An overview of existing literature on document skew detection

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Abstract

In the proposed paper we present an overview of the existing methods of skew estimation. Skew estimation is one of the major prepossessing task in document image. In this article we present the evaluation of skew estimation process from the very beginning of classical methods to the latest Artificial Intelligence methods like Convolutions Neural Network(CNN). A wide range of database which have been used by the researcher throughout the decades for the skew estimation process is also discussed in this paper. A clear understanding of different types of skew is being discussed in this article. We categorically discussed different existing methods of skew estimation in brief. We also present a comparative studies on different existing methods of skew estimation. This article will help the researchers who intend to do research on this field.

Documet Image Processing, Nearest Neighbor Clustering (NN), Hough Transform, PCA, Optical Character Recognition (OCR), Projection Profile Based Methods (PP), Connected Component Analysis(CCA), Convolutions Neural Network(CNN)

1 Introduction

One of the possible distortions that gets introduced frequently during imaging or digitization of hard copy paper documents is skew. It often happens due to improper placement of the hard copy document under the camera or on the

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scanner bed in a tilted manner. Thus, document image skew is a rotation of a page about a fixed point in the image. Such skew of a document image may vary from only a few degrees to several degrees. As a result, the horizontal text lines in a document image appear rotated by certain degrees. On the other hand, in handwritten documents, often skew occurs due to the style of writing or habits of its writers. Also, in a few cases, multi-skew can be found in certain documents like magazines, advertisements, posters etc.

Before apply OCR to the document image some pre-processing operations like binarization [23] [18], line segmentation [22] skew correction [24] [55], [83], [4], [99], [87], page layout analysis etc are applied on the documents. Among these skew correction is one of the most important. In this article we discussed skew correction in brief.

We may come across some documents for which it can be challenging to find the skew of those documents. There may be multi lingual document image, multi column document images with very little text part, in photograph images containing graphical figures, images containing photograph, table or chart, images of comics, drawing different font type size and style as well as multi script document images, old and noisy document images.

Since the architecture or structure of various available documents vary widely, a large number skew detection approaches has been proposed in the literature to accommodate different conditions of these individual documents towards estimation of their skew angles.

There need some preprocessing before process the images through OCR, they are like binarized the documents, skew and slant correction [55], [83], [4], [99], [87] and page layout analysis. One of the most important preprocessing before using OCR system is skew and slant correction which is the main topic of this paper. Document image skew is a rotation of a page image about a fixed point. At the time of scanning the document due to mistake by person papers are not placed properly on the scanner and it results skew in the image. Skew can be in a huge range and different types. In handwritten documents skew occur due to the writing style and habits of the writers. Sometimes multiskew can be noticed in many documents like magazine and different advertisement poster. In such documents skew detection and correction is a great challenge. In handwritten recognition skew correction is also a major problem.

We also see some of the other images like scanned visiting cards, license plate and number plate of moving vehicles, outdoor seen document images like banners, name plates etc. We see many applications where skew in these documents are corrected. In automatic number plate detection of a moving vehicle from close circuit TV camera for security purpose skew correction is applied in the number plate image. Furthermore, in text area detection of seen image skew detection and correction is applied. Nowadays some smart scanners provide automatic skew correction. Skew estimation of business card images by Personal Digital Assistant is also a popular application where skew correction is used.

We organised the proposed paper as follows. In section II We discussed about database of skewed document in section 2, problem areas in section 3, different methods of skew estimation in section 4, section 5 contains conclusion.

Figure 1: Block diagram of different types of skew

2 Database

This section represents about some popular databases that are being used by a wide range of students, researchers and industry persons. There are both handwritten and printed documents in these databases containing figures, diagrams, circuits, tables, architectural plans etc. Lets take an overview of some databases.

2.1 The Recognition Improvement Program Set 1 database

United States Postal Service created this database in the year 1990. This postal database was created for a program where some competing vendors would be evaluated to locate and recognize the address part. In the database more than

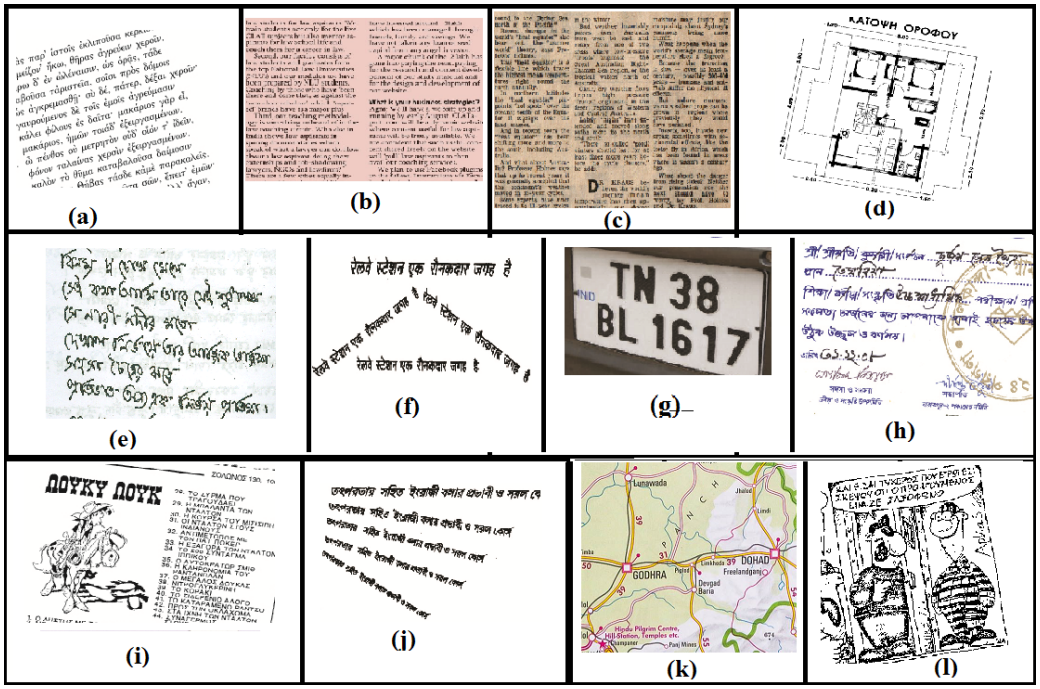

Figure 2: Different types of skewed document image, (a) Single column text skewed document, (b) Double column text skewed document, (c) Multi column text skewed document, (d) Graphical Document, (e) Handwritten manuscript, (f) Multi orientation of text line, (g) Document with perspective distortion (h) Mixed document printed and handwritten document, (i) Mixed text graphics, (j) Document with perspective distortion and multiple orientation, (k) Graphics embedded text of multiple orientation, (l) Text embedded into the graphics

100,000 envelops were scanned at 212 DPI. Most addresses of the envelops were machine printed English text. The challenging aspects in the database was that the images contained real life noise, variability in terms of style, font size and formats.

2.2 The Federal Register data set

For recognition technologies, evaluating document analysis and information retrieval systems NIST created a document image database. This database was known as Special Database 25. It consists of images from the 1994 Federal Register. In 1994 the Federal Register published nearly 250 issues that contained roughly 69000 pages. The pages were from 20 books that were published in January, 1994. The database contains 4711 pages scanned at 400 DPI. Of these 4771 images, 4519 images had ground truth. The database includes scanned images, commercial OCR results, SGML-tagged ground truth text, and image quality assessment results. Many experiments and research were done on this database.

2.3 SRI PAS, HEB, and MAR data sets

In this dataset almost 100 pages scanned at 300 DPI of scripts Marathi, Hebrew and Pashto were put together by [6]. These images were obtained from a variety of books of different scripts of different font size and style. All the texts here are vertically.

2.4 The University of Washington English Document Image Data Set I

The UWI data set was created in the year 1993 by R.M. Haralick et. al. for OCR research and due to its inclusion of real-life noise conditions it has been widely used in the character recognition and document layout detection literature. The database contains 979 binarized images along with OCR ground truth. Many of these images were degraded because of first and second generation photocopies.

2.5 UW-II English/Japanese Document Image Database

In the series of UW-I databases UW-II is the second one. At the Intelligent Systems Laboratory, a team of undergraduate and graduate students, led by Dr. Ihsin Phillips and Dr. Robert Haralick designed and constructed this database. The database contains 477 Japanese journal document image and 624 English document page images containing 43 complete articles and 63 MEMO pages. Each of the document pages has its associated text ground truth data of the text zone, bounding box for text zone, for each document page its coarse level attributes, for each zone its finer level attributes.

2.6 UW-III English/Technical Document Image Database

In the series of UW-I and UW-II UW-III is the third one. A team of undergraduate and graduate students constructed the database led by Dr. Phillips, Dr. Chanda and Dr. Haralick at the Intelligent Systems Laboratory. The database contains 25 pages of Chemical formulae, 25 pages of Mathematical formulae, 40 pages of Line drawings, 44 TIFF images of engineering drawings, 33 TIFF images of English text generated from LaTeX 33 printed and scanned pages containing English text, 979 pages from UW-I in DAFS format, corrected for skew, and the word bounding boxes for each word on these pages, 623 pages from UW-II in DAFS format corrected for skew, and the word bounding boxes for each word on 607 of these pages. For each of the type of the data there exists ground truth for corresponding data. This data may be made skewed and then subject to skew correction.

2.7 The IFN/ENIT database

For the training and testing of Arabic handwriting recognition software Technical University of Braunschweig has developed The IFN/ENIT-database [131]. More than 411 Tunisian writers have filled more than 2200 forms and from those the binary images were constructed. About 26,000 binary word images have been isolated from the forms and saved individually for ease of access. The writings were unrestricted of writing style and no writings lines or boxes were used. The documents were scanned at 300 DPI. A total of 26459 city name words were extracted from the forms where 212211 characters and ligatures were present. Each word was automatically determined and manually verified.

2.8 ICDAR DISEC 2013 database

In the year 2013 the ICDAR conference organized Document Image Skew Estimation Contest (DISEC 2013) that provides 1550 test image. The document images have figures, diagrams, block diagrams, electrical circuits, tables, architectural plans. The documents were collected from newspapers, scientific journals, poetry anthologies, course books, dictionaries, scientific books, travel guides, literature books, menus, comic books, official state documents, museum guides, museum tickets, and various other sources. The documents were written in English, Greek, Japanese, Danish, Italian, Chinese, Turkish, Bulgarian, Russian, and ancient Greek script. The images of the database contain two types of data, textual and non-textual data. Some documents contain only textual data and some contain the mixed data, of which 992 images contain only textual data and 860 images contain mixed data.

2.9 IAPR TC-11 Dataset

Technical Committee Number 11 (TC11) [161] of International Association for Pattern Recognition (IAPR) takes care of the development of the theory

and applications of automatic Reading Systems that recognize or analyse text content in handwritten and printed documents, images, and videos. Its online resources [162] include more than 50 downloadable annotated datasets of printed/handwritten characters and words, signatures, document images, handwritten and typeset mathematical expressions, video, scene texts etc. of various scripts of this world such as English, Chinese, Arabic, Hebrew, Urdu, Malayalam, Bangla etc. Some of its well-known datasets include Tobacco 800 Dataset, Arabic Text Detection Dataset, IIIT 5K-Word Dataset, ICDAR Competition Datasets, ICFHR Competition Datasets, Street View Text Datasets etc. One or more samples from a few of these datasets are shown in Fig. 3.

IAPR TC11 is the International Association for Pattern Recognition (IAPR) Technical Committee Number 11. The TC-11 dataset deals with the recognition and analysis of information in documents like document image processing, handwriting recognition, Optical Character Recognition (OCR). These topics cover both recognition of handwritten documents as well as recognition of printed texts , both on-line and off-line mode. The topics of this dataset coves almost aspect of image processing area. It includes image or planar coordinates obtained from sensors, feature extraction and selection, through image and signal-processing stages, classify, parse document contents and algorithms used to segment.

The following table show a list of dataset of TC-11.

Table 1: List of Database

Year	Author	Name of the Database
1990	USPS (United States Postal Service)	The Recognition Improvement Program, Set 1 (RIP-1)
1994	NIST: National Institute of Standards and Technology [158]	The Federal Register data set
1993	R.M. Haralick et. al.[133]	The University of Washington English Document Image Data Set I
1993	R.M. Haralick et. al.[133]	UW-II English/Japanese Document Image Database
1996	I.T. Phillips [132]	UW-III English/Technical Document Image Database
2002	Margner et. al.	The IFN/ENIT database
2016	Oussama Zayen [180]	A Dataset for Arabic Text Detection, Tracking and Recognition in News Videos - AcTiV,
2017	Guillaume Chiron [36]	Dataset for the competition on Post-OCR Text Correction 2017 (Post-OCR 2017)
2011	Rafael Dueire Lins [96]	Document Image Binarization Platform (DIB Platform),

Continuation of Table1		
Year	Author	Name of the Database
2009	K. Y. Franke et al [25]	ICDAR 2009 Signature Verification Competition (SigComp2009)
2018	Vincent Christlein [38]	ICDAR 2019 Competition on Image Retrieval for Historical Handwritten Documents Dataset (HisIR19)
2019	Harold Mouch'ere [114]	ICDAR 2019 Competition on Recognition of Handwritten Mathematical Expressions and Typeset Formula Detection (ICDAR2019-CROHME-TDF)
2010	Muhammad Imran Malik [106]	ICFHR 2010 Signature Verification Competition (4NSig-Comp2010)
2019	Yipeng Sun [159]	Arbitrary-Shaped Text (ICDAR-2019 ArT)
2019	Yipeng Sun [160]	Large-scale Street View Text with Partial Labeling (ICDAR-2019 LSVT)
2007	J. Kumar et. al. [86]	TANGO -DocLab web tables from international statistical sites
2014	Harold Mouch'ere [115]	ICFHR 2014 (CROHME-2014)
2019	Abbas Cheddad [32]	A Swedish Historical Handwritten Digit Dataset (ARDIS)
2014	Joan Andreu S´anchez [163]	Handwritten Text Recognition on tranScriptorium Datasets Bentham R0 (HTR Competition 2014)
2015	Joan Andreu S´anchez [164]	Handwritten Text Recognition on tranScriptorium Datasets: Bentham R1 (HTR Competition 2015) (HTR Competition 2015)
2016	Joan Andreu S´anchez [165]	ICFHR2016 Competition on Handwritten Text Recognition on the READ Dataset (HTR Competition 2016)
2016	Irina Rabaev [139]	Multiply oriented and curved handwritten text line dataset (VML-MOC)
2019	Christian Clausner [39]	RDCL2019 Competition Dataset (Recognition of Documents with Complex Layouts) (RDCL2019)
End of Table		

3 Problem Area

In this section we tried to categorised the different skewd documents. After considering all the dataset mentioned before we classify the document type as:

- Printed Document

Figure 3: Few example of different types of document in IAPR TC-11 Dataset: a) A Dataset for Arabic Text Detection, Tracking and Recognition in News Videos - AcTiV,[180] b)Dataset for the competition on Post-OCR Text Correction 2017 (Post-OCR 2017) [36] c) Document Image Binarization Platform (DIB Platform) [96] d) ICDAR 2009 Signature Verification Competition (SigComp2009) ,[25] e) ICDAR 2019 Competition on Image Retrieval for Historical Handwritten Documents Dataset (HisIR19) [38] f) ICDAR 2019 Competition on Recognition of Handwritten Mathematical Expressions and Typeset Formula Detection (ICDAR2019-CROHME-TDF) [114] g) ICFHR 2010 Signature Verification Competition (4NSig-Comp2010) [106] h) Arbitrary-Shaped Text (ICDAR-2019 ArT) [159] i) Large-scale Street View Text with Partial Labeling (ICDAR-2019 LSVT) [160] j) TANGO -DocLab web tables from international statistical sites[86] k) ICFHR 2014 CROHME Fourth International Competition on Recognition of Online Handwritten Mathematical Expressions (CROHME-2014) [115] l) A Swedish Historical Handwritten Digit Dataset (ARDIS) [32] m) Handwritten Text Recognition on tranScriptorium Datasets Bentham R0 (HTR Competition 2014) [163] n) Handwritten Text Recognition on tranScriptorium Datasets: Bentham R1 (HTR Competition 2015) (HTR Competition 2015) [164] o) ICFHR2016 Competition on Handwritten Text Recognition on the READ Dataset (HTR Competition 2016) [165] p) Multiply oriented and curved handwritten text line dataset (VML-MOC) [139] q) RDCL2019 Competition Dataset (Recognition of Documents with Complex Layouts) (RDCL2019) [39]

- Handwritten document
- Mixed Printed Handwritten Document
- Mixed Text Graphics Document
- Graphical Document

The block diagram of figure 3 on page 9 describe different types of document image.

3.1 Printed Document

This types of documents are primarily machined printed documents like newspapers, magazine, books, articles, journals etc. When the text lines in the image makes any angle with the horizontal direction skew is generated in the image. Some difficulties arise also in printed document image. Some examples are: multi column text documents, multiple font size and style, document containing non-textual part. If the non-textual parts are real life scene image with non-rectangular border, then it is more difficult to identify skew angle. Also some difficulties arise to detect the skew angle of the image containing graph, tables, scientific figure etc. Skew in printed documents are mainly of two types.

3.1.1 Single Skew:

When a document image makes a skew angle of only one value (in degree) single skew is generated. This type of skew occurs mainly at the time of scanning a simple document. In this case the text lines in the image are parallel to each other. As skew angle is constant for the entire document and if the image contains only textual content then correction methods are also simple having low complexity.

3.1.2 MultiSkew

In a single document image when there is more than one angle in different parts of the image, it is called multiskew document. It means that more than one text part in the document produces different angle with the horizontal line. Multiskew may occur when multiple documents are scanned together and the documents are placed on the scanned bed at various angles while scanning. Also when different text areas of a document are printed at different angles then this problem will occur. When different textual part produce different angles it is difficult to find those angles. We shall discuss different multiskew detection methods in a following section.

Again on the basis of angle with respect to horizontal direction skew can be divided into two types:

3.1.3 Positive Skew:

If the lines in the document image are rotated in anti-clockwise direction, then that skew is called positive skew. An example of positive skew is shown in the fig. 2 (a).

3.1.4 Negative Skew:

On the other hand, when the lines in the document image are rotated in clockwise direction then that skew is called negative skew.

3.2 Handwritten document

Skew angle analysis of handwritten document images is more challenging. Due to writing habits style of different writers the handwritten documents, the written lines may be nonlinear and undulating. There may be touching or overlapping lines, different orientation of individual text lines, variations in the size of characters etc. Sometimes a set of successive lines may be in vertical orientation. Poetic style writing is another challenge in skew correction problem. So, if the handwritten document is scanned with skew then it becomes more challenging and complex to estimate the skew angle of the image.

The skew we see in the handwritten document images are mainly multiskew. Sometimes words or letters are of different size in the same or consecutive lines which results in complex skew in the document. Touching lines, overlapping and slant lines creates additional problems. Also, in the same handwritten documents positive and negative skew may be present. Examples of handwritten document skew are shown in fig.6.

In the following paragraph we shall discuss about the different handwritten skew angle solving methods. In this section we shall focus on the features that work for the handwritten documents. There are also some methods which work only on the handwritten document images. We shall discuss in brief about these methods later, but the numbers of these methods are limited.

3.3 Mixed Printed Handwritten Document

These types of documents contains printed text and handwritten scripts together. These may be different application forms, challan, money receipt and articles where printed text and handwritten texts are present together. This types of documents are considered as mixed document. These kinds of documents are seen in different kinds of forms, bank cheque, certificates, answer sheet with printed question, handwritten bills with printed part etc. This is a challenging problem in skew estimation field. There are many possible skew options of skew in case of pre-printed documents. The printed part is non-skewed but due to writing style of the writer handwritten text may have skewed. Sometimes the handwritten part may overlap with the printed part or there may be

too many touching lines between printed and handwritten texts. In this case the document is skewed document. If the whole document is scanned with initial skew angle, then also skew angle occur. This skew angle is generally multiskew and the document is multiskewed document. So skew estimation processes must be multiskew detection methods.

The algorithms which are used to detect only single or printed document skew angle will not run properly on these documents. All the algorithms which are capable of detecting multiskew will produce a good result on these documents. In printed and handwritten section, we have discussed many algorithms which are used to detect multiskew in the documents. Those algorithms are also tested on mixed documents. There are some algorithms which are mainly developed for mixed documents, we shall discuss about those algorithms in this section.

3.4 Mixed Text Graphics Document

These are mainly the outdoor images like postal, banner, advertisement or any kinds of document images which are captured by camera. There may present perception distortion than skew in the image. The picture can be taken from any angle, for that there may be skew or perception distortion in the image. One example of such problem is vehicle number plate skew correction. Vehicle license plate skew correction is necessary for security purpose. In this section we include another image; i.e. business card. Although hough business card is not an outdoor seen image still we include it in this section because PDA (Personal Digital Assistant) is used to store business cards in the digital format. Here the image of the card is captured by the camera of the PDA instead of scanning. We could discuss about business card skew detection methods in printed document image section but as it is a challenging problem and many works has been done in this field independently and image is captured by the camera we chose it in this section.

Skew estimation of maps are very challenging task. A map contains different signal, drawing, straight lines, cursive lines, text lines printed in straight way, text characters may appear in different position in the map. So if there is any skew in the image of map then it is very difficult to identify the skew angle. So there need to consider some special features of map to estimate the skew angle.

3.5 Graphical Document

The graphical documents contains diagrams, tables, graphical image, engineering drawing or text with images. skew angle estimation of such graphical document is difficult job. Basically the feature selection for skew detection becomes tough job when graphical images, table or some drawings are present in the document image, because the feature for text region and graphical region are not same. In these types of problem first text and non-text regions are determined.

Then the text part is deals as normal text document. Features are selected for text part and according to features skew is detected and corrected. Next the non-text part is considered and skew angles of the non-text part detected and corrected. One important feature of the non-text region is that unlike text part there is only single skew in this region, i.e. whether it is a table, image, graph, drawing or anything only single skew angle is present. If we can detect the skew angle, we can get the de-skewed image.

4 Available Methods

In this section different methods for skew angle estimation is discussed. We classify the skew estimation methods into eight categories. They are:

- Hough Transform
- Principal Components Analysis (PCA)
- Projection Profile Based Methods (PP)
- Nearest Neighbor Clustering (NN)
- Connected Component Analysis(CCA)
- Cross Correlation
- Radon Transform
- Nural Network
- Others

4.1 Hough Transform

To detect a line or a curve in a space [142] [60] [74] Hough transform [61] is frequently used in image processing. For all the curves, like straight lines the values of the parameter are calculated that can pass through each black pixel. Votes are then cast for each such curve in a multi-dimensional accumulator array. Each dimension of the accumulator array corresponds to one of the parameters. After the entire image has been processed, the accumulator array is inspected for local maxima. Each such maximum indicates the existence of a curve in the original given by the corre-sponding parameter values on the axes. For a distinct point (x, y), the line is represented by:

$$r = xcos\theta + ysin\theta$$

Here r is the distance between origin of the angle to the normal and the θ is the angle that the normal to the line makes with the x axis of the coordinate . In the year 1981, Ballard et al. [60] proposed a novel approach to detect

arbitrary shapes in an image using hough Transform method. In the year 1987 Illingworth et al. [71] proposed a method to find line and curves in a Cartesian region. Here ranges of parameter of the selected pixels are passing through the hough Transform (HT) and HT accumulator is analyze and depending on their result final decision is made.

To detect skew in the document, image the first task is to detect lines and curves of the image so that the assumption can be made about the skew angle of the whole documents to be tested. Skew angle detection using hough transform is proposed by Rastogi et al. [6] in the year 1986 and modified by Srihari et al. [117] in the year 1989. In the year 1989 Princen et al. [135] proposed a method to detect and extract line in the image. One of the earliest researches on skew detection in document image was done by Hinds et al. [66] in 1990. The time complexity of the hough Transform method is $O(\theta N)$ where θ is the angle of skew estimation range divided by $\Delta\theta$ and N is the number foreground pixels. Daniel et al. [94] used hough Transform to detect and correct page orientation and skew in a binarized document image. In page orientation detection process, it takes a binarized document image and produces a page orientation as an output. The authors claimed that the proposed process provide 99.9% accuracy. Chaudhuri et al. [123] in 1996 also used hough Transform to detect skew angel. In this approach a slope is found and a clustering is applied on each line and further the line is determined and the clustering applied repeatedly until slope becomes 0. The proposed process was compared with some famous process of skew detection and correction process and the results are given in table 1:

Riaz Ahmad [41] proposed a Probabilistic hough Transform to (PHT) calculate the skew angle of the document image. The range of the skew angle detected is $\pm 30^{0}$.The approach is specifically tested on Latin and Arabic like scripts. A rectangular decomposition of the document image is proposed by Gatos et al. [54] in 1996. Another process of data reduction of document image for hough Transform was proposed by Younki Min et al. [107] in 1996. The method used modified version of divided horizontal histograms. Using this method, we can also determine the skew angle of graphical image. Yu et al. [175] in the year 1996 used the following two steps on preprocessing document: (1) extraction of the centroids of connected components using a graph data structure, (2) Use of Hierarchical hough Transform. Another approach for block decomposition and segmen-tation of the binary image was proposed by Perantonis et al. [75] in the year 1999. Waked et al. [169] proposed another skew estimation algorithm using hough Transform in the year 1998 by using bounding box of connected components.Y Nakano et al. [118] also used bounding box of connected components

In the year 2008 Nandini et al. [119] proposed skew detection and correction method. In this approach first centroids of the all text areas are calculated and then each word is considered as a single blob and the orientation of different blobs is calculated. After the line detection hough transform is used to estimate

skew angle. Block Adjacency Graph (BAG) was first introduced by Yu et al. [176] and used by Singh et al. [155] and Yu and Jain [175] to reduce the image pixels before applying the hough Transform to detect skew in the image.

Rashid et al. [141], Yin P Y [174], Ishitani [70], Pan et al. [125], Arulmozhi et al. [16], Le et al. [93], and Aradhya et al.[12], Amin et al. [11] also proposed efficient technique for skew estimation by hough Transform. Kumar et al. [85] presented modified hough Transform for skew estimation.

Malakar et al. [105] uses two-stage hough transform for skew estimation. In the first stage contour estimation technique [150] is used for line extraction and then hough transform is applied for skew estimation. In the next step each word is extracted using the Spiral Run Length Smearing Algorithm (SRLSA) [151] and skew in the word is corrected (if exist) using hough transform.

Skew estimation technique proposed by Arulmozhi et al. [14] based on centroid based hough transform is used for license plate skew correction. Arulmozhi et al. [14] introduces skew detection and correction technique by Modified hough transform. The numbers of pixels are reduced to reduce the total time of operation. Arulmozhi et al. [15] also introduced another approach for license plate skew using polar hough Transform correction in the year 2012. hough transform is used on the edge line of the image. Edge lines are used to reduce the processing time.

4.2 Principal Components Analysis (PCA)

Another frequently used methods for skew detection is Principal Components Analysis (PCA). To identify patterns in data PCA is used and data are expressed to highlight their differences and similarities. It is used in image processing for data compression and to detect pattern in the image. The steps of PCA are as follows:

1. From the domain area get the data.
2. From the domain area subtract the mean.
3. Calculate the covariance matrix.
4. From the covariance matrix calculate the eigenvectors and eigenvalues.
5. Choose the components and form a feature vector

The eigenvector with the highest eigenvalue is the principal components of the data set of the domain area. The operations are performed based on this principal component.

One of the earliest works on skew detection using PCA was performed by Okun et al. [120] in 1999. In the same year another work was done by Steinherz et al. [157] of skew detection of the document images by PCA. The principal components of the document image are selected from the foreground pixels. Principal components are chosen depending on the eigen vector and the eigen value. In the year 2005 Sarfraz et al. [149] proposed PCA based skew detection method. For this purpose, they first divide the image into three sub bands of different details namely Horizontal, Vertical and Diagonal details. To estimate the direction of signal distribution in each sub-band they proposed to use PCA technique. Modi et al. [108] proposed an approach for skew estimation of license plate based PCA [156] in combination with Harris Corner Detector [64]. To estimate skew angle of vehicle license plate[126] [58] [57][35] PCA is widely used.

4.3 Projection Profile Based

Projection Profile [68] based process of skew detection[3] is frequently used in image processing. In Projection Profile based approach the histogram (horizontal and vertical) of the image is used to decide whether the skew angle are present or not. In horizontal projection profile analysis if there is no skew in the document image there is clear peack of foreground pixels and valley with lowest or zero foreground pixels (as shown in figure 4 (b) on page 17) and the same of the same skewed image contain more closely peaks and valleys are filled with pixels (as shown in figure 4 (a) on page 17).

Ishitani [70] proposed a new method for detecting the skew of document images containing a mixture of texts, photographs, charts, tables etc. Suitable local regions containing only texts are automatically isolated from such a document image. The author of this work obtained an average accuracy of ± 0.12 degrees on a set of 40 documents. Using projection profile method, we can detect only angles between $\pm 10/15$ degree [143], [73] and it cannot deal with noisy documents and broken character [73]. Sun et al. [28] proposed a method of skew and slant detection and correction in the year 1997 using gradient orientation histogram. A. Bagdanov et al. [1] in the year 1997 applied fiducial reduction method of the source image with projection profile method. The authors compared their propose process with three algorithms as Baird [143], Nakano [118] and Postl [167].

Jiang et al. [79] proposed a novel approach to detect and correct skew angles in the document image in the year 1999. The process uses Focused Nearest Neighbor Clustering (FNNC) technique and shows batter result over Uniform Nearest Neighbor Clustering (UNNC). In the year 2002 another novel approach was proposed by E. Kavallieratou et al. [83]. This algorithm is suitable for both printed and handwritten documents. The proposed approach used Wigner Ville distribution and projection profile for skew angle detection. In the year 2007 Lia et al. [95] used wavelet decomposition and projection profile analysis for skew estimation . In the proposed approach first the skewed document image is decomposed by the well-known two dimensional wavelet transform [146]. As

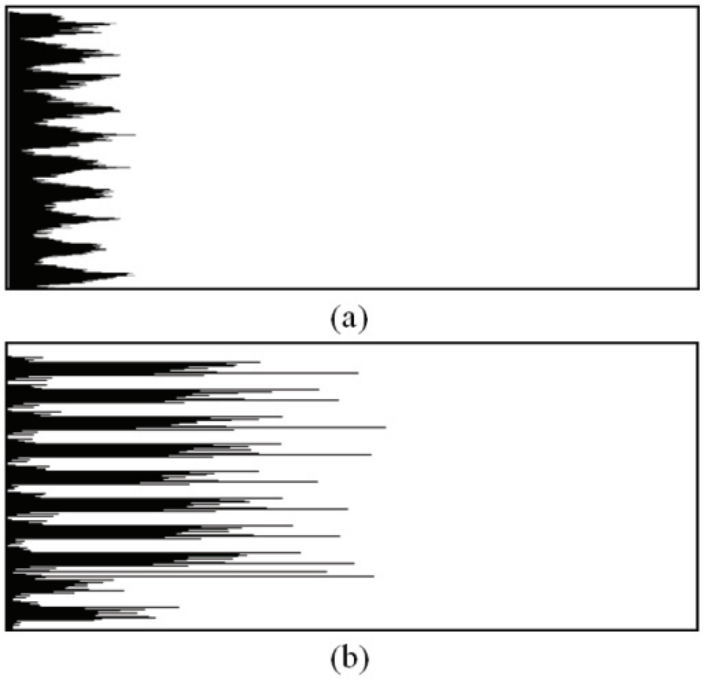

Figure 4: Projection Profile of (a) Skewed document and (b) Non-skewed document

a result of wavelet transform a matrix containing the absolute values of the horizontal sub-band coefficients is created which preserves the texts horizontal structure. The matrix is rotated through a range of angle 15^0 and for each angle projection profile analysis is calculated. The angle which maximizes the criteria function is regarded as the skew angle of the document image.

Nicchiotti et al. [53] proposed an efficient process to detect and correct handwritten cursive skew in document image in the year 1999. So far the process discussed used Projection Profile (PP) to detect skew in the document image, but this process proposed a new idea which is an extension Generalized Projection (GP). The basic idea of GP is to keep information of the neighbor pixel if it is foreground. This differ from the PP where if in the horizontal projection the same number of pixels of noise and text area present in the image PP shows the same value where as in GP it shows different value. Kavallieratou et al. [84] proposed an algorithm for skew estimation of both printed and handwritten documents. As the skew angles vary in the same page of a handwritten document, the page is segmented in to areas based upon the fact that the variation of the angle of successive non-parallel text lines causes wider valleys in the horizontal projection profile of the page, in comparison to parallel lines. In this paper an estimation of skew angle of 0.5^0 is considered.

4.4 Nearest Neighbor Clustering

In the field of pattern recognition Nearest Neighbor (NN) [69] is an important non-parametric method. In the year 1986 Hashizume et al. [69] proposed this method. O'Gorman [91] generalised this method in the year1993, in which he proposed K-NN. An object point is selected among the points by the vote of the neighbor points. In the database, known as training set, we search for the objects of the same class and grouped the classes in the training class. In a set of K nearest neighbor data we search for the similar points in the training set and depending on the similarity in the features of the points most common class is selected. K- Nearest Neighbor is used in skew detection in the documents image in a verity of way. The foreground pixels of the documents image are selected among a region of k-size in the training set. In the following we discuss different methods of skew detection using K-Nearest Neighbor (K-NN) clustering [69]. Unlike hough transform in K-NN clustering the time complexity is low. This approach can detect a wide range of skew angles.

In the year 1996 Pal and Chaudhuri [123] proposed a novel method of skew detection and correction. We discussed this proposed method before. In this method the inline slope is determined by using Nearest Neighbor methods. In the year 1992 Liu et al. [98] used K-NN method to estimate skew angle. The basic approach in this paper was joining the lowest point of the base line of each character. In the first step the lower pixel of each character is marked. After that the K-Nearest Neighbor method is used to detect the lowest baseline pixels and these pixels are connected to find skew line. This approach is mainly used for printed document images.

In the year 2003 Zhixin et al. [179] presented a novel approach of detecting and correcting skew angles for both printed and handwritten document images. In this algorithm they generte a fuzzy run length of the foreground. The result is a set of connected components along the text lines. The height of the connected components in the resulting fuzzy run length should be near the estimated text height. The authors claimed an accuracy of 70% for handwritten documents and an overall 92.1% accuracy in skew detection and correction of the test set.Nearest Neighbor Chain based approach was used by Lu et al. [173] in the year 2003. This approach works well on any script including Chinese. In this method first connected components are detected and then nearest neighbour is detected. In the next step K-Nearest Neighbor Chain (K-NNC) is detected and the final slop is detected from the K-NN. Finally this slop is used to detect skew angle.Yuan et al. [19] used centroids of the each connected components to estimate skew angle.

4.5 Connected Component Analysis

In computer graphics and computer vision Connected Component labeling [171] is one of the basic tools. Here connected components refer to the regions of adjacent pixels in the image which share the same set of intensity values. In order to label the connected components in the image the neighbor of the pixel is compared. We generally used 4-neighbor or 8-neighbor for the test of connectivity. Each time a component is found the neighbor is checked and based on their values that pixel is labeled. There are algorithms where modification is applied for determining the connected components [44][62].

R. Smith [138] proposed a new method for skew detection and correction based on finding row of text in document image. In the method the text row of the document image is first detected in the presence of broken and joined character, speckles noise and page skew. Connected components of the image are first detected and are represented by blobs. The blobs are then sorted and finding the existing row which have the most vertical overlap with the blobs. These rows are the rows of the image. In the next step the baseline of the rows are obtained by using least median of squares fit. The median gradient of the baselines provides the estimated skew angle of the page. The method is compared with Baird [143] and the author claimed that the proposed method is faster and accurate than Baird. Chaudhuri and Pal [31] used an inherent characteristics of Devnagari and Bangla for skew correction of scanned documents of these two scripts. Their strategy is based on detection of headlines of longer words of the input document. The orientations of these headlines are used to estimate the skew.

In the year 1990 Nakano et al. [118] used the connected components of the text area to detected skew angle. A bounding box for each connected component is determined. In the final stage hough transform is performed on the base line to detect skew line in the document image. Kumar et al. [86], in the year 2007, used edge based connected component approach. In the approach the original gray level or colored image is used rather than binarized image. The connected component of the text image is detected by using the Canny edge detection method [29]. Edge-Box (EB) is detected for each connected component. Canny edge detection method will detect both the inner and outer edge of the text; hence in this case two EB will be created for such text. To eliminate these unwanted EB a filter is used. Next the centroid for each EB is computed to determine the skew angle.

Another approach of skew detection and correction is proposed by Nandini et al. [119]. Two approaches are used to detect the skew angle of the line, first one is by detecting the centroids of the all text areas and second one is identifying each word as a single blob and finds the orientation of different blobs. The first method is performed by dilating each word. Next center of each word is determined. The skew angle determined by connecting these centroids. In the

second method the bounding box of each connected component of text area is determined and darkened. Next each component is dilated. Hence each component in the same word is attached in one component. The next step is thinning algorithm [7] applied on the components to determine the center line of the components. As a final step hough transform is applied to the lines found from first and second method to detect the skew angle.

Ben et al. [101] also use connected component analysis for skew estimation technique. They use SPRLC [47] algorithm for connected component analysis. Guru et al. [59] used the connected components of the textual region to detect skew in the document image. A thinning algorithm [26] is used to calculate single pixel thickness of the connected component. For each straight line the skew angle is computed. The average of the angles is selected as the final skew angle. Some other work is also done by M. Sarfraz and Zeehasham Rasheed [102] using connected component analysis.

4.6 Cross Correlation

A gray scale image can be represented as:

$$I(x, y), 0 \leq x \leq X, 0 \leq y \leq Y$$

here x and y is co-ordinate value. For two vertical lines $l_1(x = x_0)$ and $l_2(x = x_0 + d)$ the vertical cross correlation is:

$$R_1(x_0, s) = \sum I(x_0, y) I(x_0 + d, y + s)$$

Chen et al. [33] proposed an efficient approach for skew detection using modified Cross Correlation. In their proposed approach they find a W×W region from which distinct VCC (Vertical Cross Correlation) and HCC (Horizontal Cross Correlation) can be calculated. Depending on the horizontal or vertical layout of the page HCC or VCC is used to calculate candidate skew in the image. From the candidate skew degree an accurate skew is calculated using the value of d.

Another skew estimation technique is proposed by Avanindra et al. [2] in the year 1997. To obtain the skew angle they used maximum median of the cross correlation and also a Monte Carlo technique is applied to determine the number of regions over which the correlation have to be calculated. Their method is based on the interline cross-correlation in the document image as suggested by Yan [63]

There are some other proposed methods of skew estimation based on cross correlation. Some of the algorithms are proposed by Shivakumara et al. [121], Kavallieratou et al. [84], H. Yan [63], Akiyama et al. [166] and Yan et al. [63]. In the algorithm [166] the document image is first segmented by line and character then the skew correction is performed on each character of the word based on cross correlation. The authors claim to have accuracy rate of 94.8% to 97.2%.

4.7 Radon Transform

In the 2D special matrix Radon transform [122] is a function. We can apply Radon transform on images as it is also a 2D matrix. The radon transform is defined on a straight line. The Rf function for line L is defined as

$$Rf = \int_L f(x)|dx$$

Hence L with the arc length t can be represented as:

$$(x(t), y(t)) = ((tsin\alpha + scos\alpha), (-tcos\alpha + ssin\alpha))$$

Where s is the length of L and a is the angle the normal vector. If we use the parameter (s, α) to represent the spaces of line then Radon transform can be represented as:

$$Rf = \int_{-\infty}^{\infty} f\big(x(t), y(t)\big)dt$$

$$= \int_{-\infty}^{\infty} f((tsin\alpha + scos\alpha), (-tcos\alpha + ssin\alpha))dt$$

The variables are defined as:

$$\begin{bmatrix} \text{x} \\ \text{y} \end{bmatrix} = \begin{bmatrix} \cos\alpha & -sin\alpha \\ \sin\alpha & cos\alpha \end{bmatrix} \begin{bmatrix} \text{s} \\ \text{t} \end{bmatrix}$$

The angle a^* be obtained calculated by maximizing the following function:

$$a^* = \arg max - a \int_{-\infty}^{\infty} g(a, s)g(a', s)ds$$

The time complexity of Radon transform is $O(N^2M)$ of size of N×N and skew of M.

In the year 2009 Hilal et al. [65] proposed skew estimation process using Wavelet and Radon transform. In the first step the gray scale image is read and two dimensional first level Wavelet is applied and the low-low components of the transform is taken under consideration. Next these components are binarized and Radon transform is applied on the binarized image. The maximum Radon matrix is obtained and the angle corresponds to the maximum matrix. The angle of the text line is 90^o-detected angle. This algorithm produces an accuracy of 0.5^0 and angle ranges about$\pm 25^0$.

The steps of the proposed algorithms are as follows: first images are divided into several blocks. Next among the blocks the blocks with proper information are selected for further process. For the reason Radon transform is applied on the blocks to detect blocks with textual information. Block selection is performed thorough a cascade. Skew estimation is performed using Bagging estimation and refined estimation. This algorithm produces an accuracy of 0.2^0 and angle of skew ranges$\pm 90^0$. This method is tested on a large number of images of real printed English Journal.

4.8 Neural Network

Neural networks are computational models inspired by the human brain, composed of interconnected nodes (neurons) organized in layers. They're used for tasks like pattern recognition, classification, and regression in machine learning. Training involves adjusting connection weights to minimize errors, enabling the network to generalize to new data. Neural networks have various architectures, including feed forward and recurrent, and play a crucial role in deep learning, powering advancements in image recognition, natural language processing, and more.
The Convolutional Neural Network (CNN) is a model which consists of three layers. They are:

1. Convolutional layer
2. Pooling layer
3. Fully-connected (FC) layer

In the year 2015 Fischer et al. [50] used CNN for estimating orientation of real image. The problem is divided into three different level. They are a) images having angle $\pm 30^0$, b) image having orientation of angle $\pm 45^0$ and c) for angle $0^0 - 360^0$. To handle over-fitting applied image augmentation is used. For the three different level they used three different networks $Net-30, Net-45, and Net-360$. They obtained 95% accuracy in all the three Network.

In the year 2017 Joshi et. al. [80] used Convolution Neural Network to detect orientation of the image. Maji et. al. [103] (in the year 2020) proposed

a method to estimate the orientation angle detection using Convolution Neural Network and a custom loss function specially designed for angles lead to state-of-the-art result. Akhter et. al. [9], in the year 2020 proposed Deep learning based CNN architecture to detect and correct document image skew. In the paper all the 360 angles are classified with 360 classes. The CNN network is trained with trained with 2800 data and a wide range of skewed data. They claimed to have successfully achieved 99.06% accuracy on our testing dataset and 98.75% on the bench marking dataset. Gou et. al. [40] in the year 2021 used Deep Convolution Neural Network Method to classify the skew angles and to estimate the skew angles.

In the year 2023 Shadafi et. al. [152] used Hough line transformation and to estimate the skew of the document image. In this paper they used Neural Network based Machine Learning model to identify the up side down image. If any image is found upside down then the image is rotated by 180^0. In the paper they demanded to achieve an accuracy of 97%. NVlabs also uploaded a project of Rotation and skew detection using Deep Learning in GitHub [56]. In the year 2017 Daniel Saez [148] also used CNN for skew angle estimation.

4.9 Other Methods

Chen et al. [145] Recursive morphological closing and opening transformations had been used in [143] for skew estimation in document images. This skew estimation approach was simulated using UW-I English Document Image Database developed at the University of Washington. This process used a auto tune algorithm to determine skew angle Certain saw-tooth algorithm along with least squares method was used in [177] to detect the skew in a document. This method can detect the multi skew. which were skewed in the entire range of $0^0 to 360^0$.

Cinara et al. [34] used the centre of gravity [43] for detecting skew angle in the document image. W. Postl [168] used Fast Fourier Transform for finding the skew angle. The coefficient of the power spectrum of the image are calculated and stored in spectrum memory. For each number of angles the directional criteria are calculated. The angle at which directional criteria is maximum is the skew angle of the image. W. Postl also presented another piece of work on skew detection by Fourier Transform in [167].

There are some more different type of approached which are used for skew estimation, like Shivakumara et al. [153] proposed skew estimation technique based on Linear Regression Analysis (LRA) [154]. Junjuan et al. [89] used gray projection cyclo style matching algorithm [134]. Yuan et al. [178] proposed convex hull based skew estimation technique in the year 2007. Najman et al. [90], Hong-Bo et al. [67] and Morita et al. [112], Das et al. [8] used mathematical morphology. Safabaksh et al. [137] used minimum area bounding

rectangle. Arvind et al. [17] proposed entropy based skew estimation technique. Cao et al. [30] used straight line fitting method for skew estimation. Chen et al. [81] proposed skew estimation algorithm based on maximization of variance of transition-counts.

Papandreou et al. [5] proposed a unique technique to estimate skew angle in handwritten words. The process is based on core region information of the word segment. Marisa et al. [113] proposed an algorithm based on morphological pseudo-convex hull method [49] [88] [45] to detect and correct skew for handwritten text in document image. This algorithm is proposed to detect and correct handwritten word skew of dates written on bank checks. Sadri et al. [73] used Particle Swarm Optimization (PSO) [72] [179] for the first time for skew estimation. In addition to PSO, a function based on local minima and maxima of projection profiles is introduced. PSO is utilized to find the best angle (this represents the skew angle) that maximizes differences between values of local minima and maxima of projection profile.

Some of the other skew detection approaches for handwritten documents are Alaei et al. [10], Chou et al. [37] which used Piece-wise projection methods, Chinara et al. [34] used the centre of gravity, Caprari et al. [144] proposed an efficient algorithm that operates on bit mapped text pattern array to determine the up/down orientation of the page. Liolios et al. [97] proposed a method in the year 2002 to detect and correct skew of mixed printed handwritten documents. In the year 2002 Kavallieratou et al. [84] used Wigner Ville distribution and projection profile for skew angle detection. This algorithm is suitable for both printed and handwritten documents. The authors tested their method on a wide variety of pages and showed a result with 100% accuracy.

Mollah et al. [109] proposed a skew estimation technique based on block segmentation of the text areas. This method is applied for business cards. In this method first non-text part is removed [110] and then the tex. Park et al. [130] proposed another approach for skew detection and correction for business card.t part is considered for skew estimation. Park et al. [130] proposed another approach for skew detection and correction for business card. Mal et al. [104] proposed another skew estimation process based on orientation method. Orientation field is calculated using gradient-based approaches [100][76]. In this approach the image is divided in to 5×5 non-overlapping blocks and the local orientation of each block is estimated by gradient of pixels in the block. Skew angle in the image is calculated by the local maximum of the direction histogram.

Some others methods for license plate skew correction are proposed by Wen et al. [170], Zhang et al. [181], Pan et al. [128], Chirag et al. [27], Jia et al. [172] [77]. A 3D transformation is used for [170], hough Transform for [181], a hybrid method for [128] and Radon Transform for [172]. Algorithm presented in [27] is used for complex background in Indian traffic condition. Algorithm proposed by Messelodi et al. [147] is applied on real Scene image.

5 Conclusion

The problems of skew we discussed include printed and handwritten documents with single [51][52][13] and multi skew [124] [21] [116] [92] [46]. Here skew angle estimation for handwritten documents is a challenging job. Handwritten documents are dealt in [111] [136] [155] [48] [42] [140]. The script dependent methods include Pal et al.[124] for Indian script of multi-skew documents, Malakar et al.[105] for Bangla scripts handwritten documents, Chaudhuri et al.[31] for Indian scripts documents, Kapoor et al. [82] for Devnagari script, For Chinese scripts document Jiang et al. [78] and Pan [127] proposed script dependent algorithms. The documents images like business cards or license plates are treated as outdoor scene image because these images are taken by the camera. For skew detection of such document images the methods proposed by J. H. Park [130] [129], W. Pan [127], K. Arulmizhi [14] [15] [16] A. F. Mollah [109][110]. As these images are captured by cameras these algorithms are more complex and challenging. sometimes contain background and uneven light and shades. C. Paunwala [105] proposed an algorithm for complex background license plate skew estimation. Skew detection of noisy image is a challenging task. In the year 2006 Bo et al. [20] proposed skew detection algorithm which produce a better result.

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