International Journal of Computer Science and Applications,
©Technomathematics Research Foundation
Vol. 14, No. 2, pp. 47 – 63, 2017

THE DIVIDE-AND-CONQUER BASED ALGORITHM TO DETECT AND CORRECT THE SKEW ANGLE IN THE OLD AGE HISTORICAL HANDWRITTEN MODI LIPI DOCUMENTS

MANISHA S. DESHMUKH[1], MANOJ P. PATIL[2], SATISH R. KOLHE[3]

School of Computer Sciences, North Maharashtra University,
Jalgaon, Maharashtra, India
manisha_d7@rediffmail.com[1] , mpp145@gmail.com[2] , srkolhe2000@gmail.com[3]

A divide-and-conquer based algorithm is presented here to detect the skew angle in handwritten old age Modi document images. The skew angle detection range is estimated by determining the inclination of the document image. A new horizontal projection profile based criterion function is proposed and used here to compute the concentration of the black pixels. The criterion function is scrutinized to estimate the rotational angle range and detect the skew angle of the document image. The results prove that the proposed technique has corrected skew angle in diverse types of document images. This method accurately identifies skew angle in the clockwise or anticlockwise direction in estimated rotational angle range up to ±89 degree with angular resolution 0.1 degree. The Modi Lipi document image dataset and benchmark online datasets are used to test and compare the performance of the proposed approach.

Keywords: divide-and-conquer, Modi Lipi, skew detection, horizontal projection profile, criterion function.

1. Introduction

The handwritten Modi documents have valuable and rare information as historical, land records, judicial, deals and deeds etc. They are archived in the libraries, museums as well as in the government, public and private sectors from long ago. These sectors are trying to preserve these chronic and valuable documents, but most of that are likely to be in destroying state. These sectors have been trying to keep these documents in the soft form by scanning and taking photos. These document images are suffered by number of degradations like noise and skew. When these documents will be made available in soft form for utilization for different purposes, it should be processed. The document image pre-processing has been pursuing the number of application areas including the selection of encoding methods for document archiving, information retrieval, transliteration systems, document recognition systems and transcription systems etc. [Sun and Deyi (1997)]. In the pre-processing, skew correction is a vital step like de-noising and enhancement of the document image. The Modi document images are suffered by skew because of two reasons. First one is the factual reason; the skew has been introduced while scanner or camera captures the image. The second reason is that the writing style of the Modi Lipi. These documents are written on the plain paper. Before to writing the text the straight line (Shirorekha) is drawn by hand. Generally, these lines drawn in slope and text is twisted for example as shown in Fig. 1.

Fig. 1. Skewed Modi document image samples.

Following challenges are identified during the detection of skew in the highly degraded handwritten Modi documents (Table1).

Table 1. Challenges in Modi document image

Sr. No.	Challenges
1	Multiple skew text lines
2	Multiple columns
3	Highly noisy and degrade text images
4	Full or partial thin or light text area
5	Variable size of text
6	Variable distance exists in between text lines
7	Non-uniform Shirorekha
8	Cursive style script
9	Documents might be containing the picture or symbols (stamps)
10	Variable length of the text lines (long and short)
11	Document might be containing less text area
12	Different resolution of document images
13	Overlapped and very dense text lines

Among all the skew detection techniques the horizontal projection profile is highly accurate with documents containing text only. The proposed skew detection method is implemented using the divide and conquer technique based on horizontal projection profile. In this approach inclination of the document is figured out and then angle range is estimated. The main aim of this research is to efficiently correct the skew of the highly-degraded cursive handwritten Modi Lipi documents without the restriction of the identifiable angle range and with reduced computational complexity. To achieve the goal, the new projection criterion function is recommended.

After introducing the perspective of Modi documents and necessity of the de-skewing of the documents in Section 1, Section 2 reviews the related work. In Section 3 the processes of the skew estimation algorithm is illustrated. The experimental results are discussed in the Section 4. The performance and comparison of the proposed technique is presented in Section 5. Section 6 is the concluding section.

2. Existing Work

Lots of studies have been done on skew detection and correction algorithms. These approaches are classified in the five categories as: 1) Projection profile approach; 2) Hough transform approach; 3) Fourier method approach; 4) Nearest-neighbor clustering approach; and 5) Correlation approach [Sun and Si (1997)] [Lin Chin-Teng et. al. (2006)] [[Hull (1998)]. None of these methods practically works for the documents suffered by one or more degradations listed in Table1. Every approach has advantages and limitations.

The projection profile technique is applied by Postl [Postl (1986)] in combination with the Fourier transform to detect the skew in the image. Various adaptations liked to down sampling [Bloomberg and Kopec (1993)] [Bloomberg and Kopec (1994)] and recursive subdivision [Chevillat and Schindler (1982)] are included with the projection profile analysis to improve the accuracy. Baird [Baird (1999)] [Mahanta and Deka (2013)] [Singh and Kaur (2013)] and [Kavallieratou et.al. (2002a)] proposed modifications to the projection profile technique and Fourier transform for the fast and accurate iterative convergence on the skew angle. It gives higher accuracy for skew correction in printed documents and words. The limitations of these methods are, it is time consuming and restriction of the identifiable angle range. Similarly, projection profile based technique is presented in [Papandreou et.al. (2014)], eliminated all the problems in existing projection profile based techniques. But, this method is appropriate with printed documents. Most of these approaches saves temporary storage and reduces the computational complexity. Similarly, projection profile based modified approaches are presented by [Mahanta and Deka (2013)] [Irfan (2016)]. This approach has limitations and basically suffered by two problems: i) Computational and time complexity ii) Identifiable angle range. These techniques are not dealing with cursive and noisy documents [Mahnaz and Maher (2015)]. For large images, the Fourier based method can be computationally very expensive [Lin Chin-Teng et.al. (2006)]. The research work in [Papandreou and Gatos (2011)] introduced skew detection approach based on vertical projections with bounding box minimization criterion. This method is not applicable for cursive or italic script.

The approaches presented by [Sun and Si (1997)] and [Omar et.al. (2012)] are correct the skew in printed document images using gradient information. These methods are not able to find out the skew in the document image contain italic font and cursive script. A skew angle estimation algorithm for binary document images based on the FCRM (fuzzy c-regression models) clustering method is presented in [Lin Chin-Teng et. al. (2006)]. It is time consuming and having higher computational cost than cross correlation approach [Lin Chin-Teng et.al. (2006)]. The horizontal RLSA based approach is presented in [Abuhaiba (2003)]. It is accurate, robust, and flexible to various conditions and on predefined parameters. This approach is script specific.

The number of approaches illustrated in literature are based on Hough transform for skew detection and correction. For example, the paper [Hosalli and Krishnamurthy (2012)], described a scheme for skew detection and correction of handwritten Kannada document using bounding box technique, Hough transform and contour detection. Similarly, [Kwag et. al. (2002)] [Nandini et.al. (2008)] [Kaur et. al. (2013)] [Ahmad Riaz et. al. (2016)] presents the modified techniques for the detection of skew angle based on Hough transform. The main limitation of these techniques is, if text is thin or light, it is difficult to choose a peak in the Hough space [Sun and Si (1997)] [Lin Chin-Teng et.al.(2006)]. The methods described in [Ravikumar and Manjunath (2013)] [Marcus et.al.(2012)] based on nearest neighbor clustering approach. The one advantage of these methods is that they are not angle range specific. But the accuracy of the approaches reduced on the noisy documents and if subpart of character (dot on 'i') and overlapped text lines are existing [Abuhaiba (2003)]. The restriction of the identifiable angle range is the main limitation of these methods [Lin Chin-Teng et. al.(2006)] . The skew angle estimation of the document page is performed by employing its horizontal histogram and the Wigner-Ville distribution (WVD) in [Kavallieratou et.al. (2002a)]. The performance of this system perfect only for the confidence range is greater than 0.38. The Randon transform based techniques are presented in [Kapoor et.al.(2004)] [Dong et. al. (2005)] [Patel et.al. (2012)]. The accuracy of Randon transform approaches is reduced in the case of words with non-uniform Shirorekha, characters without Shirorekha, very short length text and the text contains vertical lines [Kapoor et.al.(2004)] [Dong et. al. (2005)]. The benefit of both Randon transform and Wigner-Ville distribution based approaches is that they are not limited to range of skew angle detection. The connected component based skew estimation techniques presented in [Brodić and Dragan (2012)] [Brodic et.al.(2013)] [Ray (1995)] [Okun et.al. (1999)] [Panagiotis and Papamarkos (2008)]. These approaches estimated correct skew of the printed text containing longest connected component only. They do not work with handwritten documents [Lin Chin-Teng et. al. (2006)].

[Yan (1993)] introduced the cross-correlation based approach to estimate the skew angle. This method is applicable only when lines are present at a fixed distance [Omar et.al. (2012)]. This approach not efficient the document images containing graphs and inner strokes of characters [Lin Chin-Teng et. al. (2006)].

The algorithms based on center of gravity [Al-Shatnawi and Omar (2009)] and Run Length Smoothing algorithm [Abuhaiba (2003)] are script specific. The distance transform approach is analyzing the orientation of the background and few text lines. Thus, it is detecting skew properly in the documents which containing only text [Bar-Yosef et. al. (2008)]. The computational complexity of morphological approach for skew detection is depends on skew angle range [Najman L.A. (2003)]. This method is fully parameterized.

3. Skew Angle Correction Process

The skew detection and estimation process mainly works in three steps: i) Estimation of inclination of the document text; ii) Determination of the direction of rotation; and iii) Skew angle detection. The workflow diagram for skew detection and correction is depicted in Fig. 2.

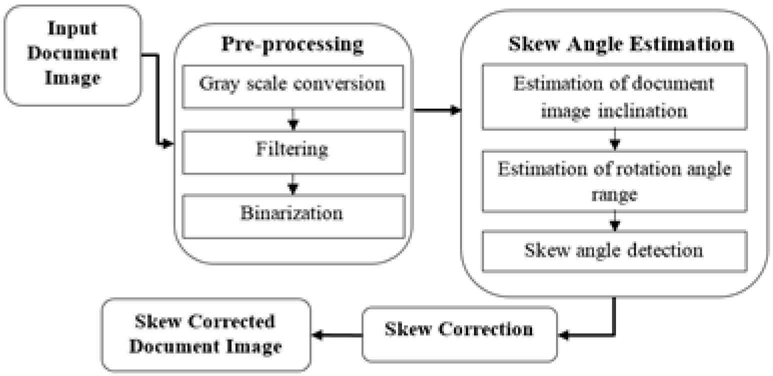

Fig. 2. Workflow diagram of skew detection and correction system.

3.1. Pre-processing

The inputted Modi document images are scanned or photocopy gray-level or colored images. The performance of the proposed approach is tested on the database of 3429 handwritten Modi document images. All these documents are gained in soft or hard form from the libraries or archives for example Rajwade Sanshodhan Mandal, Dhule, Maharashtra. These document images are scanned and camera captured images.

Initially, gray scale conversion is done in the pre-processing. Subsequently, the document image is filtered using median filter [Huang et.al. (1979)]. Filtering is utilized to smoothing the document image and removed the impulsive noise. Among all smoothing techniques median filtering is effective at removing noise in smooth patches or smooth regions of an image without affecting the edges [Arias-Castro and Donoho (2009)] [Arce (2005)]. The image binarization is used for the separation of the background and foreground pixels and characterize the image in to binary form. The foreground pixels are used to scrutinize the estimation of the skew angle. The simple Otsu's global thresholding method [Otsu N. (1979)] is employed for the document image binarization.

3.2. Skew angle range estimation

The horizontal projection profile initially illustrated by [Postl (1986)]. In the basic version of this technique, a complete pass is made over the input image for each possible skew angle with in a pre-determined angle range. The projection profile of the document is calculated at each rotational angle in the angle range. To calculate the peaked characteristic, projected profile based criterion function is used. Finally, the skew angle of the document is the angle where the criterion function is maximized [Hull (1998)] [Papandreou et.al. (2014)] [Mahanta and Deka (2013)]. The criterion function is computed by using the sum of squares of the values in the projection profile [Mahanta and Deka (2013)].

Here, a new criterion function C(θ) is proposed to compute the concentration of black pixels at a rotational angle θ. It is computed by, summation of average (μ) and standard deviation (σ) of the values in the horizontal projection profile (HPP) as described in Eq. (1).

$$C(\theta) = \mu(\mathrm{HPP}) + \sigma(\mathrm{HPP}) \tag{1}$$

The average or mean value gives the contribution of column wise foreground pixels for the entire image. While, the standard deviation is a measure to quantify the amount of dispersion of a set of foreground pixels. Generally, it is used to measure the confidence in statistical conclusions. The average(μ) and standard deviation(σ) of horizontal projection profiles gives the more accuracy to find outs the peaks in the situations of overlapped and very dense text lines, cursive and non-uniform text and non-uniform Shirorekha. The rotation of the document image is done using the Eq. (2) with angle θ′.

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} \cos\theta' & \sin\theta' \\ -\sin\theta' & \cos\theta' \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} \tag{2}$$

The skewed document should be inclined in left or right side. The proposed approach is based on the observation of the horizontal projection profile (HPP) values. These values are calculated by employing different rotational angles on the document image. If the un-skewed document is rotated towards angles nearest to the zero degree on either of the side negative or positive. The HPP value of the inclined document image is less than HPP value of the un-skewed document. For example, as shown in Fig. 4. having plot of the values C (-4^o) to C (4^o) of a document image shown in Fig. 3. i.e. HPP is determined with the rotational angle range $\pm 4^o$ and angular resolution is 1^o. Here, the value of C(-1^o) greater than value of C(0^o) and C(1^o) because of document is in positive inclination. The skew angle is determined in the rotational angle range 0.1^o to θ. Thus, instead of detecting the skew angle in the angle range –θ to +θ, it will be in the angle range either -0.1^o to –θ or 0.1^o to +θ by determining negative or positive image inclination respectively.

Here, the document image inclination is rated by calculating three values C(-0.2^o), C(0.2^o) and C(0^o). The value ±0.2 is considered because error rate up to 0.2^o is accepted

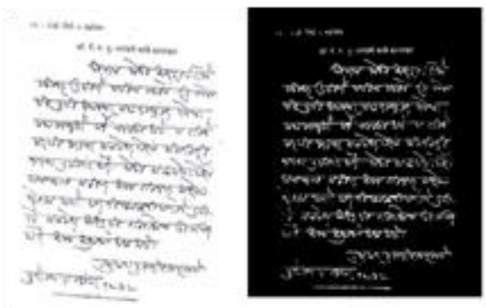

Fig. 3. Positive incline Modi document image sample with skew corrected image.

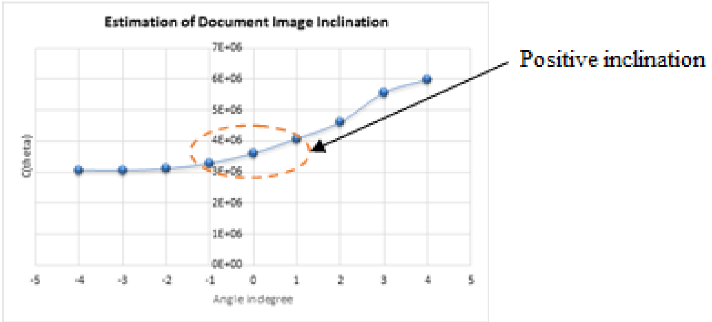

Fig. 4. An illustration for detection of text area inclination.

in skew correction. The inclination of the document image is determined by comparing these three values using Eq. (3).

$$\text{Inclination} = \begin{cases} -ve & \text{if } C\left(-0.2^{o}\right) \text{ is greater} \\ +ve & \text{if } C\left(0.2^{o}\right) \text{ is greater} \\ none & \text{if } C\left(0^{o}\right) \text{ is greater} \end{cases} \tag{3}$$

Form the inclination the skew detection angle range is estimated as follows:

(1) Negative inclination: rotational angle range is -0.1^{o} to -θ.

(2) Positive inclination: rotational angle range is 0.1^{o} to θ.

The greater value of C(0^{o}) indicates that document image is not skewed and de-skewing of document is not required.

3.3. Skew angle detection and correction

The criterion function C(θ) is computed at each angle θ' on N angles in estimated angle range using divide-and-conquer strategy. This strategy suggests splitting the inputs into k distinct subsets, $1 < k \leq N$ yielding k sub-problems. These sub-problems must be solved and then a method must be found to combine sub-solutions into a solution of the whole. To detect the skew angle of the Modi document initial rotational angle range is estimated using Eq. (3). The rotational angle range may be positive or negative means from θ_F = 0.1^{o} to θ_L= 89^{o} θ_F = -0.1^{o} to θ_L= -89^{o} respectively. The concentration of black pixels C(θ) is calculated by splitting the number of angles into k distinct subsets, $\theta_F < k \leq \theta_L$ yielding k sub-solutions using Eq.(5). The horizontal projection profile (hpp_θ) is calculated for the binarized Modi document (fig_θ) of size mXn, rotating by angle θ using Eq. (4) [Mohammed et.al. (2013)].

$$hpp_{\theta}\left(x\right) = \sum_{1 \leq y \leq N} fig_{\theta}\left(x,\ y\right) \tag{4}$$

The criterion function is estimated by using the Eq. (5).

$$C(\theta) = \frac{1}{m}\sum_{x=1}^{m} hpp_{\theta}(x) + \sqrt{\frac{1}{m-1}\left(\sum_{x=1}^{m}\left(hpp_{\theta}(x) - \frac{1}{m}\sum_{x=1}^{m} hpp_{\theta}(x)\right)\right)} \tag{5}$$

Through each iteration, the rotational angle range θ_F to θ_L is estimated by examining the value $C(\theta_F)$ and $C(\theta_L)$. The middle angle θ_M of the rotational angle range is calculated. The value of the $C(\theta_F)$ and $C(\theta_L)$ is compared if $C(\theta_F)$ is greater then the value of $\theta_L = \theta_M$ i.e. next rotational angle range is θ_F to θ_M. Otherwise $\theta_F = \theta_M$ means next rotational angle range is θ_M to θ_L. Finally, for some angle range θ_F to θ_L both the $C(\theta_F)$ and $C(\theta_L)$ are equal and θ_F is the skewed angle. Consequently, the k sub-solutions are compared and angle θ' is estimated as skew angle of the document image where the $C(\theta)$ is maximized. For example, the values calculated during the skew detection at each iteration in initially estimated angle range 0.1^o to 20^o for the document image given in Fig.3 using divide-and-conquer approach are listed in Table2 and plotted in Fig.5. For simplicity, here the angle range is determined up to $\pm 20^o$.

Table 2. The values calculated at each iteration using divide-and-conquer approach

Theta1	Theta2	C(Theta1)	C(Theta2)
0.1	20.0	70.74	54.3
0.1	10.1	70.74	66.2
0.1	5.1	70.74	110.04
2.7	5.1	94.92	110.04
2.7	3.9	94.92	113.59
3.4	3.9	102.17	113.59
3.7	3.9	108.87	113.59
4.0	3.9	113.93	113.59
4.1	4.0	114.95	113.93
4.2	4.1	114.43	114.95
4.3	4.1	115.13	114.95

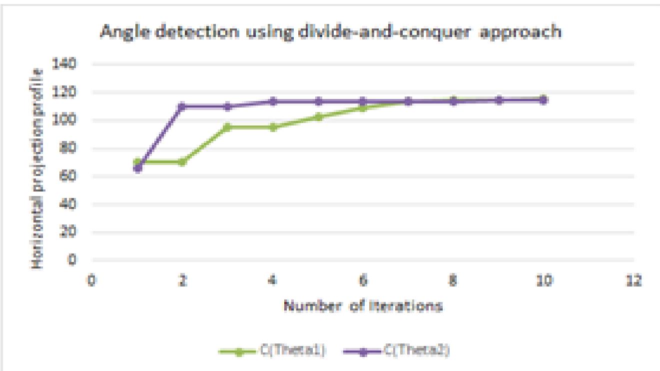

Fig. 5. Illustration of skew detection using divide-and-conquer approach.

3.4. Algorithm

The algorithm for the skew detection is given in Algorithm1 and divide-and-conquer based recursive procedure is given in Algorithm2.

Algorithm1 Divide_And_Conquer_Skew_Correction (I)
Input: Scanned or photocopy of degraded handwritten Modi Document image I

1: I_G ⟵ rgbTogray (I) // Conversion of color image to gray scale image
2: I_B ⟵ grayTobinary(I_G) // Conversion of gray scale image to binary image
3: direction ⟵ imageIncline (I_B) //Estimate the direction of inclination
4: [$Theta_F$, $Theta_L$] ⟵ rotaionalAngleRange(direction) // Estimate rotational angle range
5: Theta' ⟵ RFindSkewAngle(I_B, $Theta_F$, $Theta_L$)
6: I_S ⟵rotate_image(I_G, Theta')
7: Return I_S

Algorithm 2 Theta' RFindSkewAngle(I, $Theta_F$, $Theta_L$)

```
Begin
    ThetaM ⟵ (ThetaF + ThetaL) / 2
    HPPF ⟵ Horizontal_Projection_Profile(I, ThetaF )
    HPPM ⟵ Horizontal_Projection_Profile(I, ThetaM )
    HPPL ⟵ Horizontal_Projection_Profile(I, ThetaL )
    If HPPM > HPPL Then
        Return RFindSkewAngle(I, ThetaF , ThetaM)
    Else
        Return RFindSkewAngle(I, ThetaM +0.1 , ThetaL)
    Return ThetaF
End
```

The procedure Horizontal_Projection_Profile(I, Theta) is calculated and returns the concentration of black pixels after rotating document image I by angle Theta.

In the proposed algorithm, rotational angle range is reduced to the half by estimating the inclination of the document image. This algorithm finds a skew angle θ' recursively either in a positive or negative direction. Let, number of angles in the estimated rotational angle range is the powers of 2 i.e. $n=2^k$. Each time around the iterations, middle element is examined and the sub-range is resolute of interest 2^k. Recursively the size of n is reduced, for example at second iteration it will be 2^{k-1}. The value of n in the last iteration is 1 i.e in the k^{th} iteration. The overall recursive calls in worst case are up to depth of binary tree k, which is log n. Thus, the computational complexity of the proposed algorithm is O (log n).

4. Experimental Results and Discussion

The performance of the algorithm is checked in the form of accuracy of the skew detection and time complexity. To evaluate the performance of the algorithm fourteen document images are randomly selected from the dataset and create the skewed document images manually. The sample input images are shown in Fig. 7. and corresponding skew corrected images are shown in Fig. 8. These are the examples of Modi document images suffered by one or more challenges listed in Table1.

The technique is more efficient to detect and correct the skew angle in Modi documents suffered by variety of degradations. Time and computational complexity is reduced greatly as compared to the existing HPP based approaches. The proposed algorithm is correctly detected and corrected the skew of multi-column documents. It is efficiently dealing with non-uniform Shirorekha and non-uniform size of text line. The distance between two text lines may be vary. It is robust and appropriate for printed and handwritten text, cursive or italic text, long or short text lines, noisy and clear documents, documents with graphics or symbols, thin or light text, less text area documents. It detects the skew angle efficiently in the very dense and overlapping text lines documents. The multiple skewed text lines documents are de-skewed by estimating skew angle of the maximum voting of text lines skew, as shown in Fig. 7(d and n).

The error rate is calculated by comparing the actual skew angle and detected skew angle for the document image. Computational time of the skew detection and correction is also calculated. The results of the proposed approach with sample dataset are given in Table 3 and depicted by plot in Fig. 6. The error rate is lies in between 0.1 to 0.5 and the average error rate is 0.1 degree. The average time required for skew estimation and correction is 4.05 seconds. The error rate is 0.5 degree with document image with short text length with multicolumn. In some cases, time required for skew detection and correction is greater than 15 seconds. This situation is acceptable to get the correct results in the complex cases. The experiments have been carried out on the Xeon(R) workstation with Intel(R) X3430 @2.40GHz 2.53GHz processor and 4 GB RAM.

Table 3. Performance results for the sample database.

Document reference	**Actual skew angle (Degree)**	**Detected skew angle (Degree)**	**Error rate**	**Time**
(a) Non-uniform Shirorekha and text, multi-skew	10.5	10.7	0.2	1.12
(b) Like Name-card, multi-script	-10	-9.9	0.2	0.22
(c) Multi-script, non-uniform Shirorekha, thin text	6.4	6.4	0.0	4.07
(d) Noisy document, multi-skew	-5.2	-4.9	0.3	5.85
(e) Thin text, multi-column, non-uniform text	2.8	2.9	0.1	2.08
(f) Multi-column	3	3.1	0.0	2.75
(g) Non-text symbol	-4.6	-4.6	0.0	1.50
(h) Small text area, non-text symbol	9	9.1	0.1	10.70
(i) Light text	-9.7	-9.9	0.2	2.89
(j) Multi-column, non-uniform text line distance	-9.8	-9.9	0.0	2.49
(k) Long and short text line length	15.2	15.2	0.0	15.03
(l) multicolumn, long and short text line length	-9.3	-9.9	0.5	1.59
(m) text with Picture	8.1	8.1	0.0	5.60
(n) Multi-column, with small symbols	-7.4	-7.3	0.1	0.79
		Average	**0.1**	**4.05**

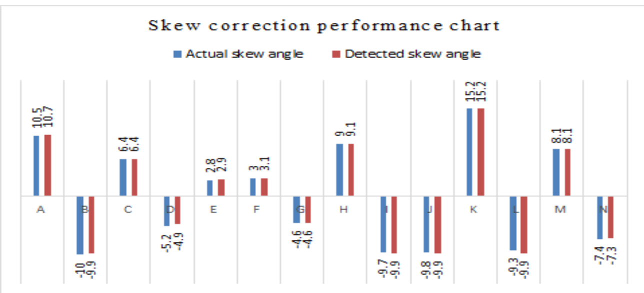

Fig. 6. Performance evaluation chart.

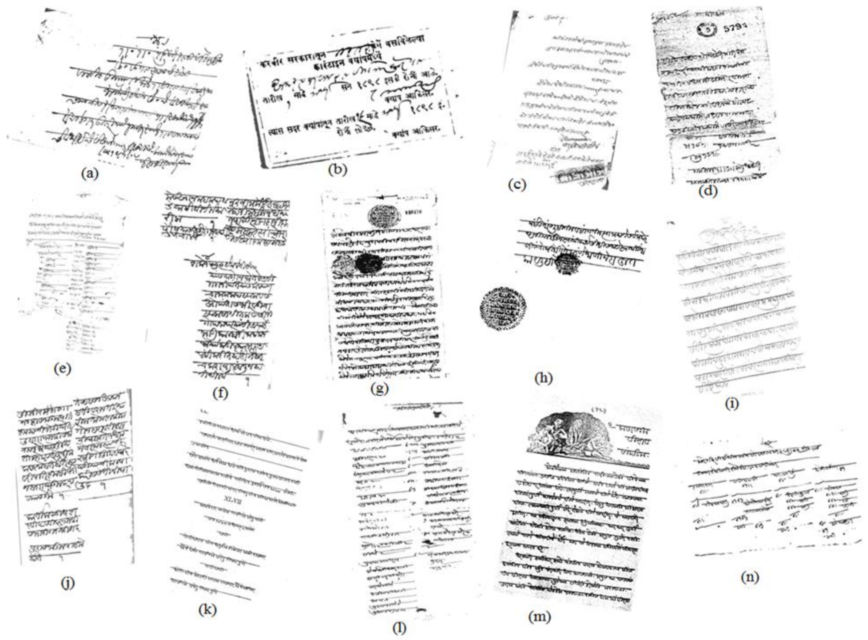

Fig. 7. Skewed sample image dataset contains all types of document types.

Fig. 8. Skew corrected sample images corresponding to the document images shown in Fig. 7. (a-n)

5. Comparison of Proposed Approach with the Benchmarking Techniques

The performance of the benchmarking techniques illustrated by [Mahnaz and Maher (2015)] is used to compare the proposed approach. Mahnaz and Maher stated the results by testing two online datasets given as follows with their own dataset of document images. The size of total dataset is 130.

(1) Maryland Tobacco800 documents database.

(2) www.mediateam.oulu.f-i image data base.

These online datasets and Modi document images dataset is used for the valuation. The comparative results are illustrated in Table 4.

Table 4. Comparison of proposed approach based on success rate and average time.

Method	Success Rate	Avg. Time(Sec)
Projection profile [Mahnaz and Maher (2015)]	86%	16.8
1-st Nearest Neighbourhood[Mahnaz and Maher (2015)]	48%	2.5
Hough transform [Mahnaz and Maher (2015)]	92%	4.9
Fourier transform[Mahnaz and Maher (2015)]	82%	2.8
Shafii and Maher method[Mahnaz and Maher (2015)]	95%	1.56
Our Approach	**96.49%**	**4.35**

The proposed algorithm shows the higher success rate as compared to other methods. It is also compared with the existing approaches in terms of the applicability on the documents categorized by some common challenges described in Table5. The state-of-art is reviewed and comparison is done. In the Table5 'Yes' or 'No' indicated that the method is appropriate or not for given type of challenge(s) respectively. As compare to all the methods our approach is suitable to detect the skew of all types of challenges in skew detection.

Table 5. Comparison of proposed approach based on applicability of approaches

Challenge / Method	Printed	Hand written	Noisy	Non-uniform text / Shirorekha	Document with picture/ non-text symbol	Overla-pped / dense text lines	Multi column	Multi skew	Multi Script
Histogram of the gradient orientation [Sun and Si (1997)][Omar et.al. (2012)]	Yes	No	No	No	Yes	No	Yes	No	Yes
Projection profile [Mahanta&Deka(2013)][Kanai & Bagdanov (1998)] [Postl (1986)]	Yes	No	No	Yes	Yes	No	Yes	Yes	Yes
Hough transform [Hosalli and Krishnamurthy(2012)] [Kwag et. al. (2002)][Nandini et.al. (2008)][Kaur et. al. (2013)][Ahmad Riaz et. al. (2016)]	Yes	Yes	No	No	No	No	Yes	No	Yes
Fourier transform [Singh and Kaur (2013)] [Postl (1986)]	Yes	Yes	No	No	Yes	No	Yes	No	Yes

Table 5. (Continued)

Fourier transform [Singh and Kaur (2013)] [Postl (1986)]	Yes	Yes	No	No	Yes	No	Yes	No	Yes
Nearest-neighbor clustering [Ravikumar and Manjunath(2013)] [Marcus et.al.(2012)]	Yes	Yes	No	No	No	No	Yes	No	Yes
Cross Correlation [Yan (1993)]	Yes	Yes	No	No	No	No	Yes	No	Yes
fuzzy c-regression models clustering [Lin Chin-Teng et al.(2006)]	Yes	Yes	No	No	Yes	No	Yes	No	Yes
Connected component [Brodić and Dragan (2012)]Brodic et.al.(2013)] [Ray (1995)] [Okun et.al. (1999)] [Panagiotis and Papamarkos (2008)]	Yes	No	No	No	No	No	Yes	No	Yes
Radon Transform [Kapoor et.al.(2004)] [Dong et. al. (2005)][Patel et.al. (2012)][15]	Yes	Yes	No	No	No	No	No	No	Yes
Morphological operation [Najman L.A. (2003)]	Yes	Yes	No	No	Yes	No	Yes	No	Yes
Centre of Gravity [Al-Shatnawi and Omar (2009)]	Yes	No	No	No	No	No	No	No	No
Distance transform [Bar-Yosef et. al.(2008)]	Yes	Yes	No	No	Yes	No	Yes	No	Yes
Run length smoothing algorithm (RLSA)[Abuhaiba (2003)]	Yes	No	Yes	No	No	No	No	No	Yes
The axis-parallel bounding box [Mahnaz and Maher (2015)]	Yes	No	No	No	Yes	No	Yes	No	Yes
Our approach	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**

6. Conclusion

A simple and fast skew detection algorithm is proposed, which make use of horizontal projection profile. The results shows that the horizontal projection profile statistical information is sufficient to estimate the skew angle. The results have proven the robustness and efficiency in handling a variety of documents, such as printed and handwritten documents; noisy documents. The novelty of this approach is that the determination of rotational angle range by finding the inclination of the document. The inclination of the document image is calculated perfectly for all types of document images. The determination of rotational angle range improves the ability to handle a great range of skew angles with 0.1 degree of angle resolution. Because of this and divide-and-conquer approach the proposed technique has reduced the time and computational complexity with increasing accuracy. The efficiency of the skew detection is not sensitive with non-text components and symbols. The accuracy of the skew detection is independent of the resolution of the document image, script, size or type of font, size of text area and page layout. This technique is tolerable to correct the skew of variety of handwritten old age Modi documents as: non-uniform text and Shirorekha documents; thin text area; documents with symbols and graphics; multicolumn and multi-skew documents; overlapped and very dense text lines. The results shows that overall higher accuracy in all types of documents as compared to state-of-art benchmarking techniques.

References

Abuhaiba Ibrahim SI (2003): Skew Correction of Textural Documents. Journal of King Saud University-Computer and Information Sciences , 73-93.

Ahmad Irfan (2016):Technique for skew detection of printed arabic documents. U.S. Patent No. 9,288,362.

Atallah M. Al-Shatnawi and Khairuddin Omar; (2009): Skew Detection and Correction Technique for Arabic Document Images Based on Centre of Gravity. Journal of Computer Science 5 (5): 363-368, ISSN 1549-363.

Babić, Ranko V.(2006): Cursive word raw segmentation based on scanning Skew slots." Journal of Automatic Control 16.1 ,51-56.

Baird H.S. (1992) :Anatomy of a versatile page reader. Proc. ofthe IEEE, vol. 80 no. 7, pp1059-1065.

Bloomberg; Dan S.; Gary E. Kopec;Lakshmi Dasari (1995): Measuring document image skew and orientation. IS&T/SPIE's Symposium on Electronic Imaging: Science & Technology. International Society for Optics and Photonics.

Boukharouba, Abdelhak (2016): A new algorithm for skew correction and baseline detection based on the randomized Hough Transform. Journal of King Saud University-Computer and Information Sciences .

Brodić Darko; Dragan R. Milivojević (2012):An Algorithm for the Estimation of the Initial Text Skew. Information Technology and Control 41.3 ,211-219.

Brodic Darko; Čedomir A. Maluckov; LiangruiPeng (2013):Estimation of the Text Skew in the Old Printed Documents. International Journal of Computers Communications & Control 8.5 , 673-680.

Chien-Hsing Chou; Shih-Yu Chu; Fu Chang (2005):Estimation of skew angles for scanned documents based on piecewise covering by parallelograms. Pattern Recognition Society. Published by Elsevier Ltd. doi:10.1016/j.patcog.

D. Lewis,;G. Agam; S. Argamon; O. Frieder; D. Grossman; J. Heard(2006):Building a test collection for complex document information processing. in Proc. 29th Annual Int. ACM SIGIR Conference , pp. 665–666,

D. S. Bloomberg; G. Kopec (1993):Method and apparatus for identification and correction of document skew. Xerox Corporation, U.S. Patent 5,187,753.

D. S. Bloomberg; G. Kopec(1994): Method and apparatus for identification of document skew. Xerox Corporation, U.S. Patent 5,355,420.

Diem, Markus, Florian Kleber, and Robert Sablatnig (2012):Skew Estimation of Sparsely Inscribed Document Fragments. Document Analysis Systems (DAS), 2012 10th IAPR International Workshop on. IEEE.

Dong, J. X., Dominique, P., Krzyyzak, A., & Suen, C. Y. (2005): Cursive word skew/slant corrections based on Radon transform. In Document Analysis and Recognition, 2005. Proceedings. Eighth International Conference on (pp. 478-483). IEEE.

E. Arias-Castro and D.L. Donoho (2009): Does median filtering truly preserve edges better than linear filtering? Annals of Statistics, vol. 37, no. 3, pp. 1172.

G. Agam; S. Argamon; O. Frieder; D. Grossman; D. Lewis(2006): The Complex Document Image Processing (CDIP) test collection project. Illinois Institute of Technology.

G.R. Arce (2005) :Nonlinear Signal Processing: A Statistical Approach. Wiley:New Jersey, USA.

Gatos Basilios; Ioannis Pratikakis; Stavros J. Perantonis (2006):Adaptive degraded document image binarization. Pattern recognition 39.3 , 317-327.

Guangyu Zhu; David Doermann (2007): Automatic Document Logo Detection. In Proc. 9th Int. Conf. Document Analysis and Recognition (ICDAR 2007), pp. 864-868.

Guangyu Zhu; Yefeng Zheng; David Doermann; Stefan Jaeger(2007). Multi-scale Structural Saliency for Signature Detection. In Proc. IEEE Conf. Computer Vision and Pattern Recognition (CVPR 2007), pp. 1-8 .

Guru, D. S.; M. Ravikuma; S. Manjunath(2013) :Multiple Skew Estimation in Multilingual Handwritten Documents. International Journal of Computer Science Issues.

H. S. Baird (1987) : The skew angle of printed documents. In Proc. SPSE 40th Symp. Hybrid Imaging Systems,pages 21{24, Rochester, NY.

H. Yan (1993): Skew Correction of Document Images Using Interline Cross-Correlation. Graphical Models and Image Processing, vol. 55, pp. 538-543.

Hinds S.C, Fisher J.L, D'Amato (1990) :D.P.A document skew detection method using run-length encoding and the Hough transform. Proc. 10th Int. Conf. on Pattern Recognition, Atlantic City NJ ,vol. I, pp464-468.

Hough, P (1962): Method and means for recognizing complex pictures, U.S. Patent no. 3069654.

Hull, Jonathan J. (1998): Document image skew detection: Survey and annotated bibliography. Series in Machine Perception and Artificial Intelligence 29 40-66.

Itay Bar-Yosef; Nate Hagbi; Klara Kedem;Itshak Dinstein;(2008) :Fast and Accurate Skew Estimation Based on Distance Transform.IEEE.

Jain, B., & Borah, M. (2013). A Survey paper on skew detection of offline handwritten character recognition system.

Javed Mohammed; P. Nagabhushan;B. B. Chaudhuri (2013): Extraction of Projection Profile, Run-Histogram and Entropy Features Straight from Run-Length Compressed Text-Documents." Pattern Recognition (ACPR) 2nd IAPR Asian Conference on. IEEE.

Jipeng Tian; G. Hemantha Kumar; H. K. Chethan;(2011): Skew correction for Chinese character using Hough transform. International Journal of Advanced Computer Science and Applications-IJACSA, (Special Issue) 45-48.

Jundale Trupti A.; Ravindra S. Hegadi (2015): Skew detection and correction of Devanagari script using Hough transform. Procedia Computer Science 45 , 305-311.

Junichi Kanai; Andrew D. Bagdanov; (1998): Projection profile based skew estimation algorithm for JBIG compressed images. 1: 43-51; IJDAR.

Kapoor Rajiv; Deepak Bagai; Tara Singh Kamal(2004):A new algorithm for skew detection and correction. Pattern Recognition Letters 25.11, 1215-1229.

Kapoor Rajiv; Deepak Bagai; T. S. Kamal (2013):Skew angle detection of a cursive handwritten Devanagari script character image. Journal of the Indian Institute of Science 82.3 & 4 ,161.

Karunanayaka M. L. M.; Chandrajith Ashuboda Marasinghe; N. D. Kodikara(2005):Thresholding, Noise Reduction and Skew correction of Sinhala Handwritten Words. MVA.

Kaur Loveleen; Mandev Singh (2012): Comparison of Skew Detection and Correction Techniques By applying on Gurmukhi Script.. International Journal of Engineering Research and Technology. Vol. 1. No. 5 .

Kavallieratou; E., N. Fakotakis; G. Kokkinakis (1999): New algorithms for skewing correction and slant removal on word-level. Proceedings of ICECS'99. The 6th IEEE International Conference on. Vol. 2. IEEE.

Kavallieratou Ergina; Nikos Fakotakis; G. Kokkinakis (2002a):An unconstrained handwriting recognition system. International Journal on Document Analysis and Recognition 4.4: 226-242.

Kavallieratou Ergina; Nikos Fakotakis; G. Kokkinakis (2002b):Skew angle estimation for printed and handwritten documents using the Wigner–Ville distribution. Image and Vision Computing , 813-824.

Koo, Hyung Il; Nam Ik Cho (2016):Robust skew estimation using straight lines in document images. Journal of Electronic Imaging 25.3, 033014-033014.

Kwag, H. K., Kim; S. H., Jeong, S. H.; Lee, G. S. (2002): Efficient skew estimation and correction algorithm for document images. *Image and vision computing*, *20*(1), 25-35.

Le, D. S., Thoma, G. R., & Wechsler, H. (1994): Automated page orientation and skew angle detection for binary document images. *Pattern Recognition*, *27*(10), 1325-1344.

Lin, C. T., Fan, K. W., Yeh, C. M., Pu, H. C., & Wu, F. Y. (2006). High-accuracy skew estimation of document images. International Journal of Fuzzy Systems, 8(3), 119-126.

Mahanta, L. B.;Alpana Deka (2013):Skew and Slant Angles of Handwritten Signature. International Journal of Innovative Research in Computer and Communication Engineering (An ISO 3297: 2007 Certified Organization) Vol. 1, Issue 9.

Mandeep Kaur; Lovnish Bansal;Jagdeep Singh;(2013):Global and Local Skew Detection of Handwritten Gurmukhi Script"International Journal of Computer Applications (0975 – 8887) Volume 82 – No 17.

Morillot Olivier; Laurence Likforman-Sulem; Emmanuèle Grosicki(2013):New baseline correction algorithm for text-line recognition with bidirectional recurrent neural networks. Journal of Electronic Imaging 22.2 , 023028-023028.

Najman, Laurent A.(2004):Using mathematical morphology for document skew estimation. Electronic Imaging 2004. International Society for Optics and Photonics.

Nandini, N., K; Srikanta Murthy; G. Hemantha Kumar(2008):Estimation of skew angle in binary document images using hough transform. World Academy of Science, Engineering and Technology 18 , 44-49.

Neha.N(2012):Language Independent Robust Skew Detection and Correction Technique for Document Images, International Journal of Electronics Signals and Systems (IJESS) ISSN: 2231- 5969, Vol-1 Iss-3.

Oleg Okun; MattiPietikainen; JaakkoSauvola;(1999): Document skew estimation without angle range restriction.2: 132-144, IJDAR .

Omar, K., Ramli, A., Mahmod, R., & Sulaiman, M. (2002). Skew detection and correction of Jawi images using gradient direction. *J. Techn*, *37*, 117-126.

Otsu, N. (1979):A Threshold Selection Method from Gray-Level Histograms, IEEE Transactions on Systems, Man, and Cybernetics, Vol. 9, No. 1, pp. 62-66.

P. Chevillat; H. R. Schindler (1982):Arrangement for determining the optimum scan angle for printed documents. International Business Machines Corp., U.S. Patent 4,338,588.

P.Shivakumara; G. Hemantha Kumar;D. S Guru; P. Nagabhushan;(2003):Skew Estimation of Binary Document Images Using Static and Dynamic Thresholds Useful for Document Image Mosaicing.National Workshop on IT Services and Applications (WITSA2003).

Papandreou, A.; Basilios Gatos.(2011):A novel skew detection technique based on vertical projections. Document Analysis and Recognition (ICDAR), International Conference on. IEEE.

Papandreou, A., Gatos, B., Perantonis, S. J., & Gerardis, I. (2014). Efficient skew detection of printed document images based on novel combination of enhanced profiles. *International Journal on Document Analysis and Recognition (IJDAR)*, *17*(4), 433-454.

Patel Jinal; Anup Shah;Hetal Patel(2015):Skew Angle Detection and Correction using Radon Transform. International Journal of Electronics, Electrical and Computational, System, ISSN

Ramappa MamathaHosalli; Srikantamurthy Krishnamurthy(2012): Skew Detection, Correction and Segmentation of Handwritten Kannada Document. image 48.

Rashid Adnan:Andrea Prati; Rita Cucchiara (2011):A real-time embedded solution for skew correction in banknote analysis. Computer Vision and Pattern Recognition Workshops (CVPRW), 2011 IEEE Computer Society Conference on. IEEE.

Sahoo, Prasanna K., S. A. K. C. Soltani, and Andrew KC Wong (1988):A survey of thresholding techniques. Computer vision, graphics, and image processing41.2 , 233-260.

Saragiotis Panagiotis; Nikos Papamarkos.(2008): Local skew correction in documents. International Journal of Pattern Recognition and Artificial Intelligence ,91-710.

Shafii Mahnaz; Maher Sid-Ahmed (2015):Skew detection and correction based on an axes-parallel bounding box. International Journal on Document Analysis and Recognition (IJDAR), 59-71.

Singh Ruby; Ramandeep Kaur (2013): Improved Skew Detection and Correction Approach Using Discrete Fourier Algorithm.International Journal of Soft Computing and Engineering (IJSCE) ISSN: 2231-2307, Volume-3, Issue-4.

Smith Ray (1995):A simple and efficient skew detection algorithm via text row accumulation. Document Analysis and Recognition, Proceedings of the Third International Conference on. Vol. 2. IEEE.

Stahlberg Felix; Stephan Vogel(2015):Document skew detection based on hough space derivatives. Document Analysis and Recognition (ICDAR), 13th Inter. Conf. on. IEEE.

Sun Changming; Deyi Si(1997):Skew and slant correction for document images using gradient direction. Document Analysis and Recognition, Proceedings of the Fourth International Conference on. Vol. 1. IEEE.

T. Akiyama ; N. Hagita (1990):Automated entry system for printed documents. Pattern Recognition 23, 11, 1141-1154.

T. Huang; G. Yang; G. Tang (1979): A fast two-dimensional median filtering algorithm. IEEE Trans. Acoust., Speech, Signal Processing, vol. 27, no. 1, pp. 13–18.

The Legacy Tobacco Document Library (LTDL), University of California, San Francisco, 2007.http://legacy.library.ucsf.edu/.

Verma Rajeev N.; Latesh G. Malik (2015) :Review of illumination and skew correction techniques for scanned documents. Procedia Computer Science 45 , 322-327.

W. Postl (1986) :Detection of linear oblique structure and skew scan in digitized documents. In Proceedings of International Conference on Pattern Recognition, pages 687-689.

Y. Ishitani (1993): Document skew detection based on local region complexity. Proceedings of the Second International Conference on Document Analysis and Recognition, 49-52.

Y. Ishitani (1996):Document skew detection/control system for printed document images containing a mixture of pure text lines and non-text portions. Toshiba, U.S. Patent 5,506,918.