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A Fast and Novel Skew Estimation Approach using Radon Transform

Prakash K Aithal, Rajesh G, U Dinesh Acharya and Siddalingaswamy P. C

Department of Computer Science and Engineering, Manipal Institute of Technology,
Manipal University, Manipal, India
prakash.aithal@manipal.edu

***Abstract*: In this paper, an effective and reliable skew estimation technique for machine printed documents and photos using radon transform is proposed and is compared with other methods used for skew estimation such as Fast Fourier Transform (FFT), Hough Transform (HT), combination of Horizontal Projection Profile (HPP) and Hough Transform, combination of Gabor filter and Radon transform, combination of Wavelet Transform (WT) and Hough Transform and Horizontal Projection Profile only. The radon transform based skew estimation approach gives faster and better results compared to other methods. The proposed technique is tested on 150 document images with skew varying from 1 to 25 degrees. It provides 100% accuracy for skew estimation with average time of execution 2.23 seconds for scanned document images containing text, 0.1404 seconds for machine printed images containing text, 1.2 seconds for scanned document images containing pictures and 0.0156 seconds for machine printed document image containing pictures.**

Keywords: machine printed documents, skew detection, radon transform, FFT, Wavelet, Hough Transform, and OCR**.**

I. Introduction

Skewness refers to the tilt in the bitmapped image of the scanned document image for Optical character Recognition (OCR). Pre-processing is a stage in typical OCR system, which focuses on enhancing the acquired image to increase the ease of feature extraction and to compensate for the eventual poor quality of the scanned document. Skew detection and correction are important pre-processing steps of document layout analysis and OCR approaches [4].

OCR systems typically assume that documents were printed with a single direction of the text and that the acquisition process did not introduce a relevant skew. The advent of flatbed scanners and the need to process large amounts of documents at high rates, made the above assumption unreliable and the introduction of the skew estimation phase became mandatory. The correctness of the results of subsequent stages of OCR systems primarily depends upon the accuracy of pre-processing stage. For instance, the OCR system which is utilizing Projection based technique will fail miserably if it under estimate or overestimate the skew angle [9].

A text line is a group of characters, symbols, and words that are adjacent relatively close to each other, and through which a straight line can be drawn (usually with horizontal or vertical orientation). The dominant orientation of the text lines in a document page determines the skew angle of that page. A document originally has zero skew, where horizontally or vertically printed text lines are parallel to the respective edges of the paper, however when a page is manually scanned or photocopied, non-zero skew may be introduced. Since it is desired to have zero skew, it is important to perform skew estimation and correction need to be done before segmentation, for proper identification. Also since a reader expects a page displayed on a computer screen to be upright in normal reading orientation, skew correction is normally done before displaying scanned pages [6].

Many different skew estimation algorithms are available in the literature. A comprehensive survey can be found in [5]. In the survey paper over 50 published works on at least 25 different methods for document image skew detection were discussed. These included approaches that calculate projection profiles at different angles directly from image data, methods that calculate projection profiles from image features, and algorithms that used the Hough transform. Another class of technique uses extracted features with local, directionally sensitive masks. B.V. Dhandra et al. have proposed a skew estimation technique based on Image dilation and region labelling approach [8]. Su Chen et al. achieved the skew estimation using recursive morphological transform [2]. Gaofeng Meng et al. determined the skew with the help of bagging method [10]. Muhammad Sarfraz et al. have estimated the skew using bounding box approach [9]. M. Sarfraz et al. have proposed a technique of detecting the skew based on principle component analysis [7]. Aithal et al. has discussed a radon transform based skew estimation for scanned document images [11].

This paper proposes skew estimation through radon transform and compares it with methods such as skew estimation using combination of Gabor Filter and radon transform, skew estimation using combination of Hough Transform (HT) and Horizontal Projection Profile (HPP), Skew detection using Fast Fourier Transform (FFT), skew estimation using combination of Wavelet Transform (WT) and Hough Transform and tilt detection using HPP. After

detecting the skew, it is corrected by rotating the document by estimated skew angle. Later the boundary of the page is adjusted so that it looks like the original image.
The rest of the paper is organized as follows: section II gives the theory behind the radon transform, Hough transform, horizontal projection profile and FFT. Subsection A depicts the algorithm for skew estimation using HPP. Subsection B illustrates skew estimation using FFT. Subsection C describes the skew estimation algorithm using combination of Hough and HPP. Subsection D elucidates the skew estimation algorithm using combination of Gabor filter and radon transform. Subsection E illustrates skew estimation technique using combination of WT and HT. Subsection F gives the skew estimation using HT only. Subsection G gives the algorithm to find the skew angle using radon transform. Skew correction technique is discussed in subsection H. Section III presents the result analysis.

II. Methodology

Optical character recognition (OCR) is a process of automatic computer recognition of characters in optically scanned and digitized pages of text. OCR is one of the most fascinating and challenging areas of pattern recognition with various practical application potentials. It can contribute immensely to the advancement of an automation process and can improve the interface between man and machine in many applications. Some practical application potentials of OCR system are: (1) reading aid for the blind, (2) automatic text entry into the computer for desktop publication, library cataloging, ledgering, etc. (3) automatic reading for sorting of postal mail, bank cheque and other documents, (4) document data compression: from document image to ASCII format, (5) language processing, (6) multi-media system design, etc. The preprocessing step in a typical OCR system includes binarization and skew estimation. Block diagram of OCR system is shown in Fig. 1.

Binarization is a preprocessing step which is used to separate the foreground from background. To binarize an image one has to calculate the threshold. If a pixel value is above the threshold it is set to one else to zero. This is extremely difficult if image is decayed or foreground and background images are of similar color. For example, text written on gray background is difficult to distinguish as foreground or background.

Skew estimation is done after binarization in an OCR system. Skew is the angle, the image makes with the corner of the page. It involves two steps, skew detection (estimation) and skew correction. Skew estimation is needed because while scanning a document image a few degree of skew is unavoidable. OCR of skewed image will give an erroneous result.

- In this paper seven methods for skew estimation are discussed and the results are analyzed. The different methods discussed are skew detection using HPP, FFT, combination of HPP and HT, combination of Gabor filter and radon transform, combination of WT and HT, HT and radon transform.

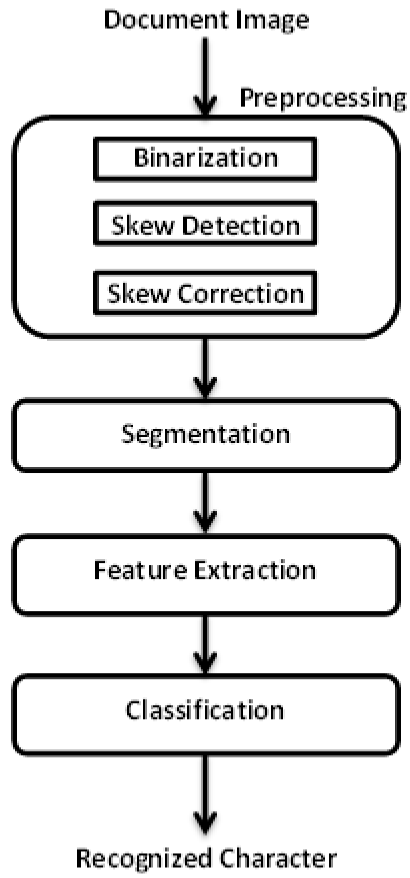

Figure 1. Block diagram of OCR system.

A. Skew detection using HPP

The horizontal projection profile is the histogram of number of pixels in the document image along with the HPP and is given in fig. 2. The document image exhibits maximum peak when skew angle is zero. This method fails to find the skew if document images contain pictures.

Figure 2. HPP of document image.

HPP based method is least reliable and consumes more time to find the skew angle. Algorithm to find the skew based on HPP is as follows

1. Find the HPP for θ ranging from -90 to 90 degree.
2. Find the peak point in HPP for each angle.
3. The θ for which the peak is maximum corresponds to zero skew.
4. Find out for how much rotation maximum peak is attained.
5. The rotation gives the skew angle.

B. Skew detection using FFT

FFT is the faster version of discrete Fourier transform. Discrete Fourier transform produces discrete frequency domain. It calculates frequency over only one period of continuous frequency domain. When the region of one frequency cycle is examined, it can be seen that there is even symmetry around the center point, the Nyquist frequency. The angle at maximum frequency is the skew angle. The formula for finding the FFT is shown in (1). If the signal X(K) is periodic, band limited and sampled at Nyquist frequency then FFT is given by

$$FFT(r) = \sum_{K=0}^{N-1} X(K) W_N^{rK} \quad (1)$$

where

$W_N = e^{-2*PI*I/N}$ and r=1, 2 … N-1

The FFT based skew estimation method can be applied for both types of document images (text/pictures)

FFT can be applied to find the skew angle for both text and document images. It is less efficient than radon transform. Algorithm to find the skew using FFT is as follows

1. Read the image.
2. Binarize the image.
3. Find the FFT of binarized image
4. Calculate the logarithm of absolute value of the transformed image call it F.
5. Find the logarithmic probability density function of the F call it P.
6. Repeat the step 3 to 5 for different angles of the image.
7. The skew angle corresponds to maximum value of P which represents maximum frequency.

C. Skew detection using HPP and Hough transform

The combination of HPP and HT can be used for skew estimation. It gives better accuracy than using either of them in isolation. The Skew detection algorithm using HPP and Hough is as follows.

1. Read the image
2. Find the HPP of the image
3. Give the output of HPP as input to the HT
4. Find the Hough peaks
5. Find the Hough lines
6. Skew angle is the angle of Hough line

D. Skew detection using combination of Gabor filter and Radon transform

Gabor filter is a feature selection method. It will select the feature of an image in the given angle. Gabor filter is basically a Gaussian with variances Sx and Sy along x and y directions modulated by a complex sinusoid with center frequencies Fx and Fy along x and y directions. It is given in (2).

$$G(x,y) = \left(\frac{1}{2*pi*Sx*Sy}\right) * \mathrm{EXP}\left(-\left(\frac{1}{2}\right) * \left(\left(\frac{\mathrm{X}}{\mathrm{Sx}}\right)^2 + \left(\frac{\mathrm{Y}}{\mathrm{Sy}}\right)^2\right) + 2 * \mathrm{PI} * \mathrm{I} * (\mathrm{Fx} + \mathrm{Fy})\right) \quad (2)$$

Gabor filter selects the feature along a particular direction under consideration. This reduces the number of points for which radon transform need to be calculated. Even though Gabor filter consider less number of points, the computation requires more time reducing the overall speed of skew estimation. Algorithm to compute skew using combination of Gabor and radon is given below.

1. Read the image.
2. Binarize the image.
3. Select the features using Gabor filter at an angle zero.
4. Apply radon transform on selected features.
5. The skew angle corresponds to maximum value of radon transform.

E. Skew detection using combination of WT and HT

The transform of an image is just another form of representing the image. The Fourier transform gives constant resolution at all frequencies where in Wavelet transform uses different resolution for different frequencies. Waves are periodic in nature. Wavelets are localized waves. It has two filters, low pass filter and high pass filter. The proposed method uses HAAR wavelet transform in horizontal direction. It is less reliable since it cannot handle a noisy image. This method cannot be applied to document images containing pictures. Wavelet transform can be applied for image compression.

HAAR based Wavelet transform is used to select the features of the image and those features are fed as input to the Hough transform. The method is least reliable but is fast. The algorithm to find skew using combination of WT and HT is as follows

1. Read the image.
2. Take the HAAR wavelet.
3. Find out low pass and high pass filters
4. Apply discrete wavelet transform
5. Binarize the image got in 4.
6. Apply the Hough transform
7. Find the Hough peaks
8. Find the Hough lines
9. Skew angle is the angle of Hough line

F. Skew detection using HT

Hough transform finds the intensity of the image and represents it in an alternative form. Hough transform is widely used for detection of lines and curves. It calculates the rho for every theta and stores it in a matrix. Rho is calculated using (3)

$$Rho = x\cos\theta + y\ \sin\theta \quad (3)$$

Hough matrix is combination of Rho and θ values. Skew angle is the angle where Rho is maximum. This method fails to find the skew if document images contain pictures.

HT finds the intensity of the image at every pixel. The skew angle is found by calculating the HT for all values of θ and calculating Rho as discussed previously. Skew angle is the angle corresponding to maximum Rho. The algorithm is as follows.

1. Read the image.
2. Binarize the image.

3. Apply the Hough transform
4. Find the Hough peaks
5. Find the Hough lines
6. Skew angle is the angle of Hough line

G. Skew detection using Radon Transform

Usually an image is represented mathematically as a function of two spatial variables f(x,y). The intensity of the image at the point (x,y) represents value of function at that point. This is called the spatial domain. Transform refers to an alternative mathematical representation of the image. Radon transform maps Cartesian rectangular co-ordinates to the polar co-ordinates. Radon transform is a function of Rho and θ for each matching points calculated whereas in Hough Transform, Rho and θ are calculated for each pixel.

The radon transform of the image is the sum of radon transform of each pixel of the image. The radon function computes projections of an image matrix along specified directions. A projection of a two-dimensional function f(x,y) is a set of line integrals. The radon function computes the line integrals from multiple sources along parallel paths, or beams, in a certain direction. The beams are spaced one pixel unit apart. To represent an image, the radon function takes multiple, parallel-beam projections of the image from different angles by rotating the source around the center of the image. Radon transform of an image is given by (4) [1, 3]. The skew angle is calculated based on the maximum value of radon function.

$$R\theta(x') = \int_{-\infty}^{+\infty} f(x' \cos\theta - y' sin\theta, x' sin\theta + y' cos\theta)\, dy' \quad (4)$$

where

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

The radon based skew estimation method is ideal for document images containing pictures. It can be applied to document images containing text as well.

Skew detection is done through novel approach which uses radon transform. This algorithm outperforms all other algorithms and can find the skew angle in just 0.0936 seconds in case of machine printed text documents for angles varying -6 to + 6. The algorithm for skew detection has following steps.

```
1.  Binarize the image. (Binarization is process of
    converting a grey scale image into a binary image. It
    separates foreground from background)
    b=binarize(I);
2.  Detect the edges. E=edge(b);
3.  Initialize m1 to zero. Angle range theta to 0:179
4.  Apply the radon transform [R,xp]=radon(E,theta)
5.  Find size of R and assign it to a and b.
6.  for i=1 to a begin
7.      for j=1 to b begin
8.          m=R(i,j)
9.          if( m>m1) begin
10.             angle=j;
11.             m1=m;
12.         end
13.     end
14. end
15. if(angle>=90) begin
16.     skewangle=angle-91
17. else
18.     skewangle=-(91-angle)
19. end
```

H. Skew Correction

Skew correction is achieved through rotating the image by estimated skewangle. Later the boundaries are adjusted in the following way.

```
1.  Find the size of the image [size1,size2]=size(image).
2.  for i=1 to size1 begin
3.  Initialize mini(i),minj(i)(left corner
    cordinates),maxi(i),maxj(i)(right corner coordinates)
    to 1
4.      for j= 1 to size2 begin
5.          if(image(i,j)==1)begin
6.              mini(i)=i;
7.              minj(i)=j;
8.              break;
9.          Else
10.             continue;
11.         end
12.     end
13. end
14. for i=1 to size1 begin
15.     for j= 1 to size2 begin
16.         if(image(i,j)==1)begin
17.             maxi(i)=i;
18.             maxj(i)=j;
19.         end
20.     end
21. end
22. for i=1 to size1 begin
23.     for k=1 to minj(i) begin
24.         image(i,k)=1;
25.     end
26.     for k=maxj(i) to size2 begin
27.         image(i,k)=1;
28.     end
29. end.
```

III. Experimental Results

The proposed system is tested on a computer with 2.27GHz processor and 2GB RAM. The dataset is prepared with a resolution of 200 dpi using an HP flatbed scanner. The document image size is 2060X1890 pixels. The data set include150 document images with skew varying from 1 to 25 degrees. The execution speed of skew estimation is on an average, 2.23seconds. Radon transform will take $O(N^2M)$ time to execute for a document image of size N X N and with the skew of M. In practice, the skew fall between 1 to 6 degrees and execution, on the average improves to 1.70 seconds. The proposed system implements several other methods. The results are discussed in Table I to Table IV for machine printed text images, scanned text images, machine printed images containing pictures and scanned images containing pictures respectively. Sample image with skew is shown in Fig. 3 and radon transform of the image is depicted in Fig.4. Fig 5 depicts the FFT of the text document with five degree skew. Fig. 6 shows the HPP for the same and Fig. 7 depicts the HT when applied to the HPP of the skewed image. Fig.8 shows the skew corrected image after rotating the image by estimated skewangle and Fig. 9 shows the image after boundary adjustment. The proposed radon transform based method not only exhibits excellent execution speed but also provides better accuracy compared to other methods.

If requirement is to find the skew in case of photos or image containing text along with picture then one can use either FFT or radon transform based method as described in section II, sub section B and G respectively. FFT has the drawback that it is slow compared to radon transform. The combination of HPP and Hough transform is slower than radon and fails to identify the skew in case of machine printed pictures. HPP based skew estimation is the slow and least reliable and radon transform is the fast and most reliable among them. All methods discussed other than radon transform and FFT failed to identify the skew angle in case of pictures, due to the noise or failure to distinguish between foreground and background.

The radon transform based method and FFT is tested on Document images containing photographs as well. The picture set includes 150 photos with skew angle varying from 1 to 25 degrees. Both radon transform and FFT exhibits 100% accuracy in estimating the skew but radon transform outperforms FFT in terms of efficiency. Fig.10 shows a photograph with 5 degree skew. The Photo with corrected skew is depicted in Fig. 11 and Fig. 12 shows the radon transform for the same. FFT of the image in Fig 10 is shown in Fig.13. Comparison of radon and FFT is given in Table III and IV. The additional advantage of radon transform is it can even be applied to images which are old and decayed. The WT based method gives a vertical line of features on which HT is applied.

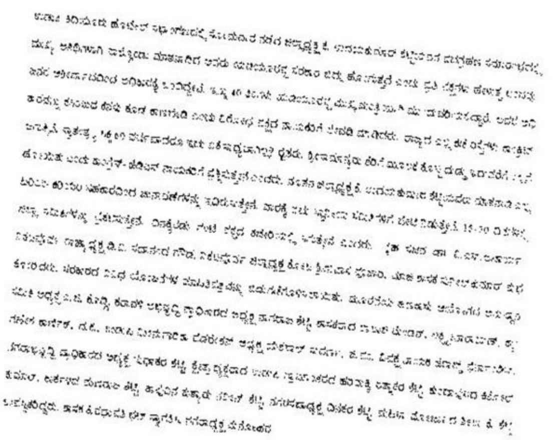

Figure 3. Sample picture with five degree skew

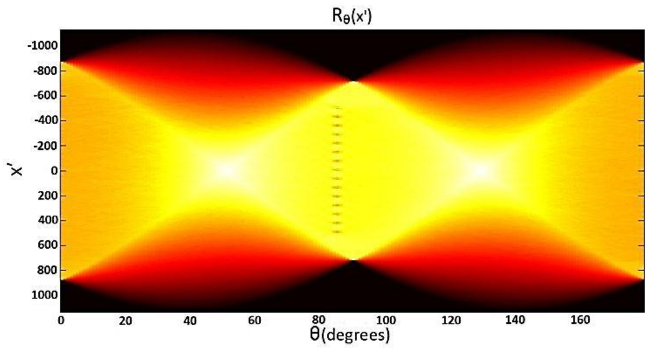

Figure 4. Radon transform of the image with five degree skew

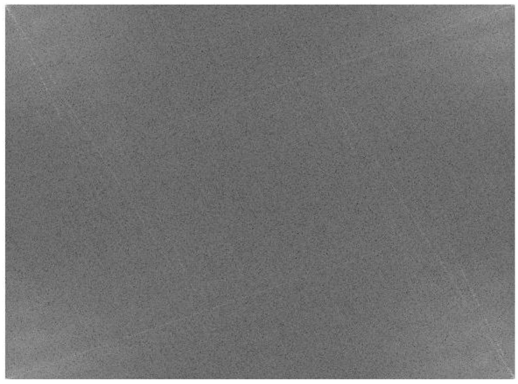

Figure 5. FFT of the image with five degree skew

Figure 6. HPP of the image with 5 degree skew which is fed as input to HT

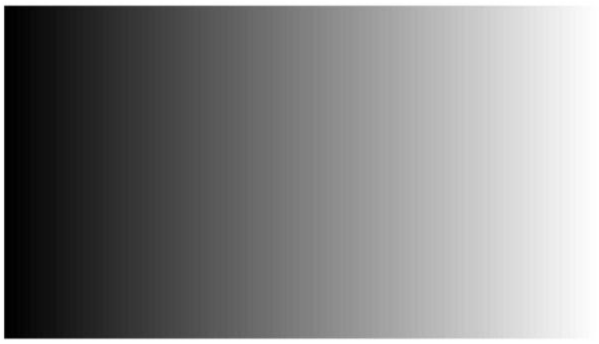

Figure 7. HT of the HPP

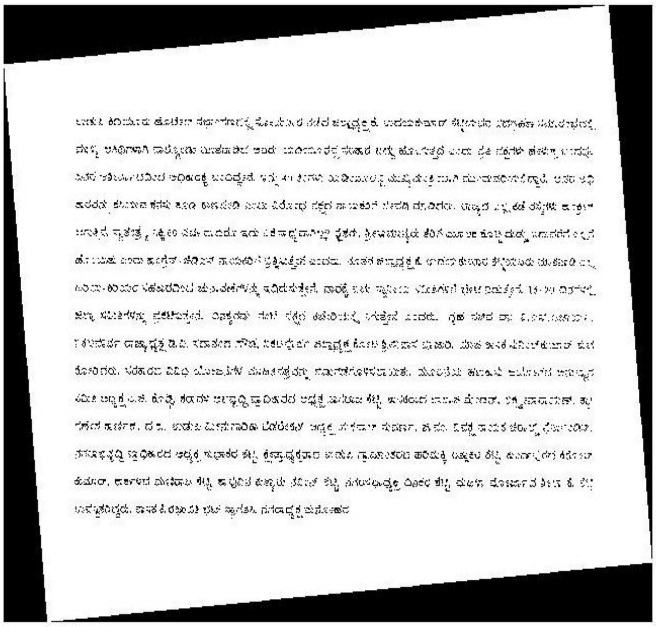

Figure 8. Image after rotation

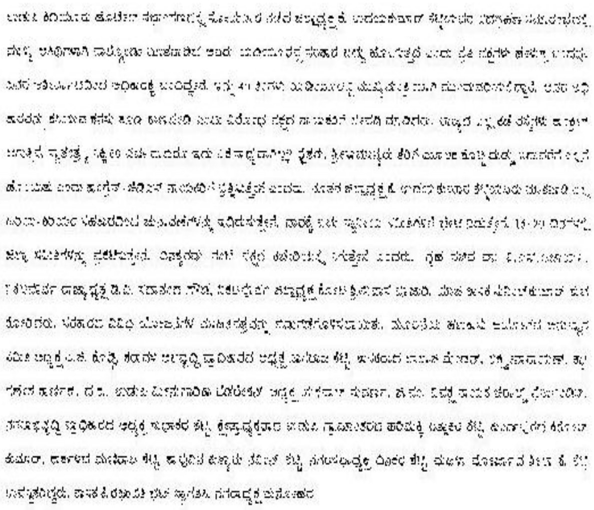

Figure 9. Image after boundary adjustment

Figure 10. Sample image with five degree skew.

Figure 11. Picture after skew Correction

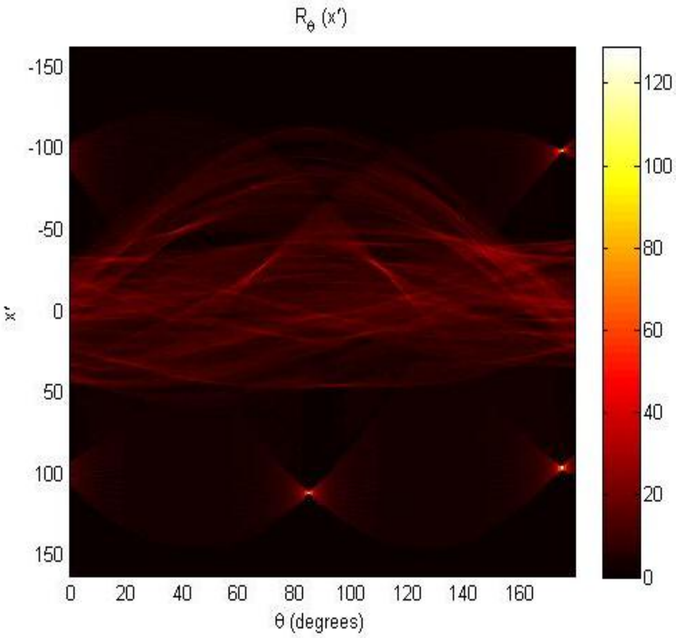

Figure 12. Radon transform for figure10

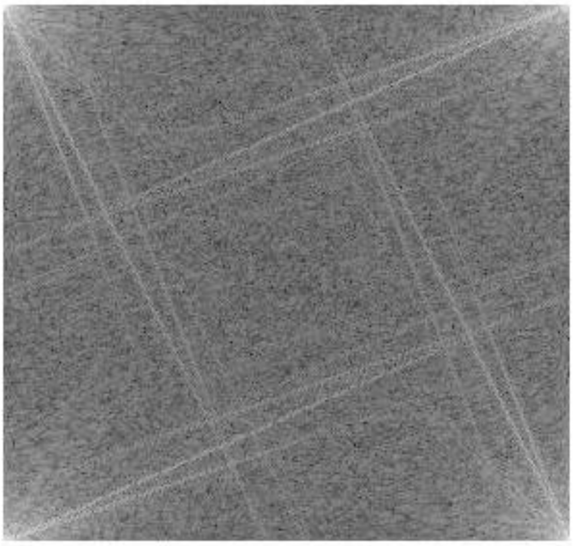

Figure 13. FFT for figure 10

*Table 1. C*omparison of results of skew estimation for document images containing text for machine printed images.

Methodology	Skew angle(original image)	Accuracy	Average time for machine printed images (in seconds)
Projection profile technique	1-25 degrees	99%	2.83
	1-6 degrees	99.6%	1.2350
Peaks and valleys analysis[9]	1-25 degrees	99.09%	1.96
Connected component analysis[9]	1-25degrees	99.50%	2.55
Radon transform	1-25 degrees	100%	0.1404
	-6 to +6 degrees	100%	0.0936
FFT	1-25	100%	29.36
	1-6	100%	3.7284
HPP+HT	1-25	99%	0.8644
	1-6	99.6%	0.7644
WT+HT	1-25	99.6%	0.56
	1-6	100%	0.1716
HT	1-25	99.6%	0.59
	1-6	100%	0.2964
Gabor Filter+ Radon Transform	1-25	100%	1.5288
	1-6	100%	0.546

*Table 2. C*omparison of results of skew estimation for scanned document images containing text.

Methodology	Skew angle(original image)	Accuracy	Average time machine printed images (in seconds)
Projection profile technique	1-25 degrees	30%	28.32
	1-6 degrees	30%	20.85
Radon transform	1-25 degrees	100%	2.23
	-6 to +6 degrees	100%	1.70
FFT	1-25	26%	473.38
	1-6	32%	363.21
HPP+HT	1-25	36%	26.56
	1-6	36%	18.37
WT+HT	1-25	26%	6.1048
	1-6	26%	4.35
HT	1-25	38%	6.31
	1-6	38%	4.83
Gabor Filter+ Radon Transform	1-25	20%	19.1413
	1-6	20%	15.82

*Table 3. C*omparison of results of skew estimation for machine printed pictures.

Methodology	Skew angle(original image)	Accuracy	Average time (in seconds)
Radon transform	1-25 degrees	100%	0.0156
Radon transform (proposed method)	-6 to +6 degrees	100%	0.00923
FFT	1-25	100%	3.78
FFT	1-6	100%	1.56

*Table 4. C*omparison of results of skew estimation for scanned pictures.

Methodology	Skew angle(original image)	Accuracy	Average time (in seconds)
Radon transform	1-25 degrees	100%	1.2
Radon transform (proposed method)	-6 to +6 degrees	100%	0.935
FFT	1-25	12%	321.54
FFT	1-6	12%	253.97

IV. Conclusion

In this paper, seven algorithms for skew estimation were discussed. HPP based skew estimation is the slow as well least reliable and radon transform is the fast and most reliable among them. For machine printed images it will estimate the skew within a short time period of certain milliseconds. For estimating skew of pictures either radon or FFT can be used and Radon transform outperformed FFT in terms of efficiency. Also Radon transform can be applied in case of blurred and decayed images while FFT fails in such cases. Combination of HPP and HT is one of the methods which can be used in case of text documents but it failed to work on pictures and is less reliable. Combination of WT and HT is faster than HPP and HT but less reliable. Radon transform based skew estimation proved to be the best among other methods discussed with document image containing text or pictures. Radon based skew estimation method can be applied for any type of document and it is 100% reliable. The combination of WT and radon transform based method is less reliable so it is not discussed in the proposed work. In case of scanned documents HT, FFT and HPP based skew estimation methods fail because they are more sensitive to noise. Radon transform succeeds in estimating the skew of scanned documents because it is less sensitive to noise. Estimation of multiple skew in a single document image can be taken as future work.

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Author Biographies

Mr. Prakash K Aithal received his B.E. degree in Computer Science & Engineering from Kuvempu University in 2000 and M.Tech degree in Computer Science and Engineering from Manipal University in 2010. He is currently working as Assistant Professor in Department of Computer Science and Engineering at Manipal Institute of Technology. He is a life member of Indian Society for Technical Education (ISTE).

Mr. Rajesh G received his B.E. degree in Computer Science & Engineering from Gulbarga University in 1999 and M.Tech degree in Systems Analysis and Computer Applications from NITK Surathkal (Deemed) in 2005. He is currently working as Assistant Professor in Department of Computer Science and Engineering at Manipal Institute of Technology and pursuing PhD in Computer Science and Engineering from Manipal University. He is a life member of Indian Society for Technical Education (ISTE).

Dr. U. Dinesh Acharya received his B.E. degree in Electrical and Electronics from University of Mysore in 1983. He received his M.Tech degree in Computer Science and Engineering in 1996 from Mangalore University and PhD in Computer Science & Engineering in 2008 from Manipal University. He is currently working as a Professor in Computer Science and Engineering at Manipal Institute of Technology, Manipal. Currently he is guiding PhD's in Pattern Recognition, Knowledge Based Systems and Database Systems. He is a life member of Indian Society for Technical Education (ISTE).

Dr. Siddalingaswamy P C received his B.E. degree in Electronics and Communication from Kuvempu University Davengere in 2000. He received his M.Tech degree and PhD in Computer Science & Engineering from Manipal University in 2003 and 2011 respectively. He is currently working as a Associate Professor in Computer Science and Engineering at Manipal Institute of Technology, Manipal. His area of research intrest are Medical Image Processing, Pattern Recognition. He is a life member of BMESI.