Automatic Neuro Disease Classification Based on Gait Analysis using Bi-stacked GRU

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Abstract. Deep learning is a branch of machine learning based on deep neural network used to train the computers without being explicitly programmed. Recurrent neural network (RNN) is a part of deep learning methods which is the first algorithm in deep learning that produce output based on the sequence of input. RNN have multiple advantages in the field of medicine to solve it. Long short term memory (LSTM) an extension of RNN solves vanishing gradient and exploding problem in RNN by using to store the long sequence of memory through cell state. Neurodegenerative disease affects the neurons in Human brain which are the blocks of nervous system includes brain and spinal cord, if it is die or damaged can't be replaced and motion of two lower limbs causing gait disorder. Such diseases are treated with LSTM model, but accurate results are not able to achieve due to gradient exploding problem. To improve the accuracy we proposed the variants of Gated Recurrent Unit (GRU) which is extension of LSTM model and it gives high accuracy when compared to LSTM model.

Keywords: Neurodegenerative diseases, Gait disorders, LSTM, GRU, BIGRU.

1. Introduction

Neurodegenerative diseases such as Parkinson's disease, Huntington disease, and Alzheimer's disease produce lesions in the central nervous system that wheels the gestures of two lower limbs [8] causing gait disorders. Machine learning technologies are efficiently smeared to the gait disorders [9] in neurological disease. The deep neural systems are based on deep Convolutional (CNN) and Recurrent Neural Networks (RNN) [4], which ascertain to be competent to course all forms of existing data and have more advantages when compared to other methods. Long Short Term Memory (LSTM) is an extended method of RNN algorithm, which solves the vanishing and gradient problem in RNN and it has cell state to maintaining the long sequence of memory values. We proposed the BIGRU method which is similar to GRU. It has an extra layer added in Bi-stack GRU. This layer is directly attached to the output layer and can be useful to add the extra features to the dataset to predict the future illness progression.

2.Background Work

Recent research build deep learning models based on above features for classifying neurodegenerative disease. S.Sivaranjini et al [1] Neurodegenerative disease identification was done based on Convolutional Neural Network (CNN). CNN technique increases the complexity with less accuracy. Donghuan Lu et al [2] are based on the early diagnosis of alzheimer's diseaseusing deep neural network. It does not described much about any specific architecture in neural network. A.Dinu et al [5] reported the study of different machine learning algorithms. It is based on the supervised and unsupervised machine learning algorithm. E. Sánchez et al [11] Minimal Gated Recurrent unit is used, accuracy is not satisfaction. A. Khorasani et al [12] Vanilla RNN, LSTM, GRU techniques are used but Precision, recall, p-measure metric values are not accurate one. H.H. Manap et al [13] Artificial Deep machine learning model is used to classify the neurodegenerative disease but accuracy is not efficient.

3. Existing System

In the Existing system Dual channel LSTM based multi-feature extraction gait [3] is used for diagnosing of neuro disease. Recurrent neural Network (RNN) is a special Artificial neural network (ANN) where links between nodes forms a direct cycle which has a dynamic behavior. RNN Handling the sequential data such as speech recognition, Handwriting recognition. Memory ability of RNN is week for longer steps.

3.1 LSTM Model

Unlike feed Forwarded network, Long Short Term memory (LSTM) naturally handling sequential data such as connected handwriting, speech recognition in the internal memory and it will stores the previous data using the

cell state [6]. This existing one uses the brain images to predict the neuro disease. In Figure 1, the architecture of LSTM has been realized with more gates with operations. It has input gate, output gate and update gate to stores the cell state.
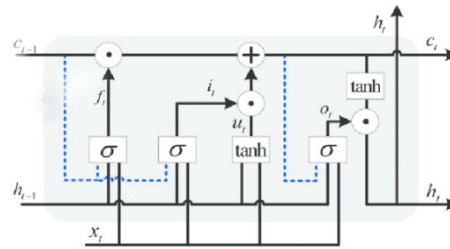

Fig. 1. Architecture of LSTM

4.Proposed System

Our proposed work depicted in figure.3 classifies the neurodegenerative diseases through the patients gait features automatically using gated recurrent unit. The diseases progression can be detected easily and it also increases the classification accuracy when compared to LSTM model. Here Gaited Recurrent Unit in Figure 2, which is the extension of LSTM model has update gate and reset gate, this two functions are used to pass the information to the output and then trained to keep the long sequence of data without losing the previous information.

Update gate is used to determine that how much information is going to pass along with future value and solves the problem of vanishing gradient in RNN. The update gate is denoted by z(t) and it is calculated by using the formula as

$Zt = \sigma\ (\ W(z)\ xt + U(z)\ ht\text{-}1)$ *(1)*

The below figure 2 depicts the overall working flow of Gated Recurrent Unit.
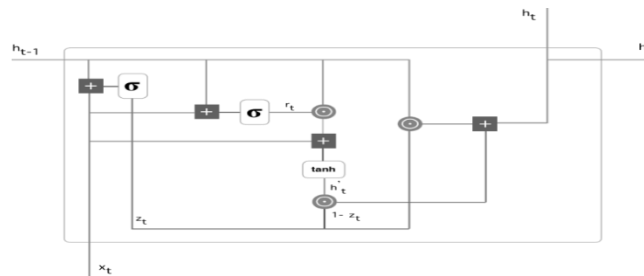

Fig. 2. Architecture of GRU

The sigmoid function (σ) having the added values of the previous state output h(t-1) and the current input x(t) along the product of their weights and the results stored in z(t).The result of sigmoid activation function lies between 0 and 1. Reset gate is used to decide how much of the past information need to be forgot. It will take same input as update gate [7] the difference takes in the weights and the gates. It is calculated by the formula,

$rt = \sigma\ (W(r)xt + U(r)ht\text{-}1$ *(2)*

Hadamard product is applied on r(t) then apply the non-linear tanh activation function to the input x(t) with r(t) and stores the result in h'(t). h'(t) and 1-z(t) combine to give the output of current state h (t). This can be expressed as follows

$h'\ (t) = tanh\ (x(t) + (R(t)\ \bigodot h(t\text{-}1)))$ *(3)*

$ht = \ + (zt \bigodot ht\text{-}1 + (1\text{-}zt)\ \bigodot h't$ *(4)*

And the extension of Gated Recurrent unit is Bidirectional gated recurrent unit and stacked gated recurrent unit. In our case the preprocessed data is given to the extension of GRU to get the result.

4.1 Bidirectional Gated Recurrent Unit (BGRU)

BGRU performs data processing in both direction that is in both forward and backward direction and concatenated the resulted output. Compared to the unidirectional process it doubles the parameter and improves the accuracy of the process. The dataset is processing using the BGRU [8] initially and then apply the Stacked Gated Recurrent unit (SGRU) for the multiple layers.

4.2 Stacked Bidirectional Gated Recurrent Unit (SGRU)

SGRU increases the depth of the layers used in the GRU model to improve the accuracy. Here neuro degenerative dataset is processing in both forward as well as backward direction with increasing depth [4] shows in the figure 3.

4.3 Contextual layer

It is an extra layer added in Bi-stack GRU. This layer is directly attached to the output layer and this layer can be useful to add the extra features to the dataset to predict the future illness progression. Extra features like Blood Pressure and blood glucose level can be added it can be useful to predict the risk of diabetes in future [7].
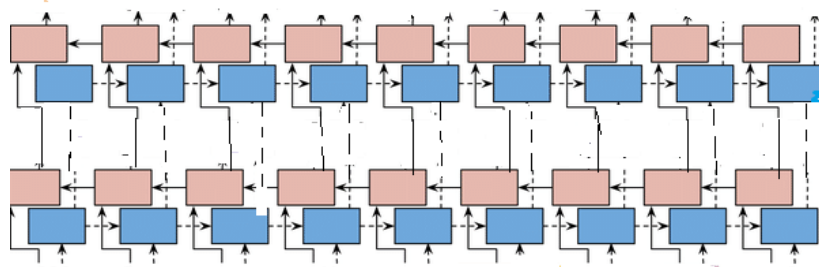

Fig. 3. Bidirectional GRU

5. System Flow

5.1 Data collection

Data collection: Data collection is the process of collecting data from different origin. Here the required dataset is collected from different sources. A real time dataset is used for neurodegenerative disease classification analysis. For this disease classification two types of signal dataset is used one is gait signal and brain signal. Gait signal is used to outline the walking gesture of the patient and the brain signal used to describes the signal from brain to various part of patient body through the images. Sensor and Electroencephalogram (EEG) is used for collecting the Gait signal and brain signal respectively.

5.2 Data Preprocessing

Data which is collected from the data collection having the possibilities of noisy data because of false apparatus this can be remove using some noise filter in order to avoid the low accuracy. Data contains imbalanced, inaccurate and contaminated value can be preprocessed, before the processing it should be removed to prevent the inaccurate results and efficiency

Signal to EDF conversion: The dataset must be in the format of .xls or .csv or edf because keras library accept this formats only. Keras contain a package to import the edf file directly into the code. Many open source tool is available for converting the EEG signal to ECG conversion. EDF browser is one of the best tools to convert EEG signal to EDF file.

Once data is converted into EDF format, through keras package it is import directly to the code or convert into csv file which contains the separate column and row for every patients. The features like Age, weight, gait speed [10], gender etc. in row and patient's diseases list is in column.

5.3 Gated Recurrent Unit

Gated recurrent unit, a deep learning model and an advanced version of Long Short Term Memory (LSTM). And it solves the vanishing and gradient problem in Recurrent Neural Network (RNN) using update gate and reset gate.

6.Implementation

Here we classify the neuro degenerative disease with feed the seeds as input in csv format. Anaconda tool is used to run the inputs using python language of tensor flow and keras packages then accuracy is obtain as output. Brain values and gait values are used to predict the disease. In this study, we take already trained data from the organization of U.S National Library of Medicine- Medline plus and physio.net.

The dataset contained stride sign of 339 patients with Neuro Disease and 19 sound people. Additional dataset is also created manually to attain more accuracy. Each data includes recorded sign of walk, swing, and stand times for every leg and twofold help signal for the two legs, the particular characteristics we utilized. The dataset had also consists of clinical information that have been recorded for each subject including age, gender, height, weight, walking speed, and a measure of disease severity or duration of the patients.

Experiments were implemented in anaconda prompt tool using tensorflow packages and jupyter notebook. The inputs are tested on an Intel core i5 computer with 8 GB RAM and 64bit processor. We conducted the experiments with the patient's disease classified into three types Parkinson's diseases, Huntington disease, and Alzheimer's diseases according to the gait speed signals [11]. The dataset consider for disease detection is illustrated in figure 6 and tabulated in table 1 as follows.

Table 1. Patient Data

Disease	Male	Female	Age
Healthy	25	25	> 40
Parkinson	45	105	> 50
Huntington	65	85	> 60

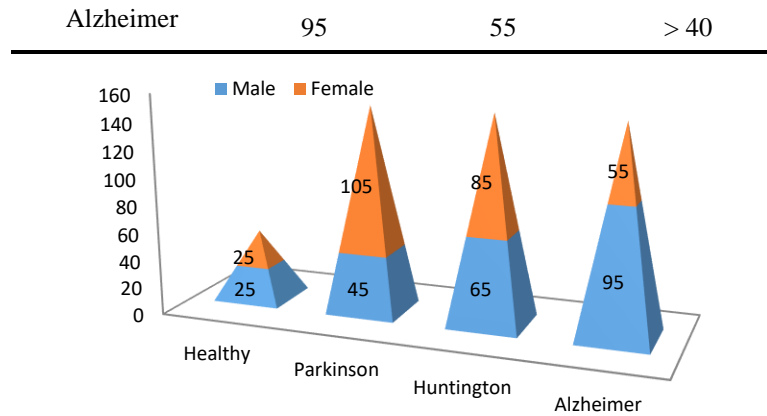| Alzheimer	95	55	> 40

Fig. 4. Patient Data Statistics

The accuracy prediction for different architectures by varying the hidden layer is illustrated as follows table 2 indicates the accuracy of hidden layer 3 corresponding graph is illustrated in figure 5.

Table 2. Hidden Layer 3

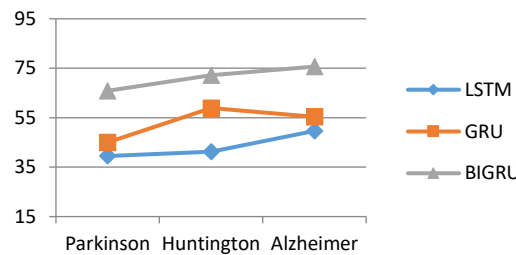| Disease	LSTM	GRU	BIGRU
Parkinson	18.70	35.01	**45.87**
Huntington	20.50	38.90	**42.23**
Alzheimer	27.41	35.70	**45.67**

Fig. 5. LSTM vs GRU vs BIGRU: Hidden Layer-3

The accuracy obtained for hidden layer with different architectures is illustrated in the figure 6 and tabulated in table 3.

Table 3. Hidden Layer 4

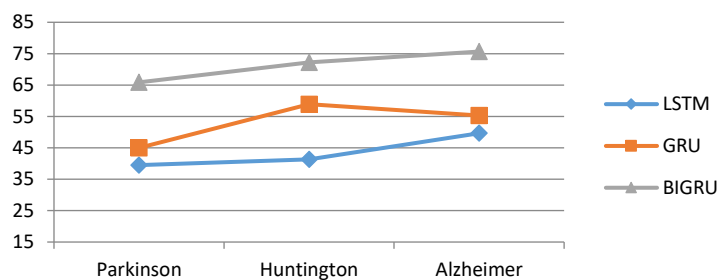| Disease	LSTM	GRU	BIGRU
Parkinson	28.7	45	**56.78**
Huntington	24.5	54.2	**62.45**
Alzheimer	37.41	45.7	**57.14**

Fig. 5. LSTM vs GRU vs BIGRU: Hidden Layer-4

The accuracy obtained for hidden layer as 5 with different architectures is illustrated in the figure 6 and tabulated in table 4.

Table 4. Hidden Layer 5

Disease	LSTM	GRU	BIGRU
Parkinson	39.5	45	65.87
Huntington	41.3	58.9	72.23
Alzheimer	49.65	55.3	75.67
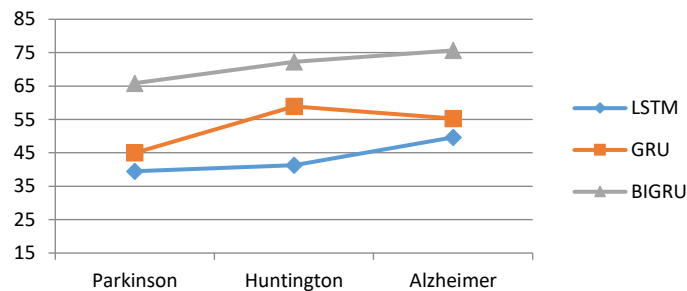
Fig. 5. LSTM vs GRU vs BIGRU: Hidden Layer-5

The dropout was set to 0.2 to avoid over fitting with the 3-dimensional hidden layer are used for output. From the above discusses results, BIGRU achieves the best classification accuracy in terms of learning rate and more number of hidden layers for all the three diseases.

7.Conclusion

Deep learning allows a doctor to analyze an image through GPU automated machines. Illness progression of the diseases is identified through deep learning. That is the possibility of future risk of diseases because of the patients current illness state is analyzed and predicted through different deep learning algorithm. Our proposed work is to classify the brain diseases through the patient's gait features automatically using gated recurrent unit and also the diseases progression can be detected with high accuracy. In Future work, we intend to be applied for some other diseases to predict. Since our proposed system uses the deep learning techniques to classify the neurodegenerative disease and predict the accuracy for valid samples of patients details.

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