Battery Electric Vehicle Range Estimation Tool Part 3

STUDENTS: Evan Murphy, Aryaman Tandon, Saad Syed, Felix Tse, Kandai Shimada

Problem Statement

This project requires a Range Estimation tool for PACCAR's Battery Electric Vehicles (BEVs) that can accurately estimate range while accounting for variability of real-world driving factors in addition to the battery being the sole source of power for all BEV components. This tool would reduce range anxiety among truck drivers by providing an accurate range estimation tool for PACCAR BEVs.

Figure 1: PACCAR BEV Truck

Approach

Vehicle dynamics were used to develop a physics-based equation for range estimation. Utilizing previous capstone work and PACCAR drive cycle data as a baseline, the model has been integrated with machine learning (ML) algorithms to further compensate for discrepancies between model predictions and ground-truth data.

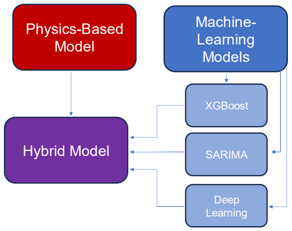

Figure 2: Flowchart of Approach

Physics-Based Model

- The physics model utilizes the **road-load equation** as described in [1], which quantifies all the forces that effect a vehicle during operation.

$$F_{total} = F_{aero\ drag} + F_{RR} + F_{accel} + F_{grad} + F_{brake}$$

- BEV **Power Consumption** and **Energy** is calculated by:

$$P_{traction} = F_{total} \cdot v_{bev}$$

$$Energy\ Consumption = \int P_{traction}$$

Model Inputs:
Velocity, Altitude

Output:
Power Consumption (see **Fig. 4**)

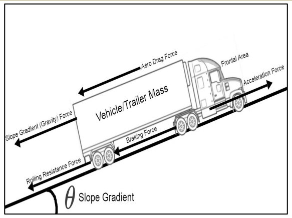

Figure 3: Forces and Parameters That Effect Power Consumption

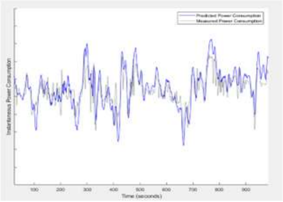

Figure 4: Model Prediction Comparison

Machine Learning Approach

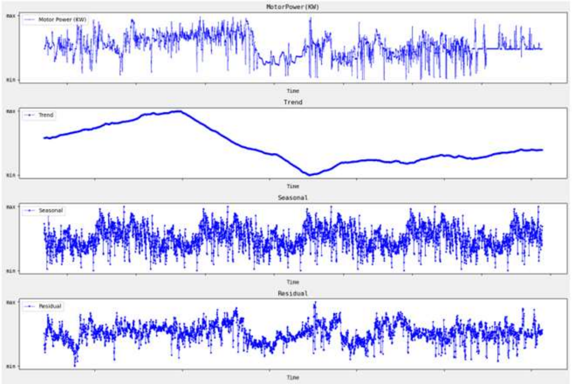

Figure 5: Time-Series Decomposition

- ML algorithms identify and improve circumstances of inaccuracy in the physics-based range estimation, significantly enhancing accuracy adapting in real-time to data variations.
- ML Models Used:
  1. **XGBoost** (boosting algorithm),
  2. **SARIMA** (statistical model)
  3. **Transformers** (advanced deep learning architectures).

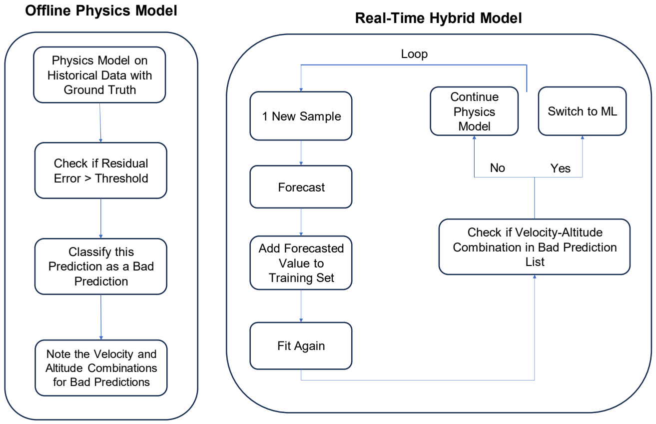

Figure 6: Hybrid Model Decision Flowchart

GUI Interface

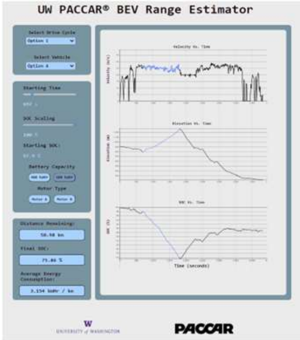

Figure 7: Range Estimator Web Application

- Hosted in web browser, developed using HTML, CSS, JavaScript, and D3.js (dynamic visualization).
- There is no end-user model calculations, references preprocessed data from the model.
- Starting time, SOC, and other parameters can be selected by the user.
- Highlights the region of the drive cycle that can be completed given these parameters.
- Also displays final SOC, average energy consumption, and distance remaining in the route.

Conclusion

- RMSE values were used as metrics to determine which model provides the most accurate range estimation.
- Multiple models were developed based on maximizing efficiency, computational power, and accuracy.
- **ML has halved the RMSE** of the initial physics-based model, a substantial increase in prediction accuracy.
- Hybrid model provides accurate range estimations for electric trucks, significantly benefiting PACCAR by enhancing the reliability and efficiency of their electric fleet.

Winner: XGBoost Hybrid |Top Accuracy: 90.4 | Least Computation: <1s

Type of Model	Physics Model	XGBoost Only	SARIMA Only	Deep Learning Only	XGBoost Hybrid	SARIMA Hybrid	Deep Learning Hybrid
RMSE	152.7	9.2	158.3	130.6	90.4	131.1	120.1
Training Time (s)	-	0.18	220.24	76.55	0.18	19.24	76.55

Table 1: RMSE Values and Training Time of Several Approaches

Future Work, References, and Acknowledgments

- Utilize Google Maps data to generate drive cycles/consumption predictions between any two destinations.
- Perform live power consumption predictions with our model/GUI hosted on the cloud.

[1] C. Fiori, K. Ahn, and H. A. Rakha, "Power-based electric vehicle energy consumption model: Model development and validation," *Applied Energy*, vol. 168, pp. 257-268, 2016. doi: 10.1016/j.apenergy.2016.01.097

Special thanks to our industry mentors Satvik Khuntia and Shweta Hardas, faculty mentor Dr. David B. Laning, and TA Amisha Somaiya. Their guidance and mentorship in this project made it into what it is today.

ELECTRICAL & COMPUTER ENGINEERING
UNIVERSITY *of* WASHINGTON

ADVISERS: DR. DAVID B. LANING, SATVIK KHUNTIA, SHWETA HARDAS, AMISHA SOMAIYA

SPONSOR: PACCAR