Practical Estimation of Rolling Energy of an Electric Vehicle using onboard GPS

Abdelhak Boudallaa, Mohammed Chennani, Karim Rhoufir and Driss Belkhayat

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Abdelhak BOUDALLAA [+2126-1428-2655] Mohammed CHENNANI [+2126-6657-1597]

Karim RHOUFIR [+2126-6776-4210] Driss BELKHAYAT [+2126-6119-3111]

Technical Science and Engineering Laboratory ENSA KHOURIBGA
Soultan Moulay Slimane University, Morocco
Electrical Systems and Telecommunication Laboratory
Cadi Ayyad University Marrakesh, morocco
boudallaa.abdelhak@gmail.com
medchennani@gmail.com
k.rhofir@gmail.com
d.belkhayat@gmail.com

Abstract.
In this paper, we have developed a practical model for measuring GPS data (i.e. latitudes, longitude, altitude and speed as well as time) during the movement of a vehicle between two geographical points in Morocco. These measures are taken between Marrakech and Safi as well as Safi and Rabat. This data will be used to estimate the power required for this movement using an onboard GPS controlled by an Arduino Mega. For electric vehicles, it is essential to know as much as possible about the current traffic situation so as not to drain the battery. To this end, knowledge of estimated energy consumption is much more relevant than knowledge of average travel time. This paper aims to provide a literature review of current energy consumption patterns and adapts current dynamic traffic information to electrical conduction.

Keywords: Matlab, Simulink, Electrical Vehicle, Energy Estimation, Arduino Mega, Onboard GPS, Memory Card.

1 Introduction

Electric vehicles (EVs) have been considered as a very promising alternative to conventional vehicles for reducing greenhouse gas emissions from transportation. However, the relatively short autonomy of most commercialized electric vehicles limits their effectiveness. Before the energetic density increases significantly, the improvement of the global efficiency of the power train of electric vehicles constitutes an economic and practical means allowing an increase use electrical vehicles. At the same time, the efficiency of the powertrain for electric vehicles reduces electrical energy consumption. Multi-speed transmissions have been widely used in traditional internal combustion engine vehicles for two reasons. Firstly, multi-speed transmissions offer better dynamic performance for vehicles, (i.e. higher maximum speed, faster acceleration and smooth start). Secondly, this allows the vehicles to function with high efficiency thanks to a gear shifting operation, which reduces fuel consumption. However, there are few commercially available electric vehicles equipped with a multi-speed transmission powertrain. The electric engine is capable of delivering a constant maximum torque from zero to base speed, and increasing rotation speed. As a result, the one-speed transmission is capable of providing a satisfactory response. On the other hand, the mass, volume, losses and cost of the transmission can be effectively reduced by using a central motor drive equipped with a one-speed transmission, which constitutes an economical solution. Research and development in the automotive field enables technical progress to be made in order to reduce vehicle consumption and consequently CO2 emissions. The four main areas of research focus on**:** conventional and alternative fuels; emission control systems for reducing exhaust emissions; engines (thermal, electric, hybrid, and fuel cell); accessories (air conditioning, tires, lightening, noise).We are interested in electric vehicles and more particularly in the dimensioning of powertrain components.[1, 2]

Our work consists in estimating the energy required as well as the autonomy on practical distances using an onboard GPS module controlled by an Arduino Mega card. The first concerns the acquisition of data, i.e. the position of the vehicle on the road and its speed to meet a specific mission or use. It seems obvious, for example, that an urban-type private vehicle does not have the same needs and characteristics as a delivery van or a vehicle delivering mail in the mountains. The idea is therefore to take into account the actual mission of the vehicle in order to optimise the dimensioning of the powertrain chain, rather than to set prior performances (maximum speed and acceleration, range, etc.). The second objective is to model the vehicle on the road in order to develop the different forces applied to the vehicle as well as their effects on the energy consumed. The final objective is to estimate the power required to travel a specific road.[3]

2 Powertrain chain

The wheels are connected to the induction machine to ensure mechanical transfer (Fig. 1). This motor is powered by a three-phase inverter, which transfers direct current to alternating current. The direct current comes from a DC-DC converter powered by rechargeable batteries [4].

Several types of traction chains have been developed to motorize vehicles:

- Internal combustion vehicle;
- Hybrid vehicle;

• Plug-in hybrid vehicle, or "plug-in";
• Electric vehicle (EV).

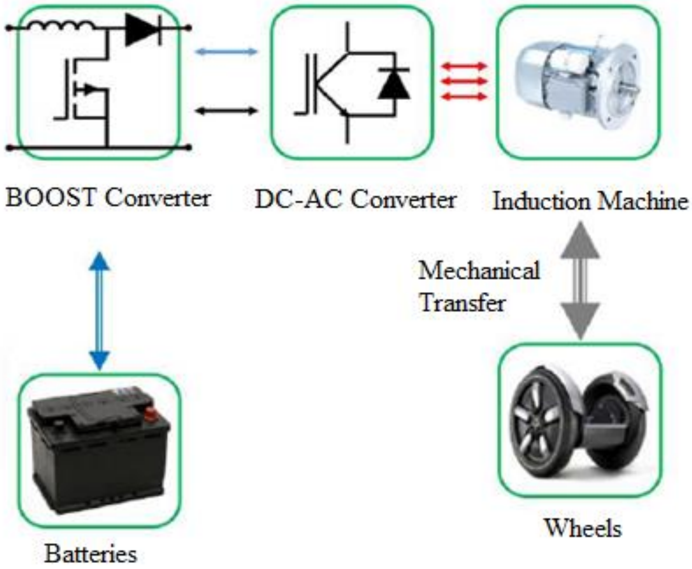


Fig. 1: Energy conversion Chain

3 Experimental model

The assembly of the figure (Fig. 2) shows the different components used to locate the vehicle on the road with acquisition of the different parameters. (Longitude, Latitude, Altitude, Speed and Time)

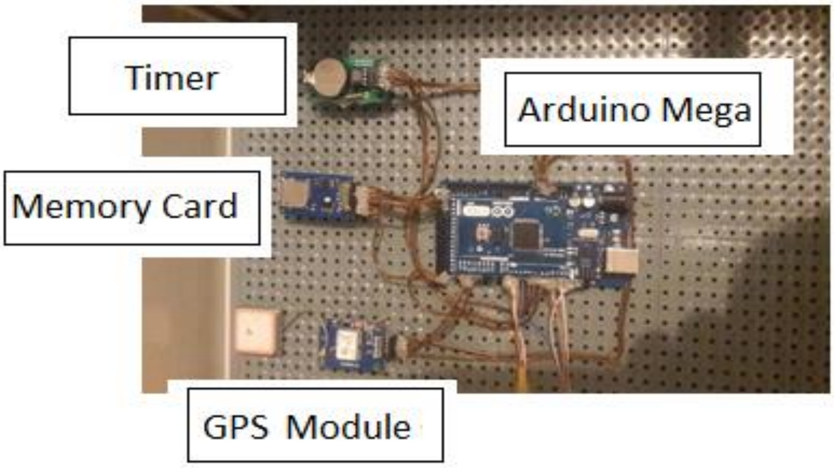


Fig2: Experimental model

The practical model consists mainly of the Arduino Mega, onboard GPS module, SD memory card module and time module. This assembly allows the acquisition of GPS data (altitude, longitude, latitude, speed and time). This data is used to estimate the power required to move the vehicle over a well-defined road, taking into account the actual driving conditions (i.e. driving speed, acceleration, deceleration, stopping and starting).

Table1: Recorded data:

LATITUDE	LONGITUDE	ALTITUDE	SPEED (Km/h)	Time Date
32.29699	-9.214521	113.9	0	14:18:53 13.05.2019
32.29787	-9.213886	113.9	28.55784	14:19:08 13.05.2019
32.29842	-9.213513	113.7	28.55784	14:19:24 13.05.2019

4 Vehicle modeling on the road

The vehicle model makes it possible to estimate the torques and the speeds required from the wheels in order to be able to follow a speed profile as a function of time. Fig. 3. diagrams the forces applied to a vehicle:[1, 5]

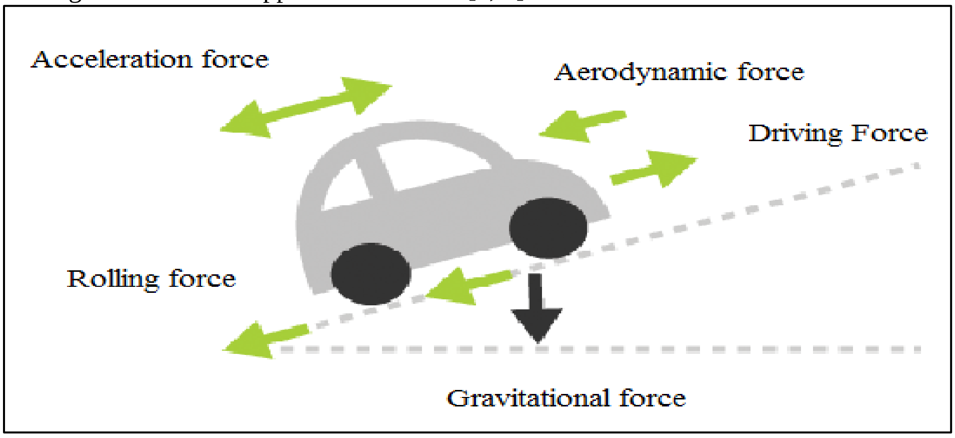


Fig3. Forces applied to a vehicle

The forces applied to the vehicle consist of:

- Force linked to aerodynamic resistance (**F_{aer}**) ;
- Tire rolling resistance force (**F_{roul}**) ;
- Force related to the slope of the road (**F_{pente}**) ;
- Force related to vehicle acceleration (**Facc**).

According to Newton's second Law, the acceleration of the vehicle can be written as[6]:

$$\frac{dV}{dt} = \frac{\sum F_t - \sum F_{tr}}{\delta M_V} \quad (1)$$

$$F_{aer} = sig(V_{veh})\frac{1}{2}\rho S_f C_x (V_{veh+}V_v)^2 \quad (2)$$

$$F_{roul} = sig(V_{\_veh}) Crr. M_{veh}. g \quad (3)$$

$$M_{veh} = M_{veh_{vide}} + M_{charge} + M_{trans} + M_{mot} + M_{ond} + M_{batt} \quad (4)$$

$$F_{pente} = M_{veh}. g. \sin(\alpha(t)) = M_{veh}. g. p_{e\_moyenne} \quad (5)$$

$$F_{acc} = \delta. M. a \quad (6)$$

$$P_v = C_T. \Omega_{roue} \quad (7)$$

$$\begin{cases} C_T = F_T. R & (8) \\ \Omega_{roue} = \dfrac{V_{Veh}}{R} & (9) \end{cases}$$

5 Itinerary on MAPS

The use of the data acquired by the onboard GPS allows the utilities to be drawn on the Google MAPS on the one hand, and to test the accuracy of this data on the other hand. Figure 4 shows the actual itinerary travelled by the vehicle.

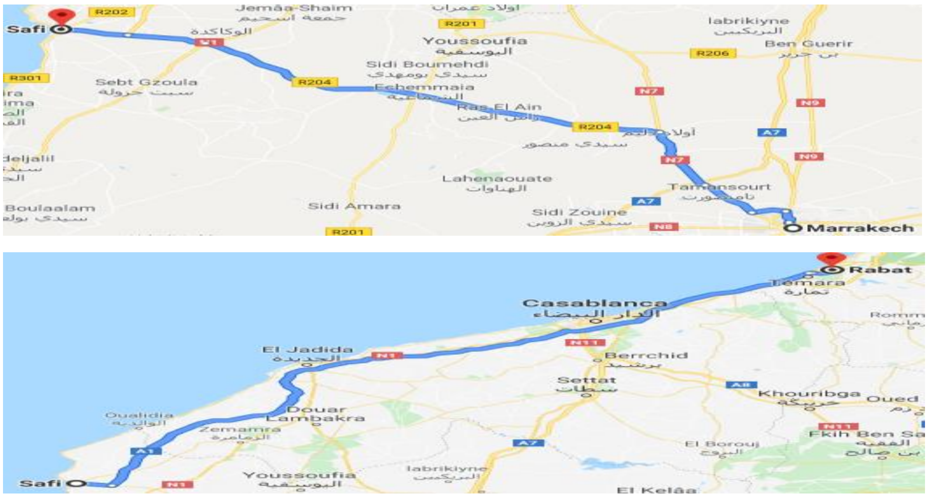
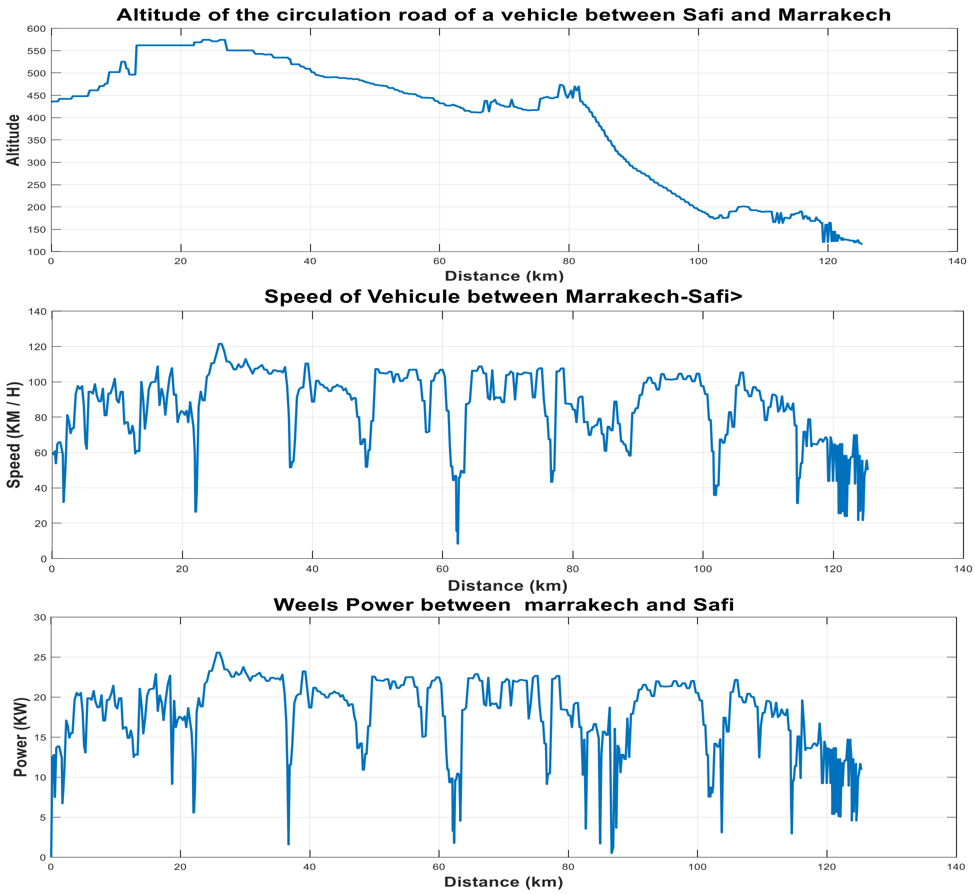


Fig. 4: The itinerary between Marrakech, Safi and Rabat

6 VE Dynamics model simulation

To estimate the power demanded to the wheels on the road in our case the actual roads chosen are the national road Marrakech and Safi and the highway Safi Rabat, these parameters are from a real vehicle, and are exploited on Matlab/Simulink.
The parameters used are:

- M =1150Kg: Vehicle mass
- C_{rr} =0.015: Rolling resistance coefficient
- C_d =0.32: Coefficient of air penetration
- S_f =2.5m^2: Front section of the vehicle
- V_v=0 m/s: Wind speed
- g=9.81m/s2: Gravity
- ρ=1.28Kg/m3: Density of air volume
- r =0.33 m Tyre radius



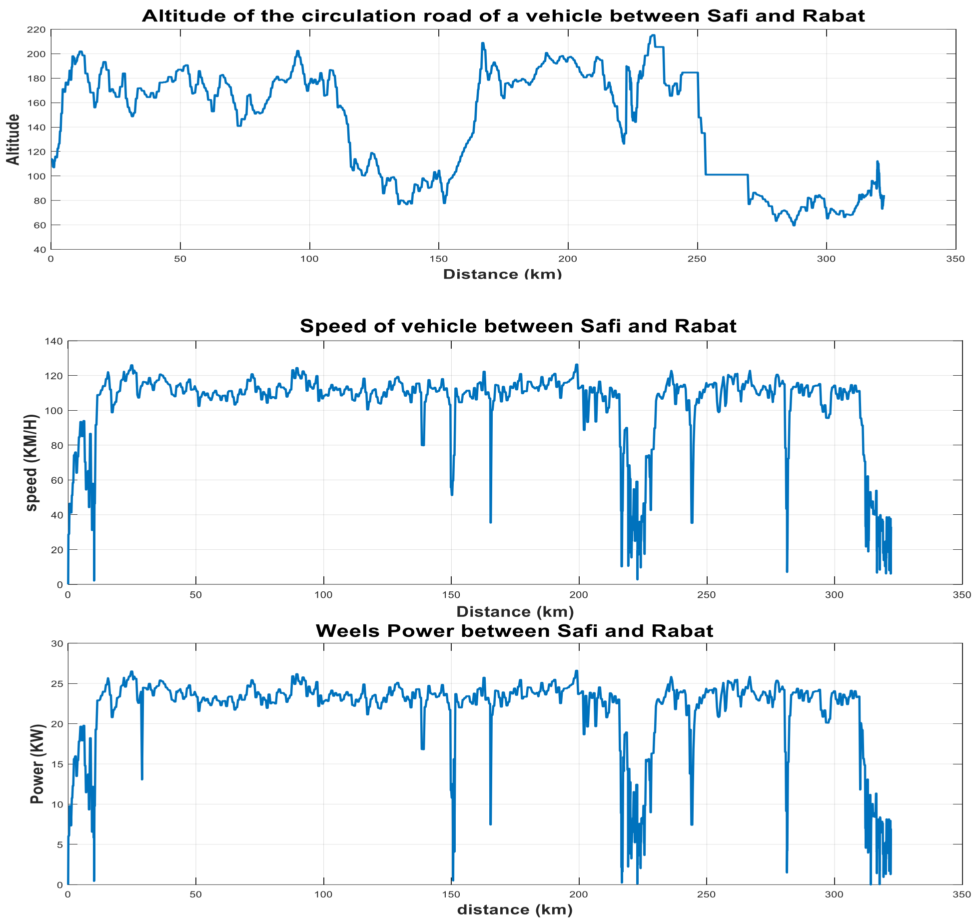


Fig. 5: Simulation results of the dynamics model of VE.

The analysis of these figures shows that the power developed at the wheels is practically constant on the Safi and Rabat highway is about 24 KW. On the other hand, the power exceeds 25KW at some point on the national road Marrakech Safi because of existing slopes on the road. Therefore, we can estimate the total power required at the wheels as well as by the engine along the road, the objective of which is to keep the autonomy of the vehicle.

7 Conclusion

In this paper, we presented a bibliographical study on electric vehicle modeling as well as a practical model based on an Arduino kit that gives a real vision of the road traveled by the vehicle. This data allow us to estimate the power required to move a vehicle over a well-defined road. Indeed, this study allows us to properly dimension the components of the drive train and more particularly the battery.

References

1. Caillard, P., *Conception par optimisation d'une chaine de traction électrique et de son contrôle par modélisation multi-physique*. 2015.
2. Zeraoulia, M., M.E.H. Benbouzid, and D. Diallo, Electric motor drive selection issues for HEV propulsion systems: A comparative study. IEEE Transactions on Vehicular technology, 2006. 55(6): p. 1756-1764.
3. Thounthong, P., S. Rael, and B. Davat, Energy management of fuel cell/battery/supercapacitor hybrid power source for vehicle applications. Journal of Power Sources, 2009. 193(1): p. 376-385.
4. Zidani, Y., A. Boulmane, and D. Belkhayat. Improvement of the Indirect Field Oriented Control for IM Drives Using Fuzzy Controllers. in 2019 6th International Conference on Electrical and Electronics Engineering (ICEEE). 2019. IEEE.
5. Okba, K., Control and Energy Management of an Electrical Vehicle.
6. Souffran, G., Dimensionnement de la chaîne de traction d'un véhicule électrique hybri*de basé sur une modélisation stochastique de ses profils de mission*. 2012.