Handwritten Artefact Identification Method for Table Interpretation with Little Use of Previous Knowledge

Luiz Antônio Pereira Neves¹, João Marques de Carvalho¹, Jacques Facon²,
Flávio Bortolozzi², and Sérgio Aparecido Ignácio²

¹ UFCG-Universidade Federal de Campina Grande,
Caixa Postal 105, 58.109-970, Campina Grande, Paraíba, Brasil
{neves, carvalho}@dee.ufcg.edu.br

² PUCPR-Pontifícia Universidade Católica do Paraná,
Rua Imaculada Conceição 1155,
Prado Velho 80215-901, Curitiba-PR, Brazil
{facon, fborto}@ppgia.pucpr.br,
s.ignacio@pucpr.br

Abstract. An artefact identification method for handwritten filled table-forms is presented. Artefacts in table-forms are smudges and overlaps between handwritten data and line segments which increase the complexity of table-form interpretation. After reviewing some knowledge-based methods, a novel artefact identification method to improve table-form interpretation is presented. The proposed method aims to detect, identify and remove table-form artefacts with little use of previous knowledge. Experiments show the significance of using the proposed artefact identification method to improve table-form interpretation rates.

1 Introduction

Tables, or table-forms, are documents composed by cells, which are determined by intersections of straight line segments, as illustrated in figure 1.

DATA:	/	/						LOTE:
REF:			PRODUTO:					
TECIDO:			QUANT:					VALOR:
FACÇÃO:								
CORES \ TAM								SOMA
TOTAL								
RENDIMENTO:								CUSTO:

Fig. 1. Example of a table-form document

Several studies have been presented on table recognition [1], [2], [3], [4], [5], [6], [7], [8], [9]. Some of these researches use tables without imperfections in the horizontal and vertical line segments to reduce the complexity of the problem. In the damaged table case, many researchers use previous knowledge for their interpretations, also aiming to minimize the complexity of the problem.

Since the table-forms considered in this work can be filled in by machines or by hand, overlaps between printed and handwritten information, as shown in figures 2-a and 2-b, might create false intersections. These occurrences are called artefacts. Besides, artefacts can result from faulty table lines, from problems with document acquisition, from binarization problems, or simply from the poor quality of the document, as illustrated by the damaged piece of paper in figure 2-c. Thus, an artefact can be defined as any object, handwritten or not, that produces false table-form intersections. Problems created by artefacts have been partially solved by other researchers. Watanabe [7],[8] presents two procedures, one to be used when no information is previously known and another one when artefacts (noise) characteristics are available in a knowledge base. Couasnon [3] uses previous noise and imperfections knowledge as grammar rules. Arias and Kasturi [1], [2] use the morphological closing operator to eliminate imperfections and to recover the extinguished segment lines for the analysis of the table-form intersections. Liang et al. [10] consider noise and imperfections as previous knowledge. Hori, Doermann [11] and Hirano et al. [12] use table models with noise and imperfections. Shinjo et al. [13] use previous knowledge to detect and correct damages of table corners. Shimotsuji and Asano [14] use table models with imperfections as previous knowledge, to be identified in the interpretation process. Pizano [15] performs image size reduction to eliminate noise and segments, combined with the use of minimum width and distance parameters to eliminate the remaining noise. Tran van Thom [6] performs image size reduction and thresholding for detecting and correcting segments with imperfections.

Figure 2 illustrates examples of artefacts in a form. The form is titled 'Ficha de Dados do Projeto XForm' and contains handwritten entries for 'Ano' (2005), 'Nome' (FRANCINY LAURIANO LEME), 'e-mail' (franciny@zipmail.com.br), 'Curso' (Engenharia de computação), 'Período' (2º), 'Número de Chaveada', and 'Número da Sala'. The form is divided into sections, and the artefacts are highlighted in (a), (b), and (c).

(a) The main form with handwritten entries and some ink smudges.

(b) A close-up of a handwritten '09' in a box, which is an artefact.

(c) A close-up of a handwritten 'Engenharia' in a box, which is an artefact.

Fig. 2. Examples of artefacts

Analyzing the solutions above, one can conclude that for all methodologies described some form of *a priori* knowledge is needed. The aim of this paper is to propose an artefact analysis method with very little use of *a priori* knowledge, to improve table-form interpretation. This method is described in Section 2. Section 3 presents some experimental results and discussions. Finally, the conclusions are given in Section 4.

2 Artefact Identification

The proposed artefact identification method is based on compactness analysis. Compactness is a property that expresses how large is the area concentrated inside a given perimeter, as shown in figure 3. Compactness is measured by the compactness factor, computed from the perimeter and the area of the analyzed shape. Given a shape of perimeter P and area S , its compactness factor is given by FC , as shown in the equation 1.

$$Fc = \frac{P^2}{4\pi S}$$
 (1)

Fig. 3. Compactness Analysis for artefact identification

Verifying the shapes in the figure 3, the circle (figure 3-a) presents the best compactness and we can say that, in general, table-form artefacts present high compactness, with values equal or around 1. Thereby, a threshold has been created for distinguishing if the value calculated for the compactness factor corresponds to that of an artefact or to a straight line segment of a table cell. For determining threshold value, compactness factors from more than 30 different artefacts were submitted to exploratory data analysis [16], characterizing a homogenous distribution with a confidence level of 99%. The range of variation $\mu \pm 2.576 * \sigma$, where μ and σ are the mean and standard deviation respectively, produces inferior and superior limits of 1.21688 and 1.37419, respectively. The

0.5% of values above the superior limit are not contemplated as artefacts. Therefore, the handwritten data that presents compactness factor below 1.4 is considered an artefact.

Figures 4-a and 4-b show several types of artefacts with the respective compactness factors.

index	artefact	compactness factor
(a)		1.28998
(b)		1.27324
(c)		1.34486
(d)		1.28857
(e)		1.27947
(f)		1.28547

(a)

index	artefact	compactness factor
(a)		1.29841
(b)		1.28477
(c)		1.27404
(d)		1.28803
(e)		1.29628
(f)		1.28137

(b)

Fig. 4. Examples of Artefacts with their compactness factors

index	segment	compactness factor
(a)		1.94365
(b)		4.98904
(c)		1.59781
(d)		5.27407
(e)		3.17814
(f)		1.96736

Fig. 5. Examples of segments that are not artefacts with their compactness factors

Figure 5 shows some table segments with compactness factor values above the established threshold. For figure 5-d, for instance, the compactness factor is 5.27407. This value indicates that the analyzed object is not an artefact, but rather a segment. Therefore, by observing figures 4-a, 4-b and 5, one can conclude that the artefact identification method can make the correct distinction between a handwritten artefact and a table segment.

2.1 Overlap Analysis Step

Overlaps between handwritten data and segments produce misleading values of compactness factors. Analyzing the Pearson variation coefficient [16], [17], using data generated from the horizontal projection profile, it is possible to carry out their elimination. The detection of a peak, which indicates the presence of an undesirable segment among the data, means that an overlap should be deleted, as shown in figure 6-a. By using again the exploratory data analysis [16], one can define the sample variation range which permits elimination of possible undesirable overlaps (table 1). High variability of pixel density values in the horizontal direction (using a confidence level of 90%), characterizes heterogeneous distributions. Then, the range of variation $\mu \pm 1.645 * \sigma$, where μ and σ are the mean and standard deviation respectively, permits to delete the 5% of superior values out of this limit, resulting in overlap elimination, as depicted in figure 6-b. Table 1 shows the data analysis for figure 6-a, where the variation coefficient is high, 74.58%. Therefore, the high standard deviation indicates that the artefact of figure 6-a contains overlaps. Consequently, the overlaps (here the segments) are removed, as illustrated in figure 6-b.

Fig. 6. Example of Artefact with overlapping

Table 1. Analysis of Pearson variation coefficient for figure 6

Analysis	Data	Analysis	Data
Line Numbers	67	Inferior Limit	-15.0473
Mean	66.3284	Superior Limit	147.704
Standard Deviation	49.4685	Variation Coefficient	0.745812

Fig. 7. Examples of analyzed handwritten data, processed without alteration

Fig. 8. Examples of artefacts with overlap

Figures 7 and 8 depict some results of artefact analysis and overlap removal. Figures 7-a and 7-b show two successful examples of isolated artefacts without overlap, which represent valid information that must not be removed. Artefact analysis has indicated that the corresponding distributions are homogeneous, since the variation coefficients of figures 7-a and 7-b are 22.96% and 29.32% respectively. So they are not removed.

Figure 8-a shows four overlaps between handwritten data and table lines. These overlaps produce incorrect compactness coefficients. The same occurs in figures 8-b and 8-c. By removing these overlaps, it is possible to correctly identify the true handwritten data. Similarly, overlap analysis makes correct artefact identification easier for figures 8-d and 8-e. Examples of artefacts due to failure in line segments are exhibited in figures 8-f and 8-g, for which overlaps have been correctly eliminated.

2.2 Artefact Cases

Figures 9-a and 9-b illustrate cases where the artefact analysis method does not perform correct artefact identification. This happens because the handwritten letter *f* (figure 9-a), as well as the handwritten digits *1* (figure 9-b) are similar to the table lines. The resulting shapes produce high compactness factors and the method does not consider them as artefacts. These cases represent challenges that will be the subject of further studies.

Fig. 9. Cases of table with artefact

3 Experimental Results and Analysis

To evaluate the performance of the proposed artefact identification approach, 305 table-form images were used to compose the test database, as exemplified in figures 10, 11 and 12. These table-form images, scanned at 300 dpi, are filled with handwritten data, handwritten overlap, and contain artefacts.

The table-form interpretation method used in the experiments has been previously described by this author [18]. The three fundamental steps are:

- Step 1. Identification of table-form intersections;
- Step 2. Corner detection and correction;
- Step 3. Table interpretation and cell extraction.

The proposed artefact identification approach is inserted between Steps 2 and 3. Tests were carried out with and without artefact analysis in order to quantify the improvement produced by the proposed approach. The rate of processed images, shown in table 2, indicates the percentage of images that went through all steps of the methodology. Rejected images are those that did not reach the final processing stage of the methodology. Correctly interpreted images are images that presented no interpretation

TEMPO	FLUXO 4 (1)			FLUXO 9			FLUXO 6 (5)		
	AUTOMÓVEL	ÔNIBUS	CAMINHÃO	AUTOMÓVEL	ÔNIBUS	CAMINHÃO	AUTOMÓVEL	ÔNIBUS	CAMINHÃO
HORA INÍCIO	BARRAS	BARRAS	BARRAS	BARRAS	BARRAS	BARRAS	BARRAS	BARRAS	BARRAS
08:00	59	2	24	1	1	12	1	1	1
08:15	59	2	24	1	1	12	1	1	1
HORA FIM	BARRAS	BARRAS	BARRAS	BARRAS	BARRAS	BARRAS	BARRAS	BARRAS	BARRAS
08:15	100	1	9	3	8	1	5	-	1
08:30	100	1	9	3	8	1	5	-	1
HORA INÍCIO	BARRAS	BARRAS	BARRAS	BARRAS	BARRAS	BARRAS	BARRAS	BARRAS	BARRAS
08:30	104	1	5	14	-	3	18	-	2
08:45	104	1	5	14	-	3	18	-	2
HORA FIM	BARRAS	BARRAS	BARRAS	BARRAS	BARRAS	BARRAS	BARRAS	BARRAS	BARRAS
08:45	110	-	14	20	-	3	15	-	-
09:00	110	-	14	20	-	3	15	-	-

Fig. 10. Example of table-form in the base of tests

Ficha de Dados do Projeto XForm		Ano	2005
Nome FRANCINY LAURIANO LEME			
e-mail fran-ny@zipmail.com.br		Número ICG 10078432	
		Nome de Guerra LANINHA	
Curso Engenharia de computação		Período 9º	Turma 1
Quantas horas você disponibiliza na semana para estudar? () 20		Número de Chaveada 1	Número da Sala 08

Fig. 11. Example of table-form in the base of tests

CONTROLE DE PRODUTO							
DATA: 26 11 103				LOTE: 54			
REF: 403		PRODUTO: MAIO TUBARÃO					
TECIDO: BRANCA				QUANT:		VALOR:	
FACÇÃO:							
CORES \ TAM	P	M	G	GG			SOMA
AZ ANIL	3	2	2	6			13
AZ MAR	3	2	2	6			13
PRETO	3	2	2				7
VERM	3	2	2	12			7
	12	8	8				40
TOTAL							
RENDIMENTO: 1,86m ÷ 7 = 26cm				CUSTO:			

Fig. 12. Example of table-form in the base of tests

Table 2. Summarized results of tests with 350 images

Method	Rate of processed images	Rate of rejected images	Rate of correctly interpreted images
Without using artefact analysis	211 (69%)	94 (31%)	196 (64%)
With using artefact analysis	299 (98%)	6 (2%)	260 (85%)

errors , i.e., their contents were 100% correctly interpreted. Initially, with no artefact analysis, 211 images (69%), were correctly processed and 94 images (31%) were rejected. From the 211 correctly processed images, 196 (64%) were correctly interpreted. The process was then repeated applying artefact analysis. 299 images (98%) were correctly processed and 6 images (2%) were rejected. For the 299 processed images, 260 (85%) were correctly interpreted. A significant result that can be observed is that without artefact analysis 31% of the table-form images in the base were rejected, whereas this index decreased to 2%, keeping an index of 85% for correctly interpreted images, by applying artefact analysis. These results are summarized in table 2.

4 Conclusions

An original identification method, for detecting and deleting smudges and overlaps between data and faulty segments in handwritten filled table-forms has been proposed in this paper. Based on the variation interval $\mu \pm 1.645 * \sigma$, on the coefficient of Pearson and on the compactness property, the proposed artefact identification method has shown to be effective in identifying different kinds of artefacts and in deleting overlaps. The experimental results presented show the significance of using the proposed artefact identification method to improve table-form interpretation rates.

Summarizing the advantages of the method, we mention the possibility of applying it to different types of handwritten filled table-forms for identification of handwritten smudges, of overlaps between handwritten data and table lines, as well as the intersection defects, all that with very little use of *a priori* knowledge.

Acknowledgments

We would like to acknowledge support for this research from UFCG, PUCPR and the PROCAD Program from CAPES/MEC (Brazilian government, project number 153/01-1).

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