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An Innovative Method to analyze the Accuracy and Prediction rate of Handwritten Digit Recognition with Dimensionality Reduction Algorithm by comparing with Connectionist Temporal Classification

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***Abstract*—Recognizing and detecting the digits from the large unbiased data and to find the best accuracy and loss using machine learning algorithms such as Connectionist Temporal Classification (CTC) and innovative Dimensionality Reduction Algorithm (DRA).: Accuracy and Loss are performed with the MNIST dataset from the Keras library. The detection of digits is performed with the Digit's Dataset. The two groups Connectionist Temporal Classification (N=20) and Dimensionality Reduction Algorithms (N=20). A DRA is used for detecting the novel handwritten digits with the color represented to each digit. The accuracy is analyzed based on identifying the exact digit of 99.90% where the CTC has the accuracy of 90.84%. The two machine learning algorithms CNN and CTC are statistically satisfied with the independent sample T-Test (=.001) value (p¡0.05) with a confidence level of 95%. Conclusion: Recognizing and detecting the handwritten digits significantly satisfied with better accuracy in DRA than in CTC.**

***Index Terms*—Innovative Dimensionality Reduction Algorithm, Connectionist Temporal Classification, Novel HDR, Principal Component Analysis, Linear Discriminant Analysis, T-distributed Stochastic Neighbor Embedding, Machine Learning.**

I. Introduction

In the digital universe era, the data size is doubling every year. ("Handwritten Digit Recognition Using Different Dimensionality Reduction Techniques" 2019) The complexity and volume of the data are increasing day by day. [4] Dimensionality Reduction algorithm (DRA) is defined as the process by which the high dimensional Figures or images are segregated and made as low-dimensional forms. [15] When the data is grouped with multiple variations, there is a lot of work to separate each other. With this model, the workload will get reduced and forms the value digits into the respective outputs. Dimensionality Reduction Algorithm helps the system to do easily by segregating and grouping the data in particular modules. [18] the Handwritten Digit Recognition is useful in the automation of mail sorting, license plate recognition, and electronic memo pads. [1] Cheque Transaction System (CTS) scanning and historical document preservation in the archeological department. [17] introduced face recognition method that generates an eight-word character code that is afterwards utilised as a bar code by using the ratios of a face to identify it.

Handwritten Digit Recognition is carried out by researchers to promote business. Totally 15 articles from Google Scholar like Science direct, ResearchGate, and 10 articles from IEEE. (Aly and Almotairi 2020) implemented Handwritten Digit Recognition with the Dimensionality Reduction Algorithm has self-organized in recognizing each number by network mapping and will give the robust of digits present in the data with the accuracy of 97.6% [4] implemented Handwritten Digit Recognition has been the size of the clustered data that may require the process and forms the grouped data as the same. The features are a descriptor that performs the best classification by correctly predicting 98.29% of the

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images present in the training dataset. ("Handwritten Digit Recognition Using Different Dimensionality Reduction Techniques" 2019) Dimensionality Reduction Techniques involve Principle Component Analysis(PCA), Linear Distributed Analysis(LDA), t-distributed Stochastic Neighbor Embedding (t-SNE). These techniques are used to classify the embedded structure to analyze the data in the dataset. The average recognition accuracy of this paper got 90.8% after applying the DRA. [28] implemented the 1D Linear Distributed Analysis is only done to the digits directly and 2 D Linear Distributed Analysis will be implemented to the images, photographs, and document form of data. The recognition accuracy of 1D LDA is 87.4% and 2D-LDA is 87% has been achieved respectively. According to the input format the dataset and data have been trained and tested with accuracy and have achieved almost the same accuracy of 87%. From the overall literature survey, [4] is the best paper that is used to detect the digits of the best classification technique with the best accuracy of 98.29%.

[2], [3], [9], [13], [16], [19], [20], [23]–[25], [27], [31], [31], [32], [34]–[37]. Now the growing trend in this area motivated us to pursue this project. [5] presents the various feature selection methodologies.

Based on the Literature review, the DRA has achieved high accuracy and the data has been collected according to each number and forms the data of each number as a group separately. The new data is not possible to insert. The goal of the study is to increase the recognition accuracy of the digits while also enhancing the correctness of the training and testing datasets' grouping of the recognised digits' data independently.

II. Material and Method

The Saveetha School of Engineering laboratory serves as the study location for the suggested research. A threshold value of 0.05 percent and a confidence interval of 95 percent were used to compute the sample size using clincalc.com while maintaining G power (Kane, Phar, and BCPS n.d.), the minimal power of the analysis, 0.8, and the maximum tolerated error, 0.5. Based on the prior literature for size computation, mean and standard deviation have been calculated. The two groups are used namely Connectionist Temporal Classification as an existing model as group 1 and Dimensionality Reduction Algorithm as a proposed model as group 2.

A. Data Preparation

The conversion of data from a high dimensional space to a low dimensional space is a novel dimensionality reduction algorithm. The digits dataset has been used to train and test the data. The dataset includes 1797 images with 8* 8-pixel sizes. The image attributes are stored in 8x8 arrays of gray scales. The sample of the digits dataset has been shown in Fig. 1.

B. Connectionist Temporal Classification (CTC)

[14] CTC is one of the classification methods of Neural Networks which is the advanced one of the Recurrent Neural Networks (RNN). CTC is done or used for the detection

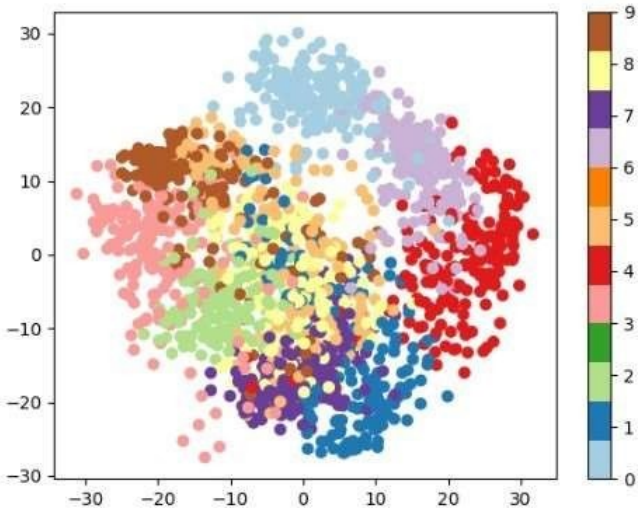

Fig. 1. Digit Recognition from Digit dataset

of face recognition, handwritten digit recognition, character recognition, and Image processing. [8] CTC can be used for assigning a probability value for any Y-axis given as X. The primary lead for calculating this probability in CTC considers the alignment of the digits according to the colors. Fig. 2 represents the working flow of the Connectionist Temporal Classification (CTC) algorithm.

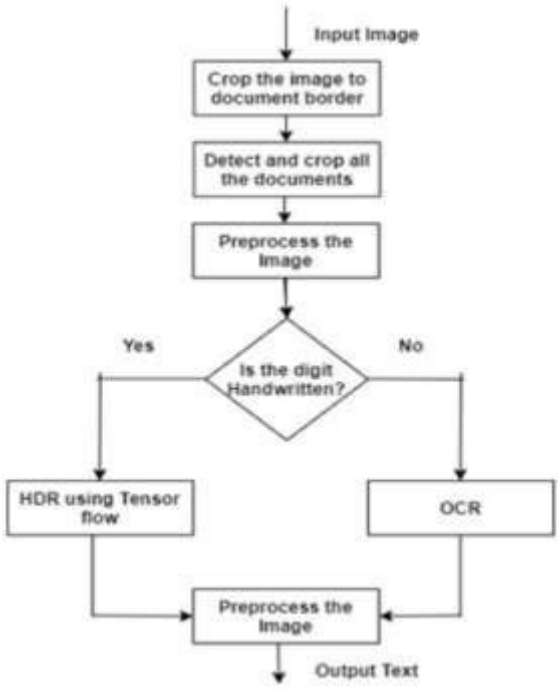

Fig. 2. Connectionist Temporal Classification

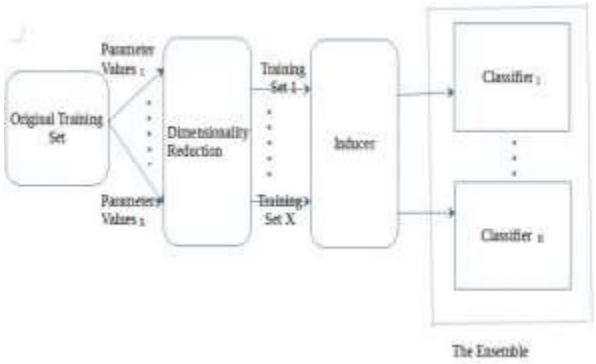

Fig. 3. Dimensionality Reduction Algorithm

1) Give the input as an image with pixel 28*28.
2) Take input and crop the image to present in the code.
3) Pre-process the image and find it handwritten or not.
4) If yes, then it will go to the TensorFlow function.
5) Once the image is in the TensorFlow function it will pre-process the image.
6) After the processing is done with the images are well processed and produce the output image with the text format i.e., which is present in the digit image.

C. Dimensionality Reduction Algorithm

[15] The dimensionality reduction algorithm is the transformation of data from a high dimensional space to a low dimensional space. It reduces the dimensions of the data and makes the clustered group data as separate data. [7] DRA is a classification technique that classifies and analyzes the components to get reduced and also reduces the man willpower and saving the time in extracting the large unbiased data. Fig. 3 represents the working flow of the Dimensionality Reduction Algorithm (DRA).

1) Install all the required packages
2) Import the packages for the declaration of required variables.
3) Train and Test the data of the dataset from parameter value 1 to parameter value x.
4) Let the system perform to reduce the dimensions of the data and get trained.
5) The trained data will get into the inducer to make sure the pixel sizes and which are needed for the ensemble.
6) Segregating the digits from the dataset and giving the values and providing the PCA, LDA, and t-SNE analysis, and making groups of data.
7) Then use the model. compile function to make values of the iterations. item Use a model. fit to cross-validate, matrics to find the accuracy and loss of the data.
8) Finally, Evaluate the data through either accuracy score or model. evaluate() function.
9) Store all the iteration values in the dataset and make it ready for the analysis of accuracy through statistical means.

TABLE I
DATA COLLECTION FROM THE N=10 SAMPLES OF THE DATASET FOR CTC WITH THE SIZE OF 8*8 PIXELS TO GAIN ACCURACY(%) AND REDUCE LOSS(%) AND DRA TO GAIN ACCURACY(%) AND REDUCE LOSS(%).

2*Samples (N)	Connectionist Temporal Classification		Dimensionality Reduction Algorithm	
	Accuracy(%)	Loss(%)	Accuracy(%)	Loss(%)
1	89.31	3.9	99.78	0.06
2	89.48	3.79	99.71	0.08
3	89.65	3.7	99.76	0.06
4	89.8	3.61	99.83	0.04
5	90.01	3.53	99.80	0.06
6	90.16	3.46	99.82	0.06
7	90.32	3.39	99.87	0.03
8	90.52	3.33	99.82	0.04
9	90.71	3.27	99.81	0.05
10	90.84	3.21	99.85	0.05

D. Statistical Analysis

The IBM SPSS version 21 statistical software is used for our study. The independent variables are shape and size and the dependent variable is accuracy (%). for our study handwritten recognition digits. Statistical Analysis The IBM SPSS version 21 statistical software is used for our study. The independent variables are shape and size and the dependent variable is accuracy (%). for our study handwritten recognition digits.

III. RESULTS

An innovative Dimensionality Reduction Algorithm reduces the dimensional space and makes the figure more clearer with the particular color defined with the sample size (N=20). The samples are reduced with the iterations of the dataset, the accuracy values change with the iteration time and produce the values of accuracy and loss concerning the period which is shown in Table 1.DRA has better accuracy and less loss than the CTC due to the techniques used for the reduction of space. CTC is used to determine the digits and gives the output but won't help to reduce the image and to give the no. of samples present in the image of one particular digit. In CTC the analysis of each component is not possible, whereas in DRA every image will be analyzed with the stages of PCA, LDA, and t-SNE which helps in clustering the data in the image. Concerning the analysis and clustering of images, the Accuracy and loss have changed and have proven DRA is better than CTC. Table 1 represents the Data Collection from the N=20 samples of the dataset for CTC with the size of 8*8 pixels to gain accuracy (%) and reduce Loss (%) and DRA to gain accuracy (%) and reduce Loss (%).

$$\text{accuracy} = \frac{T_p + T_n}{T_p + T_n + F_p + F_n} \quad (1)$$

Where, $T_p = TruePositive, T_n = TrueNegative, F_p = FalsePositive and F_n = FalseNegative$

Loss: A scalar worth that we endeavor to limit during our preparation of the model. The lower the misfortune, the nearer our expectations are to the genuine names.

In SPSS, the datasets are prepared using N=20 as the sample size for Connectionist Temporal Classification and Dimensionality Reduction Algorithm. GroupID is given as a grouping variable and accuracy is given as the testing variable. GroupID is given as 1 for CTC and group 2 for DRA.

TABLE II

COMPARISON OF THE ACCURACY AND LOSS OF HANDWRITTEN DIGIT RECOGNITION(HDR) OF CTC AND DRA. DRA ALGORITHM HAD THE HIGHEST ACCURACY (99.85) AND LOWEST LOSS(0.05)

Groups		N	Mean	Std. Deviation	Std. Error Mean
2*Accuracy	CTC	10	90.0800	.52209	.16510
	DRA	10	99.8050	.04601	.01455
2*Loss	CTC	10	3.5190	.22927	.07250
	DRA	10	.0530	.01418	.00448

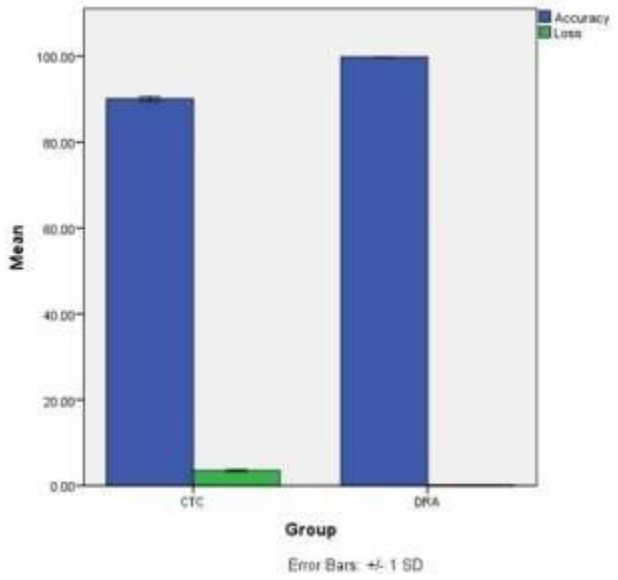

Fig. 4. Comparison of CTC and DRA with Loss and Accuracy. Simple Bar Mean of Accuracy CTC error range (0.89 - 0.91) and Loss error range (3 - 4) and DRA error range (0.98 - 0.99) and for loss error range (0.01- 0.02) with Mean accuracy of detection ± 1 SD.X-Axis: CTC vs DRA Y-Axis: Mean accuracy of detection ± 1 SD.

Group Statistics is applied for the Statistical Package for the Social Sciences (SPSS) dataset and shown in Table 2. By performing the statistical analysis group statistics represents the comparison of the accuracy and Loss of Handwritten Digit Recognition (HDR) of CTC and DRA. The DRA algorithm had the highest accuracy (99.85) and the lowest loss (0.05). CTC had the lowest accuracy (90.84) and highest loss (3.21) in Table 2.

IV. DISCUSSION

Our overall results show that there are some variations observed in the accuracy and loss values due to the component analysis techniques which proved that the Dimensionality Reduction Algorithm with Accuracy 99.85% is better than the machine learning algorithm namely Connectionist Temporal Classification with an accuracy of 90.85% in recognizing the handwritten digit recognition. There is a statistically significant difference in Handwritten Digit Recognition accuracy of two algorithms having the significant accuracy value of 0.000 (p¡0.005 Independent Sample T-Test). [18] It gives the accuracy of 100% with the InterfaceUser line which will perform the task in the process of degradation of pictures and the image is splitting up through the characters and from the data as the clusters whereas in our system we got the accuracy of 99.85% with the splitting with the component analysis method. The analysis of splitting the data is similar and the same. (“Handwritten Digit Recognition Using Different Dimensionality Reduction Techniques” 2019) has discussed various dimensionality techniques which proves that with the different analyses like HOG to reduce the loss in the data. The system has been implemented with the two datasets as similar to our system and has achieved the accuracy of 98.74% for MNIST and 83.79% for CVL SD whereas the proposed system with the different component analysis we have achieved the accuracy of 99.85% but the technique we used is similar and same. (“Handwritten Digit Recognition Using Different Dimensionality Reduction Techniques” 2019; Das, Kundu, and Saravanan 2018) the system implemented for the handwritten digit recognition with the different components is exceptionally crucial for satisfactory classification. And the system has achieved an accuracy of 98.29%. Whereas our system has done the same component analysis and got an accuracy of 99.8%. Even the process is the same but not similar due to the components used in the classification of images. [22]has done with many classification algorithms and achieved the accuracy with the analysis of HOG and neural networks which got the accuracy of 96% whereas our system got the accuracy more than the existing with the different LDA, PCA, and t-SNE techniques. The analysis classification is done using different techniques which are not similar but the process is the same. The image processing is involved in the detection of images on a handwritten recognition to use detect relevant details based on the detection by different classification process ((“Recognition and Classification of Diabetic Retinopathy Utilizing Digital Fundus Image with Hybrid Algorithms” 2019; Malathi and Nedunchelian 2018). From the overall literature, many authors have cited that the proposed as having better accuracy and less loss compared to existing methods.

Our institution is passionate about high-quality evidence-based research and has excelled in various fields [6], [10], [21], [26], [29], [30], [33] (Vijayashree Priyadharsini 2019). We hope this study adds to this rich legacy.

[11] Deeper networks usually require more time to train data, making it practically infeasible in real-world applications. The addition or deletion of data cannot be done. [12] As every research has some limitations, the algorithm is restricted only to the English numerals but not to any other type of digits or digit strings. [12](Han and Li 2015) In the future, we

TABLE III

INDEPENDENT SAMPLE T-TEST IS APPLIED FOR THE SAMPLE COLLECTIONS BY FIXING THE LEVEL OF SIGNIFICANCE IS 0.005 WITH A CONFIDENCE INTERVAL OF 95%. AFTER APPLYING THE SPSS CALCULATION IT WAS FOUND THAT DRA HAS ACCEPTED STATISTICALLY SIGNIFICANT.

3*		Levene's test for equality of variances		T-test for equality means						
		2*f	2*Sig.	2*	2*df	2*Sig. (2-tailed)	2*Mean difference	2*Std.Error difference	95% confide nce interval Lower	Upper
2*Accuracy	Equal variances assumed	2.25075	2*.000	-58.677	18	.000	-9.72500	.16574	-10.07301	-9.37699
	Equal Variances not assumed			-58.677	9.140	.000	-9.72500	.16574	-10.09906	-9.35094
2*Loss	Equal variances assumed	2*22.983	2*.000	47.714	18	.000	3.46600	.07264	3.31339	3.61861
	Equal variances not assumed			47.714	9.069	.000	3.46600	.07264	3.30187	3.63013

can improve this system to recognize characters in different languages. Systems are to be developed yet to analyze over real-time handwritten digits. In proposed work, can improve this classification for further development in Deep Architecture for the documents and the applications of some big complex noisy data

V. Conclusion

In this research, the Handwritten Digit Recognition system performed using Digit's dataset has significantly better accuracy of 99.85% using machine learning algorithms such as Dimensionality Reduction Algorithm than Connectionist Temporal Classification (90.84%). The clarity of handwritten digits is found with good accuracy and less loss is achieved.

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