2023 International Conference on Sustainable Emerging Innovations in Engineering and Technology (ICSEIET)

Deep Learning for Handwritten Character Recognition

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***Abstract*— Handwritten Character Recognition (HCR) has gained significant popularity as an Artificial Intelligence tool in today's world. Recognition of a particular character is one of the challenging tasks when every work is done digitally. This technology converts handwritten characters to machine readable or digital form by applying various machine algorithms. Since handwriting and the style of writing a particular character always varies from one person to another person. A person may write some character whose style may differ in size, shape, font and position. An implementation a Handwritten Character recognition technology that uses deep learning algorithm is used. The dataset used in this technology is EMNIST (Extended Modified National Institute of Standards and Technology) dataset. The format of this dataset is of CSV file and it contains handwritten characters, which includes both uppercase and lowercase letters along with digits and various symbols. The dataset used in this model is divided into two parts one is training and other is testing. We have performed an operation for reshaping the image into 28 x 28 pixels so that it can be fitted with Convolutional Neural Network (CNN). During the training process training data is iterated through multiple epochs. The accuracy of the model is measured simultaneously. During the testing process several grayscale images are used to test the trained model and the prediction is made accordingly This model presents the accuracy, potential and high performance of CNN model in prediction of a handwritten character. This system opens up possibilities for its usage in various other applications, as it speeds up our task of analyzing documents and digitization.**

Keywords— Convolutional Neural Network(CNN), Deep Learning, Digit Recognition, EMNIST dataset

I. INTRODUCTION

Optical character recognition is the main branch which is further divided into two broad categories –Printed Character Recognition and Handwritten character recognition. In printed Handwritten Character Recognition, characters are types through input device like keyboard. Handwritten Character Recognition is a tool based on Artificial Intelligence, recognizing pattern and Computer vision.It tool automatically detects the character that user inputs through images. Accuracy of this model depends upon processing text and and different features used for classification. While handwriting recognition can be considered as one of the easy task for human brain but can be considered a difficult task for computers since a computer needs to be trained in the same manner as required to train the human brain.

There are generally two main types of Handwritten Character Recognition (HCR) methods:

- Online handwritten character recognition: In this type of system the written character is recognized as the user is taking the input or writing the character.
- Offline handwritten character recognition: In this type of system the handwritten character is available in the form of an image.

This tools solves the problem by converting the images(in form if text) into data(in form of text) which then can be used for conducting analytics, and improving productivity.

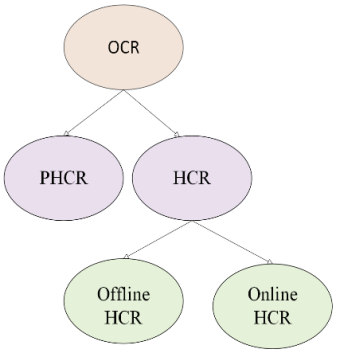

Fig. 1. Categorization of OCR.

Note*: OCR refers to optical character recognition,
PHCR refers to Printed handwritten character recognition,
HCR refers to handwritten character recognition.

This tools solves the problem by converting the images(in form if text) into data(in form of text) which then can be used for conducting analytics, and improving productivity.

One of the most common need of this application is because different people have different kind of handwriting which is inconsistent and varies time to time.Another reason is the variability of characters like small letters, capital letters, digits ,special symbols. Every individual has its own way of writing the characters. Many books in online libraries and historical knowledge are decoded with the help of this tool by scanning images found from ancient times.

Several research paper uses deep learning approach that is implemented with the help of keras library.There is a use of widely used EMNIST whose full form is Extended

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Modified National Institute of Standards and Technology dataset that is the extended form of NIST whose full form is National Institute of Standards and Technology and Modified NIST also known as MNIST which consists of CSV files. CSV refers to Comma-Separated Values which consists of grayscale intensity values for each pixel of an image. The range of these pixel values is from 0 to 255.0 refers to white whereas 255 refers to black colour intensity.

This model consist of the following steps-data pre-processing, model construction , training and evaluation. The complete CSV dataset is pre-processed by splitting it into portion of training and testing parts. The model is trained using a CNN model on a portion of a dataset commonly known as training dataset. Training refers to creating and honing a model using labelled data. During the training process, model is made to learn different kinds of variations in characters along with the intricate patterns. The proposed HCR system promises to provide accurate recognition and classification of handwritten characters. This will help in the contribution to the advancement of OCR(Optical Character Recognition) technology along with automated character interpretation. In the following sections, we will be discussing the methodology used, Literature review ,proposed work results ,conclusion and reference.

II. LITERATURE REVIEW

Writing is one of the most common method of collecting, storing and transmitting the information among each other. Handwritten Character recognition techniques has evolved into vast activity over past three or four decades. This is made a measurable impact on applications. In this field there are significant practical impact in the past decade.

In 1959 the first and early attempt in the area of handwritten character recognition was made by Grimsdale. In the early sixties only the origin of research work was carried out.It was based on analysis-by-synthesis method suggested by Eden in1968.This model proves that all characters that are handwritten are formed by a finite number of schematic features. A. Baldominos, Y. Saez, and P. Isasi's proposed research that uses data augmentation and other methods to show different affroaches that are done on EMNIST and MNIST dataset. In summary this paper this includes some top contributions thar are reported on handwritten character recognition using EMNIST and MNIST dataset. This paper also works on CNN's as they are one of the widely used approach for solving this problem. [1] M.A. Pragathi, and others presented a research paper summarizing the VGG 16 approach for character recognition. The model addressed the challenge of recognizing a large variety of handwritten Tamil characters, which often exhibit similarities. The paper introduces a Handwritten Tamil Character Recognition model. This proposed model gives 94.52 % of efficiency. [2]. Saad B. Ahmed, Salahuddin Swati, Saeeda Naz, and M.I. Razzak, make use of Recurrent Neural Network(RNN) for acquiring significant accuracy in handwritten Urdu character recognition. 500 writer's ligatures are present in this dataset with their natural handwriting. The handwriting is written on A4 size paper. This offline dataset name is Urdu-Nasta'liq handwritten dataset popular as UNHD [3]. Shalaka P. Deore and Albert Pravin, presents a work on handwritten Devanagari character recognition (HWDCR) used for recognition of Devanagari characters, one of the most popular script. This model uses MLP-BP Neural Network classifier-BP stands for Multilayer Perceptron and Backpropagation Algorithm. The average accuracy achieved by this system is 90%. This method uses online data which is inputted using pen tablet. The MLP-BP classifier receives inputs in the form of features such as coordinates, stroke information, and additional details like pressure [4].

A work done by Mayur Bhargab Bora and others published in 2020 presents Optical character recognition by combining convolutional neural network along with Error correcting output code (ECOC).This ECOC is used as a classifier for classification and CNN is used for extracting the features' dataset is used for training the model. The result of this system shows a higher accuracy when compared to other classifiers. In this paper in search of suitable CNN along with combination of ECOC, Several other popular classifiers have been explored [5].

L. Xu, Y. Wang, R. Li, X. Yang and X. Li, proposed a model that uses fuzzy logic along with stroke Bayesian method. Extraction is done using primitive stroke library that is prebuilt and contains prior knowledge. Model is constructed using Bayesian stroke program. A fitting model is produced using Monte Carlo Markov chain. The dataset involves NIST dataset alon with some industrial images.[6]

M. Mhapsekar and others implemented ResNet 34 and ResNet 50 architecture providing the proves that this method provides greater accuracy compared to other CNN methods for recognizing Devanagari characters. Residual network solves the problem of vanishing gradient, in which there is a degradation of accuracy of the model [7]. Ferdin Joe John Joseph in his research paper proposed a local feature based approach that uses supervised learning techniques that enhances the accuracy of Thai handwritten character recognition .This model make us of support vector machine or SVM as a classifier.. The accuracy of 74.32% is acquired through this model.[8] S. Albahli, M. Nawaz, A. Javed, and A. Irtaza, research paper uses regional convolutional neural network (RCNN) model for the recognition of handwritten characters. In this model DenseNet-41 is used for computing deep features. The MNIST dataset is used in this paper.[9]

In the research paper proposed by S. Jehangir and others, Feature extractor tool like Zernike moments are used for extracting the features of a handwritten Pashto characters.
The recognition tool for the system used is Linear Discriminant Analysis (LDA).The accuracy of 63.71% is obtained through this model. The model is validated using 10 fold cross validation method.[10] Juanjuan Huang and others research paper publish in year 2021 tackles the challenges of handwritten character recognition in Pashto language. They employed feature extraction using techniques such as histogram and zoning based density. This method implemented k-nearest neighbour algorithm for classification. The accuracy for histogram oriented method is 80.34% while for zoning based method is 76.42%.[11]

To address Bangla handwritten character recognition problem AKM Shahariar Azad Rabby and others propeses a

system that uses Borno model,which is a grapheme based holistic approach.In this system dataset of 1,069,132 images are trained. Borno achieves 92.61% accuracy by the use of various character classes that includes characters, modifiers, consonant diacritics [12]. N. S. Guptha, V. Balamurugan, G. Megharaj, K. N. A. Sattar, and J. D. Rose, make use of Chars74K along with MADbase digits datasets. These

Table 1. Several popular methods used

Method	Accuracy	Techniques Used
Hand printed symbol recognition.	This method gives overall 97%.	It extracts the topological, geometrical and local measurements that are essential in character recognition.
OCR for cursive handwriting.	88.8% accuracy	This method implements segmentation and recognition algorithms.
Hill climbing algorithm for character recognition.	93% only for uppercase letters.	For selecting features subset, hill climbing method is used.
Recognition based on fuzzy models.	95% accuracy for hindi and 98.4% for English.	The objective is to employ fuzzy models for character detection in both Hindi and English languages. .
Optimization of feature selection.	88% accuracy for numbers and 70% for letters.	In this method, features are selected in an optimized way.
Decision Tree	91%	Noise removal is done as preprocessing. Features extraction is done with horizontal and vertical line count.
Normalization, Thinning	97.5%	Diagonal feature extraction technique is used.
ANN	-	Freeman Chain Code
Binarization	-	Loop Detection

datasets are pre-processed with the help of two techniques one is Gaussian filtering and other is skew detection .For feature extraction IDMN and ELBP algorithms are used.The proposed model gains the accuracy of 96.66% for English, 96.67% for Kannada and 99.93% for Arabic characters [13] .Abhishek Sethy, Prashanta kumar Patra, and Soumya Ranjan Nayak have proposed an automated model designed to recognize Odia characters as well as Bangla numerals. This system uses FDCT,PCA and LDA techniques' refers to fast discrete curvelet transform, PCA refers to principal component analysis, and LDA refers to linear discrete analysis.LS-VSM and random forest are used for classification. This system achieves a superior result when compared to state of the art techniques [14]. The following table describe some method used by several researchers:

Yunxin Li and other'r research paper shows a model with the name Vanilla Compositional Network (VCN).VCN performs the coupling of Convolutional Neural Network (CNN) so as to form a two-stage architecture. To enhance robustness, they implement the deep spatial contextual information fusion network (DSCIFN). The model uses the OHCC dataset. OHCC stands for Online Handwritten Chinese Character [15]. S. Dhankhar and others, research paper addresses the recognition of text in image form by the use of support vector machine (SVM).This system incorporates histograms, edge detection, morphology and SVM classes. This model optimizes SVM by reducing unnecessary features.It also helps by improving the performance of classification. An accuracy of 96.97 % is obtained for Hindi character recognition [16]. S. K. Singh and A. Chaturvedi, research paper proposes an efficient SEMG based handwritten character recognition .An autoencoder network is applied in order to attain deep features. For ensuring the validity of the obtained results ,extensive evaluations are done. Dataset from 15 subjects is used which consists of SEMG, accelerometer and gyroscope [17].

Efficient typing on mobile devices has been a longstanding challenge due to their small touch screens. To address the existing challenges, Yuan Wu and his team have introduced DMHC, which stands for Device-Free Multi-Modal Handwritten Character Recognition system that is noise resistant and reliably recognizes characters in real life. For multiple channel fusion ,this model utilizes self-attention method thereby acquiring accuracy of 97.4% for letters [18].

O. Omayio, S. Indu, and J. Panda have proposed an efficient character recognition system based on segmentation. The system utilizes the integral histogram of oriented displacement (IHOD) technique and shape descriptor multilayer perceptron models (MLP).This system achieves accuracy of 97.45% on two datasets. In this system a new dataset of Hindi handwritten characters is created [19]. L. Agilandeeswari and others uses long short term memory (LSTM) approach thereby improving the accuracy in handwritten character recognition. In this system features are extracted by CNN's followed by a series of LSTM layers and CTC decoder stands for connectionist temporal classification. This LSTM model is made up of RNN which helps in maintain the dependencies between the characters [20]. The next section explains the methodology and dataset used.

III. METHODOLOGY

A. Convolutional Neural Network(CNN):

This neural network architecture is widely utilized in computer vision tasks as one of the commonly employed

deep learning models. They are designed to work with image data represented as a 2D grid of pixels. These pixel images are then fed into CNN. This allows us to effectively classify or identify the given image. CNNs are widely used for image recognition, object detection, and other image-related tasks.

The architecture of CNN model used is as follows:

- Convolutional Layers: The input image is passed into the CNN model, where it is initially inputted to a convolutional layer to extract relevant features.This is done by applying convolutional filters to the image and the result is then saved to the different portions of convolutional layer.
- Max pooling layer: They are employed to decrease the dimension of a feature map and are utilized for this purpose in which a small portion is extracted which consists of important features.
- Flatten Layer: This layer converts multidimensional input into one dimensional input. This single column is then passed to fully connected layer.
- Fully Connected Layers: This layer provides high level feature extraction and classification. These layers consist of neurons which classify input image into a label.
- Output Layer: This is the last layer of the CNN model.It represents 26 layers of classes for (A to Z) handwritten characters.

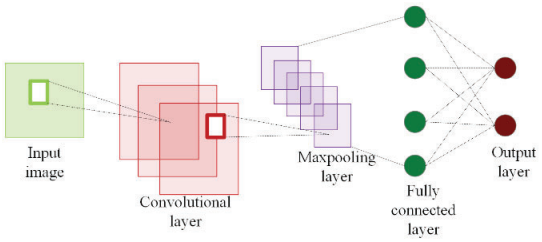

Fig. 1. Architecture of CNN

B. *Support Vector Machine(SVM)*

In the year 1963 Vladimir N. Vapnik and Alexey Ya. Chervonenkis inverted Support Vector Machine so as to use them in image, text and hypertext classification. SVMs are widely recognized as a popular supervised machine learning algorithm that is rooted in statistical learning theory. In supervised machine learning uses labeled input data for classification are used for classification and regression. The SVM classifies the data points by finding or drawing the hyperplane (lines) in an N-dimensional space to separate the groups according to the patterns. The data points are known as support vectors.

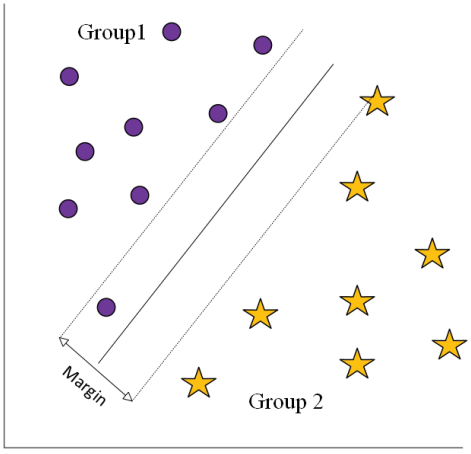

Fig. 2. Binary classification in which Group 1 and Group 2 are two different classes in a N-dimensional plane separated by a margin.

C. *Hybrid Approach*

Hybrid approaches in context of pattern recognition combines multiple methods and techniques that improves the performance of specific model. Some of the most common examples of support vector machines are Ensemble method, cascaded system, Feature fusion, transfer learning etc. In feature fusion method, several features extraction techniques such as color histogram, edge detections are combined together to form comprehensive representation of image. In transfer learning, uses knowledge of one pre trained model in another model. This technique is useful when there is unlabeled data. In cascaded systems, there are multiple stage where each task is performed at a particular stage. The output of one stage is used as a input for another stage. Ensemble method make use of individual models. These models are individually trained using different algorithms to make predictions.

D. *Hidden Markov Models(HMMs)*

HMMs is a statistical model consists of hidden states in which in turn contains outputs and observations. This model finds extensive applications in various domains such as speech recognition systems, natural language processing (NLP), and more. Some essential components of a Hidden Markov Model (HMM) include:

- States: It is assumed that there are finite number of states in a model. But the actual state is hidden and not observable.
- Observations: Observation is made on each state that is usually hidden.
- State transition: The probabilities of transition from one state to another can be represented in the form of transition matrix.
- Emission probabilities: There are probabilities of observing a particular output for each state.These emission probabilities are represented with the help of emission matrix.

HMMs are widely used for modeling sequential data. Sequential data refers to the order of elements that carries important meaning.

E. Template Matching

Template matching is a methodology in image processing that matches small parts of a particular input image with the template image. It creates a collection of templates that are pre-defined. These templates act as a representative of each character class that can be compared to input image. For this method there are few steps that needs to be followed:-

- Creating a template: templates are created through different methods like extracting them from set of training samples etc.
- Process input image: before prediction ,the input image is pre-processed by noise removal, its dimensions are resized and normalization is also done.
- Comparing both: input image is then compared with different template from the set. Similarity measures such as correlation coefficient, normalized cross-correlation methods are used.
- Best match :After the similarity matching process the template with the highest similarity is selected and considered as the best match.
- Classification: After finding the template that is matched in a best possible manner ,class associated with that template is assigned to the input image.

This type of technique is useful when the variations between the image and the template is small .This type of method can be implemented easily.

F. Dataset

The EMNIST dataset was created by Gregory Cohen, , Jonathan Tapson, Saeed Afshar and Andre Van Schaik form Neural Engineering at University of Sydney, Australia. The EMNIST stands for Extended Modified National Institute of Standards and Technology dataset is an extended form of MNIST and NIST dataset. This dataset includes both uppercase letters from A-Z and lowercase letters from a-z along with digits from 0-9 and some special characters also. This dataset consists of CSV file having handwritten characters. First column of the dataset contains the label and the other columns contains pixel value of a particular image. The EMNIST dataset is further divided into two sections: first for training and the second one for testing. Some of the points in EMNIST dataset are discussed below: -

- Dataset composition: This dataset consists of 814,255 images which is further divided into six classes:
- EMNIST By class-consists of 62 unbalanced classes with 814,255 characters.
- EMNIST ByMerge-consists of 47 unbalanced classes with 814,255 characters.
- EMNIST Balanced-consists of 47 balanced classes with 131,600 characters.
- EMNIST Letters-consists of 26 balanced classes with 145,600 characters.
- EMNIST Digits-consists of 10 balanced classes with 280,000 characters.
- EMNIST MNIST-consists of 10 balanced classes with 70,000 characters.

Each image has a resolution of 28 X 28 pixels and are grayscale. The pixel values ranges from 0 representing dark to 255 representing white. A label is associated with each image. A class having some name is associated with each label. These labels range from 0 to 61. The next section describes the proposed work of the paper.

IV. PROPOSED WORK

The method used make use of standard approach by involving data loading, pre-processing, model architecture, training, testing and saving. The methodology used in the given model includes several key points. Given below is the brief description of every methodology used:-

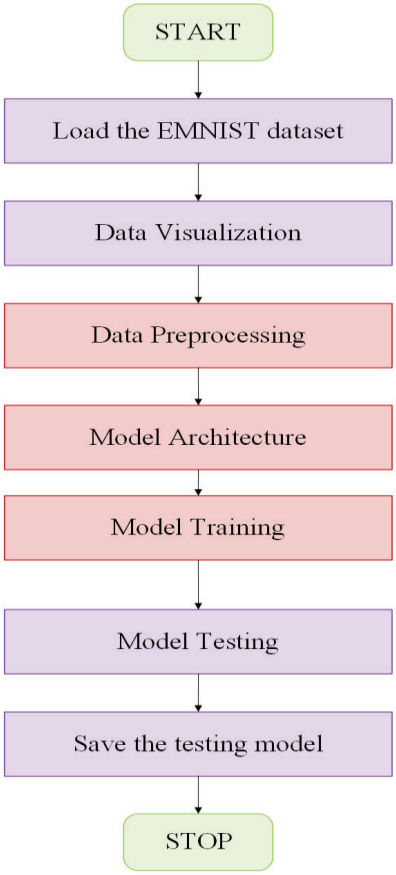

Fig. 3. This general flowchart represents different steps involved in processed work.

- Data Loading: Firstly the data which consists of CSV from EMNIST is loaded with the help of pandas library which helps in reading the CSV file.It then separates the features (X) and labels (Y).The features are in the form of pixel values of characters images and the labels is the associated characters.
- Data Visualization: This is used to showcase the distribution of characters in the dataset .This is represented by a graph which is loaded with the help of matplotlib library. Further it also displays a grid or matrix view of sample images of handwritten characters from the dataset.

- Data Pre-processing: In this step dataset undergoes pre-processing steps. Labels are encoded using to categorical function included in keras. This transforms labels into binary matrix. After that dataset is made to split into two parts one as training set and the other as testing set. Splitting is done with the help of train and test split from scikit-learn library.
- Model Architecture: During this step relevant features are extracted from images by the use of CNN's and max-pooling .The extracted features are then converted into a suitable form with the help of Flatten and Dense Layer. The final layer gives the probability of different characters.
- Model Training: Fit function is used for training the model. This process involves iterating over the training dataset in multiple epochs, with each epochs consisting of forward and backward passes. The more the number of epoch the more is the model trained.
- Model Testing: Once training step is finished ,the training code is evaluated on the testing dataset using evaluate function. It compares accuracy and losses in order to determine model performance on unseen or testing data.
- Model Saving : Finally the trained model is saved using the save method. This allows the model to be reused whenever required in future.

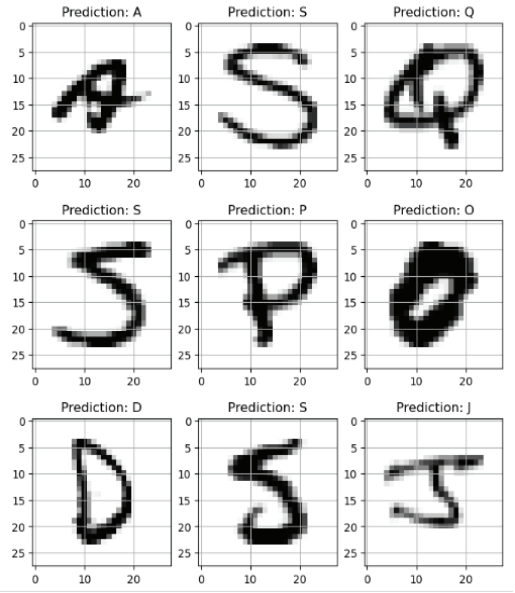

Fig. 4. The output result includes nine grayscale images extracted from the testing dataset, with the corresponding predictions displayed above each image. These grayscale images are represented in matrix form.

The proposed model enhances the handwritten character recognition mechanism by using a CSV image format and the main objectives of this proposed work are:-

- Comparatively faster : This model is trained using CSV file which consists of numerical values of pixels of an image. Therefore it can be loaded at a much faster rate than an image. In CSV format data can be directly loaded as a matrix into the memory while in image ,needs to get fetched from disk, then decoded and loaded into memory.
- Expanding Dataset: In order to achieve greater efficiency and result ,handwritten character samples from different sources or domain is added. This will improve models performance and capability.
- Deployment: This model can be applicable to use in various real-world applications. By providing handwritten inputs to the model ,it may provide accurate results.

V. RESULT

- The model gives the accuracy of training and testing dataset in the form of percentage. It also provides the information about the data loss during training and testing process. The lower the value indicates how efficient the model is. It provides the information about the validation accuracy and validation loss. The validation accuracy represents the model's performance in predicting unseen data, while the loss metric indicates the amount of data that is not accurately captured by the model when applied to the unseen dataset.

- The proposed work also includes a section representing a graph showcasing what is the frequency of characters available in the dataset.

- The output of this project shows prediction of different characters at a once given in the grid format as a grayscale images.

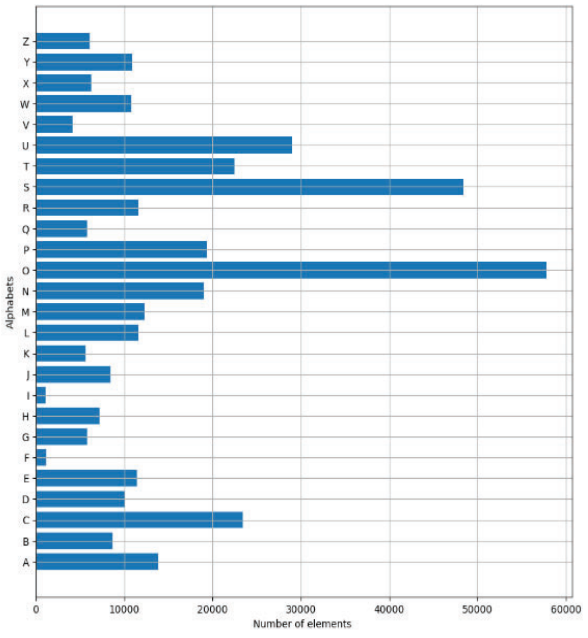

Fig. 5. The given bar graph illustrates the distribution of uppercase characters (A-Z) in the provided dataset. The x-axis indicates the how many numbers of elements are there in dataset, while the y-axis represents the frequency of each alphabet present in that dataset.

The proposed model successfully recognizes the handwritten character by the using AI and Machine Learning algorithms. Higher accuracy is achieved using convolutional neural network (CNN). The training accuracy of the model is given as 95.51% and the validation accuracy is given as 98.02 %. The validation loss is 7.2 % while the data loss during training is only 16.4%. The Use of this model can bring about various applications with significant benefit. Further this model can be enhanced by using advanced CNN architectures and more diverse dataset. Thereby increasing model's execution time, efficiency and robustness.

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