IJNRD.ORG ISSN : 2456-4184
INTERNATIONAL JOURNAL OF NOVEL RESEARCH AND DEVELOPMENT (IJNRD) | IJNRD.ORG
An International Open Access, Peer-reviewed, Refereed Journal

A Comprehensive Analysis of Various Handwritten Character Recognition Techniques

[1]Pankaj Kumar, [2]Jyoti Kumari
[1]Student, [2]Student
[1]Department of Computer Science & Information Technology,
[1]Mahatma Gandhi Central University, Motihari Bihar, India.

Abstract : In this research, numerous strategies and procedures for neural network-based handwritten character recognition are presented. It includes a variety of methods used on scanned English characters, such as skeletonization, normalization, border detection, and feature extraction. describing the preprocessing, segmentation, and classification phases of the proposed system, it also explores a diagonal-based feature extraction technique for character recognition. Another strategy emphasizes binarization, segmentation, and neural network-based classification for character recognition without a feature extraction stage. The research also explores character recognition parameter adaption using neural networks' backpropagation technique and momentum approach. To detect handwritten English alphabet letters, it offers a hybrid technique that combines feature extraction and machine learning. A neural network approach to character identification is also discussed, along with its advantages and disadvantages when compared to more conventional pattern recognition techniques. The technique for English character recognition using multilayer perceptron networks is presented in the study, along with discussion of the use of neural networks in handwritten character recognition (HCR) for banking. Overall, this study offers a thorough analysis of alternative neural network-based methods for reading handwritten characters, highlighting their advantages and potential uses in diverse scenarios.

IndexTerms - Handwritten character recognition, Image Processing, Neural Network.

1 INTRODUCTION

Due to the variety of handwriting styles and the complicated nature of the task, handwritten character identification is a difficult challenge. Neural networks have successful results in addressing these challenges and achieving high recognition accuracy. While many reports have been published on character recognition in English using neural networks, achieving high accuracy and minimum training time remains a problem. Therefore, it is important to continue developing automatic handwritten character recognition systems for the English language that can achieve these goals. This approach helps us in developing an automatic handwritten character recognition system for the English language with high recognition accuracy and minimum training and classification time. The experimental findings demonstrate how well the strategy employed in the research accomplishes these objectives. This techniques and methods helps us to reduce processing time while and provides higher recognition accuracy.

Generally, handwritten character recognition is of two types:-

- *Offline handwriting recognition* - Offline handwriting recognition of handwritten characters or text from a static image, characters are scanned and converted into an image.
- *Online handwriting recognition* - In an online system, the coordinates of the pen or stylus as it moves across a writing surface are captured as a function of time, allowing for the temporal information of the writing process to be analysed.

Online methods are superior to off-line methods in recognizing handwritten characters. This is probably due to the fact that online methods record information offline methods do not, such as the timing and order of strokes during writing. Applications for off-line handwriting recognition systems are equally significant. In reality, neural networks have been used successfully in off-line systems to accurately recognize handwritten characters. Offline systems examine the static organization of the written characters rather than the dynamic process of writing. The exact context and requirements of the activity at hand must be taken into consideration while deciding which handwriting recognition technology to use. Both off-line and online handwriting recognition systems have specific benefits and uses.

1.1 History

The earliest systems for reading and recording handwritten characters were created in the 19th century, a time when handwritten character recognition began. Herman Hollerith created the first tabulating machine that recorded data on punched cards in 1888. The device, which could read and sort punched cards with alphanumeric characters, had been used for the 1890 U.S. Census. Researchers began creating electrical gadgets that could read handwritten characters in the 1950s and 1960s. Frank Rosenblatt designed the Perceptron, a neural network that could recognize handwritten characters, which was one of the earliest systems. In the 1970s and 1980s, academics started to concentrate on creating increasingly complex handwritten character recognition algorithms. Lawrence Rabiner's creation of the Hidden Markov Model, which remains in use in many recognition systems today, which was one of the most important innovations. The emergence of machine learning methods like artificial neural networks and support vector machines in the 1990s and 2000s significantly increased the precision of handwritten character recognition. The development of systems that could accurately recognize handwriting was made possible by these methods.

1.2 Applications

- Postal Services: Handwritten character recognition is widely used in postal services for processing and sorting mails. HCR systems are used to automatically read the addresses on envelopes, which helps in sorting and routing the mails to their respective destinations.
- Banking and Finance: HCR is used in banking and finance for processing checks and other financial documents. HCR systems can automatically read the handwritten information on checks, including the account number and amount, and process the transaction.
- Healthcare: HCR is used in healthcare for digitizing patient records. HCR systems can automatically read the handwritten patient information, such as name, address, and medical history, and convert it into digital format for storage and retrieval.
- Document Management: HCR is used in document management for digitizing paper documents. HCR systems can automatically read the handwritten text in documents, such as invoices, receipts, and forms, and convert it into digital format for storage and retrieval.
- Education: HCR is used in education for grading exams and quizzes. HCR systems can automatically read the handwritten answers and grade the exams, which saves time and reduces errors.
- Retail and e-commerce: HCR technology is used in retail and e-commerce to capture handwritten signatures for transactions, as well as to recognize handwritten addresses and other details for shipping and delivery purposes
- Security: HCR is used in security applications, such as signature verification and biometric authentication. HCR systems can automatically read the handwritten signatures and compare them with the stored signatures for authentication purposes.
- Government services: HCR technology is used by government agencies to process applications, forms, and other documents. It helps in reducing the processing time and minimizing errors, leading to faster and more efficient services for citizens**.**

1.3 ADVANTAGES OF HANDWRITTEN CHARACTER RECOGNITION

Handwritten character recognition (HCR) refers to the ability of a computer or machine to recognize and interpret human handwriting. Here are some advantages of HCR:

- **Accuracy:** HCR technology has become highly advanced, allowing for highly accurate recognition of handwritten characters. The recognition accuracy of advanced machine learning algorithms has reached up to 99%.
- **Flexibility:** HCR systems can recognize a wide range of handwriting styles and forms, from cursive to printed characters, making written documents more adaptable.
- **Versatility:** HCR technology is versatile in that it can recognize characters in a range of languages, including Hindi, English, Chinese, and Arabic.
- **Accessibility:** Written documents can be made accessible to people who have difficulty reading or interpreting them, such as those with visual impairments, using HCR technology.
- **Efficiency:** HCR can automate data entry and digitalization of handwritten documents, saving individuals and organizations.
- **Speed:** Because HCR technology recognizes handwritten characters in real time, it may be used for applications such as digital signatures and form filling.
- **Security:** HCR systems can be used to authenticate signatures in a variety of applications, such as financial, legal, and government documents, preventing fraud and forgery.
- **Cost-effective:** For huge volumes of handwritten documents, HCR can be more cost-effective than human data entry or transcription services.

1.4 DISADVANTAGES

Handwritten character recognition techniques have several disadvantages, including:

- Difficulty in Recognizing Different Handwriting Styles: People have different styles of handwriting, and recognizing all of them accurately can be challenging for handwriting recognition systems.
- Complexity of the Recognition Process: Handwriting recognition systems are often complex and require significant processing power and memory to accurately recognize handwritten characters.

- Error Prone: Handwriting recognition systems can be prone to errors, particularly when characters are poorly written or smudged. This can be particularly problematic in situations where accuracy is critical, such as in financial transactions or legal documents.
- Limited Language Support: Handwriting recognition systems may have limited support for languages other than English, making them less useful in multilingual environments.
- Training Data Dependency: Handwriting recognition systems require large amounts of training data to accurately recognize characters. This can be a significant challenge in situations where there is limited or no training data available.
- Cost: Handwriting recognition systems can be expensive to develop and implement, particularly if they require specialized hardware or software.

2. Literature Review

The paper presents an approach for developing an automatic handwritten English character recognition system using neural networks. The English language consists of 26 characters, which are scanned and converted into 1024 (32X32) binary pixels. The system involves scanning the handwritten characters, performing skeletonization, normalization, boundary detection feature extraction, and classification using a multilayer perceptron neural network with one hidden layer. The skeletonization process is used to delete extra pixels that do not belong to the backbone of the character and reduce broad strokes to thin lines. Feature extraction is performed by adopting the eight-neighbor adjacent method to extract the information of the boundary of a handwritten character. The Fourier descriptors are used to find the Discrete Fourier coefficients and a set of invariant descriptors are computed by eliminating the size of the character from the Fourier descriptors. A multilayer perceptron neural network with one hidden layer is used for training and back-propagation algorithm has been implemented for training and recognition. The neural network is capable of generalizing and is insensitive to missing data, making it beneficial in recognizing handwritten character. The experimental results show that the proposed approach has high recognition accuracy and minimum training time.[1]

The paper proposes a diagonal-based feature extraction scheme for off-line handwritten character recognition. The feature extraction process involves dividing the resized individual characters of size 90x60 pixels into 54 equal zones, each of size 10x10 pixels. In the proposed approach for recognizing handwritten English alphabets, features are extracted from each zone of the input image by analyzing the pixels in a diagonal pattern. This process is repeated for all the zones, resulting in the extraction of 54 features for each character. These extracted features are then used to train a neural network, which can classify and recognize the input characters accurately. The paper presents a schematic diagram of the proposed recognition system, which consists of pre-processing, segmentation, feature extraction, classification and recognition, and post-processing stages. The pre-processing stage includes binarization, edge detection, dilation, and hole filling. In the segmentation stage of the proposed approach for recognizing handwritten English alphabets, the pre-processed input image is divided into isolated characters using a labeling process. Each character is assigned a number and then resized to a standard size of 90x60 pixels for feature extraction. This ensures that each character is of the same size and shape, which helps in accurate feature extraction and recognition . In the feature extraction stage, the proposed diagonal feature extraction scheme is applied. The 54 features are obtained by moving along the diagonals of each zone and summing up the foreground pixels present along each diagonal line . the input image is divided into 19 zones. Within each zone, various subfeatures are extracted and their values are averaged to form a single feature value. This feature value is then assigned to the corresponding zone. This process is repeated sequentially for all the zones in the image. In the classification and recognition stage, a feedforward backpropagation neural network having two hidden layers with architecture of 54/69-100-100-26 is used to perform the classification. the hidden layers utilize the log sigmoid activation function to process the input features and generate output values. The output layer of the network is designed as a competitive layer, which means that it is trained to identify a single character among a set of possible characters. This is achieved by comparing the output values of each neuron in the output layer and selecting the neuron with the highest value as the recognized character. The feature vector is denoted as X, and the number of input neurons is determined by the length of the feature vector d. The total number of characters n determines the number of neurons in the output layer. The network training parameters include the input nodes, hidden nodes, output nodes, training algorithm, performance function, training goal achieved, training epochs, and training momentum constant.[2]

Image pre-processing, the initial stage in this procedure, makes the image ready for examination. The image is pre-processed by the conversion to grayscale, noise removal, edge detection, and feature extraction processes.The image is separated into lines, words, and characters after pre-processing. Word segmentation creates space between words while line segmentation divides text into lines. Character spacing is necessary for character recognition. Pre-processing involves converting the text into a grayscale image, which is subsequently filtered to remove noise. The edge of the noiseless grayscale image is then obtained using edge detection methods.A single-layer network of sigmoid neurons is used to learn the nonlinear and linear relationships between the input and output vectors in character recognition. This network's output layer implements a linear transfer function to generate values outside of the -1 to +1 range. If the output values must be constrained, a sigmoid transfer function can be used instead. Character recognition procedures include image pre-processing, line segmentation, word segmentation, and character segmentation. The method identifies connections between the input and output vectors using a single-layer network of sigmoid neurons.[3]

A research paper that proposes a handwriting recognition system. The system consists of four stages: pre-processing, segmentation, classification, and post-processing. The paper proposes a method that does not include a feature extraction stage.In the pre-processing stage, the scanned input image is enhanced to make it suitable for segmentation. This is achieved through binarization, dilation of edges using the sobel technique, dilation of the image, and filling of holes present in the image. During the segmentation stage, an image is divided into discrete characters, each with its own unique number. These characters are then scaled to a standard size of 30X20 pixels so that a computer software may readily process them. In the classification stage, a feed-forward back propagation neural network is used for classifying and recognizing the handwritten characters. There exist two hidden layer , input layer and output layer. The output layer has 26 neurons, as the system is designed to recognize English alphabets.In the post-processing stage, the recognized characters are converted into a structured text form. This is done by calculating the equivalent ASCII value for each character using a recognition index obtained from analysing test samples. The proposed recognition system was implemented using Matlab7.1. Seven different neural network architectures were trained with 50 data sets for a target MSE of

10e-8. All seven networks were tested using 10 different handwritten data sets, and the neural network having two hidden layers each with 100 neurons was found to yield the highest recognition accuracy of 90.19%.The study describes a complete approach to handwriting recognition and provides a strategy for achieving high recognition accuracy without the use of a feature extraction stage. The use of neural networks for classification is a frequent strategy in handwriting recognition, and the research provides important insights into their construction and optimization.[4]

The back propagation algorithm and the momentum method used in neural networks to adapt parameters for character recognition. Back propagation is an iterative learning procedure that modifies the weights of a neural network incrementally according to the gradient of the error between the output of the network and the desired output. When the error reaches a predetermined value, the algorithm repeats the samples numerous times, altering the weights with each iteration. Different learning rates may be needed for each layer of the neural network since the learning rate (LR) is a crucial back propagation parameter.The momentum method is a heuristic algorithm that modifies the weight changes in two steps. First, the gradient is used to calculate the weight modification, and then the previous weight modification is added to this value. This approach helps the neural network navigate through narrow valleys in the criteria-field, reducing the training time. Both back propagation and the momentum method are optimization functions used to minimize the error in the criteria-field, which is a surface that depends on a parameter. In neural networks, the gradient descent method is the most commonly used optimization function to find the minimum of the criteria-field.[5]

The method described in the research combines feature extraction and machine learning techniques to recognize handwritten English alphabet characters. The research's objective is to create an algorithm that, regardless of handwriting style, can recognize handwritten English alphabets accurately. The authors used a dataset of handwritten English alphabet images to train and test their algorithm. The dataset consists of 26 letters, each of which is represented by multiple handwritten samples. The authors extracted various features from the input images, including edge orientation, centroid position, and horizontal and vertical projections. The authors classified the data using a multilayer perceptron (MLP) neural network after extracting the characteristics. A type of artificial neural network commonly used for classification problems is the MLP. The network was trained using the training set's extracted features, and it was then used to categorize the test set's features. The authors evaluated the performance of their algorithm using metrics such as accuracy, precision, recall, and F1 score. The results showed that their algorithm achieved high accuracy in recognizing the handwritten English alphabet characters, with an accuracy rate of over 95%. Overall, the research paper demonstrates a novel method for recognizing handwritten English alphabet characters using a combination of feature extraction and machine learning.[6]

An AT&T Bell Laboratories research group released the article "A Neural Network Approach to Handprint Character Recognition" in 1994. In the paper, a unique neural network method for character recognition is presented. The authors begin by giving a summary of earlier character recognition research, which covers both conventional pattern recognition methods and neural network-based approaches. The intrinsic variety in handwriting makes it difficult for traditional techniques to recognize handwritten characters, even though they have been effective in recognizing printed characters. The authors then describe their proposed method, which involves training a neural network to recognize characters based on their pixel values. The network architecture consists of multiple layers of neurons, with each layer responsible for identifying increasingly complex features of the input image. The authors also describe a preprocessing step that involves segmenting the input image into individual characters before feeding them into the network. The paper then presents experimental results comparing the performance of their neural network approach to other character recognition methods. The authors report that their neural network achieved superior accuracy compared to traditional pattern recognition techniques and outperformed other neural network-based methods. The authors conclude by outlining various potential uses for their methodology, such as the processing of handwritten forms and the use of optical character recognition for document scanning. The need for labelled training data and the challenge of scaling the network to recognize a large number of characters are some of the drawbacks of their approach that they also mention. Overall, the paper describes a promising new method based on neural networks and offers a thorough summary of the state-of-the-art in character recognition. The experimental outcomes show the approach's effectiveness and hint to its potential for use in real world situations.[7]

Handwritten Character Recognition (HCR) using neural networks is a popular and effective method for digitizing handwritten documents for various applications, including banking. A neural network is trained to recognize and classify handwritten characters in this technique. The neural network learns how to identify different patterns and properties of each character by being trained on a vast dataset of handwritten characters. HCR is widely used in the banking industry for operations like check processing, signature verification, and document authentication. With HCR, banks can process checks and other documents faster and more accurately, reducing errors and improving overall efficiency. To implement HCR for banking applications, the first step is to collect a large dataset of handwritten characters. This dataset is used to train the neural network to recognize different styles and variations of handwriting. The photos of the handwritten characters are then preprocessed to remove any noise or artifacts that may influence the recognition accuracy. Post preprocessing, the photos are input into the neural network, which analyses them and predicts the character represented by the image. To enhance the accuracy of its predictions over time, the neural network is trained using backpropagation and other optimization procedures. Overall, neural network-based HCR is a strong tool for financial applications, allowing institutions to process documents more efficiently and precisely. As technology advances, it is expected that it will become even more common in the banking business and other industries that rely on document processing.[8]

This research paper presents a methodology for designing an artificial neural network that can identify different English language characters using a multilayer perceptron network algorithm. The paper describes the process of character scanning, skeletonization, and normalization to ensure that all characters become equal in matrix dimensions. The boundary recognition feature removal technique is used to extract boundary information of a written character. Fourier descriptors are used to compute the distinct coefficients of a Fourier descriptors, which possess invariant characteristics with veneration to shift and rotation. A feed-forward multi layer perceptron network with a hidden layer is used to recognize the English language characters. The multi layer perceptron is considered as the most recognized and widely used neural network, and in this paper, a two-layer perceptron has been used, which has one hidden layer and one output layer. The back propagation algorithm is used to train the network with the implementation of a back propagation algorithm. The paper concludes that with repeated adjustments of their weights, the performance and recognition accuracy of the network increase. The results showed that this method was able to recognize characters with a 95% accuracy rate.[9]

Handwritten character recognition has been an active area of research for several decades, and many techniques have been proposed for character recognition using neural networks. While much of the work on character recognition has been focused on English characters, there has been a growing interest in developing recognition systems for other languages, including Hindi. Several techniques have been proposed for feature extraction in handwritten character recognition, including gradient-based methods, such as the one used in this paper. Gradient feature extraction techniques have been shown to be effective in improving the recognition accuracy of handwritten characters, and have been used successfully in other character recognition systems. Multilayer perceptron (MLP) networks have been widely used for character recognition, and have been shown to be effective in handling complex and variable character shapes. The error backpropagation algorithm has been used to train MLP networks, which involves adjusting the weights of the network based on the difference between the predicted and actual outputs. In this paper, the authors have proposed a neural network-based approach for handwritten Hindi character recognition, using a gradient feature extraction technique and an MLP network. The system was trained and tested on a dataset of 1000 samples of handwritten Hindi characters, with the results showing a recognition accuracy of more than 94%. The authors also conducted a comparative analysis between global input and gradient feature input, showing that the latter provides better recognition accuracy with reduced training time.[10]

3. Methodology

The research paper's technique entails the creation of an automated handwritten English character recognition system utilizing neural networks. Scanning handwritten letters is the first step, followed by skeletonization to reduce strokes to thin lines and boundary detection for feature extraction. By removing size variations, Fourier descriptors are used to construct invariant descriptors. For training and recognition, the system incorporates a multilayer perceptron neural network with one hidden layer and the backpropagation method. The suggested diagonal-based feature extraction approach separates characters into zones and extracts characteristics using a diagonal pattern for off-line handwritten character recognition.

A feedforward backpropagation neural network with two hidden layers is used to process the segmented characters via preprocessing, segmentation, feature extraction, and classification phases.Another method for converting detected characters to text avoids feature extraction and instead employs a neural network for classification, followed by post-processing. For modifying neural network parameters, the backpropagation algorithm and momentum technique are used. The final solution employs a multilayer perceptron network to recognize handwritten English alphabet letters by combining feature extraction and machine learning. Finally, the study provides a neural network-based character recognition approach that includes preprocessing, segmentation, and classification phases. Collectively, the offered methods highlight the importance of neural networks and feature extraction techniques in attaining accurate handwritten character recognition.

Figure 1 English Characters Set[9]

Figure 2 Skeletonization of an English Character[1]

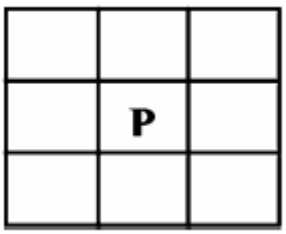

Figure 3 Pixel P and It's 8-neighbours[1]

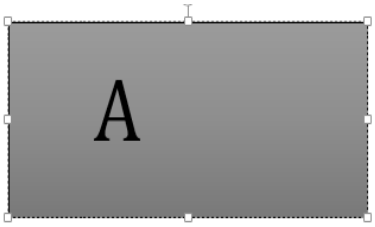

Figure 4 Tracing of Character Boundary[9]

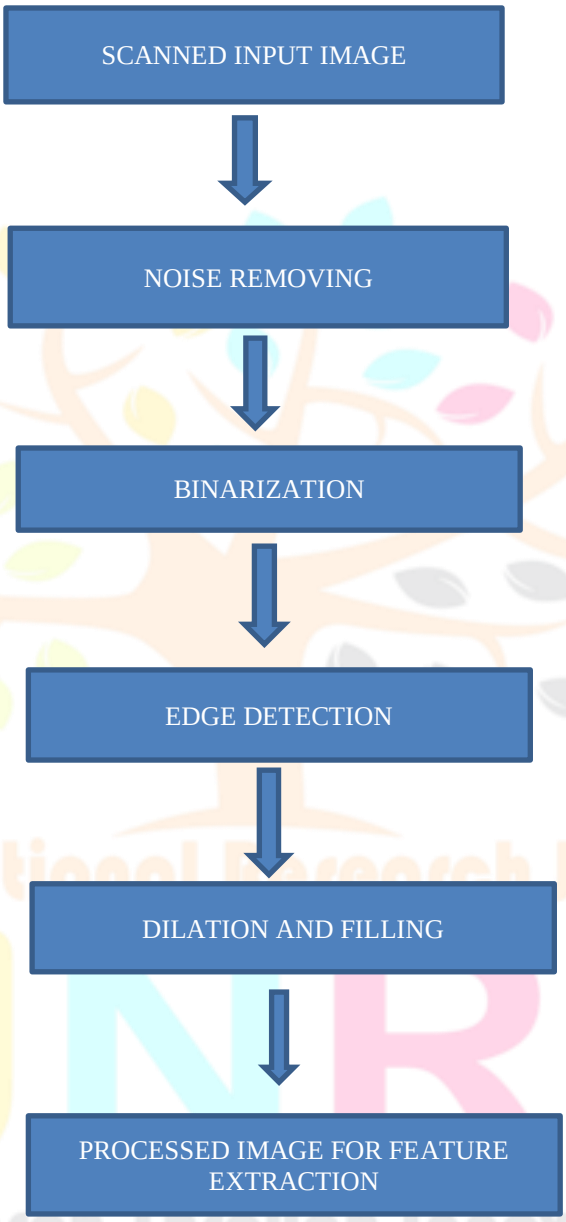

Figure 5 Pre-processing of Handwritten character

4. Problem Definition

The problem addressed in these research papers is the recognition of characters, specifically handwritten English and handprint characters, in various applications such as banking, using neural networks. The objective is to develop a system that can accurately recognize and classify characters using a neural network approach, with some papers proposing the use of feature extraction techniques and others proposing a neural network without the need for feature extraction. One paper also focuses on the recognition of handwritten English alphabets specifically, while another proposes a multi-layer perceptron network for English character recognition**.**

Table 1 Comparison of various Techniques in HCR

Author	**Preprocessing**	**Segmentation**	**Feature Extraction**	**Classification**	**Recognition Accuracy**
Anita Pal	Skeletonization, Normalization	N/A	Fourier Descriptors (8-neighbour adjacent method	Multilayer Perceptron Network	94%
J.Pradeep	Noise Removal, Binarization, Edge detection, Dilation and Filling	N/A	Diagonal feature	Feed Forward Back Propagation Neural Network	97.84%
Ankit Sharma	Size normalization, Binarization, Edge detection, Segmentation	Line Segmentation Word Segmentation	N/A	Feed Forward Network	85%
E.Srinivasan	Noise Removal, Binarization	Line Segmentation Word Segmentation	N/A	Feed Forward back Propagation	90.19%
Rokus Arnold	N/A	N/A	N/A	N/A	N/A
Poonam Bhanudas Abhale	Gray Scale Conversion ,Binarization, Noise Removal, Edge Detection, Morphological Operations	N/A	Zoning, Directional Features, Moment Invariant Features	A feed forward back propagation	N/A
L.D. Jackel	Noise Removal, Binarization	Digit-string Segmentation	LeCun's network	A new neural-net chip, known as ANNA	N/A
Shreya Mhalgi	Gray scaling	N/A	N/A	CNN	N/A
Iliyasu Adamu	Normalization, Binarization, Edge detection, Segmentation	N/A	Fourier Descriptors	Feed-forward multilayer perceptron	95%
Dayashankar Singh	Normalization, Binarization	N/A	Gradient Feature Extraction	MLP	94%

5. Future Direction

Future directions in the field of neural network-based handwritten character recognition could include investigating advanced deep learning techniques such as convolutional neural networks (CNNs) and recurrent neural networks (RNNs) to improve recognition accuracy and handle more complex character variations. Incorporating approaches such as transfer learning and data augmentation might improve model performance on small training datasets. The combination of attention processes and transformer topologies may result in improved context comprehension for sequence-based character recognition tasks. Furthermore, research might concentrate on establishing domain-specific recognition systems for languages and scripts that do not currently have powerful recognition solutions. The incorporation of real-time recognition capabilities via mobile applications and wearable devices has the potential to broaden the practical applications of handwritten character recognition to a variety of areas, including education, banking, and healthcare.

6. Conclusion

The research articles provided here highlight the importance of neural networks in the domain of handwritten character recognition. These works demonstrate a range of ways for recognizing and classifying handwritten characters, notably in the context of the English language. The use of advanced preprocessing methods such as skeletonization, border detection, Fourier descriptors, and diagonal-based feature extraction with neural network designs such as multilayer perceptrons shows the synergy between advanced preprocessing and machine learning. These approaches exhibit excellent recognition accuracy, resilience against missing data, and training efficiency. Furthermore, research into strategies that circumvent the feature extraction step, as well as the backpropagation algorithm and momentum method for parameter modification, provide vital insights for improving recognition systems. These developments not only give a better knowledge of neural network-based character recognition, but also enable practical applications in a variety of sectors ranging from banking to document processing and beyond.

ACKNOWLEDGMENT

I have made this dissertation report on the topic "**A Comprehensive Analysis of Various Handwritten Character Recognition Techniques**". I have also tried my best in this dissertation to explain all the related detail. I would like to express my sincere gratitude towards my supervisor **Dr. Atul Tripathi, Department of CS & IT**, for providing excellent guidance, encouragement, inspiration, and constant as well as timely support throughout this ongoing dissertation work.

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