An Algorithm for Identifying, Extracting and Converting Document Image Table Structures into LaTeX Format

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ABSTRACT

Paper document has been the most important and convenient source of information ever since the Chinese invented paper thousands of years ago. Paper document continues to maintain its role despite the increasing presence of the electronic counterpart. In fact, the more e-Document is deployed, the more paper document is (re)produced. This is due to volatility of electronic means and legal issues that renders *hard (paper) copy* the legitimate affidavit. Unfortunately, the inherent difficulty to store and retrieve such voluminous information calls for some forms of transformation from paper document to electronic, whereby facilitating subsequent automated processing. This paper focuses on such efforts in transforming one of the most common elements in paper document, i.e., tables. The proposed approach can also be applied to future research domains such as pattern recognition and computer vision.

Keywords: Table conversion, image to text, document processing, page segmentation.

1. INTRODUCTION

The advent of the Internet has brought about electronic exchange explosion. The advantages in processing speed from storage, retrieval, transmission, and dissemination make e-Document an ideal form of information representation. This does not limit merely to text-based document, but embedded image and other visual display artifacts as well, namely, tables, figures, illustrations (banners, graphs), and animation.

Versatile as it may be, e-Document suffers from several problems that are inherent in electronic nature. Storage media, archival and retrieval management systems, transmission and communications means, compatibility, and most important of all, volatility, are typical obstacles from which paper document does not suffer. The tangible value of physical evidence makes paper document one of the most important legal affidavit that its electronic counterpart can never substitute at present age. Thus, paper document still enjoys its strong hold on being the ultimate information archive.

One of the shortfalls of paper document lies in the needs to convert information printed on the paper to electronic form. Numerous research endeavors have been attempted to make such needs a reality. Scanning is perhaps the most well-known and widely used approach. The scanned documents are stored as image data which poses two major disadvantages: (1) they require a large amount of storage space, and (2) it is difficult to identify and locate where the required data are stored for subsequent reuse or processing.

For efficient retrieving and storage of paper document, it is necessary to generate a description of graphical elements in the document to reduce the amount of storage space required and processing time. As a consequent, this study will focus on a popular presentation element of paper document, i.e., table, in the following domain of interest:
1. To develop an algorithm for identifying and extracting a table area from a document image.
2. To convert the table structure into LaTeX format.

The rest of the paper is organized as follows. Section 2 identifies table storage problems, applications and constraints, and potential contributions. The next two sections review some literatures relating to page segmentation and table analysis. Section 5, 6, 7, and 8 discuss the proposed algorithm for identifying, extracting, and converting a table structure from a document image into LaTeX format. Section 9 explains and compares all the experimental results. The results of this study and discussion for the future work are elucidated in the Conclusion.

2. PROBLEM IDENTIFICATION

In table areas, the columns and rows in which the characters are located are very important pieces of information. This information must be known so as to store the characters in the exact location after being extracted. To obtain this information, the table boundary must first be identified so that its structure is analyzed. The results are shape of the table and positions of the characters (being recognized by Optical Character Recognition method). This information must be stored in some pre-arranged formats. This study will employ LaTeX format that can accommodate both table structure and the character contents as coded data. Such a scheme utilizes less space storage than other word processing formats. After all, LaTeX is one of the most widely used text formatting tools.

To obtain such precise results, a proposed algorithm was applied on gray scale document image without any skewed angles. In so doing, the algorithm can be straightforwardly integrated as a part of an Optical Character Recognition (OCR) system.

A document image can employ page segmentation method to divide the entire document into individual regions of text area and non-text area. The characters in each region of text area are processed by conventional OCR technique and stored as coded data. On the other hand, non-text regions are stored as image data. There may, however, be characters remain in these non-text areas such as the numbers in graphs, the descriptions of figures, the characters in each cell of a table, etc., which should be stored as coded data as well. Therefore, it is imperative that the proposed algorithm incorporate page segmentation and table analysis techniques so as to cope with such complications.

3. RELATED WORK IN PAGE SEGMENTATION

Earlier page segmentation methods were based on two basic approaches. The first approach is bottom-up method that starts from grouping all interested pixels together and merged them into larger homogeneous regions. The other approach is top-down method that divides the entire document image into a few large regions. These regions subsequently are recursively segmented into smaller sub-regions.

Most bottom-up methods divide text from components in a document image. L. A. Fletcher and R. Kasturi [1] described an algorithm for separating text strings from mixed texts and graphic images in 1988. This algorithm grouped each connected black pixels together to generate a connected component. It then used Hough transform [2] to group the connected components into text strings which were separated from graphic objects. This algorithm could be used with various font styles, sizes and orientations of texts.

In 1992, F. Lebourgeois, Z. Bublinski, and H. Emptoz [3] presented a bottom-up method for extracting text paragraphs and graphics from document images. The method used a horizontal smoothing from a Run Length Smoothing Algorithm (RLSA) [4] for linking characters and graphics to form blocks. The height and density of the blocks were used to identify blocks as text lines or graphics that subsequently merged the text lines into paragraphs.

Instead of considering black pixels in almost bottom-up methods, A. Antonacopoulos and R. T. Ritchings [5] considered the white pixels of background space. They presented an algorithm that linked the white pixels to build white regions in 1995. The other regions that were surrounded by the white regions were extracted into individual regions.

All of the above approaches required some suitable threshold values for linking the pixels, merging, or classifying the regions. In 1996, D. P. Mital and G. W. Leng [6] developed a technique for text segmentation that did not require any predefined parameters. This technique used two arrays to store the length of connected black and white pixels where the differences between neighbor values were considered as text regions.

Typically, a document image contains a very large amount of pixels. In order to segment a given image into blocks, it is not necessary to analyze every pixel. E. Trupin and Y. Lecourtier [7] introduced a technique that compressed the image with a compression factor F. Each pixel of the compressed image was set to black when there was a black pixel in an area of F pixels width and F pixels height. The connected black pixels of the compressed image were linked to form blocks. The application for page segmentation could be done in both bottom-up and top-down methods. A small compression factor would segment the image into words or pieces of word for processing with the bottom-up method. On the other hand, the result of a height compression factor value should process with the top-down method.

T. Saitoh and T. Pavlidis [8] presented an algorithm for page segmentation that could handle skewed pages other than rectangular columns. This algorithm would make a compressed image by considering each eight pixels width and four pixels height area. Then, each connected black pixel was linked to form blocks. Each block was classified by six classes according to its height, width, and half-tone. The connecting text blocks were merged to form one text block. After the skew angles were estimated using least square technique, some blocks were classified as tables with reference to the ruled lines. The blocks of text area were merged again into columns.

In 2001, S. Chuai-aree, C. Lursinsap, P. Sophatsathit, and S. Siripant [9] presented a technique for page segmentation. This technique separated a document image to blocks of the same size. Each block was classified as text, image, and background area using Fuzzy C-mean [10] with statistical features such as mean and standard deviation. Then, the class of each block and its neighborhoods were used to define its true class.

The bottom-up method is effective for every document styles, but requires considerable computation time and memory. The top-down method, on the other hand, is faster and yields good results for the document having fixed and known structure. One of the most powerful top-down technique is RLSA, first introduced by F. M. Wahl, K. Y. Wong, and R. G. Casey [4] in 1982. The smoothing rule of RLSA would change a white run to a black run if its length is less than or equal to a predefined threshold value, where a run is a sequence of the same value pixels. This algorithm contains the following four steps:

1. A horizontal smoothing is applied to the original document image,
2. A vertical smoothing is applied to the original document image,
3. The results of steps 1 and 2 are combined by a logical AND operation, and
4. A horizontal smoothing is applied to the output of step 3.

This four-step RLSA requires scanning the whole image four times. In 1992, it was improved to be a two-steps RLSA by F. Y. Shih, S. S. Chen, D. D. Hung, and P. A. NG [11]. The whole image was scanned only two times. F. Y. Shih et al. used this algorithm to extract a document image into individual blocks. Each block comprised of text, horizontal or vertical lines, and graphics having properties such as the height, aspect ratio, density, and the number of changed pixels per unit length. The results of their algorithm were presented in 1996 [12].

The RLSA approach gave a good result when the input was a horizontally written document. However, it did not work well for a vertically written document. N. Amamoto, S. Torigoe, and Y. Hirogoki [13] developed an algorithm for both horizontally and vertically written documents. The algorithm extracted a group of black pixels that were surrounded by white spaces as a block. The block, which did not have any long black runs, was decided as the horizontal or vertical writing. Then, every block was classified using similar properties to the previous approach accompanied by thin and long black lines.

In 1996, N. Papamarkos, J. Tzortzakis, and B. Gatos [14] developed a technique that calculated the threshold values for the RLSA automatically. This technique was based on the values of mean character length and mean text line distance of a document that were estimated from the distribution of the horizontal and vertical black and white runs.

Another widely used top-down method for page segmentation was Recursive X-Y Cut (RXYC) algorithm. The RXYC cut an image recursively into blocks. At each step of the recursive process, the algorithm computed the sum of black pixels along horizontal and vertical axes to create document projection profile. This document projection profile was a waveform whose deep valleys corresponded to blank areas of the document. A deep valley with a width greater than a threshold could be cut as the edge of a block. H. Wang, S. Z. Li, and S. Ragupathi [15] used this algorithm for document segmentation and explained a classification process with tested results in 1997.

Page segmentation by RLSA or RXYC uses a fixed threshold for the entire document, so there might be problems with some document styles such as a text lines with different font size or font styles, etc. To solve these problems, K. C. Chan, X. Huang, and P. Bao [16] presented a page segmentation method based on the concepts of fuzzy set theory. This method determined the thresholds in any positions in the document automatically.

Both bottom-up and top-down methods have their own advantages. As such, attempts were made to combine these two methods. Y. Hirayama [17] presented a block segmentation method that started in bottom-up fashion by linking black connecting pixels to form rectangles. They were classified as character strings, horizontal and vertical lines, and picture elements based on their properties. These character strings were merged into text groups. The threshold of merging was determined by analyzing the height and distance of character strings. In the meantime, top-down approach started detecting the borderlines of columns by linking the edges of text groups. As a consequence, the entire page was segmented into blocks of text and picture areas based on the borderlines and projection profile.

In 1998, A. K. Jain and B. Yu [18] presented an algorithm for page segmentation based on a top-down method which was constructed from bottom up. They defined blocks of regular small connected components as text regions and large connected components as non-text regions.

4. RELATED WORK IN TABLE ANALYSIS

Table analysis involves table identification and table recognition. The goal of table identification is to separate table areas from non-table areas in a document image. Each table area contains important data that are related by positions (column and row). Table recognition determines the structure of the table area and stores the table in some pre-arranged formats.

Typical page segmentation methods encompass table identification capability to identify embedded table areas by considering blocks that have different characteristics from conventional text blocks during page segmentation process. For example, T. Saitoh and T. Pavlidis [8] classified some blocks as table area based on ruled lines. They defined a block as a table area if it had at least two horizontal lines (at top and bottom sides) and one vertical line (not so close to the side edges).

N. Amamoto et al. [13] defined a block as a table area according to certain properties of the block. A table block had to have a number of thin and long solid black lines higher than other classes.

A. K. Jain and B. Yu [18] identified table areas from non-text blocks by first extracting horizontal and vertical lines. The horizontal top and bottom lines should have the same length without any skew lines. The height of all connected components should be small.

Y. Hirayama [19] presented a process for table identification from non-text blocks that had both horizontal and vertical lines. The block was assumed to be

1	2	3	4	5
6	7	8	9	10
11	12	13	14	15
16	17	18	19	20
21	22	23	24	25
26	27	28	29	30
31	32	33	34	35
36	37	38	39	40
41	42	43	44	45
46	47	48	49	50
51	52	53	54	55

Fig.1: *An example of a table with cells labeled by numbers.*

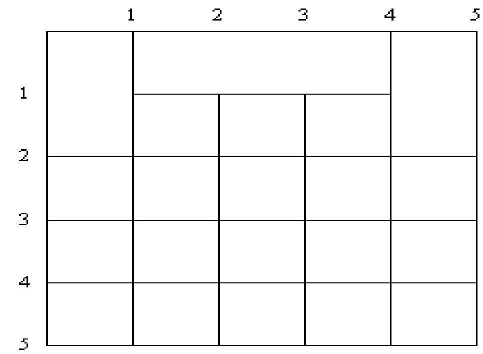


Fig.2: *An example of individual column and row number assignment.*

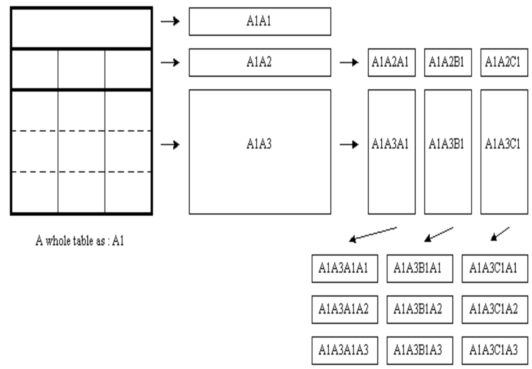


Fig.3: *Illustration of the labeling process by letters and numbers.*

a table area and was further divided into small areas by the horizontal and vertical lines. Each small area was classified as a celled area or non-celled area. If the non-celled area had less space than one thirds of the whole block area, the block should be a table area.

Y. Wang, I. T. Phillips, and R. Haralick [20] presented a table identification algorithm that analyzed background. They used large horizontal blank blocks to construct table candidates. The table candidates were then identified based on some predefined parameters such as the ratio of total large vertical blank block area over the table candidate area, the maximum difference of the cell baselines on a row, and the maximum difference of the justification in a column. These parameters could be estimated from any real table instances.

Most approaches did not concentrate on table identification but focused on table recognition. S. Chandran and R. Kasturi [21] used the horizontal and vertical projection profile of a table image to extract data as cells in the table. Each cell was labeled by a number and arranged in order of positions (left to right and top to bottom) as shown in Figure 1. The data and its corresponding label were stored with the number of columns in the table.

However, the above method could not be used for complicated tables. K. Itonori [22] presented a method that was applicable for all styles of tables. It used the projection profile to assign row and column numbers in a table image. Each cell could be stored with its right and bottom coordinates as shown in Figure 2.

E. Green and M. Krishnamoorthy [23] gave each cell a label by a series of letters for columns and numbers for rows. The label consisting of one letter followed by a number was used for each level of cell in the table image. An example of a complete labeling appears in Figure 3.

J. F. Arias, A. Chhabra, and V. Misra [24] used the information about horizontal and vertical lines to extract the structure of a table image. They used bit strings for labeling each cell of the table. The label indicated the column and row to which the cell belonged. The length of the label was equal to the number of columns and rows that contained in the table. Each bit indicated an order of column and row. The bit was 1 if the cell corresponded to a given column and row. An example of bitstring cell labeling of a table is shown in Figure 4.

T. Watanabe, Q. Luo, and N. Sugie [25] used a binary tree to represent the structure of a table. Each node corresponded to a block of one or more cells. The nodes were arranged in vertical node v, horizontal node h, and the terminal node t. The type of node represented the relation to its left and right child nodes as illustrated in Figure 5. Figure 6 presents a sample of table structure and its corresponding binary tree.

H. Saiga, Y. Kitamura, and S. Ida [26] extracted all dotted and solid lines in a table image and defined their names. Then, they constructed cells from the horizontal and vertical line intersections. Each cell was stored by name which referred to the horizontal and vertical lines that formed it. This algorithm was easily combined with character recognition.

Y. Hirayama [19] presented a dynamic programming matching method to detect the correspondence between strings in two columns. They applied this method to multi-column tables. As a result, the information arrangement was easily detected and transformed into other data formats.

<table>
<tr><th></th><th>1</th><th>2</th><th>3</th><th>4</th></tr>
<tr><td>1</td><td rowspan="2">100011000</td><td colspan="3">011110000</td></tr>
<tr><td>2</td><td>010001000</td><td>001001000</td><td>000101000</td></tr>
<tr><td>3</td><td>100000100</td><td>010000100</td><td rowspan="2">001000110</td><td>000100100</td></tr>
<tr><td>4</td><td>100000010</td><td>010000010</td><td>000100010</td></tr>
<tr><td>5</td><td>100000001</td><td>010000001</td><td colspan="2">001100001</td></tr>
</table>

Fig.4: *An example of bit-strings cell labeling.*

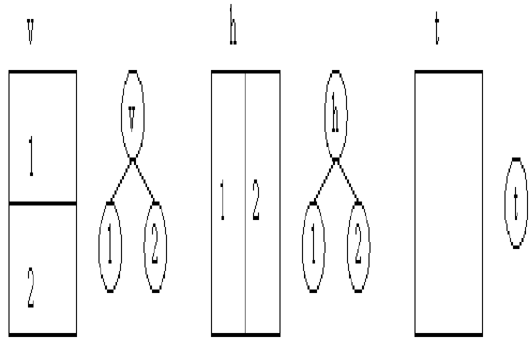


Fig.5: *Node types in binary tree for table structure representation.*

K. Zuyev [27] introduced a concept of table grid which represented a complex structure table as a simplified table. The grids of the table was formed by every row and column using the horizontal or vertical lines and the space between the rows or columns.

In the case of a table with large amount of data, it was difficult to represent by labeling method. S. Tsuruoka, K. Takao, T. Tanaka, T. Yoshikawa, and T. Shinogi [28] described an algorithm of segmentation and conversion for a table image. First, they segmented a table by the ruled lines into some regions. Then, the segmented regions were further divided into cells by the projection profile. The results were converted into a HyperText Markup Language (HTML) file.

A. Amano, N. Asada, T. Motoyama, T. Sumiyoshi, and K. Suzuki [29] designed table analysis and synthesis system of formed document that cooperated between the users and the computers. The computer detected the boxes formed by horizontal and vertical lines. These boxes were classified semi-automatically into four types, namely, blank, insertion, indication, and explanation. The relationships between each box and its neighbors were analyzed. As such, the system generated LaTeX code of the synthesized document with blank and insertion boxes that were filled with text or image data given by the users.

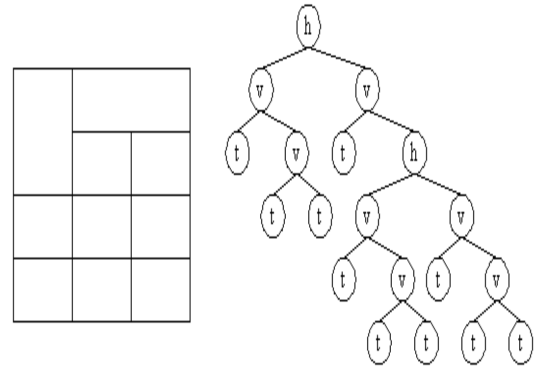


Fig.6: *An example of a table and its structural binary tree representation.*

5. MODEL AND ALGORITHM

This Section explains the dichotomy of the proposed model of this study to be processed in three steps. Firstly, a document image is extracted from individual blocks. Next, each block is identified as a table area or a non-table area. Lastly, the table area is converted into LaTeX format.

The document image used in this study is a gray scale image. The value of each pixel ranges from 0 to 255 to denote color intensity. The pixels whose value is close to 0 are called black pixels. On the contrary, the value of white pixels is close to 255. A table image from the scanned document is stored in a two dimensional array, whereby the number of columns and rows define the width and height of a table, respectively.

5.1 BLOCK EXTRACTION APPROACH

This study focuses on the table areas of a document image. All table areas have rectangular shapes. Thus, the proposed algorithm will extract a document image to rectangular blocks that are easy for subsequent processing. In block extraction, an image smoothing algorithm is applied to a document image to combine neighboring pixels of the block. The result of image smoothing is a blurred document image. Each pixel of the blurred image is determined by the adjacent pixels according to the following equation:

$$B_{i,j} = \frac{\sum_{k=i-I}^{i+I} \sum_{l=j-I}^{j+I} P_{k,l}}{(2I+1)^2} \tag{1}$$

where

$B_{i,j}$ is the value of the pixel in the i^{th} row and j^{th} column of the blurred image.
$P_{k,l}$ is the value of the pixel in the k^{th} row and l^{th} column of the document image.
$I \in \{1, 2, 3, ..., N | N \text{ is the number of columns}\}$

The value of I depends on the space between text lines in the document image.

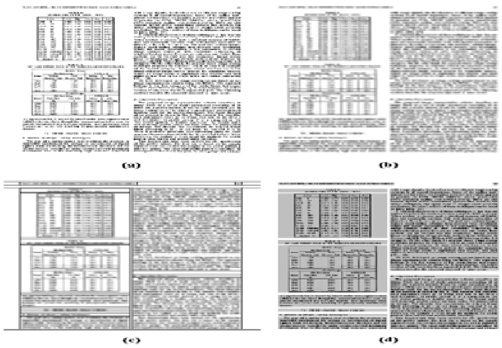


Fig. 7: *An example of process in the block extraction method: (a) a document image, (b) a blurred image, (c) a blurred image with the cutting lines, (d) the result of applying the cutting lines on the document image.*

We consider the blurred image to construct cutting lines that are used for extracting the document image to rectangular blocks. The blurred image is scanned horizontally or vertically from one edge to the opposite edge. The scanned results are classified into two types. The first type has only white pixels that are designated as blank lines. The second type has some black pixels which become data lines. A horizontal cutting line is a data line that is next to the blank lines. An algorithm for constructing the horizontal cutting line is as follows:

Cutting Lines Construction Algorithm

```
1. If the first row is a data line then
2.    Set this row as the top edge of a new block.
3. For i=2 to number of row do
4.    If this row is a data line
      AND the (i-1)^th row is a blank line then
5.      Set this row as the top edge of a new block.
6.    If this row is a blank line
      AND the (i-1)^th row is a data line then
7.      Set the (i-1)^th row as the bottom edge of a block.
8. End for
9. If the last row is a data line then
10.  Set the last row as the bottom edge of a block.
```

The algorithm is repeated three times. The first time is mainly for constructing the horizontal cutting lines that extract the blurred image into smaller blocks. The second time is applied on each column in each block for vertical cutting lines. The third time is for the horizontal cutting lines that lie inside the vertical block. All cutting lines are used for extracting the document image into rectangular blocks. Figure 7 illustrates an example of the process in the blocks extraction method.

5.2 TABLE IDENTIFICATION METHOD

Each block from the last step is assumed as a table block. The groups of black pixels in every block represent lines and data of the table. Data and lines are then analyzed and stored in a text file that is suitable for subsequent identification and conversion to LaTeX format. The text file preparation process starts by determining the positions of the lines enclosing each block. This block is then split into small rectangular areas using the lines as their border. The coordinates of each area are calculated from the information of the enclosing lines, namely, top, left, bottom, and right positions. The algorithms for line detection and block separation are given below.

Lines Detection Algorithm

```
1. List L is empty.
2. For each row of a block do
3.   If there are some black runs that are longer than α
     then
      (The value of α depends on the size of the character
      string in the block being considered)
4.     Store their beginning and ending positions as
       the row number in list L.
5. End for
6. For each column of a block do
7.   If there are some black runs that are longer
     than one fifths of the number of rows then
8.     Store their beginning and ending positions as
       the column number in list L.
9. End for
```

Block Separation Algorithm

```
1. List B is empty.
2. For i= 1 + β to number of rows - β do
3.   For j= 1 + β to number of columns - β do
      (The value of β depends on the thickness of
      block border from the extraction step)
4.     If W_{i,j} is a white pixel and not in the range of
       the coordinates in list B then
5.       Set W_{i,j} to be the point of a new borderline.
6.       Direction = 1.
7.       If there are some white pixels around W_{i,j} then
8.         Do
9.           Find the next pixel of this borderline.
9.1            Start at the opposite of the last direction as
               illustrated in Figure 8.
9.2            Find a white pixel around the point in
               clockwise direction.
9.3            Stop when a white pixel is found.
10.            Set this pixel to be the new point of
               consideration.
11.        Until the point is W_{i,j}
12.        Define the coordinate of this rectangular area
           from the pixel positions in this borderline.
13.        Add the coordinates of the area to list B.
14.  End for
15. End for
16. For all rectangular areas in the list do
17.  For each edge of the area do
18.    If the edge is close to the border of table
       block and there is no line from list L lying between
       the border and the edge then
19.      Define this edge to contain no line.
20.    Else
21.      Define this edge to contain a line.
22.  End for
23. End for
```

Next, the algorithm deletes the lines from a block and applies the image smoothing algorithm on the block without line. The algorithm defines the coordinates of the data block inside each rectangular area and the border lines as follows:

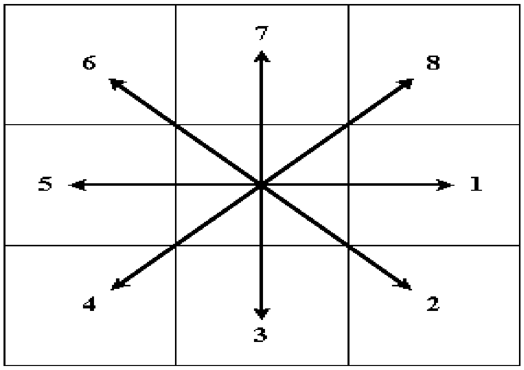


Fig.8: *Search directions starting from the middle pixel.*

Data Block Coordinate Defining Algorithm

1. List D is empty.
2. **For** each rectangular area in list B **do**
3.   **For** i = the first row **to** the last row of this area **do**
4.   **For** j = the first column **to** the last column of this area **do**
5.   **If** $B_{i,j}$ is a black pixel and not in the range of the coordinates in list D **then**
6.   Set $B_{i,j}$ to be the point of a new borderline.
7.   Direction = 1.
8.   **If** there are some black pixels around $B_{i,j}$ **then**
9.   **Do**
10.   Find the next pixel of this borderline.
10.1   Start at the opposite of the last direction as illustrated in Figure 8.
10.2   Find a black pixel around the point in clockwise direction.
10.3   Stop when a black pixel is found.
11.   Set this pixel to be the new point of consideration.
12.   **Until** the point is $B_{i,j}$
13.   Define the coordinate of this data block from the pixel positions in this borderline.
14.   Add the coordinates of the data block to list D.
15.   **End for**
16.   **End for**
17.   **For** all data blocks in the rectangular area **do**
18.   **If** the size is too small **then**
19.   Remove it from list D.
20.   **End for**
21.   **If** there are more than one data block in the rectangular area **then**
22.   **For** all data blocks in the rectangular area **do**
23.   **For** each edge of the data block **do**
24.   **If** the edge position is close to the border of rectangular area **then**
25.   Set the border as the edge.
26.   **Else**
27.   Define this edge to contain no line.
28.   **End for**
29.   **End for**
30. **End for**

Every data block expands to form a rectangular cell that fits in the table. The boundary of the data block is designated by the adjacent data blocks in four directions (top, left, bottom, and right). We then find the relation of each data block to set the row or column. The data blocks with the same value of the left, right, or center position are assigned to the same column. Hence, the data blocks in the same column must have the same left and right boundary values. Similarly, the data blocks in the same row must have the same top and bottom boundary values. There may be some areas in the block which are not covered by any table cells. In which case, we add those areas to the adjacent cells, provided that the edges of the adjacent cells do not have lines separating them. Figure 9 shows an example of table cell formation.

Table Cell Forming Algorithm

1. **For** each data block **do**
2.   **If** there are some data blocks over it **then**
3.   Set its top boundary = the bottom edge of the nearest data block on the top.
4.   **Else**
5.   Set its top boundary = 1.
6.   **If** there are some data blocks under it **then**
7.   Set its bottom boundary = the top edge of the nearest data block on the bottom.
8.   **Else**
9.   Set its bottom boundary = the number of pixel height.
10.   **If** there are some data blocks to the left of it **then**
11.   Set its left boundary = the right edge of the nearest data block on the left.
12.   **Else**
13.   Set its left boundary = 1.
14.   **If** there are some data blocks to the right of it **then**
15.   Set its right boundary = the left edge of the nearest data block on the right.
16.   **Else**
17.   Set its right boundary = the number of pixel width.
18. **End for**
19. Construct the rows of the table.
20. Construct the columns of the table.
21. **For** each row of the table **do**
22.   **For** each data block in this row **do**
23.   Set its top boundary = max (all top boundaries in this column).
24.   Set its bottom boundary = min (all bottom boundaries in this column).
25.   **End for**
26. **End for**
27. **For** each column of the table **do**
28.   **For** each data block in this column **do**
29.   Set its left boundary = max (all left boundaries in this column).
30.   Set its right boundary = min (all right boundaries in this column).
31.   **End for**
32. **End for**
33. **While** some edges are not equal to their boundary **do**
34.   **For** each data block **do**
35.   Decrease the value of its top edge.
36.   Decrease the value of its left edge.
37.   Increase the value of its bottom edge.
38.   Increase the value of its right edge.
39.   **End for**
40. **End do**
41. **For** each area that is not covered by any table cells **do**
42.   **If** the edge of the cell that connects to the area does not have the line **then**
43.   Add this area to that cell.
44. **End for**

After table cell formation is complete, the cell coordinates, lines, and data information are stored as a text file. Figure 10 shows an example of this text file. The first row denotes the number of cells and the size of the block. The remaining rows store the line coordinates and data information for each cell. Each column is denoted by a cell number, top position, left

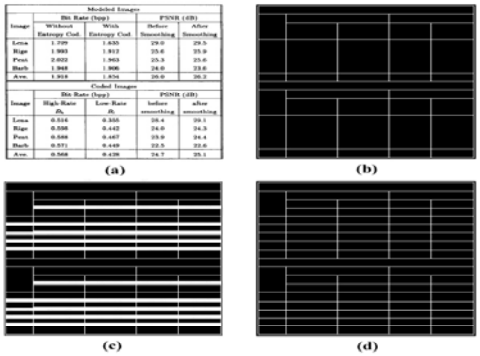


Fig.9: *An example of table cell formation: (a) a sample block, (b) the rectangular areas, (c) the coordinate boxes of the data blocks, (d) the coordinate boxes of the table cells.*

74	1	1	176	193					
1	1	1	14	193	1	1	1	1	1
2	14	41	24	113	1	1	1	1	1
3	14	113	24	193	1	1	1	1	1
4	14	1	42	41	1	1	1	1	1
5	24	41	33	76	1	1	0	1	1
6	24	76	33	113	1	1	0	1	1
7	24	113	33	143	1	1	0	1	1
8	24	143	33	193	1	1	0	1	1
9	33	41	42	76	0	1	1	1	1
10	33	76	42	113	0	1	1	1	1
11	33	113	42	143	0	1	1	1	1
12	33	143	42	193	0	1	1	1	1
13	42	41	51	76	1	1	0	1	1
14	42	76	51	113	1	1	0	1	1
15	42	113	51	143	1	1	0	1	1
16	42	143	51	193	1	1	0	1	1
17	42	1	51	41	1	1	0	1	1
18	51	1	61	41	0	1	0	1	1
19	51	41	61	76	0	1	0	1	1
20	51	113	61	143	0	1	0	1	1
21	51	143	61	193	0	1	0	1	1
22	51	76	61	113	0	1	0	1	1
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
70	164	41	176	76	1	1	1	1	1
71	164	1	176	41	1	1	1	1	1
72	164	76	176	113	1	1	1	1	1
73	164	113	176	143	1	1	1	1	1
74	164	143	176	193	1	1	1	1	1

Fig.10: *A text file example of cell coordinates and line information.*

position, bottom position, right position, line information of top edge, left edge, bottom edge, right edge, and the appearance of the data inside the table cells.

This text file is used for identifying the table blocks based on the arrangement of the cell and line positions. Every block is initially assumed to be a table block. Two conditions are utilized to validate any non-table blocks. The first condition imposes that any two table cells should not overlap each other as depicted in Figure 11. The second condition checks the appearance of the border lines. Cell C_i can overlap cell C_j in four scenarios.

1. The top position of C_i is between the top and bottom position of C_j, while the bottom position of C_i is greater than the bottom position of C_j.
2. The bottom position of C_i is between the top and bottom position of C_j, while the top position of C_i is less than the top position of C_j.
3. The left position of C_i is between the left and right position of C_j, while the right position of C_i is greater than the right position of C_j.
4. The right position of C_i is between the left and right position of C_j, while the left position of C_i is less than the left position of C_j.

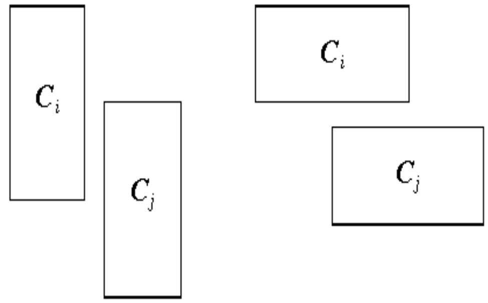


Fig.11: *Illustration of the possibilities of cell overlapping.*

After cell overlap check is complete, the second condition is applied to separate a matrix block from a table block. A matrix has two vertical lines, one on the left and the other on the right side of the block. The cells are uniform and arranged consecutively. There may not be any overlapping cells in a matrix. Consequently, a table block identification algorithm is needed to distinguish a table from a matrix as the text file is processed.

Table Identification Algorithm

1. Let $T = 1$.
2. **For** each table cell **do**
3.   **If** it overlaps other table cells **then**
4. $T = 0$.
5. **End for**
6. **If** $T = 0$ **then**
7.   This block is not a table block.
8. **Else**
9.   **If** there are only two lines on the left and right sides **then**
10.   This block is not a table block but a matrix.
11.   **Else**
12.   This block is a table block.

5.3 CONVERTING TABLE INTO LaTeX FORMAT

The table block, which is identified in the previous step, will be further processed so that structural information from the text file gets converted into LaTeX format. LaTeX can align text in columns as a table by means of tabular environment. From left and right positions in the text file, the required number of columns can be determined at the beginning of the tabular environment. We start a LaTeX code with "`\begin {tabular}{cccc}`", followed by the command for the line on the top of the table. The number of c in cccc is equal to the number of columns. The command for the line takes on two forms, namely, "`\hline`" and "`\cline`". The "`\hline`" command is used if there is a line along the row. If the lines lie in some cells on the same row, the "`\cline`" command is used instead. Next, we determine the number of cells in each row to specify the number of columns and positions of the line. For each cell, we use the

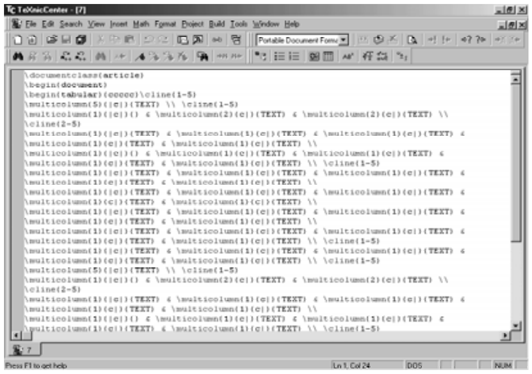


Fig.12: *An example of a table conversion LaTeX file.*

TEXT				
TEXT	TEXT		TEXT	
	TEXT	TEXT	TEXT	TEXT
	TEXT	TEXT	TEXT	TEXT
TEXT	TEXT	TEXT	TEXT	TEXT
TEXT	TEXT	TEXT	TEXT	TEXT
TEXT	TEXT	TEXT	TEXT	TEXT
TEXT	TEXT	TEXT	TEXT	TEXT
TEXT	TEXT	TEXT	TEXT	TEXT
TEXT				
TEXT	TEXT		TEXT	
	TEXT	TEXT	TEXT	TEXT
	TEXT	TEXT	TEXT	TEXT
TEXT	TEXT	TEXT	TEXT	TEXT
TEXT	TEXT	TEXT	TEXT	TEXT
TEXT	TEXT	TEXT	TEXT	TEXT
TEXT	TEXT	TEXT	TEXT	TEXT
TEXT	TEXT	TEXT	TEXT	TEXT

Fig.13: *An example of a table generated from converted LaTeX file.*

"`\multicolumn`" command to denote the cell width. A "`|`" is put between two cells if there is a vertical line in that position. An "`&`" is used to separate each cell. Each row is delimited by the "`\\`" command. Figure 12 and Figure 13 show examples of a LaTeX file and a table generated from this algorithm.

6. EXPERIMENTAL RESULTS

The proposed algorithm is implemented by C programming language. The tested samples consist of actual blocks extracted from real document images and synthesized blocks. Seven document images having small skewed angles and noises are extracted and placed in rectangular blocks. The contents of these blocks consist of text paragraphs, pictures, graphs, tables, and matrices that are identified as table blocks and non-table blocks.

The table blocks with various styles of lines and data arrangement are synthesized for testing. Table 1 presents the tested samples that are correctly identified. Test results of samples table area and non-table area are summarized in Table 2 and Table 3. Table 4 depicts the results of identification method. Most table blocks are correctly identified and converted. Comparison of the table blocks and their respective structure obtained from LaTeX are shown in Table 5. Nevertheless, some mis-identifications were resulted due to excessive cell overlapping. Figure 14 shows an example of a table misidentified as a non-table block because of cell overlapping in the circles.

The cause of misidentification

MSE		probability[%]					
var.		5	6	7	8	9	10
100	a	1138	1349	1556	1758	1965	2164
	b	104.6	106.5	109.1	111.9	114.1	116.7
	c	140.7	144.1	148.0	152.5	155.7	159.3
	d	311.7	338.9	366.3	393.6	420.4	449.0
	e	140.5	143.9	147.8	152.3	155.5	159.1
	f	119.5	123.0	127.2	131.4	134.9	138.7
200	a	1233	1443	1649	1850	2056	2254
	b	131.1	133.6	137.1	140.5	143.4	146.7
	c	178.2	182.4	187.4	193.0	197.0	201.4
	d	322.4	349.6	376.9	404.3	431.1	459.4
	e	178.1	182.3	187.3	192.9	196.6	201.3
	f	143.7	147.8	152.7	157.6	161.7	166.0
300	a	1328	1537	1742	1942	2147	2344
	b	158.3	161.5	165.7	169.9	173.5	177.6
	c	214.2	219.1	225.2	231.9	236.8	242.1
	d	333.1	360.2	387.4	414.9	441.6	469.8
	e	214.1	219.0	225.2	231.8	236.7	242.0
	f	169.2	173.9	179.5	185.1	189.9	194.8
400	a	1423	1631	1835	2034	2238	2434
	b	186.5	190.2	195.3	200.3	204.6	209.6
	c	249.1	254.9	262.1	269.8	275.4	281.5
	d	343.8	370.9	398.0	425.4	452.1	480.1
	e	249.1	254.9	262.1	269.7	275.3	281.5
	f	196.1	201.5	207.8	214.2	219.8	225.3

Fig.14: *An example of a table block misidentified as a non-table block.*

7. CONCLUSION

A new algorithm is proposed in order to identify various styles of table from scanned document. The extracted tables are converted into LaTeX that is suitable for modification, storage, retrieval, and transmission. The proposed algorithm examines the line appearance and the position of cells inside the table in determining the table area. Thus, a matrix will be identified as a non-table area. In the case of a table without any lines, the algorithm uses only the position of cells as the parameter for decision.

From the experimental results, this algorithm can correctly identify many types of table. However, the algorithm fails to distinguish the table if there exists pockets of excessive overlapping as appeared in Figure 4 and Figure 14.

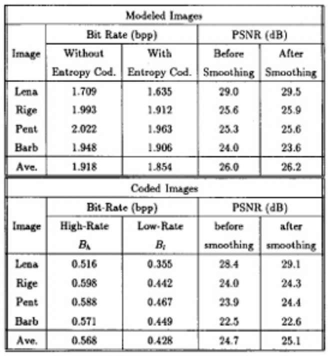
Experimental results show that the algorithm yields a 94.12 % correct identification rate for the actual table area and a 100 % for the synthesized ones. Future enhancements can be considered in the following issues:

1. Develop a faster method for preparing cell and line positions.
2. Support tables that encompass non-table areas.
3. Establish detailed information of block classification for more sophisticated LaTeX representations.

8. ACKNOWLEDGMENTS

A special thank to Miss Atchara Mahaweerawat for her tireless assistance to fix some of the manuscript typesetting problems.

Table 1: *Examples of tested samples and their identified results.*

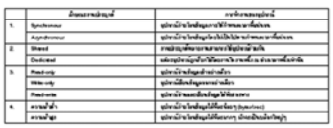


Modeled Images				
	Bit Rate (bpp)		PSNR (dB)	
Image	Without Entropy Cod.	With Entropy Cod.	Before Smoothing	After Smoothing
Lena	1.709	1.635	29.0	29.5
Rige	1.993	1.912	25.6	25.9
Pent	2.022	1.963	25.3	25.6
Barb	1.948	1.906	24.0	23.6
Ave.	1.918	1.854	26.0	26.2
Coded Images				
	Bit-Rate (bpp)		PSNR (dB)	
Image	High-Rate B_h	Low-Rate B_l	before smoothing	after smoothing
Lena	0.516	0.355	28.4	29.1
Rige	0.598	0.442	24.0	24.3
Pent	0.588	0.467	23.9	24.4
Barb	0.571	0.449	22.5	22.6
Ave.	0.568	0.428	24.7	25.1

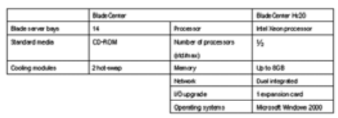
Table

Table

Table



Table



Table

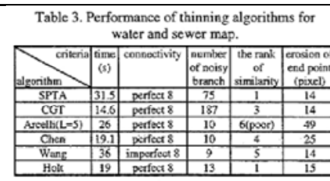


Table 3. Performance of thinning algorithms for water and sewer map.

criteria / algorithm	time (s)	connectivity	number of noisy branch	the rank of similarity	erosion of end point (pixel)
SPTA	31.5	perfect 8	75	1	14
CGT	14.6	perfect 8	187	3	14
Arcelli(L=5)	26	perfect 8	10	6(poor)	49
Chen	19.1	perfect 8	10	4	25
Wang	36	imperfect 8	9	5	14
Holt	19	perfect 8	13	1	15

Table

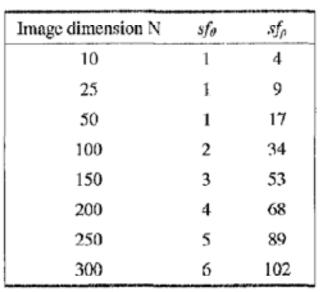
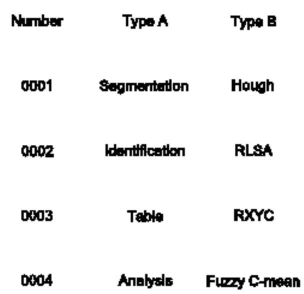


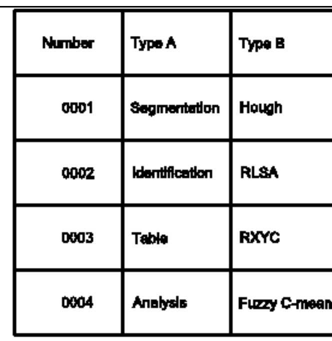
Image dimension N	sf_θ	sf_ρ
10	1	4
25	1	9
50	1	17
100	2	34
150	3	53
200	4	68
250	5	89
300	6	102

Table



Number	Type A	Type B
0001	Segmentation	Hough
0002	Identification	RLSA
0003	Table	RXYC
0004	Analysis	Fuzzy C-mean

Table



Number	Type A	Type B
0001	Segmentation	Hough
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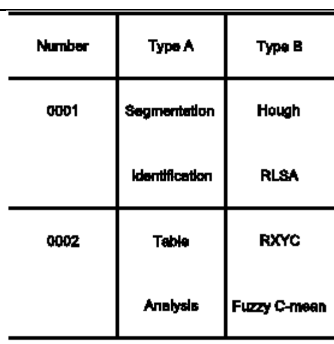
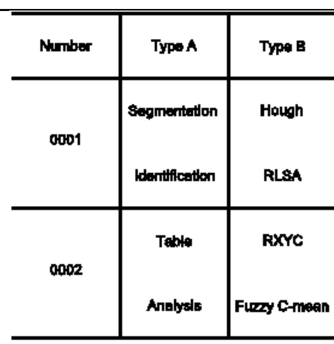
0004	Analysis	Fuzzy C-mean

Table



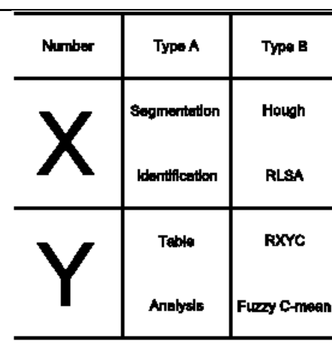
Number	Type A	Type B
0001	Segmentation	Hough
	Identification	RLSA
0002	Table	RXYC
	Analysis	Fuzzy C-mean

Table



Number	Type A	Type B
0001	Segmentation	Hough
	Identification	RLSA
0002	Table	RXYC
	Analysis	Fuzzy C-mean

Table



Number	Type A	Type B
X	Segmentation	Hough
	Identification	RLSA
Y	Table	RXYC
	Analysis	Fuzzy C-mean

Table

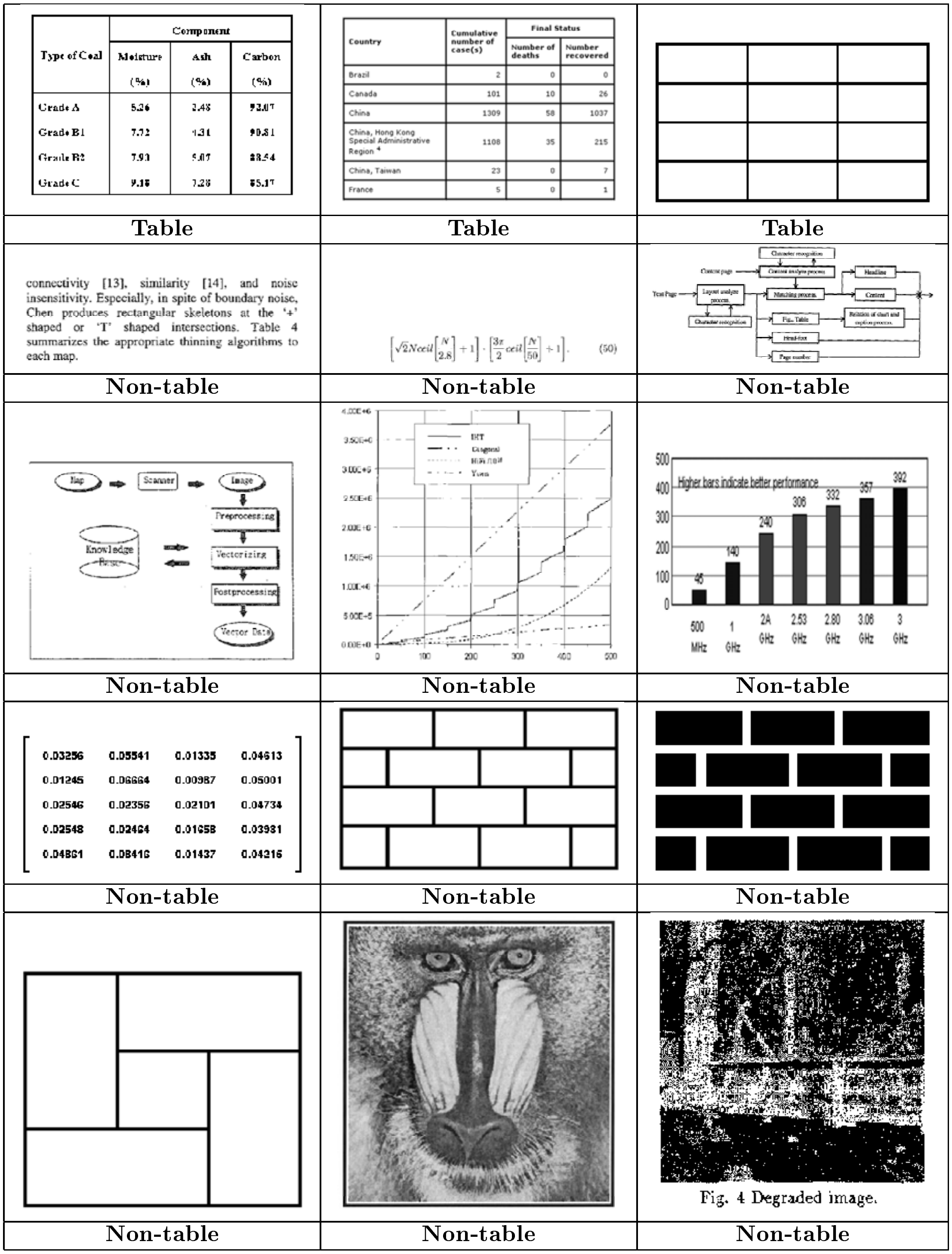


Table
Table
Table
Non-table
Non-table
Non-table
Non-table
Non-table
Non-table
Non-table
Non-table
Non-table
Non-table
Non-table
Fig. 4 Degraded image.
Non-table

Table 2: *The table samples.*

Table	Components		
	Line	Data	Line and Data
Actual	-	-	17
Synthesis	1	2	16

Table 3: *The non-table samples.*

Non-table	Picture	Graph	Diagram	Matrix	Others
Actual	2	4	2	-	20
Synthesis	-	-	-	1	4

Table 4: *Tested results of table identification.*

Samples		Number of tests	Results		Correct identification rate (%)*
			Correct	Miss	
Table	Actual	17	16	1	94.12
	Synthesis	19	19	-	100
Non-table	Actual	28	28	-	100
	Synthesis	5	5	-	100

*Correct identification rate = Number of correct results/Number of tests

Table 5: *Comparison of the table blocks and their structures obtained from LaTeX.*

[illegible] (Activity)			[illegible] (budget)	[illegible]
[illegible] (Group of Activity)	[illegible] (Activity)	[illegible] (Sub-Activity)		
[illegible]	1. [illegible]	1.1 [illegible]		[illegible]
		1.2 [illegible]		[illegible]
	2 [illegible] 3 [illegible]	[illegible] proposal [illegible]		[illegible]

TEXT			TEXT	TEXT
TEXT TEXT	TEXT TEXT	TEXT TEXT	TEXT TEXT	
TEXT	TEXT TEXT	TEXT TEXT TEXT		TEXT
		TEXT TEXT		TEXT
	TEXT TEXT TEXT	TEXT TEXT TEXT		TEXT

Table 3. Performance of thinning algorithms for water and sewer map.

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Chen	19.1	perfect 8	10	4	25
Wang	36	imperfect 8	9	5	14
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TEXT TEXT

TEXT	TEXT TEXT	TEXT	TEXT TEXT TEXT	TEXT TEXT TEXT	TEXT TEXT TEXT
TEXT	TEXT	TEXT	TEXT	TEXT	TEXT
TEXT	TEXT	TEXT	TEXT	TEXT	TEXT
TEXT	TEXT	TEXT	TEXT	TEXT	TEXT
TEXT	TEXT	TEXT	TEXT	TEXT	TEXT
TEXT	TEXT	TEXT	TEXT	TEXT	TEXT
TEXT	TEXT	TEXT	TEXT	TEXT	TEXT

	Blade Center		Blade Center Hs20
Blade server bays	14	Processor	Intel Xeon processor
Standard media	CD-ROM	Number of processors (std/max)	½
Cooling modules	2 hot-swap	Memory	Up to 8GB
		Network	Dual integrated
		I/O upgrade	1 expansion card
		Operating systems	Microsoft Windows 2000

	TEXT		TEXT
TEXT	TEXT	TEXT	TEXT
TEXT	TEXT	TEXT TEXT	TEXT
TEXT	TEXT	TEXT	TEXT
		TEXT	TEXT
		TEXT	TEXT
		TEXT	TEXT

[illegible]	[illegible]	description
1		[illegible]
2	ASIM	[illegible]
3		[illegible]
4		[illegible]

TEXT	TEXT	TEXT
TEXT	TEXT	TEXT TEXT
TEXT	TEXT	TEXT
TEXT	TEXT	TEXT
TEXT	TEXT	TEXT

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