문자 인식에서 단어 간의 활자 인쇄선 위치 분석과 클래스 분류

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요 약

본 논문은 활자 인쇄선 분석과 이에 따른 클래스 분류를 제안한다. 활자 인쇄선 분석은 영문 인쇄체 인식에 있어 불가결한 요소이다. 활자 인쇄선 분석은 문자 인식에서 문자 분할을 위한 전처리 단계이다. 본 논문은 두 부분으로 나뉘는데, 첫 부분에서는 단어 간 활자 인쇄선 분석을 통한 단어 활자선 클래스를 정의한다. 두 번째 부분에서는 문자 간 활자 인쇄선 분석을 통한 문자 활자선 클래스를 정의한다. 이렇게 정의된 단어 활자선 클래스와 문자 활자선 클래스는 문자 분할시 정확한 문자 분할을 위하여 사용된다.

키워드 : 문자 분할, 문자 인식, 단어 활자선 클래스, 문자 활자선 클래스

Typographical Analyses and Classes of Characters and Words in Optical Character Recognition

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ABSTRACT

This paper presents a typographical analyses and classes. Typographical analysis is an indispensable tool for machine-printed character recognition in English. This analysis is a preliminary step for character segmentation in OCR(Optical Character Recognition). This paper is divided into two parts. In the first part, word typographical classes from words are defined by the word typographical analysis. In the second part, character typographical classes from connected components are defined by the character typographical analysis. The character typographical classes are used in the character segmentation.

Key Words : Character Segmentation, Optical Character Recognition, Word Typographical Classes, Character Typographical Classes

1. Introduction

Character recognition, also known as optical character recognition(OCR), is concerned with the automatic conversion of an image of a character, or of characters in running text, into the corresponding symbolic form, which is then accessible for any information processing system. Character segmentation is to partition touching characters into isolated and complete characters, which in turn serve as input to a character classifier. Touching characters are responsible for the majority of errors in the machine-printed character recognition, since touching characters make it difficult to extract the exact set of features needed for the identification. As long as characters are correctly segmented, the degradation of individual characters does not significantly affect the overall system performance. If recognition is unacceptable, generally it is because characters were difficult to segment[1].

Words in European language can be decomposed into three typographical zones: the ascender zone, the x-height zone, and the descender zone. Takehiro and A. Lawrence [2] used this characteristics to determine European language from other languages. E. Lee[3] presented a Korean/English font character recognition algorithm invariant to scaling, translation and rotation using vertical/horizontal projection and hybrid pattern vector informations in printed Korean and English documents. Lu Da, Brendan, and Pu Wei[4] proposed character preclassification based on fuzzy typographical analysis to im-

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prove character recognition rates.

This paper presents a typographical analyses and classes of touching characters.

Typographical zones of touching characters can be estimated to know its structure, which gives us a precise way of a character segmentation and a character classification.

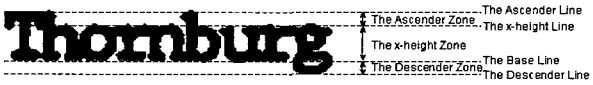
This paper defines both word typographical classes and character typographical classes. These two types of typographical classes can be used to a character segmentation and a character classifier to improve their performances.

2. Word typographical analysis

The objective of word typographical analysis is to assign each word to a word typographical class.

2.1 Typographical structure of a word

One of the most distinctive and inherent characteristics of English is the existence of ascenders and descenders. In (Fig. 1), a word image is composed of three typographical zones: the ascender zone, the x-height zone, and the descender zone, which are delimited by four virtual typographical lines, the ascender, the x-height, the base, and the descender lines. While the ascender zone and the descender zone depend on the text content, the x-height zone is always occupied regardless of characters. The distance between the x-height line and the base line is called x-height.



(Fig. 1) Typographical structure of a word

2.2 Projection profile

When image function $I(x, y)$ takes on two values (say, black and white), the projection profile is obtained by counting the black pixels in the vertical (P_v) or horizontal direction (P_h).

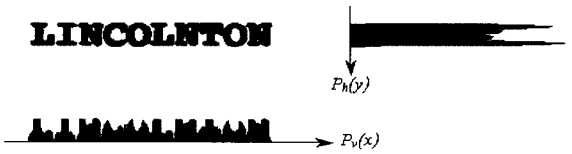
- Vertical Projection Profile: Sum of black pixels perpendicular to the x-axis

$$P_v(x) = \sum_y I(x, y) \tag{1}$$

- Horizontal Projection Profile : Sum of black pixels perpendicular to the y-axis.

$$P_h(y) = \sum_x I(x, y) \tag{2}$$

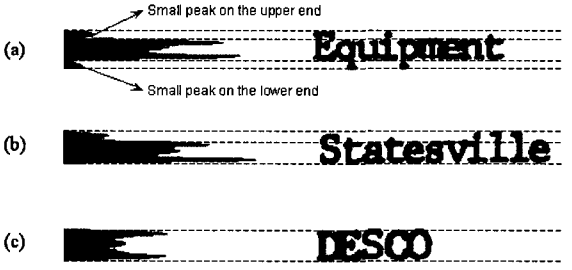
(Fig. 2) shows horizontal and vertical projection profiles of a word. The vertical projection profile is slant invariant but the horizontal projection profile is slant variant [5].



(Fig. 2) Horizontal and vertical projection profiles of a word.

2.3 Word structure from the horizontal projection profile

Typographical structure of a word is obtained by the horizontal projection profile. As shown in (Fig. 3) (a), the presence of ascenders in a word (including small overhanging dots as in 'i' and 'j') makes a small peak on upper end of the horizontal projection profile. Similarly, the presence of descenders in a word makes a small peak on the lower end of the horizontal projection profile. Long black runs generally occur near both the x-height line and the base line, resulting in two significant maxima at these positions. A word consisting of all capitals, all numerals, or all x-height words such as "area", "come", or "essence" leads the absence of both small peaks (Fig. 3(c)).



(Fig. 3) Word structure from the horizontal projection profile

2.4 Typographical line estimation of a word

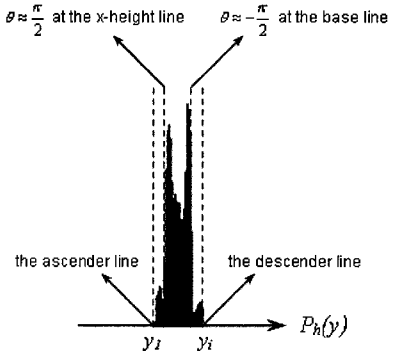
Typographical line estimation is useful to know a word structure. In this paper, the typographical lines are simply estimated from the horizontal projection profile as follows:

The slop at the two neighboring pixel points $(P_h(y_i), y_i)$ and $(P_h(y_{i+1}), y_{i+1})$ to the y-axis can be calculated from

$$\theta = \tan^{-1}\frac{\Delta x}{\Delta y} = \tan^{-1}(P_h(y_{i+1}) - P_h(y_i)) \tag{3}$$

$$\frac{\Delta x}{\Delta y} = \frac{P_h(y_{i+1}) - P_h(y_i)}{y_{i+1} - y_i} = P_h(y_{i+1}) - P_h(y_i) \tag{4}$$

(Fig. 4) illustrates a horizontal projection profile that is rotated to -90 degree. In the figure, the slope θ, from the equation (3) is close to π/2 at the x-height line and to -π/2 at the base line. The start point ($y=y_1$) and the end point ($y=y_i$) of black pixels in the horizontal projection profile are the ascender line and the descender line, respectively in this example. If the slope θ is close to π/2 at the start point ($y=y_1$), the ascender line does not exist. That implies the word does not have ascenders.

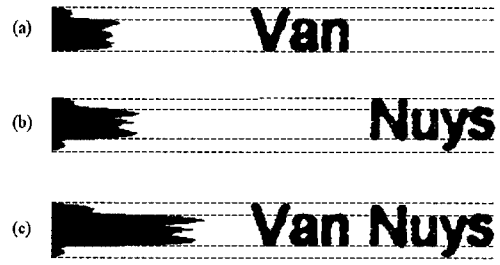


(Fig. 4) Typographical line estimation using horizontal projection profile (-90 rotated).

Every word has both the x-height line and the base line. The three zone ratio is used to verify the estimation results, i.e., ascender zone : x-height zone : descender zone $\fallingdotseq$ 1 : 2 : 1.

2.5 Word concatenation

The above typographical line estimation method is accurate for long words, but is failure-prone for very short words. Stable estimates of the typographical lines can be achieved from the horizontal projection profile of an entire text line. However, a longer text is more sensitive to the skew. Therefore, the method usually cannot be used in a whole line without the skew correction. M. Kim[6] stated, "Skew detection and correction needs a lot of processing time and it may distort the character on the document".



(Fig. 5) Word concatenation for a new entity of longer length: Two short words (a) and (b) are concatenated into one long word (c) for more accurate estimation of typographical lines.

In this paper, it was applied for two-phase estimations of typographical lines to solve the problem of the horizontal projection profile of a short word. The first phase is based on a word. English word length averages 4-5 characters[7]. In most of the cases, the first phase is enough to estimate typographical lines. If the first phase fails, the second phase is activated. That is, the failed word and its neighboring word are concatenated into a new word of longer length. (Fig. 5) illustrates that two short words are concatenated into one long word. This two-phase strategy makes the estimation method more accurate and effective.

2.6 Word typographical classes

In this paper, word typographical analysis of the horizontal projection profile of a word assigns it to one of three classes shown in <Table 1>.

〈Table 1〉 Word typographical classes

Word Typographical Classes	Description
One-zone Class	The presence of the x-height zone
Two-zone Class	The presence of two zones Type 1: the ascender and the x-height zones Type 2: the x-height and the descender zones
Three-zone Class	The presence of the ascender, the x-height, the descender zones

In <Table 1>, a word in a one-zone class consists of either all capitals or all x-height characters. A word in a one-zone class has neither ascenders nor descenders. That is, without character recognition, we can estimate whether a word has ascenders or descenders by the word typographical classes. For example, (Fig. 3) (a) belongs to a three-zone class, (Fig. 3) (b) to a two-zone class: type 1, and (Fig. 3) (c) to a one-zone class.

3. Character typographical analysis

Characters occurring in a text line are generally related to typographical lines by their location. The objective of character typographical analysis is to assign each connected component including touching characters to a character typographical class.

3.1 Connected components

A line adjacency graph (LAG) is obtained from a run-length representation of a binary image[8]; its nodes correspond to runs of object pixels and its edges correspond to adjacent runs. 'Blobs' are found as connected compo-

nents of the LAG. Each component, defined as a connected area in a word image, identifies a single character or touching characters except for 'i' and 'j'. (Fig. 6) shows bounding-boxed connected components of a word.

(Fig. 6) Bounding-boxed connected components

3.2 Character typographical classes

All characters and numerals can be classified into four character typographical classes. <Table 2> shows character typographical classes[9, 10].

〈Table 2〉 Character typographical classes

Character Typographical Classes	Description
Ascender Class	All Capitals, Numerals, and b, d, f, h, k, l, t, i
Descender Class	g, p, q, y
x-height Class	a, c, e, m, n, o, r, s, u, v, w, x, z
Full-height Class	j, J and Q (in some fonts).

Character typographical classes are useful to solve the following confusion characters:

- 9(nine)/g(gee), or 8(eight)/g(gee)
- C/c, O/o, P/p, S/s, U/u, V/v, W/w, X/x, Z/z

The size normalization is a transformation of an input image of arbitrary size into an output image of a fixed pre-specified size, while attempting to preserve structural details. The size normalization makes it impossible to distinguish between the above pairs[11]. Most of us cannot distinguish between the upper and the lower case version of those characters, if the characters are presented in isolation. S. Liang classified only 'j' to a full-height class[9, 10]. However, this should be extended because a few more characters belong to the full-height class according to a font. The classification should be defined by the location of a character, not by the content. In this paper, it has been classified 'J' (in Palatino) and 'Q' (in Bookman, Courier, New Century, Palatino, and Times) to the full-height class as shown in Table 2. In this paper, one connected component as a merged character can be classified to a character typographical class. For example, a merged character, "ag" is classified to a descender class, and a merged character, "bg" to a full-height class. This classification is also defined by the location of a connected component, not by the content.

3.3 Character typographical class estimation

When two connected components are neighboring, the character typographical classes of two connected components can be estimated by the relative location of one with respect to the other. In this paper, the relative locations are summarized at <Table 3>. <Table 3> shows every possible combination of two neighboring connected components.

〈Table 3〉 Character typographical class combinations of two connected components: 'A' stands for an ascender class, 'X' for an x-height class, 'D' for a descender class, and 'F' for a full-height class

AA	AX	AD	AF
XA	XX	XD	XF
DA	DX	DD	DF
FA	FX	FD	FF

If it is considered only the scalar of the typographical line displacements of two connected components, those 16 combinations in <Table 3> are simplified to 7 combinations as follows:

- an ascender and an x-height classes (AX/XA)
- an ascender and a descender classes (AD/DX)
- an ascender and a full-height classes (AF/FA)
- an x-height and a descender classes (XD/DX)
- an x-height and a full-height classes (XF/FX)
- a descender and a full-height classes (DF/FD)
- the combinations of the same classes (AA/XX/DD/FF)

(Fig. 7) shows two connected components. The first connected component, "Pl" belongs to an ascender class and the second connected component, "easan" to an x-height class.

(Fig. 7) Character typographical class estimation.

Let the minimum (y_1) be top_w and the maximum (y_4) be $bottom_w$ among four y-coordinates. Then, let y_2 be top_c and let y_3 be $bottom_c$. The difference between $bottom_w$ and top_w is $height_w$, and the difference between $bottom_c$ and top_c is $height_c$. In this paper, the ratios top_r, $height_r$, and $bottom_r$ are defined as follows:

$$top_r = \frac{top_c - top_w}{height_w} \quad (5)$$

$$height_r = \frac{height_c}{height_w} \quad (6)$$

$$bottom_r = \frac{bottom_w - bottom_c}{height_w} \quad (7)$$

$$top_r + height_r + bottom_r = 1 \quad (8)$$

Equation (8) shows the sum of top_r, $height_r$, and $bottom_r$ is one. The above proposed formulas applied for 7 combinations of character typographical classes and constructed <Table 4>. <Table 4> shows the calculated values of top_r, $height_r$, and $bottom_r$ for 7 combinations of character typographical classes. Those values are taken the average of three fonts, Times, Helvetica, and Courier.

<Table 4> Typographical zone ratios of two connected components

top^r	$height^r$	$bottom^r$	Class Combinations
0.3	0.7	0.0	AX/DF
0.2	0.6	0.2	AD/XF
0.0	0.7	0.3	AF/XD
0.0	1.0	0.0	AA/XX/DD/FF

Using this table, we can estimate a combination of two character typographical classes regardless of fonts. In the example of (Fig. 7), $top_r : height_r : bottom_r \fallingdotseq 0.3 : 0.7 : 0.0$. From <Table 4>, we can estimate that the combination is either "an ascender class and an x-height class" or "a descender class and a full-height class". Since the word typographical class of the two connected components is a two-zone class in <Table 1>, we can conclude that two connected components of (Fig. 7) are composed of both an ascender class and an x-height class. Two connected components that consist of a descender class and a full-height class belong to a three-zone class among word typographical classes in <Table 1>.

4. Conclusion

The performance of OCR systems can be improved using the contextual information that are proposed in this paper. Word and Character typographical classes can be used as the contextual information. For example, the character typographical contextual information is used to verify the segmented patterns in character segmentation. If a bounding box of touching characters belongs to an ascender class, the segmented patterns should belong to either an ascender class or an x-height class. Similarly, if a bounding box of touching characters belongs to an x-height class, the segmented patterns should belong to an x-height class. For example, when we segment touching characters "easan" in (Fig. 7) that belongs to the x-height class, a segmented pattern "s(lowercase)" can be a neither "S(uppercase)" or "5(number five)" that belongs to the ascender class. This information of typographical classes is useful to improve the performance of the character segmentation, the character classification, the post-processing, etc.

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