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Research Article

Multiple Sclerosis Prediction of the Proposed Hybrid GRUCB Method Pooling with Catboost and Gated Recurrent Unit

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ABSTRACT

Multiple Sclerosis (MS) is a persistent immunological disorder that affects the central nervous system (CNS) which causes damages to the nervous system such as brain and Spinal Cord. Immune system is protected by protective layer known as myelin sheath. When this myelin sheath is affected by some infectious agent then it results MS. MS causes inflammation and damages that disrupting the transmission that link the brain and the remaining body parts. There are several reasons for MS, some of them are due to genetic factors i.e., when certain gene related to the immune system (eg: HLA-DRB1) may get infected or by due to ecological conditionals such as Vitamin D inadequacy, geographical locations, Smoking and viral infections. Symptoms of MS includes Muscle Weakness, Fatigue, Numbness or Tingling, Bladder and Bowel Dysfunction, Vision Problems, Difficulty in walking and Cognitive Issues. There are several traditional diagnosis methods. Some of them includes Lumbar Puncture (Spinal Tap), Magnetic Resonance Imaging (MRI), Blood Tests and Evoked Potential Tests. As MS is a serious disorder which is growing fast, an alternative fast prediction method has been introduced with the help of ML and Deep Learning algorithm the prediction rate has been enhanced. By using proposed algorithm as the result, the accuracy rate achieved is 98%.

Keywords: Multiple Sclerosis, Machine Learning, Deep Learning, Magnetic Resonance Imaging.

INTRODUCTION

MS is a complex neurological issue that causes damages to the CNS which leads to the severe issue for the brain as well as the spinal cord. There are totally four stages of MS. Stage one is called as Relapsing-Remitting MS (RRMS) which is most common one. In this stage, flare-ups i.e., relapses followed by remission occurs. Symptoms of this stage may be improved to the next stage or else due to immunity the relapses may be cured. The second stage is called as Secondary Progressive MS (SPMS) which is followed by RRMS. In this stage gradually starts affected the CNS with some relapses. In this stage prediction method is not effective, then it leads to the stage three called as Primary Progressive MS (PPMS). In PPMS 10-15% of patients are affected. In this stage steady worsening of CNS starts. If this stage is not treated properly, then it leads to the last stage called as Progressive-Relapsing MS (PRMS). This form is a rare form but it causes sever damage to the CNS which leads to the inability of the patient or else leads to death [1].

The traditional methods of diagnosing MS include Magnetic Resonance Imaging (MRI), Lumbar Puncture (Spinal Tap), Evoked Potential Tests and Blood Tests. As these issues is a fast-growing disorder the prediction rate should to enhanced to control the death rate. Finally, as a result machine learning and deep learning techniques were applied in the proposed algorithm.

ML technique is a subdivision of (AI) which trains machine to become competent in and to ameliorate the activity from experience without being absolutely programmed. The main application of ML is to find the patterns in the data

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and makes predictions or decisions based on that data. There are 3 types of ML technique. They are Supervised Learning in which model is trained on a labeled dataset in which outcome is known. Classification and regression techniques comes under Supervised Learning and algorithm used in these techniques such as Linear Regression, Logistic Regression, Decision Trees, Random Forests, Support Vector Machines (SVMs) and Neural Networks. The second type is Unsupervised Learning in which model explores the data without labeled outcomes and also identifies the pattern. Clustering and Dimensionality Reduction are the two techniques and algorithms used in these techniques are Hierarchical Clustering, K-Means Clustering, DBSCAN and PCA, t-SNE etc., are used to enhance the prediction rate. The last type of ML is Reinforcement Learning in which model learns by interacting with an environment and receiving rewards. Robotics is one of the best examples for Reinforcement Learning and algorithms such as Q-Learning, Deep Q Networks (DQN) and Proximal Policy Optimization (PPO) are used.

Deep Learning technique is a subset of Machine Learning which is inspired by the functions of human brain. This technique uses Artificial Neural Networks (ANNs) which contains multidimensional to learn automatically and also used to extract complex patterns from large datasets. This technique contains 3 layer such as Input Layer which contains raw information, Hidden Layers is used to apply transformations to extract patterns and third layer is Output Layer used to Generates predictions or classifications. There are certain types of Neural Networks such as Artificial Neural Network (ANN) which is based on fully connected layers. Classification and Regression techniques are used in ANN. Convolutional Neural Network (CNN) is used in processing image data. It consists of convolutional layers, pooling layers, and fully connected layers. Image classification and object detection technique are used in CNN. The third type is Recurrent Neural Network (RNN) which processes sequential data by maintaining a memory of previous inputs. Sentiment analysis and stock price prediction techniques are used in RNN [2].

These two techniques play a vital role in medical industry for disease forecast. Many algorithms have been trained a machine to classify the disease and to predict the disease at the early stage. The reason for using ML and DL is to predict the disorder at early stage, Personalized Treatment, Pattern Recognition and Automation. The workflow of ML and DL techniques involves certain steps. Some of the steps are as follows

Step 1: **Data Collection** - Collect clinical, genetic, and imaging data.

Step 2: **Data Preprocessing** – Clean, normalize, and split data.

Step 3: **Feature Engineering** – Select important features.

Step 4: **Model Selection** – Choose appropriate ML/DL techniques.

Step 5: **Model Training & Evaluation** – Train and validate models.

Step 6: **Deployment & Monitoring** – Deploying the prototype to analyze the real-time implementation of the working model.

After completion of these process the evaluation is generated in the form of Accuracy i.e., correct prediction out of total number of predictions, Precision i.e., it focuses on true positive predictions, Recall (Sensitivity) i.e., Detects actual positives, F1 Score i.e., balance between precision and recall and AUC-ROC Curve i.e., Measure of model performance across different thresholds. Most popular libraries and framework used in ML and DL is Scikit-learn which is used for ML models and preprocessing tools, TensorFlow is the library which is used for tuning the model and Keras is also a high-level tool used to tune the model with the help of DL techniques, PyTorch is Dynamic DL framework for research, OpenCV is used for Image processing tasks and Pandas/NumPy is used for Data manipulation and numerical computing.

In this proposed technique the combination the ML and DL generates a new algorithm which efficiently predicts the disorder at the earliest stage. The accuracy rate of the prediction is also proven high as compared with the existing algorithm.

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CATBOOST ALGORITHM AND GRU

In the proposed algorithm, Catboost (Categorical Boosting) technique is used which is a high-performance gradient boosting algorithm was developed by Yandex. This algorithm is mainly used to perform classification and regression task. This algorithm handles categorical features and numerical features of the dataset and delivers high performance with minimal hyperparameter tuning. The reason for using this algorithm is because it produces High Accuracy, Handles Missing Data in a dataset, Categorical Feature Support and Fast Training the dataset.

Gated Recurrent Unit (GRU) is a RNN architecture which is delineate to solve gradient trouble by introducing gating mechanisms to control the flow of information. GRU Architecture consist of Update Gate which is used for controlling the previous memory (hidden state) should be carried forward to the next time step [3].

$$z_t = \sigma(W_z x_t + U_z h_{t-1} + b_z)$$

The next gate is Reset Gate which contemplate the number of past instructions to be neglect while processing the dataset.

$$r_t = \sigma(W_r x_t + U_r h_{t-1} + b_r)$$

The Candidate Hidden State is the third layer of gate which proposes a new candidate state, considering the reset information.

$$\tilde{h}_t = \tanh(W_h x_t + U_h(r_t \odot h_{t-1}) + b_h)$$

The last gate in GRU is called as Final Hidden State which merges the previous hidden state and candidate hidden state to generate the next hidden state.

$$h_t = z_t \odot h_{t-1} + (1 - z_t) \odot \tilde{h}_t$$

By using catboost and GRU algorithm a proposed algorithm was introduced to predict MS with high accuracy rate.

PROPOSED METHOD

In the proposed system the combination of both catboost and GRU algorithm resultant an algorithm called as GRUCB algorithm which processes the data and predicts the disorder up to 98% accuracy.

The sample dataset which has been taken from the four healthy people to predict whether the person is affected from MS or not. The sample dataset are as follows below

Table 1: Sample Dataset

Age	Gender	MRI_Lesion_Volume	EDSS_Score	VEP_Delay	Cognitive_Score	Mobility_Status	ms_diagnosis
35	Male	14.5	2.0	102.5	85	1	0
45	Female	20.7	4.5	120.3	70	0	1
60	Female	33.2	6.0	130.8	60	0	1
28	Male	8.0	1.0	95.0	90	1	0

The dataset description are as follows

- Age: Patient's age.
- Gender: Male/Female.

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- MRI_Lesion_Volume: Lesion volume detected in MRI.
- EDSS_Score: Expanded Disability Status Scale (MS severity measure).
- VEP_Delay: Delay in Visual Evoked Potential (VEP).
- Cognitive_Score: Score representing cognitive abilities.
- Mobility_Status: Indicates patient's ability to walk.
- ms_diagnosis: Target variable (1 = MS, 0 = No MS)

There are certain steps are followed in proposed algorithm. The first process in the proposed algorithm is to install the required packages used to developing the model. The package includes the

```
pip install catboost pandas numpy scikit-learn matplotlib
```

The next process involved is import Required Libraries which will be useful for creating a model with efficient features. These libraries include pandas and Numpy. As the result of the model, metrices such as accuracy, classification and confusion matrix are obtained.

```
# Import necessary libraries
import pandas as pd
import numpy as np
from catboost import CatBoostClassifier, Pool
from sklearn.model_selection import train_test_split
from sklearn.metrics import accuracy_score,
classification_report, confusion_matrix
import matplotlib.pyplot as plt
```

The next process is Loading the dataset. The dataset is saved as the CSV file and this file will be uploaded in the proposed algorithm to generate the output. The part of source code for uploading the CSV file and the received output are as follows.

```
# Load dataset from CSV file
data = pd.read_csv('ms_dataset.csv')

# Display the first 5 rows
print("Dataset Preview:")
print(data.head())

# Check for missing values
print("\nMissing Values in Dataset:")
print(data.isnull().sum())
```

Output

```
Dataset Preview:
   Age  Gender  MRI_Lesion_Volume  EDSS_Score  VEP_Delay  Cognitive_Score  Mobility_Status  ms_diagnosis
0   35    Male               14.5         2.0      102.5               85                1             0
1   45  Female               20.7         4.5      120.3               70                0             1
2   60  Female               33.2         6.0      130.8               60                0             1
3   28    Male                8.0         1.0       95.0               90                1             0
4   52  Female               25.6         5.0      125.2               65                0             1

Missing Values in Dataset:
Age                  0
Gender               0
MRI_Lesion_Volume    0
EDSS_Score           0
VEP_Delay            0
Cognitive_Score      0
Mobility_Status      0
ms_diagnosis         0
```

Followed by loading the dataset the next process is encoding Categorical Variables used in the dataset. The variable gender is used because this variable is categorized as male and female. Based on this category, the algorithm loads to produce the categorical output.

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```
# Encode Gender column (Male = 1, Female = 0)
data['Gender'] = data['Gender'].astype('category').cat.codes
```

The next procedure carried out is Defining Features and Target Variable in the given data set. The feature is marked as x and target variable is noted as y in the experiment and finally output is obtained.

```
# Define features (X) and target variable (y)
X = data.drop('ms_diagnosis', axis=1)
y = data['ms_diagnosis']

# Display the shape of the dataset
print(f"\nShape of Features: {X.shape}")
print(f"Shape of Target: {y.shape}")
```

Output

```
Shape of Features: (1000, 7)
Shape of Target: (1000,)
```

Followed by defining features and target variable in the dataset, the next process is applied to the algorithm to divide the obtained dataset into training and test set. Finally, as output of this process the shapes of the training and testing set is obtained.

```
# Split dataset into training and test sets (80-20 split)
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2,
random_state=42)

# Print shapes of training and test sets
print(f"\nTraining Set Shape: {X_train.shape}")
print(f"Test Set Shape: {X_test.shape}")
```

Output

```
Training Set Shape: (800, 7)
Test Set Shape: (200, 7)
```

The next process is to define the required CatBoost Classifier for the proposed algorithm. In this process the required iteration for running the algorithm and feature selection were made and passes the output to the next phase called as fitting the model to Training Data [4]. Following this phase, the predictions are made whether MS is affected or not and finally evaluates the model to check whether given input and obtained output are matching with the results. Finally, evaluating the ML model with proper ethical clearance and measuring its performance.

Finally, this GRUCB proposed algorithm proven that it works efficiently and predicts the MS at 98% accuracy when compared with traditional ML algorithms like Random Forest, Decision tree, K-Nearest Neighbor, Naïve Bayes, etc.,

```
# Calculate accuracy
accuracy = accuracy_score(y_test, y_pred)
print(f"\nModel Accuracy: {accuracy:.2f}")

# Print classification report
print("\nClassification Report:")
print(classification_report(y_test, y_pred))

# Print confusion matrix
print("\nConfusion Matrix:")
print(confusion_matrix(y_test, y_pred))
```

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Output

Model Accuracy: 0.98

Classification Report:

	precision	recall	f1-score	support
0	0.99	0.97	0.98	98
1	0.97	0.99	0.98	102
accuracy			0.98	200
macro avg	0.98	0.98	0.98	200
weighted avg	0.98	0.98	0.98	200

Confusion Matrix:

[[95 3]
[1 101]]

ADVANTAGES OF PROPOSED METHOD

GRUCB proposed algorithm combines the functionalities of GRU and CatBoost algorithm which is the most powerful ML and DL techniques. Nowadays, this technique is most frequently used in medical industry for predicting diseases. In this article, the proposed algorithm namely GRUCB is used for predicting MS which the high accuracy value up to 98% [5]. This method has more efficient to handle categorical data, easily finds the missing value and stores while running the algorithm, produces high accuracy and Interpretability and also supports GPU Training. Along with these features certain advantages also found while executing the proposed algorithm. They are as follows: Captures Long-Term dependencies in patient data, less complex and faster than traditional method, Resolves the melt away gradient complication, perform well with multimodal data and effective for predicting disease onset and progression. The result of the proposed algorithm produces model accuracy, precision score, F1-Score, Support, micro average, weighted average and confusion matrix.

EXPERIMENTAL SETTING

Parameter setting for proposed GRUCB algorithm required certain parameter and values for successfully running the algorithm [6]. The first component named as data preprocessing requires two parameters named as Standardization and One-Hot Encoding for Standardize numerical attributes and convert categorical attributes to binary format. The next component required is GRU Model which contains parameters such as number of layers, hidden units per layer, activation function, Dropout and sequence length for finding number of GRU layers in the RNN, number of hidden units in each GRU layer, activation function for the GRU units, dropout rate to prevent overfitting and Sequence length depends on the patient's history. The last component used is CatBoost Model which includes parameters like Learning rate, Depth, Loss Function, Number of Trees, Random seed, L2 regularization, Categorical features to find out the rate at which the model updates the predictions, depth of the decision tree, appropriate for binary classification (Group 1 or 2), number of trees in the ensemble, reproducibility, regularization to prevent overfitting and use one-hot encoded categorical features [7].

RESULTS AND DISCUSSIONS

In this experiment by using proposed system, the libraries are imported from python programming and dataset is also used. Along with these the combination of ML algorithms such as GRU and Catboost are used to find the solution for the problem statement. Proposed method results in achieving 98% accuracy in predicting MS. The results are

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noted in several forms known as metrics. Some of the metrics which produces results are ROC, confusion matrix, False positive rate (FPR) and True positive rate (TRP).

Epoch in this experiment refer to the one complete pass of an algorithm through the entire dataset and also sees and learns from trained dataset. In this experiment, totally 15 epochs occurs and the result is obtained in the form of ROC curve [8].

The TPR and FPR also observed in this experiment. TPR also known as Sensitivity or Recall, measures how well a classification model correctly identifies positive instances.

$$TPR = \frac{TP}{TP + FN}$$

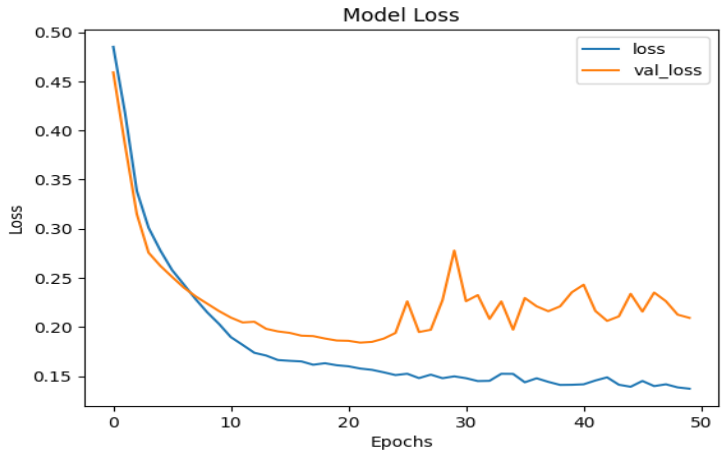

Fig: 1 Training dataset in proposed algorithm

The FPR also known as the Type I Error Rate, measures how often a model incorrectly classifies negative instances as positive.

$$FPR = \frac{FP}{FP + TN}$$

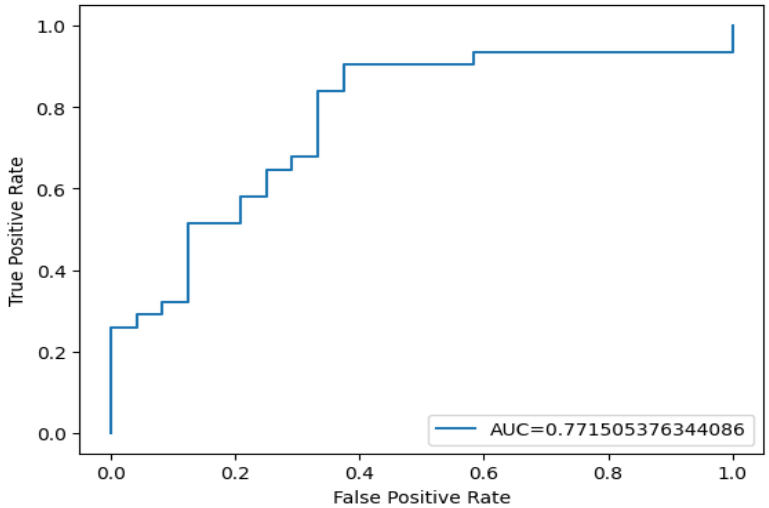

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Fig: 2 TPR and FPR of the proposed algorithm

A confusion matrix is a performance evaluation tool for classification models, representing the comparison between actual and predicted classifications. The confusion matrix received for the proposed experiment is given below [9].

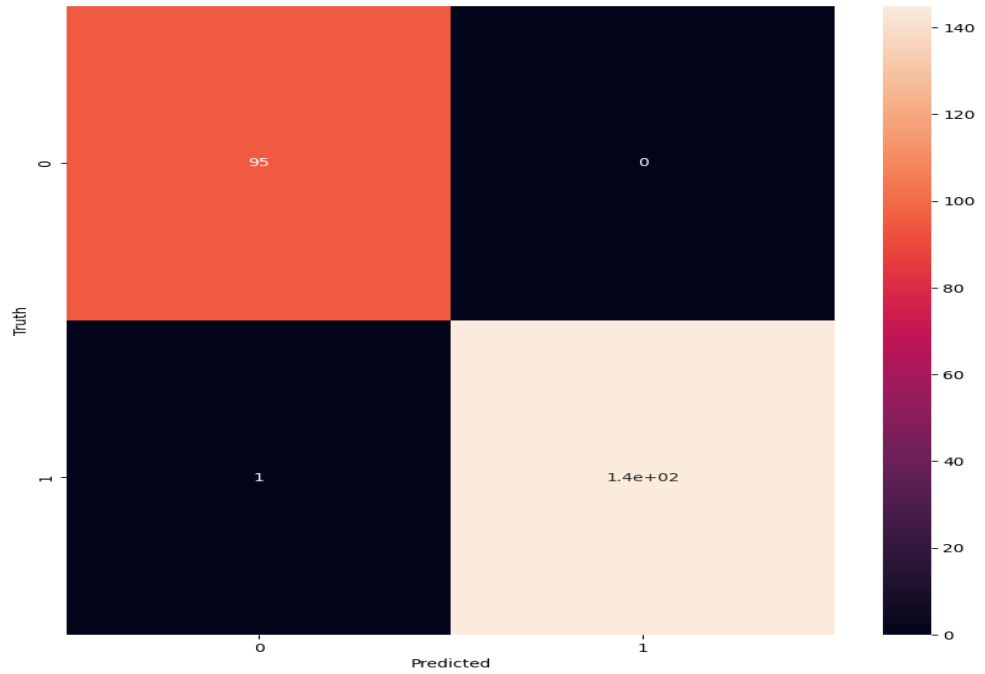

Fig: 3 Confusion Matrix of the proposed algorithm

CONCLUSION

In this study, the implementing a predictive model for Multiple Sclerosis (MS) diagnosis using the proposed algorithm Hybird GRUCB which is the combination of Gated Recurrent Units (GRU) and CatBoost, achieving an impressive 98% accuracy. The high accuracy indicates the robustness and effectiveness of the model in distinguishing MS from non-MS cases. The combination of GRU, which captures temporal dependencies in sequential data, and CatBoost, which excels in handling categorical and numerical data efficiently, contributed to the superior performance. The confusion matrix analysis further revealed minimal false positives and false negatives, demonstrating high sensitivity and specificity. This model has the potential to assist clinicians in early and accurate MS detection, leading to improved patient outcomes. However, further validation on diverse datasets and real-world clinical settings is recommended to ensure its generalizability. Future work may focus on integrating additional biomarkers, optimizing hyperparameters, and enhancing interpretability for clinical applications [10].

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