion is easily perceived by the HVS. In the most cases, text can be represented as binary image and thus any coding error is easily perceived too. As a result, text compression methods are typically lossless (e.g. MH [4], MMR [5] or JBIG [6]). On the other side, looking at the continuous-tone images, the HVS is much more tolerant to the loss of fine image details (high frequency content) and this fact is widely used for construction of lossy compression algorithms (e.g. JPEG [7] or JPEG2000 [8]). Consequently, every compression algorithm is developed for specific use, regarding the image type and its characteristics, and is not equally successful for all image types.

Mixed Raster Content method for compressing compound images takes a different approach. Rather than using a single compression algorithm, MRC uses a multi-layered imaging model and applies multiple (or even different) compression algorithms to compress these layers. The basic 3-layer MRC model represents a color image as two multi-level (color image) layers (Foreground or FG, and Background or BG) and one binary layer image (Mask or M). The mask layer describes how to reconstruct the final image from the FG/BG layers:

$$IMAGE = (1-M) * FG + M * BG \qquad M \in \{0,1\} \qquad (1)$$

Depending on the mask value on a certain position, a pixel from the FG or BG on the corresponding position is selected (e.g. 0 for FG selection and 1 for BG). Thus, the FG layer is poured through the mask onto the BG layer. The basic 3-layer model is MRC's most common form (Fig. 1). The imaging model, however, is composed of basic elementary plane (layer) pairs: foreground and mask. Given a background, a foreground plane is imaged onto it through the mask plane composing a new background image. Another foreground layer can be imaged onto this new foreground background through another mask plane and the process can be repeated several times.

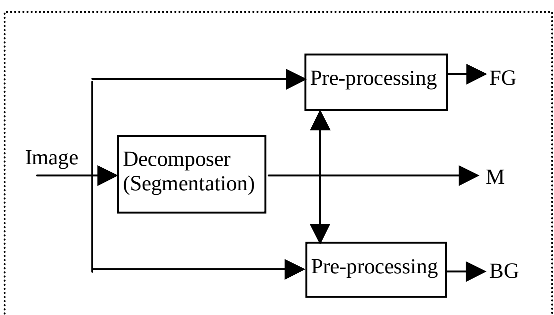

Figure 1. Diagram of a segmenter

2.2 MRC and Colored Engravings

In a sense, colored engravings may be considered as a very special form of compound documents. The underlying layer of the printed engraving is equivalent to the text content of modern documents, and the colored layer is equivalent to a continuous-tone image. In this context, the MRC imaging model mimics the sequence of the original imaging process: printing the etched lines first, Blake or someone else later painted the colored layer over them.

The segmentation algorithm we used to separate the above-mentioned layers is a combination of K-mean algorithm and local thresholding where threshold was separately calculated for each pixel based on local image statistics in the pixel neighborhood [9].

Figure 2. (a) Original image is segmented and (b) binary Mask, (c) Foreground and (d) filled Background components are identified

Upon successful image segmentation, we essentially have separated original (but colored) print of the etched/engraved plate and color overlay in non-overlapping regions. Background layer pixels at the positions masked by 0 values in the mask layer may be set in the manner that enables optimal BG layer compression. That process is known as data filling [10] (Fig 2).

When properly filled upon successful removal of the FG layer, the BG layer gives an accurate representation of the author's coloring. At the same time, if faithfully segmented, the Mask layer is an approximation of the original etched/engraved print, before coloring.

Further, each layer (FG, BG, or Mask) is separately compressed by the most appropriate compression method for the given image type. At this point, compression methods are not limited by MRC.

Using the relation given by equation (1), we are able to fully reconstruct the original image.

3 MASK LAYER PROCESSING

The original MRC equation (Eq. (1)) is designed to describe compound documents, where the text edges are the result of modern printing processes, and therefore have sharp fall-outs. Accordingly, the Mask layer is binary, because it has the sole task to discriminate between the FG and BG.

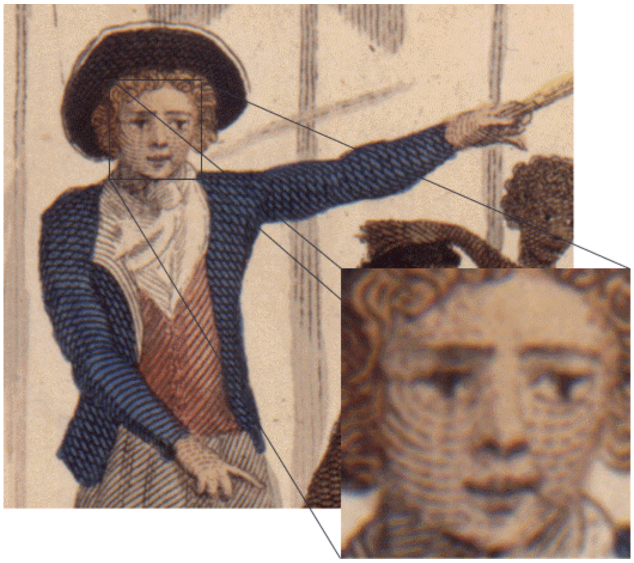

Figure 4. Under-lying lines of color engravings do not have sharp edges

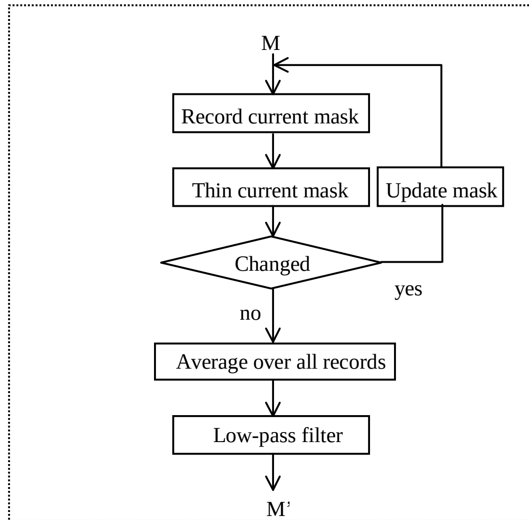

Figure 5. Mask processing algorithm: Original mask (M) is binary, and processed mask (M') is gray-level, with gradual fall-outs

The colored engraving consists of an intaglio print and an over-painted color layer. Hence, even if the edges of the originally printed lines were sharp --and they are not-- they would be smeared by coloring (Fig 4.). If applied directly as described, MRC would result in an artificially sharpened image, even after compression. Although that result may look good, it is very different from the original, and it is too sensitive to the segmentation errors.

For the above reasons, we altered the basic MRC imaging model through mask post-processing at the receiver side:

$$IMAGE = (1-M') * FG + M' * BG \qquad M' \in [0,1] \qquad (2)$$

The mask processing algorithm (Fig 5.) consists of iterative morphological thinning steps, which are repeated until no further changes occur. Each step is recorded, and results are summed and averaged, so the dynamic range of the mask remains [0,1]. Further smoothing is then obtained by means of low-pass filtering.

4 RESULTS AND EXAMPLES

For testing purposes, we used a characteristic set of Blake's commercial colored engravings, originally printed in Stedman's book *Narrative, of a Five Years' Expedition, against Revolted Negroes of Surinam* [11].

As an algorithm of choice --for compression of MRC layers-- we used JPEG2000. For compression of colored layers we used 5 levels of wavelet decomposition, while the binary layer was not wavelet decomposed (zero levels) but rather passed unchanged to the arithmetic coder.

We used *subjective fidelity criteria* to compare our results to other compression methods. Viewers were asked to point to the best image, comparing the original to the JPEG, JPEG2000 and MRC reconstructed images at compression ratio 40:1. While at low-resolution devices (computer monitors) viewers could not agree which compression method produced the best images, the vast majority voted for the MRC when presented with high-resolution image versions such as high-quality color prints and zoomed images on the screen (Fig. 6).

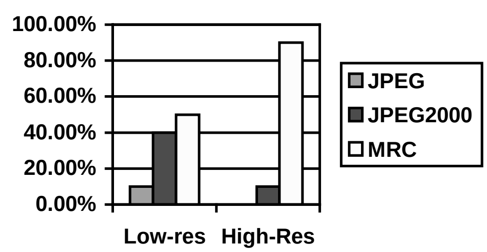

Figure 6. Results of subjective fidelity testing: majority of testers voted for the MRC compressed image

Such results were expected, because JPEG compressed images showed blocking effects and both JPEG and JPEG2000 compressed images completely "lost" engraved lines in some areas. At the same time modified MRC preserved (but somewhat smeared) the lines in the same image areas where other algorithms failed to do so. One such example is presented in Fig. 7.

Figure 7. (a) Original image, (b) JPEG compressed, (c) JPEG2000 compressed and (d) MRC compressed image. Images are compressed at 40:1 compression ratio.

5 CONCLUSIONS

In this paper, we have been able to demonstrate the successful use of the MRC compression approach for the compression of *WBA* documents, even when the compressed documents are not compound images.

When used in conjunction with the upcoming JPEG2000 compression standard, MRC compression scheme enables additional reduction of archive storage space (by using multiresolution image representation) and a more efficient download process (by offering lossy-to-lossless compression in the same codestream) than other compression and archiving schemes.

Besides efficient image compression, the presented approach offers additional benefits to the user of *The William Blake Archive*. For the first time, archive users are able to study Blake's engravings (Mask layer) separately from his coloring, and even to recreate the whole process. Further benefits may include authorship authentication, classification of Blake's work based on different stages of the extracted copperplate prints, and automated image enhancement based on separate processing of image layers.

REFERENCES

[1] *The William Blake Archive*, http://www.blakearchive.org

[2] ISO/IEC 16485:2000, "Information technology -- Mixed Raster Content"

[3] R. de Queiroz, R. Buckley, M. Xu, "Mixed raster content (MRC) model for compound image compression", Proc. EI'99, VCIP, SPIE Vol.3653, pp. 1106-1117, Feb. 1999.

[4] ITU-T Rec. T.4, Standardization of group 3 facsimile apparatus for document transmission, July 1996.

[5] ITU-T Rec.T.6, Facsimile coding schemes and coding control functions for group 4 facsimile apparatus, November 1988.

[6] ITU-TITU-T Rec. T.82, Information technology – Coded representation of picture and audio information – Progressive bi-level image compression, March 1995

[7] W. P. Pennebaker and J. L. Mitchell, *JPEG: Still image compression standard*, Van Nostrand-Reinhold, New York, NY, 1993.

[8] ISO/IEC 15444-1:2000, "Information technology -- JPEG 2000 image coding system -- Part 1: Core coding system"

[9] V. Misic, R. R. Buckley, K. J. Parker, "Encoding and processing of color engravings (using MRC) ", *IEEE Intl. Conf. on Image Processing*, ICIP, Rochester, NY, USA, 2002

[10] R. de Queiroz, "On data-filling algorithms for MRC layers", *Proc. IEEE Intl. Conf. on Image Processing*, ICIP, Vancouver, Canada, 2000.

[11] Robert N. Essick, *William Blake's Commercial Book Illustrations*, pp. 71 - 75 Clarendon press, Oxford, 1991