A new predictive electric bus model using big data for estimating battery pack capacity

Emrah YİRİK[1],Umut IRMAK[2],Çağla DERİCİOĞLU[2],Erdem ÜNAL[2],Mehmet Uğraş CUMA[3]

[1] *Corresponding Author, TEMSA Global A.S., emrah.yirik@temsa.com*

[2] *TEMSA Global A.S., { umut.ırmak, cagla.dericioglu, erdem.unal }@temsa.com*

[3] *Adana Science and Technology University, mcuma@adanabtu.edu.tr*

Abstract

This paper describes a new predictive neural network model for electric buses by using big data analysis tools. Electric buses are often used for public transportation with many routes. Each route in a city has different parameters such as length, elevation, number of bus stops, traffic density which determines battery pack capacity. Moreover average number of passengers and ambient temperature are other important parameters that must be considered. In this paper, a new predictive model for electric buses is proposed using aforementioned parameters. To develop the model, the study takes the advantages of the Big Data Analysis tools by gathering the data from real vehicles.

Keywords: Electric Bus, Battery Pack Size Estimation, Big Data

Introduction

One of the biggest critical issue for electric vehicles is range anxiety and this problem definitely requires Big Data analysis. Existing diesel buses are expected to be used in all conditions with uniform vehicle designs, however electric buses have different designs according to different usage conditions. The reason for this is that a design must be made according to the route the vehicle is used and the number of passengers it carries. This can only be determined by constant monitoring of the conditions of use of the vehicle. For this reason, Big Data tools have an important place in electric bus designs. With this method, the vehicle will be designed in the most suitable way to meet the conditions to be used and the power consumption will be prevented in excess amount. The analysis of energy consumption and driving range estimation for EVs are mentioned in literature. Besides, power-train simulation and driving behavior analysis issues are prevalently researched by other EV manufacturers and related departments of esteemed universities. The aim of this research is reducing range anxiety that is the one of the serious problem of electric vehicles. In addition, solution for improving driving range estimation there are experiments which are include battery simulation and driver behavior analysis [6].

This paper focused on this topic but some papers in literature focuses on other different issues such as overcoming the range anxiety, collecting data for Autonomous Vehicles (AVs), improving the driving range estimation, improving the dynamic road driving conditions and understanding Electric Vehicle (EV) customers dynamics [1] [2].

Also, there are several issues about Big Data application of electric vehicles in literature. These issues generally concentrated on the EV design, battery management and information technology fields. The Big Data analysis methods are not only able to change the future of transportation and but also information exchange technologies. Collecting data from electric vehicles helps to develop battery model and characteristic features of electric vehicle. The related literature paper about this topics is examined when the working for estimating battery pack capacity [4]. It is very important for battery and vehicle manufacturers to follow the warranty conditions of batteries.

1. Data Collection Process

1.1. Data Collection from an Electric Bus

In order to collect the data we used a CAN bus data collecting device of our own design. The device connected to vehicle's CAN line reads the messages and sends them to the server continuously over a certain period of time. To reduce the size of the data, the telemetry device selects the required fields from the messages and sends only those fields to the server at the desired time interval, since the data size is increased by sending the read messages directly to the server. Some of the fields in the messages consist of blank or repetitive fields, as the devices on the CAN line of vehicle are messaging the J1939 protocol. When the CAN bus data collecting device receives the necessary data from the CAN message, it performs an operation again, multiplying these fields by the required deviation value and converting them to meaningful data.

1.2. Data Collection to Big Data Tool

Splunk was used as Big Data tool because it supports many data types and data transfer protocols. It is necessary to instantly process the data from many sources and to extract the necessary reports and analysis instantly [11].

An important parameter for the electric buses is route planning. The bus battery requirement of an electric bus is changes according to the route of the bus. So, main object of the tracking the vehicle's GPS and passenger data is to predict the requirement of a route in a city. In Figure-1, position of the vehicle on a city map is shown. This route planning prediction is a key parameter for the smart city applications [9].

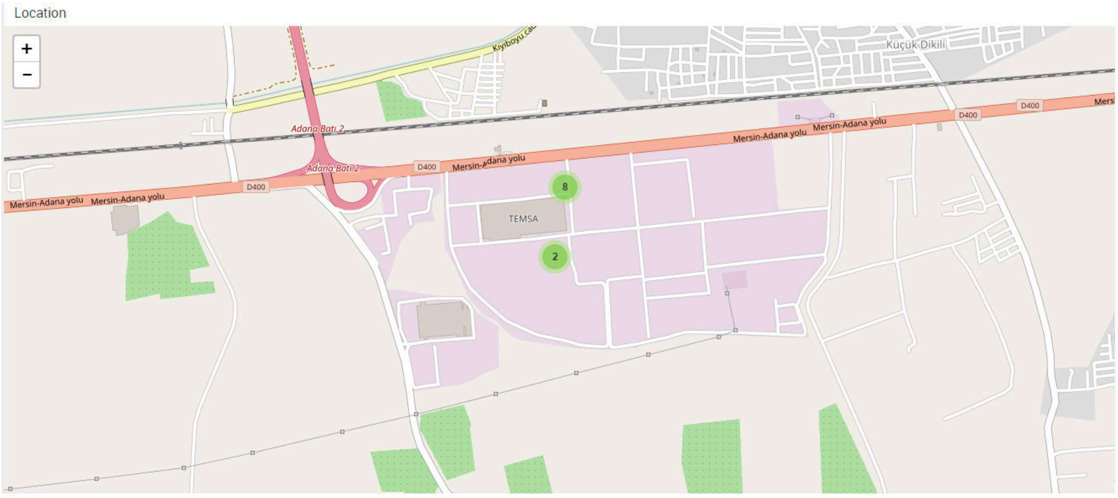


Figure 1: City Map Tracking of An Electric Bus

In Figure-2, A Structure of a vehicle data is shown. A general communication protocol (TCP) is used to send the data to Big Data Tools. After getting this data from the bus, an indexer system runs on the Big Data System and then data becomes ready for detailed analysis [10].

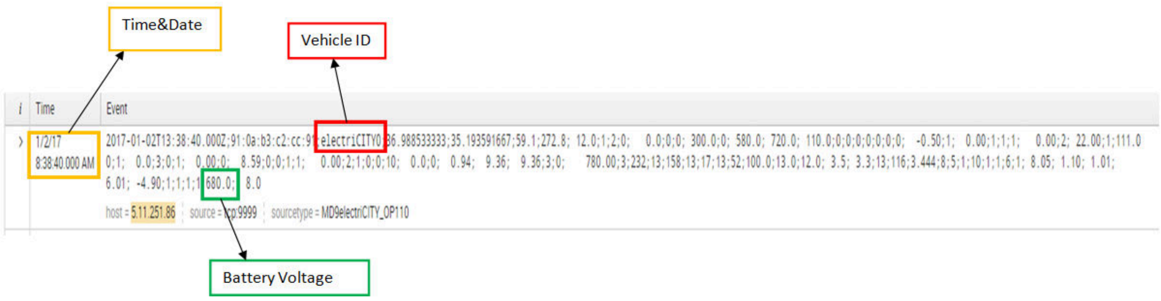


Figure 2: Data Structure of A Received Bus Data

1.3. Neural Network

Longitudinal Vehicle Dynamics Models (LDM) consists of some vehicle parameters which are used to model two axle vehicle with four equally sized wheels. These parameters are; center of gravity, front cross-sectional area, aerodynamic drag coefficients. This study indicates a neural network model by appending LDM parameter with elevation of the vehicle's route, ambient temperature, vehicle total weight with passengers, traffic status of the route and auxiliary high voltage systems like Air Conditioner, Air Compressors, etc.. The aim of this study to create a neural network model to predict the required total vehicles battery in kWh according to the requirements of the cities bus route topology. So this model will be used if the vehicle has a route that it never ran before. An extra driver behavior parameters like steering angle, brake pedal level also can be added to understand the driving of the vehicle and this new model can be used to develop an autonomous bus driving.

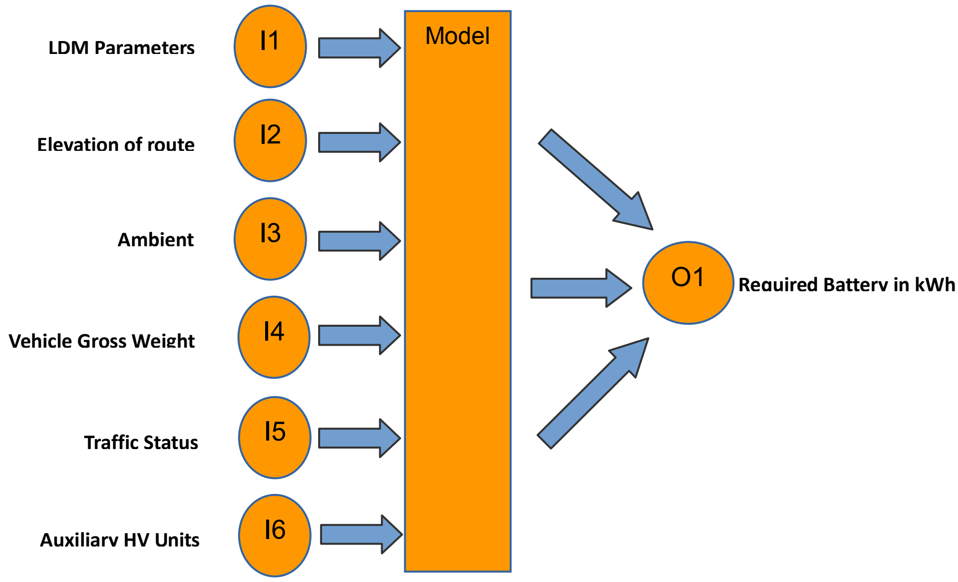


Figure 3: Neural Network Model for Predicting of Required Battery

2. Generation of Input and Target Data Sets

In this study neural network structure is formed by using Matlab Neural Network Toolbox. Matlab Neural Network Toolbox provides algorithms, pretrained models, and applications to create, train, visualize, and simulate both shallow and deep neural networks. The user can easily perform classification, regression, clustering, dimensionality reduction, time-series forecasting, and dynamic system modelling and control [13].

In order to make battery capacity estimation, the vehicle dynamics and environment parameters are used. The vehicle parameters contain acceleration and vehicle weight informations, the environment parameters contain elevation of route and ambient temperature values.

For establishing neural network structure, the input, target and sample data sets are required. The input data sets consists of very important parameters such as acceleration, elevation, ambient temperature and vehicle weight information. Input dataset is consists of a 4x100 size matrix. A small part of input data sets are shown in Table 1.

Table 1: A Part of Input Data Set Matrix

Input Data Set (4x100 matrix)									
Acceleration (m/s^2)	0	0	0.01	0	0	0	0	-0.1	0.1
Elevation	0	0.079	-0.007	-0.05	-0.04	0	0.02	0.03	0
Ambient_Temp (C^o)	34	34	34	34	34	34	34	34	34
Vehicle_Weight (kg)	10200	10200	10200	10200	10200	10200	10200	10200	10200

Target data set is consists of measured energy consumption of battery in a sample time. The sample time is determined as 700 ms in this situation. Target data is comprise of a 1x100 size matrix. A small part of target data set is given in Table 2.

Table 2: A Part of Target Data Set Matrix

Target Data Set (1x100 matrix)									
kWh Consumption per 700ms	0.00513	0.00688	-0.00453	-0.00288	-0.00243	0.00513	0.00623	0.00818	0.00713

Sample data is the test data which simulated on neural network, the output of network returns with predicted value (kWh per 700 ms) for given sample data**.** In this study sample data is 4x10 matrix as shown in Table 3.

Table 3: Sample Data Set Matrix

Sample Data (4x10 matrix)										
Acceleration (m/s²)	0	0.03	0	0	0	-0.01	0.01	-0.01	0	-0.11
Elevation	0	0.01	0.007	0	-0.01	-0.05	0	0.05	0.13	0.06
Ambient_Temp (C°)	34	34	34	34	34	34	34	34	34	34
Vehicle_Weight (kg)	10200	10200	10200	10200	10200	10200	10200	10200	10200	10200

2.1. Neural Network Simulation with Matlab

In Matlab Neural Network Toolbox input, target and set data are imported to toolbox and “Battery Estimation” network created as shown in Fig. 4.

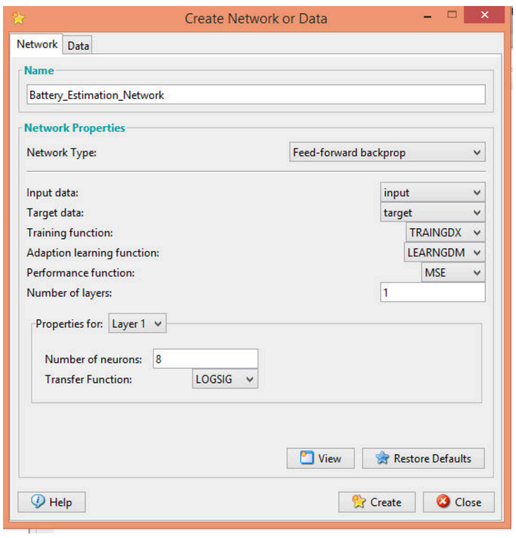


Figure 4: Creating of Battery Estimation Network in Matlab

After creating the network, the data training tool is started. The training was done until successful regression established between output of neural network and target. In this study, after 279 iterations the successful regression was achieved.

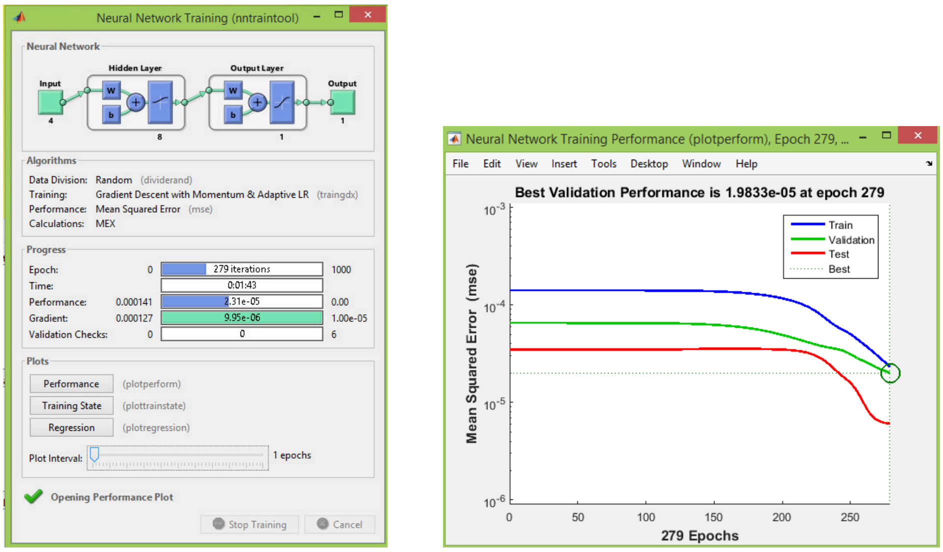


Figure 5: Neural Network Training and Performance Windows

3. Results and Discussions

The following regression plots display the network outputs with respect to targets for training, validation and test sets. The fit is reasonably good for all data sets, with R values above the 0.93. This means that the output of network is very close the target values.

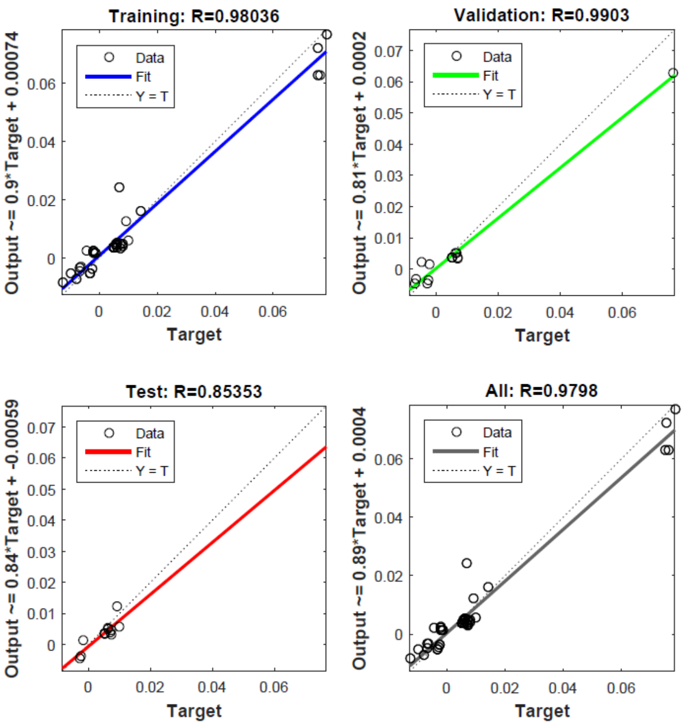


Figure 6: Regression Plots of Network Outputs

Neural Network output results and target for sample data input are shown in Table 4. The simulated values and measured values are nearly same. Network outputs fits the measured values approximately 96%.

Table 4: Comparison of Neural Network Outputs and Target Outputs

Predicted KWh consumption per 700ms	0.0049	0.0068	0.0060	0.0048	-0.0018	-0.0068	0.0060	0.0097	0.0760	0.0088
Measured KWh consumption per 700ms	0.0051	0.0072	0.0057	0.0051	-0.0017	-0.0067	0.0061	0.0100	0.0783	0.0092

Conclusion

In this paper the successful data collection from an electric bus has been achieved. Battery monitoring, traction monitoring,, elevation data and other detailed data has been sent from bus and APIs to the data collection center. Also, these datas are used for the prediction of the electric bus route planning in a city center. In this study a predictive model has been developed to design a battery model according to the different usage scenarios, so effective battery capacity can be chosen by using this model. This results saves user from more battery price, more battery weight.

This paper provides a detailed data collection, analysis of the electric bus data, creating reports by using Big Data Tools. Monitoring results from the Splunk data analysis tools are shown on to the developer of the electric buses. Many reports has been created for the electric bus component suppliers and this situation can enumarable as most important contribution of this study.

Acknowledgements

This work was supported by the TEMSA Global A.S. We thank our volunteer participants who kindly donated their time and shared pearls of their wisdoms. We are also immensely grateful to TEMSA R&D Center for their valuable contributions to the researches and improvement of new designs.

Nomenclature

- **EV :** Elecric Vehicle
- **AVs :** Autonomous Vehicles
- **CAN :** Controller Area Network
- **GPS :** Global Positioning System
- **TCP :** Transmission Control Protocol
- **LDM :** Longitudinal Vehicle Dynamics Model
- **HV :** High Voltage
- **APIs :** Application Programming Interfaces

References

[1] JEON J., LEE W., CHO H.Y., LEE H., 2015. "A Big Data System Design to Predict the Vehicle Slip", 2015 15th International Conference on Control, Automation and Systems (ICCAS 2015) Oct. 13-16,2015 in BEXCO, Busan, Korea.

[2] NAJDA H. A., Mahgoub I., 2016. "Autonomous Vehicles Safe-Optimal Trajectory Selection Based on Big Data Analysis and Predefined User Preferences", Florida Atlantic University, 2016 IEEE.

[3] QUI R.G., WANG K., Lİ S., DONG J., XIE M., 2014. "Big Data Technologies in Support of Real Time Capturing and Understanding of Electric Vehicle Customers Dynamics", IEEE 2014.

[4] LEE C.H., WU C., 2015. "Collecting and Mining Big Data for Electric Vehicle Systems Using Battery Modeling Data", 2015 12th International Conference on Information Technology - New Generations.

[5] SOARES J., BORGES N., CANIZES B., VALE Z., 2015. "Probabilistic Estimation of the State of Electric Vehicles for Smart Grid Applications in Big Data Context", GECAD – Knowledge Engineering and Decision-Support Research Centre Polytechnic of Porto (ISEP/IPP), 2015 IEEE.

[6] LEE C., WU C.H., 2015. "A Novel Big Data Modeling Method for Improving Driving Range Estimation of EVs", Electrical Engineering Department, National Kaohsiung University of Applied Sciences, Kaohsiung 807, Taiwan, 2015.

[7] MAO M., YUE Y., CHANG L., 2016. "Multi-time Scale Forecast for Schedulable Capacity of Electric Vehicle Fleets Using Big Data Analysis", Hafei University of Technology, HeFei 23009, China, 2016 IEEE.

[8] BARON B., SPATHIS P., RIVANO H., AMORIM M., 2014. "Vehicles as big data carriers: Road map space reduction and efficient data assignment", UPMC Sorbonne Universites, 2014 IEEE.

[9] BERNARD MARR, 2015, "Using Smart Big Data, Analytics and Metrics to Make Better Decisions and Improve Performance", 2015, John Wiley & Sons Ltd

[10] Zadrozny, Peter, Kodali, Raghu, "Big Data Analytics Using Splunk Deriving Operational Intelligence from Social Media, Machine Data, Existing Data Warehouses, and Other Real-Time Streaming Sources", 2013

[11] Operational Intelligence, Log Management, Application Management, Enterprise Security and Compliance

[12] Splunk, http://www.splunk.com/

[13] Mathworks, https://www.mathworks.com/help/nnet/

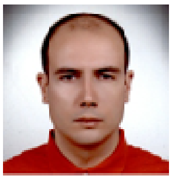
Authors

Emrah Yirik received his BSc and MSc degrees in Electrical and Electronics Engineering (EEE) from Çukurova University in 2006 and 2013 respectively. His research interests are automotive electronics, Controller Area Network (CAN) and embedded software programming. He is working as section manager in an automotive company in Adana.

Umut Irmak received his BSc and MSc degrees in Electrical and Electronics Engineering (EEE) from Çukurova University in 2006 and 2010 respectively. His research interests are automotive electronics, power electronics and automation. He is working as R&D engineer in an automotive company in Adana.

Cagla Dericioglu received her BSc degree in Electrical and Electronics Engineering (EEE) from Çukurova University in 2015. Her research interests are automotive electronics, power electronics and electric vehicles charging system. She is working as R&D engineer in an automotive company in Adana.

Erdem Unal received his BSc degree in Electrical and Electronics Engineering (EEE) from Middle East Technical University (METU) in 2015. His research interests are computer architecture, software developping and power electronics. He is working as R&D engineer in an automotive company in Adana.



Assist. Prof. Dr. Mehmet Ugras Cuma received his BSc, MSc and PhD degrees in Electrical and Electronics Engineering (EEE) from Çukurova University in 2004, 2006, and 2010 respectively. His research interests are power quality, power quality devices and microcontroller applications. He is presently Asst. Prof. Dr. in EEE Department of Çukurova University. He has worked in several research projects supported by Scientific and Technological Council of Turkey.