Recognition of Off-Line Handwritten Kannada Words Using Enhanced Skew Detection and Correction Method

Shakunthala B. S[1], Ullas H. S[2] & Pillai C. S[3]

[1]*Associate Professor, Department of ISE,*
Kalpataru Institute of Technology, Tiptur, Karnataka, India.
[2]*Research Scholar, Department of E & C,*
Sri Siddhartha Institute of Technology, Tumkur, Karnataka, India.
[3]*Professor, Department of CSE.*
ACS College of Engineering, Bangalore, Karnataka, India.
***DOI**: https://doi.org/10.34293/acsjse.v3iS1.93*

***Received Date:** 24.05.2023* ***Accepted Date:** 30.11.2023* ***Publilshed Date:** 02.01.2024*

Abstract - *Handwritten character image is taken as dataset for this method. In the proposed system, extracting text lines, word, charactersand skew correction are done based on Enhanced Skew Detection and Correction for Words algorithm for estimating and correcting skew lines. The algorithm will be used for finding the height andwidth of the entire handwritten word. In case of no skew, minimum valuewill be considered for the height of the wordand maximum value will be considered for the width of the word. Once skew is corrected with approximateskew angle repetition of the same process, only busy zone is considered for performing precise skewcorrection. The recommended approach has tested roughly 3364 Kannada items and achieved the best performance of 97.05 percent.*
***Keywords**: Skew detection and correction, Preprocessing, Segmentation.*

I INTRODUCTION

In our everyday lives, we come with letters, texts, and records at every turn. We read those comments and also the scribbles penned everywhere our eyes cross by, whether we realize it or not. We may understand the poem even if we only catch a glimpse of it. When we manage handwritten materials, these recent evolution follow, but things can get complicated because writing scripts might be ambiguous. It is significantly harder to read ancient records. The complexity rises owing to the use of archaic types and the prose style. Furthermore, the size, form, and form of words vary from place to place. Individuals' writing styles are influenced by their mood and environment. However, we are fully part of deciphering perplexing symbols or digits. We may read text that are unreadable, disconnected, overloaded, or even target. We are able to recognize them because of the information we have gained throughout our lives.

During 1980 to 2000, this OCR [1] software method was designed and applied in academic institutions, survey OCR, and identification of imprinted letters on metallic bars. Clustering methods were started in the early 2000s to archive ancient texts in visual file and offer academics with recourse to these papers. The usage of mutable fonts, printed noise, and space were among the obstacles in segmentation of ancient manuscripts. Multiple servers for different manner persons were launched in the mid-2000s. Such applications aided these individuals in improving their reading and writing abilities. Scientists in the present decade having focused on several machine learning algorithms. To improve the accuracy of the

computer vision system, carrying ability machine learning approaches with imaging techniques. Furthermore, academics have concentrated on developing approaches for digitising textual data, especially using machine learning. That paradigm change has been triggered by the adaptation of computer clusters and GPUs, as well as improved results by machine learning designs.

We just had paper records prior to the increasing use of computers. Recorded histories, big events, great books, granthas, and key information to preserve all of this vital knowledge, we must digitise it. Manually entering all of these papers takes time and is prone to errors. As a result, the desire for a wheel system emerged. The Handwritten Character Recognition (HCR) system was developed in response to the requirement for an automatic document image reader. It is a 'herculean task' to replicate a human's identical capabilities in with an HCR program. HCR methods should be sufficiently clever to differentiate words and grammar in all circumstances in order to realise all of the features.

Handmade character recognition [2] is used in areas such as robotic pin-code detection, form collection, check analysis, observed, and others. Domains where documents be interpreted or processed are among the potential possible applications. Offline segmentation method is used in feedback picture or video databases allowing storage and retrieval, as well as extracting texts from complex images. Because of the growing use of the online, offline methods for content-based broadband internet on paper files are required. Handwriting recognition systems, when combined with voice processing, will provide an interface for the partially sighted.

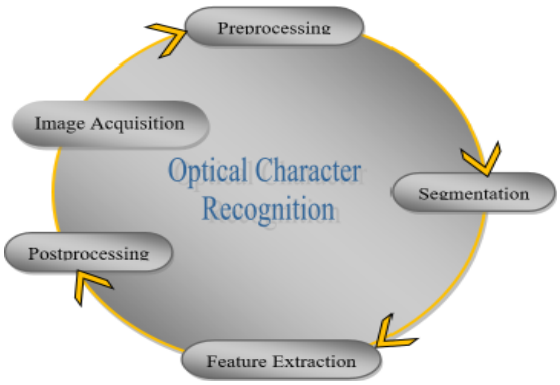

Figure 1: Basic OCR Algorithm

Basic OCR Algorithm as shown in Figure 1, The technology, i.e. OCR, makes use of an Android mobile device. The camera aids in the recording of handwritten papers. This is simply the scanning procedure. The original photograph can be converted to a digital image using the scanning procedure. The original photos are displayed in bolded font on a white backdrop. This method converts a digital photo to an image pixels. One of its most critical stages in feature extraction is pretreatment. It contributes to grayscale photos being more legible by technology. It removes imperfections from the photos. For handwritten pictures that are more susceptible to noise, preparation is essential. Preprocessing [3] tasks include greyscale conversion, binarization, thinning, convergence, and distortion, with separations

being the most important. Splitting is used to distinguish among specific stories. The handwritten writing is first split into lines, then into words, and finally into characters.

The feature extractor [4] is where OCR recognises alphabets depending on several classes. The translation of input information into a number of characteristics is known as product extraction. It extracting features of the text picture. Attributes are what set features apart. The letters are classified based on their tilt angle, length, bends, and so on. The specified phrase is matched to the program's sql dataset and the collection, and the letter with the largest effect is picked and announced. Signal representation is the focus of extracting features. Once a letter has been identified based on categorization, it is converted into form. In order to identify elements in a text, object recognition offers information on the features of digits or letters separately. Only the machine understands the retrieved output. As a result, they must be saved in a suitable format (.txt). The ASCII-formatted data that has been recognised.

1.2 Recognition of Handwritten Techniques

There are two types of authorship identification systems: online and offline. Also in former, data is recorded while writing with a steno pad or an electronic screen. The two-dimensional locations of subsequent points of penning are recorded in sequence, and the author's stroke order is placed available. After the writing procedure is completed, the data is captured by a scanner. Proposed method, feature extraction, and then classification are the three stages of an offsite HCR system. Because of the existence of distortion in the information gathering phase and the loss of spectral analysis such as the writing pattern and pace, offline handwriting identification is more sophisticated than online methods.

People's penmanship varies for a variety of reasons. There is also a group of characters who resemble one another. The differences among these characters are quite minor. Even humans have difficulty recognising them. These changes have an impact on the character recognition. The following are some of the difficulties that researchers encountered in implementing an HCR system:

- Characters can be shaped in an infinite number of ways
- Characters' Similarities
- Characters who are deformed and unreadable
- Characters with flaws
- Characters who are overlapping and intersecting
- Unsent papers and complicated characters are present
- The presence of several languages and integers
- The document's grade
- The linen and pen's functionality
- Scanner resolution was chosen
- Perception on the back cover
- Camcorder lighting conditions
- Because of the complicated algorithms, there is a high level of time load

- Time complexity have increased as a result of the huge training examples

The initial phase in the HCR method is feature extraction, which involves digitising a text-containing document. The image is then subjected to a series of preparatory processing procedures in order to make it acceptable for Feature Extraction (FE) [5]. During separation, lines are discovered and languages and characters get isolated from these threads. The image will now be subjected to feature extraction. To portray the image in such a clearly accurate manner, features are extracted. Finally, the image of its character is recognised. The big strides involved in the response are summarised in Table 1.

Table 1: Steps Involved in HCR System

Picture Acquisition Digitization
Preprocessing Segmentation, Binarization, Noiseremoval, Normalization,Thinning
Feature Extraction Extraction of main features
Recognition Recognition of letter

The primary areas lead to the emergence of the HCR system are Image Processing (IP), Pattern Recognition (PR), and categorization. The manipulation of digital photographs using a teletype machine is referred to as Digital Image Processing (DIP). For image processing, DIP includes a number of algorithms. Image improvement, recognition, binarization, noise reduction, normalisation, and thinning procedures are among them. Recognition system is an aspect of data science that can be characterised as the activity of taking in source code and, after some analysis, making a conclusion based on the data categorization.

1.3 Pattern Recognition in Handwritten Documents

Pattern recognition categorises [6] data (patterns) related to existing knowledge or analytical information collected from the rhythms. A realistic pattern recognition system comprises of gathering the views to be classed or described; an image retrieval technique that extracts valid information from both these sightings; and a diagnosis or description ceramide on the recovered features. The scheme for categorisation or description might be either centralized or decentralized. In deep classification, method is validated based on a combination of previously known or defined patterns. Unsupervised learning occurs when the network is not provided an a priori classification of patterns and categories itself based on the occurrences of the motifs.

Associated with a set of attributes, a classifier assigns the input image to the ascending order. The accuracy of the classifier determines the performance about an HCR system. Parametric classifiers and brain classifiers are two prominent classifiers. Deep Neural

Networks (DNN), Particularly Multilayer Perceptron (MLP) [7], function best in pattern classification. After the advent of artificial neural networks, the flow of skills in the area of information processing has primarily taken severe bends in modern years. Deep learning, as opposed to feature detection and extraction proceeded by computations, is solely based on data, allowing the approaches to be applied as a response to a wide range of problem expressions, including language modeling. Because of their adaptability and sturdiness, artificial neural networks have emerged as the face of machine learning. The technique is applicable to problems involving pattern spatial organisation, such as language modeling. Artificial Neural Networks, apart from OCR and some other machine continuing to learn edge detection approaches, perform actions with the largest feature in mind.

Furthermore, typical techniques which have proven successful with English language offline handwritten are not easily applicable to Mysore due to morphological variances between the linguistic characters. Data mining techniques become particularly useful in fixing the problem as a result of this. The issue statement, involving foreign languages such as English, French, Arabic, and Japanese, has been quickly worked on with great performance presentation, thanks to notable contributions to the subject from numerous writers. OCR has consistently produced good results, but only in context domain partitions. The increased access to data and venues, aided by cloud-based processing method, has increased the quality and range of solutions available, enabling way for cutting-edge technologies such like Machine Learning.

Several authors have successfully persuaded readers to recognise handwritten characters. Mori et al. expanded out the first efforts, a historical viewpoint to the field. The work examines the OCR technology from a historical standpoint and delves deeply into highly recognized and structure statistics, with a comparison between economic Factors development and research and technology on the technique. The authors present a clear picture of the trajectory of growth in the subject, using OCR as a frame of comparison.

Amin et al. discuss their work into off-line Arabic template matching, which is seen as machine execution of human comprehension. The writers take a stand on the intricacy of grammatical structures and the relative lack of effort put on the subcategory. They make use of the most crucial aspects of the writing process, such as quickness and other temporal factors. The writers have also brought to light limitations such as composing space limitations in their effort.

As previously stated, the difficulty in recognising Arabic characters extends to the understanding of Indian language systems. Differences, intricacies, and personalizations all relate to the difficulties in resolving the situation. The fact that all Indian languages are descended from Brahmi, as well as the resemblance of letters and the colourful dispersion of art style within the speech, contributes to the procedure's difficulty. Other than vowel sounds, those translations, unlike English, feature combinational letters. Width and written style variances must also be addressed as portion of the problem description. As a result, the authors use a variational position to deal, with classification methods such as implicit and explicit segmented, to identify simple and complicated characteristics. Hidden Markov

Processes and Neural Networks were introduced into the investigation, providing significant results.

Manjunath et al attempted to classify completely handwritten documents Kannada personalities have used Fourier transform focused Structural Equation Evaluation and Iterative Neural Networks and obtained a validity of 88.64 percent, whereas Niranjan et al. contacted a certain issue of classifier of handwritten documents Kannada protagonists utilising FLD and obtained a reliability of 88.64 percent. Naveena et al. utilize ridgelet changes to describe monodimensional discontinuities in two - dimensional field, which is a fresh solution to the same issue.The advent of learning algorithms was likewise welcomed by the domain of handwriting letter names, given the problem's broad application area. The algorithms technique entails extracting features from information and identifying connections using these features. Because the data flow in virtually all models is sequential, the feature based procedure is designed to avoid variable outbursts. The likelihood factors for the recurrence of the characteristic are addressed, and the issue is great on the error signal using the conjugate gradient method.

Researchers have also prioritised OCR-based approaches, with an emphasis on language-specific codes. The writers Jayaram et al. provide an outline of OCR on the Telugu film industry. The writers investigate numerous strategies and methodologies utilised in the process of resolving the challenge of offline handwritten in Telugu language. The script is related to Kannada in that it is separated into vowels and consonants. Its script provides a comprehensive insight of technological breakthroughs to begin investigation in this sector. Handwritten character identification of Kannada characters receives far less attention. Shaila et al. offered an excellent methodology overview. The endeavour will aid in knowledge of several different strategies utilised to solve the stated challenge of Kannada handwritten letter names. Countless recent works in the area are illustrative. The researchers take a proper trust network-based technique, employing a quick replacement image features to HOG, the global averaged of slopes. Mirabdollah et al. developed an alternative DAG region proposals in which the picture is partitioned into standard-sized blocks and frames, and the averaged of the adjacent pixels from each frame is joined to the description to generate the feature map. Karthik et al. in separated the vowels and consonants but used 400 pictures per letter to teach the deep learning model. They claim to provide an accuracy rate of 97.04 percent.

II PROPOSED METHODOLOGY

2.1 Deskewing Method for Text Line Segmentation

Existing study suggests using a deskewing method to separate the path from a handwritten documents Kannada manuscript. The proposed algorithm employs preprocessing, dilatation, and tagging of associated elements of the source images, deskewing of handwritten text letters, and attaching words to the newly acquired picture. The block schematic for it is shown in Figure 2.

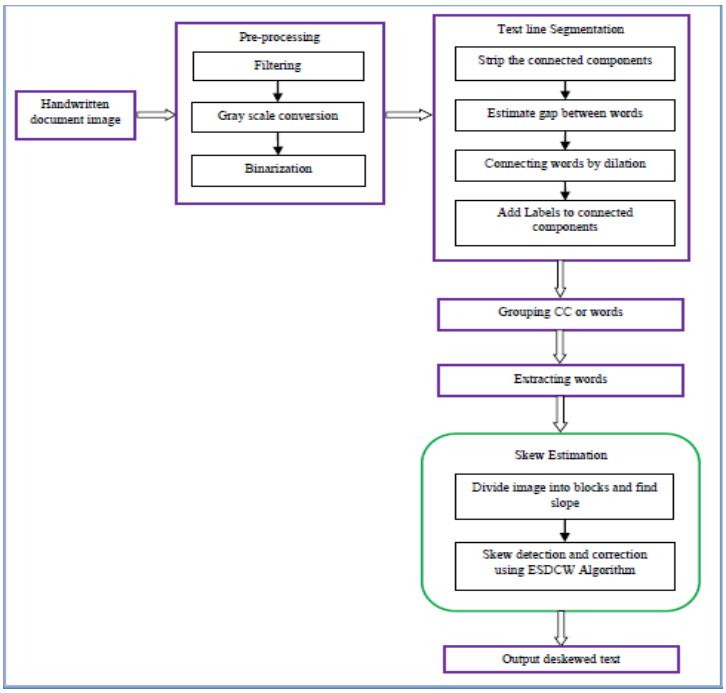

Figure 2: Block Schematic Diagram of Deskewing Text Line & Word Segmentation Model

2.2 Preprocessing

- ***Filtering***: This entails removing unnecessary pixels or distortion from the lines of text of the source handwritten picture, making the character lines suitable for classification.
- ***Gray Scale Transformation and Binarization:*** The document picture is processed to extract rows and letters from text lines. Following filtration, the image is transformed to grayscale, which serves as a threshold to produce the binary picture.

2.3 Text line Segmentation

- ***Remove the related components:*** The finalized picture may contain some few stripes that are taller than the remainder of the patterns. Typically, such stripes represent a zone that is interacting or overlapping. To reduce these stripes, a dynamically threshold ‘T' depending on normal altitude is computed. Smaller rectangular patterns (dotted line, dashes, etc.) are properly deleted to boost segmentation result.
- ***Calculate the gap between phrases:*** The gap measure for lines of text specifies the space into two clusters. In addition, the gap mimics space between two overlapping components with vertically linked projection patterns. The overlapping elements are taken account instead of the clusters when computing the distance value. This ED (Euclidean Distance) is the spacing metric used here, which corresponds to the minimal ED between the Euclidean distances among all node pairs from the two neighbouring overlapped elements. A global level is described in the picture for gap categorization. Computing the black to white changes in every scanned image of the text line picture yields the threshold.

- ***Dilation method for connecting components:*** The dilatation process includes additional pixels to the related components. To properly partition lines and phrases, it is essential to calculate the skew (oriented) degree from the handwriting text file that can be calculated by considering either a single component, an isolation word, or the entire line as a picture. Each approach has advantages and disadvantages. Because there are compounding characters, calculating orientation angle via specific characters causes trouble when saving photos as a word. Because of the variance of the orientation angle amongst the letters, identifying the angular position for entire lines might be difficult. As a solution, words must be used to calculate the skew angle. As a result, the dilatation operation that is applied also on binary picture for portraying text characters in the type of clusters becomes important. Then, dilated pictures are labelled or used in another way.
- ***Introducing labels to CC:*** Labeling means applying label column per column, so that elements connected with a text line could be detected using a revolutionary method.

2.4 Combination Words or CC

Labeling denotes allocating labels section-wise, so that letters associated with a line of text could be detected using a new method. For letter clustering, every dilated element is developed to determine the boundaries parameters such as rmin, rmax, cmin, cmax, as well as the labeling integer. The indicators are as follows: rmin ->minimal row, rmax-> maximal row, cmin ->minimal column, and cmax ->maximal column. The IB contains boundary parameters for all overall clusters (Information Base). The rmin number in the border coordinates matches the location of the syllable in the textual picture, which can be used to cluster words connected with the same line of text. As a result, the study employs a novel strategy for clustering the words connected with the same text line by utilising rmin numbers. In the first phase, the total results of the rmin characteristic are sorted and stored in the set of vectors KB1. The items are then grouped in a path by matching the absolute distinction between different subsequent rmin values to the experimentally determined threshold value (79). Whenever the differential is less than the threshold level, the rmin is saved in the same line of the KB2 matrices; otherwise, it is put in the next line of the KB2 structure. The procedure is iterated for the remaining dilated elements.

2.5 Words Extraction

The skew is calculated here by identifying the words connected with the line of text, which are identified using the row component of the KB3 matrices. The perimeter coordinates are placed over the uses elements picture to carry out the extractor operation.

2.6 Skew Estimation

Estimation of Skew in Handwriting documents are usually slanted. In any handwritten word line segmentation, calculating the gradient and connecting the gaps between the stripes is critical. The dilatation technique is the best method for bridging the space between the striping. Though the procedure is not ideal for severely skewed documents, it works well for less skewed lines of text (approx. 2). In the case of a heavily skewed material, text characters

may cross or overlap, resulting in inefficient output. To address this problem in dilation, the study proposes a method for determining the gradient of text lines based on a modular design.

A) Determining the Slope Angle

The picture block is divided between vertical and horizontal halves. The gradient of every rectangular band is calculated as follows in Equation 1:

$$slant = \frac{1}{n}\sum_{j=1}^{n}\frac{l_j(t) - m_j(u)}{l_j(t) - m_j(u)} \quad (1)$$

Where lj (t, u) and mj (t, u) are boundary points.

B) Skew Detection and Correction

- ***Skew Detection and Diagnosis Using the ESDCW Method:*** The suggested technique takes into account the length and width of the complete handwritten word. In the absence of skew, there appears to be a smallest value for the altitude of each word and a highest amount for the breadth of any word. Skew Detection and Mitigation algorithm As Shown in Table 2. Following skew correction using an approximate distortion angle, the procedure is iterated with only the busiest zone in mind for accurate bias correction.

Table 2: Skew Detection and Mitigation Algorithm

Step 1: Assume that (g, h) is the pixel of sentence, and calculate the min and max values of the h axisas minh and maxh, respectively.
Step 2: Height estimation = maxh - minh
Step 3: Rotate all pixels in the page by one degree counterclockwise as shown in equation 2 & 3. For coordinates, rotate by angle (g,h)
$g' = gr + (g - gk)\cos\theta - (h - hk)\sin\theta$ (2)
$h' = hk + (g - gk)\sin\theta + (h - hk)\cos\theta$ (3)
Where g and h are the new and existing values, and gk and hk signify the centroid of the term for coordinate as stated in Eqn 4.2 and 4.3.
Step 4: Word height is computed by continually rotating 1 degree.
Step 5: If the word's elevation is less than a certain value, estimate the inclination and stop the spinning.
Step 6: Assume attributes (g, h) for all units if the height of the string is less for even more than one edge. Ming and maxg are calculated.
Step 7: In the same way, determine the word width=maxg – maxg, as well as the total angle.
Step 8: Assume an angle with a reasonable level for maximum width.
Step 9: Locate the active section of the word, fix the skew, and eliminate the unnecessary part.
Step 10: Repeat the preceding words for the relevant section of the handwritten paper.
Step 11: The scribbled word is correctly skewed.

2.7 Insertion of Words into a New Image

There may be variations in the bounding boxes of the deskewed imagery while doing word deskewing. As a result, it is critical to avoid word overflowing in a new image by comparing the preceding word's boundary coordinate cmax with the cmin amount of the present word image. If cmax is smaller than cmin, cmin is adjusted as shown in Equcation 4:

$$H \min t + 1 = H \max t + \text{const.}\ 1 < t < w \quad (4)$$

The CC of the input word are grouped first on a new picture by equalising all the rmin to the smallest amidst the cumulative rmin values of the textual line's constituents. The other device's parameters are converted via the deskewing procedure so that all related words relate to the same linear array.The sample image consists of words situated in the same grid location after deskewing, which is repeated for the balance of the text route's words. The image shows text in the same location. The technique is repeated for the remaining text lines.

2.8 Mathematical Morphology Model

The mathematical morphology tool will enable in the extraction of image components that can be used to characterise and describe region shape, such as boundaries, skeletal, and the convex surface. Dilation is a simple morphological technique that enlarges or deepens binary image elements. The amount and method of thickening are controlled by a shape known as the structural element. Structuring elements are similar to small sets or subimages used to probe an image for important features. Set functions can be used to depict dilation mathematically. The dilatation of A by B, represented by CÅD, is defined as shown in Equcation 5,

$$C \text{ Å } D = \{z/\ (D\hat{}\ ) Z \cap C \neq \Phi\} \quad (5)$$

C and D are sets, and Φ represents the blank set, D the structuring element, and z the displacement sets. The term "erosion" refers to the "shrinking" or "thinning" of discrete image objects. The erosion of C by D, abbreviated C ⊖ D, is mathematically represented in Equation 6.

$$C \ominus D = \{z/\ (D)\ Z \cap BI \neq \Phi\} \quad (6)$$

Initially, all of the CC in a captured images can be identified and removed using the active contour analysis algorithm. If the total number of pixels is less than a predefined threshold, the component is eliminated. Following that, the suggested method applies morphology operation, in which erosion and dilation are inferred across the binary picture using a sufficient size of steel structure. In erosion, the last blank value pixel that survives at the image threshold is converted to zero, whereas in dilation, the last one element pixel that appears at the image boundaries is changed to zero. The process entails removing unnecessary pixels/dots from the scanned image using erosion and joining the unconnected components using dilation. The dilated image is reversed after dilatation, and the input image

is trimmed by recognising the rows. The upper and lower limits positions of the nonexistent pixels are computed to identify the rows. The line small structural aids in the segmentation of information into lines, whereas the rectangle structural element aids in the separation of lines into words and sentences.

III RESULTS & DISCUSSIONS

The preferred deskewing approach is evaluated using photographs from a handwritten Kannada manuscript with 166 line stuff and 823 characters as shown in Figure 3. The average line recognition accuracy is 96.38 percent, and the text categorization accuracy is 92.10 percent. In terms of segmentation of slanted lines/words, the recommended approach performs well. The approach is capable of subdividing lines that contain compound characters and have skew variable of up to 4 degrees. Though the prevalence of uneven spacing between words and fractured consonants can impede the execution of the word segmentation procedure. The results of line and character segmentation are shown in Table 3. The examination of the recommended technique is also undertaken for handwritten letters by collecting information from persons from various backgrounds. The experiment is carried out by entering around 5,800 Kannada handmade words. Among the total words, 42 percent are used for classifier training relating to previous work, with the remainder being used for testing. The recommended approach has tested roughly 3364 Kannada items and achieved the best performance of 97.05 percent. Proposed deskewing method's performance as shown in Table 4.

Table 3: Proposed deskewing method's performance

Total lines	Segmented lines	Segmentation accuracy
166	160	96.38%
Total words	Extracted words	Word Extraction accuracy
823	758	92.10%

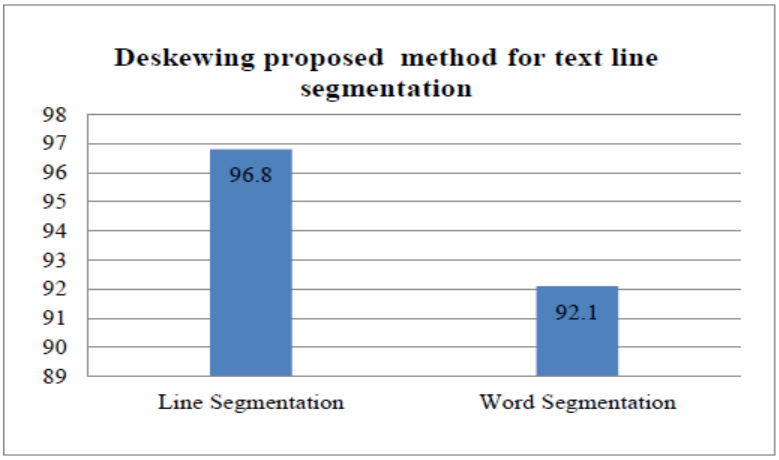

Figure 3: Proposed Line and Word Segmentation Accuracy

Table 4: Proposed Deskewing Method's Performance

Number of words	Skewed count	Rectified	Not rectified	Corrected Skew accuracy
4900	3225	2800	89	96.45%

A deskewing technique for line and character segmentation from a handwritten character Kannada document is proposed in the study effort. Following that, words related to the text blocks are categorised using an existing optimization. Following that, the recognised words are extracted and saved in a new picture. Unwanted information is carefully deleted during word recovery using the locality preserving approach, and overlaying of words is avoided while recording in a new picture file. Furthermore, the study compares enhanced horizontal projection profiling and CC (Connected Component) approaches for text line recognition in Kannada handwritten files to purely unregulated handwritten Kannada papers. The reported average division rate is approximately 97.5 percent.

The approaches work well for establishing the orientation, calculating the deskewing of the orientated word, and saving the characters in the appropriate matched line. Aside from variations in cast of characters and the presence of consonant and vowel modifications, the line and text categorization method performs admirably. Though it has been noticed that the occurrence of spatial similarities between words and characters influences the word segmentation technique.

IV REFERENCES

[1] Khan, R. A., Meyer, A., Konik, H., & Bouakaz, S. (2019). Saliency-based framework for facial expression recognition, *Frontiers of Computer Science*, 13(1), 183-198.

[2] Kumar, M., Jindal, S. R., Jindal, M. K., & Lehal, G. S. (2018). Improved recognition results of medieval handwritten Gurmukhi manuscripts using boosting and bagging methodologies. *Neural Processing Letters*, 50, 43-56.

[3] Radwan, M. A., Khalil, M. I., & Abbas, H. M. (2017). Neural networks pipeline for offline machine printed Arabic OCR. *Neural Processing Letters*, 48(2), 769-787.

[4] Thompson, P., Batista-Navarro, R. T., Kontonatsios, G., Carter, J., Toon, E., McNaught, J., Timmermann, C., Worboys, M., & Ananiadou, S. (2016). Text mining the history of medicine. *PLoS ONE*, 11(1), 1-33.

[5] LeCun, Y., Bengio, Y., & Hinton, G. (2015). Deep learning. *Nature*, 521(7553), 436-444.

[6] Parvez, M. T., & Mahmoud, S. A. (2013). Offline Arabic handwritten text recognition: A survey. *ACM Computing Surveys*, 45(2).

[7] Breuel, T. M., Ul-Hasan, A., Al-Azawi, M. A., & Shafait, F. (2013). High performance OCR for printed English and Fraktur using LSTM networks. *12th International Conference on Document Analysis and Recognition,* 683-687.