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An Enhanced Transformation Model to Remove Staircase Effect while Transforming Arc-form-text to Linear-form-text

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Abstract—Arc-form-text is an artistic-text which is quite common in documents such as certificates, advertisements and history documents. Optical character readers (OCRs) fail to read such arc-form-text and it is quite necessary to transform the same to linear-form-text. In this paper, we present an enhancement made to an existing transformation model to overcome the limitations of staircase effect for better readability by OCRs. The method takes the segmented arc-form-text as input. Initially two concentric ellipses are approximated to enclose the arc-form-text and later the enhanced transformation model transforms the characters in the arc-form to linear-form without variations in character size. The proposed method restructures the transformed text to uniform size and is implemented on several upper semi-circular arc-form-text inputs and the readability of the transformed text is analyzed with an OCR.

Keywords—Arc-form-text; Linear-form-text; Transformation; staircase effect; OCR

I. INTRODUCTION

Document image analysis (DIA) is an important research discipline in the area of Image Processing. Many researchers are working on different problems of document images starting from image acquisition to image understanding [1,2]. The research in this field is focusing to come out with generic approaches to accomplish automation in document reading, extracting contents from documents and these have lead to many vibrant research problems [2]. The results of the research on the above problems are converging towards the generic solutions to major issues in DIA. In spite of considerable research work in the area of DIA, a major issue which is not sufficiently addressed is, reading or extracting the contents of the text which appear in artistic-form in a document. Many documents, especially certificates, marks cards, sign boards, logos, etc., have artistic text. The contents of such artistic-text definitely have some valuable information that has to be processed. If such document has to be processed by an OCR, it should be able to read such artistic-text or proper pre-processing is required to make such text readable by OCR. Samples of few such artistic-texts are shown in Fig. 1. The contents of such text normally conveys information regarding identity like company's name, type of document, etc., which is the main source for the classification of the document.

Fig. 1 Samples of Artistic-Form text in document

OCRs when fed with documents containing artistic-text, are unable to read the contents as they are developed to read horizontal linear texts. Hence, it is necessary to transform artistic-text to horizontal

linear-text such that OCRs are able to read the contents efficiently. Approaches developed for general skew detection and correction are not suitable to transform such artistic-text documents into linear form. Hence, it is required to come out with different approaches that can transform artistic-form text into linear-form text and make the same suitable for reading by an OCR.

One of the major problems encountered in DIA is inherent skew noticed in documents [3,4]. Inherent skew, is due to the natural inclinations of text lines in the document. Considerable amount of work is reported in literature on explicit skew detection [5-14]. Each of the approaches reported in literature on explicit skew detection has its own advantages and limitations and these approaches are not extendable for detecting inherent skew. Since artistic texts also have inherent orientation in the document, artistic-texts are said to have inherent skew. To the best of our efforts while surveying for literature in the direction of inherent skew detection and correction, we could find the work of Pal et al., [3] in detecting multiple skewed lines within a document, i.e., detecting lines within the document having different orientations and the work carried out by Vasudev et al., [15] to transform arc-form-text to linear-form. The work proposed by Vasudev et al., performs transformation to considerable extent but suffers from tilt deformation and an additional stage is required for tilt corrections. The average readability efficiency after transformation is claimed as 90% in this method. Further, the work proposed by Vijayashree et al., [16] performs modified transformation to the work proposed by Vasudev et al., [15] which transforms the arc-form-text to linear-form-text to overcome the tilt deformations and the average readability after transformation is claimed around 95%. The work proposed by Vijayashree et al., [16] makes use of line drawing algorithm [17] for transformation and the staircase effect in line drawing causes variations to the sizes in the transformed characters. The limitations of variations in size of the transformed text of approach [16] has motivated us to continue the work to design an even better efficient transformation model that transforms the arc-form-text to linear-form-text without tilt deformations and size variations to produce the output more suitable to OCR for better readability.

The proposed work assumes that the arc-form-text has been segmented out from document, is free from noise and is limited to only in the upper half circle or ellipse as input. The proposed model initially works as given in [16] and the same is described in section 2. The enhancement incorporated in transformation to reduce the staircase effect is provided in section 3. Experimental results are discussed in section 4. The conclusion about the work is given in section 5.

II. INITIAL TRANSFORMATION

The transformation model to transform arc-form-text to linear-form requires two imaginary elliptical arcs [17] to be searched which encloses the arc-form-text. The procedure developed in [16] is made use in this work. Fig. 2 shows sample of arc-form text as input and Fig. 3 shows the estimation of two imaginary elliptical arcs enclosing the arc-form-text under consideration using the algorithm given in [16].

Fig. 2 Arc-Form Input Text

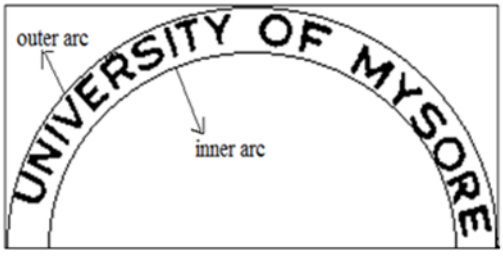


Fig. 3 Two Imaginary Arcs to Enclose Arc-Form-Text

Though the inner arc does not contribute much during the process of transformation, it is useful in detecting the height of the text and to prevent any transformation process, which would occur within the arc-form region. After enclosing the arc-text between two imaginary suitable arcs, it is required to transform all the points on this elliptical band into a linear band of points and the same is explained subsequently.

In this transformation model, a set of points representing line in one orientation is transformed to represent a line of points in another orientation. Extending this concept, an arc-form text can be considered as a set of n consecutive lines in different orientations, where n being the distinct points on surface of the outer arc. These n lines with different orientations projecting to the centre of arc are transformed to n vertical lines and this result in the text appearing horizontally linear. For comprehension Fig. 4 shows how *n* lines within two arcs having different orientation with respect to centre of arc are represented as *n* vertical lines.

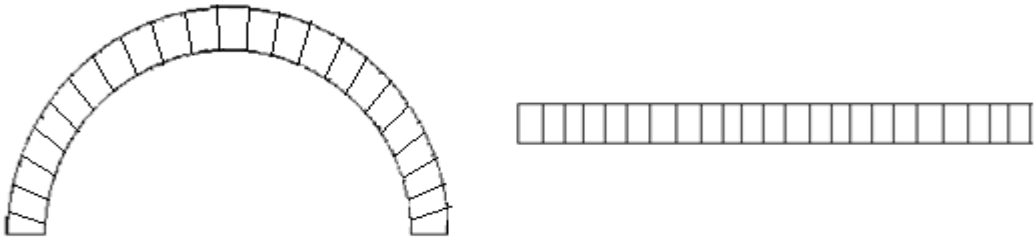


Fig. 4 Representation of n lines in different orientations within two arcs as n vertical lines

A transformation function **T** can be expressed as,

$$S = T[F] \quad (1)$$

where

$F = \{l_1, l_2, \ldots, l_n\}$, l_i $\forall$ i = 1,…,n is the i^{th} line within arcs having m points

$S = \{l_{t1}, l_{t2}, \ldots l_{tn}\}$, l_{ti} $\forall$ i = 1,…,n is the i^{th} transformed line having m points

T is the transformation function that simply puts the points of l_i on l_{ti} and

$l_i = \{p1, p2, \ldots, pm\}$, p_j $\forall$ j= 1,…,m is the j^{th} point on the i^{th} line within the arc

$l_{ti} = \{q_1, q_2, .., qm\}$, q_j $\forall$ j = 1,…,m is the j^{th} point on the i^{th} transformed line

$q_k = T[p_k]$ $\forall$ k = 1,… m, m is the number of points in the k^{th} line l_k and transformed line l_{tk}

To transform arc-form text to linear form, a series of lines from the centre of the arc are drawn to each point on the surface of the outer arc, as shown in Fig. 5.

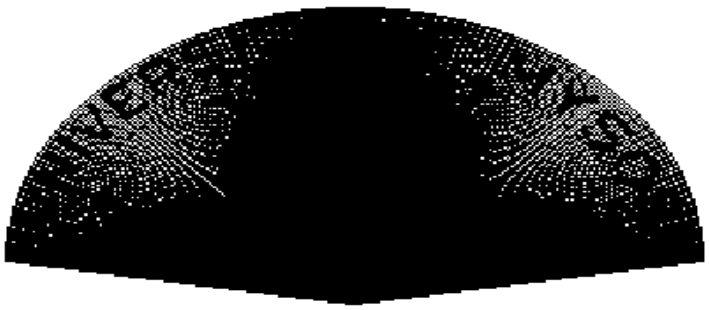


Fig. 5 Lines drawn from the centre of the ellipse to the outer ellipse

The transformation algorithm [16] is used to transform distinct n lines in different orientations appearing between two arcs is shown in Fig. 6 for the input shown in Fig. 3 It is evident from Fig. 6 that arc-form-text gets transformed to linear form, without tilt deformations. However, variations in

height in few characters and distortions are noticed due to the contributions of staircase effect in the lines.

Fig. 6 Transformed text to Linear-Form

III. ENHANCED TRANSFORMATION MODEL

It is quite clear from computer graphics [17], that all the lines drawn which are not vertical and horizontal are not smooth. These un-smooth lines exhibit staircase structures resulting in variations in the number of pixels in the lines for the same distances in different orientations as shown in Fig. 7.

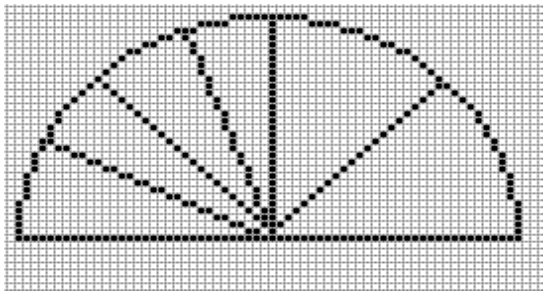


Fig. 7 Variation in number of pixels in lines of the same size

It is noticed from Fig. 7 that the number of pixels in a line keeps reducing with orientations from 0^o to 45^o and keeps increasing from 45^o to 90^o. Similarly, the number of pixels in a line keeps decreasing from 90^o to 135^o and keeps increasing from 135^o to 180^o. The variations in the number of pixels in the lines with different orientations cause the variations in the size of the transformed text as shown in Fig. 6. The transformation is enhanced to overcome the size variation limitation through incorporating a correction process during the transformation as described below.

Let S_n be the standard pixel width between two arcs and L_n be the number of pixels found in a line for transformation. The number of pixels reduced in the line is given by

$$R_n = (S_n - L_n) \quad (2)$$

The interval distance (I) of pixels in the line where a new pixel is to be introduced for correction is given by

$$I = L_n / R_n \quad (3)$$

Next, the color of the new pixel to be inserted at position P is decided as

Black if pixel at P or (P-1) is ***Black*** else ***White***

The output of the enhanced transformation for the input in Fig. 2 is shown in Fig. 8, which illustrates the elimination of size variations in the transformed characters.

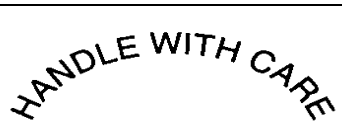
Fig. 8: Result of Enhanced Transformation

IV. EXPERIMENTAL RESULT

Experiments are conducted on the arc-form-text with different sizes and different arc shapes for English texts. The results of experiments establish readability ranging between 93% - 100% with an overall average readability of 98% which is considerably a quite better result than the results claimed by earlier approaches [15, 16]. The result of the enhanced transformation provides a better and more suitable pre-processed input for OCRs. Few experimental results are illustrated in Table-1 along with

the results of approach [16] to visualize the improvement in the enhanced transformation. Analysis of readability by an OCR of the text after transformation is performed with respect to English text using the OCR "Readiris Pro 9"[18].

Table-1: Output Results of Transformations Made from Approach [16] and the Enhanced Model

Input arc-form-text	Transformation Using[16]	Enhanced Transformation
	SPORTS CLUB	SPORTS CLUB
	SOURCE OF RICHNESS	SOURCE OF RICHNESS
	Many researcher are have	Many researcher are have
	HANDLE WITH CARE	HANDLE WITH CARE
	ADVENTURE SPORTS	ADVENTURE SPORTS
	ROYAL RAJASTHAN	ROYAL RAJASTHAN

Around 150 input samples were considered for experimentation consisting of different font size, font style and radius. The samples shown in Table-1 were resized to fit in the page for documentation. OCR failed to read certain transformed characters which were more distorted and connected. Certain amounts of distortions were introduced in the transformed characters while inserting new pixels. Table-2 shows the comparison of average readability by OCR after transformation for the three approaches.

Table-2: Comparison of Average Readability by Different Transformations

Transformation Proposed by	Average Readability by OCR
Vasudev et al [15]	90%
Vijayashree et al [16]	95%
Enhanced approach	98%

V. CONCLUSION

The proposed approach efficiently transforms an arc-form-text without tilt deformations and no variations in the sizes of the transformed characters. The transformed text serves as better preprocessed input to the OCR for better readability. OCR shows an average readability of 98% after transformation which is relatively better than the earlier approaches. The method can be extended comfortably to transform text from other languages. Some amounts of distortions are noticed in the transformed character because of new pixels added during transformation. In addition slight variations are noticed in the alignment of the transformed text due the error in estimating the ellipses enclosing the arc-form-text. Further, there is scope to produce a much better distortion free, smooth and neatly aligned text in the transformation which is under investigation.

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