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Skew Detection & Correction in Scanned Document Images

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Thesis submitted in partial fulfillment
of the requirements for the degree of

Bachelor of Technology

in

Computer Science and Engineering

by

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Certificate

This is to certify that the work in the thesis entitled *Skew Detection* & *Correction In Scanned Document Images* by *Avinash Chandra Kishan* & *Varun Sharda* is a record of an original research work carried out by them under my supervision and guidance in partial fulfillment of the requirements for the award of the degree of Bachelor of Technology in Computer Science and Engineering during the session 2005–2009 in the department of Computer Science and Engineering, National Institute of Technology Rourkela. Neither this thesis nor any part of it has been submitted for any degree or academic award elsewhere.

Date: 11 May 2009

Pankaj Kumar Sa
Lecturer
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We would like to thank all our friends , especially Shikhar for helping us. We would also like to thank all those who have directly or indirectly contributed in the success of our work.

Last but not the least, NIT Rourkela for providing us such a platform where we learned a lot and gained so much experience.

Avinash Chandra Kishan

Varun Sharda

Abstract

During document scanning, skew is inevitably introduced into the incoming document image. Skew detection is one the first operations to be applied to scanned documents when converting data to a digital format. Its aim is to align an image before processing because text segmentation and recognition methods require properly aligned next lines.

Different algorithms of skew detection are implemented. The first one is Scan line based skew detection. In this method the image is projected at several angles and the variance in the number of black pixels per projected scan line is determined. The angle at which the maximum variance occurs is the angle of skew.

The second one is based on the Hough transform. Hough transform is performed on the scanned document image and the variance in ρ values is calculated for each value of θ. The angle that gives the maximum variance is the skew angle.

The third approach is based on the base-point method. Here a concept of base-point is introduced. After the successive base-points in every text line within a suitable sub-region were selected as samples for the straight-line fitting. The average of these baseline directions is computed, which corresponds to the degree of skew of the whole document image.

All the above mentioned algorithm have been implemented and the results of each have been compared for accuracy.

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Chapter 1

Introduction

1.1 Image Processing

The sense of vision has been one of the most vital senses for human survival and evolution. Humans use the visual system to see or acquire visual information, perceive, i .e. process and understand it and then deduce inferences from the perceived information. The field of image processing focuses on automating the process of gathering and processing visual information. The process of receiving and analyzing visual information by digital computer is called *digital image processing*.

An image may be described as a two-dimensional function I.

$$I = f(x, y) \tag{1.1}$$

where x and y are spatial coordinates. Amplitude of f at any pair of coordinates (x, y) is called intensity I or gray value of the image. When spatial coordinates and amplitude values are all finite, discrete quantities, the image is called digital image [1].

Digital image processing may be classified into various subbranches based on methods whose: [1]

- input and output are images and
- inputs may be images where as outputs are attributes extracted from those images.

Following is the list of different image processing functions based on the above two classes.

- Image Acquisition
- Image Enhancement
- Image Restoration
- Color Image Processing
- Multi-resolution Processing
- Compression
- Morphological Processing
- Segmentation
- Representation and Description
- Object Recognition

For the first seven functions the inputs and outputs are images where as for the rest three the outputs are attributes from the input images. With the exception of image acquisition and display most image processing functions are implemented in software. Image processing is characterized by specific solutions, hence the technique that works well in one area can be inadequate in another. The actual solution of a specific problem still requires a significant research and development [2].

Out of the ten sub-branches of digital image processing, cited above, this thesis deals with image restoration. In thesis various restoration methodology are used and various inputs are restored using these methods.

This is chapter is organized as follows. Document Image Processing is discussed in Section 1.2. The problem definition is described in Section 1.3. Motivation behind carrying out the work is stated in Section 1.4. Organization of the thesis is outlined in Section 1.5.

1.2 Document Image Processing

Methods for the creation and persistent storage of text have existed since the Mesopotamian clay tablets, the Chinese writings on bamboo and silk as well as the Egyptian writings on papyrus. For search and retrieval, methods for systematic archiving of complete documents in a library were developed by monks and by the clerks of emperors and kings in several cultures. However, the technology of editing an existing document by local addition and correction of text elements has a much younger history. Traditional copying and improvement of text was a painstakingly slow process, sometimes involving many man years for one single document of importance. The invention of the pencil and eraser in 1858 was one of the signs of things to come. The advent of the typing machine by Sholes in 1860 allowed for faster copying and a simultaneous on-the-fly editing of text. The computer, finally, allowed for a very convenient processing of text in digital form. However, even today, methods for generating a new document are still more advanced and mature than are the methods for processing an existing document.

This observation may sound unlikely to the fervent user of a particular common word-processing system, since creation and correction of documents seems to pose little problems. However, such a user has forgotten that his or her favorite word-processor software will only deal with a finite number of digital text formats. The transformation of the image of an existing paper document - without loss of content or layout - into a digital format which can be textually processed is mostly difficult and often impossible. Our user may try to circumvent the problem by using some available software pack- age for optical-character recognition (OCR). Current OCR software packages will do a reasonable job in aiding the user to convert the image into a document format which can be handled by a regular word-processing system, provided that there are optimal conditions with respect to:

- image quality
- separability of the text from its background image
- presence of standard character-font types

- absence of connected-cursive handwritten script and
- simplicity of page layout

Indeed, in those cases where strict constraints on content, character shape and layout do exist, current methods will even do quite a decent job in faithfully converting the character images to their corresponding strings of digital character codes in ASCII or Unicode. Examples of such applications are postal address reading or digit recognition on bank checks.

On the other hand, if the user wants to digitally process the hand-written diary of a grandparent or a newspaper snippet from the eighteenth century, the chances of success are still dim. Librarians and humanities researchers worldwide will still prefer to manually type ancient texts into their computer while copying from paper rather than entrusting their material to current text-recognition algorithms. Not only is the word processing of arbitrary-origin text images a considerable problem. Even if the goal can be reduced to a mere search and retrieval of relevant text from a large digital archive of hetero- geneous text images there are many stumbling blocks. Furthermore, surprisingly, not only the ancient texts are posing problems.

Even the processing of modern, digitally created text in various formats such as web pages with their mixed encoded and image-based textual content will require reverse engineering before such a digital document can be loaded into the word processor of the recipient.Indeed, classification of text within an image is so difficult that the presence of human users of a web site is often gauged by presenting them with a text fragment in a distorted rendering which is easy on the human reading system but an insurmountable stumbling block for current OCR systems. This weakness of the artificial reading system thus can be put to good use. The principle is known as CAPTCHA: Completely Automated Public Turing Tests to Tell Computers and Humans Apart . During recent years, yet another exciting challenge has become apparent in pattern-recognition research. The reading of text from natural scenes as recorded by a camera poses many problems, unless we are dealing with a heavily constrained application such as, e.g., the automatic recognition of letters and digits in snapshots of automobile license plates. Whereas license-plate recognition has become a mere technical problem, the camera-based reading of text in man-made environments, e.g., within support systems for blind persons , is only starting to show preliminary results. [3]

1.3 Problem Definition

Document Image Processing has many different tasks and methods to accomplish those tasks. During document scanning, skew is inevitably introduced into the incoming document image. Skew is any deviation of the image from that of the original document, which is not parallel to the horizontal or vertical. Skew Correction remains one of the vital part in Document Processing.

1.4 Motivation

A literature survey of the existing solutions to the problem of skew detection leads to the following conclusions:

- Solutions that provide accurate skew angles are slow.
- Solutions that reduce the required time result in lesser accuracy in skew angle determination.

So a trade-off between accuracy and time complexity is the motivation for the work.

1.5 Thesis Organisation

The rest of the thesis is organized as follows:

Chapter 2 proposes two methods of skew detection. One is based on the *scanline method.* And the other one based on the *Hough transform.* This method outperforms its counterparts in terms of accuracy.

Chapter 3 proposes a method based on the *base-point method.* But this one gives more emphasis on the connected component and is more accurate when the document has clear connected components.

Finally **Chapter 4** presents the concluding remarks, with scope for further research work.

Chapter 2

Scan Line based Skew Detection

There are various methods to detect skew in an scanned document image. But here we focus on the methods based on scanline i.e. on the scanline method and on the Hough transform. Finally the result obtained from our implementation is added.

2.1 Scan Line

This method projects the image at several angles and determines the variation in the number of black pixels per projected scan line. The angle at which the maximum variance occurs is the angle of skew. [4]

2.1.1 Algorithm

1. Calculate the coordinates, in the image plane, for each of the parallel scan lines, that lie at a slope $\tan(\theta)$ in the image plane.The coordinates are calculated using the Bresenham's Line Drawing Algorithm.

2. For each scan line, count the number of non-background pixels that lie on the line.

3. Calculate the variance v in the number of black pixels that lie on each scan line for a given angle θ.

4. The angle of skew θ is given by the angle at which the maximum variance v_{max} is found.

Table 2.1: Comparative Results in Skew of different scanned document images as calculated and original angles (as measured) using Scanline based skew correction.

Angles⇒ Scanned Document Images ⇓	Calculated Skew (θ_s)	Original Skew (θ)
fig 2.6(a)	3	2
fig 2.6(c)	2	2
fig 3.3(a)	-8	-8
fig 3.3(c)	6	6
fig 3.4(a)	-7	-7
fig 3.4(c)	15	15
fig 3.5(a)	16	16
fig 3.5(c)	-18	-18

The following are the results of the correction figures of the scanned document images using Scanline based detection : fig. 2.1 , fig. 2.2, fig. 2.3, fig. 2.4

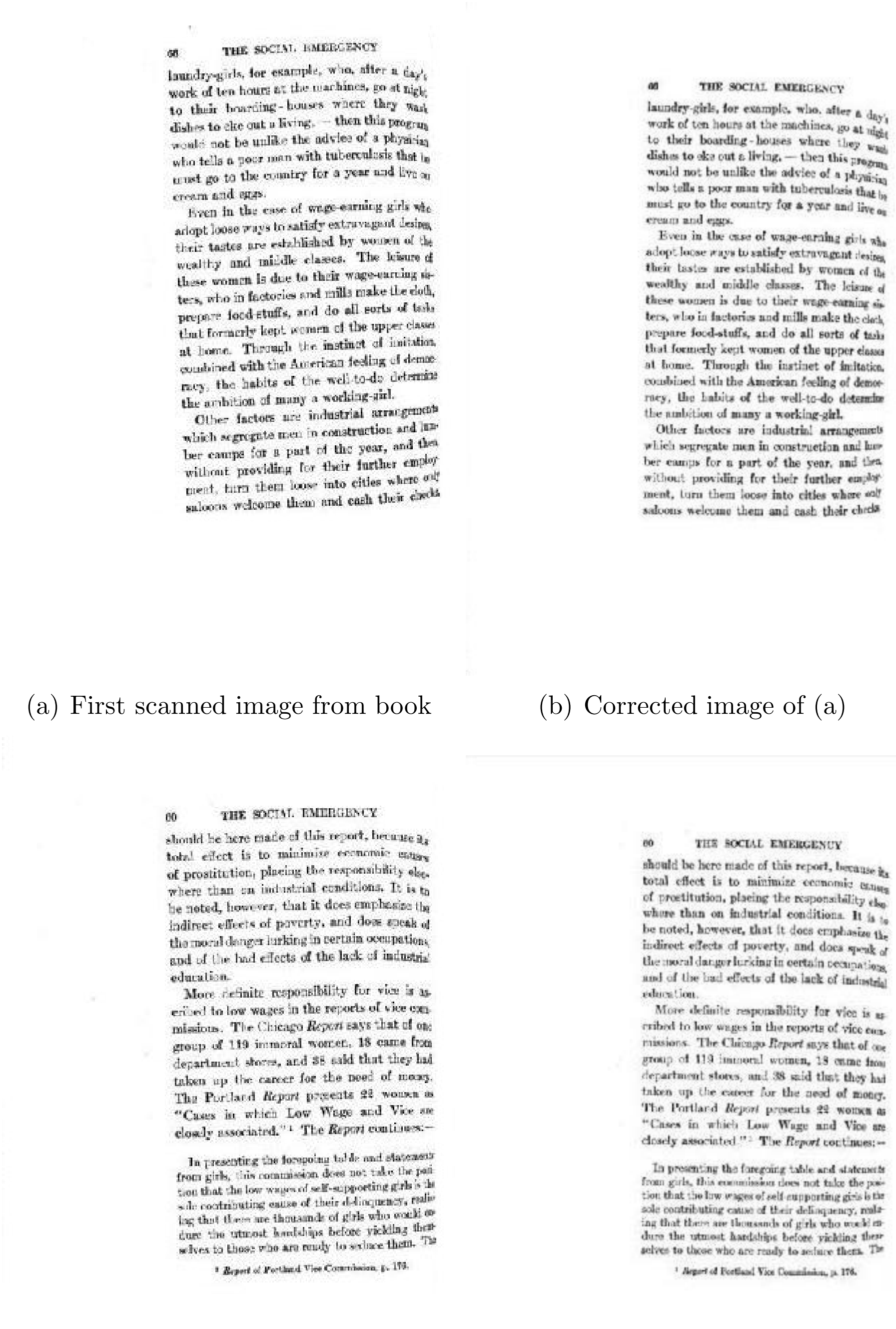
2.2 Time Complexity

Let N be the number of pixels in the scanned document image. Then, the time complexity is O(N).

2.3 Hough Transform

The Hough transform is an edge linking and boundary detection technique used in image analysis. The purpose of the technique is to find instances of objects within a certain class of shapes by a voting procedure. This voting procedure is carried out in a parameter space, from which object candidates are obtained as local maxima in a so-called accumulator space that is explicitly constructed by the algorithm for computing the Hough transform.

Consider a point (x_i, y_i) in the xy-plane and the general equation of a straight line in slope-intercept form, $y_i = ax_i + b$. Infinitely many lines pass through (x_i, y_i), but they all satisfy the equation for $y_i = ax_i + b$ for varying values of a and b. However writing this equation as $b = -x_i a + y_i$ and considering the ab-plane (also



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laundry-girls, for example, who, after a day's work of ten hours at the machines, go at night to their boarding-houses where they wash dishes to eke out a living, — then this program would not be unlike the advice of a physician who tells a poor man with tuberculosis that he must go to the country for a year and live on cream and eggs.

Even in the case of wage-earning girls who adopt loose ways to satisfy extravagant desires, their tastes are established by women of the wealthy and middle classes. The leisure of these women is due to their wage-earning sisters, who in factories and mills make the cloth, prepare food-stuffs, and do all sorts of tasks that formerly kept women of the upper classes at home. Through the instinct of imitation, combined with the American feeling of democracy, the habits of the well-to-do determine the ambition of many a working-girl.

Other factors are industrial arrangements which segregate men in construction and lumber camps for a part of the year, and then without providing for their further employment, turn them loose into cities where only saloons welcome them and cash their checks

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(a) First scanned image from book

(b) Corrected image of (a)

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should be here made of this report, because its total effect is to minimize economic causes of prostitution, placing the responsibility elsewhere than on industrial conditions. It is to be noted, however, that it does emphasize the indirect effects of poverty, and does speak of the moral danger lurking in certain occupations, and of the bad effects of the lack of industrial education.

More definite responsibility for vice is ascribed to low wages in the reports of vice commissions. The Chicago *Report* says that of one group of 119 immoral women, 18 came from department stores, and 38 said that they had taken up the career for the need of money. The Portland *Report* presents 22 women as "Cases in which Low Wage and Vice are closely associated."[1] The *Report* continues: —

> In presenting the foregoing table and statements from girls, this commission does not take the position that the low wages of self-supporting girls is the sole contributing cause of their delinquency, realizing that there are thousands of girls who would endure the utmost hardships before yielding themselves to those who are ready to seduce them. The

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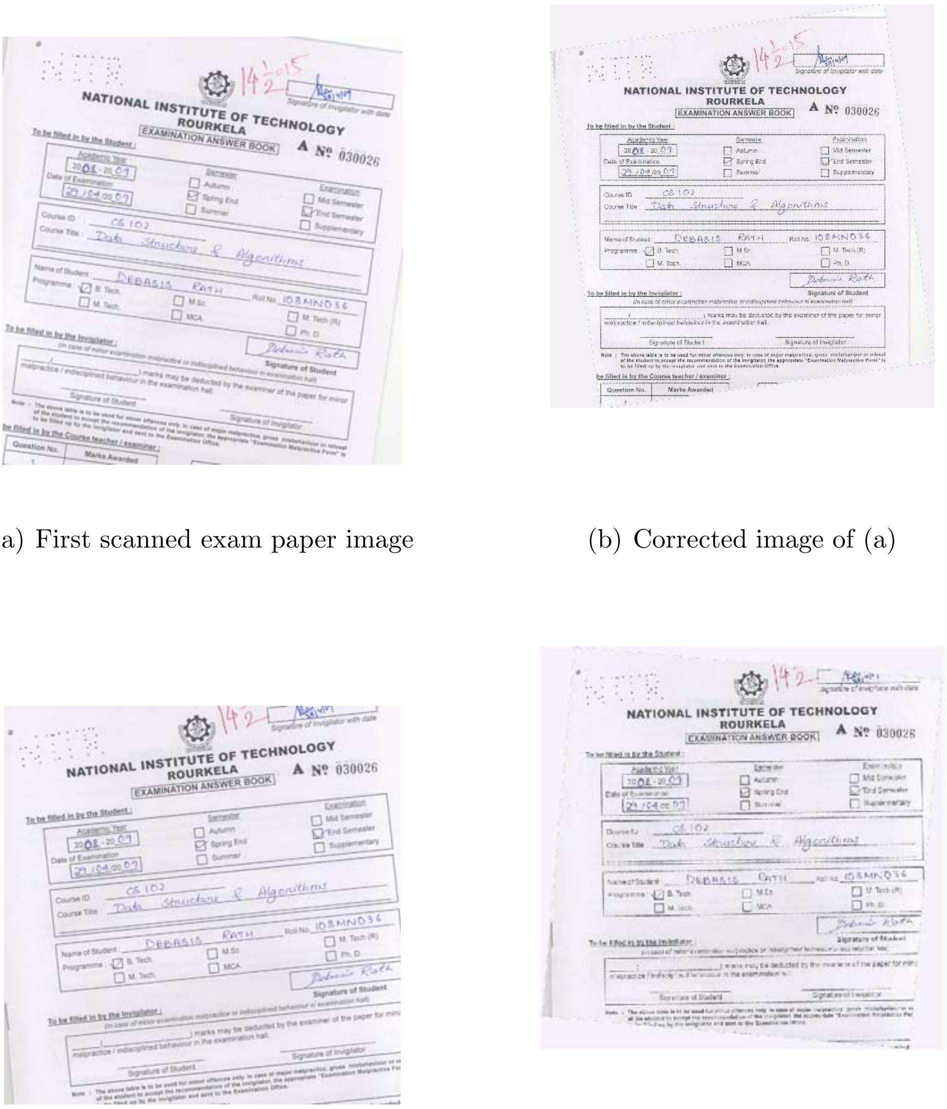
[1] *Report* of Portland Vice Commission, p. 176.

(c) Second scanned image from book

(d) Corrected image of (c)

Figure 2.1: Deskewed document image of scanned book page with scan line scheme



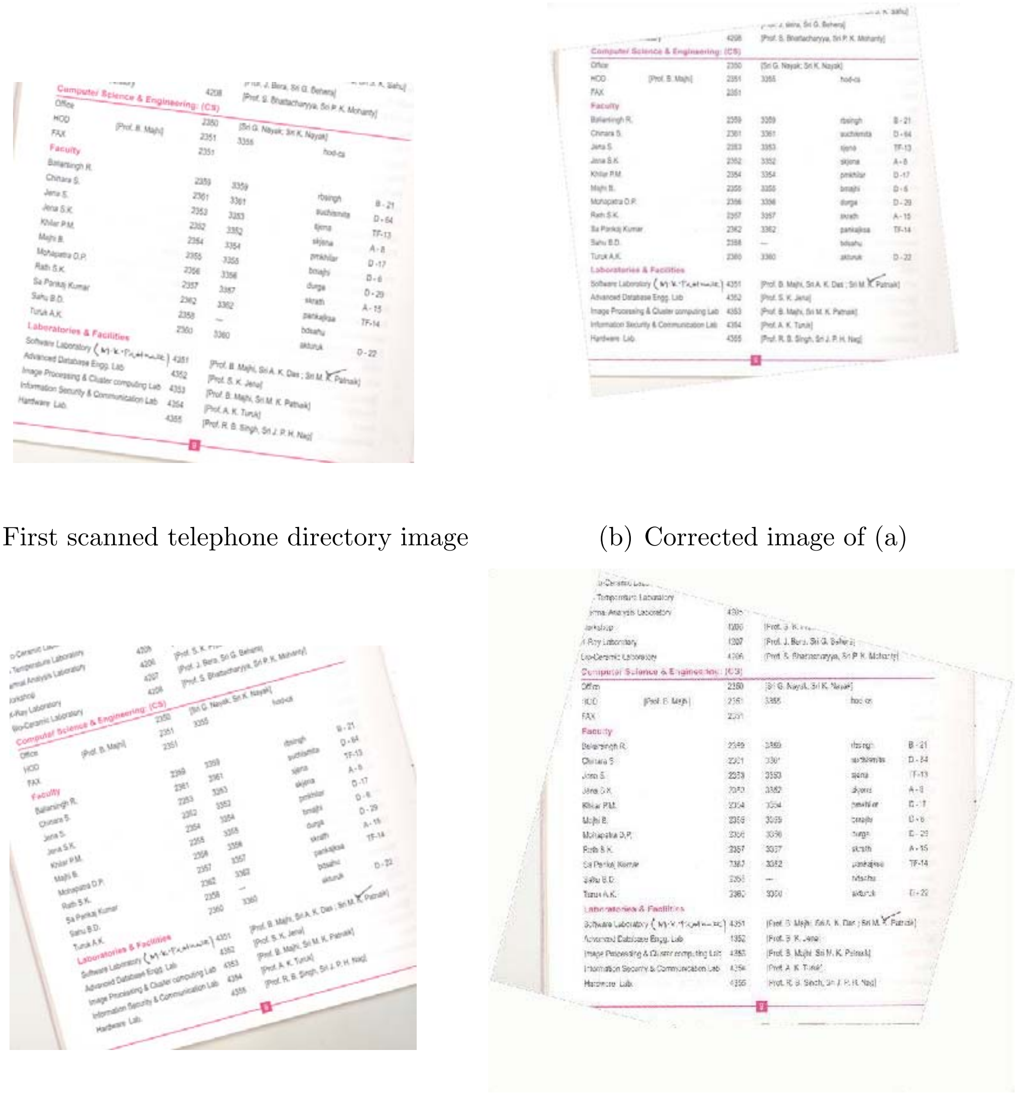
(a) First scanned exam paper image

(b) Corrected image of (a)

(c) Second scanned exam paper image

(d) Corrected image of (c)

Figure 2.2: Deskewed document image of scanned exam paper with scan line scheme



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Hardware Lab.		4355	[Prof. R. B. Singh, Sri J. P. H. Nag]		

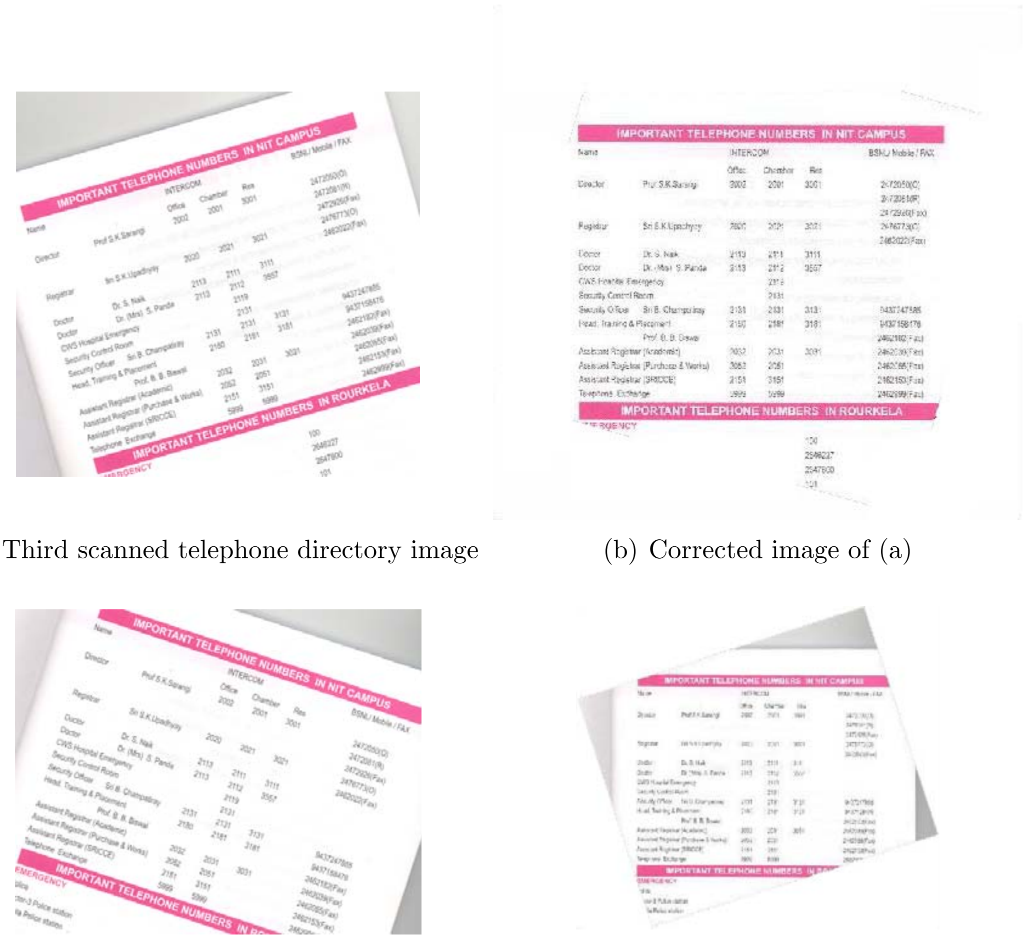
(a) First scanned telephone directory image

(b) Corrected image of (a)

(c) Second scanned telephone directory image

(d) Corrected image of (c)

Figure 2.3: Deskewed document image of scanned telephone directory with scan line scheme



(a) Third scanned telephone directory image

(b) Corrected image of (a)

(c) Fourth Scanned telephone directory image

(d) Corrected image of (c)

Figure 2.4: Deskewed images applying the Scan line scheme

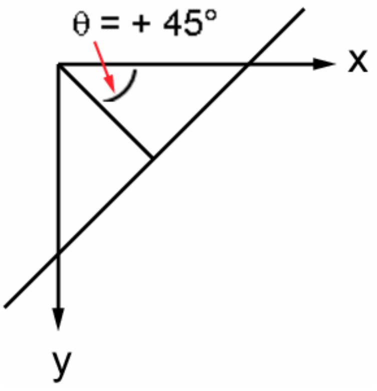


Figure 2.5: Normal Representation of a line

called parameter space) yield the equation of a single line for a fixed pair (x_i, y_i). Furthermore, a second point (x_j, y_j) also has a line in parameter space associated with it, and unless they are parallel, this line intersects the line associated with (x_i, y_i) at some point (a', b'), where a' is the slope and b' the intercept of the line containing both (x_i, y_i) and (x_j, y_j) in the xy-plane. In fact, all the points on this line have lines in parameter space that intersect at (a', b').

In principle, the parameter-space lines corresponding to all points (x_k, y_k) in the xy-plane could be plotted, and the principal lines in that plane could be found by identifying points in parameter space where large numbers of parameter-space intersect. A practical difficulty with this approach, however, is that a (the slope of a line) approaches infinity as the line approaches the vertical direction. This problem can be solved by using normal representation of a line:

$$x \cos\theta + y \sin\theta = \rho$$

Fig. 2.5 represents the geometrical interpretation of the parameters θ and ρ. A horizontal line has $\theta = 0°$, with ρ being equal to positive x-intercept. Similarly, a vertical line has $\theta = 90$, with ρ being equal to positive y-intercept or $\theta = -90$, with ρ being equal to negative y-intercept. Each sinusoidal curve in figure 1.2 represents the family of lines that pass through a particular point (x_k, y_k) in the xy-plane. The intersection point (ρ', θ') in fig. 2.5 corresponds to the line that passes through both (x_i, y_i) and (x_j, y_j) in fig. 2.5.

The computational attractiveness of the Hough Transform arises from subdividing the $\rho\theta$ parameter space into so-called accumulator cells where (ρ_{min}, ρ_{max}) and $(\theta_{min}, \theta_{max})$ are the expected ranges of the parameter values: -90°$\leq \theta \leq$ 90°and -D $\leq \rho \leq$ D, where D is the maximum distance between opposite corners in an image. The cell at coordinates (i, j), with accumulator value $A(i, j)$, corresponds to the square associated with parameter-space coordinates (ρ_i, θ_j). Initially, these cells are set to zero. Then, for every non-background point (x_k, y_k) in the xy-plane, we let θ equal each of the allowed subdivision values on the θ axis and solve for the corresponding ρ using the equation $\rho = x_k cos\theta + y_k sin\theta$. The resulting ρ values are then rounded off to the nearest allowed cell value along ρ axis. If a choice of an angle θ_q results in solution ρ_p, then we let $A(p, q) = A(p, q) + 1$. The number of subdivisions in the $\rho\theta$-plane determines the accuracy of the collinearity of the points.

The steps for finding skew angle using Hough transform is as follows:

1. For each non-background pixel $P('x'_i, 'y'_i)$.

2. Calculate the corresponding values of ρ, ρ_j for each $-90 <= \theta_i <= 90$. The value of ρ is rounded of to the nearest allowed cell value along ρ axis.

3. Increment the corresponding Hough matrix cell, $H(j, i)$, by one.

The above process results in a Hough matrix, whose each cell, (i, j), gives the number of points that lie on the line with parameters ρ and θ, (ρ_i, θ_j). Each column of the Hough matrix gives all points that lie on a set of parallel lines, irrespective of the ρ values. Thus, finding the variance v of the values along each column gives us the variance in the number of background pixels that lie on a set of parallel scan lines. Again, the angle of skew is the angle at which this variance is maximum.

2.3.1 Implementation of Hough Transform

An input image is taken and Hough transform was implemented. The value of θ was incremented across the rows and the value of ρ was incremented across the columns. The variance was calculated for values in each column i.e. variance in the number of

Table 2.2: Comparative Results in Skew of different scanned document images as calculated and original angles (as measured) using Hough Transform Method.

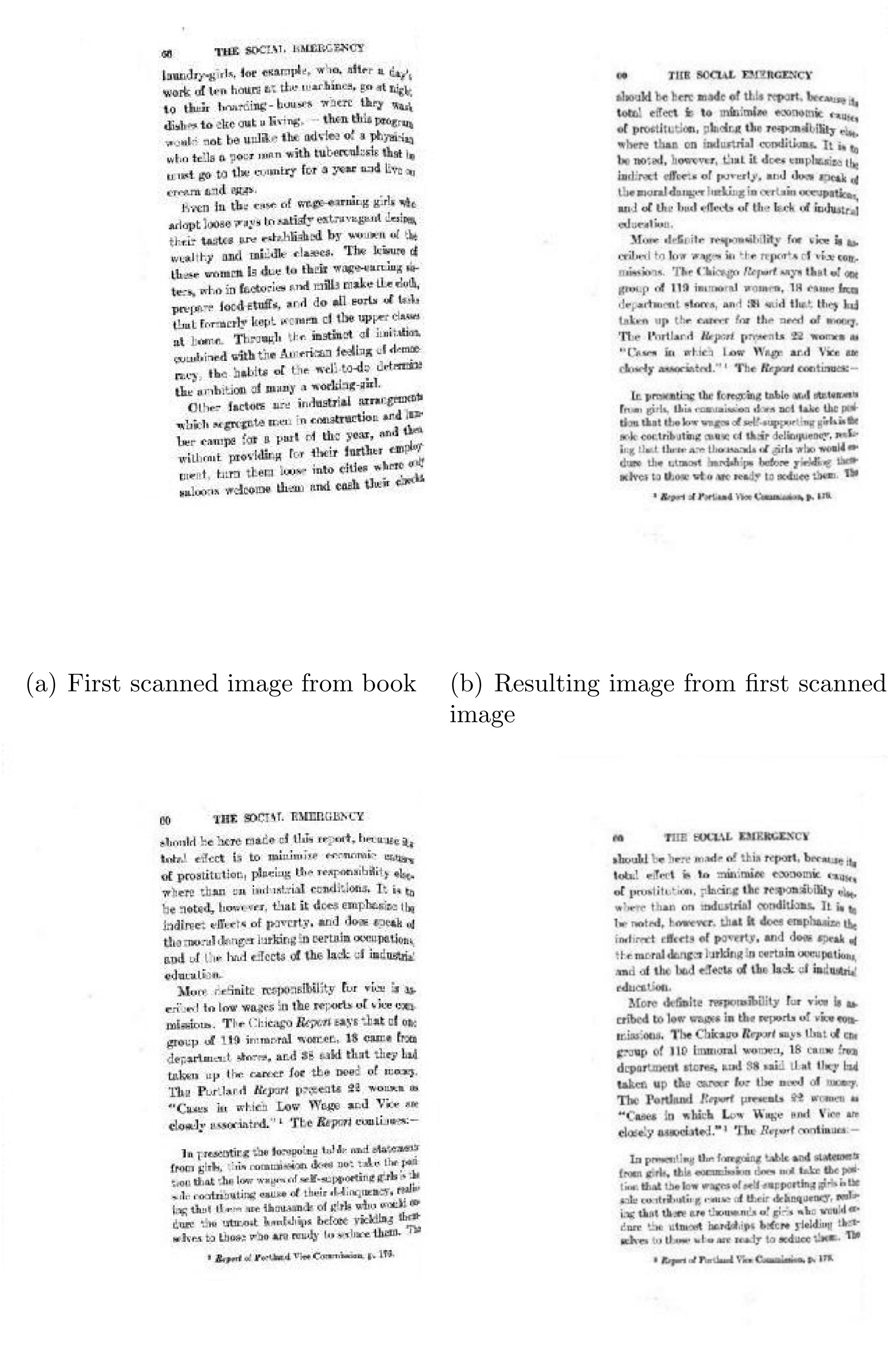
Angles⇒ Scanned Document Images ⇓	Calculated Skew (θ_s)	Original Skew (θ)
fig 2.6(a)	1	2
fig 2.6(c)	1	2
fig 3.3(a)	−8	−8
fig 3.3(c)	6	6
fig 3.4(a)	−7	−7
fig 3.4(c)	15	15
fig 3.5(a)	16	16
fig 3.5(c)	−18	−18

points between the number of points that lie on a set of parallel lines. The θ that gave the maximum variance is the skew angle.

The following are the results of the corrected figures of the scanned document images using hough based detection: fig. 2.7 , fig. 2.8, fig. 2.9

2.4 Time Complexity

Let N_{nb} be the number of non-background pixels in the scanned document image. And let N_θ be the number of angles used to calculate the Hough Transform. Then the time complexity is O($N_{nb}N_\theta$)



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In presenting the foregoing table and statements from girls, this commission does not take the position that the low wages of self-supporting girls is the sole contributing cause of their delinquency, realizing that there are thousands of girls who would endure the utmost hardships before yielding themselves to those who are ready to seduce them. The

[1] *Report of Portland Vice Commission*, p. 178.

(a) First scanned image from book

(b) Resulting image from first scanned image

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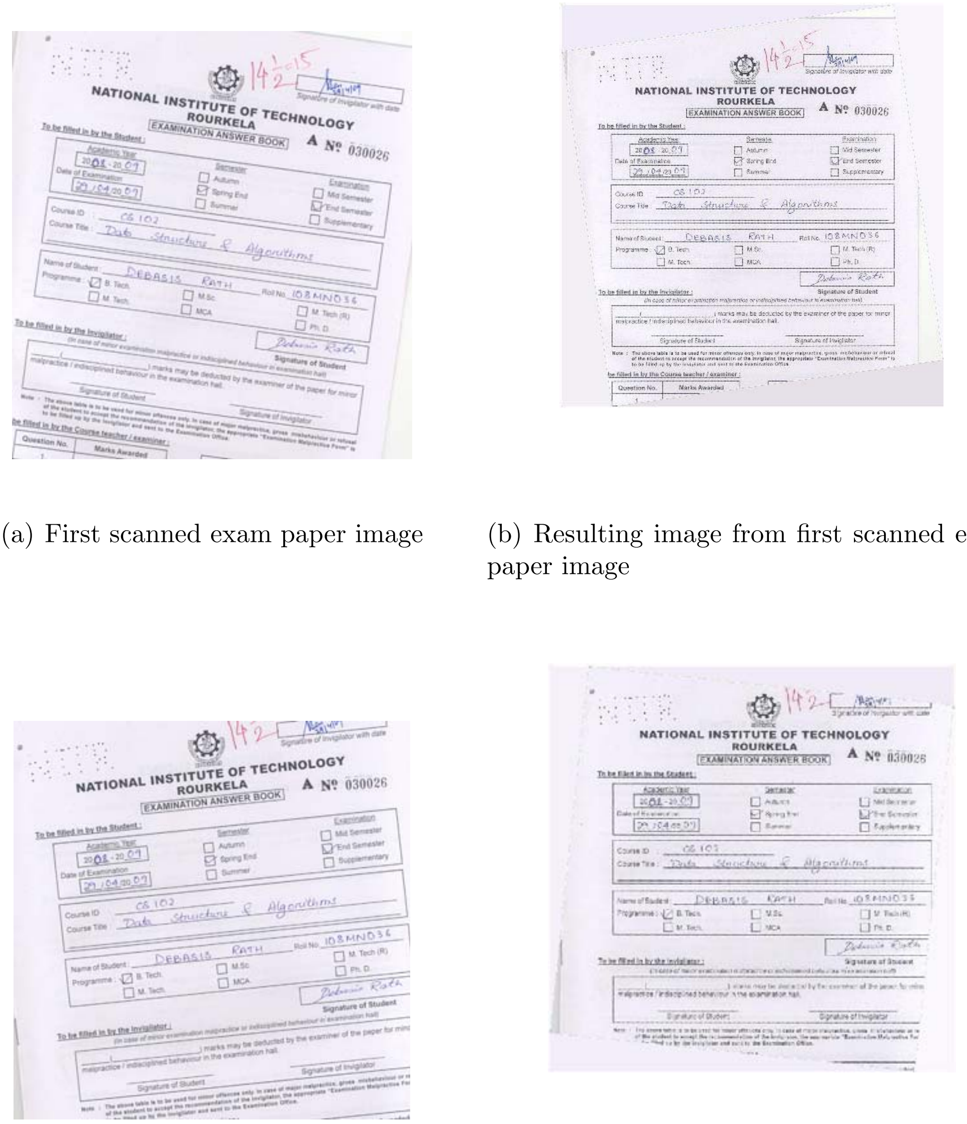
[1] *Report of Portland Vice Commission*, p. 178.

(c) Second scanned image from book

(d) Resulting image from second scanned image

Figure 2.6: Deskewed document image of scanned book page with the Hough transform scheme



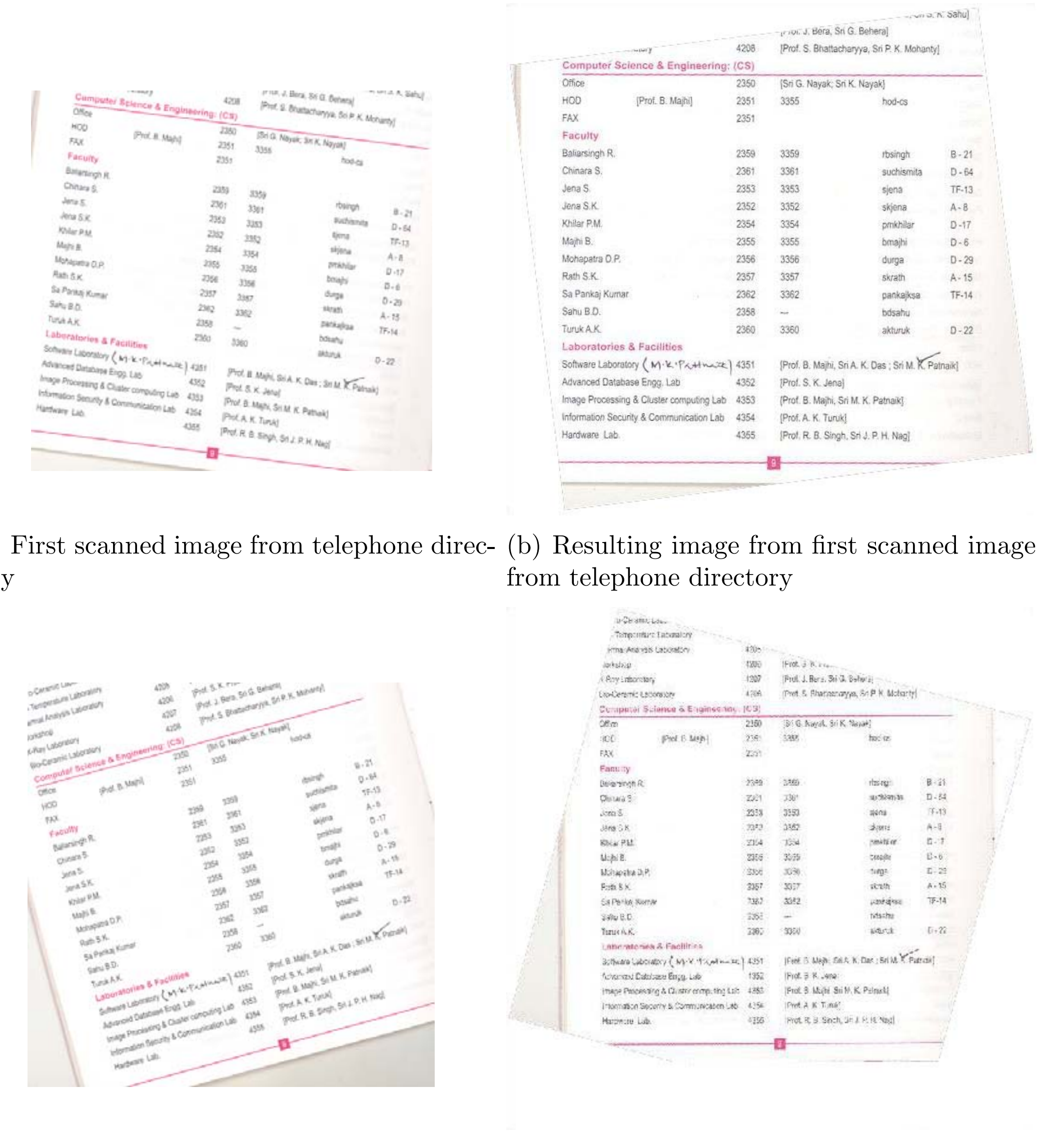
(a) First scanned exam paper image

(b) Resulting image from first scanned exam paper image

(c) Second scanned exam paper image

(d) Resulting image from second scanned exam paper image

Figure 2.7: Deskewed document image of scanned exam paper with Hough transform scheme



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Jena S.		2353	3353	sjena	TF-13
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Information Security & Communication Lab		4354	[Prof. A. K. Turuk]		
Hardware Lab.		4355	[Prof. R. B. Singh, Sri J. P. H. Nag]		

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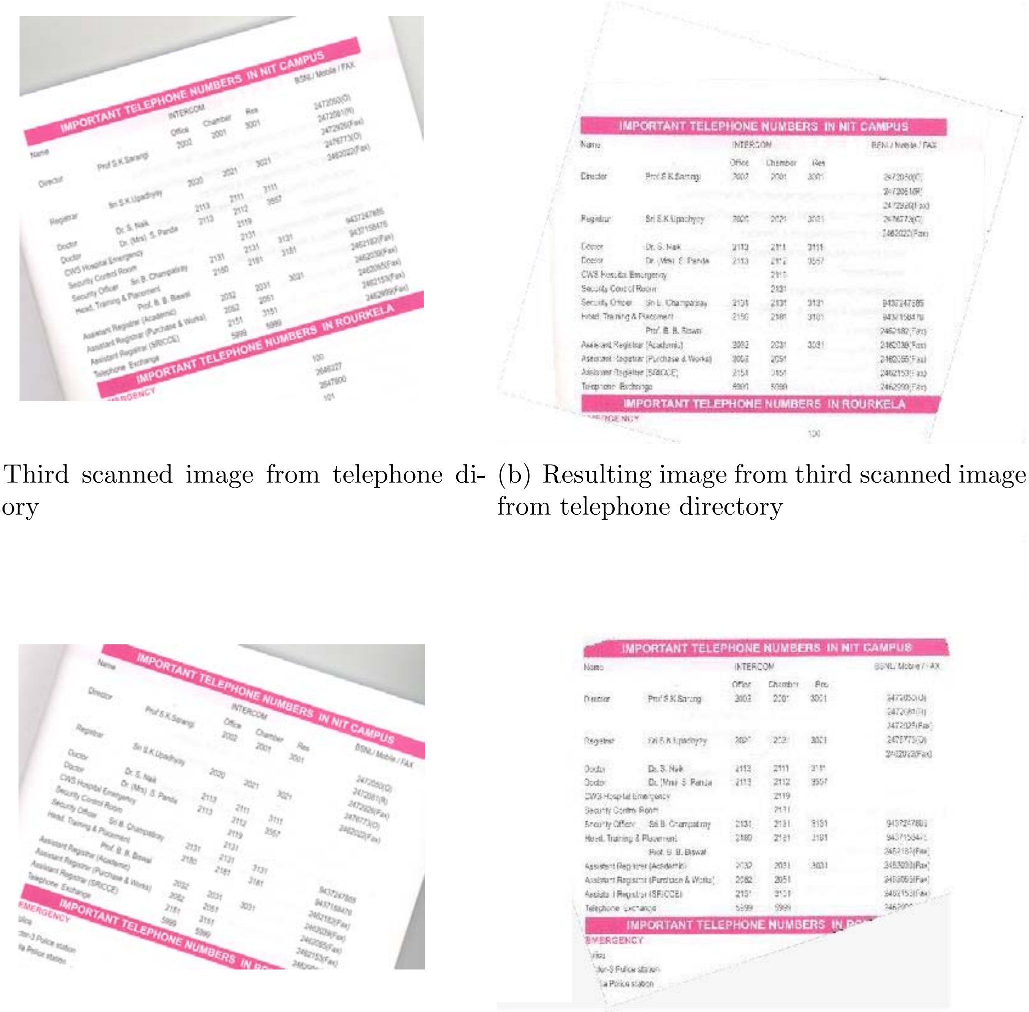
(a) First scanned image from telephone directory

(b) Resulting image from first scanned image from telephone directory

(c) Second scanned image from telephone directory

(d) Resulting image from second scanned image from telephone directory

Figure 2.8: Deskewed document image of scanned telephone directory with Hough transform scheme


IMPORTANT TELEPHONE NUMBERS IN NIT CAMPUS
IMPORTANT TELEPHONE NUMBERS IN ROURKELA
EMERGENCY

(a) Third scanned image from telephone directory

(b) Resulting image from third scanned image from telephone directory

(c) Fourth scanned image from telephone directory

(d) Resulting image from fourth scanned image from telephone directory

Figure 2.9: Deskewed images applying the Hough transform scheme

Chapter 3

Skew Detection based on Base-Point

In this chapter we are going to discuss the methods of skew detection using a staight line fitting algorithm. The various steps involved and the additional criteria which increases the efficiency of these algorithms have been discussed. Finally, the implementation with suitable examples are given.

3.1 Selection of a sub-region and objects

3.1.1 Sub-region selection

Text lines in a document are generally parallel to one another in the horizontal direction, and the space between two successive text lines is relatively constant. Since scanning every pixel in the whole document image is time-consuming, it is appropriate to select a suitable sub-region to calculate the text line direction that corresponds to the skew angle of the image.

Though pixels in one page image express all kinds of information, it is time-consuming to analyze all the pixels in the image. Connected component, which is the aggregation of related pixels, can also express the information in many aspects such as page layout [5].

In a scanned document image, there might be some black edges that not only affect the algorithm accuracy but also increase the computing cost. In order to avoid the possible negative effects of black edges, the edges of a document image should not be included in the selected sub-region. Furthermore, the size of the sub-region should be carefully selected to achieve higher speed and better accuracy. The selected sub-region R should satisfy the following condition:

$$R = \{(x, y)|w_1 \leq x \leq w_2, h_1 \leq y \leq h_2, (w_2 - w_1) \geq W_c, (h_2 - h_1) \geq T_h\} \tag{3.1}$$

Here W_c is the average width of the alphanumeric characters, and T_h is the space threshold between the successive text lines. Given that the width of a document image is W and the height is H, the left boundary of the sub-region should be $w_1 = W/3$, the right boundary $w_2 = W2/3$, the top boundary $h_1 = H/3$ and the bottom boundary $h_2 = H2/3$. Statistically, the number of connected components in one text line n should be over 10, and the number of text lines in the subregion k should be more than 3, which can ensure the precision of this algorithm.

At the same time the relationships between the adjacent connected components are analyzed with some algorithms such as projection, which can make sure the selected sub-region contains only one text column.

3.1.2 Objects choosing

The bounding box of every connected component is generated firstly. And a single character or touched characters contained in the bounding box are regarded as an object.

Statistically, most of the alphanumeric objects bottoms are on a baseline, such as $'$ A$'$,$'$ s$'$,$'$ x$'$, etc. Only a very few alphanumeric objects$'$ bounding boxes pass through a baseline, such as $'$ p$'$,$'$ q$'$, etc. The sizes of the punctuation mark objects are obviously smaller than the alphanumeric ones. In order to remove the negative effects of these punctuation marks, only the objects satisfying the following condition can be selected as candidates for the skew detection algorithm:

$$C = \{C_i|W(C_i) \geq D_w \vee H(C_i) \geq D_h, 1 \leq x \leq k\} \tag{3.2}$$

Here C is the set of candidates for the skew detection algorithm, $W(C_i)$ and $H(C_i)$ are the width and the height of the bounding box of the object C_i, respectively, D_w

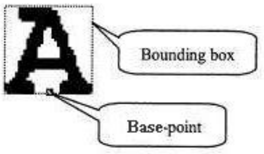


Figure 3.1: Representation of Bounding-box and Base-point for a scanned character

is the threshold of the width of the objects$'$ bounding box, D_h is the threshold of the height of the objects$'$ bounding box, and k is the number of candidate objects.

3.2 Base-points clustering

3.2.1 Definitions

Definition 1. Base-point of an object is the center at the bottom within the bounding box of an object fig. 3.1.

Definition 2. Base-group is a group containing all the base-points in the same text line.

3.2.2 Base-points clustering

In a pure text sub-region where the text lines are parallel, the base-points in different text lines can be grouped into different base-groups according to the space threshold T_h. The following is the detailed procedure.

Step 1. Initialize every base-point so that it is not in any base-group, and set $k = 0$.

Step 2. In the selected sub-region R, if the lefttop base-point $P_i(x_i, y_i)$ not in any basegroup is found, set $k++$ and put P_i, into a new base-group $G(k)$.

Step 3. Within the rectangle area $\{(x_i, y_i - T_h/2)\}, \{(w2, y_i + T_h/2)\}$, if the leftmost base-point $P_j(x_j, y_j)$ not in any base-group is found, put P_j into $G(k)$ and set $P_i = P_j(i.e.x_i = x_j, y_i = y_j)$. Repeat this step until all the base-points are in a certain base-group within this rectangle area.

Table 3.1: Comparative Results in Skew of different scanned document images as calculated and original angles (as measured) using Base-Point Method.

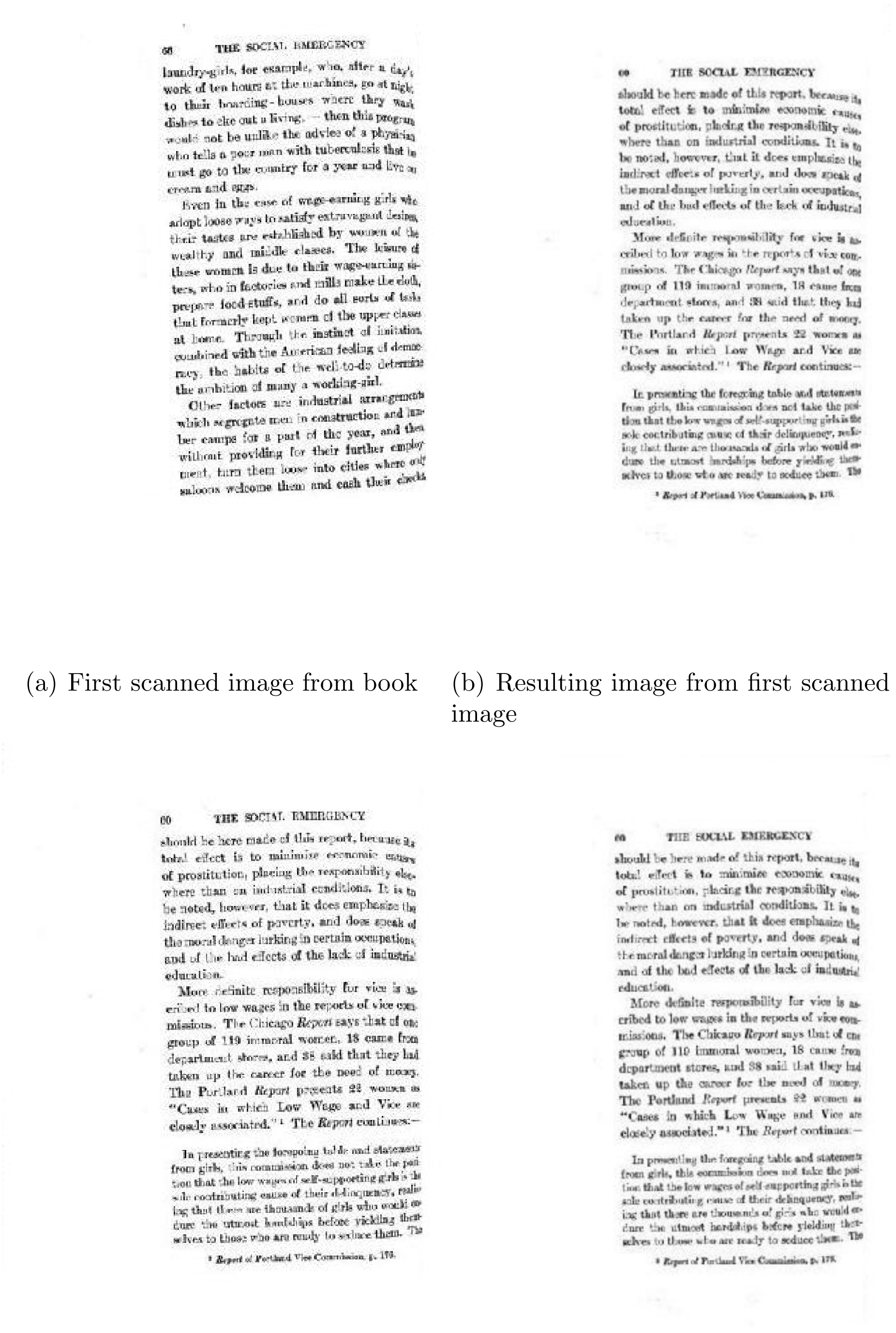
Angles⇒	Calculated Skew (θ_s)	Original Skew (θ)
Scanned Document Images⇓		
fig 2.6(a)	1	2
fig 2.6(c)	1	2
fig 3.3(a)	-4	-8
fig 3.3(c)	-2	6
fig 3.4(a)	-1	-7
fig 3.4(c)	-1	15
fig 3.5(a)	-4	16
fig 3.5(c)	-3	-18

Step 4. Go to Step 2 until all the base-points in the sub-region R have been put into different base-groups.

Apply straight line fitting, using least squares method, for each of the cluster obtained at the end of Step 4 to get the slope of the line that is a best fit for each cluster. Take the average of all slope values obtained in the previous step. This is our skew angle.

3.3 Time Complexity

Let the number of pixels in the subregion R be N_R. Then the base-point algorithm has a time complexity of O(N_R).



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laundry-girls, for example, who, after a day's work of ten hours at the machines, go at night to their boarding-houses where they wash dishes to eke out a living, — then this program would not be unlike the advice of a physician who tells a poor man with tuberculosis that he must go to the country for a year and live on cream and eggs.

Even in the case of wage-earning girls who adopt loose ways to satisfy extravagant desires, their tastes are established by women of the wealthy and middle classes. The leisure of these women is due to their wage-earning sisters, who in factories and mills make the cloth, prepare food-stuffs, and do all sorts of tasks that formerly kept women of the upper classes at home. Through the instinct of imitation, combined with the American feeling of democracy, the habits of the well-to-do determine the ambition of many a working-girl.

Other factors are industrial arrangements which segregate men in construction and lumber camps for a part of the year, and then without providing for their further employment, turn them loose into cities where only saloons welcome them and cash their checks

(a) First scanned image from book

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should be here made of this report, because its total effect is to minimize economic causes of prostitution, placing the responsibility elsewhere than on industrial conditions. It is to be noted, however, that it does emphasize the indirect effects of poverty, and does speak of the moral danger lurking in certain occupations, and of the bad effects of the lack of industrial education.

More definite responsibility for vice is ascribed to low wages in the reports of vice commissions. The Chicago *Report* says that of one group of 119 immoral women, 18 came from department stores, and 38 said that they had taken up the career for the need of money. The Portland *Report* presents 22 women as "Cases in which Low Wage and Vice are closely associated."[1] The *Report* continues:—

> In presenting the foregoing table and statements from girls, this commission does not take the position that the low wages of self-supporting girls is the sole contributing cause of their delinquency, realizing that there are thousands of girls who would endure the utmost hardships before yielding themselves to those who are ready to seduce them. The

[1] *Report of Portland Vice Commission*, p. 178.

(b) Resulting image from first scanned image

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(c) Second scanned image from book

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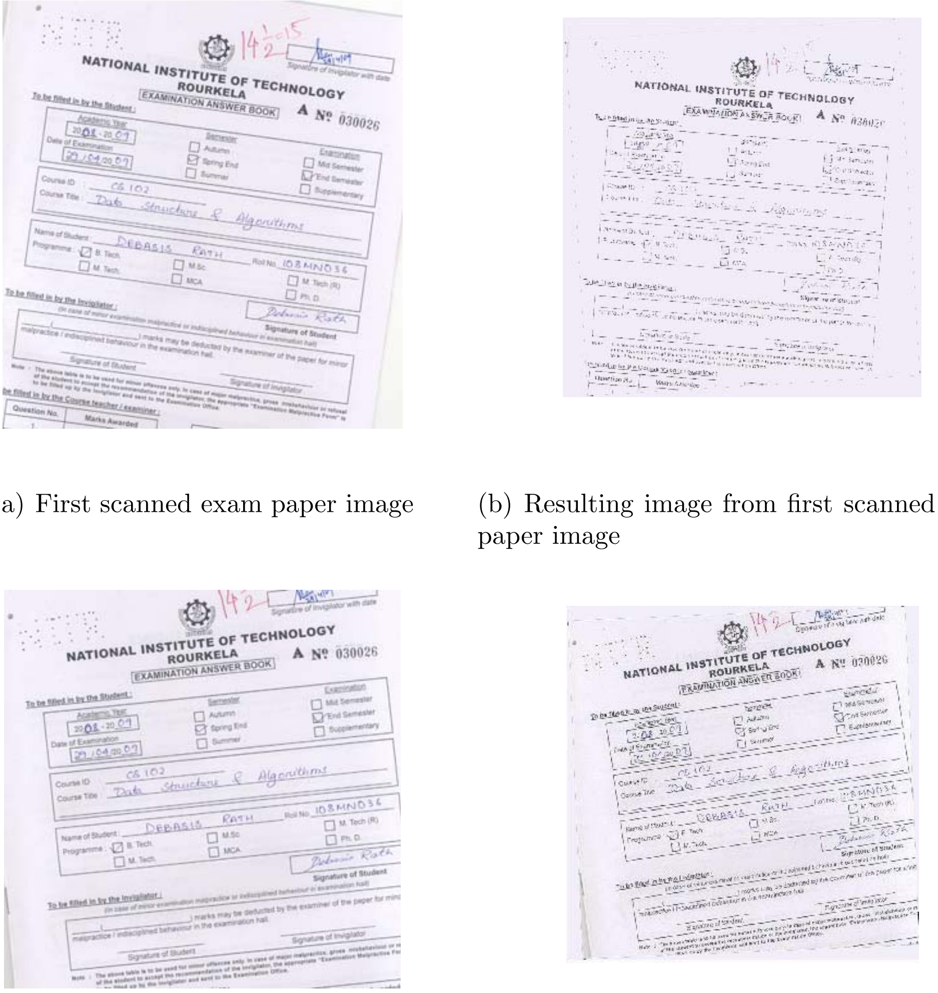
[1] *Report of Portland Vice Commission*, p. 178.

(d) Resulting image from second scanned image

Figure 3.2: Deskewed document image of scanned book page with Base-point scheme



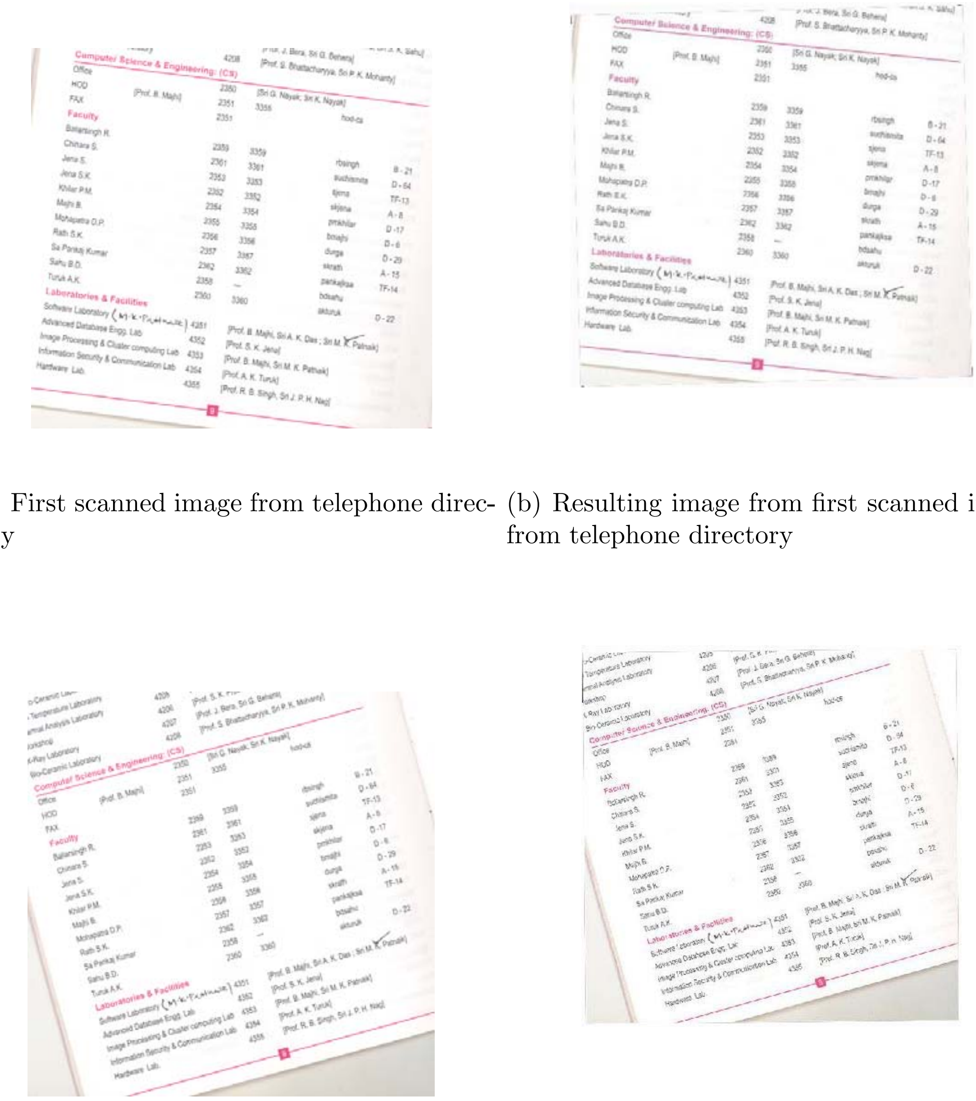
(a) First scanned exam paper image

(b) Resulting image from first scanned exam paper image

(c) Second scanned exam paper image

(d) Resulting image from second scanned exam paper image

Figure 3.3: Deskewed document image of scanned exam paper with Base-point scheme



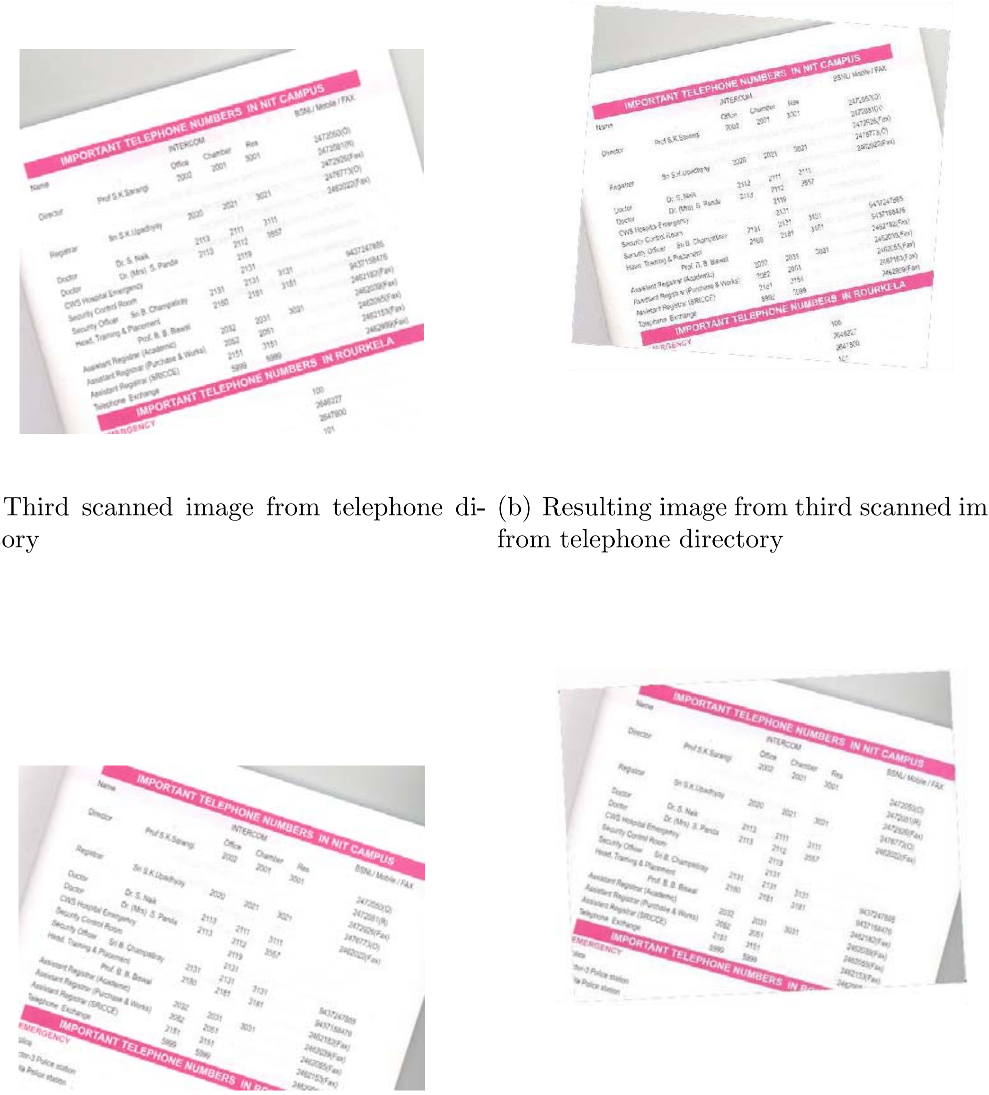
(a) First scanned image from telephone directory

(b) Resulting image from first scanned image from telephone directory

(c) Second scanned image from telephone direrectory

(d) Resulting image from second scanned image from telephone directory

Figure 3.4: Deskewed document image of scanned telephone directory with Base-point scheme



(a) Third scanned image from telephone directory

(b) Resulting image from third scanned image from telephone directory

(c) Fourth scanned image from telephone directory

(d) Resulting image from fourth scanned image from telephone directory

Figure 3.5: Deskewed images applying the Base-point scheme

Chapter 4

Conclusions

The work in this thesis, primarily focuses on skew detection in scanned document images. The work reported in this thesis is summarized in this chapter. Sec. 4.1 lists the pros and cons of the work. 4.2 provides some scope for further development.

4.1 Achievements and Limitations of the work

The scan line algorithm, based on calculating the coordinates of lines in the image plane and finding the number of non-background image pixels on a line and then finding the skew angle on the basis of variance is a successful method, in terms of skew detection and was found to reliably detect a range of skew angles over a range of text document images. However, it has a drawback of being painstakingly slow as compared to the other methods.

The hough transform method was found to be as good as the scan line algorithm in terms of skew detection and has a much lesser time complexity.

The above two methods were found to provide the correct skew angle even when the document image consists of many lines that are parallel to the text, since these lines increase the number of votes because the number of votes along the direction of these lines is much more as compared to any other direction. These methods are particularly useful for detecting skews in documents that contain for scripts which have lines as a major part of the script. For example, many Indian scripts such as Devanagri, Bangla, Gurmukhi,etc. have lines, called headlines, connecting letters of a word.

The base point method has a much lesser time complexity than the other two, since it operates on eigen points instead of working on all non-background image pixels. Since this method relies on connected components to find the eigen points, if the connected components so found are not distinct characters, the base point method can result in false results. This was evident in the test images.

4.2 Further Development

The algorithms we have discussed works well with tilted skews and not with shear skews in scanned document images. We can try to implement and/or modify the existing algorithm so that it can detect also detect shear skews in scanned document images.

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