A Novel Skew Detection Technique Based on Vertical Projections

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Abstract— **Document skew detection is often done by the use of horizontal projections. In this paper, we introduce a new document skew detection approach that is based on vertical projections as well as bounding box minimization criterion. We motivated by the fact that the majority of the Latin characters have vertical strokes. We claim that the proposed approach is more efficient and gives more accurate results compared with the state-of-the-art skew detection algorithm based on horizontal projections since it is noise and warp resistant. For these reasons, it can be efficiently applied to historical machine printed documents. Experimental results on a database with representative historical printed documents prove the efficiency of the proposed approach. Moreover, an analysis of the performance of the main elements of the proposed technique is also done.**

Keywords – Document Skew Detection; Vertical Image Projections; Historical Document Image Processing

I. INTRODUCTION

One of the most important document image analysis step is the detection and correction of its skew. Some degree of skew is unavoidable either a paper is scanned manually or mechanically. This results in a skewed image. A reliable skew estimation and correction technique has to be used in scanned documents as a pre-processing stage in almost all document analysis and recognition systems. In the literature, a variety of skew detection and correction techniques are available. Skew estimation approaches are classified into four main categories according to the basic approach they adopt [1]. It includes Hough transform [2], projection profile [3-7], nearest neighbor clustering [8] and interline cross correlation [10].

The traditional projection profile approach is a simple solution to detect skew angle of a document image. It is initially proposed by Postl [3] and is based on horizontal projection profile. According to this approach, a series of horizontal projection profiles are calculated at a range of angles. The profile with maximum variation refers the best alignment to the text lines. At this stage, projection angle is the actual skew angle of the skewed document. In order to reduce high computational costs, several variations of this basic method have been proposed. Baird [4] proposes a technique for selecting the points to be projected: for each connected component the midpoint of the bottom side of the bounding box is projected. The objective function is to compute the sum of the squares of the profiles. Ciardiello [5] projected selected sub-region (one with high density of black pixels per row) of the document image; the function is to maximize the mean square deviation of the profile. Ishitani [6] uses a profile which is defined in a different style. A cluster of parallel lines on the image is selected and the bins of the profile store the number of black/white transitions along the lines. Bloomberg [7] reduce computational complexity of projection profile based approach by extracting a sample image in the skewed document. Skew angle is calculated by sample image rather than whole document and this results in a faster skew estimation method.

To conclude, projection profile based approaches are computationally expensive as different projections are calculated at different angles in a particular range. Additionally, projection profile methods are limited to estimate skew angle within ±10° to 15° [4] [9]. Moreover, the accuracy depends upon the angular resolution of the projection profile. Finally, projection profile based approaches cannot deal with noisy documents and broken characters [9].

After examining all the skew detection methodologies that are based on projection profiles we observe that only horizontal projections are used. In this work, we are motivated from the fact that the majority of the Latin characters have vertical strokes and we propose a new skew correction approach based on vertical projections that are noise and warp resistant.

II. PROPOSED METHODOLOGY

The horizontal projection profile is based on the histogram of black pixels along horizontal scan-lines. For a script with horizontal text lines, the horizontal projection profile will have peaks at text line positions and troughs at positions in between successive text lines [10]. This concludes to the fact that any noise and warp will ruin those peaks and troughs of the horizontal projection histogram and the efficiency of this technique. The proposed skew estimation methodology is based on vertical projections, which we claim to be noise and warp resistant. In the vertical approach, in a script with horizontal orientation, we don't expect any troughs but we seek for higher density of black pixels, concentrated in certain columns when the text is properly aligned. This is due to the nature of the Latin alphabet, with the majority of its characters (33/52) having at least one major vertical oriented stroke (see Fig.1).

Figure 1. The latin alphabet with the major vertical strokes circled. There are secondary vertical strokes which also contribute in the performance of the proposed method.

According to relative frequency of Latin alphabet characters in several languages (English [11], Spanish [12], French [13] and German [14], see Table I), we jumped into the conclusion that over 61% of the characters in a random text have at least one major vertical stroke.

TABLE I.   RELATIVE FREQUENCY OF LATIN ALPHABET CHARACTERS IN THE MOST COMMON LANGUAGES

| Characters of Latin Alphabet	Common Languages with Latin Alphabet			
	English	*Spanish*	*French*	*German*
A	8.167%	7.636%	6.51%	12.53%
B	1.492%	0.901%	1.89%	1.42%
C	2.782%	3.260%	3.06%	4.68%
D	4.253%	3.669%	5.08%	5.86%
E	12.702%	14.715%	17.40%	13.68%
F	2.228%	1.066%	1.66%	0.69%
G	2.015%	0.866%	3.01%	1.01%
H	6.094%	0.737%	4.76%	0.70%
I	6.966%	7.529%	7.55%	6.25%
J	0.153%	0.545%	0.27%	0.44%
K	0.772%	0.049%	1.21%	0.01%
L	4.025%	5.456%	3.44%	4.97%
M	2.406%	2.968%	2.53%	3.15%
N	6.749%	7.095%	9.78%	6.71%
O	7.507%	5.378%	2.51%	8.68%
P	1.929%	3.021%	0.79%	2.51%
Q	0.095%	1.362%	0.02%	0.88%
R	5.987%	6.553%	7.00%	6.87%
S	6.327%	7.948%	7.27%	7.98%
T	9.056%	7.244%	6.15%	4.63%
U	2.758%	6.311%	4.35%	3.93%
V	0.978%	1.628%	0.67%	0.90%
W	2.360%	0.114%	1.89%	0.02%
X	0.150%	0.387%	0.03%	0.22%
Y	1.974%	0.308%	0.04%	0.90%
Z	0.074%	0.136%	1.13%	0.52%
Characters with Major Vertical Strokes	**62.42%**	**61.51%**	**62.4%**	**61.02%**

In this way it can be observed that by summing the black pixels of each column and computing the energy at a number of angles that we rotate the document, the higher energy will be matched with the correct skew angle in which the vertical strokes of all rows are aligned and so we have bigger concentration of black pixels in certain columns. This concludes in the estimation of the skew angle. In order to compute the highest concentration of black pixels we detect the angle in which the energy function $A(\theta)$ is maximized:

$$A(\theta) = \sum_{i=1}^{m} c_i^2(\theta) \qquad (1)$$

where m is the width of the image and $c_i(\theta)$ is the number of black pixels counted in the i-th column while the document was rotated by angle θ.

As you can see from the histograms in Fig.2, when the document is properly aligned (see Fig.2a) great peaks are observed in certain columns, which show great concentration of black pixels and consequently vertical-stroke alignment. On the other hand when there is skew in the document all of the peaks will be average (see Fig.2b). It is observed that in documents as the number of the rows, more and more vertical strokes will be aligned in the correct skew angle. That results in even greater difference between the peaks of the histogram. Also the black border of a scanned page might be formed of vertical lines and this will also contribute in deskewing the document when the proposed method is applied (see Fig.3).

Since we are not expecting or depending on any troughs, noise will not affect our results, if it is relatively uniformly distributed, and not in random lines. Moreover warp, which is majorly affecting the troughs in the horizontal projection profiles, has no impact in our method, since the vertical strokes remain almost inviolated.
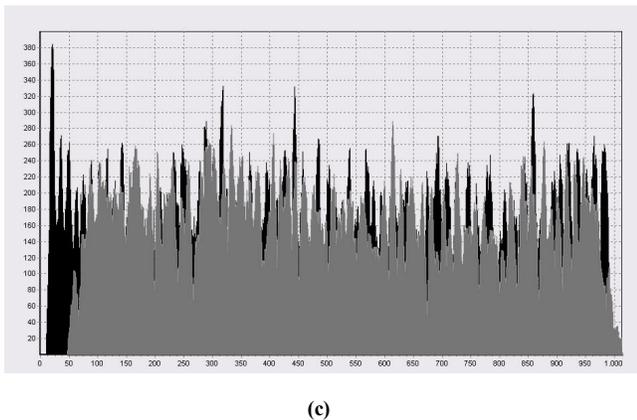

(a)

(b)

(c)
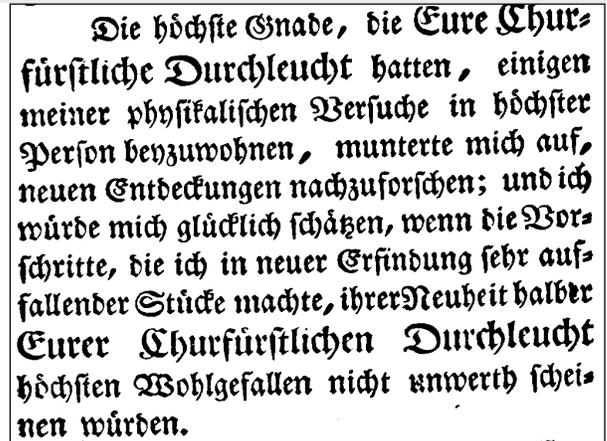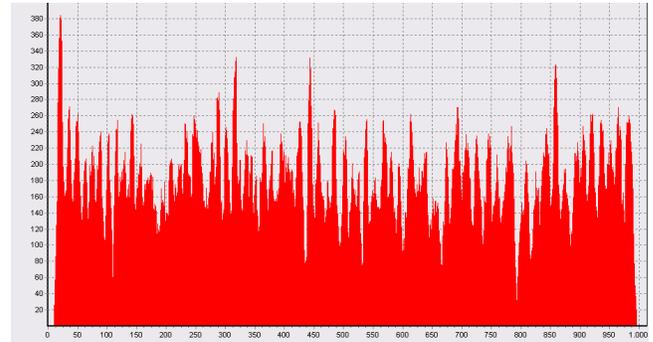
Figure 2. Sample of german historical document with significant warping (a) vertical histogramm / document with no skew, (b) vertical histogram / document with 5 degrees skew, (c) comparison of histograms of a and b.

Additionally, we improved our vertical projection algorithm by combing it with a bounding box approach. Techniques based on the same idea are common is skew detection [15]. We estimate the area of the rectangle that includes the 4 extreme points of the text and then we use it to divide the energy that we calculate from eq.1.
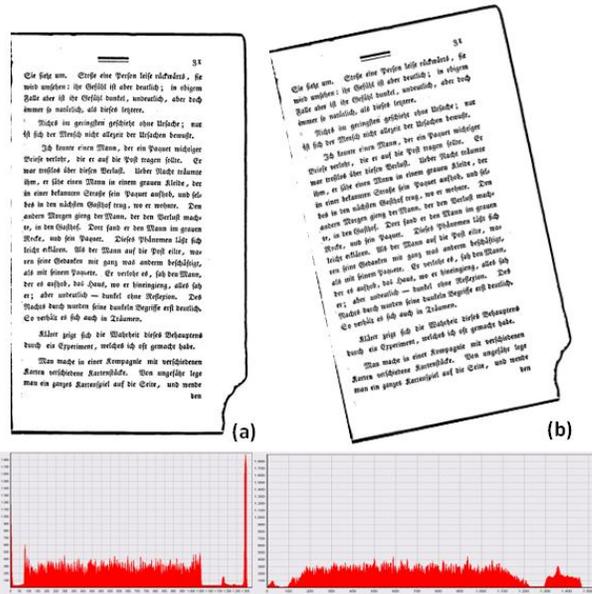

Figure 3. The histograms of a deskewd (a) and a skewed (b) image show the contribution of the black borders of the page when it's aligned.

$$T(\theta) = \frac{A(\theta)}{0.3(X_a - X_b)(Y_a - Y_d)} \qquad (2)$$

where X_a, X_b, Y_a and Y_d are the coordinates of the extreme points of our bounding box (see Fig.4), while 0.3 is the specified weight that we use to adjust the contribution of each technique.
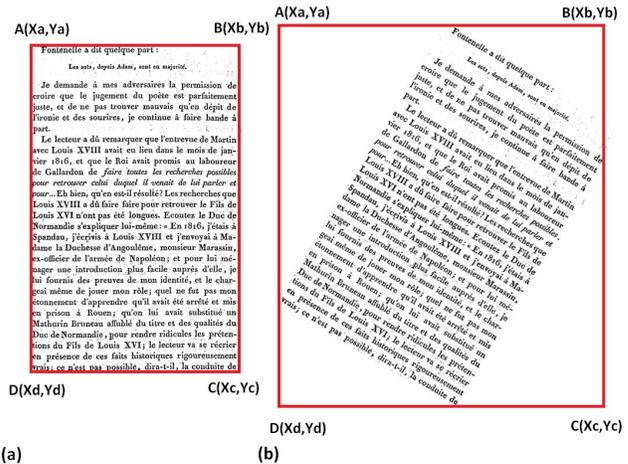

(a) **(b)**

Figure 4. The area of the bounding box $((Xa\text{-}Xb)*(Ya\text{-}Yd))$ that includes the text is minimum when the image is aligned.

Since the area of the boundary box is minimum for a text with no skew and the energy maximum, when we compute their ratio, $T(\theta)$ maximizes.

III. Experimental Results

In order to test the proposed methodology two historical books were used. One from Eckartshausen, which was published in 1788 and is owned by the Bavarian State Library [16], and a French historical book, which was published in 1838, and is owned by the Bibliothèque nationale de France [17]. Some of the images of the book suffer from several problems such as warp, noise and degradations (see Fig. 5 and 6).

We rotated the scanned printed document images in different angles and we estimated the skew with 4 different algorithms. A horizontal projections profile methodology based on [3], the horizontal projection profile methodology combined with the minimization of the bounding box technique, the proposed vertical projection profiles approach and the proposed vertical projections profile algorithm combined with minimization of the bounding box.

A. Testing in Fullpage Images

Our test-set was formed by 144 simply scanned and binarized document images, with the page borders, noise and blank spots included. Neither segmentation, nor denoising or dewarping or any other pre-process took place. We rotated each image for 11 different angles, from -5° to 5° with 1° step, while the accuracy that the algorithms presumed adequate was 0.2°, as their step in the successive rotations in order to estimate the skew was also 0.2°. The results presented are from a 1584 different estimations for each of the algorithms (see Table II).

TABLE II.   RESULTS FROM DEGRADED FULL-PAGE IMAGES

Different Skew Estimation Techniques	Error Deviation in Degrees	Percent of Correct Estimation
Simple Vertical Projection Profile Technique	**0.17**	**54.42%**
Simple Horizontal Projection Profile Technique	0.26	36.87%
Combined Vertical Projretion Profile Technique	**0.14**	**58.46%**
Combined Horizontal Projretion Profile Technique	0.23	40.65%

B. Testing only in Text Region of the Images

Afterwards the images of the test–set were segmented excluding the page borders. We also rotated each image for 11 different angles, from -5° to 5° with 1° step, while the accuracy that the algorithms presumed adequate was 0.2°, as their step in the successive rotations in order to estimate skew was 0.2°. The results presented are from a 1584 different estimations for each of the algorithms (see Table III).

TABLE III.   RESULTS FROM DEGRADED SEGMENTED IMAGES

Different Skew Estimation Techniques	Error Deviation in Degrees	Percent of Correct Estimation
Simple Vertical Projection Profile Technique	**0.27**	**40.35%**
Simple Horizontal Projection Profile Technique	0.40	27.65%
Combined Vertical Projretion Profile Technique	**0.22**	**46.65%**
Combined Horizontal Projretion Profile Technique	0.40	28.85%

The results demonstrate that in degraded images with noise and warp the proposed method is more accurate than the horizontal projection profiles method. Also the contribution of the minimizing of the bounding box technique that we combined is clear in all cases. Last but not least it is easily observed that the borders of the scanned documents help in the accuracy of all the methods tested, since all algorithms had better results in full pages than in segmented documents.
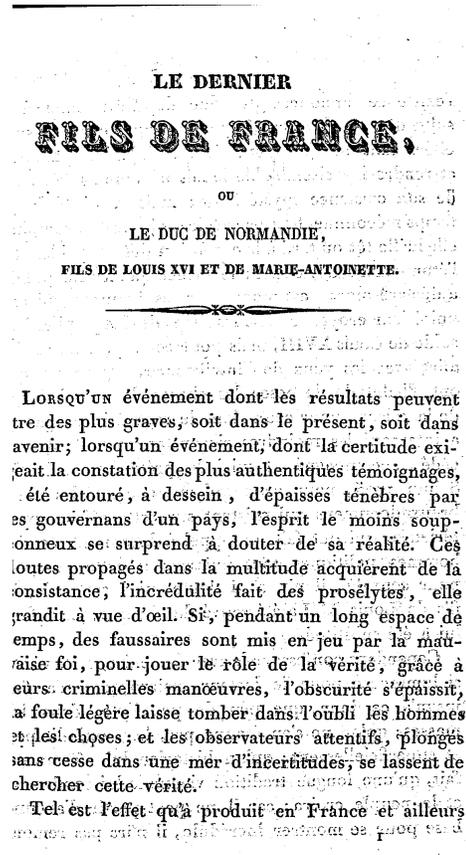

Figure 5.   Sample of french historical document with significant noise and warp from our test-set.

IV. CONCLUSION

A new efficient skew detection technique is presented, that can be applied in degraded documents without any previous segmentation, denoising or dewarping. Our technique proves to be resistant in noise and warp in contradiction to what is claimed for projection profile based approaches [9]. Our technique has better and better results as more and more strokes from different rows are vertically aligned and as it is easily observed the black borders of the images contribute in the correct estimation of the proposed method since in segmented images the results are worse than in full unprocessed images. Furthermore the contribution of the minimization of the bounding box technique, which we combined with the projection profile approach, is clearly demonstrated, since it improves both horizontal and vertical projection profile approaches. In addition we observed that our vertical approach is complimentary to the horizontal, since it has excellent results in documents that the horizontal approach fails, and we expect even better results for smaller step of rotation in our algorithm, since accuracy is very important in the alignment of the vertical strokes, especially as the height of the document increases. Finally, we have to point out that since most of the documents scanned from a book suffer from warp, noise and the image includes the page outline, our technique should be more efficient, especially in historical books with major degradations.
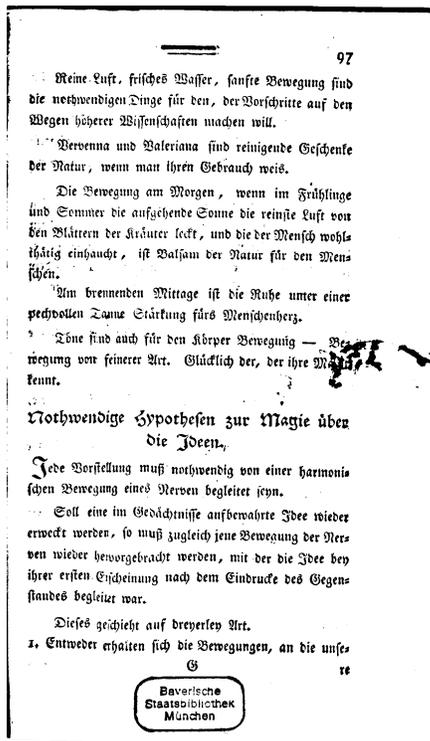

Figure 6. Sample of german historical document with significant noise and warp from our test-set.

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