BATTERY ELECTRIC VEHICLE (BEV) RANGE ESTIMATION TOOL

STUDENTS: Dylan Denq, Yang Li, Franky Lin, Yijia Lu, Xinwen Liu, Xiaohan Zhang

Project Background

- With multiple new BE powertrains under development, there is an urgent need to optimize component sizing and select the right configuration for different real-world vehicle applications.
- Accurate estimation of the range of a BEV based on different configurations is critical for the successful adoption and integration of electric vehicles into our daily lives.
- It is also important to have a graphical user interface in place due to the necessity of data visualization and interactivity.

Kenworth K270E/K370E Battery Electric Trucks

Common Digital Dashboard Display of Range Estimation on Electric Vehicles

Energy Consumption Prediction

- According to last year's capstone project sponsored by PACCAR, an equation obtained from machine learning model has been proposed to predict energy consumption of vehicles.

$$P_{road} = \frac{1}{2} * \rho * C_{D*}FA * v^3 + RRC_0 * M_{veh} * g * v + M_{veh} * v * \frac{dv}{dt} + M_{veh} * g * \frac{dh}{dt}$$

Terms	Coefficients	Estimated Coefficient	Variable
Aero resistance term	Air density (ρ) drag coefficient (Cd) Frontal Area (FA)	$0.5 * 1.225 \frac{kg}{m^3} * 0.67 * 8.052(m^2) * v\left(\frac{km}{hr}\right)^3 * \left(\frac{1}{3.6^3}\right) = 0.0706$	Velocity(v)^3
Rolling resistance term	Rolling resistance coefficient (RRC0) Mass of vehicle (M_{veh}) gravity(g)	$0.87\left(\frac{kg}{ton}\right) * \frac{1}{1000} * 11794kg * 9.8 * \frac{v}{3.6} = 27.93$	Velocity(v)
Acceleration term	Mass of vehicle (M_{veh})	909	Velocity(v)*Acceleration(dv/dt)

Range Estimation Equation

Based on the model developed last year, we further developed range estimation equation as shown:

- C_{rr} is Coefficient of Rolling Resistance, typical value for passenger cars ranges from 0.012 to 0.016.
- C_d is Coefficient of Drag, typical value for passenger cars ranges from 0.2 to 0.4.
- rho is Air Density, represents the density of air at sea level and at a standard temperature of 15°C (59°F)

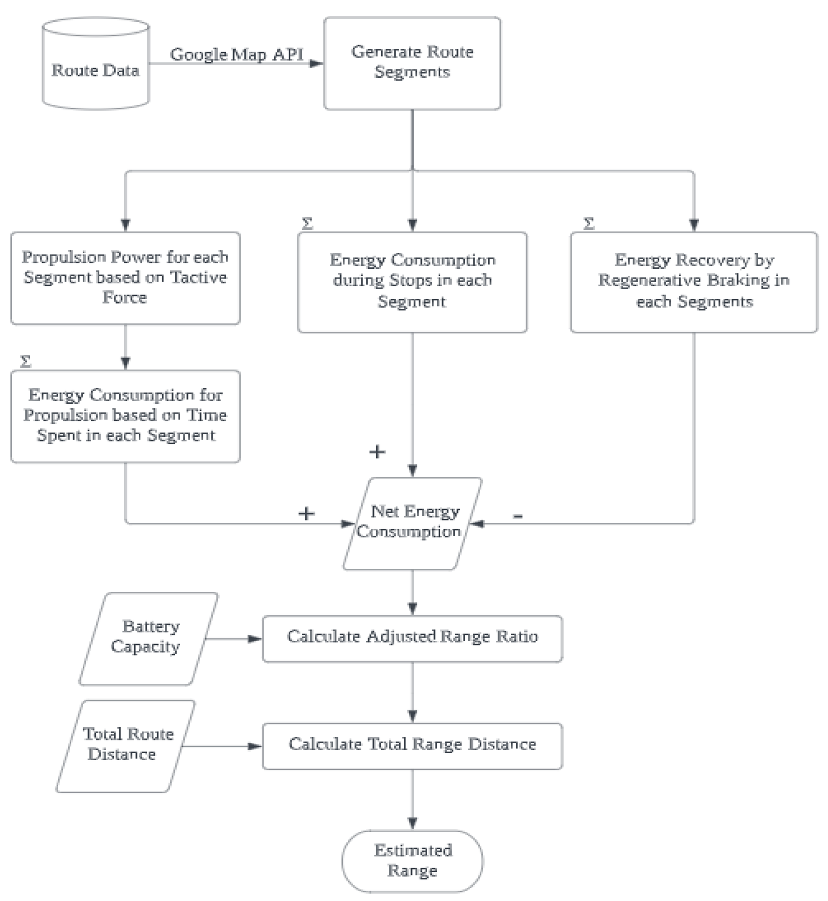
$$F_{rolling} = Crr * M_{total} * g$$
$$F_{air} = \frac{1}{2} Cd * A_{frontal} * rho * v_{max}^2$$
$$F_{grade} = M_{total} * g * sin(angle_{rad})$$
$$P_{rquired} = (F_{rolling} + F_{air} + F_{grade}) * v_{max}/100$$
$$E_{stop} = P_{stop} * t_{stop} * N_{stop}$$
$$E_{recovery} = E_{stop} * P_{braking}$$
$$E_{net} = \sum P_{rquired} * t_{driving} + E_{stop} - E_{recovery}$$

The estimated range is calculated as a ratio indicating how many times the battery could support the truck to operate on the route. For example, 0.5 tells that the truck, with the current battery configuration, can only travel half the distance.

$$\mathbf{R_{range}} = C_{battery}/E_{net}$$
$$\mathbf{E_{perhour}} = E_{net}/t_{total}$$
$$\mathbf{S_{truck}} = S_{total}/times$$

Algorithm Workflow

1. Fetch segment parameters based on route, including distance (km), number of stops, and road slope.
2. Iterate through each segment and calculates energy consumption based on:
   - Grade resistance for each segment based on the slope and total weight.
   - Total tractive force as a sum of rolling resistance, aerodynamic drag, and grade resistance.
   - Power for propulsion in each segment.
   - Energy consumption for each segment based on power required and time spent.
3. Energy consumption during stops in each segment.
4. Energy recovery due to regenerative braking in each segment.
5. Sum up total net energy consumption.
6. Divide battery capacity to get range ratio.
7. Calculate total range distance by multiplying total route distance.



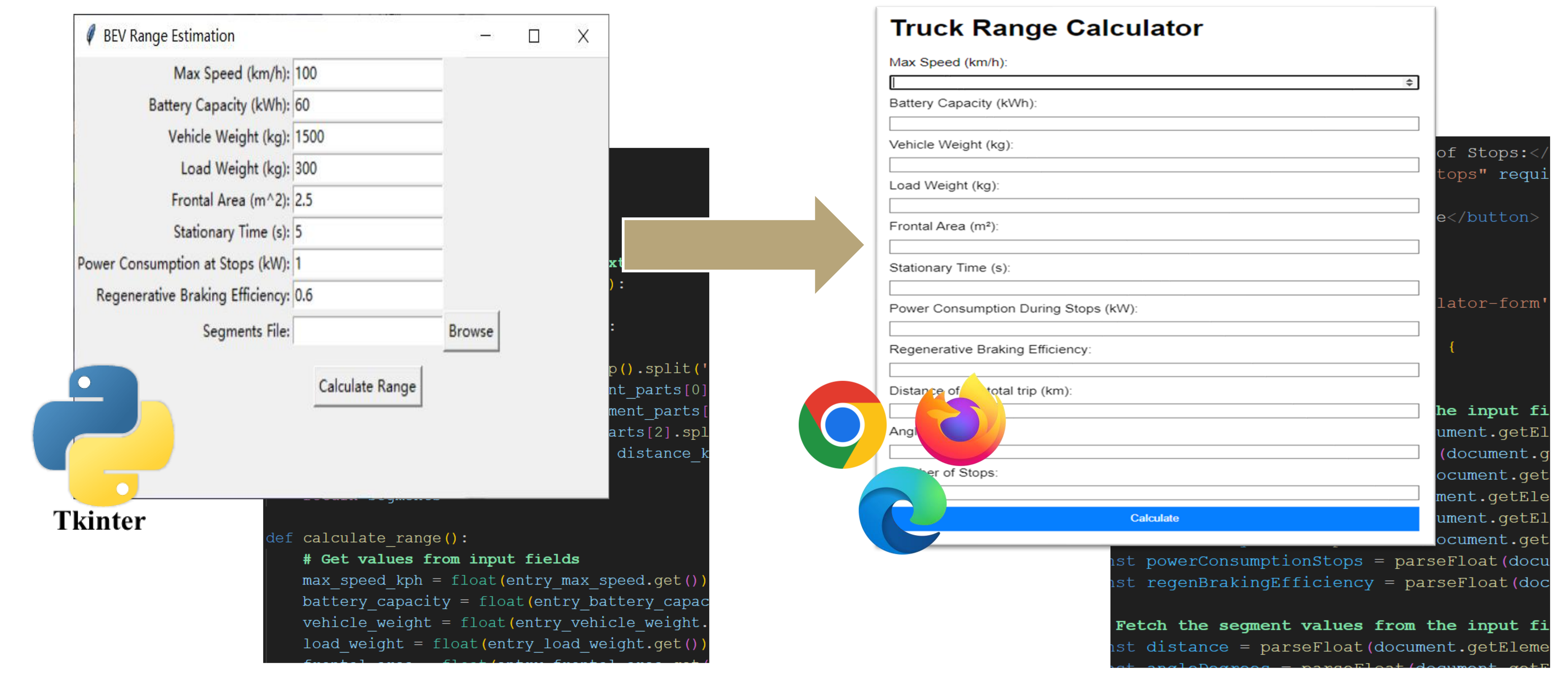
Test & Verification

	15 mph	20 mph	25 mph	30 mph	35 mph	40mph	45 mph	55 mph
Relative Accuracy	92.955%	*N/A	77.422%	67.953%	66.092%	67.115%	72.251%	95.253%

The average testing accuracy of the model on real-world datasets provided by PACCAR is 76.856%. We can see that our model performs well in low and high-speed scenarios.

Graphical User Interface Design & Implementation

- The algorithm for range estimation is programmed as a Python script and a *Tkinter* (Python's de facto toolkit) based GUI was embedded for initial prototype of the tool.
- Meanwhile, a Python based segment generator is developed to grab route data through Google Map API and formulated it into data files for the use of range calculation.
- The Python programs are considered as the calculator engine.
- In the next steps, we developed the HTML version of it for potential web hosting to enhance the accessibility of the tool.
- https://faculty.washington.edu/dblaning/bev_paccar/bev_paccar_range_estimator.html

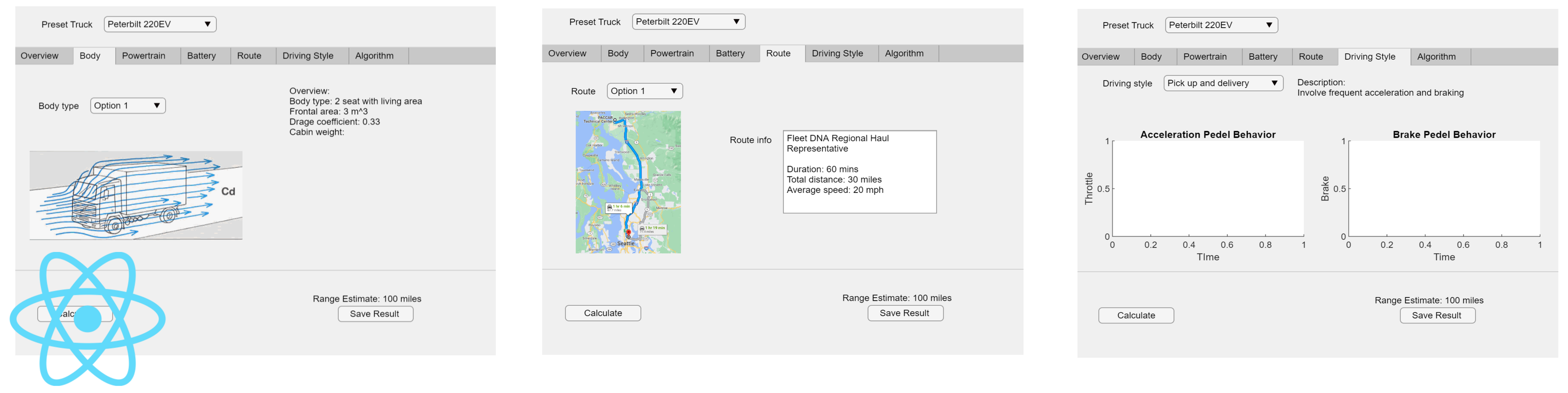


Future Work and Acknowledgments

For future work, we have several directions in mind to improve this range estimation tool.

Testing & Algorithm Validation: With real-world collected data, we can test and improve our existing algorithm to make it more accurate. For instance, in our current algorithm, the stationary time is set to a constant value. However, we believe that there should be a better way to calculate live stationary time as the driver is operating the vehicle.

GUI Upgrade: Due to the time limitation of the project, the GUI implemented is quite naïve. At the beginning of this project, we proposed conceptual React based GUI sketches with integrated functionality design as follow. We plan to implement the React based GUI and migrate the current calculator engine to it for better usability, responsive design and platform independence.



Sincere thanks to our industry mentor, Nick Hertlein and faculty mentor, Prof. David B Laning for their invaluable guidance. Also, thanks to PACCAR INC, University of Washington and ECE department for the supportive learning environment.

ELECTRICAL & COMPUTER ENGINEERING
UNIVERSITY of WASHINGTON

ADVISERS: Nick Hertlein (PACCAR), Prof. David B Laning (UW)

SPONSOR: PACCAR INC, ELECTRICAL & COMPUTER ENGINEERING DEPARTMENT, UNIVERSITY OF WASHINGTON