A Model For The Electronic Representation Of Brazilian Bank Checks

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***Abstract*—The substitution of physical bank check exchange by electronic check image transfer brings agility, security and cost reduction to the clearing system. In this paper, we propose a model for the electronic representation of bank checks based on the Mixed Raster Content (MRC) model for compression of color and gray-scale images. The binary image is sent first and only if necessary the other MRC image planes are sent to reconstruct the color image of the check. We conducted careful subjective evaluation to indicate the best binarization technique that even involved check clearing professionals. For compression, we used JPEG 2000 to compress all the MRC image planes. Tests indicate that JPEG 2000 is as good as other compressors to compress binary images and it is simpler to have one coder for all planes. We also explain the image processing that has to be applied to all check image MRC planes in order to enable efficient compression. Furthermore, we also propose a new watermarking technique to embed a digital signature into the check image for protection.**

***Index Terms*—Binarization, Checks, Image compression Mixed Raster Content.**

I. Introduction

ELECTRONIC representation of documents has become commonplace. Nevertheless, many bank check exchange and clearing systems are not electronic. Some countries like France and Spain already use electronic check images instead of paper checks for most of their check exchange systems [1], [2]. In the USA, the Check 21 Act [3] is supposed to encourage banks to use check images instead of paper checks. In Brazil [4], paper checks are still exchanged between banks, as is also the case in many other countries. .

Electronic exchange of bank checks may lead to cost reduction in transport and logistics, while increasing security and agility. Adequate image processing techniques have to be used in order to make the electronic transfer of check images viable. The easiest format for electronic representation of check images is the black-and-white binary image. Binary images save memory and are very legible. Hence, scanned color images are often binarized, i.e. converted to a black-and-white image. Some applications may require a high quality color or gray-scale representation of the bank checks. Since checks have both text and images, they are not efficiently compressed by typical compression algorithms. The Mixed Raster Content (MRC) [5]-[8] model separates the image in layers that can be more efficiently compressed. We propose to use the MRC model for representing and exchanging checks. In order to protect the check images against alteration and fraud, watermarking techniques can be used to insert a digital signature into the image.

An early proposal to use multiple layers for checks was made [9]. Our proposal consists in binarizing the check images, compressing the images using the MRC model and protecting the image with its digital signature. We propose to use the flow in Fig. 1.

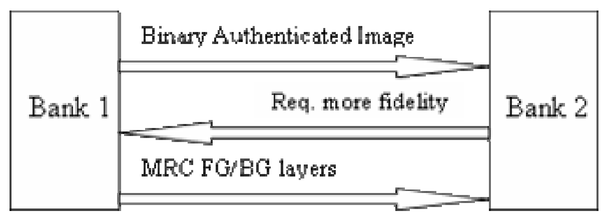


Figure 1. Proposed framework for check exchange. First the BW image is sent, and, if necessary, the foreground and background layers are also sent.

II. Binarization and Thresholding

Binarization is the act of converting a color or gray-scale image onto a black-and-white binary image. There are many techniques for that purpose, typically trying to separate objects from the background. In some applications, the gray level of the object pixel is relatively distant from the gray level of the background pixels. This is the case of bank check images. In this case, thresholding is a simple and efficient way to binarize an image [10]. The first step, if necessary, is to convert a color image to gray-scale representation. Then, a gray level value t is chosen and considered as the threshold. Pixels with a gray level value lower than t are considered object pixels, and pixels with a gray level value higher than t are considered background pixels, .i.e pixels from the resulting binary image $\{y(i,j)\}$ are calculated as $y(i,j)=u(t-x(i,j)-1)$, where t is the chosen threshold. $u(k)$ is the discrete step function ($u(k)=1$ if $k \geq 0$ and $u(k)=0$ if $k < 0$), and $\{x(i,j)\}$ are the gray-scale image pixels.

In order to use thresholding techniques to binarize a bank check image, it is essential to choose the correct threshold level. A wrong choice can produce an unreadable and useless image. Thresholding techniques can be divided into "global" and "local". A global technique chooses a unique threshold to the whole image, while a local technique chooses many thresholds, which depend on the local characteristics of each image region. Global thresholding techniques have the advantage of using less processing resources for threshold calculation, and generally yield good results when the foreground and background gray levels are distant. Local thresholding techniques are better suited for images with great variation. The problem with local thresholding is that, when the background is complex, there is often high pixel misclassification.

In order to achieve a successful segmentation of the objects and the background of the image using thresholding techniques, it may be necessary to pre-process the gray-scale image, and to post-process the resulting binary image.

Thresholding techniques have been evaluated by many authors. In [11], 11 local thresholding techniques were evaluated for scanned hydrographic maps. Such maps are basically digits and lines and the objective was to find techniques that are suitable to character recognition. Some of the techniques that have shown good results were Niblack's [12], Eikvil's [13] and Bernsen's [14]. In [10] 40 global and local thresholding techniques were evaluated, for 40 scanned documents. These documents had only text. In order to compare the techniques, a combination of 5 criteria was used: misclassification error, edge mismatch, region non-uniformity, relative foreground area error, and shape distortion penalty via Hausdorff distance. Some of the best techniques were found to be Sauvola's [15], White's [16] and Bernsen's [14]. In [17] 13 global and 3 local thresholding techniques were evaluated, using scanned Brazilian bank checks. All test checks were blank or had been filled mechanically. Their comparison was made using character recognition engines and some of the best techniques were found to be Otsu's [18], and Bernsen's [14].

III. THRESHOLDING TECHNIQUES APPLIED TO BANK CHECKS

The choice of the best binarization technique depends on the application. We want to find the best binarization technique to represent a bank check. Six techniques were chosen, primarily because of the efficiency shown in other comparative works: Otsu's, Niblack's, Eikvil's, Bernsen's, Sauvola's and White's. Besides these 6 techniques, a variation of Otsu's technique applied locally was also tested.

We collected 33 Brazilian checks of 11 different banks, each type hand-written by 3 different persons. The checks were scanned at a 200 dpi resolution.

The parameters for each technique were adjusted for the best performance and applied to all checks throughout. Furthermore, in order to enhance performance, it was necessary to pre-process the gray-scale image, and to post-process the binary image. The pre-processing and the post-processing were used identically to all checks and methods and will be described next.

Before using the thresholding techniques, each image was processed by a sigma filter [19]. This filter changes the value of each pixel by the mean value of its neighboring pixels that are within a certain gray value difference Δ from the central pixel. This filter smoothes the image and preserves edges. A 3x3 filter with $\Delta = 16$ was found to be adequate.

The objective of post-processing is to clean the binarized image from noise. We used an area-ratio algorithm, which changes the values of a pixel if less than a given percentage of its neighboring pixels have the same value as the central pixel. We used a 3x3 filter and a 30% parameter, i.e. a simple binary filter wherein a pixel is considered an object pixel if it is marked as an object pixel and at least 3 of its neighbor pixels are also marked as an object pixel. Otherwise the pixel is marked as background.

Parameterization and technique adaptation

Otsu's thresholding technique does not require any parameters. Niblack's thresholding technique [12] requires two parameters: the window size, and a constant value that is multiplied by the image standard deviation to calculate the threshold. We tried many combinations of parameters. However, we were not able to separate the text from the background adequately for the checks we tested. Since the background of the Brazilian checks have complex figures, the algorithm tends to segment parts of the background as objects, as illustrated in Fig. 2. In order to enhance the algorithm's performance, we used a variation: if the standard deviation calculated inside the window is below a limit, the pixel is considered background, otherwise Niblack's threshold is calculated. We used 25 as the standard deviation limit, with a 15-pixel-wide window and the constant k=-0.2, as suggested in [11]. The result of the algorithm variant is shown in Fig. 3.

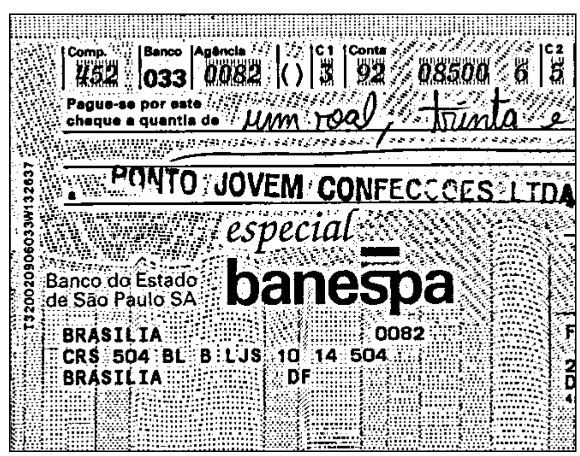


Figure. 2. Niblack's thresholding technique applied to a Brazilian bank check.

Figure. 3. Binary Check image using a variation of Niblack's technique.

Sauvola's technique is different for image regions and text regions. In this work, we did not use the image region technique, since we are interested in segmenting text. The application of the text region technique yields the same problem of Niblack's technique, i.e. segmentation of the background. The solution was to use yet another variation, where the Sauvola's threshold is used only if the standard deviation inside the window is higher than a limit. If the standard deviation is lower than this limit, the pixel is considered background. We used 25 as the standard deviation limit, with a 15-pixel-wide window and the parameters k=0.5 and R=128, as suggested in [15].

We also tested a variation of Otsu's thresholding technique. For each pixel, the Otsu's threshold was calculated inside a window centered on the pixel. If the inter-class variance is higher then a limit, Otsu's threshold was used to determine if the pixel is object or background. If the inter-class variance is lower then this limit, the pixel is considered as background. We used a 15-pixel-wide window, and a limit for the inter-class variance of 500.

Eikvil's thresholding technique [13] did not binarize the checks successfully. We, then, used a variation of Eikvil's technique. When the mean values of each class differ by a value lower than k, instead of using the mean value of the classes of previous windows to define if all pixels (within a bxb window) will be object or background, we always classify all pixels as background. We used k=45, a 3-pixel-wide window for pixel classification, and a 15-pixel-wide window for threshold calculation. For Bernsen´s thresholding technique, we used a 15-pixel-wide window and a limit of 100 for the difference between the maximum and minimum value of the pixels inside the window. For White´s thresholding technique, we used a 15-pixel-wide window and a bias of 1.25 [16].

IV. Evaluation of Binarization Techniques for Brazilian Bank Checks

In order to compare the performance of the binarization techniques applied to bank checks, we carried a subjective evaluation of the visual aspect of the printed black-and-white images. For each one of the 33 checks, we applied the 7 binarization algorithms. Then, for each check, we printed the original color image and the 7 binary images. Each binarized image was identified with a letter, from A to F. It is important to note that the algorithms were not identified with the same letter for all bank checks, nor were they in the same position on the printed pages. The order varies from check to check to avoid inducing the observer.

Evaluations of the images were carried by two sets of observers. The first set was composed by 20 observers: co-workers, friends, and students. They have ranked, for each check, the 3 binary images with the best visual aspect. We instructed the observers to consider intelligibility and legibility. The second set was made by 3 experts. These experts have worked for Banco do Brasil bank in check conference and clearing areas. They have also ranked the 3 best techniques for each check. Each check image chosen by the observers was given a score. The best algorithm for each check had a score of 3, the second had a score of 2, and the third had a score of 1.

Table 1 shows the final result of the evaluation carried by the common observers set. Table 2 shows the same result for the expert observers set. The results of both subjective tests indicate that Otsu's global thresholding is the most effective.

TABLE I - FINAL RESULT OF THE EVALUATION WITH 20 COMMON OBSERVERS

BERNSEN	411
EIKVIL	867
NIBLACK	357
OTSU	1263
OTSU LOCAL	663
SAUVOLA	251
WHITE	148

TABLE II - FINAL RESULT OF THE EVALUATION WITH 3 EXPERTS

BERNSEN	87
EIKVIL	109
NIBLACK	58
OTSU	147
OTSU LOCAL	121
SAUVOLA	47
WHITE	25

Parameter adjustment on the other techniques improved the performance for one type of check, but degraded performance for other types of checks. It is important to note that for a specific type of check, other techniques can perform better then Otsu's algorithm, since we can adjust the parameters for the best performance. This can be the case where a bank binarizes only its own checks. Nevertheless, the test results are important for applications where a bank has to binarize checks from different banks.

Otsu's thresholding technique, combined with the pre-processing of the gray-scale image with the sigma filter, and the post-processing of the binary image with the area-ratio algorithm, has achieved good legibility for all the 33 checks. This is not true for other binarization techniques.

Figure 4 shows the value field for all checks binarized with Otsu's technique. The pre-processing and post-processing steps were essential to the good performance of the binarization algorithms. Figure 5 depicts a check binarized with Otsu's threshold, with and without pre- and post-processing stages.

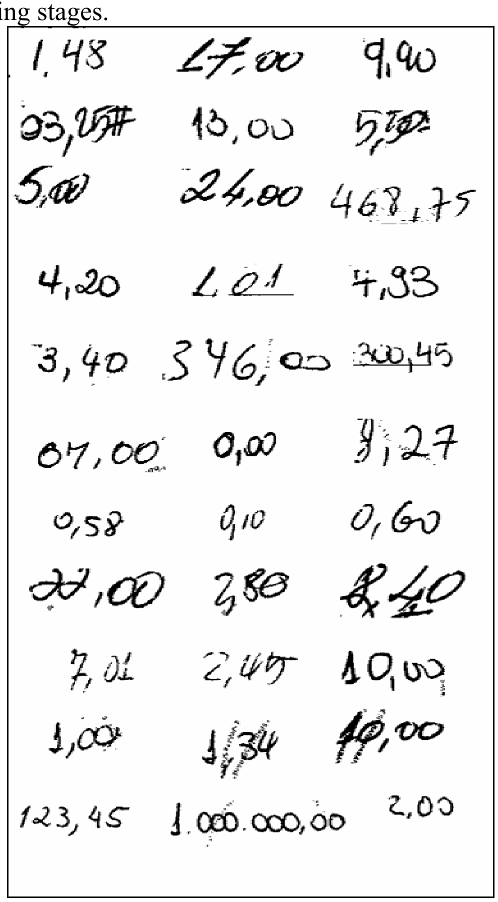


Figure 4. "Pay amount" fields for the 33 checks using Otsu's threshold.

V. Compression using the MRC model

The MRC model decomposes the image into layers in order to achieve better compression [5]. The basic model uses 3 layers: the background (BG) of the image; the foreground (FG) containing the color of the text; and the mask layer, which indicates which pixels will be taken from the background and which ones will be taken from the foreground to produce the final image. Figure 6 illustrates the MRC model.

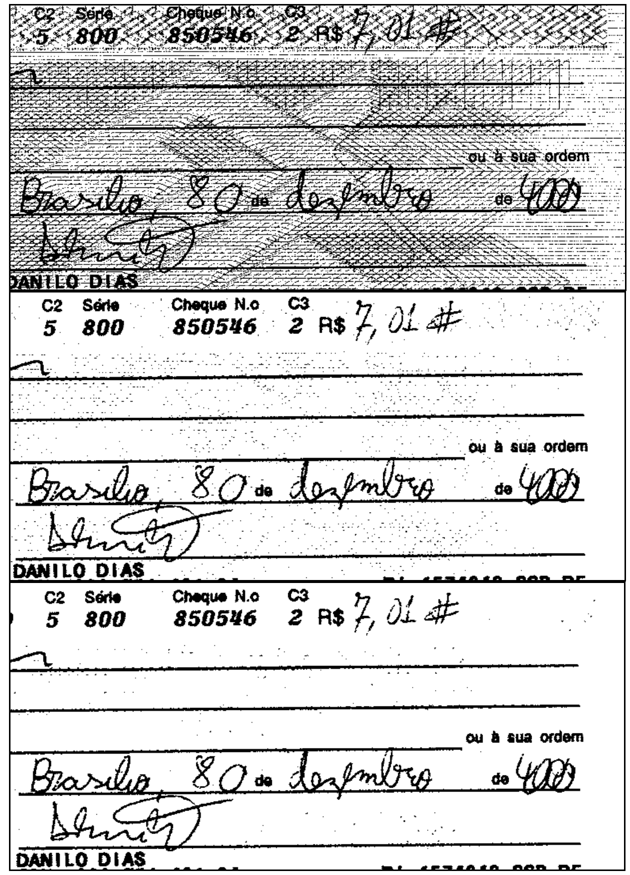


Figure 5. Example of Otsu´s thresholding: without pre- or post-processing (top), with only pre-processing (middle), and with both pre- and post-processing (bottom).

In order to achieve better compression, the 3 layers have to be easily compressed. The black-and-white mask is easily compressed by appropriate compression algorithms. The FG and BG layers have to be smooth images in order to achieve greater compression. Pre-processing techniques are used to replace unused image portions in both planes (FG and BG) by image data that produces smooth images. There are many techniques for that [6], mostly applicable to sharp (not scanned) images. The use of the MRC model in scanned images like bank checks has the problem that the borders of the text are not sharp. This means there will be pixels in the border with an intermediate value between the bright pixels of the BG and the dark pixels of the FG. When we find the mask using a binarization technique, these intermediate border pixels will be classified either as FG or as BG. Hence there will be a halo around the border of the text, which might hinder compression. Figure 7 shows an example of this problem.

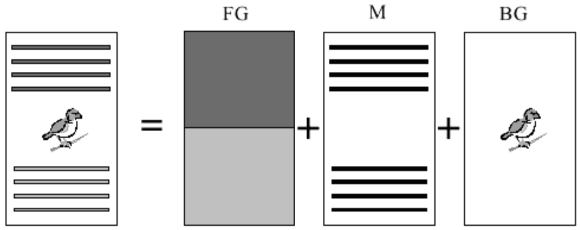


Figure 6. The decomposition of an image into the 3 layers of the proposed MRC model: foreground (FG), mask (M) and background (BG).

Figure 7. Halo around the text makes the image more difficult to compress. Left: unprocessed; right: pre-processed.

In order to avoid this problem, we pre-process the image, using the mask as reference. We find the text borders, where a FG pixel in the mask has BG neighbors, and vice-versa. We, thus, change the values of these pixels by the weighted average of its neighbor pixels, giving a higher weight of 10 to pixels that are not border pixels. Otsu's binarization usually classifies intermediate pixels as FG. Hence, we used this technique to change only FG pixels. However, it could be applied to BG pixels as well. An example is shown in Fig. 7.

After pre-processing of the image, we use the mask to find the FG and BG layers, and use a regular data filling algorithm to fill the unused pixels of the 2 layers [6],[7]. Figure 8 shows the mask, FG and BG of a check image, after using the data filling algorithm.

For compressing the MRC planes we employed a JPEG 2000 codec for all layers. In order to lossless compress binary images with JPEG 2000, one may set the number of wavelet levels to 0 and the bit-depth to 1, i.e. the coder will solely rely on context-adaptive arithmetic coding, just like it does for the regular subband bit-planes. It turns out that this compression is quite effective. Table 3 shows a comparison of lossless compression algorithms for 33 check images binarized with Otsu´s technique. JPEG 2000 is as good as G4 and almost as good as JBIG and JBIG2.

Using combinations of MRC and JPEG 2000 we envision three methods for conveying check images from one bank to another: (1) the proposed method, wherein the binary plane is sent first and then the FG/BG planes are sent in separate; (2) a scheme where a binary mask is sent first and then the full image is sent compressed with JPEG 2000; (3) the image is compressed with JPEG 2000 and sent. Hence, in order to test our method we need to compare it (3-layer JPEG 2000) against a single layer JPEG 2000. However, in order to compare with the second method we need to compare the compression of the FG/BG layers (without the mask) against single-layer JPEG 2000. We compared the PSNR results from check compression using the proposed method (Otsu's binarization mask and MRC with 3-layer JPEG 2000 compression) against single layer JPEG2000 for all checks. Results for 3 different checks are shown in Fig. 9.

TABLE III - AVERAGE RATE (IN BITS PER PIXEL OR BPP) ACHIEVED AFTER COMPRESSION OF 33 BINARY CHECK IMAGES WITH EACH ALGORITHM.

Compression algorithm	Rate (bpp)
LZW	0.21
G4	0.12
JBIG	0.11
JPEG2000	0.12
JBIG2	0.09

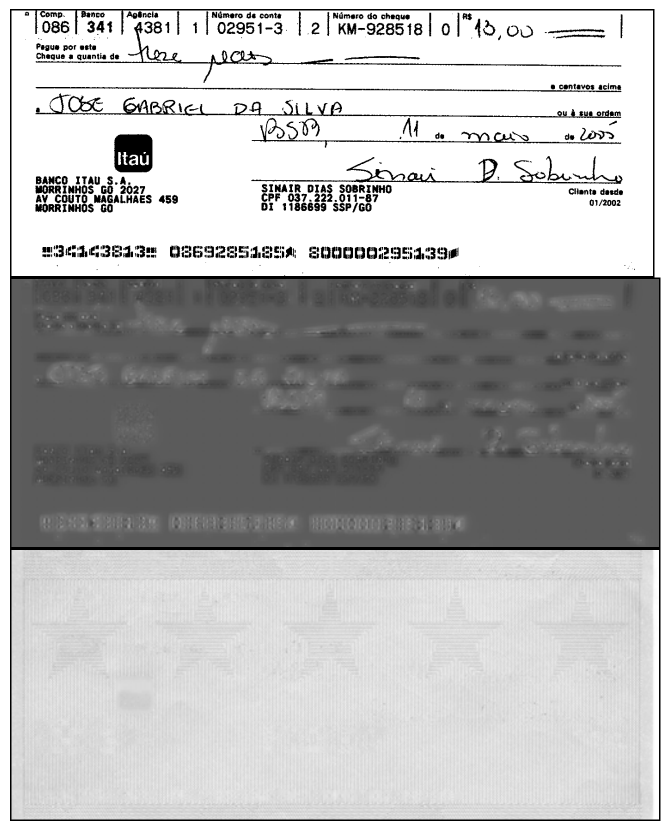


Figure 8. From top to bottom: mask, FG and BG planes of a check image, after using the data filling algorithm.

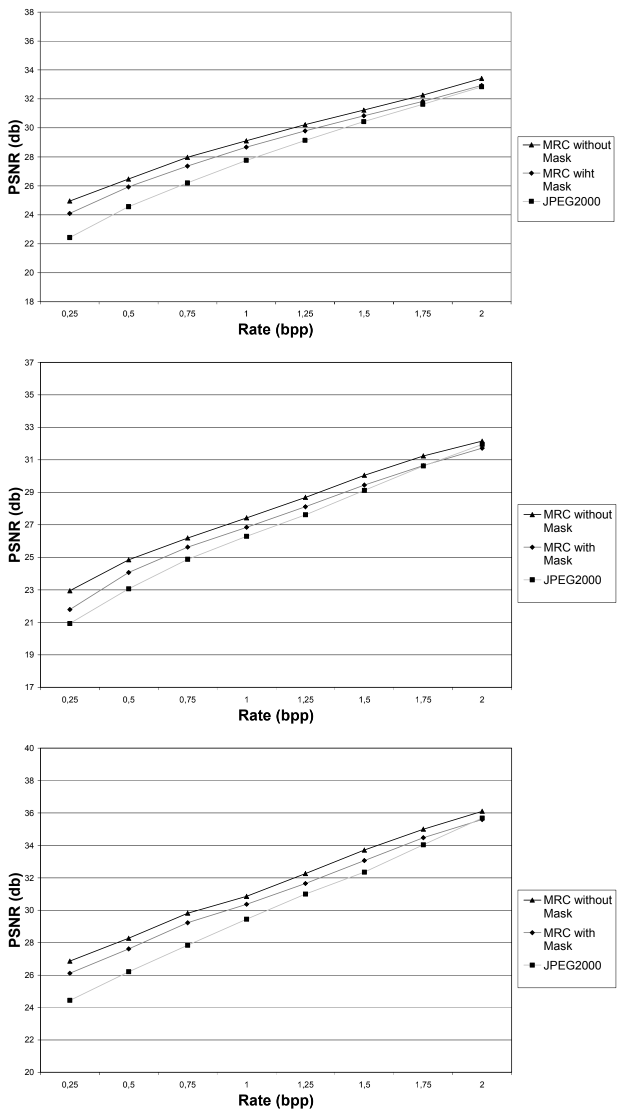
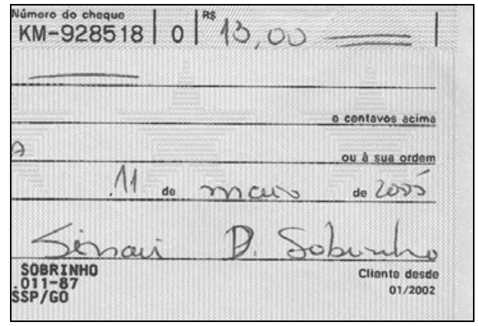
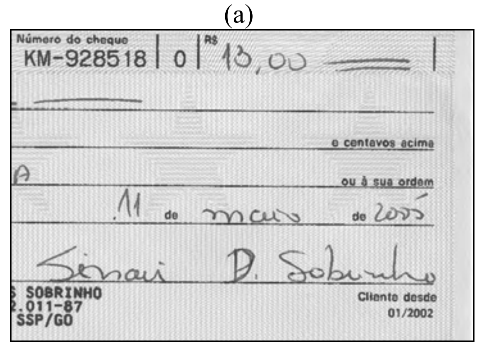


Figure 9. PSNR(dB) comparison among MRC with 3-layer JPEG 2000, FG/BG MRC compression using JPEG 2000, and single-layer JPEG 2000, for 3 different checks.

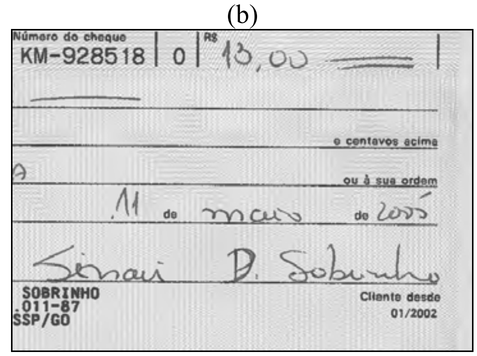
Another advantage of using the MRC model is that, since the mask is compressed without losses, the legibility of the image for low bit rates is not compromised. Only the background and the text colors are degraded. Figure 10 shows a comparison of an 8bpp uncompressed check image against images compressed using the MRC model at different rates.



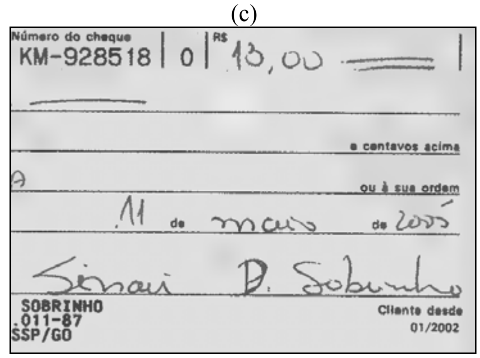
(a)



(b)



(c)



(d)

Figure 10. Zoom of (a) 8 bpp uncompressed check image and reconstructed images after compression at (b) 1 bpp, (c) 0.25 bpp and (d) 0.11 bpp.

VI. Authenticating and Watermarking the Check Image

In order to protect the check images from alteration and fraud, apart from all security measures the transaction might be dealt with, we want to add an image authentication feature to it through digital signatures and X.509 certificates. The data should be embedded into the image itself, without changing its visual aspect. In black-and-white images, we have to toggle white and black pixels that are not visually important and the receiver has to be able to detect the pixels used to insert the digital signature.

We propose a new algorithm for watermarking black-and-white images. The image is divided into 3x3 blocks. We, thus, rank the 256 block patterns, discarding the center pixel, from what we consider the least visually important to the most visually important. We consider a block as visually unimportant if we can change the center pixel without visually altering the image significantly. Figure 11 shows the block pattern we considered the least visually important and is meant as an example that could be changed. The pattern set in Fig. 11 includes the 8 mirrors and rotations of such a pattern.

We compute a hash of the mask excluding the pixels that will be used to embed the signature, as explained next. Then, we encrypt the hash obtaining a string or signature to be embedded. We start with the least visually important pattern. We search for blocks with that pattern, inserting a bit of the digital signature into the center pixel of each block found. The algorithm will end when all bits of the digital signature are inserted. If there are less block of a given pattern than digital signature bits, we start searching for the second least visually important pattern, and so on. We tested the algorithm for 33 check images, searching for blocks like the one in Fig. 11. All had more than 1024 blocks possessing such a pattern, meaning that 1024-bit digital signatures could be inserted only using this pattern. If a longer signature is to be inserted, more patterns need to be searched.

1	1	1
1	X	0
0	0	0

Figure 11. Block pattern with low visual importance, i.e. if we change the center pixel X, the image aspect will not be significantly altered. Set includes all 8 rotations and mirrors of such a pattern.

VII. Conclusions

In this paper we propose a model for the electronic representation of bank checks for the substitution of paper check exchange by electronic check image transfer between banks. The depositing bank would send the check binary images to the paying bank, which might or not request more image data. In this way much storage and band will be saved.

We found that Otsu's thresolding algorithm yields the best legibility after subjective tests involving 7 binarization techniques applied over 33 checks which were evaluated by 20 common observers and 3 experts. We also concluded that the MRC representation using JPEG 2000 compression of all planes (BG, FG, and mask) leads to a sizeable improvement over singe layer compression using JPEG 2000. Although that was pointed by a few authors before, in this case we have soft-edged scanned images of bank checks. Finally, we propose an image authentication algorithm for binary images, to be used to secure the binary versions of the check. Further work is planned on improving FG/BG pre-processing and implementing the system for real check exchange/clearing tasks.

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