

# Study of Electric Vehicle Charging Prediction using Different Machine Learning Algorithms

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**Abstract**—Electric Vehicles (EVs) have become a necessary companion of humans in the last 5-6 years since these solely work on electricity. People are preferring EVs over regular vehicles since they are more energy efficient. However, there is a major problem of constant charging requirements and a limitation of charging stations. The basic purpose of the proposed work is to predict the average charging time through different machine learning algorithms, which would provide a precise idea about the best algorithm that could be used for the prediction. The next decades will depend on EVs, so having such a model would be a boon for the EV owners and the charging stations, too, as it would help set up new charging stations and see the average charging time of each vehicle.

**Keywords**—Machine Learning, Electricity, Electric vehicles, Charging, Charging time, Prediction, Algorithms, Charging stations.

## I. INTRODUCTION

Electric Vehicles (EVs) have seen significant growth in recent years. These vehicles are easy to operate and have fewer maintenance requirements since the components used are less than regular gasoline vehicles. These vehicles have given a possibility to reduce pollution in recent times since they don't emit harmful pollutants from the vehicles. EVs have been a major part of the industry in the last 5-6 years and have gathered huge recognition among users, which has led to a sudden increase in demand. In the current decade, the prices of petroleum-based fuels have faced huge hikes, which is making it difficult for the public to refill their vehicle regularly. Also, less efficient vehicles require more fuel to work, causing problems for people. So, in such a scenario EV has become the best choice for people.

EVs have become a necessary companion for humans in recent times, but there have been problems related to frequent charging requirements after certain intervals since the battery capacity is limited to some kilometres, and after the limit is reached, they again need charging. Charging a single EV only takes a considerable amount of time but in contrast, only a minimal number of charging stations are available to fulfil the current demand [3]. If a single station is constantly overloaded, consequently it would cause problems to the station, hamper the EV battery, and deteriorate the efficiency of the battery, which may result in bad output from the vehicle. It is the need of the hour to set up more stations, which would tackle the problem of charging for EVs and help to reduce the load on a single charging station [12, 13]. The increased number of stations would help to divide the load, and the waiting time for charging the vehicles would be reduced. Hence, a machine

learning model is being developed for the same. The main motive of the model would be to predict the average charging time of the vehicles, which would help set up the required number of stations, hence reducing the load on a single station [9]. The charging prediction would require a large dataset since much development depends on the proposed model. If any data is missed or any parameter needs to be input correctly, the prediction can go wrong, and the whole model would be inefficient. The dataset for the proposed model is sourced from Kaggle. Hence, the dataset used for the model contains information about the start and end times of charging a particular vehicle. Information about the different locations of charging stations is also provided with the help of the location ID along with the station ID. With the mentioned parameters, the model could predict the location where more charging stations are required and the average charging time. This way, the user will also have a brief idea about all the parameters they must consider while using an EV.

The proposed model majorly focuses on the average charging time output, so to have an efficient output, a suitable algorithm is required, for which a comparative study of different algorithms is being done in this paper. The model will be trained, where the inputs would be the charging start time, charging end time and time taken for charging and would help in studying the EV charging behaviour using the various classification and regression techniques of machine learning [2,8]. The output of each algorithm would be compared to each other, helping to identify the best algorithm suited for the desired output. The data would be processed, cleaned, and filtered according to the requirements to avoid unnecessary inputs. The model provides an efficient output, and with the provided data and the processed data, the average charging time of different vehicles and their charging frequency would be predicted, which would provide an estimate of the required number of charging stations to be installed in a particular area. This way, the users would reach the charging stations easily and could travel longer distances without worrying about the constant charging of the vehicle. Since the dataset is from an open source, the privacy concerns are minimal, In real time application, the dataset can be encrypted to secure the model and is easy to use.

The major purpose of choosing the proposed model is to highlight the importance of EVs in the current world and the coming years. The world will see a rapid rise in EV demand in the coming decades, which will simultaneously increase the load demand on the grids and hence, more charging stations will be required for the vehicles [1,5]. The model is

a part of sustainable development so that future generations do not have to face problems related to grid failures, depleting battery efficiencies and rush hours.

## II. METHODOLOGY OF THE PROPOSED MODEL

### A. Functioning of the charging of an Electric Vehicle

Fig 1 depicts the block diagram for the regular charging method of an electric vehicle (EV). The block diagram depicts a conventional off-board DC charger for an electric vehicle. AC power from the grid first enters the AC/DC converter, transforming it to pulsating DC. The power control unit then smooths and regulates this DC, ensuring optimal battery charging [7]. Meanwhile, the battery management system closely monitors the battery's health, preventing damage from overcharging or overheating. Finally, the conditioned DC flows to the electric vehicle's motor, driving it forward. Safety interlocks throughout the system safeguard against electrical faults, protecting the charger, battery, and vehicle. The diagram illustrates the essential stages of DC fast charging, enabling convenient and safe electric vehicle operation.

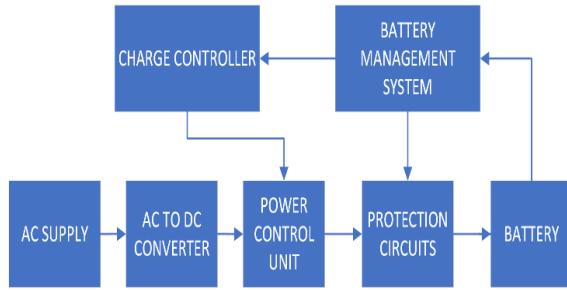


Fig. 1. Block Diagram of Electric Vehicle Charging Process.

### B. Functioning of the proposed model

Fig. 2. shows the block diagram for the proposed work. The block diagram traces a model designed to predict the average charging time of electrical vehicles (EVs). The phase at which the data is given as the input has the variables start time, end time, and total charging time, which represent the starting phase, completion phase, and duration of battery charging, respectively. Data filtering and the preprocessing follows filtering, which involves cleaning unwanted data and outliers to enhance the model's performance. In the training and testing phase of the model, the processed data helps to train a model capable of handling the complexities of EV charging. For the testing or cross-validation of the model, 40% of the data was taken and 60% data was used for the training of the model. The model type could vary from linear regression to different model types such as decision tree, random forest, or neural network, which enhances the relations within the data. After the training, the model can predict the average charging time for all data points. This good prediction efficiency holds the potential to enhance the charging qualities. The block showcasing the charging time gives an idea about the stage after the prediction, where the average charging time is used to calculate the expected charging time for a specific EV charging moment. The focus of the block diagram is to represent a machine learning model for the prediction of battery charging of an EV [10,13]. The model contributes to informed decision-making charging strategies, potentially battery management systems. The optional stages allow for

continuous improvement and application-specific calculations, showcasing the adaptability and potential impact of the presented machine learning approach.

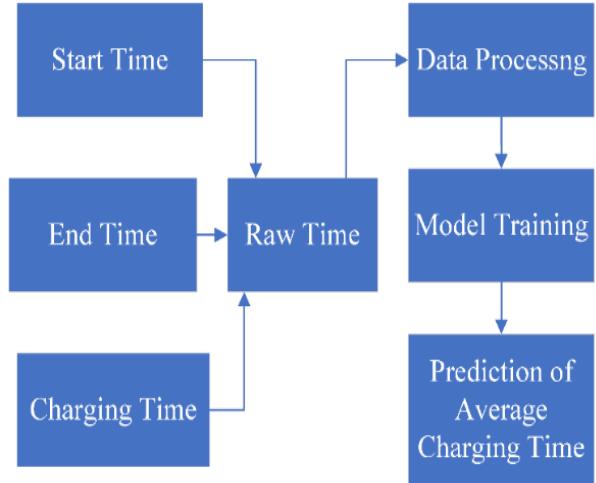


Fig. 2. Block Diagram for Proposed Model.

*1) Data Cleaning and Preprocessing:* Data preprocessing is a critical step in preparing raw data for machine learning applications, involving various strategies to enhance the quality and applicability of the dataset. The preprocessing task addresses missing values, where instances with missing data may be removed, or missing values can be filled. Also, outliers can distort model training, so preprocessing steps are required to mitigate such a situation. In the context of the proposed model, the dataset has been filtered after removing the columns – ‘dollars’, ‘distance’, ‘Mon’, ‘Tues’, ‘Wed’, ‘Thurs’, ‘Fri’, ‘Sat’, ‘Sun’, ‘reportedZip’. The deleted columns are not important in the context of the proposed model and contain values which would hamper the efficiency of the output. Fig 3, Fig 4 and Fig 5 depict the dataset before preprocessing, the scatter plot for the original dataset and the output after preprocessing. After the preprocessing, the eliminated columns, i.e. ‘dollars’, ‘distance’, ‘Mon’, ‘Tues’, ‘Wed’, ‘Thurs’, ‘Fri’, ‘Sat’, ‘Sun’, ‘reportedZip’, are not shown in the workspace.

sessionId	kwhTotal	dollars	created	ended	\			
170	188170	6.89	0.00	2015-01-15 13:59:53	2015-01-15 17:37:04			
171	2564911	6.28	0.00	2015-01-21 14:39:13	2015-01-21 17:06:04			
172	7028441	2.76	1.25	2015-01-21 18:57:38	2015-01-21 23:01:04			
173	2162299	4.10	0.83	2015-01-26 18:09:47	2015-01-29 01:24:04			
174	5859533	7.21	1.58	2015-01-27 17:27:24	2015-01-27 23:00:06			
175	4317364	7.02	0.00	2015-01-28 20:32:43	2015-01-28 22:57:05			
startTime	endTime	chargeTimeHrs	weekday	platform	...			
170	13	17	4	Thu	ios ...			
171	14	17	3	Wed	ios ...			
172	18	23	5	Wed	ios ...			
173	18	1	-17	Mon	ios ...			
174	17	23	6	Tue	ios ...			
175	20	22	2	Wed	ios ...			
facilityType	Mon	Tues	Wed	Thurs	Fri	Sat	Sun	reportedZip
170	4	0	0	0	1	0	0	0
171	2	0	0	1	0	0	0	0
172	2	0	0	1	0	0	0	0
173	4	1	0	0	0	0	0	0
174	2	0	1	0	0	0	0	0
175	2	0	0	1	0	0	0	0

Fig. 3. Original Dataset.

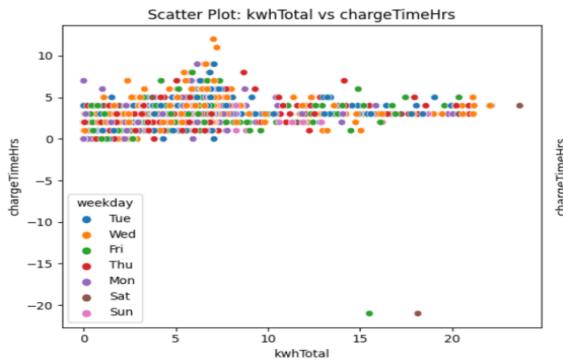


Fig. 4. Scatter Plot for The Dataset.

	sessionId	kwhTotal	created	ended	startTime	\		
170	1881770	6.89	2015-01-15 13:59:53	2015-01-15 17:37:04	13			
171	2564911	6.28	2015-01-21 14:39:13	2015-01-21 17:06:04	14			
172	7028441	2.76	2015-01-21 18:57:38	2015-01-21 23:01:04	18			
173	2162299	4.10	2015-01-26 18:09:47	2015-01-29 01:24:04	18			
174	5859533	7.21	2015-01-27 17:27:24	2015-01-27 23:00:06	17			
175	4317364	7.02	2015-01-28 20:32:43	2015-01-28 22:57:05	20			
	endtime	chargeTimeHrs	weekday	platform	userId	stationId	locationId	\
170	17	4	Thu	ios	65023200	863084	751082	
171	17	3	Wed	ios	65023200	987396	978130	
172	23	5	Wed	ios	65023200	366832	978130	
173	19	1	Mon	ios	65023200	863084	751082	
174	23	6	Tue	ios	65023200	987396	978130	
175	22	2	Wed	ios	65023200	987396	978130	
	managerVehicle	facilityType						\
170	1	4						
171	1	2						
172	1	2						
173	1	4						
174	1	2						
175	1	2						

Fig. 5. Dataset After Preprocessing.

### III. MACHINE LEARNING ALGORITHMS AND OBSERVATIONS

For any machine learning model, various algorithms are available, among which the best one is chosen according to the performance of each algorithm on a particular dataset. The paper studies every algorithm based on classification and regression methods [9] to find the best-suited algorithm.

#### A. Naïve Bayes

1) *Classification:* In classification, the algorithm is used to predict the category or class of a given instance according to the features. Naïve Bayes is used to change the probability of a data instance that belongs to each possible class and assigns it to the class which has the highest probability. Fig 6 and Fig 7 shows the confusion matrix and training vs validation losses for the Naïve Bayes classification method.

```
Confusion Matrix:
[[ 1  0  0  0  0  0  0  0  0  0  0  0]
 [ 0 42  0  0  0  0  0  0  0  0  0  0]
 [ 0  0 125  0  0  0  0  0  0  0  0  0]
 [ 0  7  0 346  0  0  0  0  0  0  0  0]
 [ 0  7  0  0 459  0  0  0  0  0  0  0]
 [ 0  7  0  0  0 293  0  0  0  0  0  0]
 [ 0  0  0  0  0  44  0  0  0  0  0  0]
 [ 0  0  0  0  0  0 20  0  0  0  0  0]
 [ 0  0  0  0  0  0  0  0  4  0  0  0]
 [ 0  0  0  0  0  0  0  0  0  1  0  0]
 [ 0  0  0  0  0  0  0  0  0  0  1  0]
 [ 0  0  0  0  0  0  0  1  0  0  0  0]]
```

Fig. 6. Confusion Matrix for Naïve Bayes Classification.

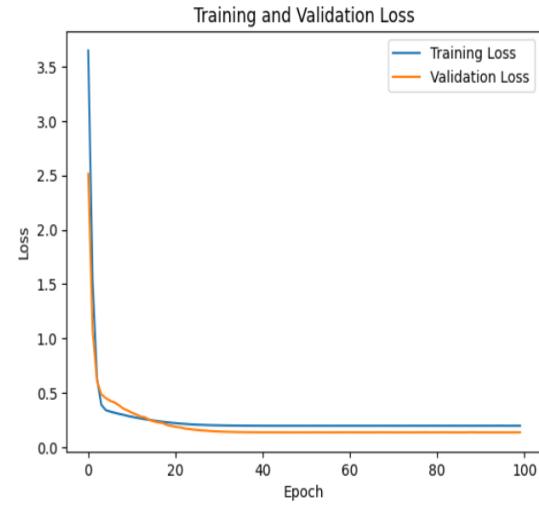


Fig. 7. Training and Validation Losses Output for Naïve Bayes Classification.

2) *Regression:* The Naïve Bayes algorithm, mainly used for classification, can sometimes be used for regression methods when the dataset is continuous, as in the case of the dataset for the proposed model. Here, the column 'chargeTimeHrs', also a target variable, is continuous. Hence, the regression method is possible. Fig 8. and Fig 9. depict the outputs for Naïve Bayes Regressor.

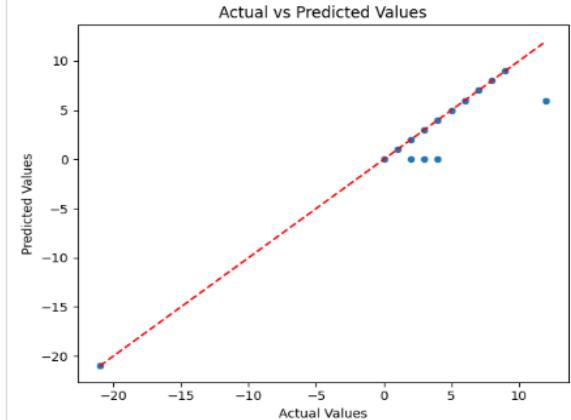


Fig. 8. Output Plot for Naïve Bayes Regressor.

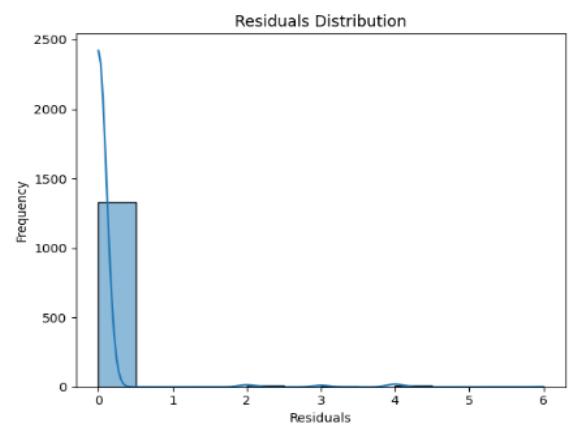


Fig. 9. Residual Distribution Output of Naïve Bayes Regressor.

### B. K-Means

1) *Classification (Clustering)*: K-means clustering is an unsupervised ML algorithm used for classification tasks. The algorithm takes an iterative approach to assign each data point to one of the K clusters. For classification, K-Means can identify natural groupings within the data. K-Means is not mainly related to classification but can be used after processing the clusters. The K-Means clustering plot is shown in Fig 10.

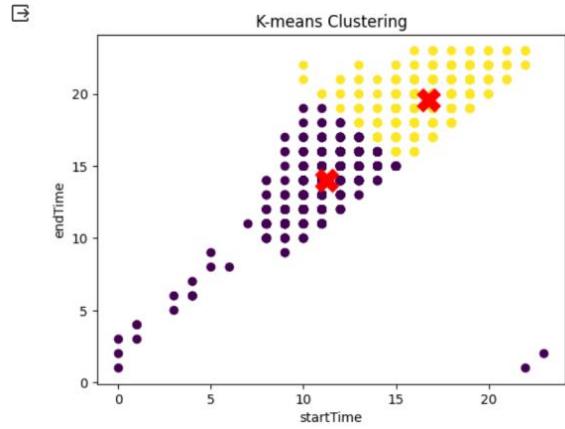


Fig. 10. K-Means Clustering Output.

2) *Regression*: K-means regression is an approach that uses means clustering to make separate regression models for certain data clusters. The algorithm can be employed where there are distinct patterns within the data that a single regression model might not capture. After clustering, a separate regression model is trained for every cluster, providing a more nuanced and accurate prediction for every group. Fig 11 depicts the output plot for the K-Means Regression algorithm.

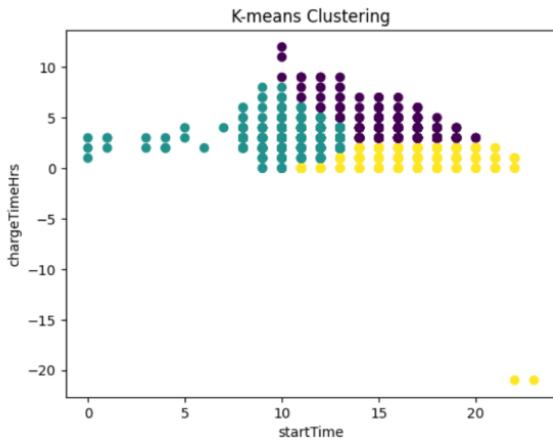


Fig. 11. K-Means Regression Output.

### C. K-Nearest Neighbors (KNN)

KNN is an easy and intuitive algorithm. In KNN classification, the algorithm assigns a start data point to the most common class among its k-nearest neighbours. The algorithm calculates distances between the data points to be classified and all other points in the dataset and selects the k-nearest neighbours in which the class with the most

neighbours finalizes the class of the data point. Fig 12 and 13 shows the plot for training and testing accuracy.

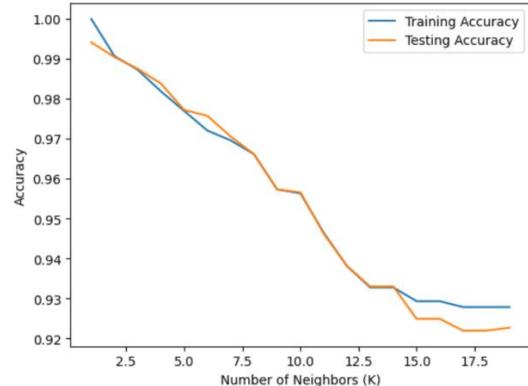


Fig. 12. Training and Testing Accuracy Plot of KNN Classification.

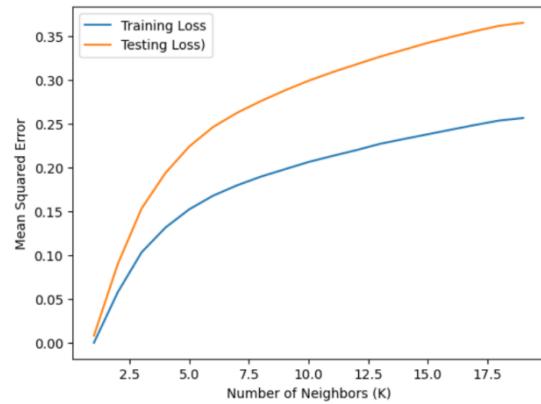


Fig. 13. Training and Testing Loss Plot of KNN Regressor.

In the KNN regression method, the focus is to predict a continuous target variable. The algorithm predicts the target value for a data point by averaging or taking the weighted average of the target values of its k-nearest neighbours. Compared to the classification algorithm of KNN, the regression model is nonparametric and takes more time to complete the process.

### D. Dimensionality Reduction

In classification, dimensionality reduction involves reducing the number of features or variables in a dataset while keeping the major information. The focus is to simplify the dataset's structure and eliminate irrelevant features, improving the classification efficiency. This results in more efficient and accurate classification models. For regression, too, dimensionality reduction focuses on addressing the problem of dimensionality, like the classification algorithm. This algorithm retains the most relevant information for predicting the target variable by removing the least important data. Whether for classification or regression, the algorithm transforms the original high-dimensional data into lower-dimensional data.

### E. Support Vector Machine (SVM)

For classification, SVM finds a hyperplane in an N-dimensional space, which distinctly classifies the data points into certain classes. The target of the algorithm is to find the hyperplane which maximises the margin between different classes. The regression technique is an extension

of the SVM classification method, which can be used for regression algorithms. The algorithm predicts a continuous output instead of classifying the data points as in the classification method.

#### F. Artificial Neural Networks (ANN)

ANN is a sophisticated algorithm that works with inspiration from the human brain's structure and function [4,11]. In classification tasks, the algorithm intricate relationships between input features and categorical outcomes through interconnected layers of nodes. On the other hand, for regression, ANN predicts continuous numerical outcomes. The architecture for classification and regression are similar, but the regression model typically features a single-node output layer representing the regression output. ANN is best suited for regression techniques where tasks contain nonlinear or complex patterns.

#### G. Decision Tree

Decision Trees are one of those algorithms which can be employed both for classification and regression methods. The algorithm is known for interpretability and ease of visualisation. Regarding classification, the algorithm recursively splits the dataset based on feature conditions to create a tree-like structure. Every node represents a decision based on a particular feature. During the training, the tree learns to make decisions that optimise the separation of different classes. In regression, the algorithm predicts numerical values rather than discrete classes. The tree structure is similar to the structure of the classification model, but the difference is that the leaf nodes contain the predicted numerical values. The goal is to minimize the variance of predicted values under each leaf, allowing the tree to capture complex relationships in the data.

#### H. Random Forest

Random Forest is an algorithm that is particularly effective in managing high-dimensional data. For classification, the algorithm builds multiple decision trees during training and outputs the mode of the classes predicted by individual trees. A certain tree is constructed depending on a random subset of the data which is being trained and a random subset of features. In a regression model, the algorithm predicts numerical outcomes by taking out the average of the predictions of individual decision trees. Similar to the classification model, each tree is trained on a random subset of the training data and features, contributing to the model's generalisation ability. With the ensemble approach mentioned above, the algorithm has the quality to become resilient to outliers and noise, which results in efficient output.

#### I. Long-Short-Term Memory (LSTM)

LSTMs are special Recurrent Neural Networks (RNN) made to mitigate the challenges of learning long-range dependencies in data which are sequence-related and the problem of vanishing gradient. In the case of the classification model, the algorithm is good at understanding and predicting patterns in sequences and has memory cells which store and recover information over long periods, which allows them to capture intricate relationships at certain moments. For the regression model, the LSTM algorithm targets to predict numerical values in a particular

sequence. Here the algorithm maintains memory cells but, in such a structure which produces continuous output. A structure like this makes LSTM suitable for applications related to time-dependent numerical prediction tasks.

#### J. Gradient Boost

The gradient boost algorithm combines the predictive power of multiple weak learners to form a robust and accurate predictive model. In the classification model, the algorithm builds a series of decision trees in a sequence, with an individual tree correcting the error of the preceding tree. The final output is a weighted sum of individual tree predictions, resulting in a strong and accurate classifier. On the other hand, the regression model focuses on predicting the continuous data. The algorithm constructs regression trees in a sequence, each targeting the residual errors of the preceding tree. After the iteration of predictions, the model converges towards accurately representing underlying data relations.

### IV. RESULTS AND OBSERVATIONS

Table I and Table II show the outputs of all the machine learning algorithms metrics applied to the dataset with classification and regression models. All the algorithms have certain metric outputs which are different and comparatively efficient or inefficient to each other. The comparison of all the algorithms is shown through the mentioned tables, which would help the user to decide the best algorithm to predict the average charging time of an EV and which model would help find the most efficient vehicle since the demand behaviours may fluctuate from place to place [6]. Since the model is being designed for real-time applications, the focus is kept on accuracy, precision and various other metrics for a better output as mentioned in the Table I and Table II respectively.

TABLE I. OBSERVATION OF CLASSIFICATION METHODS

Machine Learning Algorithms	Metrics			
	Accuracy	Precision	F1	Recall
Naïve Bayes	0.94	0.91	0.92	0.94
KNN	0.98	0.99	0.99	0.99
DR	0.99	1.0	1.0	1.0
SVM	0.996318	0.9963319	0.996316	0.996181
ANN	0.975	0.95	0.96	0.98
DT	0.96	0.96	0.94	0.96
RF	0.33	0.11	0.16	0.33
LSTM	0.31	0.10	0.15	0.31
GB	0.29	0.26	0.21	0.29

TABLE II. OBSERVATION OF REGRESSION METHODS

ML Algorithms	Metrics					
	MAE	MSE	RMSE	R <sup>2</sup>	Train Accuracy	Test Accuracy
Naïve Bayes	0.06	0.22	0.46	0.89	0.9	0.89
KNN	0.03	0.22	0.47	0.89	0.92	0.89
DR	0.00	0.00	0.00	1.0	1.0	1.0

SVM	0.046	0.002 4	0.0489	0.98	0.92	0.99
ANN	2.28	6.77	2.60	-2.82	-2.45	1.0
DT	1.0	2.07	1.44	0.00	0.00	1.0
RF	1.01	1.65	1.28	0.0	0.0	1.0
LSTM	1.00	1.64	1.28	0.0	0.0	0.0
GB	1.01	1.65	1.28	0.0	0.0	1.0

## V. CONCLUSION AND FUTURE SCOPE

There are phases where even after data filtering and preprocessing, certain data might be an outlier for a particular algorithm and would not give a satisfactory output. Hence, in such a scenario, a comparative study of all the algorithms can be done to find the best machine learning algorithm that would give the best output and can be employed to get the expected output. Several machine learning algorithms can be employed for prediction and classification but only a few algorithms give the expected and efficient output. If Table I and Table II are observed, it could be concluded that for the proposed model, dimensionality reduction and support vector machine are the two algorithms which provide the most accurate metrics in the case of classification and regression models respectively. If a single algorithm is required to be employed for the prediction or classification purpose, dimensionality reduction is the best among all the other algorithms employed for the proposed model. Also, the metrics show that the model is transparent and can be employed for the proposed purpose. Considering the current era, where pollution levels are very high, along with the ever-growing prices of petroleum-based vehicles, EVs are the best solution for all the problems of the present and the coming decades to a certain extent. Also, the world is shifting towards renewable energy sources, seeing the rapid depletion of natural resources like coal, petroleum, CNG, etc. EVs are one of the best approaches since the vehicles can be charged using solar energy by fixing the solar panels on the vehicles. If the proposed model is employed, it could be a boon for all EV users since the model would predict the average charging time, which would, in turn, help to get a rough idea of the requirement of EVs in a particular location because the count of the EVs in the coming era is going to be very high which would in turn lead to higher demand of charging from time to time. If the dimensionality reduction machine learning algorithm is employed, the proposed model would be quite helpful in mitigating a situation of grid failure due to a sudden increase in demand. Also, the model is software-based, hence, it can update itself with the varying charging patterns from time to time and provide the necessary outputs.

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