Automatic Slope Evaluation of Handwritten Text

Georgi Gluhchev, Federico Thomas

Abstract: *A new approach for the evaluation of the average slope of the vertically oriented strokes of handwritten characters is described. It is based on the properties of the Fourier Transform which allow accumulating energy of pixels lying on straight lines of same slope alongside a single straight line in the frequency domain. The slope of the latter determines straightforwardly the stroke slope since both slopes differ in p/2.*

Key words: *Handwriting, Line slope, Segmentation*

INTRODUCTION

The slope evaluation is essential part in handwritten document processing. It may either support other processing steps like segmentation of words and characters or be an important identification feature for writer recognition. A new emerging area of interest concerns the increased people mobility and development of fast and reliable authentication systems based on biometric parameters, including handwriting. The ever increasing threats of illegal access to specific information or equipment require developing of reliable and non-abusive access-permit systems where the one- or off-line signature processing is included as well.

The slope of the strokes is one of the parameters that are always used. It reflects the established writer's dynamic stereotype. It may play a significant role in cases where no forgery is expected, or in case of specific handwriting. However, strictly determined slope does not exist at all due to the natural variations of handwriting from the one hand, and different stroke slope inherent to specific characters and connections between them, on the other hand. This specificity has lead to the qualitative estimation of the slope in terms of categories as "left", "upright", right", "predominantly right" and like. But they do not indicate exactly how big the slope is and do not make it possible to distinguish between different "right" slopes for example. But the slope measurement is tedious and time consuming work and is prone to subjectivity. By this reason an objective measure of the "average" slope of the strokes is desirable.

Different heuristics and Hough Transform (HT) based techniques have been used for the detection of line slope [1,4,5]. Since HT is generally applied to binarized images, to apply it for halftone images V. Shapiro [4] replaces the original image by a simulated one, using the DH (Digital Halftone) transform and showing the closeness of the obtained results to those obtained from RD (Radon transform) applied to the original half tone image. Thus the computational cost inherent to RD is reduced. However, it is hardly applicable to the problem of stroke slope evaluation. In [1] an attempt in this direction is made, also based on HT, where a method is proposed making the HT-approximation error close to zero. Thus, evaluating maximums in HT-space the row slope and character tilt could be evaluated. The major problem in all HT-based cases concerns the calculation workload.

In this paper an approach is suggested dealing with halftone images and giving the possibility for fast and reliable stroke slope evaluation. It is based on the well known properties of the Fourier Transform (FT) which is an additional advantage, because one can use optimized FT procedures included in the libraries of scientific oriented software products like Matlab.

THE APPROACH

The approach is based on the fact that the Fourier Transform of a straight line of slope *?* is a straight line of slope *? + p/2*. This statement could be checked in the following way.

Let the image *f(p,q)* of size *NxN* contains only the horizontal line l_o: *q*=0, i.e. $f(p,q)=\begin{cases}1, & if \quad q=0\\ 0, & otherwise\end{cases}$.

Its DFT (Discrete Fourier Transform) is obtained according to the following formula [2]

$$g(m,n)=\frac{1}{N}\sum_{p=0}^{N-1}\sum_{q=0}^{N-1} f(p,q)\exp(-2pj\frac{mp+nq}{N}) = \frac{1}{N}\sum_{p=0}^{N-1} exp(-2pj\frac{mp}{N}) \quad (1)$$

The summands from the last sum are terms of a geometric progression with a quotient $\exp(-2pjm/N)$, therefore

$$g(m,n)=\frac{1}{N}\frac{(\exp(-2pjm/N))^N-1}{\exp(-2pjm/N)-1} = \begin{cases}1, & if \;\; m=0\\ 0, & otherwise\end{cases} \quad (2)$$

Thus, DFT of l_o is the vertical straight line at *m* = 0, which may be taught as a rotation of l_o at 90^0 about the origin.

Let now the horizontal line l_o be shifted at the position q_o ? 0. According to the shifting property of FT [2,3] we will have

$$\hat{g}(m,n)=g(m,n)\exp(-2pj\frac{nq_o}{N}) \quad (3)$$

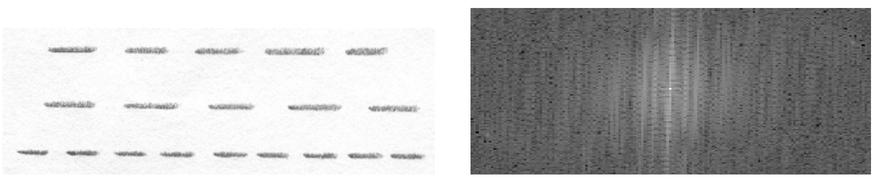
$\hat{g}(m,n)=0$ for *m* > 0 and an arbitrary *n* < *N* since $g(m,n)=0$ in that case. At *m* = 0 the value of $\hat{g}(0,n)$ will be $g(0,n) = \exp(-2pj\frac{nq_o}{N})$, i.e., again the only non-zero column will be the first one. This result shows that if we have a few horizontal straight line segments in *f*(*p,q*) their DFT will result in a non-zero column at the origin. This is so because the image *f*(*p,q*) could be presented as a sum of as many as the number of segments is images, each of them containing just one segment. Therefore, DFT of a set of horizontal lines will be an image of zero entries except the ones alongside the first vertical column.

In the same way using the rotation property of FT we may claim that the FT of a line $l_?$ of slope *?* will result in the rotation at angle *?* of the FT of line l_o. Therefore the FT of the rotated line will be a non-zero line rotated at the angle *? + p/2.* Same will be valid for a set of line segments oriented at an angle *?.* This suggests the following technique for the detection and extraction of straight lines of same slope in a source image *f*(*p,q*).

1. Evaluate *g*(*m*,*n*) as a centered DFT of *f*(*p,q*).
2. Using a circular scan of *g*(*m*,*n*) about the center detect the peaks alongside the circle.
3. Evaluate the angle of line through the center and the maximal peak.

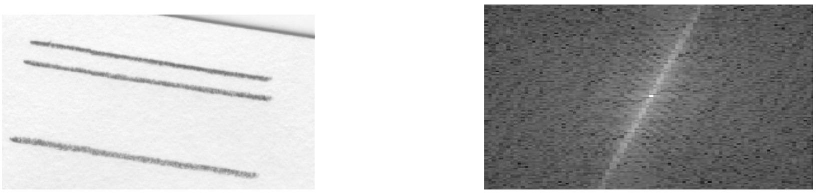
EXPERIMENTAL RESULTS

To check the efficacy of the approach different experiments have been carried out in Matlab environment. In the first experiments gray scale images with line segments of almost same orientation were used. Fig. 1 shows dashed lines oriented horizontally. Its DFT is shown in Fig. 1b. The bright vertical line through the origin is clearly visible. The evaluated slope is about 87^0 which means a declination of the lines at an angle of about 3^0. In Fig. 2 sloped line segments are present together with their DFT. An angle of 76.2^0 is detected from the image in Fig. 2b which corresponds to -13.8^0 of slope for the original image.



a) b)

Fig. 1. a) Dashed horizontal lines, b) DFT of the image from a)



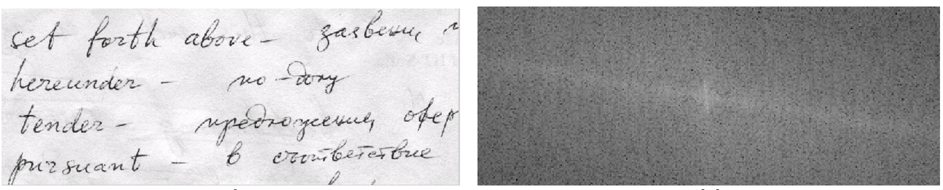
a) b)

Fig. 2. a) Slant lines, b) DFT of the image from a)

The background around the vertical line in Fig 1b and the sloped line in Fig. 2b is not uniform which is due to the non-zero background in the original image. Also, the lines drawn by pencil are not fully black and of same width as it could be seen in Fig. 1a and Fig. 2a. This may cause problems with the correct detection of the slope. To avoid random bright pixels in the DFT image that may produce false maximums, it is better to use different radii of circular scanning. In these simple cases a value of about 1/6 of the image height was used without problems.

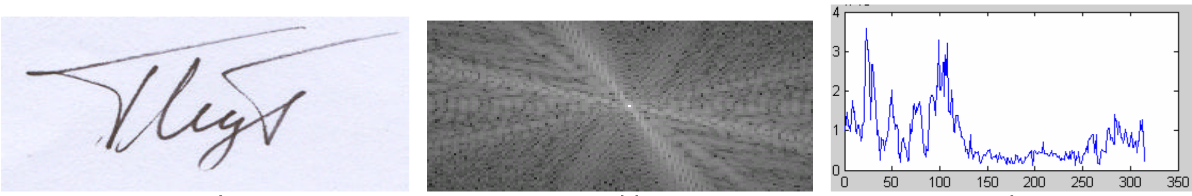
The above examples contained simple images. To be useful in practice the approach has to have the ability to detect the slope in more complicated cases, consisting of strokes of different orientation, provided predominant orientation exists. For this, pieces of handwriting have been checked (Fig. 3 and Fig. 4). It was interesting to know weather the length of the handwritten line could hamper the proper detection of handwriting slant. For the image in Fig. 3a) a slant angle of 81^0 is found which seems to correspond to the real situation. It's worth noting that despite the predominant text length a correct slope angle was detected. The background is non-homogeneous to such an extent that it is actually not possible to eliminate it without character distortion. However, in case of a single row consisting of a few words the maximal value may correspond to the row's direction. This suggest that the circular scanning has to be carried out in the range of [3p/4, p] and [0, p/4], assuming that a stroke slope less than p/4 is not possible.

In Fig. 4 an example of a signature is shown. An angle of 75^0 was evaluated. The longest line in DFT image corresponds to the stroke slant. The other two bright lines describe the slope of the upper signature strokes inclined less than p/4 and the slope of the intermediate connecting elements.



a) b)

Fig.3. a) source image, b) DFT of the source image



a) b) c)

Fig. 4. a) Signature, b) DFT of the signature, c) Plot of circular scanning

Detecting the slope angle one could apply inverse FT preserving only the values alongside the corresponding line in the FT domain. Fig. 5a) presents the result of such an operation for the image in Fig. 4a). Applying a proper threshold one will obtain the image in Fig. 5b) where the lines correspond to the major vertically oriented strokes in the signature. Distances between them may be used as another quantitative identification parameter.

a) b)

Fig. 5. a) Inverse FT alongside the slope, b) Extraction of the black lines

CONCLUSIONS AND FUTURE WORK

In this paper a DFT (Discrete Fourier Transform) based approach is described which allows automatic detecting of the slope of straight line segments. It does not assume a binarized image as an input. Basic properties of FT are used to prove its adequacy. Using the well developed procedures for the evaluation of FT, the approach does not require many efforts for its implementation and it is computationally inexpensive. The preliminary experiments have shown that it is robust to the background structure and to the quality of the foreground object. It also has the possibility to extract the more prominent strokes in signatures, thus allowing for the objective evaluation of quantitative features and segmentation. This is the problem where the future work will be aimed at.

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ABOUT THE AUTHORS

Assoc. Prof. Georgi Gluhchev, Ph.D., Institute of Information Technologies, BAS, (+359)2 870-6493, e-mail: gluhchev@iinf.bas.bg

Assoc. Prof. Federico Thomas, Institute of Industrial Robotics and Informatics, CSIC, Barcelona, Spain, +34 934015783, e-mail: *fthomas@iri.upc.es*