BINARY NONLINEAR SUBBAND DECOMPOSITION STRUCTURES FOR TEXTUAL IMAGE COMPRESSION

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ABSTRACT

Efficient compression of binary textual images is an important issue in document archiving. Most popular textual image compression methods exploit the fact that document images are composed of repeating character images. By determining the locations of the characters, a textual image can be efficiently coded. The image can then be reconstructed from a character library according to the character locations. In this paper, new nonlinear subband decomposition structures are presented and they are used in a textual image compression scheme in which the character libraries and locations are determined in the subband domain.

1. TEXTUAL IMAGE COMPRESSION

A typical textual image compression (TIC) method consists of the following steps [1]:

- Find and extract the characters in the image,
- construct a library containing all of the different character images,
- find the locations of the remaining characters and remove them from the image,
- compress (i) the constructed library and (ii) the symbol locations.

The resulting scheme is a lossy method because the character images for the same letter are not exactly the same throughout the document. The TIC methods can produce compression ratios of 60:1 to 100:1. A further step is proposed in [1] to encode the residue image and in this way, lossless compression can be achieved.

In this paper, new nonlinear subband decomposition structures are presented and they are used in a TIC scheme in which the character libraries and locations are determined in the subband domain.

2. NONLINEAR SUBBAND DECOMPOSITION METHODS

Nonlinear subband decomposition structures have been successfully used in image compression [2] - [7]. In this section, new nonlinear subband decomposition schemes are introduced. The new schemes produce binary outputs for binary input images which will then be compressed by the TIC methods.

The nonlinear decomposition structures presented here are based on M-band polyphase representations as shown in Fig. 1. The systems P_i and G_i are nonlinear filters. It can be shown that perfect reconstruction can be achieved for not only real arithmetic but Galois Field - N (GF-N) arithmetic, as well. In the case of GF-2 (or GF-N) arithmetic, the nonlinear filters should be defined in such a way that they produce binary (N-ary) outputs for binary (N-ary) inputs. The perfect reconstruction can be achieved as follows:
In the analysis stage,

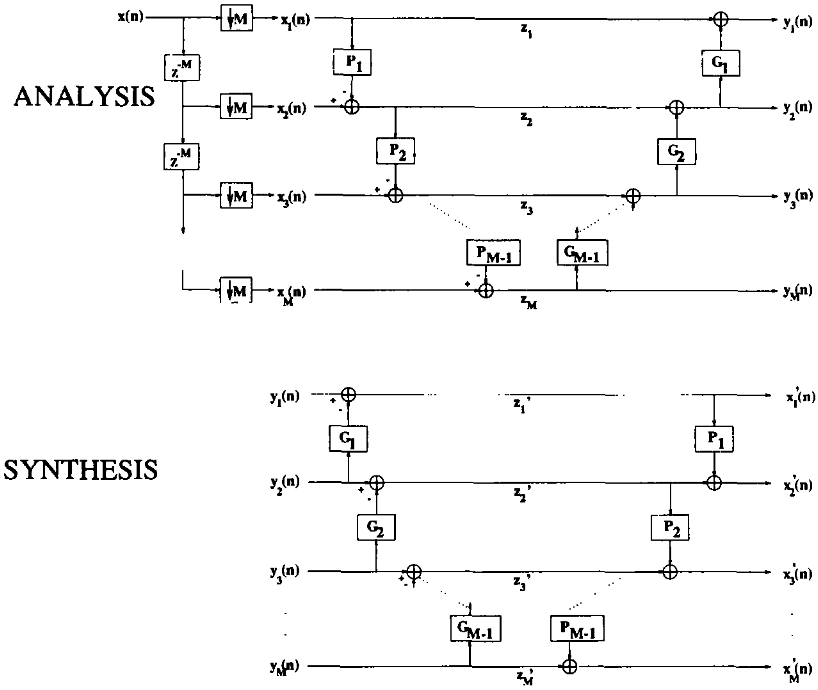

Figure 1: *Multi-band decomposition analysis and synthesis*

$$
\begin{aligned}
z_1 &= x_1 \\
z_i &= x_i - P_{i-1}(z_{i-1}), \quad i = 2, 3, ..., M \\
y_i &= z_i + G_i(y_{i+1}), \quad i = 1, 2, ..., M-1 \\
y_M &= z_M
\end{aligned}
$$

and in the synthesis stage,

$$
\begin{aligned}
z_i' &= y_i - G_i(y_{i+1}) &&= z_i, \quad i = 1, ..., M-1 \\
z_M' &= z_M \\
x_1' &= z_1 &&= x_1 \\
x_i' &= z_i' - P_{i-1}(z_{i-1}') &&= x_i, \quad i = 2, ..., M
\end{aligned}
$$

The outputs, x_i', of the synthesis filters are the same as the polyphase components, x_i, at the analysis filter bank. Notice that there are no restrictions on the nonlinear filters P_i and G_i.

It can also be shown that additional nonlinear filters can be introduced to the structure of Fig. 1 without disturbing the perfect reconstruction property. In Fig. 2, the analysis and synthesis filter banks with additional filters are shown for a two-band case. This structure provides flexibility for implementing complex nonlinear decompositions by cascading simple nonlinear filter components. The schemes in [2] - [7] are special cases of the new nonlinear subband structures.

These nonlinear structures can be easily extended to a 2-D case in a separable manner. In Fig 3 and Fig 4, three band decompositions of a textual image and the image of the letter "a" are shown.

3. COMPRESSION IN THE SUBBANDS

Let us consider the textual image in shown in Fig. 4-a. This image is first decomposed into subimages as in Fig. 4-b using a 2-D structure obtained from the filter bank of Fig. 1 for a downsampling factor $M = 3$. The TIC procedure takes advantage of the repetitions of the characters in a document image. Similar patterns corresponding to each character occur in the subimages. Therefore, a character image can be characterized by a set of patterns in the subbands.

Since the locations of the character images and their subimage representations are at similar locations in all subbands, the extraction of the character image in the TIC procedure can be carried out only inside the low-low subimage. The locations of the patterns inside the remaining subimages are determined according to the low-low coordinates.

The whole textual image is then represented by the pattern library composed of the subband

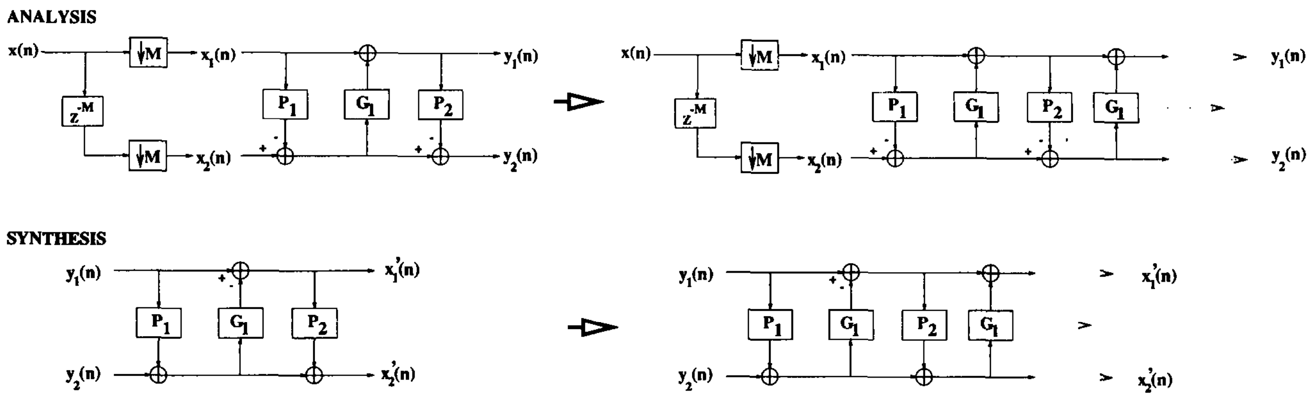

Figure 2: *Cascaded nonlinear filter banks*

character images and the locations of these patterns. The textual image coding method is made lossless by encoding the residual image as well [1]. The sample textual image is compressed to 0.052 bpp (CR = 19.23:1) using the nonlinear subband decomposition method with two bands and median filters. For the binary inputs, the output of the binary median filter is defined as "1" if the number of "1"s in the structuring element is more than the number of "0"s, otherwise the output is "0".

The same compression ratio is achieved by the three-band decomposition with minimum and maximum type linearities. If the TIC method is used without the nonlinear subband decomposition, then 0.058 bpp is achieved. In the lossy mode, the compression ratio of 98 (0.010 bpp) is obtained with the use of median filters in the filter bank.

The new algorithm produces better results than the JBIG standard which compresses the same image to 0.079 bpp. Furthermore it is computationally simpler and it provides multiresolution viewing capabilities.

4. EXPERIMENTAL RESULTS AND CONCLUSIONS

In Table 1, the lossless compression results for various nonlinearities with different levels of decompositions are presented. It can be observed that decomposing to two or three levels give best compression ratios for these nonlinear filters. The median filter is superior to other nonlinearities for the

	median	min	max	open	close
none	0.058	0.058	0.058	0.058	0.058
decomp. 2	0.052	0.055	0.055	0.054	0.057
decomp. 3	0.052	0.054	0.055	0.054	0.058
decomp. 4	0.057	0.063	0.062	0.066	0.065
decomp. 5	0.071	0.078	0.075	0.080	0.078

Table 1: *Experiment results (bits/pel) for 2-5 band decompositions and for nonlinear operations: median, min, max, opening, closing*

cases that are considered in the experiments.

In this study, the improvement that is achieved by the nonlinear subband decomposition structures over the TIC method is observed. The nonlinear subband decomposition can be used to compress other images such as 8-bit gray level, color images, fingerprint images, etc. to increase coding efficiencies.

5. REFERENCES

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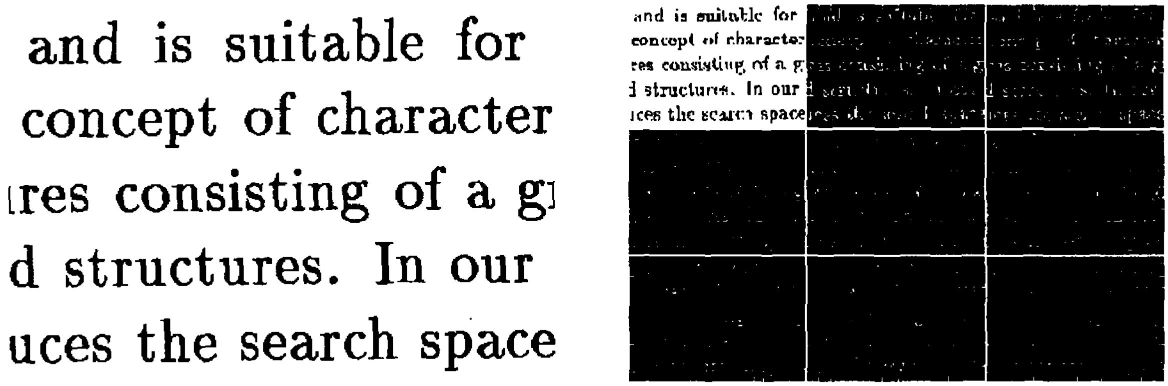

Figure 3: *Part of the textual image and its 3-band nonlinear subband decomposition*

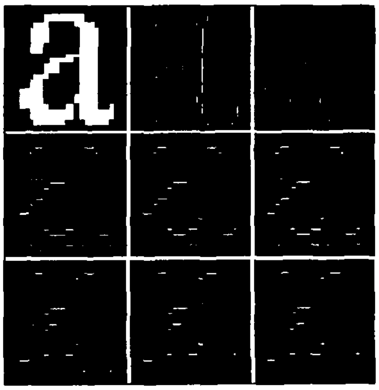

Figure 4: *A 3-band nonlinear subband decomposition of the letter "a" image.*

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