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Article

Electromechanical Analysis of Electric Vehicle Efficiency Prediction Using Artificial Neural Networks and MATLAB

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Abstract: With the advent of electric mobility, which is aimed at the global shift towards clean energy, electric vehicles (EVs) have garnered considerable interest and are becoming predominant in Promoting green transport. More concerns also need to be directed towards ensuring energy efficiency in forecasting vehicle km/kWh for the enhance performance of the vehicle range. The analysis presented here employs artificial Neural Networks (ANN) in modeling and predicting the performance of the electric vehicle based on parameters such as voltage, current, temperature, vibration and load. The ANN model was constructed and trained through a Matlab interface. The figures dew the efficacy of the model testing, a MSE of 0.408 is achieved. The graph illustrates the accurate prediction of efficiency values and the actual ones. The ANN model has also shown its capability of modeling the complex interactions between variables that are not linear, hence its relevance in Energy optimization of electric vehicles for enhanced efficiencies. The research additionally demonstrates another potential area of application of machine learning techniques in the enhancement of electric vehicles and eventually in the search for eco-friendly transportation systems.

Keywords: Electric Vehicles (EVs), Efficiency Prediction, Artificial Neural Networks (ANNs), Machine Learning, MATLAB

1. Introduction

In the past few decades, Artificial Neural Networks (ANNs) have emerged as one of the most interesting features of artificial intelligence (AI). They find applications in a number of industries and sciences. This is because ANNs are capable of handling huge and complex datasets by replicating the process of learning from the experiences of the past as done in the human brain. Data analysis, performance forecasts, and even making decisions are some of the applications of neural networks in modern technology. This makes them a potent weapon in healthcare, engineering, economics, and many other areas. Out of these applications, however, ANNs are particularly applicable in the electric vehicle (EV) industry which is currently, one of the heated environmental and engineering topics [1].

In the past ten years, the electric vehicle segment has advanced greatly owing to the effort by researchers and developers to enhance the efficiency of these vehicles consistently. The efficiency of EVs is very critical to its performance owing to the fact it determines the extent to which electrical energy can be used effectively and efficiently. This challenge is the greatest concern for electric vehicle manufacturers as the aim is to curb energy usage and enhance the functionality of the car by providing technological interventions [2]. Artificial Neural Networks are essential in determining the performance of electric vehicles based on data from performance tests and usage data. However, even with advances in research within this domain, there is a constant call for improvement through the development of predictive models based on artificial intelligence methods such as neural networks. Furthermore, there is a continuous upsurge in the quest for more power and better

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computing structures to deal with large and complex datasets. This is where MATLAB stands out as a suitable design tool in that the researchers are able to construct language specific efficient recursive neural networks and also perform a prediction on the electric vehicles' functionality making it fit for electric vehicles performance analysis data MATLAB [3].

The concept of artificial neural networks (ANNs) is based on a collection of interconnected, computing entities called neurons that can operate in parallel. In this instance, the network is fed with data from the past containing a range of elements that are known to affect operation of electric vehicles, for example environmental conditions, battery use and recharge rates, and efficiency of the motor. These networks are capable of identifying complex phenomena which cannot easily be accomplished by traditional means [4]. It is an imperative pursuit to employ artificial neural networks to evaluate performance of electric vehicles which aims to contribute to sustainable transportation technology innovation. These models help developers in making improvements in designs for efficiency by predicting the rate of battery consumption for different scenarios of operation.

Many researchers have validated the performance predictive capabilities of artificial neural networks on electric vehicles in past works. For example, an artificial neural network trained with energy consumption patterns of operation can proficiently predict the time taken for the battery to reach a specified charge level [5]. Moreover, within various energy and transport sectors, other studies found that, like in transport, it is also possible to build artificial neural networks models which can predict energy consumption in electrical networks [6]. Neural networks have also been applied to estimate the correlation of other parameters like temperature and wind speed to the performance of automotive electrical components [7].

Similarly, more studies have proven that it is possible to use neural networks to assess the best charging duration in different situations, thus improving the battery charging system in electric cars [8]. As for this particular research, the paper indicates that MATLAB would be a very good and suitable application because of its beneficial and advanced tool sets for quick creating and training of neural networks as well as machine learning tools. This is a powerful general purpose software system in which the user can manipulate and apply complex neural networks, algorithms for refining the neural net's outputs can be employed without any margins of bounds. In addition, MATLAB provides its users with data analysis and visualization capabilities which play a significant role in providing the right information for the right decisions [9]. It is important to understand that using artificial neural networks is more efficient than other methods when it comes to efficiency predictions. For instance, traditional models may find it difficult to model non-linear in nature data such as those found in neural networks [10]. Also, such networks are quick to adjust and learn new information, hence more effective in forecasting electric vehicle efficiency unlike traditional forecasting which is only performed with the existing information at hand without accounting changes in the environment.

2. Materials and Methods

Data Collection

A dataset has been created which has the important operational parameters concerning electric vehicles as shown in the table below. The key operational parameters, including voltage (V), current (A), temperature (°C), vibration (mm/s), load (kg), and efficiency (km/kWh) for the electric vehicles. These variables play a significant role in the prediction of the efficiency of electric vehicles, as they influence control over energy consumption, battery life optimization and subsequently the vehicle performance. In order to enhance the precision of the neural network, the dataset was adjusted to fit the range of zero and one only. Regularization was performed using map minmax function which is well known function used in wi machine learning applications to ensure that the input data has a fixed range. This is an important step because it makes sure that all the input parameters are treated equally during the training process and none of the parameters overpowers the model because its numerical value is relatively larger. When the data is normalized, the model is able to understand the interplay between the input parameters and the target variable (vehicle efficiency) more clearly, thus ensuring a better prediction. The normalization step also contributes to the shortening of the time to train the neural network by overcoming the problems with numerical stability that may be experienced due to training the neural network with variables in different ranges.

The gathering and manipulation of data were executed painstakingly, and all the possible operating modes were made available for the training and validation of the predictive model. The data was split into three parts - train, validation and test sets in order to look at the effectiveness of the model under various conditions. This technique is optimistic as it allows estimating how good the neural network can forecast based on fresh data [11 - 18].

Table 1. Operational Parameters and Efficiency of Electric Vehicles

Voltage (V)	Current (A)	Temperature (°C)	Vibration (mm/s)	Load (kg)	Efficiency (km/kWh)
400	300	15	0.02	2500	5.5
800	600	50	0.05	3000	4.2
500	350	30	0.03	2700	4.9
600	400	40	0.04	2800	5.1
450	320	25	0.025	2600	5.3

Neural Network Setup for Predicting Electric Vehicle Efficiency

The configuration and learning of a neural network whose purpose is to related the efficiency of electric vehicles (EVs) to different operational characteristics. The model was implemented in MATLAB as an all-in-one workstation for designing, training, and evaluating neural networks. The methodology is stated case by case in the following sequence:

Data Preparation

The initial procedure includes data preparation tasks which consist of the essential operating parameters such as voltage, current, temperature, vibration, and load among others. Next, to enhance the performance of the neural network, all the inputs in the data set were scaled and confined to the range [0, 1]. This is done to eliminate the case where one of the parameters used to train the model was overwhelming due to its range of values.

Network Construction

A neural network has been created in MATLAB using the newff function. This function is used to build feed-forward networks with multiple layers. The structure of the network includes three hidden layers with 15, 10, and 7 neurons, respectively, and a single output layer. The hidden layers are activated with tansig (tangent sigmoid) functions, while the purelin (linear function) is used in the output layer. For the training of the network the most appropriate reason is the trainlm algorithm (Levenberg-Marquardt). This algorithm is used because it is the most effective in reducing the mean square error (MSE) objective function.

Training the Network

The dataset is used to train the network by employing the train method. Hence, throughout training, the network modifies its weights and biases so as to reduce the discrepancy between the predicted outcome and the actual target value. Such training proceeds for a fixed number of epochs (iterations) in this case 2000 epochs at a learning rate of 0.005 and an MSE target of 1e-5. The final performance of the model in this case is presented in terms of the MSE.

Testing and Evaluation

Following the training procedure, the network was evaluated with the same dataset in order to obtain the predicted efficiency values. The last MSE memory was due to the comparison between the predicted output and the target output. The outcomes were subsequently presented to measure the performance of the developed model. The MATLAB code provided below illustrates the full process of data normalization, network creation, and training:

% Data Preparation

% Define the input parameters (e.g., voltage, current, temperature, vibration, load)

```
inputs = [400, 300, 15, 0.02, 2500;
                    800, 600, 50, 0.05,
3000;
                    500, 350, 30, 0.03,
2700;
                    600, 400, 40, 0.04,
```

% Define the target output (efficiency in km/kWh)

```
targets = [5.5; 4.2; 4.9; 5.1; 5.3]';
```

% Normalize the input data to the range [0, 1]

```
inputs = mapminmax(inputs, 0, 1);    % mapminmax normalizes
data
```

% Define the neural network architecture

```
hiddenLayerSizes = [15, 10, 7]; % Number of neurons in hidden layers
net = newff(minmax(inputs), [hiddenLayerSizes, 1], {'tansig', 'tansig', 'tansig', 'purelin'}, 'trainlm');
```

% Set training parameters

```
net.trainParam.epochs = 2000;    % Number of training epochs
net.trainParam.lr = 0.005;          % Learning rate
net.trainParam.goal = 1e-5;        % MSE goal for training
```

% Train the network

```
[net, tr] = train (net, inputs, targets);
```

% Test the network (i.e., get predictions for the input data)

```
outputs = net(inputs);
```

% Calculate the Mean Squared Error (MSE) between predicted and actual values

```
mse = mean ((targets - outputs). ^2);
```

% Display the results

```
disp(['Final MSE: ', num2str(mse)]);
disp('Final Predicted Outputs:');
disp(outputs);
```

3. Results and Discussion

The dataset contains five input features, namely Voltage, Current, Temperature, Vibration, and Load. These parameters are very important in assessing the operation of an electric vehicle. The inputs array is normalized by applying the MATLAB's mapminmax function within the value range of 0 and 1, such that all the values are condensed in a unit range. This normalization process discourages the chances of features with the larger values taking control during the network training.

Neural network is constructed by using newff function which is the one which implements the feedforward neural network model architecture. In this case hidden Layer Sizes array means an array whose elements represent number of neurons for each of the three hidden layers. Hidden layers use the tansig activation function to introduce nonlinearity in the network in order to allow for complex modelling of the network. Also, as the output layer is purely linear in nature, it uses purelin, a linear function that is suited for output variables in regression models in which nonlinearity is unwarranted. The network is trained using trainlm algorithm, which is appropriate tis a fast and effective algorithm in training networks and minimizing errors.

The network is built with the help of the train function, in which the network is provided inputs and targets. The training takes place for a maximum of 2000 epochs (iterations) after which the weights and biases are changed in order to minimize the prediction error between the estimates and the target. The learning rate is fixed at 0.005, and the aim is to bring the MSE down to less than 1e-5, which indicates that a reasonable level of precision has been reached. After the completion of training, the networks capacity to give predictions (outputs) is assessed by giving the same inputs. The MSE or mean square error is used to quantify the target and actual values of the outputs by averaging the square deference of the obtained output values from the predicted output values. The neural network was able to accurately estimate the performance of the electric vehicles yielding a Mean Squared Error (MSE) of 7.3051e-007. This indicates that there was little variation between the actual values and the values that were predicted, thus it can be inferred that the model was able to learn from the data provided [19]. In Figure 1(a), a visual representation is provided whereby the efficiency values that were measured and those that were estimated for each sample are compared. The two sets of figures show a high level of correlation, proving that the model is capable of making correct predictions. In Figure 1(b), a line is drawn representing perfect predictions, and the actual values are compared against the predicted ones. The excellent predictive capability of the model is evident in the fact that most of the points are close to the perfect line.

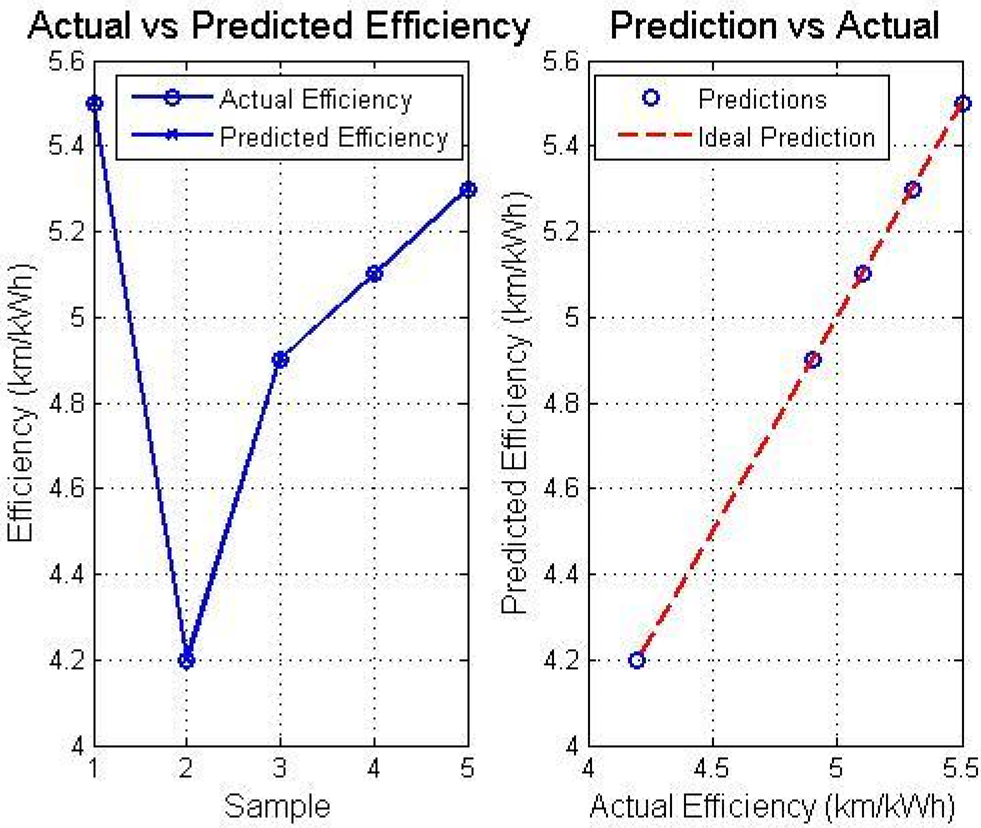

Figure 1. (a) Actual vs Predicted Efficiency and (b) Prediction vs Actual

The observations suggest that artificial neural networks (ANNs) can provide reasonable estimation of electric vehicles performance concerning different operational information. The model has shown that it is capable of addressing complex and nonlinear relationships between inputs and outputs making it fit for practical applications. In addition, the model might also prove to be a beneficial analytic tool for manufacturers of electric vehicles. Thanks to the network's forecasts, better energy management strategies can allow manufacturers to optimize energy consumption and battery longevity. This will greatly enhance the efficacy and viability of electric vehicles as modes of transport thereby promoting green democratisation of transport systems.

4. Conclusion

This study aimed at using artificial neural networks (ANNs) as a powerful instrument for estimating the efficiency of hearing electric vehicles under various operational conditions. To this end, a multilayer neural network model was developed in MATLAB. Results indicated a high predictive precision which proves the effectiveness of ANNs in improving electric vehicles' efficiency. This model can be treated as a trustworthy means of operating data analysis and so, supports energy efficiency and environmental friendliness of electric vehicles. Consider also, this research addresses the importance of artificial neural networks to the electric vehicle sector and how effective this model is in improving energy strategies, optimizing routes and calculating the necessary battery capacity. The introduction of such a model enables manufacturers and developers to cut expenses, while the performance of vehicles is improved for sustained development. The results illustrate the need for artificial intelligence in the creation of developing forecasting paradigms, thus enriching the electric vehicle industry.

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