Electric Vehicle Simulation and Animation

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Abstract
Range anxiety is a chief concern for all electric vehicles (EVs). Range anxiety summarizes the fear of being stranded in an electric vehicle due to insufficient battery. Therefore, we need a way to simulate and animate use and charging of battery for electric vehicles to assure users of the range of EVs. The application we designed can provide simulation and animation of EVs energy use and charging based on the physical characteristics of specific vehicles, terrain information, and driving route information. The application can accurately predict the range, energy use, and energy costs of these vehicles. Simulation can provide comparison of different models of EVs in terms of energy use, cost, and range. Moreover, our simulation can assist deployment of charging stations. Animation offers an overall picture of what is occurring while driving and charging an electronic vehicle on Google Earth and Google Map.

1. INTRODUCTION

The demand for transportation worldwide is constantly increasing. Meeting this demand with traditional modes of transportation powered by fossil fuels is challenged by both environmental concerns and the rising cost and limited supply of petroleum. The need for alternative fuel vehicles is higher than ever, and perpetuation of the implementation of alternative-fuel transportation is a top priority for the current governments of many countries. Electric vehicles represent efficient, emissions-free transportation that can assist in meeting the goals of long-term emissions reduction and help to lower the world's dependence on petroleum. This is true of both regulated ("criteria") emissions and greenhouse gas emissions. Electric is a very mature transportation technology, having been used in the vehicles since the early 1900's. Electric cars have comparable acceleration and top-speed performance to gasoline and diesel powered equivalents, but have a more limited range. Electrically powered mass transit solutions, however, do not have comparable performance characteristics to their traditional counterparts. Electric buses and shuttles also have the added challenge of peak power production. Electric buses and shuttles must be designed with this in mind, and proper batteries, drive systems, and routes selected. Electric buses have additional benefits such as quiet operation and zero tailpipe emissions, highly desirable attributes for urban, campus, and medical center applications involving substantial pedestrian activity and/or noise- and emission-sensitive populations.

Our developed technique and tool can assist decision makers in predicting the power needs of EVs and help in determining the best locations for charging stations. The simulator relies on vehicle data such as weight, battery and charging properties, surface area, and acceleration characteristics provided by vehicle manufacturers. It uses this information in conjunction with road information and driving route calculation from the Google Maps service [1], and altitude data from the United States Geological Survey

(USGS) Seamless Elevation data service [2]. The three-dimensional (3-d) animation is accomplished using the Google Earth [3] plug-in which is complemented by a two-dimensional (2-d) view using Google Maps. Charts and gauges show the energy level, energy level history, current speed, and altitude information. The simulator is currently in early stages of development, and a working model is currently in beta testing.

1.1 Vehicle Specifications

Our tool can simulate energy consumption of various electric vehicles with given specification. The electric vehicle shown in Table 1 is a sample we used to measure energy consumption. This electric vehicle is powered by an AC Inductive Drive System with Direct-Drive and Regenerative Braking. The data logger shown in the foreground was used to record the energy restored to the vehicle during charging.

Table 1 Vehicle Specifications

Curb Weight	2460 lbs	1116 kg
Length	164 inches	4.16 m
Width	70 inches	1.78 m
Height	56 inches	1.42 m
System Power	42 kW	42 kW
Drag Coefficient	0.31	0.31
Top Speed	70 mph	112.6
Specified Efficiency at 45 mph (72.5 kph)	137 W/mi	85.1 W/km
Specified Range @ 45 mph (72.5 kph)	50 miles	80.5 km
Acceleration 0 to 50 mph (80 kph)	18 seconds	

The vehicle is powered by thirteen (13) gel-type 12 volt lead acid batteries rated at 86.4 Ah each, which results in a capacity of 13.4 kWh at 100% State of Charge (SOC) when in new condition. Current condition of the batteries was determined to be such that a 100% SOC represents approximately 9.8 kWh of useable energy. The vehicle is equipped with an on-board charger rated at 1.5kW/110V AC.

1.2 Energy Consumption and Cost.

Energy consumptions models are developed from first principles of mechanics and known vehicle parameters. These are combined with digital maps and topographical date through data fusion methods to produce a user friendly animated three-dimensional simulation that can be programmed to emulate the driving experience. To predict energy use, standard physics formulas used are:

$$P_{Inertia} = m * \frac{\Delta v^2}{2\Delta t}$$

$$P_{Hill} = v * m * g * \frac{\Delta e}{\Delta d}$$

$$P_{Roll} = \mu * v * m * g * \frac{\Delta h}{\Delta t}$$

$$P_{Drag} = \frac{\rho}{2} * v^3 * C_d * A_f$$

v: current speed
m: vehicle mass
g: gravity
e: elevation
d: distance over land
h: distance horizontal
µ: rolling resistance
ρ: air density
C_d: coefficient of drag
A_f: vehicle frontal area
t: time

Raw input for these formulae come from vehicle manufacturers, elevation data from the USGS, and road information from the Google Maps service. The simulator refines the data by taking into account acceleration behaviors, peak power outputs, and terrain conditions such as steepness of ascent or descent.

2. SIMULATION AND EV EVALUATION

We simulated energy use of aforementioned EV during driving and charging phases with source, intermediate, and destination addresses from user input. Power levels, speed, and vehicle status are represented on a dashboard-type display within the simulator. For this particular run of the simulator, our dashboard in Figure 1 indicates current energy (11.13kWh), driving duration (19.25 minute), current altitude (309 meters), driving distance (3.9 miles) and current speed (10.9 mph), and current status (maintaining speed) of the electric vehicle.

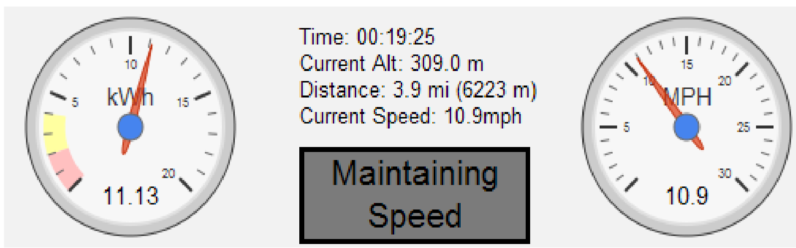

Figure 1 Dashboard

The saw tooth pattern represented in the energy chart in Figure 2 (a) shows the depletion of energy as a vehicle runs a continuously looped route, and the increase in energy level as the vehicle takes on a charge at the completion of each route. The curve in Figure 2 (b) represents change of altitude from source to destination addresses which are retrieved from USGS in real-time.

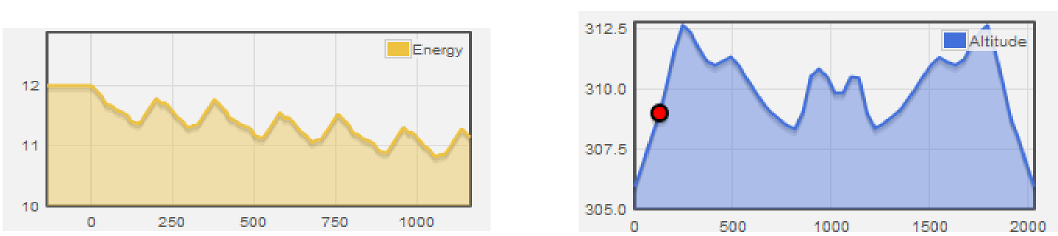

Figure 2 (a) Energy Chart (b) Altitude Chart

Since altitude is changing during driving of a vehicle, our simulation considers change of elevation. The energy required to climb a hill can be estimated as the product of vehicle weight and change in elevation.

2.1 Range Predication

By calculating the power use of specific electric vehicles along custom user-entered routes, our simulator provides the very important functionality of range prediction. The simulator is designed to allow for dynamic inputs. Routes are specified by the end user selecting starting and ending locations, and several waypoints in between. Charging stations along the route can be specified, and in the case of mass transit vehicles, passenger loading stops may also be identified. The simulator predicts the energy use of the vehicle along the chosen route, taking into account the charging and loading stops. This allows the user to know such things as how many times an EV can run a route prior to requiring a full charge, or how far along an interstate an electric vehicle can travel before depleting its batteries.

One potential application of the simulation model would be to autonomously select every possible route from a single point of origin, and calculate the range extents from this point and represent them visually. This would be highly useful to electric vehicle infrastructure planners who must make the decisions of where to locate charging stations.

2.2 Comparison between Electronic Vehicles

By allowing for vehicle input from the end-user, the simulator can effectively compare the energy use characteristics of multiple vehicles along the same routes. This functionality is highly useful to individuals such as transportation officials who must select a particular bus for a planned electric shuttle route, or as a tool for consumers to see which electric vehicle might most ideally suit their purposes.

3. ANIMATION ON GOOGLE MAP AND EARTH

One shortcoming of many vehicle simulation programs is the detachment from the actual route being driven. By combining our simulator with an animation component, the end-user can see the energy-use behavior of a vehicle while watching it traverse the route virtually.

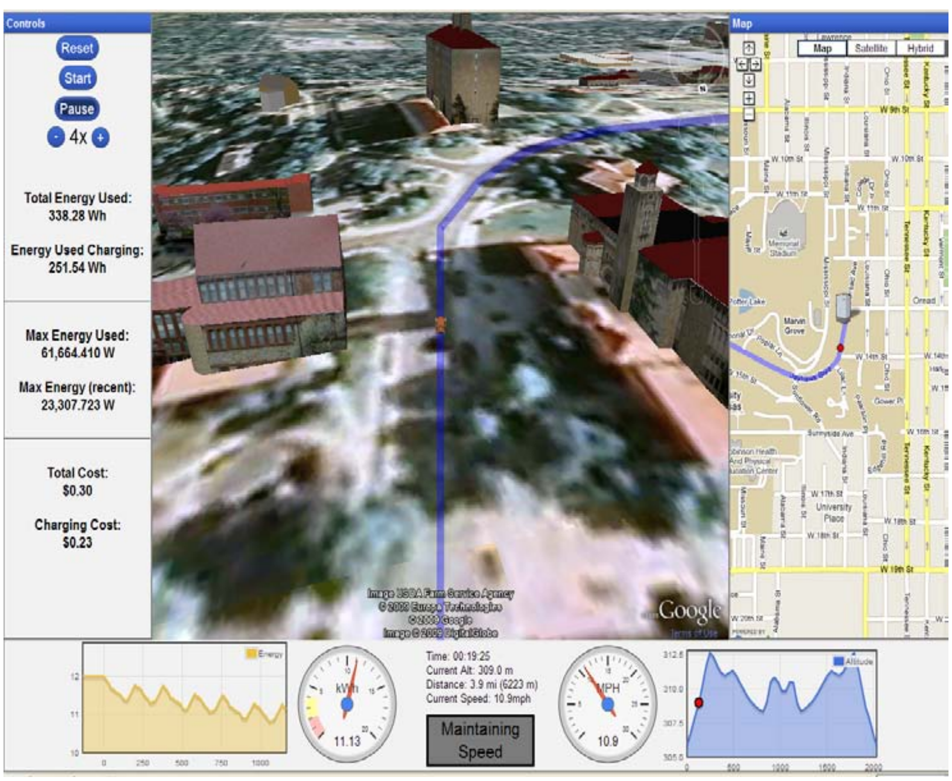

Figure 3. Animation and Simulation of an Electric Car

Figure 3 above shows a vehicle travelling on a route through the University of Kansas, where 3-d images of campus buildings designed by users of Google Earth can be seen. Google Earth's 3d terrain and building imagery provide a bridge between the numerical data generated by the simulator and the actual route that is being traversed. The 2-d map adds an overhead perspective for easy location tracking of the vehicle. The current location of the vehicle is also represented on the altitude graph, so current elevation gradient can quickly be seen. Figure 4(a) is a screenshot of driving on 3d Google Earth, and Figure 4(b) is a screenshot of driving on 2d Google Map. Both of them can take user input on waypoints information between the starting location and the final destination. Users can input location of charging stations as well.

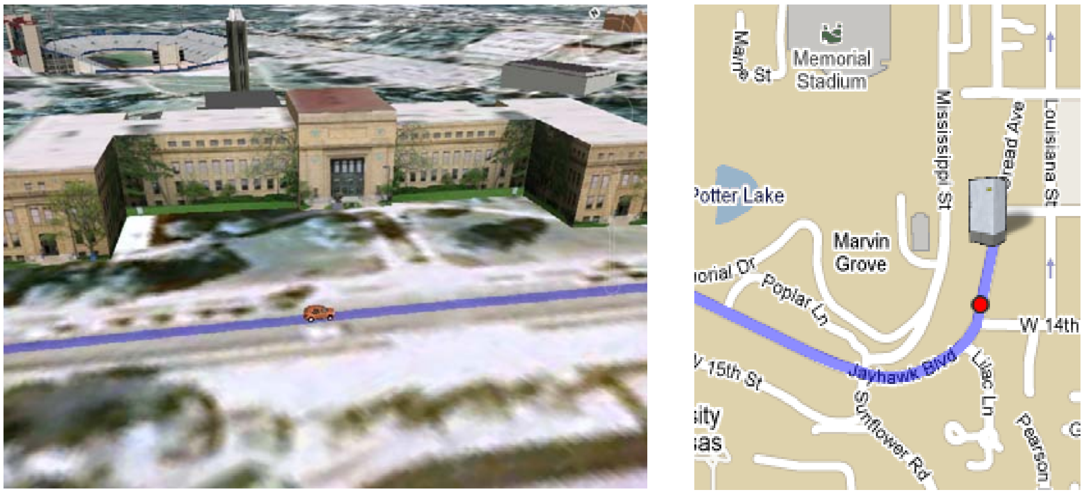

Figure 4. (a) Driving on Google Earth   (b) Driving on Google Map

4. ESSENTIAL FEATURES AND PROMISING APPLICATIONS

Our simulator can find its application in multiple fields such as sales tool, EV performance evaluation, range prediction, and charging station deployment.

Firstly, the simulator would serve as a *Sales Tool* to demonstrate to potential electric vehicle buyers how well an electric vehicle would suit their daily lives. Potential buyers would be able to see how far their electric vehicle would be able to take them on a single charge and how far they would be able to drive using the area’s existing charging infrastructure. Custom simulations could be run that demonstrate the vehicle’s performance on routes from the potential buyer’s home to their place of work, recreational destinations, and other common driving points. This simulation provides a tool that a potential owner of single electric vehicle or a fleet of electric vehicles can use to simulate daily use. The potential customers can be able to access the application through the manufacturer’s website as well.

Secondly, manufacturers of electric vehicles would be able to use this simulator to *evaluate the performance* of their vehicles along routes with varying elevation, speeds, and driver behaviors. This information would be useful in planning charging station infrastructures as well helping the manufacturers judge the feasibility of their vehicle in various regions.

Thirdly, integration of the simulator's underlying model into in-car GPS units would allow for more accurate *real-time range prediction* than is currently possible in systems not created for electric vehicles that do not rely on elevation and physical car data for their calculations.

Finally, this simulator can help *deploy commercial charging stations*. This simulation model can be used to validate the strategic placement of all the commercial charging stations that will be deployed in and around a given city as part of the electric vehicle infrastructure project.

During development, the feasibility, accuracy, and marketability of potential applications of the vehicle simulator will be carefully examined. An accurate model will assist potential electric vehicle buyers in making purchasing decisions, as well as helping manufacturers to plan infrastructure and increase consumer awareness of the performance of their products.

4. CONCLUSION

We developed a user friendly simulator with a graphical interface that allows the user to draw a route on Google Map with given starting point (e.g. home address) and a series of destinations or way points representing perhaps a regular travel routine. The simulation will then play back a "movie" showing the three dimensional movement of the vehicle over the planned route, with on screen indicators for distance traveled, elapsed time, SOC for the battery, etc. The location of commercial charging stations will be included so the user can include simulated recharging stops as needed along the way.

REFERENCES

[1] Google Map: http://maps.google.com/
[2] United States Geological Survey: http://www.usgs.gov/
[3] Google earth: http://earth.google.com/