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An efficient modified block coding technique

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Abstract: In this paper a new pel modification technique which preserves some topological properties of two-tone image is proposed. This technique creates more uniform gray-level blocks than were present in the original two-tone image. This change enhances the compression efficiency of the block coding for two-tone image. The technique is applied on two different types of images and the results show that due to pel modification the compression efficiency is increased by a considerable amount. A suitable post processing smoothing technique is also proposed to recover the quality of the modified image to a great extent during decoding.

Key words: Block coding, decoding, pel multiplicity, image topology, connectivity, data compression, pel modification.

1. Introduction

The efficient coding of two-tone images such as handwritten and printed texts, finger print cards, maps of different kinds, engineering drawings and charts etc., is one of the important problems in image processing. The literature on two-tone image coding is quite rich (Huang, 1977; Yasuda, 1980). One of the popular coding techniques is the two-dimensional block coding, where the picture is devided into blocks of size $m \times n$ pels where m and n are the number of pels in horizontal and vertical directions respectively. The blocks are coded according to their probability of occurrance. To simplify the coding strategy, a suboptimum technique was proposed (Kunt and Johnson, 1980) where the white block is coded with 1 bit, black block is coded with 2 bits and all other blocks are coded with $(2+mn)$ bits code words. These techniques result in substantial data compression. However, further data compression can be achieved through suitable rearrangement of pels before actual coding process. The present paper is motivated to this end. Similar work has been done by Kunt et al. (1980) where topological properties were not considered.

Märgner (1982) proposed a technique of pel rearrangement where topological properties are utilized. In his technique, a set of template block patterns that depends on the picture at hand is used for rearrangement.

The rearrangement of pels is done here in such a manner that higher data compression is achieved while preserving some of the topological properties of the image. This is achieved by changing all possible blocks configurations to a minimum number of block configurations. The method, discussed in Section 2, is independent of the picture at hand. The distortion caused due to pel modification can be kept within a visual tolarable limit when the degree of modification is low. It is shown that distortion caused due to a high degree of modification can be greatly reduced by a suitable post processing technique. This technique is also discussed in Section 2. The results of applying those techniques is discussed in Section 3.

2. Pel modification

The topological properties preserved during pel modification are connectivity of regions and the number of components in a picture. In a two-tone picture it is convenient to define the different kinds of neighborhoods. A direct (d) neighbor of a pel (candidates) is defined as the pel with unit distance from it, while the indirect (i) neighbor is the pel with $\sqrt{2}$ distance from the candidate pel. The contour (c) neighbor of a pel belonging to a contour 'C' are those pels, which are defined as previous and next pels to it along the contour during contour traversal. To find the C-neighbors it is necessary to distinguish the contour pels. A pel is a multiple pel if one or more of the following conditions hold (Pavlidis, 1982).

(i) It is traversed more than once during contour tracing.

(ii) It has no neighbor in the interior of the region or it has at most one nonzero neighbor.

(iii) It has at least one d-neighbor which belongs to the contour but which is not one of its C-neighbors.

Before pel modification, different weights are assigned to different kinds of pels. The weights are '1' for interior pel, 0 for back-ground pel and 2 for contour pel. Modified weights are assigned to the contour pels depending on the following five pel configurations (Figures 1-5) or its rotated versions in multiples of 90°. The modified weighting scheme is given in Table 1. The pels having weight

Table 1
Weight assignment to a pel depending on its neighborhood condition (the weight is the same for rotated versions in multiples of 90° for each figure)

Template to be matched	Assigned weight to the candidate (central) pel
Figure 1 and its rotations	5
Figure 2 and its rotations	6
Figure 4 and its rotations	7
Figure 5 and its rotations	8
Figure 3 and its rotations	9

more than or equal to 2 are only considered for pel modification.

For simplicity and convenience, only blocks of size (2×2) are considered here for pel modification. Either one pel or two pels of a block may be modified, the choice of which is decided from block under consideration.

(i) *One pel modification*

One pel modification may be done when the (2×2) block contains either 3 white or 3 black pels. By one pel modification the blocks are made either all black or all white. However, a block of 3-white or 3-black pels is modified only when it satisfies

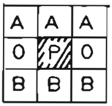


Figure 1

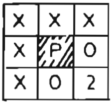


Figure 2

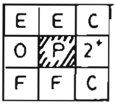


Figure 3

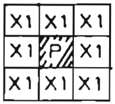


Figure 4

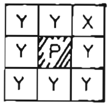


Figure 5

Figures 1-5. The templates for assigning weights to a contour pel.

P – Candidate contour pel,
A – At least one of the pels labelled A should be nonzero,
0 – Pel not in the set,
1 – Interior pel,
2 – Contour pel,
2* – Contour pel belonging to more than one contour,
B – At least one of the pels labelled B should be nonzero,
X – Pels can have any value,
C – At least one of the pels labelled C should be nonzero,
E, F – If both pels labelled C are nonzero then E and F may have any value. Otherwise at least one of each E E and F F should be nonzero,
X_1 – May be anything except 1,
Y – At most one $Y \neq 0$.

certain conditions, so that the modified blocks preserve the topological properties. The procedure is given below where the blocks of 3 white and 3 blacks are treated separately.

(a) *Modification of a block with* 3 *white pels*

In the 3 white pels block, the black pel (candidates) may be of different weights. Depending on the weight of candidates pel, its neighborhood is tested for different conditions. The modification of the block is made depending on the outcomes of those tests. The modification process can be explained through the following algorithm.

```
(*Routine modification 1 black pel*)
Begin
Let 'P' be a black pel
case P of
  2 : Set modification←true; (*logical variable*)
5,6 : Set modification←false;
  8 : Perform P1;
7,9 : Perform P2;
End  (*of case*)
If modification = true then set P←white;
(*logical end of routine*)
P1 : If one of the 8 neighbors of P is black then
     set modification←true,
     Else set modification←false,
P2 : Set count←number of black d-neighbors
       of P;
     If count = 2 then set modification←true;
     Else if count = 1 then
     If N(P) = 4 then set modification←false;
     Else set modification←true;
     N(P) is the total number of black pels in the
       8 neighborhood of P
End  (*of modification 1 black pel*)
```

(ii) *Modification of a block with* 3 *black pels*

In the case of a block with 3 black pels, the neighborhood of the candidate pel (white) is tested for various conditions and modification strategy is decided on the results of those tests. The procedure for 3 black pels block modification is described in the following algorithm.

```
(*Routine 1 white pel modification*)
Begin
Let R be a white pel;
If R has a black i-neighbor 'Q' and two white
d-neighbors adjacent to 'Q'
  then set modification←false;
  (*logical variable*)
Else if all d-neighbors of 'R' are black
  then set modification←false;
Else if i-neighbor 'Q' is white and two
  d-neighbors adjacent to 'Q' are white
  set count←number of black neighbors of R
If count = 5 then set modification←false;
Else set modification←true;
If modification = true than set R←black;
End  (*of 1 white pel modification*)
```

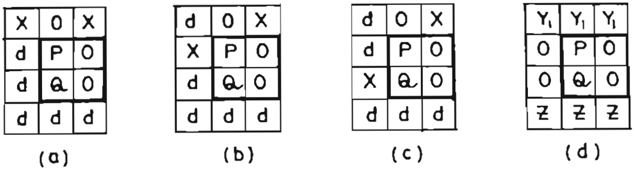
(b) *Two pels modification*

The 2×2 blocks with equal distribution of black and white pels are basically of two types. In one type two black or two white pels are mutually d-neighbors, while in the other type they are mutually i-neighbors. The different neighborhood pattern templates are used to decide the type of modification to be made for those blocks. The attempts made on such blocks are to convert them, if possible into uniform white, or otherwise, into uniform black blocks. The algorithm for this process is as follows.

```
(*Routine two pels modification*)
Begin
Let P and Q be the black pels in a (2×2) block W
call PIX 2BM  (*two black pels modification*)
If modification = true;
  then set W←white,
Else begin;
call PIX 2WM  (*two white pels modification*);
If modification = true
then set W←black;
end;  (*retain weights of P, Q*)
End  (*of two pels modification*)
```

(i) *Two black pels modification*

A block with two (d-connected or i-connected) block pels say P and Q, can be modified to an uniform white block by changing P and Q to two white pels. This is done only if the surrounding of P, Q satisfies certain conditions. The process of modification is described in the following algorithm.



Figures 6(a)-(d). The templates for two black pels modification.

X – Black pel,
d – Don't care,
0 – White pel,
Y_1 – At least one $Y_1 \neq 0$,
Z – At least one $Z \neq 0$,
P, Q – Candidate pels pair.

(•Routine PIX 2 BM•)
Begin
Let P, Q be black pels
If P, Q are i-neighbors then
If one of (P, Q) is of weight 8
then set modification←true;
Else set modification←false;
End;
Else begin;
If P, Q are d-neighbors then
If one of $(P, Q) = 8$
then set modification←true;
Else if $N(w)$, the neighborhood pattern of P, Q, matches with one of the patterns shown in Figures (6a–d) and its rotations in steps of 90° or patterns generated on rotation of surrounding in steps of 90° with respect to candidate block;
then set modification←false;
Else set modification←true;
end;
If modification = true then set P, Q←white;
(•of PIX 2 BM•)
End

(ii) *Two white pels modification*

If the process of modification called 'PIX 2 BM' discussed in the previous subsection could not be done then two white pels modification process is tried. In this process also the surrounding of P, Q is tested for certain conditions different from which were described in 'PIX 2 BM'. The modification of block, i.e. changing P, Q by white pels is done depending on the outcome of testing. The algorithm for the process can be described as follows.

(•Routine PIX 2 BM•)
Begin
Let P, Q be pels
If P, Q are i-neighbor
then begin
If $N(w)$, the neighborhood pattern of block W, matches with pattern Figures 7(a)-(b) or its rotated versions in multiples of 90°, then
set modification←false;
else set modification←true;
end;

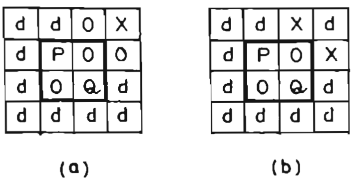


Figure 7. The templates for two white pels modification.

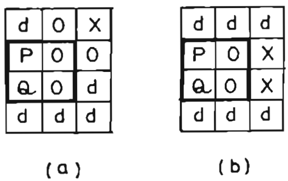


Figure 8. The templates for two white pels modificatio

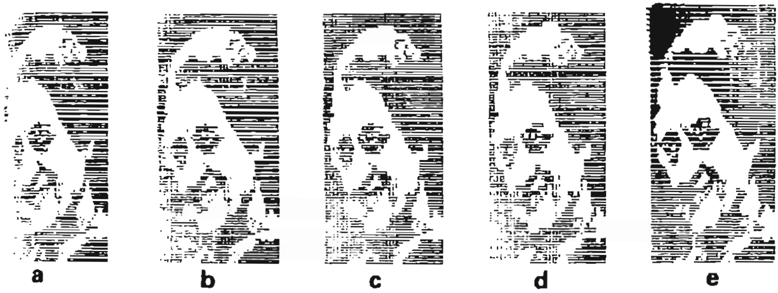


Figure 9. (a) Original digitised images of Mrs. Indira Gandhi. (b) Images after one black modification. (c) Images after one black and one white pel modification. (d) Images after one (both black and white) and two pels modification.

else begin;
If P, Q are d-neighbors then begin
If $N(w)$ matches with Figures 8(a)–(b) or its rotated versions,
set modification ← false;
else set modification ← true;
end;
If modification = true then set P, Q ← black
End; (•of PIX 2 WM•)

Post processing

With the two pels modifications of the image, especially, a silhouette type image has a staircase-like appearance on the borders. A smoothing algorithm enhances the visual quality of the image to a large extent. Here a modified version of majority logic smoothing (Ting and Prasado, 1980) is used, where the topological properties are preserved. The algorithm could be used after the descending process.

3. Results and discussion

To test the efficiency of the present data compression technique, two images of different types, a contour map and a silhouette (that of India's ex-prime minister Mrs. Indira Gandhi) as shown in Figures 9–10 were taken. The images of size (128×128) were processed in EC-1033 Computer. Due to the lack of a suitable hardcopying device, the output was taken in computer overprint mode. To see how the data compression improves with pel modification discussed in Section 2, the results are shown in stages in Figures 11 and 12. In the figures, 'B' corresponds to modification of blocks of three white pels while 'C' corresponds to modification blocks of three white pels as well as blocks of three black pels. Similarly, 'D' corre-

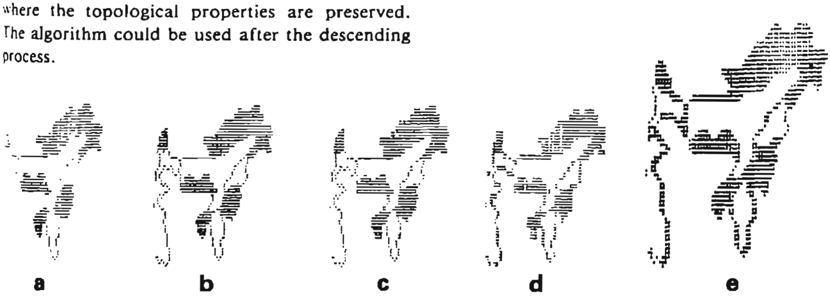


Figure 10. (a) Original digitised images of a contour map. (b) Images after one black modification. (c) Images after one black and one white pel modification. (d) Images after one (both black and white) and two pels modification.

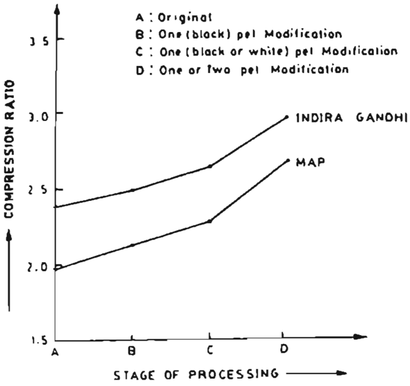


Figure 11. Plots of compression rational different stages of processing for (2 × 2) sub-optimum block coding.

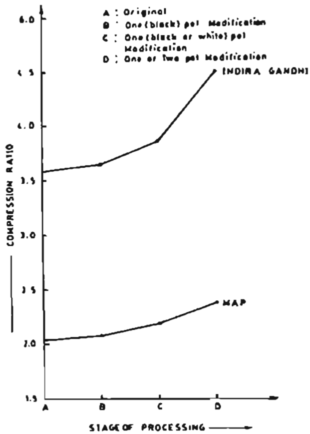


Figure 12. Plots of compression ratio at different stages of processing for (4 × 4) sub-optimum block coding.

sponds to the modification of all types of blocks. In Figure 12, the results of a 4×4 conventional block coding (Kunt et al., 1980) on the data at all stages of modifications are also shown for comparison.

The images at corresponding stages B, C and D are shown in Figures 9(b)–(d) and Figures 10(b)–(d). It is seen that the picture quality deteriorates with the stages of pel modification and a staircase like contour appears at stage D. The post processing smoothing discussed in Section 2 is applied on the Figures 9(d) and 10(d) and the result is shown in Figures 9(e) and 10(e). The improvement in visual quality is quite apparent. The technique can be extended to gray-level pictures when it is represented in bit-plane form.

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