Simple Algorithm for Page Layout Analysis

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Abstract—An algorithm for page layout analysis (segmentation) is suggested in the paper. It allows whitespace between text blocks to be detected on a document page. The algorithm could be used in document analysis and recognition problems. In particular, it can be used for column recognition in multicolumn text and tables. The suggested algorithm is quite simple for implementation.

INTRODUCTION

The number of documents in the world is growing rapidly; this is discussed in [6] in particular. Document analysis and recognition (DAR) systems are developed for automation of information extraction from document images [7]. Document layout analysis or page segmentation is used for dividing document into specific parts (e.g., columns, figures, tables). This is an important DAR problem. Different methods of document layout analysis are discussed in [3].

Conventionally, there are two approaches to the problem of page or table column segmentation. The first approach is to analyze of text layout (text blocks); this usually requires the use of complex data structures. For example, such an approach with the use of a Voronoi diagram for page segmentation is suggested in [5]. The second approach is to analyze whitespace (free of text) on a page. Gaps separate text and table columns on a page, as is shown in Fig. 1. Algorithms using whitespace analysis are suggested in [1, 2, 8]. Algorithms [1, 8] are briefly considered in [2]. They can be used for detecting whitespace between text blocks. The authors of [2] point out that the algorithms [1, 8] are difficult for implementation. A geometrical layout analysis algorithm, simple for implementation, is presented in [2]; it provides for detecting whitespace gaps in multicolumn text and is described in terms of the largest empty rectangle problem [4]. The algorithm input is a bounding box including obstacles (rectangles). The algorithm [2] finds the largest empty rectangle among obstacles inside the bounding box. To find whitespace gaps on a page, n-better solutions (empty rectangles) in descending order are found on the page. The algorithm [2] is greedy. The found i-largest empty rectangle becomes an obstacle when searching for the next $i + 1$-largest empty rectangle. However, it is probable that some of n-better solutions (largest rectangles found) are not gaps between columns, but, e.g., horizontal gaps between paragraphs or tables on the page. This is the disadvantage of the algorithm [2].

In the paper, we suggest an unconventional simple algorithm for detecting whitespace gaps on a document page. It allows detecting vertical gaps (visually they are stretched up vertically), as well as horizontal gaps if the X and Y axis are exchanged. The suggested algorithm is simple; its Object Pascal implementation consists of about 60 lines of code (expressions).

1. PROBLEM FORMULATION

The geometrical objects considered in this work are presented in the Cartesian coordinate system, where the x-coordinates increase from left to right and y-coordinates increase from the top down. The following assumptions are used in this work. The rectangle (e.g., an obstacle, bounding box, or gap) $r = (x_l, y_t, x_r, y_b)$ is defined by the coordinates of its sides (boundaries): left $c_l = x_l(r)$, top $y_t = y_t(r)$, right $x_r = x_r(r)$, and bottom $y_b = y_b(r)$; in addition, its sides are parallel to the corresponding coordinate axes. The vertical line $l = (x, y_t, y_b)$ is normal to the X axis and is defined by its coordinates: $x = x(l)$ by the x-coordinate, $y_t = y_t(l)$ by the minimum (top) y-coordinate, and $y_b = y_b(l)$ by the maximum (bottom) y-coordinate.

It is assumed that the bounding rectangle b and the set of obstacles (rectangles) $R = \{r_1, ..., r_n\}$, $n \in \mathbb{N}$ are specified. The rectangle b usually bounds a document page or its part (e.g., a table), while the obstacles are bounding rectangles for text blocks (e.g., words or lines). The obstacles from the set R are totally inside the bounding rectangle b and do not overlap each other.

Let us define two sets of obstacles (rectangles) $R' = \{r_l, r_1, ..., r_n, r_r\}$ and R'' $= \{r_t, r_1, ..., r_n, r_b\}$, where $r_l = (x_l, y_t, x_l, y_b)$, $r_r = (x_r, y_t, x_r, y_b)$, $r_t = (x_l, y_t, x_r, y_t)$, $r_b = (x_l, y_b, x_r, y_b)$, $x_l = x_l(b)$, $y_t = y_t(b)$, $x_r = x_r(b)$, and $y_b = y_b(b)$. Let us also define the gap as a rectangle bounding a certain part of whitespace inside the bounding rectangle b.

If any two rectangles r and $\tilde{r}$ from the set R' satisfy the following conditions,

(1) their projections to the X axis do not intersect, i.e.,

$$x_r(r) < x_l(\tilde{r}), \tag{1}$$

(2) there is no other rectangle of the set R between them, i.e.,

$$\nexists \bar{r}\colon \bar{r} \in R,\ \bar{r} \neq r,\ \tilde{r} \text{ and } \bar{r} \subset w, \text{ where}$$
$$w = (x_r(r), \min\{y_t(r), y_t(\tilde{r})\}, \tag{2}$$
$$x_l(\tilde{r}), \max\{y_b(r), y_b(\tilde{r})\}),$$

then the rectangles r and $\tilde{r}$ should be separated by a gap. The state problem consists in separation of all rectangles of the set R', satisfying conditions (1) and (2), by a minimum number of gaps.

2. ALGORITHM

The algorithm consists of two steps. The following actions are executed for each rectangle at the first step:

(1) The first line (or rule) is extended from the left boundary of the obstacle r: $r \in R$ upward and downward, while it is hampered from top and bottom by another obstacle $\tilde{r}$: $\tilde{r} \in R$, $\tilde{r} \neq r$ or the bounding rectangle b, as is shown in Fig. 2a. In this case, the resulting line is added to the set L.

(2) The second line (or rule) is extended from the right obstacle boundary r: $r \in R$ by analogy with the first case. In this case, each resulting line is added to the set $\tilde{L}$.

Pairs of lines $(\tilde{l}, l)$ are formed at the second step; the first line $\tilde{l}$ in each pair either belongs to the set $\tilde{L}$ or is the left side of the bounding rectangle b, and the second line l belongs to the set L or is the right side of the bounding rectangle b. Each pair of lines $(\tilde{l}, l)$ satisfies the condition

$$y_t(l) = y_t(\tilde{l}) \text{ and } y_b(l) = y_b(\tilde{l}); \tag{3}$$

i.e., their y-coordinates are equal. In addition, there is no obstacle between the lines $\tilde{l}$ and l of each pair, i.e.,

$$\nexists r\colon r \in R \text{ and } r \subset w, \text{ where}$$
$$w = (x(\tilde{l}), y_t(l), x(l), y_b(l)). \tag{4}$$

Each such a pair of lines $(\tilde{l}, l)$ forms a gap, as is shown in Fig. 2b. The set of such gaps $g = (x_t(\tilde{l}), y_t(l), x_r(l), x_b(l))$ is the algorithm output.

Below the algorithm is represented as a pseudocode. It is assumed that all sets are represented as lists. The function SORT(S, (c_1, c_2)) sorts elements (e.g., lines, rectangles) in the list S lexicographically in (c_1, c_2)-coordinates ascending order; i.e., any two elements s, $\tilde{s}$ of the list S satisfy the condition $s < \tilde{s}$, if

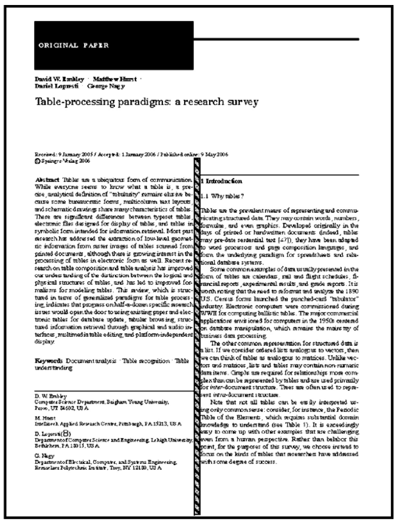
ORIGINAL PAPER

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Table-processing paradigms: a research survey

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Abstract Tables are a ubiquitous form of communication. While everyone seems to know what a table is, a precise, analytical definition of "tabularity" remains elusive because some bureaucratic forms, multicolumn text layouts, and schematic drawings share many characteristics of tables. There are significant differences between typeset tables, electronic files designed for display of tables, and tables in symbolic form intended for information retrieval. Most past research has addressed the extraction of low-level geometric information from raster images of tables scanned from printed documents, although there is growing interest in the processing of tables in electronic form as well. Recent research on table composition and table analysis has improved our understanding of the distinction between the logical and physical structures of tables, and has led to improved formalisms for modeling tables. This review, which is structured in terms of generalized paradigms for table processing, indicates that progress on half-a-dozen specific research issues would open the door to using existing paper and electronic tables for database update, tabular browsing, structured information retrieval through graphical and audio interfaces, multimedia table editing, and platform-independent display.

Keywords Document analysis · Table recognition · Table understanding

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1 Introduction

1.1 *Why tables?*

Tables are the prevalent means of representing and communicating structured data. They may contain words, numbers, formulae, and even graphics. Developed originally in the days of printed or handwritten documents (indeed, tables may pre-date sentential text [47]), they have been adapted to word processors and page composition languages, and form the underlying paradigm for spreadsheets and relational database systems.

Some common examples of data usually presented in the form of tables are calendars, rail and flight schedules, financial reports, experimental results, and grade reports. It is worth noting that the need to reformat and analyze the 1890 U.S. Census forms launched the punched-card "tabulator" industry. Electronic computers were commissioned during WWII for computing ballistic tables. The major commercial applications envisioned for computers in the 1950s centered on database manipulation, which remains the mainstay of business data processing.

The other common representation for structured data is a list. If we consider ordered lists analogous to vectors, then we can think of tables as analogous to matrices. Unlike vectors and matrices, lists and tables may contain *non-numeric* data items. Graphs are required for relationships more complex than can be represented by tables and are used primarily for *inter*-document structure. Trees are often used to represent *intra*-document structure.

Note that not all tables can be easily interpreted using only common sense: consider, for instance, the Periodic Table of the Elements, which requires substantial domain knowledge to understand (see Table 1). It is exceedingly easy to come up with other examples that are challenging even from a human perspective. Rather than belabor this point, for the purposes of this survey, we choose instead to focus on the kinds of tables that researchers have addressed with some degree of success.

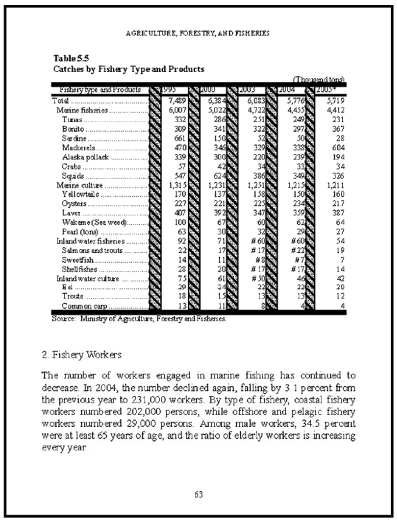
AGRICULTURE, FORESTRY, AND FISHERIES

Table 5.5
Catches by Fishery Type and Products

(Thousand tons)

Fishery type and Products	1995	2000	2003	2004	2005*
Total	7,489	6,384	6,083	5,776	5,719
Marine fisheries	6,007	5,022	4,722	4,455	4,412
Tunas	332	286	251	249	231
Bonito	309	341	322	297	367
Sardine	661	150	52	50	28
Mackerels	470	346	329	338	604
Alaska pollack	339	300	220	239	194
Crabs	57	42	34	33	34
Squids	547	624	386	349	326
Marine culture	1,315	1,231	1,251	1,215	1,211
Yellowtails	170	137	158	150	160
Oysters	227	221	225	234	217
Laver	407	392	347	359	387
Wakame (Sea weed)	100	67	60	62	64
Pearl (tons)	63	30	32	29	27
Inland water fisheries	92	71	#60	#60	54
Salmons and trouts	22	17	#17	#22	19
Sweetfish	14	11	#8	#7	7
Shellfishes	28	20	#17	#17	14
Inland water culture	75	61	#50	46	42
Eel	29	24	22	22	20
Trouts	18	15	13	13	12
Common carp	13	11	8	4	4

Source: Ministry of Agriculture, Forestry and Fisheries.

2. Fishery Workers

The number of workers engaged in marine fishing has continued to decrease. In 2004, the number declined again, falling by 3.1 percent from the previous year to 231,000 workers. By type of fishery, coastal fishery workers numbered 202,000 persons, while offshore and pelagic fishery workers numbered 29,000 persons. Among male workers, 34.5 percent were at least 65 years of age, and the ratio of elderly workers is increasing every year.

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▨ Vertical gaps

Fig. 1. Whitespace gaps separate columns in multicolumn text and a table.

either $c_1(s) < c_1(\tilde{s})$ or $c_1(s) = c_1(\tilde{s})$ and $c_2(s) < c_2(\tilde{s})$. An obstacle is formed in line 01 with the help of the upper boundary of a bounding rectangle (in line 02).

The obstacles r_0 and r_{n+1} are added to the list R (in line 03). The obstacles in the list R are lexicographically (y_t, x_l)-coordinate ascending ordered from the top down and from left to right (line 04). Obstacles of the list R are sorted out from the top down and from left to right in lines 05–22 and from right to left and from the bottom upward in lines 07–11. In this case, lines are extended upward from the left and right boundaries of the current rectangle. Obstacles of the list R are sorted out from the top down and from left to right in lines 12–16, and lines from the left and right

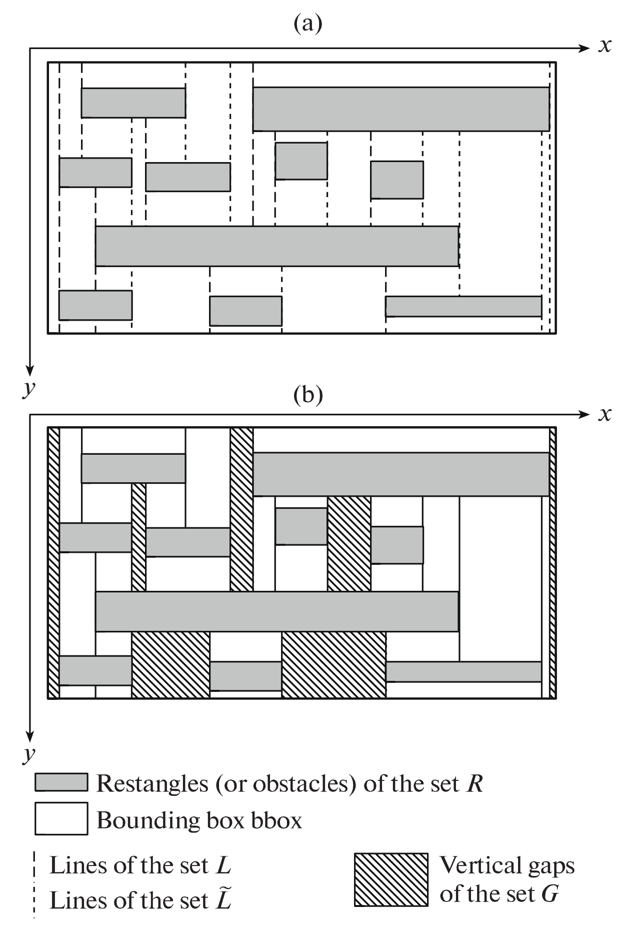
(a)
x
y
(b)
x
y
Restangles (or obstacles) of the set R
Bounding box bbox
Lines of the set L
Lines of the set L̃
Vertical gaps of the set G

Fig. 2. Detecting whitespace gaps.

boundaries of the current rectangle are extended downward. If the following nonempty sets of lines

$$L = \{l_1, \ldots, l_p\}, \quad \tilde{L} = \{\tilde{l}_1, \ldots, \tilde{l}_s\}, \quad p, s \in \mathbb{N}$$

are obtained after executing step 1, then step 2 is executed. The line $\tilde{l}$ is formed with the help of the left boundary of the bounding rectangle (line 23), and line l, with the help of the right boundary (line 24). The line $\tilde{l}$ is added to the list $\tilde{L}$ (line 25), and the line l, to the list L (line 26). Lines in the lists L and $\tilde{L}$ are lexicographically (x, y_t)-coordinate ascending ordered from left to right and from the top down in lines 27–28. Lines of the list $\tilde{L}$ are sorted out from left to right and from the top down in lines 29–34. Lines of list L are sorted out from left to right and from the top down in lines 30–34. Then, the lines satisfying conditions (3) and (4) are selected and gaps are formed.

The pseudocode of the first algorithm step is presented below.

Input: b, $R = \{r_1, \ldots, r_n\}$, $n \in \mathbb{N}$
Output: $G = \{g_1, \ldots, g_m\}$, $m \in \mathbb{N}$

```
01 create $r_0 \longleftarrow (x_l(b), y_t(b), x_r(b), y_t(b))$
02 create $r_{n+1} \longleftarrow (x_l(b), y_b(b), x_r(b), y_b(b))$
03 add $r_0, r_{n+1}$ to $R$
04 SORT($R$, $(y_t, x_l)$)
05 for $i = \overrightarrow{1, n}$ do
06   $\overline{y}_l, \overline{y}_r, \underline{y}_l, \underline{y}_r \longleftarrow$ null
07   for $j = \overrightarrow{i-1, 0}$ do
08     if $y_t(r_i) > y_b(r_j)$ then
09       if $\overline{y}_l$ = null
         and $x_l(r_j) < x_l(r_i) < x_r(r_j)$
         then $\overline{y}_l \longleftarrow y_b(r_j)$
10       if $\overline{y}_r$ = null
         and $x_l(r_j) < x_r(r_i) < x_r(r_j)$
         then $\overline{y}_r \longleftarrow y_b(r_j)$
11       if $\overline{y}_l, \overline{y}_r \neq$ null
         then exit for $j$
12 for $j = \overrightarrow{i+1, n+1}$ do
13   if $y_b(r_i) < y_t(r_j)$ then
14     if $\underline{y}_l$ = null
       and $x_l(r_j) < x_l(r_i) < x_r(r_j)$
       then $\underline{y}_l \longleftarrow y_t(r_j)$
15       if $\underline{y}_r$ = null
         and $x_l(r_j) < x_r(r_i) < x_r(r_j)$
         then $\underline{y}_r \longleftarrow y_t(r_j)$
16       if $\underline{y}_l, \underline{y}_r \neq$ null
         then exit for $j$
17       if not $L$ contains $(x_l(r_i), \overline{y}_l, \underline{y}_l)$
         then
18         create $l \longleftarrow (x_l(r_i), \overline{y}_l, \underline{y}_l)$
19         add $l$ to $L$
20       if not $\tilde{L}$ contains $(x_r(r_i), \overline{y}_r, \underline{y}_r)$
         then
21         create $\tilde{l} \longleftarrow (x_r(r_i), \overline{y}_r, \underline{y}_r)$
22         add $\tilde{l}$ to $\tilde{L}$
```

The pseudocode of the second algorithm step is presented below.

```
23 create $\tilde{l} \longleftarrow (x_l(b), y_t(b), y_b(b))$
24 create $l \longleftarrow (x_r(b), y_t(b), y_b(b))$
25 add $\tilde{l}$ to $\tilde{L}$
26 add $l$ to $L$
```

```
27 SORT($L(x, y_t)$)
28 SORT($\tilde{L}$, $(x, y_t)$)
29 for $i = \overrightarrow{1, s+1}$ do
30    for $j = \overrightarrow{1, p+1}$ do
31       if $x(\tilde{l}_i) < x(l_j)$ and $\bar{y}(\tilde{l}_i) = \bar{y}(l_j)$
         and $\underline{y}(\tilde{l}_i) = \underline{y}(l_j)$ then
32          create $g \longleftarrow (x(\tilde{l}_i), \bar{y}(\tilde{l}_i), x(l_j)\underline{y}(l_j))$
33          add $g$ to $G$.
```

CONCLUSIONS

The suggested algorithm could be used for document page segmentation. For example, it can reveal columns inside multicolumn text and tables. The algorithm is used in the method for detecting tables in a document, suggested in [9]. The algorithm is quite simple; its computational complexity is $O(n^2)$.

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